Appendix 5

Reentry Vehicle Recovery

Air Force Eastern Test Range

Early in the development of reentry vehicle design it was discovered that a telemetry blackout period occurred due to the formation of plasma from the ionized air layer at the point of highest temperature during reentry. Data recorders were included in the reentry vehicles so that critical information during this period would not be lost but with no rapid replay capability, this required recovery of the data recorders.

Water depths along the flight path of the Air Force Eastern Test Range precluded recovery after impact. Two solutions were devised for critical data recovery. The first was the use of buoyant data capsules with radio beacons which were ejected from the Mark 2 reentry vehicle prior to impact. This concept sufficed for the early heatsink reentry vehicles.

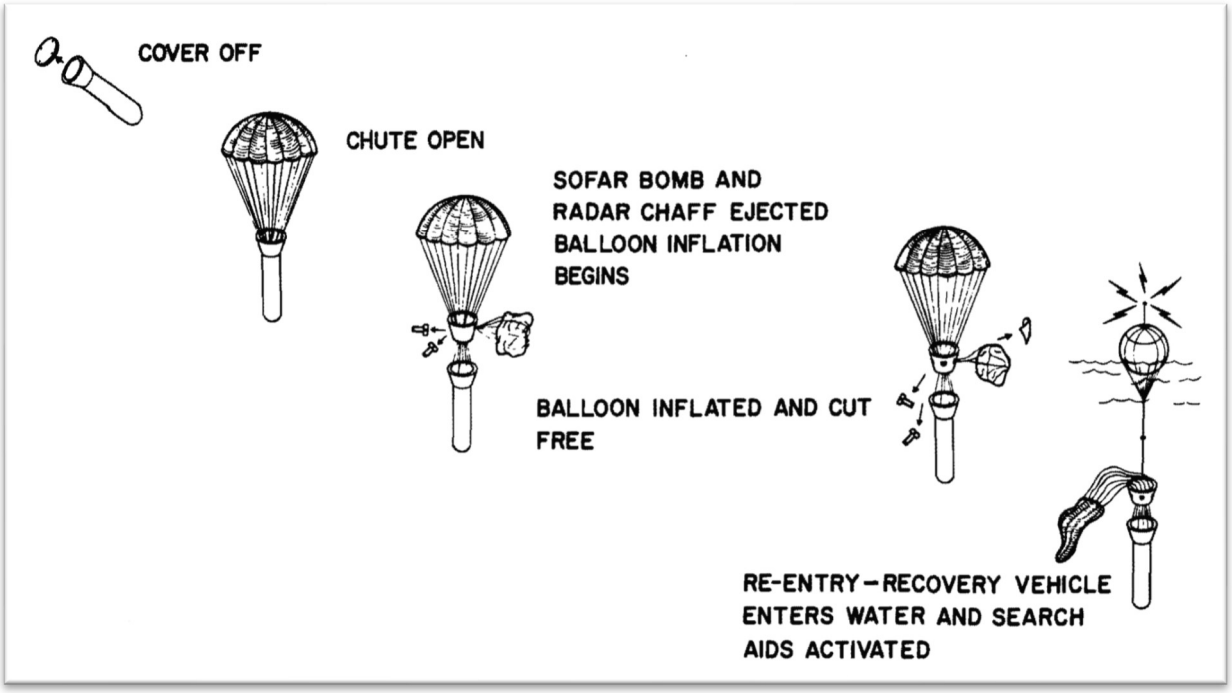

Figure 1. Reentry vehicle parachute recovery sequence. Adapted from *GE Progress in Reentry Vehicle Recovery Development.*

The second was the use of a parachute recovery system to permit recovery of the intact reentry vehicle (Figure 1). This system consisted of a parachute design for deployment at supersonic speeds and a flotation balloon to keep the vehicle afloat in the ocean until retrieval. The flotation balloon would deflate after a preset time to prevent recovery by the ubiquitous Russian trawlers.

Two small Sound Fixing and Ranging (SOFAR) bombs released on contact with the water to aid in locating the reentry vehicle. The bombs sank at different rates to a depth of approximately 3,000 feet to detonate in the sound channel found at that depth. If they did not release from the reentry vehicle they would still detonate after a preset time to assure that the reentry vehicle sank (Figure 2).

