ARMY BALLISTIC MISSILE PROGRAMS
AT CAPE CANAVERAL
1953 – 1988

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45th SPACE WING
History Office

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Preface

The United States Army has sponsored far fewer launches on the Eastern Range than either the Air Force or the Navy. Only about a tenth of the range's missile and space flights can be attributed to Army programs, versus more than a third sponsored by each of the other services. Nevertheless, numbers seldom tell the whole story, and we would be guilty of a grave disservice if we overlooked the Army's impressive achievements in the development of rocket-powered vehicles, missile guidance systems, and reentry vehicle technologies from the late 1940s onward. Several years of experimental flights were conducted at the White Sands Proving Ground before the Army sponsored the first two ballistic missile launches from Cape Canaveral, Florida, in July 1950. In June 1950, the Army moved some of its most important guided missile projects from Fort Bliss, Texas, to Redstone Arsenal near Huntsville, Alabama. Work began in earnest on the REDSTONE ballistic missile program shortly thereafter. In many ways, the early Army missile programs set the tone for the development of other ballistic missiles and range instrumentation by other military branches in the 1950s. PERSHING missile launches continued at the Cape in the 1960s, and they were followed by PERSHING 1A and PERSHING II launches in the 1970s and 1980s.

This study begins with a summary of the major events leading up to the REDSTONE missile program at Cape Canaveral. It includes an overview of RAF Bomber Command's raid against Peenemünde in August 1943 and the U.S. Army's recruitment of Wernher von Braun and his 'hand-picked' team of rocket experts in 1945. It continues with a sketch of the Army's early missile projects at Fort Bliss, Texas, and the recommendations that shaped the REDSTONE missile. The study also provides detailed descriptions of flight performance objectives, missile specifications, launch locations, ground support equipment, range instrumentation, and the results of REDSTONE, JUPITER, JUNO II, PERSHING, PERSHING 1A, and PERSHING II operations on the Eastern Range. It concludes with the Intermediate Nuclear Forces (INF) Treaty signed on 8 December 1987 and the dedication ceremony that followed the final INF Treaty inspection at Cape Canaveral in May 2001. The history of Army missiles at the Cape has been a rich one, and we do well to acknowledge and remember it.

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October 2006

INTRODUCTION

On the night of 17/18 August 1943, RAF Bomber Command launched nearly 600 heavy bombers on one of the most significant air raids of World War II. The raid's objective was the destruction of Nazi Germany's V1 and V2 research station and industrial complex at Peenemünde, located about 100 miles north of Berlin on the Baltic coast. The Germans began work on Peenemünde in 1936. Strict Gestapo security kept the installation's purpose hidden for years, but the secret eventually leaked out from a variety of sources (e.g., documents smuggled to the British Embassy in Oslo, information from foreign workers at the complex and *Enigma* decryptions of secret messages). The extent of the facility's threat to Britain was confirmed by reports of the successful launch of a V2 in early October 1942 and photos gathered by allied aerial reconnaissance. By early 1943, the British were convinced that Peenemünde was the Nazis' main rocket center for the development of the pulse-jet-powered V1 and the rocket-powered V2.[1] Though the first of these *Vergeltungswaffen* (reprisal or 'vengeance' weapons) would not fall on London until 13 June 1944, the threat demanded swift and decisive action. Consequently the task of planning and executing the destruction of Peenemünde was given to Air Chief Marshal Arthur "Bomber" Harris and RAF Bomber Command.[2]

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[1] The V1 was a gyroscopically controlled unmanned aircraft built of pressed steel and plywood. With a wingspan of approximately 18 feet, the 26-foot-long V1 (including its 1,870-pound Amatol high explosive warhead) weighed about 5,000 pounds. The V1 was launched by an aircraft or catapulted from a steam-piston ramp, and it typically flew somewhere between 3,000 and 5,000 feet in altitude at a cruising speed of about 350 miles per hour. (Top speed: 410 miles per hour.) The V1 approached its target on a preset compass heading. Once the pre-programmed distance to the target had been reached, an air log directed the V1's elevators to turn down to crash-land or "dive" the vehicle into the ground. In contrast to the V1, the V2 was an internally guided ballistic missile with a range of 200 statute miles and a maximum speed of more than 3,300 miles per hour. It weighed approximately 28,000 pounds, and it carried a 2,200-pound warhead. Like the V1, the V2 was not terribly accurate. With a Circular Error Probability (CEP) of 11 miles, the V2 could be aimed at city-sized area targets and staging areas, but it was virtually useless against smaller targets or forces on the move. However, with the emergence of relatively small thermonuclear weapons in the 1950s, the V2's *potential* evolution into a much more capable ballistic weapon system made it a remarkable (and ominous) development for the future.

[2] Robin Neillands, "The Bomber War," pp 257, 258, 259, Barnes & Noble, 2005; John Cornwell, "Hitler's Scientists," pp 255, 386, Viking Penguin, 2003; "Fi-103/V-1 "Buzz Bomb," Warbirds Resource Group; undated; "Statistics of the V2," v2rocket.com, undated.

Harris and his staff planned the raid on Peenemünde as both a precision strike and an area bombing mission. Photo interpreters conducted a thorough examination of aerial reconnaissance photos, and they were able to identify the principal facilities specifically. Due to a recent advance in targeting technology known as H_2S, pathfinder aircraft crews would be able to mark three main specific target areas — the V2 production plant, the experimental station and the homes of the leading scientists — with Target Indicators (TIs) to ensure those locations received special attention. In addition to the precision strikes, the entire area would be bombed heavily to hamper V2 program recovery efforts. Due to the 'top secret' implications of the target and the mission, RAF bomber crews were *not* told that Peenemünde was an experimental rocket complex. Instead, briefing officers explained the facility was a high-priority target because it was developing radar aids for *Luftwaffe* fighters. The importance of the mission was stressed, and crews were given to understand that they would have to return to the target on later raids if it were not effectively smashed on the first (or any later) raid. As such, the Peenemünde raid on 17/18 August 1943 was mounted as a 'maximum effort' by RAF Bomber Command.[3]

The raid was launched during a full-moon period to improve navigation to the target. Though some aircraft had to turn back with mechanical problems, 560 of the 596 bombers dispatched against Peenemünde reached their targets and dropped a total of 1,800 tons of bombs. The first Target Indicators missed the rocket shops and fell on the forced labor workers' camp at Tressenheide[4] where approximately 500 foreign workers were killed in the first attacks. As the raid continued, the master bomber noticed the bad TI drop, and pathfinders were redirected to mark the targets properly. The development works buildings and administrative offices were heavily damaged, but the rocket assembly areas remained largely intact. The raiders also struck engineers' homes and barracks. One hundred and seventy civilians (including Chief Engine Designer Walter Thiel and his family) were killed during the attack on the main facility. Including foreign workers, more than 700 people lost their lives in Peenemünde during the night. RAF losses were heavy as well: German flak batteries and night fighters shot down 40 aircraft

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[3] Neillands, "The Bomber War," pp 257, 258, 259.

[4] Despite the Gestapo's mania for secrecy, wartime necessity compelled Nazi officials to look beyond Germany for additional sources of labor for Peenemünde. Forced labor workers began arriving from France and Holland in 1941, and a small concentration camp was constructed in 1942 to house slave laborers. The 12,000 workers living in Peenemünde in 1943 included 3,000 foreign workers "living behind the wire."

including 17 bombers from 5 Group, which was just wrapping up the raid when the first night interceptors arrived. Significantly, Dr. Wernher von Braun and his team of V2 scientists (apart from Dr. Thiel) survived the raid, and Peenemünde was producing approximately 20 V2s per month (for research purposes) by September 1943. That fact aside, it is quite clear that the raid delayed V1 and V2 production sufficiently to ensure neither *Vergeltungswaffe* was available to oppose the D-Day landings on 6 June 1944.[5] In the meantime, the Germans left Peenemünde's damaged and destroyed buildings untouched for appearance's sake to discourage further allied attacks.[6]

Following the raid in August 1943, the Peenemünde Planning Committee selected three new locations for V2 production facilities: 1) a southern plant consisting of two facilities in the Vienna-Neustadt area and Friedrichshafen, 2) an eastern plant near Riga, Latvia, and 3) a central plant in the Harz Mountains near the city of Nordhausen. As events unfolded, allied air raids on the Southern Plant's facilities were so severe that only partial assembly operations were ever possible there. The Russians captured the Eastern Plant in July 1944. That left the Mittelwerke (Central Works) as the major center for V2 production. Under the brutal administration of the SS, the Nordhausen plant became literally a 'hell on Earth' for the concentration camp prisoners working there.[7] Starvation, sickness, physical collapse due to overwork, beatings and executions

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[5] The first V1 struck London on 13 June 1944, and the first two V2s launched from Holland landed on East and West London on the evening of 8 September 1944.

[6] Neillands, "The Bomber War," pp 259, 260, 261; Cornwell, "Hitler's Scientists," p 344; Paul H. Satterfield and David S. Akens, "Historical Monograph, Army Ordnance Satellite Program," p 17, ABMA History Office, 1 Nov 1958.

[7] Of the 10,000 people working at Nordhausen at any given time, fully 9,000 were foreign workers, concentration camp inmates and prisoners of war. The top layer of the workforce consisted of "skilled German employees," but most of the rest were brutalized slave laborers. Intimidation was the order of the day, so no one challenged the SS' administration of the Mittelwerke's factories, storage depots, facilities and prison camps. The stage was set for this abomination within days of the raid on Peenemünde. In late August 1943, Reichsführer-SS Heinrich Himmler got Hitler to agree to let the SS share in the management of the V2 program. Though Armaments Minister Albert Speer retained ultimate control of the V2 program through the "A-4 Special Committee" he had set up in December 1942, SS-Brigadeführer Hans Kammler was given executive responsibility for construction of the underground factory in a pair of mile-long railway tunnels under Kohnstein Mountain near Nordhausen. Four thousand male prisoners were drafted within six weeks to complete the Mittelwerke factory including the first 20 cross-tunnel connections between the existing railway tunnels. By November 1943, 8,000 prisoners

of workers suspected of sabotage were commonplace occurrences at the facility. Estimates vary, but at least 20,000 of the 60,000 prisoners employed at Nordhausen — mostly Russians, Poles, Frenchmen and Jews of various nationalities — died at the facility during its operations or during SS efforts to relocate prisoners before American forces arrived in April 1945.[8]

Observers are quick to note that more people died *manufacturing* V2s than died in V2 attacks, but the number of bombing victims was still quite considerable. Approximately 10,000 V2s were built at Nordhausen, and about 3,300 V2s (from all sources) were launched by tactical units during the war. More than 1,000 V2s were sent against London and Southern England, and perhaps as many as 1,700 V2s were fired on greater Antwerp after the Allies captured the port city to support their forces in the fall of 1944. In late April 1945, the *Manchester Guardian* reported 2,754 killed and 6,523 seriously injured in the V2 attacks on Britain between 8 September 1944 and 27 March 1945. Casualties from V1 and V2 attacks on greater Antwerp came to more than 3,700 civilians killed and 6,000 injured.[9] The final V1 attacks were launched on 29 March 1945, just a few weeks before Germany's final surrender on 8/9 May 1945. This would not close the book on the V1 cruise missile or the V2 ballistic missile. Allied plans to acquire Germany's latest technology for future military applications were well underway, as we shall see.[10]

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were being worked to exhaustion at the Mittelwerke. Many more slave laborers would be needed as replacements before the end of the war.

[8] Neillands, "The Bomber War," p 335; Cornwell, "Hitler's Scientists," p 345; Satterfield and Akens, "Historical Monograph, Army Ordnance Satellite Program," pp 16, 17; Paul Grigorieff, "The Mittelwerk/Mittelbau/Camp Dora Mittelbau GmbH – Mittelbau KZ," p 1, undated, v2rocket.com.

[9] Approximately 30,000 V1s were built during World War II. The Germans launched more than 10,000 of them against England and 8,000 against targets on the continent of Europe. Reports indicate 2,419 V1 warheads exploded in Britain's Central Defense Region resulting in 6,184 civilian deaths and 17,981 serious injuries. The combined total of military casualties from V1 attacks came to 1,200 killed or wounded.

[10] Satterfield and Akens, "Historical Monograph, Army Ordnance Satellite Program," pp 17, 18; "V2 Guided Ballistic Rocket," constable.ca website, undated; Cornwell, "Hitler's Scientists," p 387; "V-2 Rockets," Spartacus, Schoolnet.co.uk, undated; Captain George W. Cully, USAF, "A KIND OF DÉJÀ VU: Some Historical Perspectives on Cruise Missile Defense," *Airpower Journal*, Spring 1990; "Antwerp X: The AAA War Against the Buzz Bombs," undated, skylighters.org; "Antwerp – City of Sudden Death," p 10, v2rocket.com.

Roughly two years before the end of World War II in Europe, Allied commanders and their staffs began discussing serious plans for the capture and exploitation of Germany's wartime technology, scientists and engineers. As the Commander of the Eighth Air Force's Service Command, Brigadier General Hugh J. Knerr was one of the first senior leaders to voice this sentiment. Around the middle of 1943, Knerr recommended the Army Air Forces "make full use of established German technical facilities and personnel before they were destroyed or disorganized." Discussions with the British ensued. By early June 1944, Lieutenant-General Sir Ronald Weeks (Deputy Chief of Britain's Imperial General Staff) declared his conviction that the seizure of German research and development programs was "vitally important" to Britain's immediate postwar goals. Anglo-American collaboration along those lines led to a plan in late 1944 to identify and secure the services of Nazi scientists (ECLIPSE) as a subset of the larger effort (Project OVERCAST) to capture the aforementioned programs. By April 1945, Major General Knerr (then Deputy Commanding General of U.S. Air Forces in Europe) was advocating the transfer of important German scientists and their families to the United States under Project OVERCAST. U.S. Secretary of State Cordell Hull approved the transfer of Dr. von Braun and a collection of 'handpicked' rocket experts to the United States in late June 1945. The first seven German experts arrived at New Castle Army Air Base on 20 September 1945, and they were transferred to the Aberdeen Proving Ground, Maryland, to begin sorting out more than 40 tons of captured V2 program documents. Dr. von Braun and about 120 German scientists and engineers were sent to Fort Bliss, Texas (near El Paso) to train American personnel and to assist with the refurbishment, assembly and launch of V2s collected in Germany at the end of the war.[11]

In light of reliable intelligence on the V2, American leaders also saw the need for a 'home grown' rocket development program. With that goal in mind, the Chief of Army Ordnance's Technical Division established its Rocket Branch in September 1943 to manage rockets and missiles as newly emerging weapon technologies. The Army Ordnance Department capitalized on its excellent working relationship with the nation's scientific community and commercial industry to field new weapons, but it also required a core establishment of highly skilled people and special facilities to perform research and development *within* Ordnance Department installations. Put simply, the Army began orchestrating various missile programs

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[11] Saterfield and Akens, "Historical Monograph, Army Ordnance Satellite Program," pp 25, 26, 36; Cornwell, "Hitler's Scientists," p 420.

from its own facilities, university ‘think tanks,’ and other commercial and government laboratories before transferring production to industrial plants and factories as these technologies became mature. In later years, the Army’s guided missile development programs also required coordination with similar efforts by the U.S. Air Force and U.S. Navy under the auspices of the Defense Department’s Research and Development Board to help curb unnecessary and costly duplication of effort.[12]

Before we continue, it must be noted that the Army’s first guided missile effort grew out of an initiative in the mid-1930s. The Army Ordnance Department sponsored Project ORD-CIT (Ordnance-California Institute of Technology) in 1936 to design and launch small rockets. The project yielded America’s first mass-produced Jet Assisted Take-Off (JATO) units for aircraft. In January 1944, Army Major General Gladeon M. Barnes authorized expansion of ORD-CIT to develop the PRIVATE and (later) WAC CORPORAL instrumented rockets to test basic rocket launching principles and conduct atmospheric research at altitudes up to and (later) above 100,000 feet.[13] As work on the PRIVATE continued, the Ordnance Department placed a $3.3 million contract with California’s Jet Propulsion Laboratory in May 1944 for general research on guided missiles. More significantly, Ordnance signed a contract with the General Electric Company (GE) on 20 November 1944 to develop various kinds of long-range guided missiles that could be used against ground targets and high-altitude aircraft. This was the first of the Army’s Project Hermes contracts. The contract did not include full-scale development of the missiles or the production of their warheads and fuzes, but GE agreed to design, develop and

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[12] John W. Bullard, “History of the Redstone Missile System,” pp 3, 5, 6, 7, Army Missile Command Historical Division, 15 October 1965.

