FROM H.G. WELLS TO UNMANNED PLANETARY EXPLORATION

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The possibility of planetary exploration has been a dream of the human race since Galileo discovered the moons of Jupiter in 1610. Visual sightings of bodies entering Earth's atmosphere have been made by Earth's inhabitants over the centuries.

Over time, the many meteor showers (Leonid, Perseid) have provided dramatic evidence of the intense heat generated by a body entering Earth's atmosphere at hypervelocity speeds. More recently (in 1908), few viewed the Tunguska meteor that impacted in Siberia, but the destructive power on the countryside was awesome.

As an aside, Edward Teller (a physicist and friend), who was born in 1908, used to tell stories of how he and several of his Hungarian colleagues (Von Karmen, Von Neumann, Szilard) came to Earth on this meteor. Many years ago Edward also wore a tie with the letters "ET" on it, long before the movie. Then he claimed to be a Martian.

I have often wondered if Harvey Allen (born in 1910), developer of the blunt body that made entry probes possible, was somehow affected by that event, or by Teller.

I want to mention one more event before we talk about Allen and his impact on planetary probes. From the accounts of H.G. Wells' War of the Worlds written in 1898, the Martians had already solved the entry problem in the last century. From accounts, it was a 30-meter diameter cylinder with a circular nose.

Fig. 1. Mars to Earth entry probe.

There was no indication of the heat shield material except to say that it flaked off when touched.

I would like to take a more serious view and talk about a man to whom all of us in the planetary probe world owe much. H. Julian Allen's work made possible the safe return of all of our Mercury, Gemini and Apollo astronauts as well as the successful entry of our planetary entry probes.

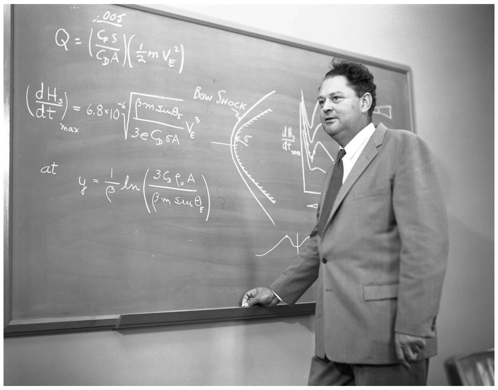


Fig. 2. H.J. Allen.

He was the originator of the concept of bluntness as an aerodynamic technique for greatly reducing the severe heating problem of spacecraft entering the atmosphere. His concept also revolutionized the basic design of ballistic missiles, for which he received the Air Force Association Science Trophy.

This audience does not need a tutorial on the rationale for a blunt body. I will just say that Harvey knew that the kinetic energy lost by a missile, or a warhead, as it enters the earth's atmosphere is totally converted into heat. The heat comes from two sources, and, significantly, is generated in two places: inside and outside the boundary layer. The heat appearing outside the boundary layer is generated by shock-wave compression. Of the heat generated in the boundary layer, some results from compression but much more arises from viscous shear or skin friction. The heat generated by the shock wave outside the boundary layer is for the most part well removed from the body and cannot reach it by convection through the insulating blanket of boundary layer. The answer seemed quite obvious to Harvey – make the nose blunt in order to strengthen the bow shock wave.

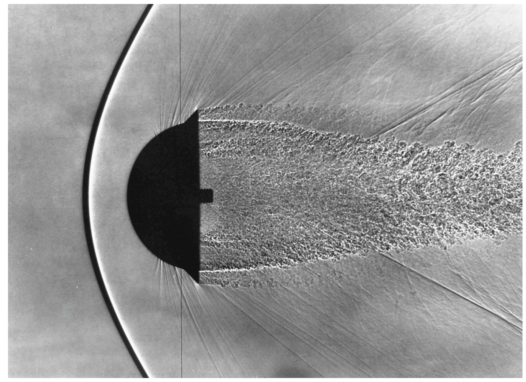


Fig 3. Blunt/Cone

One of Harvey's earliest scientific contributions of significance to the aviation industry was the development of a general theory of subsonic airfoils. The so-called low-drag airfoils, used on aircraft such as the Mustang Fighter in World War II, were improved considerably through this general theory. Beginning in the mid-1940s, his technical leadership was a driving force behind the development of the various high-speed wind tunnels, hypervelocity ranges and arc jets at the NASA Ames Research Center, which now represent one of the country's primary resources used in the development of advanced aircraft and spacecraft. These national facilities, in a sense, are a monument to his career.

In addition to being a distinguished scientist and engineer himself, Harvey was also an inspiring leader. A whole generation of aeronautical engineers was guided and inspired by him at the Ames Research Center. He served in a number of leadership positions at Ames, capping his career by a term as Center Director from 1965 to 1969.

