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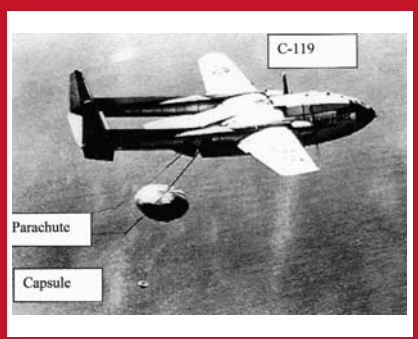
First Operational Heat Sink Reentry Vehicle—Mk 2 on Atlas ICBM

First Operational Ablative ICBM Reentry Vehicle—Mk 3 on Atlas ICBM



Air Force C-119 snares the CORONA/Discoverer XIV Capsule in Mid-Air

The need for a successful reentry technology stemmed from World War II and the subsequent Cold War. The development of World War II ballistic and nuclear weapons was a legacy given to the United States and the Soviet Union, but before these weapons could be truly successful it was necessary to develop a way to get these weapons up outside the atmosphere and back in again without vaporizing them on reentry. Both countries realized that there would be a distinct military advantage in developing a successful reentry system, and this goal became one of the military's top priorities in the 1950s. As described by Theodore Von Karman, "Reentry is … perhaps the most difficult problem one can imagine."

The result of this need was the establishment in 1956 of the General Electric (GE) Company's Re-entry Systems' facility at 3198 Chestnut Street in Philadelphia, which became home to the thousands of engineers and technicians who solved the problem of vehicles successfully reentering the Earth's atmosphere. The history of their accomplishments from 1956 to 1993 indicates the integral part they played in the development of U.S. weapon and space systems.

First Operational Heat Sink Reentry Vehicle (Atlas Mk 2)—In 1955, the General Electric Company was invited to bid on a contract to develop the reentry vehicle (RV) for the Atlas Intercontinental Ballistic Missile (ICBM) and the Thor Intermediate Range Ballistic Missile (IRBM). The reentry vehicle was designated the Mk 2. The subsequent award to GE was based on GE's very important work on Project HERMES, dating to 1944, and on the impressive capabilities of GE's vast group of highly skilled engineers and scientists.

Drawing on the work of H. Julian Allen of NACA, and the joint Government-Industry team, GE selected a blunt cone, heat-sink solution for this first RV, primarily because more was known about heat-sink materials than about other potential solutions. A heat sink is an environment or object that absorbs and dissipates heat from another object using thermal contact. The configuration was designed to maintain laminar flow as late as possible in the flight, and the heat shield was produced from high purity copper alloy. Another reason to use well-understood approaches was that the schedule had become urgent when President Eisenhower declared the Atlas Program to be the country's highest R&D priority.

The first Mk 2 flight was on June 1958, followed by 35 additional successful flights, at ranges to 6500 nautical miles. The system became operational two years later on the Atlas ICBM and on the Thor IRBM. The United States had its first operational ICBM to counter the Soviet Union missile threat.

First Space Payload Recovery (Mk 2 Data Capsule)—As a backup for the problem of telemetry blackout during reentry, GE Re-entry Systems developed the Mk 2 data capsule, an 18" sphere, that was carried inside the Mk 2 reentry vehicle. The data capsule was the first to use 3-axis (individual) stabilization, an important contribution for future orbiting spacecraft. The first successful recovery occurred on June 13, 1958 on a Thor IRBM launch, followed by 13 more successful recoveries. This led to a contract for the Mk 2 Space Lab program to recover scientific experiments during Atlas missile test flights. To commemorate this very significant accomplishment, a data capsule recovered by the Mk 2 was presented to the Smithsonian Institution on May 15, 1959 by General Bernard Schriever, Commander,

U.S. Air Force Research & Development Center, and Hilliard W. Paige, General Manager, GE Re-entry Systems.

First Operational Ablation RV and Longest ICBM Flight (Atlas Mk 3)—The GE Re-entry System's Mk 3 RV was the first operational reentry vehicle to use ablative materials. Ablative material is designed to slowly burn away in a controlled manner, so that heat can be carried away from the spacecraft by the generated gases, while the remaining solid material insulates the craft from superheated gases. Mk 3 was a sphere-cone-cylinder-flare design, and in May 1960 made the longest reentry flight on record, 9000 miles.