[13] The first solid-propellant PRIVATE rockets were launched from Camp Irwin Reservation near Barstow, California, before the end of 1944. Since the second-named missile was expected to fly higher than the PRIVATE, its designers dubbed it the CORPORAL. It was a liquid-fueled rocket designed to carry about 25 pounds on instrumentation to an altitude of at least 100,000 feet. The first WAC (Without Attitude Control) CORPORAL was launched at White Sands in October 1945.The WAC CORPORAL exceeded its designers’ expectations and routinely achieved altitudes above 200,000 feet. The WAC CORPORAL was about 16 feet long and weighed 700 pounds. It was used as an upper stage on some V2 experimental launches at White Sands in the late 1940s, and a slightly modified version of the rocket (WAC CORPORAL B) was featured as the second stage on both BUMPER (V2) missiles launched from Cape Canaveral in July 1950.

engineer the missiles as well as provide any guidance controls, ground equipment and homing devices that might be needed for these research vehicles.[14]

GE planned to accomplish the contract work in three phases. First, the company would conduct a thorough search of all available literature on the subject of guided missiles. Then it would dispatch of a group of scientists and engineers to Europe to study captured guided missile documents and hardware. Finally, GE would design and develop experimental vehicles and support equipment as outlined in the terms of the contract.[15]

Thus, in early 1945, three important threads in our story were about to cross paths. As Russian forces approached Peenemünde from the east in early April 1945, Dr. von Braun and about 500 members of his group fled south to Nordhausen to avoid the Russians and await capture by American forces. Major General Barnes (noted previously in connection with Project ORD-CIT) managed to get some Ordnance Department men assigned to Army Intelligence in October 1944, and Colonel Holger N. Toftoy was chosen to lead Ordnance's technical intelligence teams when they went into Germany to secure German ordnance and equipment as part of Project OVERCAST. With this charter in mind, the Army sent GE's Hermes Project Manager Richard Porter and several members of his staff to Europe in March 1945 to assist Colonel Toftoy's teams as they advanced into Germany. Over the next five months, Dr. Porter and his staff would be instrumental in conducting interviews with German rocket experts, arranging the transportation of rocket components, equipment and documents with British assistance, and expediting the transfer of German rocket experts and their families to the United States under a continuation of OVERCAST later known as Project PAPERCLIP.[16]

After waiting patiently for several weeks for the Americans to contact him, Wernher von Braun sent his brother Magnus "down the mountain on a bicycle" on 10 May 1945 to report his

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[14] Saterfield and Akens, "Historical Monograph, Army Ordnance Satellite Program," pp 23, 40, 42; Bullard, "History of the Redstone Missile System," pp 7, 8; Andreas Parsch, "JPL RTV-G-1/RV-A-1 *WAC Corporal,"* Designation-Systems Directory of U.S. Military Rockets and Missiles; "WAC CORPORAL," *Space Race* website, undated.

[15] Bullard, "History of the Redstone Missile System," p 8.

[16] Saterfield and Akens, "Historical Monograph, Army Ordnance Satellite Program," footnote, p 28; Biographical Summary, "Holger Nelson Toftoy, Major General United States Army," Arlington Cemetery website, undated; Mark Kahn, "Richard Porter Collection, Historical Note," National Air And Space Museum Archives Division, NASM website, undated.

group's location to the local Allied authorities. Colonel Toftoy's assistant, Major James P. Hamill, made contact with the rocket scientists and engineers and arranged for the initial interviews and background checks. Strictly speaking (and totally contrary to the goals of OVERCAST), Major Hamill had written orders to leave Nordhausen's resources intact for the Russians because the facility was in the Soviet zone of occupation. Nevertheless, the Russians were no angels when it came to grabbing anything of value, and Army Ordnance wasn't about to let a technological gold mine slip through its fingers. Major Hamill was told "unofficially and off the record" to remove as much equipment, hardware and documentation as possible "without making it obvious that we had looted the place." With British help, the equivalent of nearly 100 complete V2s — together with spare parts, ground equipment, manuals, plans and other documents — were transferred to Antwerp and shipped to the United States. The haul came to about 300 train carloads of material. Colonel Toftoy flew to Washington D.C. in May 1945 to secure the transfer of approximately 300 members of von Braun's staff via OVERCAST.[17]

Approximately 150 German rocket scientists and technicians were offered five-year contracts in the United States and a chance to bring their families to America at a later date. One hundred twenty-seven accepted the offers, and they arrived at the Aberdeen Proving Ground or Fort Bliss, Texas, before the end of 1945.[18] The Russians captured much of von Braun's production team, but von Braun assured his new employers that the U.S. "got the best of our group."[19]

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[17] In a secret memo initialed and dated 19 March 1946 (long since declassified), Headquarters Army Air Forces changed the code word 'OVERCAST' to 'PAPERCLIP' on 13 March 1946 due to a compromise of the code word. The meaning of OVERCAST was not compromised, so it was attached to PAPERCLIP *after that date*. Strictly speaking, von Braun and his team came to the United States under the auspices of OVERCAST, but as more Germans and Austrians arrived under Project PAPERCLIP, they became known collectively as the Project PAPERCLIP scientists. (Source: Declassified Memo, Brigadier General N. B. Harbold, Chief Air Info Div, Asst Chief Air Staff, "Changing of the Code Word "OVERCAST," stamped 19 Mar 46.)

[18] By May 1948, a total of 1,136 German and Austrians (including 644 dependents) were living in the United States thanks to Operation PAPERCLIP. Of the rocket experts, 177 were working for the U.S. Army, 205 for the Air Force, 72 for the Navy and 38 for the Department of Commerce.

[19] Saterfield and Akens, "Historical Monograph, Army Ordnance Satellite Program," pp 27, 28, 29, 32, 33, 34, 36; Biographical Summary, "Holger Nelson Toftoy, Major General United States Army," Arlington Cemetery website, undated.

In addition to Aberdeen Proving Ground and Fort Bliss, the Ordnance Department considered three other facilities (e.g., Picatinny Arsenal, Frankford Arsenal and Watertown Arsenal) to support its guide missile research program in the last half of the 1940s. Unfortunately, none of the three were large enough to support V2 flight tests, so Ordnance looked to the White Sands Proving Ground, New Mexico, which it had acquired for other 'in-house' missile programs in the spring of 1945. Though considerably smaller than the (future) Atlantic Missile Range, White Sands measured 125 by 40 miles, and its isolation, flat topography and desert environment were ideal for launching V2s, early experimental rockets (i.e., PRIVATE –F, WAC CORPORAL, CORPORAL-E, HERMES A1 through A3, and LACROSSE), upper stages and instrumented payloads.[20] Since planners expected White Sands to support guided missiles built elsewhere, shops and labs on the Proving Ground were geared mainly toward final missile assembly operations and minor changes to various components. Fort Bliss remained the research hub, and it provided the laboratories, component testing facilities and a small production shop required to support the majority of activities undertaken by the PAPERCLIP scientists and their domestic colleagues. The Ordnance Department established the Ordnance Research and Development Division Suboffice (Rocket) at Fort Bliss, Texas, to oversee a whole host of rocket research projects.[21]

The U.S. Army sponsored and eventually fielded the CORPORAL and LACROSSE surface-to-surface tactical missile systems,[22] but it also invested more than $100 million in

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[20] Ordnance realized White Sands was not as large as "might be desired," but it could be used for early missile types like the V2 and small-scale prototypes of larger missiles. The proving ground was located in Otero County, New Mexico, situated mainly in the Tularosa Basin between the Organ, San Andres and Sacramento Mountains. The Headquarters area at White Sands was about 40 miles north of El Paso and 28 miles from Las Cruces, New Mexico. The first work began onsite on 25 June 1945, and White Sands Proving Ground was activated per a Chief of Army Services Forces special order dated 13 July 1945. Army troops began moving into the White Sands cantonment area on 10 August 1945, and the V2s started arriving about a month later.

[21] Satterfield and Akens, "Historical Monograph, Army Ordnance Satellite Program," pp 39, 47; Bullard, "History of the Redstone Missile System," pp 16, 17; "To the firing table for 1947," (White Sands Missile Range History), pp 1, 2, 4, official White Sands Missile Range website, undated.

[22] The 11,400-pound CORPORAL surface-to-surface missile was an outgrowth of the CORPORAL E test vehicle, which had its first flight in May 1947. The Jet Propulsion Laboratory (JPL) was the main contractor for the CORPORAL, but the missile's production contract went to the Firestone Tire and Rubber Company in 1951. The Army activated three

Hermes missile research projects between November 1944 and the end of 1954.[23] None of the Hermes research projects led to the successful deployment of a missile system, but the Ordnance Department looked back on the Hermes effort as a solid investment in the future. When GE started work on the Hermes projects, the company had very little practical experience with rocket propulsion systems, missile fuels, guidance and control systems and testing equipment. By the end of 1954, GE had the necessary equipment to control, track and evaluate missile flights, and it had a solid statistical foundation for rocket motor design. The company also compiled a vast collection of aerodynamic and technical data which would invaluable to anyone planning to design future missile airframes and component structures. General Electric developed better rocket fuels, more rugged and efficient motors and America's first inertial guidance system. (A similar system would be used in the REDSTONE later on). Fifty-two V2s in various configurations were launched from White Sands and Cape Canaveral between 1946 and the end of June 1950. White Sands recorded its longest V2 flight (111 miles) on 5 December 1946 and its highest V2 flight (116 miles) on 17 December 1947. Those experiences, accomplishments and technical advances would serve the Army well as it moved ahead with the REDSTONE program in the early 1950s.[24]

CORPORAL missile battalions in March 1952, and the first CORPORAL battalion was deployed to Europe in 1955. The CORPORAL remained in service with Army field units until the SERGEANT replaced it in 1962 and 1963. The LACROSSE started as a project at the Applied Physics Laboratory (APL) at John Hopkins University in 1947. Cornell Aeronautical Laboratory, Inc. joined the effort under contract to the Navy Bureau of Ordnance in the same year. The project was transferred to Army Ordnance in August 1950, and the 2,300-pound LACROSSE short-range missile was deployed in 1959. It was declared obsolete in 1964.

[23] GE's Hermes subcontracts included: 1) a short series of Hermes A1 guidance and control system component flights on V2s in 1950 and 1951, 2) the Hermes A2 solid propellant missile research project, 3) the Hermes A3 liquid-fueled surface-to-surface ballistic missile project (which persisted in one form or another until November 1954), 4) the Hermes B1, B2 and Hermes II ramjet-powered surface-to-surface cruise missile projects (which led to an accidental V2 landing on a barren hillside in Juarez, Mexico in May 1947), and the Hermes C — a series of long-range surface-to-surface guided missile studies and design efforts. The Hermes C1 project was transferred from GE to the Ordnance Guided Missile Center in September 1950. It led (with information from other Hermes projects) to the very successful REDSTONE effort a few years later.

[24] Bullard, "History of the Redstone Missile System," pp 14, 15, 16; Andreas Parsch, "SSM-A-16, General Electric SSM-A-16 *Hermes* A-3B (and other *Hermes* variants)," pp 2, 3, 4, 5, 6, 8, Designation-Systems Directory of U.S. Military Rockets and Missiles, Appendix 1: Early

The Army's missile projects outgrew their original support systems well before 1950, but a remedy to that situation was not long in coming. As Chief of the Rocket Branch, Colonel Holger N. Toftoy complained to his superiors in April 1948 that Ordnance's facilities (i.e., Fort Bliss and White Sands) were no longer adequate to meet the agency's requirements for guided missile research and development. Toftoy recommended the Ordnance Department establish a more suitable Ordnance Rocket Laboratory as a first step. Ordnance agreed — a larger and longer flight test area than the White Sands Proving Ground was needed, and a new research and development center closer to the new testing range made sense. With the transfer of the recently inactivated Banana River Naval Air Station to the Air Force in September 1948, it became obvious that the Air Force planned to develop Cape Canaveral as a hub of a major new guided missile range over (and into) the Atlantic Ocean. Following a survey of possible sites for an arsenal closer to this new missile range, the Chief of Ordnance announced on 18 November 1948 that Redstone Arsenal at Huntsville, Alabama, would be reactivated as a new guided missile facility. The Ordnance Rocket Center was established there on an interim basis in February 1949, and Redstone Arsenal went back on active status on 1 June 1949. In the meantime, Huntsville Arsenal (a Chemical Corps facility adjacent to Redstone Arsenal) was inactivated by Third Army. It, too, was pressed back into service to support the Army's guided missile programs. On 15 April 1950 the Ordnance Guided Missile Center was established at Redstone Arsenal as the Ordnance Department's key center for guided missile research and development.[25]

Orders to move the Fort Bliss missile experts to Redstone Arsenal were issued on 21 March 1950. Approximately 800 Army personnel and GE employees were transferred along with von Braun and his team in June 1950. By that time, the War Department Equipment Board and the Army Field Forces Board had been recommending various tactical missile studies, reevaluations and updates for about five years. Significantly, none of those recommendations spelled out missile requirements in precise terms. Finally in 1950, the Office, Chief of Army Field Forces directed agencies to focus their efforts on developing requirements for an Army

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Missile and Drones; Satterfield and Akens, "Historical Monograph, Army Ordnance Satellite Program," pp 42, 43, 44, 45; "REDSTONE," redstone.army.mil website, undated; "CORPORAL," redstone.army.mil website, undated; "The Corporal Program," official White Sands Missile Range website, undated; "LACROSSE," redstone.army.mil website, undated.

[25] Bullard, "History of the Redstone Missile System," pp 17, 18, 19; Dr. Kaylene Hughes, "Pioneering Efforts in Space," p 2, redstone.army.mil website, undated.

surface-to-surface missile with a range up to 500 miles.[26] The Office, Chief of Ordnance directed the Ordnance Guided Missile Center to begin a preliminary study of technical requirements for the 500-mile missile on 10 July 1950. Detailed military characteristics were lacking, so researchers were instructed to consider all possible choices — solid-fueled or liquid-fueled rockets, rockets with a ramjet upper stage, two-stage ballistic missiles and glide rockets. Any vehicle type or combination of types could be recommended, as long as the proposed missile could carry a 3,000-pound warhead at a speed of Mach 2 or higher out to a distance of 500 nautical miles. The warhead could be any length, but no more than 44 inches in diameter. In August 1950, the Office, Chief of Ordnance expanded the instructions to include consideration of an additional missile capable of carrying a 32-inch diameter warhead weighing 1,500 pounds the required distance at similar speed. Both instructions specified a Circular Error Probability (CEP) of 1,000 yards for the missiles.[27]

On 11 September 1950, the Ordnance Department ordered the transfer of responsibility for the Hermes C1 project from the General Electric Company to the Ordnance Guided Missile Center. The project was given a high priority, but Army officials expected it to continue as only a preliminary study through the end of Fiscal Year 1951. In the meantime, scientists and engineers struggled to convert facilities at Redstone Arsenal into proper offices and laboratories. The Center's personnel office also had trouble finding and recruiting additional qualified personnel. Remarkably, von Braun completed his report on the Center's study of the 500-mile missile very quickly, and he briefed the Committee on Guided Missiles on his team's findings and recommendations during the Committee's 30th Meeting on 25 January 1951.[28]

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[26] In its final report in October 1950, the Army Field Forces Board confused the issue by listing requirements for missiles capable of reaching targets at 35, 150 and 750 nautical miles. The Board recommended development of short-range (5 to 35 nautical miles) missiles first, with mid-range (20 to 150 nautical miles) and longer range (150 to 750 nautical miles) missiles to follow in descending order of importance. Fortunately, the Ordnance Guided Missile Center developed a more focused plan of action.

[27] Lloyd S. Swenson, Jr., James M. Grimwood, and Charles C. Alexander, "This New Ocean, A History of Project Mercury," p 21, NASA SP-4201, 1966; Bullard, "History of the Redstone Missile System," pp 20, 21, 22, 23, 24; MSFC History Office, "Notes on the Von Braun Team's Move to Huntsville," msfc.nasa.gov website, undated; "REDSTONE," redstone.army.mil website, undated.

[28] Bullard, "History of the Redstone Missile System," pp 24, 25, 27, 28.