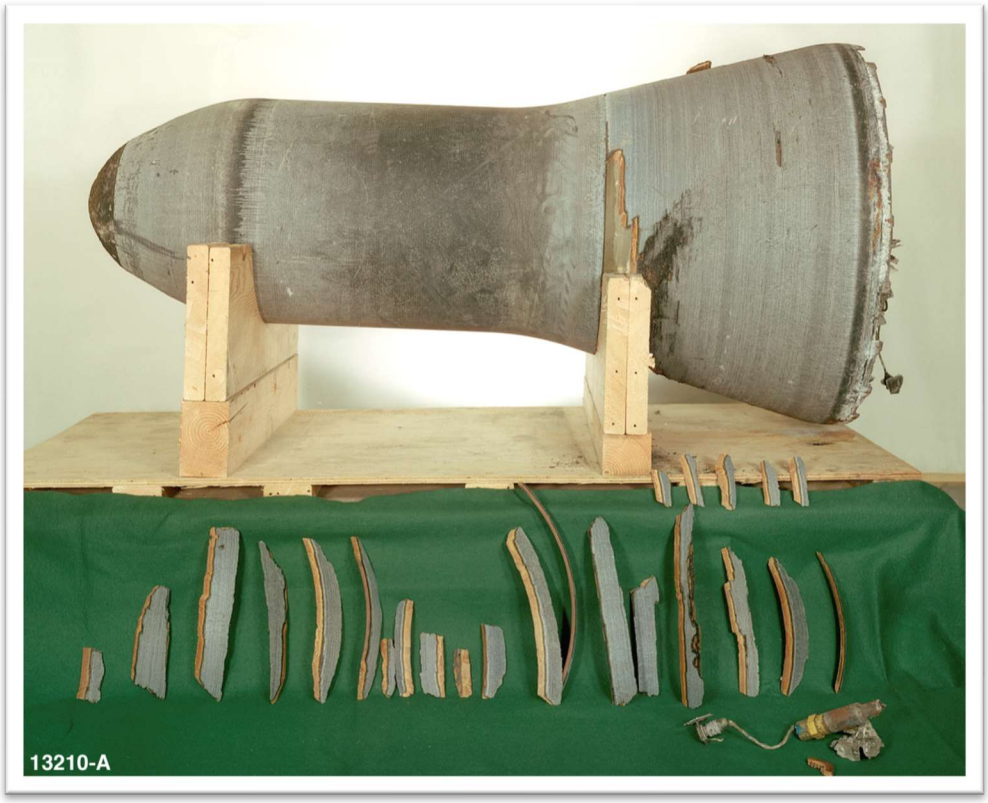

Figure 2. Recovered Mark 11C. Courtesy Phil Fote.

Phil Fote, an Avco engineer that was part of the team that designed the Mark 5, recalls that during the first attempted recovery of a Mark 5 reentry vehicle, the SOFAR bombs did not detonate. The splash was detected by sonar and an approximate impact point was determined. The question was then whether or not the reentry vehicle sank as programmed to prevent recovery by the Russians.

When the missile had been built up at the Cape, it was slightly overweight so the ballast in the reentry vehicle, which replaced the warhead, had been reduced. Avco engineers took a Mark 5 to Cape Cod and removed the same amount of ballast. They dropped it in the ocean only to find that it did not sink enough to flood and bobbed back to the surface. Fote was assigned the task of designing a vent system to assure that the reentry vehicle was flooded enough to sink after predetermined amount of time.[1]

Air Force Western Test Range

Eniwetok Atoll

The size of the lagoon at the Eniwetok Atoll is approximately 400 square statute miles. The lagoon varies in depth between 160 and 215 feet, with the average recovery depth between 185 and 190 feet. Search and recovery was by divers using SCUBA gear, working off a recovery barge. SCUBA equipment was used instead of hard-hat due to the extremely fine silt that covers the floor of the lagoon, which if disturbed by walking, precluded continued searching for extended periods of time. The search process involved two diver teams. If the reentry vehicle was immediately visible the pair of divers played out a 100-foot line anchored to the marker buoy which was placed based on coordinates from the radar and camera data collected at the time of impact. The divers positioned themselves on the line at their limit of visibility and then swam in a circle around the buoy anchor. If unsuccessful in locating the reentry vehicle, the marker buoy location was refined and the process repeated. The "bottom time" for divers depended on the depth; at 40 to 50 feet this could be hours, while at 200 feet was limited to 10 minutes. Divers could only make one 200-foot depth dive per day.[2,3]

Army Kwajalein Missile Test Range

Since 1964, United States Army has operated the Kwajalein Missile Test Range in conjunction with the development of the ballistic missile defense system. The site supports numerous Air Force, Army and Navy programs.

Kwajalein Atoll

The size of the lagoon at the Kwajalein Atoll is approximately 900 square statute miles with an average depth of 200 feet. Search and recovery techniques are similar to those of Eniwetok, however, at Kwajalein the search and recovery effort is augmented through the use of small submarines that serve to locate the reentry vehicle before diving takes place. Two Perry PC 3A1 two-man submarines were used from 1965 to 1972 (Figure 3,4).[4]

Figure 3. Perry 2-man submarines used in reentry vehicle recovery operations. Army photograph.