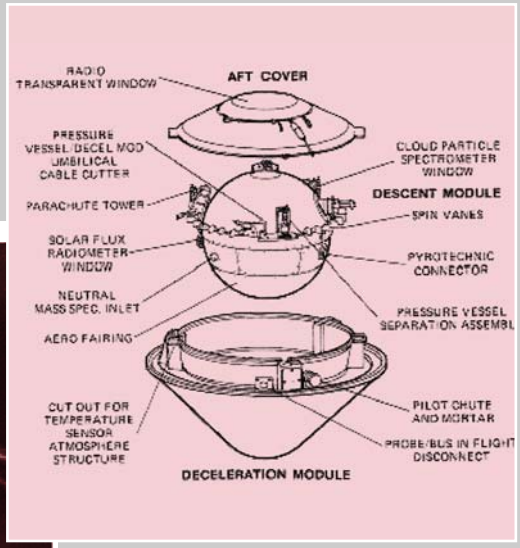
First Return and Recovery of a Man-made Object from Earth Orbit (CORONA/Discoverer XIII)—Beginning in the late 1950's, the United States attempted to take pictures from space and return those pictures to earth for analysis. The initial CORONA launches were obscured as part of a unique "cover story," a space science technology program called Discoverer. The first test launches were in early 1959, and the first launch with a camera was in June 1959. Called Discoverer IV, it was a 750 kg satellite launched by a Thor-Agena rocket. But instead of space science, the satellites returned film canisters to Earth in capsules, called "buckets," which were to be recovered in mid-air by a specially equipped aircraft during their parachute descent. The buckets or capsules were designed to float in water for a short period of time, and then sink, if the mid-air recovery failed.

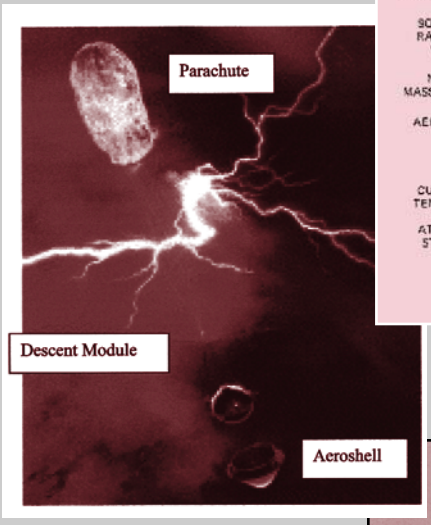
GE Re-entry Systems was responsible for the "bucket" design and the recovery system. On August 12, 1960, the first successful return and recovery of a man-made

The Building

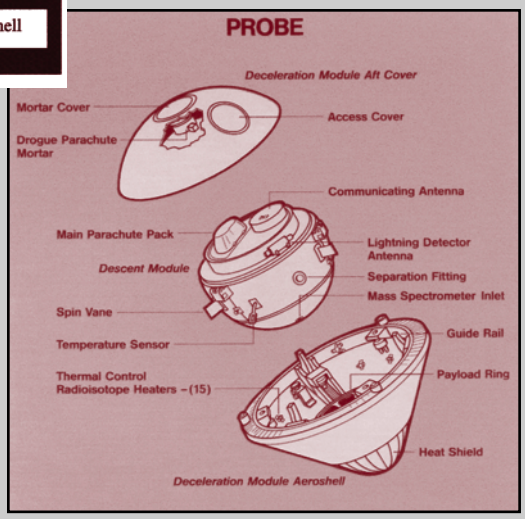
Originally constructed as the Pennsylvania Railroad Freight Building in 1929, in a restrained Art Deco style, the first floor is sheathed in limestone, with the upper stories clad in buff colored brick with limestone details. Rising six stories above track level, with over 650,000 sq. ft., the building was originally designed as a combination freight station, warehouse, and showroom, and is characterized by immense concrete massing, typical of industrial architecture. Later, the Railroad leased the facility to A&P Markets, Raymond-Rosen & Company, and the U.S. Post Office, among others. In 1956, GE leased the building to serve as headquarters for the newly formed Missile and Space Vehicle Department, which was started by moving approximately 250 people from Schenectady, NY, to Philadelphia. The main floors were converted to offices and engineering laboratories, while the track was converted into a machining and production center for reentry vehicles and subsystems. In 1961, the Space part of the business moved to Valley Forge, PA, while the Re-entry Systems business remained at 3198 Chestnut Street. The site was the headquarters for GE Re-entry Systems' business from 1956 until 1993, when the department moved to Valley Forge. Between 1998 and 2001, Dranoff Properties renovated and converted the structure into luxury apartments, with a massive open courtyard carved from the interior. The main entrance was relocated from Chestnut Street to Walnut Street and several businesses and restaurants were opened to serve the local community. Today, the track level houses the University of Pennsylvania's Maintenance and Real Estate offices. In 1999, the facility was added to the National Registry of Historic Places.