The study's recommendations emphasized the use of proven and available components to ensure the missile met the Army's needs in a timely manner. In keeping with that strategy, the Center's engineers favored North American Aviation's XLR43-NA-1 power plant. The engine had been developed as a booster for the Air Force's NAVAHO winged missile, but it was actually an improved version of the V2 rocket engine.[29] As such, the engine could be used to power a single-stage ballistic missile or a rocket-assisted ramjet vehicle. Since much of its development was completed, officials estimated the North American engine could be put into production before the end of 1951. Researchers considered two different missile guidance systems built by GE and the Consolidated Vultee Aircraft Corporation respectively, but they did not recommend either one. GE's system employed phase-comparison radar technology deemed vulnerable to countermeasures, and the Consolidated AZUSA system had not been tested or proven. Given the state-of-the-art in guidance systems, von Braun's team favored the inertial guidance system GE had developed in the late 1940s. The study concluded with the recommendation that the Army's new long-range weapon should be a single-stage, liquid-fueled ballistic missile equipped with a North American XLR43-NA-1 rocket engine. It should have an inertial guidance system supplemented with radio navigation to provide greater accuracy. Efforts should be made to perfect a homing guidance system to reduce the missile's CEP to as little as 150 yards.[30]

The Hermes C1 project was in line with the study's recommendations for the 500-mile missile when Colonel Toftoy [31] informed the Guided Missile Center in February 1951 that the payload requirement for the new missile had been changed upward to 6,900 pounds. The Army wanted a practical missile quickly. It was needed to carry an efficient (but heavy) nuclear warhead selected from America's available inventory of weapons. The missile's range was less important than its payload capacity, but a range of at least 100 nautical miles would be required.

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[29] The Center thought Aerojet Engineering Corporation's new AJ-10-18 engine had considerable potential as the main engine for a two-stage liquid fueled ballistic missile. As proposed, the AJ-10-18 might develop as much as 160,000 pounds of thrust (versus about 75,000 pounds of thrust from North American's engine). Unfortunately Aerojet's engine was still in the planning stage when the preliminary study concluded.

[30] Bullard, "History of the Redstone Missile System," pp 28, 29, 30, 31, 32.

[31] At the time, Colonel Toftoy was Chief of the Rocket Branch at the Office, Chief of Ordnance.

At this point, the Army wanted to concentrate its tactical missile efforts on the CORPORAL, Hermes A3, and Hermes C1 to carry three different atomic warheads. The Army recommended rapid development of all three missiles,[32] and Mr. K. T. Keller (Director of Guided Missiles, Office of the Secretary of Defense) readily agreed to accelerate the Hermes C1 Research and Development (R&D) program. On 10 July 1951, the Office, Chief of Ordnance transferred responsibility for the Hermes C1 to the Redstone Arsenal, and the Guided Missile Center was given primary responsibility (except for certain warhead components).[33] The Hermes C1 was eventually renamed the REDSTONE on 8 April 1952.[34] The Chrysler Corporation received a letter order contract for the REDSTONE in October 1952, and the deal was sealed on 19 June 1953. The Office, Chief of Ordnance wanted Chrysler to produce as many of the missiles as possible, but the first twelve missiles were fabricated and assembled by the Guided Missile Development Division at Redstone Arsenal. The Division also assembled twelve more REDSTONEs (missiles 18 through 29) using Chrysler-procured components. The Guided Missile Center conducted the first REDSTONE launch at Cape Canaveral on 20 August 1953.[35]

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[32] As events turned out, only two warheads were needed to satisfy Army requirements, and the Hermes A3 was dropped in 1954. Work continued on the other two missile projects, and the CORPORAL was deployed to Europe in 1955. The REDSTONE was deployed in 1958.

[33] Picatinny Arsenal became responsible for the warhead's adaptation kit, radio proximity fuze and Safe and Arm (S&A) mechanism. Picatinny delegated the fuze and S&A work to the Diamond Ordnance Fuze Laboratory. The Atomic Energy Commission and the Sandia Corporation were responsible for the explosive components in the warhead.

[34] Though the Defense Department and the Department of the Army referred to the missile as the Hermes C1, it was designated the XSSM-G-14 and (later) as the XSSM-A-14 within the national guided missile program's list of projects. Some officials in the Ordnance Guided Missile Center referred to the missile as the URSA, then the Office, Chief of Ordnance changed the name to MAJOR. As noted above, the missile received its final name in April 1952 — REDSTONE.

[35] Bullard, "History of the Redstone Missile System," pp 35, 36, 37, 42, 49, 50, 88; Satterfield and Akens, "Historical Monograph, Army Ordnance Satellite Program," p 49; "REDSTONE," p 2, redstone.army.mil website, undated.

REDSTONE

Before we discuss the REDSTONE missile's principal features, flight tests, personnel training programs and combat unit deployments, we should look at the organizations, plans, facilities and range instrumentation that were essential pre-conditions for the missile's early development. Plans often change, and the REDSTONE project acquired several new objectives when Army planners refocused it to support development of the JUPITER Intermediate Range Ballistic Missile (IRBM) in the mid-1950s. Changes aside, the project achieved its original goal when the REDSTONE was deployed as a weapon system in 1958. The missile also supported unmanned and manned space missions in 1960 and 1961.

As the Hermes C1/REDSTONE Research and Development (R&D) effort began at Redstone Arsenal in 1951, the Guided Missile Center's immediate objectives were to: 1) demonstrate the new weapon system's components and 2) begin production and assembly of the complete (prototype) missile. The Center planned to fabricate and assemble the first 12 missiles 'in-house'. Those missiles would be built in three lots of four identical REDSTONEs each, which still allowed for changes among the lots. Chrysler would produce 50 additional missiles at the Naval Industrial Reserve Aircraft Plant in Warren, Michigan,[36] for delivery to the Guided Missile Center. Once the missiles arrived, the Center's people planned to perform additional inspections, run static tests, and install special equipment. The Center also had a three-phased plan for overall development of the project. In the first phase, the Center would act as the prime contractor. The Center's development shops would build about a third of the REDSTONE's components. The rest of the hardware would be received from subcontractors, and the development shops would complete fabrication and assemble, inspect, test and release the completed missiles for flight testing. In the second phase, the Center planned to contract out

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[36] Chrysler planned to use about 200,000 square feet of this Navy jet engine plant to build and assemble REDSTONEs. The Navy's Bureau of Aeronautics approved the use of the plant "for other defense production when it was not being used [to produce] naval aircraft jet engines" on 22 December 1952. Chrysler was essentially a tenant during its early years at the plant, but the Corporation received funding to restore the facility and its equipment to support REDSTONE production in 1954. The contract was expanded to include support for the JUPITER missile program in October 1956. The Navy transferred the plant to the Army in October 1957.

fabrication and assembly of the major structural components (e.g., warhead section, center section and tail section) but continue 'in-house' inspections, assembly operations and final preparations for flight testing as before. In the final (pilot production) phase, contractors would accomplish the basic fabrication and final assembly of the missiles. Nevertheless, the new missiles would still be sent through the Arsenal's shops to receive measuring equipment, final inspections and final preparations for launch.[37]

Unfortunately, the Guided Missile Development Division ran into trouble with long lead times on component delivery. By October 1951, it became clear that contractors would have to begin building major assemblies as well as components as soon as the designs were completed. A significant number of the missiles would be built at Redstone Arsenal, but contractors would be involved early in the process.[38] With that constraint in mind, the Division combined the first and second phases of the development plan and began looking for various contractors to serve as active partners in the design and fabrication process.[39]

The Ordnance Corps already had a cost-plus-fixed-fee letter order contract with North American Aviation to modify the design and performance characteristics of the XLR43-NA-1 rocket engine to meet Hermes C1 requirements.[40] North American eventually delivered seven different (and interchangeable) versions of the NAA 75-110 engine for the REDSTONE project. The Division completed the preliminary design for the REDSTONE's fuselage in December

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[37] John W. Bullard, "History of the Redstone Missile System," pp 43, 44, 46, 47, 82, 103, Army Missile Command Historical Division, 15 October 1965.

[38] According to John Bullard, the first 11 REDSTONE missiles were built by Redstone Arsenal. Officials also attached "RS" designators to ten additional missiles modified for the JUPITER Research and Development and EXPLORER space programs. "RS/CC" designators (indicating Redstone Arsenal and Chrysler co-production) were assigned to five vehicles used on JUPITER AND EXPLORER missions and four space vehicles used on Mercury/Redstone missions. The assembly of two other Mercury/Redstone vehicles (MR-1 and MR-2) was credited to Redstone Arsenal alone.

[39] Bullard, "History of the Redstone Missile System," p 55, 162, 163, 166, 167.

[40] The contract had been placed on 27 March 1951. It was worth $500,000 initially, and North American agreed to deliver a mock-up and two complete prototypes of the new engine, which was designated NAA 75-110. By April 1952 a contract supplement raised the number of prototypes from 2 to 19, and other contract changes added provisions for spare parts, test equipment and engine modifications per Guided Missile Development Division direction. The contract was completed in September 1960 at a total cost of $9,414,813.

1951, but it got the Reynolds Metals Company of Louisville, Kentucky, to manufacture it.[41] The Division completed about 85 percent of the design for a prototype guidance and control system in December 1951, but it decided to give the Ford Instrument Company (a division of the Sperry Corporation) a contract to simplify and finalize the design and build "a prototype of the complete, gyroscopically stabilized guidance system and the components of the control system."[42] Finally, the Office, Chief of Ordnance issued an edict on 1 April 1952 to "get a prime contractor into the project as quickly as possible."[43]

The Division submitted a proposal for the R&D contract and requested funds and permission to award a cost-plus-fixed-fee contract and a 100-percent letter contract for the R&D program. Three of nine potential contractors submitted proposals, but none of the three were considered fully qualified. The Chrysler Corporation was fully qualified, but it declined to bid on the first round. Fortunately, the cancellation of a Navy jet engine production run freed up floor space, equipment and workers at the Naval Industrial Reserve Aircraft Plant in Warren, Michigan, and Chrysler reconsidered. The Division judged Chrysler to be the best qualified of the contractors, and the Office, Chief of Ordnance approved Chrysler's selection as prime contractor for the REDSTONE R&D program on 15 September 1952. To expedite the program, the Ordnance Corps required Chrysler's acceptance of North American Aviation, Ford Instrument Company and Reynolds Metals Company as major subcontractors. The condition was accepted, and Chrysler received the letter order contract in October 1952. A supplemental agreement to the basic contract provided the definitive version of the contract in June 1953.[44]

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[41] Supplements to the basic contract allowed the Division to make major changes to the fuselage design as the R&D program continued (e.g., lengthening the center section by nine inches and modifying the tail section for the A-4 engine). Reynolds continued manufacturing fuselage components as a subcontractor to the Chrysler Corporation.

[42] Engineering change orders, orders for additional components, and an extension of Ford's R&D effort raised the contract's value from $1,135,607 in August 1952 to more than $6,600,000 in March 1956. Three other contracts with Ford covered: 1) a six-month-long study of lateral and range computers in the guidance and control system, 2) design, development, fabrication and testing of a container for guidance system's stabilized platform, and 3) development of final test and calibration requirements for the platform and construction of some guidance and control components.

[43] Bullard, "History of the Redstone Missile System," pp 57, 58, 59, 61, 65, 67, 68, 69, 75.

[44] Bullard, "History of the Redstone Missile System," pp 75, 76, 77, 78.

As outlined in the REDSTONE Operations Directive (May 1954), the project's initial objectives were to test and evaluate: 1) the power plant, 2) missile structures, 3) the booster control system, 4) the missile's acceleration and performance shortly after lift-off, 5) the roll control system's performance after engine cut-off, and 6) automatic separation of the warhead from the missile. Only a small group of maintenance and liaison people would be sent to the Air Force Missile Test Center (AFMTC) at Patrick AFB initially, but a firing group of about 50 men were expected to take up residence there once the test program at Cape Canaveral expanded to about one launch per month. Until that time, the Missile Firing Laboratory at Redstone Arsenal moved people to Patrick and Cape Canaveral for final missile preparations about 30 days before a scheduled lift-off. Army personnel began moving to Patrick in June 1953 to set up an advance headquarters for the REDSTONE project.[45]

As the project got underway, the Army arranged for hangar space and launch facilities at the Cape. REDSTONE required new range instrumentation and data collection services from AFMTC, and the Army had to accommodate its launch procedures to Air Force range safety protocols.[46] Some facilities were not ready for the first REDSTONE operations at the Cape, so substitutes were found. The very first launches were supervised by the people who designed and developed the missile, but follow-on launches were delegated to the Experimental Testing Branch. The latter learned their craft via a combination of previous work experiences with the Ordnance Department, indoctrination at Redstone Arsenal and on-the-job training at Huntsville

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[45] AFMTC History, January – June 1953, Vol I, pp 258; AFMTC History, January – June 1954, Vol I, pp 169, 219.

[46] Each type of missile launched from Cape Canaveral had its own firing system tailored to meet the requirements of the project, but the range's sequencing system was a different matter. On 29 July 1954, Dr. Kurt Debus (REDSTONE Missile Firing Laboratory) objected to AFMTC's authority to interrupt REDSTONE firing sequences via control circuits. He maintained that an untimely interruption by "a person untrained in REDSTONE firing techniques" could damage or destroy the missile. The circuits were a standard feature of the AFMTC sequencing system, and they were applicable to all major launches at the Cape. Mr. H. M. Powers (RCA Systems Engineering) assured Dr. Debus that the hold-fire circuits could be used *without* wiring them into the REDSTONE's firing circuits. Dr. Debus replied that no space had been provided in the new REDSTONE control center (Blockhouse 56) for the hold-fire system. Mr. M. S. Friedland (RCA Long Range Planning Section Chief) made it clear that the AFMTC equipment *did not* have to be located in the blockhouse, though that was the most desirable location for it. In any event, the AFMTC sequencing system *would be used*. It was essential for RCA's control of range instrumentation equipment and the overall safety of the Range.

and the Cape. The first six REDSTONE test flights were controlled from the north half of Blockhouse 34 and launched from Complex 4 (i.e., BOMARC facilities).[47] REDSTONE also shared space in a BOMARC hangar until a new missile assembly building could be built for the project. Construction of Missile Assembly Building "D" for the REDSTONE project began in the latter half of 1953. It was one of five new hangars planned for the Cape. Construction of permanent *launch* facilities for REDSTONE (launch pads 5 and 6 and Blockhouse 5/6) began in the latter half of 1954. Hangar "D" was finished and dedicated to REDSTONE operations in early 1955, and REDSTONE's permanent 161-foot-tall Missile Service Stand was assembled onsite in February 1955.[48] The Army moved into Blockhouse 5/6 by the end of March 1955. (AFMTC transferred Blockhouse 34 and Complex 4 to Convair for the latter's reentry vehicle project shortly thereafter.) Complex 6 made its operational debut by supporting a night launch of the Army's seventh REDSTONE on 20 April 1955.[49]

From 1954 through early October 1988, the Air Force operated the AMR under a series of contracts with Pan American World Airways.[50] Pan American, in turn, had a series of contracts with the Radio Corporation of American (RCA) to provide range instrumentation support. Put simply, Pan American managed and operated the range, and RCA ran the

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[47] A 135-foot-tall vertical launch stand for the REDSTONE project was built by the Noble Company in California and erected on Complex 4 in early August 1953. The stand was 26 feet wide and 61 feet long, and it weighed 308,000 pounds. It was designed to be mobile, so it was placed on two sets of railroad tracks for movement on an off the launch pad. It featured a 15-ton crane, four movable work platforms, an air-conditioned work room, elevators and a standby power plant for emergencies.

[48] The Missile Service Stand weighed 150 tons. It was disassembled, moved three and one-half miles, and reassembled over a period of seven days by the Noble Company, Leonard Brothers (Miami, Florida), Pan American World Services (the range contractor) and members of the AFMTC Installations Division.

[49] AFMTC History, January – June 1953, Vol I, pp 268, 404; AFMTC History, July – December 1953, Vol I, pp 197, 198, 322; AFMTC History, January - June 1954, Vol I, p 123; AFMTC History, July – December 1954, Vol I, pp 196, 281, 282, 283; AFMTC History, January - June 1955, Vol I, p 412.