I worked very closely as his colleague and assistant for about twenty years. When Ames was established in 1939/40 at this site selected by Charles Lindbergh, Harvey was working at Langley and demanded they transfer him or he would resign – they called people who transferred from Langley to Ames the "Mayflower Society."

They did transfer him and Ames flourished because of it. I have no doubt that this man was a genius. He was a true original with startling scientific insight and the uncanny ability to forge paths into entirely new areas and to inspire others to follow him.

He also had a lifelong fascination with airships though he knew they were impractical. In fact, he could have been considered an expert on the subject of airships. At noontimes he told many stories of the various near accidents of airships. The most famous was when he was at Mines Field in Los Angeles and witnessed the takeoff of the Graf Zeppelin as piloted by Hugo Eckhart. Evidently the airship was having difficulty lifting off – so much so that the crew was madly throwing excess weight, including lettuce and other foods, off the airship. Harvey would tell this story and relate its absurdity quite vividly. We had some fun and unusual lunchtime conversations with Harvey.

Allen became Ames' second Director in 1965, and used the position to maintain Ames' preeminence in basic and applied research. He had little use for the political game-playing of Washington, preferring to send subordinates to the endless meetings at Headquarters, and worked hard to keep Ames' essential character as a research center. He continued his well-known habits of casually popping into the offices of his fellow researchers to discuss interesting ideas, thus making sure that he was continually aware of every aspect of Ames' work. Not content with the paper-pushing duties of a senior administrator and always a scientist at heart, Harvey continued his own research during his tenure as Director, while constantly encouraging and nurturing new scientific and engineering talent. He trusted younger researchers to follow their own ideas wherever they led, without the imposition of arbitrary restraints and conditions from above.

As mentioned earlier, under Allen's direction there began the development of hypervelocity ranges and arc jets to confirm and expand on his theories. Over a period of several decades, Ames engineers designed and built a stable of hypervelocity ranges and arc jets that simulated entry conditions, from Earth orbital velocities to speeds in excess of Earth escape speed.

The hypervelocity ranges were critical for understanding the aerodynamics of the Mercury, Gemini, and Apollo entry capsules. The ranges also served this purpose for the atmospheric entry probes that followed. The arc jets have been critical for the TPS development of all of NASA's entry vehicles.

In 1958 when NACA evolved into NASA, the staff whose research was mainly focused on aircraft began looking toward space. From what little we knew at the time of the atmospheric composition of our two closest neighbors, Mars and Venus, they had atmospheres composed primarily of CO_2.

About that time we had a visit from a famous astronomer from Pic du Midi Observatory in the Pyrenees Mountains (Zdenek Kopal). He assured us that CO_2 was the predominant gas in the atmosphere of Mars and Venus. With Harvey's support, in 1959 several of us proposed a project to look at the effects on the drag and stability of several shapes in CO_2.

Using one of the hypervelocity ranges we conducted tests, and the results published in TMX642 showed the stability of some of the shapes was considerably different than in air, and we were off in an exciting new direction.