First Operational Multiple Independently Target RV (MIRV) Reentry System—Minuteman III





Artist Conception of Pioneer Venus Entry at Planet Venus



Project Galileo

object from Earth orbit, Discoverer XIII, was achieved. A few days later, Discoverer XIV was successfully recovered in mid-air by a C-119 aircraft, and the imagery data was recovered and analyzed. The film retrieved by CORONA/Discoverer XIV provided more coverage than all the previous U-2 flights over the Soviet Union combined and was critical to U.S. national security. The age of the photographic spy satellite was born.

First Vehicle Recovered after Flight in the Van Allen Belt (NERV)—The Nuclear Emulsion Recovery Vehicle (NERV) was a NASA-sponsored program. The program objective was to measure the characteristics of the inner Van Allen belt, determine the effect of the radiation upon mold spores, and return the data to earth. GE Re-entry Systems was responsible for the reentry vehicle and the recovery capsule design and manufacture. The unique NERV ablative heat shield design allowed a probe to be extended through the nose cone and data to be collected. Then the probe was retracted and the heat shield resealed for reentry and recovery. NERV was launched from Point Arguello, part of the Pacific Missile Range, on September 19, 1960 with the capsule being recovered some three hours later, nearly 1200 miles away.

First Full Scale RV to Transmit Telemetry Throughout Reentry (TVX)— In April 1961, the U.S. Army awarded the TVX contract to GE Re-entry Systems. The contract was for target vehicles for the Nike-Zeus anti-ICBM program. A first successful flight was conducted in November 1961. One of the primary objectives of the program was to develop a method to transmit telemetry data during the reentry blackout period, particularly the miss distance between the TVX target

vehicle and the Nike-Zeus interceptor missile. This was accomplished using a sharp-nosed biconic configuration for the TVX design. In addition, the flight tests showed that graphite- and Teflon-based materials held promise for future operational sharp-nosed reentry vehicles.

Largest Operational Reentry Vehicle (Titan II Mk 6)— Based on the success of the GE Century Series ablative materials, as demonstrated on the RVX-2A program, GE Re-entry Systems was awarded a contract for the MK 6 RV for the Titan II ICBM. This sphere-cone design was the largest RV in the U.S. arsenal, with a length of 14' and a weight of 8000 lbs. The Titan II with its Mk 6 RV was initially deployed in 1962, and remained on active duty until the mid-1980s.

First RV test with Complete Flight Control During Hypersonic Reentry (MBRV)—In the 1960s, the U.S. Air Force began to investigate the use of aerodynamic control surfaces and on-board guidance and control subsystems to control the Reentry Vehicle during reentry. The objectives were to enhance target penetration by evading potential defense missiles and to reduce the reentry contribution to overall system impact errors. An early experiment was conducted on a modified Mk 3 RV. Subsequently, a contract was awarded to GE Re-entry Systems in 1963 for the Maneuvering Ballistic Reentry Vehicle (MBRV) program. MBRV had a sophisticated guidance system to control the vehicle's preset trajectory and impact point. Three vehicles were successfully flight tested over the Pacific in the mid-1960s. The flight series demonstrated the aerodynamic controls, and pointed to modifications needed for future designs.

First Multiple Independently Targeted Reentry Vehicles (MIRV) System (Minuteman III)—Minuteman III was the first U.S. ICBM to utilize Multiple Independently Targeted Reentry Vehicles (MIRV). The Minuteman III had three RVs, a small post-boost liquid-fuel restartable engine, and a new guidance system. This post-boost rocket was used for course changes between the releases of the individual Mk 12 RVs for truly independent targeting. A new guidance unit was developed to control these maneuvers. GE also designed, built, and tested the first passive decoy for high-ballistic-coefficient RVs, designed and built chaff to mask the RV at high altitude, and designed and built the mechanisms to deploy these penetration aids as part of the Minuteman III system. Development of the Minuteman III started in July 1965, and the first launch occurred in August 1968. Deployment began in April 1970, and eventually 550 Minuteman III missiles were placed in silos, and became the backbone of the U.S. land-based ICBMs throughout the Cold War.