[50] In 1988, the range contract was divided into two separate contracts — Launch Base Services (LBS) and Range Technical Services (RTS). Pan American (later known as Johnson Controls) won the LBS contract in August 1988 and July 1992. Computer Sciences Raytheon (CSR) won the RTS contract in June 1988 and July 1993. As of 2006, CSR continues to operate range instrumentation under its latest RTS contract with the Air Force.

equipment. The work included maintaining facilities and equipment, planning range test support (including collection and reduction of missile test data) and developing engineering criteria for the procurement of instrumentation to meet new launch program requirements.[51]

From the outset, range planners knew the REDSTONE ballistic missile needed more precise range safety radar coverage than winged missiles (i.e., MATADOR and SNARK) required from the Atlantic Missile Range (AMR). Put simply, the REDSTONE flew higher and faster than winged missiles, and its flight time was typically 350 seconds or less. The AMR's first radars were essentially World War II vintage S-Band anti-aircraft gun laying SCR-584s that had been modified to track winged missiles. They were called MOD I radars, and they had a beacon tracking error of ±80 yards and 2.5 mils in direction out to a distance of 150 miles. They would be upgraded to MOD II radars with a kit that reduced distance error to ±15 yards and directional error to 1 mil. Two physically separated MOD II units (each with its own display) were needed at each downrange station to provide the necessary redundancy, accuracy and range safety. The MOD II radars on Grand Bahama Island (GBI) were operational in July 1955, and a master control radar unit provided automatic positioning of radars via a chain-radar system between Cape Canaveral and GBI. All AMR stations except Mayaguana had operational MOD II radars by the end of August 1955.[52]

The AZUSA radar system also played an important part in the development of the REDSTONE and other ballistic missile projects in the 1950s. Named for its home town in Southern California, AZUSA was a very precise continuous wave tracking system.[53] It was used

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[51] ATMTC History, January – June 1955, Vol I, p 24; 45th Space Wing History Office, "The 45th Space Wing, Its Heritage, History & Honors, 1950 – 1996," p 33, Jan 1997.

[52] AFMTC History, July – December 1953, Vol I, p 163; AFMTC History, January - June 1954, Vol I, pp 104, 105; AFMTC History, January - June 1955, Vol I, pp 120, 121; AFMTC History, July - December 1955, Vol I, p 228.

[53] A 5,060-megacyle frequency-modulated carrier wave was transmitted from a ground station up to the missile's transponder which returned the same modulation on a 5,000-megacycle carrier to receiver antennas on the ground. AZUSA measured range by comparing the phase of the transmitted modulation with the phase of the return. The system could measure the difference within about 1/360 of a cycle. AZUSA employed three modulated frequencies in sequence to lessen ambiguity in the measurement of the phase shift. The AZUSA at the Cape had eight servo-directed antennas, a transmitter, a digital counter, playback equipment and associated power supplies.

in conjunction with an IBM-704 computer and a vertical plotting board as a range impact prediction system. It also provided metric data reduction for ballistic missile flights. The Consolidated Vultee Aircraft Corporation (Convair) began developing AZUSA as a ballistic missile guidance system in the late 1940s, but Air Materiel Command gave the project to the Rome Air Development Center after the contract ended in 1950. Technical responsibility for the system was transferred to AFMTC in July 1952, and an AZUSA building, complete with ground equipment and antennas, was completed at Cape Canaveral around the end of August 1954. In addition to the system's other roles, the Air Force wanted AZUSA to become a part of the ATLAS missile guidance system. An early AZUSA tracking test in May 1954 was cancelled, but engineers began a series of AZUSA tests in mid-1954 that continued through the end of 1955. The initial plan called for two AZUSA stations — one at the Cape and the other on the island of Eleuthera — but the Cape's AZUSA station alone was able to track missiles as far downrange as 600 miles by the end of 1958. Procurement of the design for miniaturized AZUSA transponders began around September 1955, and in September 1956 the Army agreed to put AZUSA transponders on all future JUPITER missiles.[54]

Ballistic missile flights on the AMR required several different kinds of optical support, including ribbon-framed cameras, infrared tracking equipment, cinetheodolites and (by the late 1950s) long-range tracking telescopes.[55] One early innovation was the Doppler Velocity and Position (DOVAP) optical system. The Army sent its van-mounted DOVAP optical system to Patrick AFB in March 1954 to support REDSTONE flight tests on the Atlantic Missile Range later in the year. DOVAP was a continuous wave trajectory measuring system, and it was used in conjunction with BC-4 ballistic cameras to collect ballistic trajectory and inertial guidance data.

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[54] AFMTC History, January – June 1953, Vol I, p 280; AFMTC History, July – December 1953, Vol I, pp 183; AFMTC History, January - June 1954, Vol I, pp 106, 108; AFMTC History, July – December 1954, Vol I, p 137; AFMTC History, January - June 1955, Vol I, p 117; AFMTC History, July - December 1955, Vol I, p 223; AFMTC History, July – December 1956, Vol I, p 258, 293; AFMTC History, July – December 1958, Vol I, pp 274, 275.

[55] The Army's JUPITER and the Air Force's ATLAS ballistic missiles were designed to fly much farther than the REDSTONE, so two long-range optical systems — the Recording Optical Tracking Instrument (ROTI) and the Intercept Ground Optical Recorder (IGOR) — were introduced on the AMR in the late 1950s. Four IGOR towers were nearing completion in February 1957, and one ROTI was operational by mid-March 1957. In November 1956, the Army got White Sands to send an IGOR and crew to Patrick AFB to cover missile flights until IGOR support could be obtained locally.

Three BC-4s were part of an interim optical network supporting REDSTONE in 1954. DOVAP data was collected at both ends of a mission, and the hand-off from the Cape's cameras to cameras downrange was accomplished via voice command from the Cape Central Control Building during the 'free fall' portion of the REDSTONE's flight. Cinetheodolites also gathered data in the launch area and impact area,[56] and they recorded azimuth and elevation angles as they tracked the missile. Deployed in an array to provide triangulation on the target, Askania cinetheodolites provided an accurate record of the missile's position up to 25 miles away.[57]

While officials hoped for a successful flight every time, missiles sometimes flew erratically and had to be destroyed. Each missile contained an automatic self-destruct mechanism in the event of a flight mishap, but ground controllers needed a system to send destruct commands to a missile if it slowly veered off-course and headed outside its pre-programmed flight envelope. With this requirement in mind, AFMTC safety officials set up Command/Destruct (C/D) transmitters at key ground stations, and engineers placed C/D receivers aboard every missile launched on the AMR. An interim C/D system was installed at the Cape for the first REDSTONE missile flights. It used AN/ARW-55 airborne radio control transmitters that were modified to operate in the 406-420 megacycles-per-second frequency band. AFMTC ordered new dual Ultra High Frequency (UHF) C/D transmitters for the range in 1954. The new transmitters were installed at the Cape and GBI by the end of June 1955, and more transmitters were prepared for shipment to stations on Eleuthera and Grand Turk by the end of the year. New UHF Command antennas were shipped to AFMTC in July 1955.[58]

The REDSTONE's weight, payload and range did not change very much during the life of the project,[59] but plans for the missile's development changed *dramatically* in late 1955 when

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[56] An acquisition aid was required to use radar data to position the cinetheodolite on the target as the reentry vehicle impacted.

[57] AFMTC History, January - June 1954, Vol I, p 171; AFMTC History, July – December 1954, Vol I, pp 116, 118, 123; AFMTC History, January - June 1955, AFMTC History, July – December 1956, Vol I, p 258; AFMTC History, January - June 1957, Vol I, pp 258, 259, 262, 267; AFMTC History, July – December 1958, Vol I, p 211.

[58] AFMTC History, January - June 1953, Vol I, p 304; AFMTC History, January - June 1955, Vol I, p 135.

[59] In 1952, the overall weight of the REDSTONE was expected to be about 57,000 pounds (including a 6,900-pound warhead, a 3,100-pound warhead assembly and 40,200 pounds of

the Defense Department directed the Army to proceed with a newly emerging Intermediate Ballistic Missile (IRBM) program. Earlier in the year, the Army planned to complete REDSTONE research and development flights by July 1957. A two-year-long series of engineering and field suitability tests was expected to close out the flight test program by January 1960. But, in September 1955, Army officials decided to use the remaining REDSTONE R&D flights to support America' IRBM #2 program (later known as the JUPITER program). The Defense Department entrusted this new program to the Army and the Navy jointly, but the Navy managed to bow out of the effort in 1956.[60] Nevertheless, JUPITER was given a priority equal to the Air Force's THOR IRBM program.[61]

On 6 December 1955, the Army informed AFMTC that it expected IRBM #2 launches to begin at the Cape in the fall of 1956. Two types of missiles were proposed for the first phase of a two-phased R&D program: 1) a converted REDSTONE featuring an elongated booster and upper stages containing eleven and three SERGEANT solid propellant rockets respectively and 2) a composite REDSTONE carrying a nose cone similar to the one planned for IRBM #2. Within a few months, JUPITER became a three-phased IRBM program. In the first phase, a REDSTONE *instrumented* like a JUPITER would be flown to test IRBM #2 components up to 200 nautical

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liquid oxygen, alcohol and hydrogen peroxide). The missile's NAA 75-110 rocket engine was rated at approximately 75,000 pounds of thrust, and the REDSTONE was expected to have a range of about 155 nautical miles. The preliminary design indicated the missile was 62 feet 10 inches long and 70 inches in diameter in 1951. The diameter did not change, but later documents indicate the missile's length was 65 feet in 1955 and 69 feet 4 inches in November 1958. Engine thrust increased to 78,000 pounds during development, and the warhead weight dropped to 6,305 pounds. The missile could be launched against targets anywhere from 50 to 175 nautical miles away (according to an Army Ordnance Missile Command fact book published in November 1958).

[60] The Navy was given responsibility for all shipboard launches of the liquid-fueled JUPITER, but the service managed to avoid the matter by proposing a solid-fueled IRBM for the Navy instead. On 8 December 1956, the Secretary of Defense gave the Navy permission to delete the JUPITER and proceed with development of the solid-fueled POLARIS IRBM.

[61] AFMTC History, January - June 1953, Vol I, p 269; AFMTC History, July – December 1954, Vol I, pp 116, 118, 123; AFMTC History, January - June 1955, Vol I, p 327; AFMTC History, July – December 1955, Vol I, pp 188, 208, 209, 210; AFMTC History, January - June 1956, Vol I, pp 203; Bullard, "History of the Redstone Missile System," pp 54, 100; James M. Grimwood and Frances Strowd, "History of the Jupiter Missile System," pp 34, 35, U.S. Army Ordnance Missile Command History Branch, 27 July 1962.

miles downrange. This reconfigured REDSTONE was designated the JUPITER-A. In the second phase, a REDSTONE equipped with an elongated booster and SERGEANT upper stages would carry a new nose cone 1,500 miles downrange to gather reentry vehicle data. It became known as the JUPITER-C. The JUPITER prototype would be flight-tested in the third phase of the program, and it would lead to the production version of the missile.[62]

The REDSTONE was overshadowed and diverted by the JUPITER program in 1956, but the missile returned to the Cape in February 1958 (albeit to support the first of four JUPITER-related missions). The REDSTONE was deployed as an operational missile system in 1958, but there was a REDSTONE Artillery Training launch in 1958 and a short series of "Engineering-User" and "Field Suitability" flight tests in the latter half of 1959, 1960, and 1961.[63] Other REDSTONE vehicles were used on six MERCURY missions for NASA in 1960 and 1961. A total of 33 REDSTONE missiles/space vehicles were launched on the Atlantic Missile Range between 20 August 1953 and 22 July 1961.[64]

Overlaps aside, REDSTONE flight tests at Cape Canaveral proceeded through three discernable periods: 1) the early developmental launches through 5 December 1955, 2) the JUPITER-related, Engineer-User, and Field Suitability tests, and 3) the Project MERCURY missions. Let's look at the early launches first. As mentioned earlier, only a small group of Redstone Arsenal people were stationed at Patrick AFB initially to support the REDSTONE project.[65] The Missile Firing Laboratory preferred to move its launch team to Patrick from

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[62] AFMTC History, July – December 1955, Vol I, p 209; AFMTC History, January - June 1956, Vol I, pp 203, 204.

[63] The Army conducted one final REDSTONE Field Suitability flight test on the AMR on 26 June 1961, but two REDSTONEs were launched on the Pacific Missile Range in July and August 1958, and 25 REDSTONEs were launched at White Sands between June 1958 and 6 October 1963. Twenty-two of the missions launched from White Sands and the Pacific Missile Range were completely normal, but the other five suffered malfunctions of one sort or another (e.g., booster, spatial or both).

[64] AFMTC History, July – December 1958, Vol I, pp 190, 191; Marven R. Whipple, AFMTC History Office, "Atlantic Missile Range Index of Missile Launchings, July 1961 – June 1962," p 30, 26 Oct 62; 45 SW History Office, Launch Database, "Listing by Vehicle – REDSTONE," undated; Bullard, "History of the Redstone Missile System," pp 166, 169, 171.

[65] The Army maintained a field office at Patrick AFB under one title or another from 1949 right through to the end of the PERSHING II program. The field office was not a Redstone Arsenal unit originally, but Redstone Arsenal detachments could be placed under it for local

Huntsville about 30 days before each scheduled launch. But, in March 1955, Detachment B of the 9330th Technical Unit sent some people to Patrick to assist in the REDSTONE effort. Though Detachment B was terminated on 26 January 1956, its people were transferred to Detachment A, Army Ballistic Missile Agency (ABMA) on the same date. Owing to the growing importance of ballistic missile programs, the Army had established ABMA on 1 February 1956. Consequently, the Redstone Arsenal's Guided Missile Development Division (and the REDSTONE project) came under ABMA.[66]

In 1952, Army officials scheduled their first REDSTONE launch to occur on 18 August 1953. Remarkably, there was only a two-day slip in the schedule, and the missile lifted off Complex 4 on 20 August 1953. The launch was delayed for about an hour due to a radar receiver problem, but the REDSTONE lifted off its firing table at 0937 hours.[67] Acceleration appeared steady, and the missile was visible until it passed through some clouds about 42 seconds into the

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administrative control. In brief, the Army Command, Joint Long Range Proving Ground was established on 1 May 1949. It was redesignated the 8702d Army Administrative Unit on 15 May 1950, and it became the U.S. Army Element, AFMTC on 1 January 1957. The U.S. Army Element was discontinued on 1 March 1962, and its mission and activities were transferred to the Atlantic Missile Range Army Field Office (AMRAFO). The latter was a field office for Army Ordnance Missile Command. It had been "re-established" on 23 July 1958 following the demise of the Army Ballistic Missile Agency Project Office. For the purposes of this study, we will focus on the Army units and agencies participating in the missile programs directly. The Army Field Office (under its various names) certainly deserves credit for maintaining good relations with the Air Force and arranging range support for the Army's programs at the Cape. (Sources: Marven R. Whipple, "AFMTC Index of Military Units Assigned and Attached, October 1949 – December 1960, p 99, 10 Feb 61; Marven R. Whipple, "AFMTC Index of Military Units Assigned and Attached, January 1961 – December 1962, pp 44, 50, 1 May 1963.)

[66] AFMTC History, January – June 1953, Vol I, pp 258; AFMTC History, January – June 1954, Vol I, p 219; Marven R. Whipple, "Index of Military Units Assigned and Attached to AFMTC, October 1949 – December 1960, p 150, AFMTC Historical Branch, 10 Feb 61; AFMTC History, January – June 1955, Vol I, pp 24, 37; Satterfield and Akens, "Historical Monograph, Army Ordnance Satellite Program," pp 49, 50.