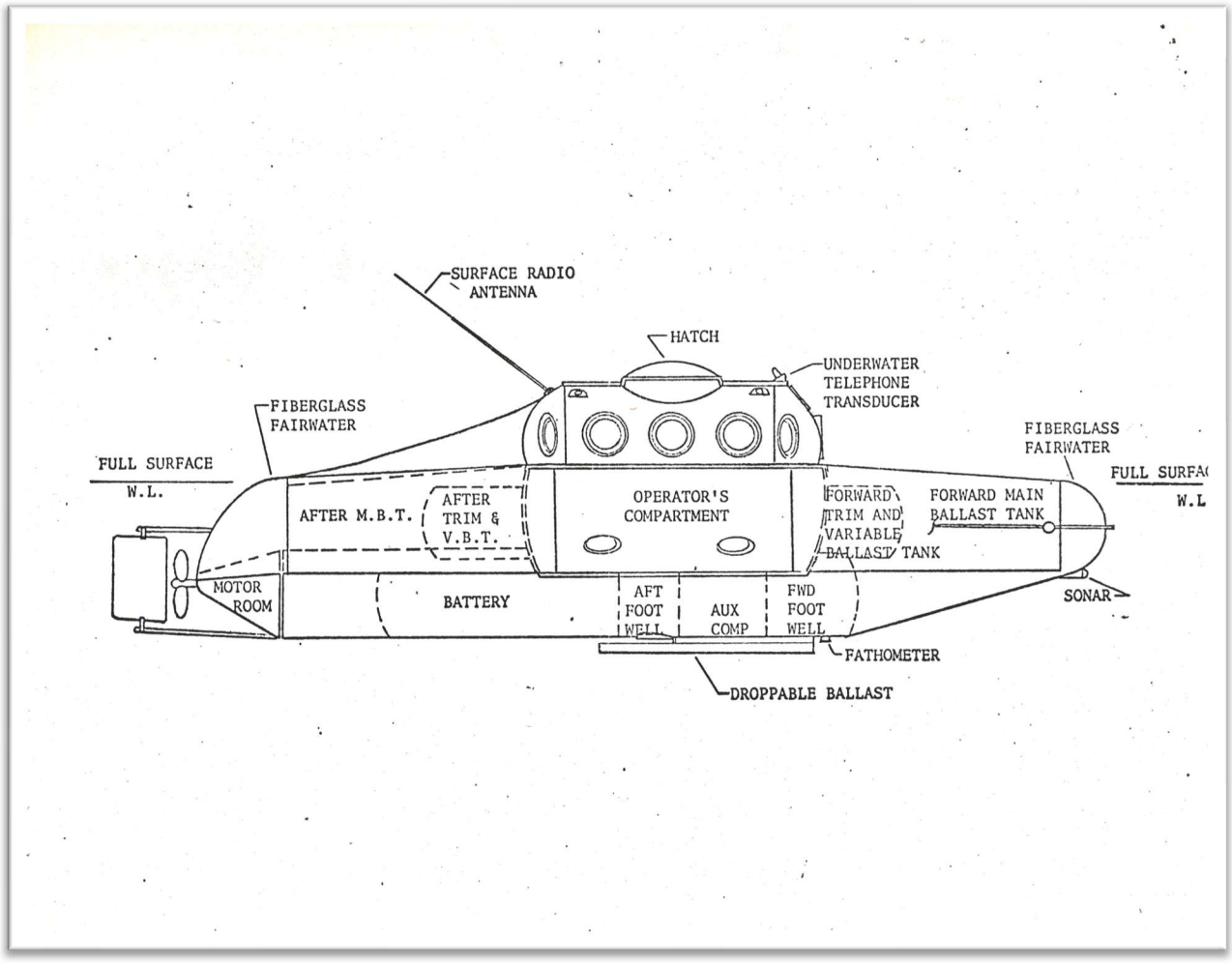

Figure 4. Perry PC 3A1 two-man submarine components

Endnotes

1. Phil Fote, personal interview by author, May 2015.

2. *History of the Air Force Western Test Range: 15 May- 31 December 1964*, (Air Force Systems Command Historical Publication Series 65-250-I), Air Force Historical Research Agency (AFHRA), IRIS 00484561, K 241.011 V. I, Reel 15363, 2.

3. Michael E. Golder, Recovery-Air Force Ballistic Weapons Systems, (The Space Congress Proceedings, Embry-Riddle Aeronautical University, 7 March 1966), 633-638.

4. *Kwajalein Missile Range Historical Summary: July 1954-June 1970, Volume I Narrative* , (U. S. Army Safeguard System Command, Huntsville, Alabama, 2 August 1972), Section I-1,7. Interview with Edward Stewart, U.S. Space and Rocket Museum, Huntsville, AL., May, 2016.