First Recovery from Earth Orbit of a Fully Instrumented Primate (Biosatellite)—In the late 1960s, NASA/Ames awarded a program to GE Re-entry Systems, to study the prolonged effects of weightlessness and radioactivity on living organisms. Called Biosatellite, NASA conducted three flights: the first two with plants and organisms, and the third with a primate. Biosatellite consisted of a blunt conical reentry vehicle, which contained the recovery capsule, and a cylindrical adaptor section.

The capsule, containing 13 plant- and animal-specimen experiments that would be subjected to doses of radiation, was launched on September 7, 1967, and was scheduled to orbit for three days. The mission was cut short after 45 hours due to

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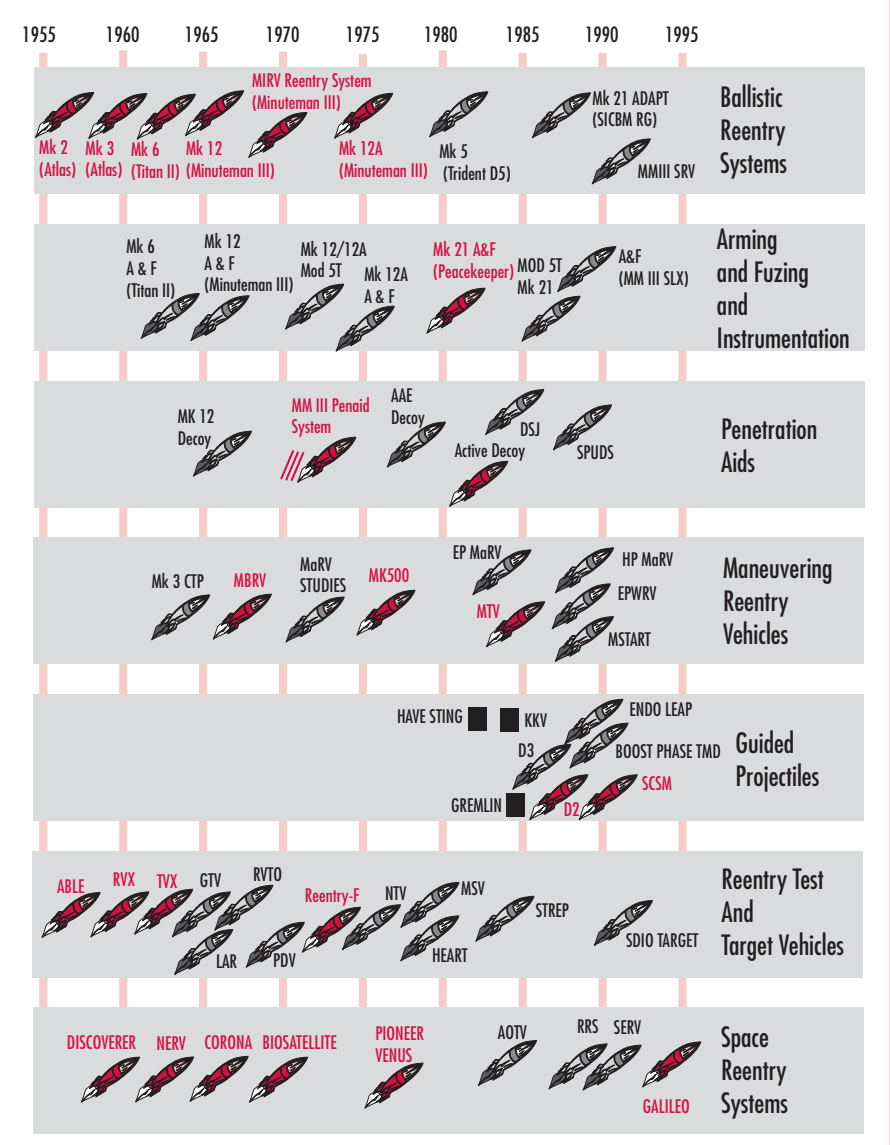
Major Programs at 3198 Chestnut Street—1956 to 1993

Red = Aerospace "Firsts"



communication problems and the threat of severe weather in the recovery area. But the capsule was successfully recovered after deorbit and reentry.