[67] All times in this narrative are in local time unless they are distinguished with a "Z" for Greenwich Mean Time. ("Z" time was used from 1982 onward to avoid confusion between Eastern Standard Time [EST] and Daylight Savings Time.) "EST" appears constantly in activity reports and indexes for launch times in the 1950s and 1960s, but that designation is somewhat suspect since Daylight Savings Time (DST) is not referenced for launches that occurred in the spring and summer months. It appears that the early references are citing local time in all instances.

flight. Telemetry confirmed the missile began to roll almost immediately after lift-off, but the flight became “completely erratic” about 50 seconds later. Telemetry also indicated the power plant operated normally during the first 18 seconds of flight, but combustion chamber pressure began to drop thereafter and remained low for most of the flight. The Range Safety Officer (RSO) initiated command cut-off about 106 seconds into the flight as the REDSTONE approached the edge of the AMR’s safety area. The engine’s burn terminated, and the missile body/warhead section separation occurred as planned. The missile was not recovered despite an extensive search of the shallow water impact area by divers, but the flight data was satisfactory. The Army was very pleased with the first flight’s results overall, and the launch team went back to Huntsville to study the data and prepare for the next REDSTONE flight.[68]

Pre-launch activities for REDSTONE #2 began in December 1953, and the missile was flown to Patrick AFB in a C-124 aircraft on 6 January 1954. The REDSTONE was trucked to the Cape following unloading operations at the airfield, and launch preparations got underway the following day. Technicians installed recorders in Blockhouse 34, and they ran cables out to the launch pad. Engineers and technicians raised the gantry crane, checked communications equipment, installed panels in the blockhouse, and weighed the launching table for load cell pre-calibration. Some pressurization tests on the 8th revealed a faulty alcohol vent valve, and it was replaced. Engineers completed the missile’s assembly, and technicians moved the REDSTONE out to Complex 4. A load cell adjustment was required, so the technicians removed the missile, rebalanced it, and re-erected it on 11 January 1954. One unscheduled hold of two hours’ duration was called for cloud cover over the launch area. The count was recycled to X minus 30 minutes, and it resumed at 0950 hours. The REDSTONE lifted of the pad at 1020 hours on 27 January 1954, and radar plots indicated the missile followed the pre-planned trajectory closely. The flight took five minutes and forty seconds, and the missile impacted in deep water approximately 150 miles downrange. A total of 345 seconds of telemetry data was collected, and analysts considered the quality “excellent.” All in all, the flight was highly successful.[69]

The Army’s people conducted missile tests and analyses at Redstone Arsenal over the next several weeks, and they began preparing for the next launch shortly thereafter. REDSTONE

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[68] AFMTC History, July - December 1953, Vol I, pp 128, 262, 263, 264, 265, 267, 268.

[69] AFMTC History, January - June 1954, Vol I, pp 169, 170, 171.

#3 was flown to Patrick on 13 April 1954, and it was trucked to the REDSTONE Interim Assembly Building at the Cape. The firing table was positioned once again, and "load alls" were installed on Complex 4. Redstone Arsenal and AFMTC personnel cooperated to complete command receiver and radar beacon tests. Redstone Arsenal had dispatched its DOVAP optical system to Patrick in early March to support REDSTONE flight tests, so technicians were able to complete DOVAP tests in preparation for the REDSTONE #3 flight.[70]

The Army launched REDSTONE #3 at 1224 hours on 5 May 1954. Though ignition and lift-off were normal, early reports indicated missile thrust did not develop properly. After rising about one missile-length into the air, the REDSTONE's dome header exploded and the missile settled back onto the launch table. The fuel tanks split, casting burning alcohol a distance of 150 feet in all directions. The warhead section of the missile fell onto the pad, but it suffered relatively little damage — engineers believed most of the section's components could be recovered and reused. Complex 4's surface was damaged of course, and in places it was caved in about eight inches below grade. Three sections of concrete had to be replaced, but the pad conduits were intact. Most importantly, no one was injured in the launch mishap, and the Army would be ready to launch again in August 1954.[71]

REDSTONE #4 arrived at the Air Force Missile Test Center on 27 July 1954, and pre-launch tests began immediately. The launch from Complex 4 was scheduled for 0700 hours on 18 August 1954. The countdown on that date was held up for 35 minutes to check for possible power plant leaks, and there was another unplanned hold at X minus 22 minutes caused by a frozen liquid oxygen topping valve. Two more holds (i.e., to adjust a plotting board and deal with some radar beacon interference) contributed to the length of the countdown, but the REDSTONE lifted off successfully at 0905 hours on the 18th. Radar confirmed the missile flew properly, and metric camera results were deemed "exceptionally good." Three hundred and twenty-seven seconds of telemetry data were gathered. Surveillance aircraft spotted dye markers in the impact area, thereby confirming the booster and warhead section had impacted intact. The flight test was a success.[72]

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[70] AFMTC History, January - June 1954, Vol I, p 172.

[71] AFMTC History, January - June 1954, Vol I, pp 172, 173.

[72] AFMTC History, July – December 1954, Vol I, pp 277, 278.

REDSTONE #5 was not launched, so #6 became the fifth REDSTONE to be launched from the Cape. REDSTONE #6 arrived on 26 October 1954, and technicians transported it to Complex 4 three days later. In addition to routine data on the power plant, the missile structure and separation of the warhead section from the booster, the Army wanted data on turbulence effects during the powered flight and dive phases of the mission. The DOVAP and AZUSA systems' performance would also be evaluated. The countdown began on the morning of 17 November 1954. It was delayed initially by a lack of alcohol in the fueling trailer that was needed to 'top off' the missile's fuel tanks.[73] A surveillance aircraft radar problem and bad weather created additional delays. An AZUSA equipment failure, a broken valve in the launching platform, and a leak in the liquid oxygen topping line merely compounded the difficulty, and a 60-minute hold was called to correct the problems. Ultimately, lift-off occurred at 1314 hours on the 17th. Radar technicians confirmed the missile was "almost exactly" on track during its 40-mile flight downrange. An altitude of 129,000 feet was achieved, and the booster and warhead separated neatly before impacting 43 nautical miles and 46 nautical miles from the launching pad respectively. However, the flight was *supposed* to go 133 nautical miles. Preliminary analysis suggested disturbances during the third of three "planned maneuvers" may have led to over-control and an excessive error angle in yaw. Attitude control failed, and the missile rolled. Still, the power plant's operation was termed "flawless," by the engineers, and there was no indication of structural failure. No break-up of the booster or warhead section occurred.[74]

The sixth REDSTONE flight from the Cape involved REDSTONE #8. It was scheduled for 8 February 1955, but a heavy overcast and intermittent rain forced range officials to reschedule the launch for the following day. The countdown on the February 9th got off to a bad start: technicians detected a leaky fuel valve, and it took them five hours to replace it. Telemetry

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[73] The lack of fuel was not the only problem encountered during these early REDSTONE operations. Liquid oxygen for the REDSTONE was supplied via 1,700-gallon storage tanks mounted on semi-trailers, but even two tanks together were not enough to fill the REDSTONE missile properly. The trailer-mounted tanks were unsatisfactory, and delays in getting additional tanks prompted officials to award a contract to build a liquefied gases plant at the Cape in 1954. Construction work and equipment installation were both on schedule at the new plant by the end of 1954.

[74] AFMTC History, July – December 1954, Vol I, pp 278, 279, 280, 281, 343.

interference forced another unscheduled hold, and a series of other complaints (e.g., accidental film exposure, a high pressure regulator system leak, the appearance of small boats in the launch danger area, and heavy clouds over the pad) delayed the lift-off until 1515 hours. Nevertheless, the missile flew well on 9 February 1955, and its flight was normal until booster/warhead section separation. The actual separation "appeared rough," and analysts believed this was due to the tardy detonation of an explosive bolt. The warhead appeared to spiral during freefall, but pre-planned maneuvers after reentry went well. There was no missile break-up during the flight, and the booster splashed down about 108 nautical miles from the pad. The warhead's impact was noted by a dye marker about 115 nautical miles downrange. Data coverage was deemed satisfactory, and the flight test was another success.[75]

REDSTONE #9 was the seventh in the series launched from the Cape, and the flight marked the shift of REDSTONE launches from Complex 4 to Complex 6. The missile sections were flown to the Cape's Skid Strip from Huntsville on two separate C-124 flights on 8 and 9 March 1955. Technicians delivered the booster and warhead section to the newly built (and recently occupied) Missile Assembly Building "D." Missile processing was held up at "D" for a week because some air-conditioning contractors needed clearances to finish installing the building's air conditioning system. Since REDSTONE #9 would be the first night flight of the program, Army and AMR officials moved the launch from 5 April to 19 April 1955 "to obtain a longer period of complete darkness" for the new Wild BC-4 camera installations at Walker Cay and Carter Cay (south of the REDSTONE impact area). The countdown began at 1430 hours on the 19th, and the lift-off was scheduled for 2038 hours. Unfortunately, the scheduled surveillance aircraft was not on station at the appropriate time, and the alternate aircraft aborted the mission. A third B-17 aircraft had to be called up, and it supported the flight.[76] Bad weather, a safety generator breakdown, loss of range timing, and the time required to muster the surveillance

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[75] AFMTC History, January – June 1955, Vol I, pp 329, 330, 331.

[76] Tracking the missile with BC-4 cameras in complete darkness would be difficult, so the surveillance aircraft was needed over the camera sites to "evaluate sky obscurity." The cameras were new, and technicians had very little time to practice with them before the launch. Messages from the Cape to GBI had to be relayed to the cays via voice radio. Despite these handicaps, optical coverage of the mission was successful. The range's Askania cinetheodolites even managed to track the missile beyond the burnout phase by the glow of the missile's carbon jet vanes.

aircraft raised the total delay in the countdown to about five hours, but the REDSTONE finally lifted off Complex 6 at 0151 hours on 20 April 1955.[77]

The missile's engine performed well, and it cut off as planned 102 seconds into the flight. Warhead separation and attitude control were excellent, and the desired distance was achieved according to data collected by DOVAP, AZUSA and telemetry sources.[78] Lateral control was excellent through engine cut-off, but post-flight analysis revealed that friction in the air-bearing gyros led to loss of lateral control about 170 seconds into the flight. Lateral accuracy was not known, but Huntsville's engineers knew the guidance system failed to operate satisfactorily during missile reentry. They suspected an air leak may have occurred after booster/warhead separation, and this area would require further study. Radar performance on this mission was reportedly "poor' for the most part, but a radar system at Patrick managed to skin-track the descending missile in a sideward view, and the flight appeared to be successful. Telemetry began fading in mid-flight, but engineers considered the data gathered at the Cape and GBI to be usable for 331.5 seconds of flight time. REDSTONE #9 was thus a valuable —though not entirely successful —addition to the Army's flight test series. It also accomplished a number of 'firsts' for the REDSTONE project: 1) it was the first night flight, 2) the first REDSTONE to carry a form of terminal guidance, and 3) the first mission to utilize newly installed BC-4 camera sites downrange.[79]

The eighth missile in the series (REDSTONE #10) was another night mission, and it was scheduled to launch from Complex 4 at 2100 hours on 24 May 1955. The missile was the first REDSTONE to carry a complete set of guidance equipment up to engine cut-off.[80] The missile booster arrived by truck on 4 May 1955, and the warhead section was delivered in a C-119

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[77] AFMTC History, January – June 1955, Vol I, pp 331, 332, 333, 334.

[78] DOVAP data was collected at both ends of the range based on a voice command 'hand-off' from the Cape Central Control building during the freefall portion of the flight. The DOVAP data gathered on this mission was reported to be usable at both ends of the flight.

[79] AFMTC History, January – June 1955, Vol I, pp 336, 337, 338, 339, 329.

[80] REDSTONE #9 featured lateral guidance, but REDSTONE #10 carried both lateral guidance and range guidance on its stabilized platform.

aircraft.[81] The mission went as planned through the launch, cut-off, and warhead separation phases of the flight, but there was a "spatial reference anomaly" during the freefall phase that caused the missile's gyros to tumble the missile out of control. The flight was supposed to last 337 seconds, but it continued for a total of 370 seconds. That difficulty aside, downrange cameras picked up the missile's flashing lights, and the data they recorded indicated the impact was "in the vicinity of the predicted impact point." Since telemetry confirmed the cut-off occurred as programmed, engineers reasoned the splashdown could not have been "too far off-course."[82]

Once again, radar coverage was generally poor, but the radar system at Patrick AFB skin-tracked the missile and obtained good results. The problem seemed to be flame attenuation —the radar beacon was in the tail of the REDSTONE which, in retrospect, might not have been the best place to put it. Officials decided to move the beacon and its antenna to the nose of the REDSTONE on later missions, and the relocation certainly helped. Though AZUSA went out about two seconds after engine cut-off, AZUSA data proved usable on the first 104 seconds of the flight. On a brighter note, DOVAP performance was good up and down the range, and film quality was good.[83]

The next flight was REDSTONE #7, and it was set to launch from Complex 6 on 30 August 1955. The primary objective of the flight was to test the Diamond Ordnance Fuze Laboratory's new fuzing system.[84] A special telemetry station was set up on Carter Cay near the

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[81] The deliveries were the first instance of truck and C-119 transportation of a REDSTONE missile to the AMR. C-124 aircraft had been used to deliver the missiles previously, but the C-124 had a steep ramp, and a winch was required to unload the warhead section. The C-119 was a more convenient delivery vehicle because the warhead dolly could be rolled directly aboard the aircraft. With regard to the booster's road trip, technicians removed all vibration-sensitive components from the missile, and the booster trailer was equipped with a vibration recorder to monitor the delivery. Speeds up to 35 miles per hour were recorded, but a close inspection of the booster and rocket motor upon arrival at AFMTC revealed no damage to either one.

[82] AFMTC History, January – June 1955, Vol I, pp 338, 339, 340, 341.

[83] AFMTC History, January – June 1955, Vol I, p 242.

[84] The Diamond Ordnance Fuze Laboratory (DOFL) and the Picatinny Arsenal were both organized as military units, but they functioned as subcontractors for warhead fuzes and equipment in various Army missile programs. Harry Diamond Laboratories was established in 1953, and it was named for Harry Diamond, the American government scientist who invented the proximity fuze for the Allies during World War II. REDSTONE #7 was the first in the series

target area, and an evening lift-off was scheduled to take advantage of reflected light at high altitude during that time of the day. Radar interference between two radars held up the countdown for about 25 minutes, but the lift-off occurred on 30 August 1955 as planned. The warhead flew 85 miles down the flight path, but a control system disturbance may have shut down the rocket motor three seconds early. That speculation aside, a "yellow ball of fire" about 200 seconds into the flight indicated the booster exploded with about 2,200 pounds of fuel onboard. Telemetry on GBI and at the special telemetry station failed to capture data during the terminal phase of the missile's trajectory, so the flight test was considered unsuccessful.[85]

The next two REDSTONE flights from the Cape (REDSTONE #11 and REDSTONE #12) tested the complete, active, "final-type" guidance system in addition to the standard list of performance objectives (e.g., power plant performance, structural integrity, booster/warhead section separation and flight control).[86] REDSTONE #11 was delayed on 22 September 1955 for about 90 minutes due to heavy rain. Several gallons of water leaked out of the missile when alcohol fueling operations began shortly thereafter, so officials were forced to delay the launch

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to carry the DOFL fuzing system. Picatinny Arsenal's Field Test Unit was established at Cape Canaveral on 28 May 1958, and it was renamed the Picatinny Arsenal Field Engineering Unit in January 1960. The unit was organized under Feltman Research and Engineering Laboratories, Dover, New Jersey.

[85] AFMTC History, July – December 1955, Vol I, pp 180, 181; AFMTC History, July – December 1959, Vol I, pp 32, 35; AFMTC History, January – June 1960, Vol I, pp 19, 127; "Adelphi Laboratory Center [Harry Diamond Laboratories] US Army Research Laboratory," globalsecurity/org website, undated.

[86] According to pages 81 and 151, "History of the Jupiter Missile System" written by James M Grimwood and Frances Strowd and published by Helen Brents Joiner, Chief, History & Reports Control Branch, U.S. Army Ordnance Missile Command (27 July 1962), RS #11 and RS#12 were JUPITER-A flights. On page 155 (of the same history) Grimwood and Strowd count three other REDSTONE flights (numbers 46, 43 and 48) as JUPITER-A missions. AFMTC histories covering the missions show all five flights as REDSTONE missions with JUPITER program objectives either implied (RS #11 and #12) or clearly stated (RS # 46, 43, 48). Curiously, the AFMTC History lists RS #54 as a REDSTONE employed on a JUPITER support mission as well, but RS #54 is not included by Grimwood and Strowd as a JUPITER-A mission. The confusion appears to stem from the Army's decision in September 1955 to use the remaining REDSTONE R&D flights to support the JUPITER program. The Air Force Missile Test Center assumed JUPITER-A launches began on 14 March 1956 *because the Army informed AFMTC on 6 December 1955 that IRBM #2 flights would begin in 1956*. In fact, the Army considered RS #11 a JUPITER-A mission as soon as the decision was made to divert the remaining REDSTONE R&D flights in 1955 to support the JUPITER program.

another hour while technicians drained the missile's surge chamber and let it dry out. Without further ado, the missile lifted off Complex 6 and flew properly for about 70 seconds. Then a "wildly erratic yaw" indication was noted on the real time telemetry display, and ground controllers sent a command to steer the missile back on-course. Unfortunately, the Flight Safety Officer (FSO) decided the deviation had exceeded safety limits, so he commanded an emergency engine cut-off about 78 seconds into the flight. The total flight time was 158 seconds. Several observers reported an explosion on or shortly before splashdown, and divers subsequently confirmed there was a 15-foot-wide crater with a large number of missile fragments in the shallow water impact zone.[87] Though the flight failed to test the guidance system fully, engineers maintained that the final-type guidance system had operated "satisfactorily."[88]

Analysts blamed a new shortened tail design for the flight anomalies on the REDSTONE #7 and REDSTONE #11 missions. REDSTONE #12 also featured the shortened tail, so its flight was delayed six weeks to change the tail design.[89] As if to confirm the analysts' suspicions, the modified REDSTONE #12 flew much better than its immediate short-tailed predecessors. The flight from Complex 6 on 5 December 1955 lasted about 342 seconds, and the warhead impacted 145 nautical miles downrange. Terminal phase guidance was operative, and the flight deviation did not exceed 400 meters. The missile attempted to correct for the deviation, and "lateral error was negligible." Thirty different color film cameras had been set up in 20 different locations to collect data on the new tail design during the flight, and test results confirmed the design changes

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[87] Other missile fragments were detected as much as 200 feet from the center of the crater. The warhead's quarter-inch plating was "crumpled and torn like paper." The evidence suggested the explosion occurred just before contact with the ocean surface, and analysts surmised the crater was formed by hydraulic action.