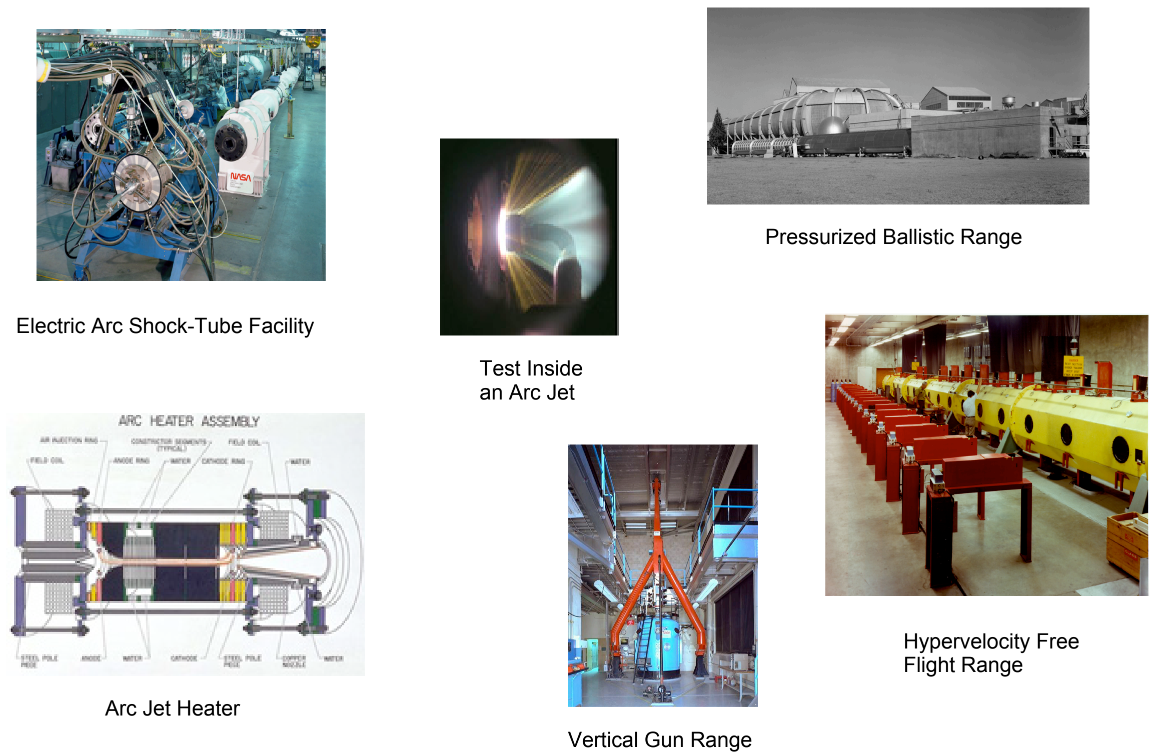


Figure 4: Ranges/Arc Jets.

I believe Ames' first serious effort in Entry probes was the PAET Project, which was tested in our ballistic ranges and launched in June 1971 with a successful reentry in the earth's atmosphere, and we will speak of it later. I would like to look briefly at a wide range of these vehicles developed by this country and others.

The first of these was FIRE II, which was a technology demonstrator for Apollo launched in 1965 with an entry velocity of over 11 km/sec. This was followed by the early unmanned Apollos, PAET, Viking, Venus probes, etc. Most recently we have had the strikingly successful MER rovers, Spirit and Opportunity.

We are also looking forward to several upcoming entry events:

- Genesis – to collect solar wind particles and return them to Earth; Earth return, Sept. 2004;
- Huygens: to explore Saturn's moon, Titan; Jan. 2005;
- Stardust: to collect comet material; Earth return, Jan. 2006.

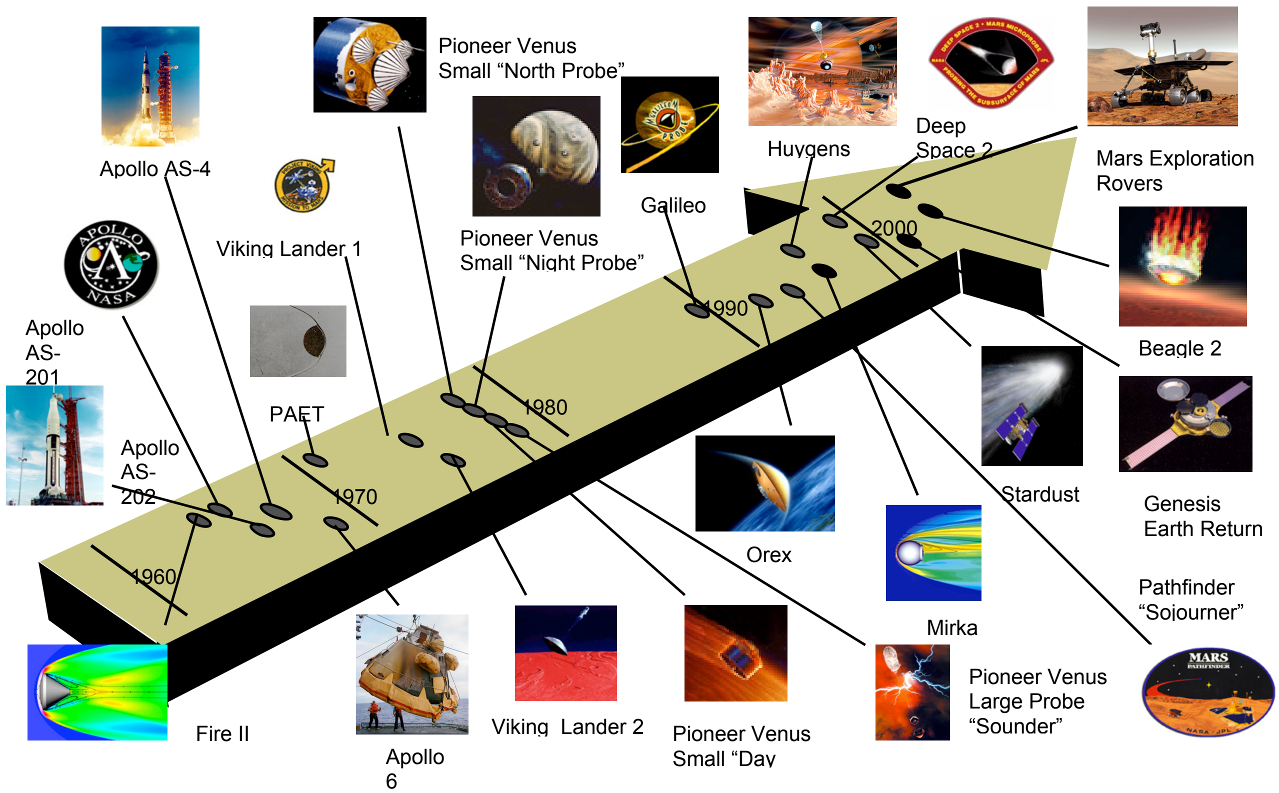


Figure 5. Entry vehicles.