The third Biosatellite capsule, Bios 3, with a pig-tailed monkey on board, was launched on June 28, 1969. The monkey was attached to 24 sensors to study the effects of weightlessness on various bodily functions. He had been trained to feed himself by pushing various buttons, but once in orbit he became sluggish and refused to eat. NASA aborted the scheduled 30-day mission after nine days. The capsule containing the primate was successfully recovered.

First U.S. Planetary Probe to Utilize Aerothermal Protection to Survive Venus Entry (Pioneer Venus)—Under subcontract to Hughes Aircraft Company, GE Re-entry Systems designed and built the aerothermal protection subsystem for the four probes which successfully entered the atmosphere of the planet Venus. Launched August 8, 1978, the Pioneer Venus bus carried one large and three small atmospheric probes.

All four probes entered the Venus atmosphere on December 9, 1978. As the probe slowed down, a parachute designed by GE was deployed to further slow its entry into the atmosphere. The three identical small probes were targeted at different parts of the planet, and named accordingly. The North probe entered the atmosphere at about 60 degrees north latitude on the day side. The Night probe entered on the night side. The Day probe entered well into the day side, and although not designed to withstand impact with the planet's surface, continued to send radio signals back for 67 minutes after impact.

First Planetary Probe to Successfully Enter Jupiter's Atmosphere (Galileo)— The Galileo mission consisted of two spacecraft: an orbiter and an atmospheric probe. NASA's Ames Research Center and Jet Propulsion Laboratory managed the project. Hughes Aircraft Company designed and built the probe, and its subcontractor, GE Re-entry Systems, designed and built the probe's heat shield and aerothermal subsystem for this historic mission. GE also designed the thermal control subsystem. The launch occurred on October 18, 1989 on the Shuttle Inertial Upper Stage. The probe was released from the Galileo spacecraft orbiter on July 13, 1995 and entered the Jovian atmosphere on December 7, 1995. The descent probe slammed into the top of the Jovian atmosphere at a speed of 170,000 kilometers per hour (106,000 miles per hour). In the process, the probe withstood temperatures twice as hot as the Sun's surface. The probe slowed by aerodynamic braking for about two minutes, then deployed its parachute and dropped its heat shield. The probe kept transmitting data for nearly an hour as it parachuted down through Jupiter's atmosphere.

Awards

The site and its employees have been recognized for their achievements, including the award of the Charles Stark Draper prize by the National Academy of Engineering for GE's role as a key member of the CORONA/ Discoverer project team; selection of several GE engineers and managers as CORONA pioneers; recognition from England's Royal Air Force for GE Re-entry Systems' role in Project Emily, which established an operational Thor IRBM base in England with each Thor carrying a GE Mk 2 Reentry Vehicle; and acclaim by NASA/Ames and Hughes Aircraft for GE Re-entry Systems' critical role as part of the Project Galileo team's remarkable achievement of successfully entering Jupiter's atmosphere.

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THE AIAA HISTORIC AEROSPACE SITES PROGRAM

For over 75 years, the American Institute of Aeronautics and Astronautics (AIAA) has served as the principal society of the aerospace engineer and scientist. Formed in 1963 through a merger of two earlier societies, the American Rocket Society (ARS) and the Institute of Aerospace Sciences (IAS), the purpose was, and still is, "to advance the arts, sciences, and technology of aeronautics and astronautics, and to promote the professionalism of those engaged in these pursuits." Today, AIAA has more than 30,000 professional and 7000 student members.

In addition, AIAA sponsors many technical conferences, seminars, and short courses per year, and publishes *Aerospace America,* the *AIAA Student Journal,* and seven archival technical journals (including one online journal). The Institute also publishes conference papers and proceedings, technology assessments, position papers, audiovisual information packages, many books, and a variety of career-related educational materials. The Institute conducts a rigorous public policy program and works closely with other societies and governments in broad areas of mutual concern.

AIAA established the Historic Aerospace Sites Program in January 2000 to promote the preservation of, and the dissemination of information about, significant accomplishments made in the aerospace profession. In addition to the GE Re-entry Systems, other sites recognized by the committee include the Cincinnati Observatory, Cincinnati, Ohio; the Boeing Red Barn, Seattle, Washington; Kitty Hawk, North Carolina; the site of the first balloon launch, in Annonay, France; and Tranquility Base, on the moon.

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