[88] AFMTC History, July – December 1955, Vol I, pp 209, 181, 182, 183; AFMTC History, January - June 1956, Vol I, pp 203, 204.

[89] Laboratory analysis of missile fragments from the crater left by REDSTONE #11 led to the following six changes in the tail design: 1) enlargement of the rudder housing's protective cover, 2) enlargement of carbon blocks ringing the motor exhaust outlet, 3) removal of the baffle for liquid oxygen venting (to avoid channeling liquid oxygen into the base of the missile), 4) asbestos wrapping for all tail cables, 5) installation of a cover to close ground cable disconnect plugs at lift-off, and 6) placement of fuzes in all test lines from the tail of the missile to the warhead.

were effective. Nevertheless, the temperature in the tail section remained high, and the Arsenal's engineers believed additional changes would be needed.[90]

The REDSTONE #12 flight test on 5 December 1955 was the last of eleven developmental missions launched from Cape Canaveral for the REDSTONE project.[91] As AFMTC saw it, the first JUPITER-related REDSTONE flight (#46) lifted off Complex 6 on 11 February 1958, and three more REDSTONE flights (#43, #48 and #54) followed on 27 February, 11 June, and 24 June 1958 to support JUPITER test program objectives. All four flights were designed to evaluate the performance of an inert warhead and fuzing system, and all four were aimed at shallow water impact areas near GBI. Three of the four hit their targets about 137 miles downrange, but REDSTONE # 48 overshot its impact area.[92] While REDSTONE launches continued on Complex 6, members of Battery A, 217th Field Artillery Battalion, 40th Field Artillery Missile Group, conducted the Army's first successful troop launching of a tactical REDSTONE missile on 16 May 1958.[93] The operation was conducted on Complex 5, and it

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[90] AFMTC History, July – December 1955, Vol I, pp 184, 185.

[91] As mentioned earlier in this chapter, JUPITER-related, Engineer-User, and Field Suitability tests for REDSTONE did not begin at the Cape until February 1958. In retrospect, it is clear that the Army considered the RS # 11 and #12 flights to be JUPITER-A missions, but AFMTC believed they were REDSTONE developmental missions. No matter how those flights were perceived, ballistic missile activity shifted away from REDSTONE to the JUPITER IRBM test flight program in 1956 (see next chapter).

[92] REDSTONE #48 flew about 8 nautical miles farther than planned because of an improper adjustment in the missile's thrust controller. Officials attributed the anomaly to human error.

[93] The 217th was activated as a training cadre at Redstone Arsenal on 5 April 1956, and it began training in May 1956. The 40th Field Artillery Missile Group was the Army's first heavy missile group. It was transferred from Fifth Army (Fort Carson, Colorado) to Third Army (Redstone Arsenal) where it was reorganized on 9 September 1957. In addition to the 217th Field Artillery Missile Battalion, the 40th had a headquarters and headquarters battery, the 630th Ordnance Company and the 580th Engineer Support Company. The 217th included a battalion headquarters, a service battery and two firing batteries. Each firing battery operated a single launcher equipped with a basic load of one missile per launcher. The REDSTONE was assembled in the field, and it was transported in three sections: 1) warhead, 2) aft and 3) thrust. The first two sections made up the missile body, and the thrust section contained the fuel tanks and rocket engine. Firing batteries were responsible for drawing, storing, transporting, assembling, fueling, and firing their missiles. They also maintained all test equipment and handling equipment used in the field. The engineering company supplied liquid oxygen for the missiles and manned firefighting teams. The ordnance company handled really tough maintenance jobs and supplied missile spares, warheads, tools, parts, and specialized equipment.

featured REDSTONE #1002, a liquid oxygen trailer, a tactical firing van and other tactical ground equipment. All objectives were accomplished during the mission, and the missile hit its target in a deep water area about 170 miles downrange.[94]

Two more missiles were launched in the latter half of 1958, and those missions completed the REDSTONE Research and Development (R&D) flight test program at Cape Canaveral. The first of the two (#56) was launched from Complex 6 on 17 September 1958. It flew 183 nautical miles downrange, and it yielded reentry data on dive phase dynamics. The second one (#57) was launched from Complex 6 on 5 November 1958. It provided data on the missile's pneumatic system and A7 rocket engine. The flight also supported certification testing for the REDSTONE warhead and fuzing system. All systems performed properly, and the nose cone landed on target approximately 137 nautical miles downrange.[95]

Following an eight-month hiatus, the Army wrapped up REDSTONE missile tests at the Cape with three "Engineer-User" and six "Field Suitability" flights between late July 1959 and late June 1961. Before we review them, we should mention the Army organizations that were actually stationed at Patrick AFB to support those — and other — Army tests. The U.S. Army Element, AFMTC had been representing the Army's various interests on the AMR since January 1957. It continued to do so until it was replaced by the Atlantic Missile Range Army Field Office (AMRAFO) on 1 March 1962. Neither of the two units was very large — AMRAFO, for example, only had 6 officers, 21 enlisted people and 6 civilians in December 1962 — but other units were larger.[96]

Detachment "B" of the 9330th Technical Unit arrived at Patrick in March 1955, and it reported to the Officer-in-Charge of Redstone Arsenal personnel at the base. Detachment "B" was eliminated on 26 January 1956, but its personnel were transferred to Detachment "A" of the

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[94] AFMTC History, January - June 1958, Vol I, pp 158, 159, 160; AFMTC History, July – December 1958, Vol I, p 191; Bullard, "History of the Redstone Missile System," p121, 96, 97, 116, 117, 119.

[95] AFMTC History, July – December 1958, Vol I, p 191.

[96] Marven R. Whipple, "AFMTC Index of Military Units Assigned and Attached, October 1949 – December 1960, p 99, 10 Feb 61; Marven R. Whipple, "AFMTC Index of Military Units Assigned and Attached, January 1961 – December 1962, p 44, 1 May 1963; AFMTC History, 1 January – 31 December 1962, Vol I, p 67.

9377th Technical Unit. The latter had 10 officers, 33 enlisted people, and 95 civilians assigned in 1956, and the unit operated at Patrick for nearly a year in support of the JUPITER program. Detachment "A" departed Patrick in October 1956, but Detachment "C" of the 9377th Technical Unit arrived around the same time to replace it. The new detachment had 3 officers, 42 enlisted people, and 154 civilians assigned, but the force grew to 3 officers, 63 enlisted people, and 224 civilians by the end of December 1957. Detachment "C" became 9302-1 Detachment "A" on 1 April 1958, and it was redesignated 4436-1 Detachment "A" effective 1 March 1959. 4436-1 Detachment "A" had 346 personnel at its peak, but the detachment was discontinued on 15 December 1960. Its personnel, supplies, and equipment were transferred to Detachment "A" U.S. Army Ordnance Missile Command (AOMC) on the same date. The AOMC detachment had only 19 civilians less than a year later. Picatinny Arsenal's representation on the AMR dwindled from four people to two people in June 1963, and its Field Engineering Unit was discontinued around 1 October 1963.[97] The REDSTONE, JUPITER, and even the first PERSHING flight test program had departed the Cape by that time. Nevertheless, the Army Field Office still had ten officers, 22 enlisted people, and four civilians at Patrick at the end of 1963, and the PERSHING 1A and PERSHING II programs were yet to come.[98]

Now that the organizations have been mentioned, let's look at the REDSTONE Engineer-User and Flight Suitability missions at the Cape. Missile #2003 was launched from Pad 26A [99]

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[97] Picatinny Arsenal continued to manufacture explosives and ammunition through the early 1970s, but its manufacturing activities gave way to small caliber munitions and weapons research a few years later. It was redesignated the U.S. Army Armament Research, Development and Engineering Center in 1986, and it joined the Tank Automotive and Armaments Command (TACOM) in 1994.

[98] Marven R. Whipple, "AFMTC Index of Military Units Assigned and Attached, October 1949 – December 1960, pp 150, 151, 152, 153; AFMTC History, 1 July – 31 December 1956, Vol I, pp 44, 64; AFMTC History, 1 July – 31 December 1957, Vol I, p 35; AFMTC History, 1 July – 31 December 1960, Vol I, p 35; AFMTC History, 1 January – 30 June 1961, Vol I, p 37; AFMTC History, 1 January – 31 December 1962, Vol I, p 67; AFMTC History, 1 January – 31 December 1963, Vol I, pp 22, 42; "Picatinny Arsenal," globalsecurity.org website, undated.

[99] Complex 26 included a blockhouse and two launching pads (26A and 26B), and it was built specifically for the REDSTONE and JUPITER missile programs. The construction contract was let in June 1956, and the Army occupied the blockhouse and both pads in May 1957. The facility's "brick and mortar" cost was about $6,808,000. More than 30 REDSTONE, JUPITER, JUPITER C, and JUNO II flights were launched from the Complex 26 before it was deactivated

on the Cape's first REDSTONE Engineer-User flight test on 21 July 1959. Engineer-User tests assessed the "ruggedness, reliability and accuracy" of the missile. REDSTONE #2004 lifted off Pad 26A on the second Engineer-User mission on 4 August 1959. Both missiles carried dummy warheads built by the Sandia Corporation and adaptations kits manufactured by Picatinny Arsenal. Both flights were successful, and their impacts were recorded to within one nautical mile of the target. The Cape's third and final REDSTONE Engineer-User flight test was cancelled on each of three days (e.g., 16, 17, and 18 March 1959) due to bad weather, but the missile (#2020) lifted off Complex 6 successfully on 21 March 1960. Missile-borne telemetry transmitters and the radar beacon fell silent during the terminal dive phase of the mission, but government contractors confirmed all test objectives were accomplished successfully.[100]

The six REDSTONE Field Suitability flights came next. Like the Engineer-User flights, the Field Suitability flights were accomplished to confirm the REDSTONE's ruggedness, reliability and accuracy. All six REDSTONEs chosen for the flights were designated Engineering Qualification Production (EQP) missiles. They featured Picatinny adaptation kits and DOFL fuzing systems. All six missiles were launched from Complex 6, and their targets were approximately 174 nautical miles downrange. Missile #2023 lifted off Complex 6 on the first Field Suitability flight on 9 August 1960. Post-flight analysis confirmed the missile flew properly, but "the RSO [Range Safety Officer] may have destroyed a perfectly normal missile following its prescribed trajectory" about 112 seconds into the flight. The official AMR test activity report maintained the RSO's action was prompted by bad impact prediction data, but the Army remained skeptical. In any event, both services agreed that the missile was destroyed "in error." The missile impacted 110 nautical miles downrange, and no test objectives were achieved during the flight.[101]

The other five Field Suitability missions were successful. Missile #2037 was launched on 5 October 1960. The flight was normal, but there was a complete loss of telemetry data just

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in 1964. The complex was reassigned to the Air Force, and it became the USAF Space & Missile Museum. The museum was opened to public visitors in 1966.

[100] AFMTC History, 1 July – 31 December 1959, Vol I, p 181; AFMTC Report, "Atlantic Missile Range Test Activity Report for March 1960," dated April 1960.

[101] AFMTC Report, "Atlantic Missile Range Test Activity Report for August 1960," dated September1960; Bullard, "History of the Redstone Missile System," p 171.

before impact. Nevertheless, the warhead hit its target 173.9 nautical miles downrange. Missile # 2038 lifted off Complex 6 on 21 January 1961. It flew its prescribed trajectory and impacted on target 173.869 nautical miles downrange. Missile #2040 completed the next Field Suitability test flight without incident on 8 March 1961, and it also hit its target approximately 174 nautical miles downrange. Missile #2042 tested "accuracy at burst point" within the target area, and all its primary test objectives were accomplished on 17 May 1961. Missile #2043 completed the REDSTONE program's final Field Suitability flight from the Cape on 26 June 1961. Once again, all primary test objectives were accomplished.[102]

While the Army was wrapping up the last of its REDSTONE flights from Complex 6 in 1960 and 1961, six REDSTONE vehicles were launched from Complex 5 to support Project MERCURY for the National Aeronautics and Space Administration (NASA). The story of NASA's creation has been told many times, so a brief summary of the essential facts should be sufficient to illustrate how the Army's REDSTONE (and the Air Force's ATLAS and TITAN) came to be used by NASA for its 'man in space' projects. The summary also explains why the JUPITER-C, the JUPITER, and a modified JUPITER (called JUNO II) were used to support NASA's unmanned space missions in the early 1960s.

Following the Soviets' successful launch of *Sputnik I* on 4 October 1957, the U.S. Defense Department volunteered to carry out manned space programs. It recommended the Air Force be allowed to lead the effort. President Dwight D. Eisenhower rejected the offer —he called on Congress to establish a civilian space agency instead. Congress passed the National Aeronautics and Space Act, and NASA was established on 29 July 1958. Under Executive Order Number 10783, NASA became the controlling agency for America's *non-military* scientific space projects on 1 October 1958. The Army continued to support NASA space research projects under its own auspices, but at President Eisenhower's urging, Congress eventually transferred all of ABMA's space missions to NASA on 14 March 1960. A new facility — The Marshall Space Flight Center (MSFC) — was established in Huntsville, Alabama, to oversee the transferred

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[102] AFMTC Report, "Atlantic Missile Range Test Activity Report for October 1960," dated November 1960; AFMTC Report, "Atlantic Missile Range Test Activity Report for January 1961," dated February 1961; AFMTC Report, "Atlantic Missile Range Test Activity Report for March 1961," dated April 1961; AFMTC Report, "Atlantic Missile Range Test Activity Report for May 1961," dated June 1961; AFMTC Report, "Atlantic Missile Range Test Activity Report for June 1961," dated July 1961.

missions. While *military* space projects remained with the Defense Advanced Research Projects Agency (DARPA) and/or the United States Air Force, Wernher von Braun and his team of rocket experts moved with other Army personnel from ABMA's Development Operations Division at Redstone Arsenal to MSFC on 1 July 1960. Facilities and other resources associated with the Army's space projects were transferred to NASA as well. Von Braun became the Marshall Space Flight Center's first director.[103]

NASA had no space vehicles of its own in the late 1950s and early 1960s, but liquid-fueled ballistics missiles offered NASA a practical and speedy solution to the agency's space lift requirements. Some vehicle modifications would be required, but ballistic missile contractors were happy to assist in the effort. Working from new rocket drawings designed specially for the APOLLO program, NASA's contractors developed and tested the SATURN I, SATURN IB, and SATURN V, but MERCURY and GEMINI manned space flights were completed in the early and mid-1960s with man-rated versions of REDSTONE, ATLAS, and TITAN ballistic missiles originally developed for the Army and Air Force. JUPITER and THOR ballistic missiles were modified for unmanned space missions as well. While not the first ballistic missile to support a civilian space mission, REDSTONE was the eldest of the lot.[104]

The Mercury-Redstone missions were all suborbital flights, and the first one was the shortest of the bunch. Since the flight was the first in the Mercury-Redstone series, NASA designated the capsule "MR-1." Officials scrubbed the first MR-1 countdown on 7 November 1960 due to a loss of helium pressure in the capsule's Reaction Control System (RCS). The problem was analyzed and corrected, and the next countdown led to the launch on 21 November 1960. Engine ignition occurred normally, but a power ground plug malfunctioned and cut the main engine's power just one second after ignition. The REDSTONE lifted up about three inches and settled back on the pad. The capsule received the cut-off signal, and the main and reserve parachutes deployed to drape down the side of the vehicle. The capsule was used on the next Mercury-Redstone mission as MR-1A. That flight occurred on 19 December 1960, and all mission objectives were met. The vehicle's apogee was recorded as 116 nautical miles, and the

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[103] Mark C. Cleary, "The 6555th: Missile and Space Launches Through 1970," p 158, November 1991; NASA, "Marshall Space Flight Center (MSFC)," history.nasa.gov website, undated.