Following in the same spirit of innovation exhibited by Harvey Allen, his colleague Al Seiff proposed in 1963 that small probes be sent to Mars and Venus to determine the structure and composition of their then relatively unknown atmospheres. Al's concept was to measure the structure (density, temperature and mean molecular weight) of the unknown planetary atmospheres from the aerodynamic response of a blunt-bodied vehicle throughout its entry from hypersonic to subsonic flight. His concept of "inverting" the entry physics "problem" into a tool for planetary science was brilliantly demonstrated by the Planetary Entry Experiment Test (PAET).

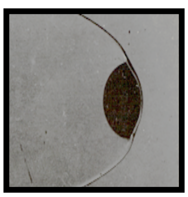
Fig. 6. Al Seiff (right) with his Project manager for PAET, Dave Reese.

Next, we see a photograph of the forebody of the PAET vehicle showing various instrument windows and ports. It had a beryllium nose cap and an ablator on the flank of the forebody. The inset shows a shadowgraph of a PAET model in flight in the Ames Ballistic Range.

Along the right of the figure are artists' concepts of the three probe missions to Mars, Venus and Jupiter. Al was the PI on the atmospheric structure investigations for all three, and he and his teams clearly met and exceeded the goals set in 1963. Thus we see that the seminal PAET demonstration led to humankind's vastly increased knowledge of the atmospheres of Mars, Venus and Jupiter via the Viking, Pioneer-Venus, and Galileo probe missions.

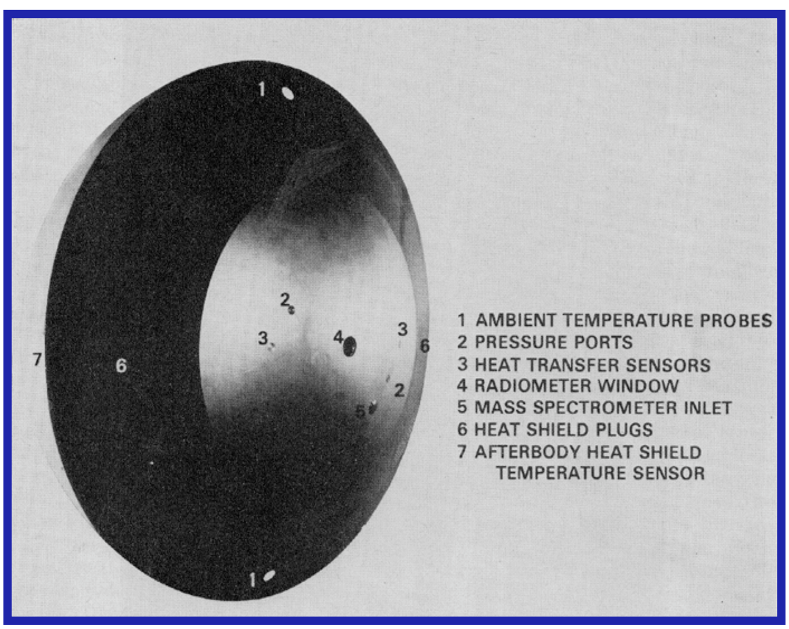
Having known Al and his work, I can say that he was a wonderful man who literally "touched the stars" with his intellect and instruments. Al was an inspiration to those he led and they generally had great fun doing their work. His example and mentoring gave rise to a considerable number of persons who went on to achieve much in space science, space technology and NASA management.

In conclusion I would like to share with you some artifacts that Harvey Allen gave me for safekeeping thirty-five years ago. They are authentic heat shield plugs taken from Glenn's 1962 Mercury capsule, White's 1965 Gemini capsule, and Apollo 6's unmanned capsule in 1968, presented to Harvey by JSC in recognition of his solution to the re-entry heating problem.



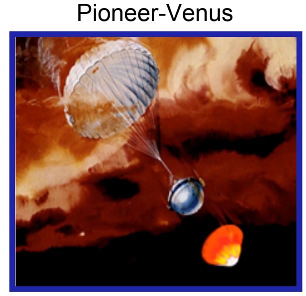
Ballistic

PAET (1971), An Entry Probe Experiment in the Earth's Atmosphere



Viking

Pioneer-Venus



Galileo (1995

Fig 7. PAET, Viking, Pioneer-Venus and the Galileo Probe