[104] Cleary, "The 6555th: Missile and Space Launches Through 1970," p 158, November 1991.

capsule splashed down 205 nautical miles downrange. The flight ended nine miles farther downrange than planned, but it was successful. A helicopter from U.S.S. *Valley Forge* retrieved the capsule, and a Marine Corps helicopter delivered the capsule to the Cape's Skid Strip after *Valley Forge* returned to the local area.[105]

Thanks to very strong competition from the Soviet Union in what the media termed the "Space Race," NASA had a very aggressive schedule for Project MERCURY. Two manned missions were scheduled before the end of 1961, and NASA needed some additional assurance that Mercury-Redstone flights were safe for humans. Consequently, the agency arranged for a chimpanzee named Ham to fly the Mercury-Redstone 2 (MR-2) mission. The MR-2 flight from Complex 5 was completed on 31 January 1961. The vehicle's lift-off was normal, but higher-than-normal hydrogen peroxide pressure — coupled with high pressure in the thrust chamber and rapid liquid oxygen depletion — boosted the REDSTONE's velocity above mission parameters. The vehicle's abort/escape rockets contributed additional thrust, and the capsule splashed down 100 nautical miles farther than planned. Nevertheless, Ham came through the mission safely, and he and the capsule were retrieved in satisfactory condition by Landing Ship Dock (LSD) *Donner*. A Marine Corps helicopter delivered the capsule to the Skid Strip, and the spacecraft was transported to Hangar "S" on 1 February 1961. The mission was successful.[106]

The MR-BD mission was launched from Complex 5 on 24 March 1961, and it featured a dummy Mercury capsule. This time the flight went as planned. There were no unscheduled holds during the countdown, and the capsule splashed down 267 nautical miles from the Cape. The vehicle achieved an altitude of 98.8 nautical miles, and radar units on GBI tracked the vehicle for the entire 503 seconds of the flight.[107]

The two manned suborbital Mercury-Redstone flights were the highlights of Project MERCURY as far as REDSTONE was concerned.[108] Commander Alan B. Shepard became the

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[105] AFMTC, "Atlantic Missile Range Test Activity Report for November 1960," Dec 1960; AFMTC, "Atlantic Missile Range Test Activity Report for December 1960," Jan 1961; Oral History Interview with Mr. Terry D. Greenfield, 8 April 2008.

[106] AFMTC, "Atlantic Missile Range Test Activity Report for January 1961," Feb 1961.

[107] AFMTC, "Atlantic Missile Range Test Activity Report for March 1961," Apr 1961.

[108] The first of seven *orbital* Mercury-Atlas missions was launched from Complex 14 on 25 April 1961. Five of the seven orbital missions featured the chimpanzee "Enos" and astronauts Glenn,

first American in space when he completed the MR-3 mission on 5 May 1961. The boost, reentry, and recovery phases of the mission were all normal, and the capsule flew 260 nautical miles downrange (four miles farther than planned). The Navy recovered Commander Shepard and his "Freedom 7" capsule ten minutes after splashdown, and U.S.S. *Lake Champlain* returned them to Florida to complete the support mission. The final Mercury-Redstone mission (MR-4) featured Captain Virgil I. Grissom. It was launched from Complex 5 on 21 July 1961. The capsule splashed down 265 nautical miles from the launch site (five miles farther than planned). The vehicle reached an altitude of 103 nautical miles. Captain Grissom suffered no ill effects, but his capsule — Liberty Bell 7 — became flooded and sank before it could be retrieved. U.S.S. *Randolph* returned Grissom to Florida following the flight.[109]

The MR-4 mission was the last of 33 REDSTONE flights from the Cape, but 25 additional REDSTONE missiles were launched at White Sands between 2 June 1958 and 6 October 1963. The first of those flights featured REDSTONE #1004, and it was launched by Battery B, 217th Field Artillery Battalion, 40th Field Artillery Missile Group, on 2 June 1958. As noted earlier in this chapter, Battery "A" launched REDSTONE #1002 from the Cape on 16 May 1958. Now that its firing batteries and all its other units had completed their stateside training, the 40th Field Artillery Group was ready to depart for its new assignment with Seventh Army in Europe. The Group's main force embarked on 18 June 1958, and it arrived in early July 1958. The 46th Field Artillery Group was the next REDSTONE unit to deploy, and it participated in two REDSTONE Engineer-User test flights at White Sands in January and February 1959 before shipping out to Europe to support Seventh Army and NATO. The 46th arrived at its new post in Neckarsulm, Germany, on 25 April 1959.[110]

As part of its field readiness program, the Army required each of the 40th and 46th Groups' firing batteries to launch one REDSTONE missile per year. Consequently the batteries had to return to the United States to conduct practice firings at White Sands, and those operations used up about four missiles per year. The first of the annual REDSTONE launches was

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Carpenter, Schirra and Cooper. Those flights were completed between 13 September 1961 and 16 May 1963.

[109] AFMTC, "Atlantic Missile Range Test Activity Report for May 1961," Jun 1961; AFMTC, "Atlantic Missile Range Test Activity Report for July 1961," Aug 1961.

[110] Bullard, "History of the Redstone Missile System," pp 120, 121, 122, 123, 124, 169, 171.

completed successfully in March 1959. The Army established the 209th Field Artillery Missile Group to support Strategic Army Forces and arrange annual service practice firings at White Sands. In addition to its headquarters and headquarters battery, the 209th had the 4th Battalion of the 333rd Artillery (Regiment), the 89th Ordnance Company and the 76th Engineer Company. The 209th was deployed to Fort Sill, Oklahoma, in the spring of 1958. Though the 209th had two firing batteries of its own, those units trained with the 40th and 46th Groups' firing batteries. The 209th Group's firing batteries did not launch any missiles themselves.[111]

The REDSTONE was a viable ballistic missile weapon system in 1959, but its liquid-fueled propulsion system made it very cumbersome to operate in the field. More to the point, missile technology continued to advance very rapidly in the early 1960s, and the Army considered the REDSTONE virtually obsolete by 1963. Consequently, the Army replaced the REDSTONE with the first in series of more practical solid-propellant missiles in 1964. The new missile was named PERSHING.[112] The first of 56 PERSHING test missiles was launched from Cape Canaveral on 25 February 1960. Following the Cape's last PERSHING test launch in late April 1963, U.S. Army Missile Command (MICOM) received the Department of the Army's approval to implement the REDSTONE deactivation plan on 21 June 1963. Thus, the REDSTONEs and their combat gear were returned to the United States as the Army began deploying PERSHING equipment overseas in April 1964. All tactical REDSTONE units were inactivated by the end of June 1964, and some REDSTONE equipment was released for applications elsewhere in the Defense Department. The missiles themselves were retained by MICOM for air defense needs, and a contract was awarded to the Chrysler Corporation on 15 April 1965 to inventory, inspect, repair, refurbish, and launch the remaining 23 REDSTONEs as the Army directed. Ultimately, 15 REDSTONE missiles were transferred to the Advanced Research Projects Agency (ARPA), and 8 REDSTONEs were assigned to the Army's Air Defense Systems agency for the Hawk anti-missile development program. Together with the

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[111] Bullard, "History of the Redstone Missile System," pp 124, 125, 169, 171.

[112] The missile was named after U.S. Army General John J. Pershing, Commander of the American Expeditionary Force (AEF) in France in World War I. During his long and remarkable career General Pershing commanded a black cavalry regiment during the Spanish-American War, fought Moro guerrillas in the Philippines, and led 5,000 troops on a highly publicized punitive expedition into Mexico in 1916 against Pancho Villa. Pershing became the U.S. Army's Chief of Staff in 1921, and he retired in 1924.

cancellation of the JUPITER Combat Training Launch (CTL) program in February 1963, the inactivation of REDSTONE tactical units marked the end of an era for the Army. In a ceremony on the Redstone Arsenal's parade field, the REDSTONE was retired officially on 30 October 1964.[113]

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[113] Bullard, "History of the Redstone Missile System," pp 131, 132, 134, 135; PBS, "General John J. Pershing (1860-1948)," pbs.org website, undated.

JUPITER

Though the Army fielded the REDSTONE in 1958, Redstone Arsenal refocused its ballistic missile research effort on an Intermediate Range Ballistic Missile (IRBM) — the JUPITER — more than three years earlier. In January 1955, the Office, Chief of Ordnance tasked Redstone Arsenal to prepare a study on a family of ballistic missiles for Army use. The Air Force had just confirmed that Convair was working on a 5,000-mile-range Intercontinental Ballistic Missile (ICBM) for the Air Force that would become known as the ATLAS. The Army also learned in February 1955 that the Air Force planned to "invite proposals for the development of a 1,000-mile missile using existing hardware." Further prompting came in the form of the Killian Committee's [114] recommendations on 14 February 1955, which urged officials to start a 1,500-mile-range IRBM program immediately to complement the Air Force's ICBM program.[115]

The rationale for the Army's involvement in an IRBM program was, first and foremost, a matter of logistics. Modern air transport allowed the Army to move troops literally hundreds of miles with ease, but similar movement of REDSTONE and SERGEANT theater nuclear weapons would be more difficult. An Army IRBM far behind friendly lines "might prove quite effective as well as economical" since its great range would allow it to cover widely spaced targets along its arc of lethality. The Army's Assistant Chief of Staff for Training added his voice to the argument in late March 1955 when he recommended the creation of an Army 1,000 to 1,500-mile-range missile development program. The Redstone Arsenal ballistic missile study ordered in January 1955 came out in May 1955, and it recommended the IRBM as the largest of

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[114] The Killian Committee was the Technological Capabilities Panel chaired by MIT President James Rhyne Killian. As executive assistant to Massachusetts Institute of Technology (MIT) President Karl Taylor Compton from 1939 onward, James Rhyne Killian was appointed executive vice president at the institute in 1943. Mr. Killian had a bachelor's degree in management, and he directed MIT's government-funded research and development operations while Dr. Compton worked on the National Defense Research Committee. Mr. Killian became MIT's tenth president in 1948, and he served on many governmental advisory panels in the 1950s and 1960s.

[115] Grimwood and Strowd, "History of the Jupiter Missile System," pp 5, 6, published by Helen Brents Joiner, History & Reports Control Branch, U.S. Army Ordnance Missile Command, 27 Jul 1962; MIT Archives & Special Collections, "James Rhyne Killian, 1904-1988," libraries.mit.edu website, undated.

three Army ballistic missile systems. Redstone Arsenal dropped its support for the other two ballistic missile systems in July 1955, and Dr. Wernher von Braun made a persuasive argument for the 1,500-mile IRBM in his briefings to the Armed Services Policy Council and Defense Secretary Charles E. Wilson in July and September 1955.[116]

As outlined by Dr. von Braun, proven REDSTONE components would be used as much as possible in the Army IRBM effort, but a new swivel-mounted 150,000-pound-thrust North American Aviation rocket engine would be employed to power the single-stage, liquid-fueled JUPITER missile. The new missile would be wider and taller than the REDSTONE, and it would weigh about 107,000 pounds at lift-off. The missile would be equipped with two 1,000-pound-thrust vernier thrust nozzles and six small spatial attitude nozzles for flight control. The JUPITER would carry a 2,000-pound warhead up to 1,500 miles, and its inertial guidance system would give it a Circular Error Probability (CEP) of 1,500 meters. Reentry temperatures at full range would be difficult to overcome due to the higher velocities and altitudes that were required to reach the target, but the scientists and engineers at Redstone Arsenal felt the Army and its contractors were up to the challenge. (This achievement alone would be vital to the success of other long-range ballistic missile efforts and manned space programs.) By August 1955, the Office, Chief of Ordnance estimated a six-year-long JUPITER development program would cost about $240 million, but other Army officials believed the total cost might run as high as $500 million. In any event, national security remained the overriding concern, and Secretary Wilson decided in September 1955 that the United States would be two IRBM programs. Army Secretary Wilbur M. Brucker championed the Army's cause before the National Security Council on 1 November, and the Army's JUPITER program was approved as one of America's two IRBM programs on 8 November 1955.[117]

Upon learning of Secretary Wilson's decision in September 1955, the Army did not hesitate to use its remaining REDSTONE research and development flights to support IRBM development. Consequently, the Army considered five REDSTONE flight tests (#11, 12, 46, 43 and 48) to be JUPITER-A missions. Nevertheless, the Air Force Missile Test Center (AFMTC) was under the impression that JUPITER flight tests started in 1956, so it counted the JUPITER-A

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[116] Grimwood and Strowd, "History of the Jupiter Missile System," pp 5, 6, 11.

[117] Grimwood and Strowd, "History of the Jupiter Missile System," pp 8, 9, 10, 11, 12, 148.

flights from 14 March 1956 onward. The five REDSTONE/JUPITER-A flights have been covered in the REDSTONE chapter already, so we will begin with the JUPITER-A mission on 14 March 1956. This chapter will use the Air Force's scheme for numbering the progression of JUPITER-A launches, but it will also identify each missile by its unique number in parentheses. The Army and Air Force recognized the unique number, so its use should dispel any lingering confusion over what missile was launched on a given day or night.[118]

JUPITER-A missiles were essentially REDSTONEs instrumented to carry JUPITER components in support of the JUPITER IRBM program. Proof-testing the components and gathering data for the JUPITER program were their primary mission objectives, but JUPITER-A flights also collected REDSTONE performance data as a secondary objective. REDSTONE #18 was used for what AFMTC called the first JUPITER-A flight test on 14 March 1956. The missile was the third REDSTONE to carry the complete active "final type" guidance system. It was launched from Pad 6. Though the countdown on the 14th was held up for liquid oxygen difficulties, a telemetry problem and a gate valve replacement, the missile finally got off the ground at 1936 hours.[119] The lift-off appeared normal, but rocket thrust was low and the warhead separated before the missile achieved the proper velocity. Consequently, the missile splashed down about 134 nautical miles downrange, and the impact was approximately ten miles short and five and a half miles to the right of the intended target. Despite those shortcomings, the guidance system functioned properly and flight was considered successful.[120]

The Cape's second JUPITER-A (REDSTONE #19) was launched from Pad 6 at 2312 hours on 15 May 1956. The missile carried a nose cone beacon, and the MOD II radar at Patrick AFB tracked the signal continuously from ignition to X plus 175 seconds. It continued to track the signal intermittently from X plus 180 seconds to X plus 264 seconds. In contrast to earlier flights when the beacon had been housed in the missile's tail section, the radar track on this

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[118] AFMTC History, July – December 1955, Vol I, p 209; AFMTC History, January – June 1956, Vol I, pp 203, 204; Grimwood and Strowd, "History of the Jupiter Missile System," pp 81, 151, 155.

[119] As noted in the previous chapter, all times will be presented in local time unless a "Z" (for Greenwich Mean Time) accompanies the number. The shift to "Z" time in range documents occurred in 1982 to avoid confusion over Eastern Standard Time and Eastern Daylight Time.

[120] AFMTC History, January – June 1956, Vol I, pp 204, 205; AFMTC Monthly Test Status Report, March 1956; Grimwood and Strowd, "History of the Jupiter Missile System," p 151.

mission did not suffer any significant loss of signal due to flame attenuation. The flight provided data on the warhead's fuzing components and angle of attack, and it tested components common to both the REDSTONE and JUPITER programs. It also gave RCA an opportunity to evaluate fuel flow meters and test the usefulness of GE #50 flash bulbs and flares used in conjunction with the range's ballistic cameras. AFMTC did not evaluate the flight, but radar plots indicated the missile veered to the left during reentry. The Army later confirmed engine cut-off was tardy, and the missile turned left before splashing down several miles to the left and six and a half nautical miles farther downrange than planned. Flight analysts suspected the #2 actuator fin on the warhead malfunctioned. On balance, the missile flew the proper trajectory, and the Army considered the flight successful.[121]

The first Chrysler-built and assembled JUPITER-A (REDSTONE #13) arrived at the Cape in late June 1956,[122] and engineers erected it on Pad 5 for the third JUPITER-A mission. The launch was scheduled for 10 July 1956, but officials had to scrub it on the 10th due to bad weather and a radar beacon failure. The second launch attempt on 19 July 1956 was successful, and the JUPITER-A lifted off at 0345 hours. The missile splashed down about 142 nautical miles downrange, and the impact was less than 1,100 meters from the intended target in a shallow water area between Grand Bahama Island (GBI) and a line extending from Walker, Carter and Allens Cay to the north. Data collection was nearly 100 percent successful on the mission, and the results helped confirm the effectiveness of sensors north of GBI.[123]

The fourth JUPITER-A (REDSTONE #20) experienced unscheduled missile holds for about 25 minutes before lifting off Pad 6 at 0325 hours on 8 August 1956. The primary objectives of the flight were to: 1) test the guidance system's accuracy and 2) gather data useful to the design of the JUPITER missile. The mission also featured the first controlled operation of the engine's combustion chamber pressure in the JUPITER-A series. Once again, the impact was

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[121] AFMTC History, January – June 1956, Vol I, pp 206, 236, 237; AFMTC Monthly Test Status Report, May 1956; Grimwood and Strowd, "History of the Jupiter Missile System," p 151.

[122] Chrysler opened a field office for its operations at the Cape under the MIRA Corporation (a subsidiary) in May 1956. The field office was renamed the Chrysler Corporation Office on 1 November 1956.

[123] AFMTC Monthly Test Status Report, July 1956; Grimwood and Strowd, "History of the Jupiter Missile System," p 152; AFMTC History, July –December 1956, Vol I, p 47.

in a shallow water area about 140 nautical miles downrange between GBI and the line of cays to the north. A survey of the impact crater confirmed the warhead fell within 715 meters of the predetermined impact point. Other data also confirmed the guidance system functioned properly through engine cut-off.[124]

The fifth and sixth JUPITER-A missions were launched from Pad 6 on 18 and 30 October 1956 respectively. REDSTONE #14 (the fifth JUPITER-A) carried AZUSA as a passenger for impact prediction, and REDSTONE #25 (the sixth JUPITER-A) carried a Sandia inert warhead and a Diamond Ordnance Fuze Laboratory (DOFL) fuze. REDSTONE #14 was scheduled to lift off on 10 October, but officials had to reschedule it of the 18th due to an annoyingly persistent failure in a booster relay. Technicians required several days to correct the problem, but the missile was launched without any major unscheduled holds at 0405 hours on the 18th. A survey of the impact area suggested the missile splashed down just 20 meters behind and 150 meters to the right of the target, but the Army later confirmed the distances as 72 meters and 338 meters respectively. AZUSA only managed to predict the impact to within two miles of the actual splashdown, but there had been a terminal maneuver that AZUSA could not anticipate. Consequently, range officials considered AZUSA’s performance satisfactory, and Redstone Arsenal considered the flight successful.[125]

Unfortunately, the same could not be said of the JUPITER-A flight on 30 October 1956. Range officials delayed the launch about an hour to clear out some stray vessels that wandered into the launch danger area. Lift-off occurred without any apparent problems at 2104 hours, but the missile developed a severe yaw to the left about 13 seconds into the flight. Post-flight analysis suggested the yaw was caused by a malfunction between the yaw gyro potentiometer and the mixing computer’s yaw amplifier. As the missile continued to veer to the left (still very much over the Cape), it reached an altitude of 4,000 feet before the Flight Safety Officer (FSO) sent the required destruct command to end the flight 48 seconds after lift-off. The missile and its inert warhead fell back onto the Cape, and the missile exploded on impact. Fragments were thrown as far as 500 feet, and the explosion created a 40 x 30-foot crater approximately three feet

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[124] AFMTC Monthly Test Status Report, August 1956; Grimwood and Strowd, “History of the Jupiter Missile System,” p 152.

[125] AFMTC Monthly Test Status Report, October 1956; Grimwood and Strowd, “History of the Jupiter Missile System,” p 152.

deep. Fortunately, there were no injuries, but a missile storage building, the Cape's fire station and Hangar "C" sustained damages. The missile and its inert warhead came down about 150 feet apart, so engineers were able to recover the DOFL fuze and Sandia warhead. The primary objective of the mission was to test the missile's power plant, but the flight was quite obviously unsuccessful.[126]

The seventh and eighth JUPITER-A missions were launched from Pad 6 on 13 and 29 November 1956. Both flights were successful. The first of them involved REDSTONE #28, which carried the LEV-3 in lieu of the ST-80 guidance system. The primary objective of that flight was to test the Sandia payload, and the missile demonstrated active angle-of-attack control during the mission. The missile was launched without any major holds at 2105 hours, and it impacted in a deep water target area between Walker Cay and Carter Cay about 152 nautical miles downrange. REDSTONE #15 was launched at 0823 hours on November 29th, and it demonstrated the accuracy of the complete guidance system as well as JUPITER control components. Redstone Arsenal was pleased with the results: after flying nearly 140 nautical miles, the missile impacted within 260 meters of the center of the target. The mission also featured the first use of a new, more potent fuel called U-DETA (a mixture of unsymmetrical dimethylhydrazine and diethyleneglycol). U-DETA required extra safety precautions at the railhead and during tanking operations, but its performance met the Army's expectations.[127]

The ninth JUPITER-A mission was a curious one. It was launched from Pad 6 at 2230 hours on 18 December 1956. It featured REDSTONE #22, and it demonstrated the ability of an angle-of-attack meter to control a missile *deliberately configured for unstable flight* during the ascent portion of the mission. The mission was doubly odd because its range was extended to more than 300 nautical miles to allow more time to simulate unstable flight conditions. As events turned out, the missile flew even farther than planned. It achieved an altitude of 585,000 feet and

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[126] AFMTC Monthly Test Status Report, October 1956; Grimwood and Strowd, "History of the Jupiter Missile System," p 152; AFMTC History, July –December 1956, Vol I, p 199.

[127] AFMTC Monthly Test Status Report, November 1956; Grimwood and Strowd, "History of the Jupiter Missile System," p 152; AFMTC History, July –December 1956, Vol I, p 200.

splashed down 401.6 nautical miles from the pad — almost 85 miles farther than intended. The new U-DETA fuel burned well, and the mission was considered a complete success.[128]

The next ten JUPITER-A missions were launched from Pad 6 during 1957. Two of the flights (REDSTONE #38 and #41) were unsuccessful, but all the other missions were successful. The table below summarizes the basic features and results of each of those missions.[129]

VEHICLE # And Pad #	DATE/LOCAL TIME	OBJECTIVES	OUTCOME
16 Pad 6	18 January 1957/2037 hours	Guidance system accuracy at short range (61.5 NM).	400 meters left and 0.21 NM over impact point (IP)
32 Pad 6	14 March 1957/0312 hours	Flight test missile directly from the Chrysler factory.	Missile impacted 2.2 NM under /1250 meters left of IP ~138 NM downrange.
30 Pad 6	27 March 1957/2022 hours	Guidance system accuracy at short range.	220 meters short and 320 meter right of IP.
31 Pad 6	26 June 1957/0609 hours	Guidance system accuracy and impact/fuzing system performance at 135 NM.	0.42 NM over and 389 meters left of IP.
35 Pad 6	12 July 1957/0130 hours	Guidance system accuracy at 130 NM.	0.15 NM over and 285 meters left of IP.
37 Pad 6	25 July 1957/2317 hours	Test warhead and fuze as a functioning system.	Test successful. Impact was 147 meters short/182 meters left of IP.
38 Pad 6	10 September 1957/2141 hours	Short range flight utilizing prototype ground handling and launching equipment.	Mechanical failure of guidance tilt program resulted in 75 NM trajectory and impact ~17 NM from launch pad.
39 Pad 6	2 October 1957/1429 hours	Second use of prototype ground handling and launching equipment.	445 meters long and 452 meters right of IP.
41 Pad 6	30 October 1957/2352 hours	Test flight to 130.588 NM.	Erroneous guidance instructions to control system caused sharp yaw 70 seconds into the flight. Range Safety Officer cut missile thrust at 98 seconds. Impact at 48 NM.
42 Pad 6	10 December 1957/1936 hours	Test flight to 141.895 NM.	94 meters over and 121 meters left of IP.

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[128] AFMTC Monthly Test Status Report, December 1956; Grimwood and Strowd, “History of the Jupiter Missile System,” p 153.

[129] Grimwood and Strowd, “History of the Jupiter Missile System,” pp 153, 154, 155; AFMTC History, January – June 1957, Vol I, pp 219, 220; AFMTC History, July – December 1957, Vol I, p 188.

The Cape's final JUPITER-A mission was launched from Pad 6 at 2024 hours on 14 January 1958. REDSTONE #45 was chosen for the flight, and the operation demonstrated the complete guidance system. The flight also provided the fifth complete flight test of the inert warhead and fuzing system. U-DETA fuel was used for increased performance, and detachable telemetry pods were tested on the flight. All mission objectives were accomplished, and the splashdown 142.4 nautical miles downrange was 370 meters over and 86 meters to the right of the predetermined impact point. The telemetry coverage of the mission yielded excellent data, and the mission provided a satisfying conclusion to the JUPITER-A series of launches on the Atlantic Missile Range.[130]

The second phase in the JUPITER's development got underway with the first JUPITER-C launch from the Cape in late September 1956. The JUPITER-C flights were few in number, but they were crucial to the success of the IRBM program because they were designed to prove the flight-worthiness of the JUPITER nose cone design. The JUPITER-A had been essentially a REDSTONE missile equipped with JUPITER components to prove propulsion system thrust control, guidance system accuracy and the effectiveness of warhead and fuzing systems at relatively short (e.g., 130-140 nautical-mile) distances. But the JUPITER-C would have to fly more than 1,000 nautical miles downrange to prove a scaled-down version of the JUPITER nose cone could withstand the stresses of IRBM reentry.[131] For *that* mission a faster, higher-flying three-stage ballistic missile was needed. Consequently, the JUPITER-C utilized a REDSTONE equipped with an elongated fuel tank for its first stage, a cluster of eleven scaled-down (six-inch diameter) SERGEANT solid propellant rockets for its second stage, and three scaled-down SERGEANT rockets of its third stage. The first stage had a range of 535 nautical miles, and it weighed approximately 63,500 pounds. The second stage was much lighter (e.g., 1,268 pounds) but, perched atop the first stage, it extended the vehicle's range to 1,200 nautical miles. The third

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[130] AFMTC Monthly Test Status Report, January 1958; Grimwood and Strowd, "History of the Jupiter Missile System," p 155.

[131] Reentry heating was a significant problem for an IRBM. Since the JUPITER would have to fly faster and higher to reach a much more distant target than the REDSTONE, its nose cone would encounter temperatures upon reentry hot enough to melt steel. The engineers at Redstone Arsenal considered heat sink, radiation and transpiration as three possible means of dealing with the reentry heating problem, but they ultimately settled on ablation (i.e., removing heat by surface erosion) when their experiments with plastics, fibers and ceramics indicated that method showed the greatest promise.

stage weighed 537 pounds, and it would carry a scaled-down JUPITER nose cone the rest of the way and possibly farther (1,563 nautical miles).[132]

Twelve JUPITER-C missiles were allocated for reentry test flights, but only three were needed to complete that phase of the JUPITER program. Following several unscheduled holds for weather, the first JUPITER-C (#27) lifted off Pad 5 at 0147 hours on 19 September 1956.[133] No scaled-down nose cone was carried on the flight, but the payload included 20 pounds of instruments attached to an inactive fourth stage. The primary objective of the mission was to test the proper operation of all three active stages of the vehicle. The mission was successful, and the vehicle reached an altitude of 682 statute miles.[134]

The second JUPITER-C (#34) was launched from Pad 6 at 0255 hours on 15 May 1957. The vehicle carried the first 314-pound version of the JUPITER nose cone, and it was targeted for impact 1,112 nautical miles downrange. The mission appeared normal up to the first stage's burn-out, but the vehicle suddenly pitched up to the left approximately 134 seconds into the flight. The second stage fired at a nearly vertical angle, and the third stage did not fire at all. Consequently, the nose cone came down 420 nautical miles short of the target. Fortunately, data collected during the reentry phase indicated the warhead's ablative protection worked. The flight was considered successful, and the Army agreed to let the range contractor call off the nose cone recovery effort scheduled earlier.[135]

The third JUPITER-C (#40) lifted off Pad 6 at 0158 hours on 8 August 1957. The flight was a complete success. The nose cone attained an altitude of 260 miles and a velocity of 4,004 meters per second. It survived reentry heating (more than 2,000 degrees Fahrenheit), and it

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[132] Grimwood and Strowd, "History of the Jupiter Missile System," pp 31, 60, 62, 81; John W. Bullard, "History of the Redstone Missile System," pp 141, 144, Army Missile Command Historical Division, 15 October 1965; AFMTC Monthly Test Status Report, January 1958.

[133] Grimwood and Strowd list the date and time as 0145 hours on 20 September 1956, but Marven R. Whipple's "Index of Missile Launching by Missile Program, July 1950 – June 1960" and the AFMTC Monthly Test Status Report for September 1956 maintain the flight occurred on 19 September 1956. The 19th was chosen for this narrative, but the 20th might be correct.

[134] Grimwood and Strowd, "History of the Jupiter Missile System," p 156; AFMTC Monthly Test Status Report, p 16, September 1956.

[135] Grimwood and Strowd, "History of the Jupiter Missile System," p 156; AFMTC History, January – June 1957, Vol I, p 220.

splashed down 1,168 nautical miles downrange. All nose cone recovery aids worked properly, and the U.S. Navy recovered the nose cone less than three hours after launch. Exterior erosion was less than expected, and the interior of the nose cone was not damaged by the reentry. Following its presentation on national television, the nose cone was placed on exhibition at the Smithsonian.[136]

As a result of the highly successful flight in August, eight JUPITER-C missiles were available for other types of missions in the fall of 1957. Prompted by the Soviets' successful orbit of *Sputnik I* on 4 October 1957, the Secretary of the Army proposed modifying the remaining JUPITER-Cs to launch satellites. The JUPITER-C certainly demonstrated the potential for such a mission earlier, and recent events (including the relatively lackluster performance of Project VANGUARD) persuaded the Secretary of Defense to lift his earlier prohibition on Army involvement in 'space activity.' On 8 November 1957, he directed the Army to modify two JUPITER-C missiles for satellite operations. America's first attempt to launch a satellite on a VANGUARD rocket failed spectacularly on 6 December 1957, but the Army was up to the challenge. The fourth JUPITER-C boosted America's first satellite (EXPLORER I)[137] into orbit from Pad 26A on 31 January 1958. Ultimately, six JUPITER-C flights were launched from the Cape between 31 January and 23 October 1958 on EXPLORER and BEACON missions. EXPLORER I, III, AND IV were orbited successfully on 31 January, 26 March, and 26 July 1958 respectively. EXPLORER II, EXPLORER V, and a BEACON inflatable sphere failed to orbit on 5 March, 24 August, and 22 October 1958 respectively.[138]

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[136] Bullard, "History of the Redstone Missile System," pp 141, 142; Grimwood and Strowd, "History of the Jupiter Missile System," p 156; AFMTC Monthly Test Status Report, August 1957.

[137] EXPLORER I weighed approximately 31 pounds including its 18-pound instrumented payload. A standard JUPITER-C (#29) missile equipped with a SERGEANT rocket as its fourth stage propelled EXPLORER I into orbit from a new launch pad (26A) near Complex 5/6. EXPLORER I is best remembered for the discovery of the Van Allen cosmic radiation belt, but the satellite also collected and relayed data on atmospheric densities and confirmed Earth was not exactly spherical but slightly oblate (flattened).

[138] Bullard, "History of the Redstone Missile System," pp 143, 145; AFMTC History, January – June 1958, Vol I, p 162; Marven R. Whipple, "Index of Missile Launchings by Missile Program, July 1950 – June 1960," p 17-5, 15 Dec 1950; Whipple, "Index of Missile Launchings by Missile Program, July 1960 – June 1961," p A-6-1, 10 Oct 1961.

The first JUPITER test missile was launched on 1 March 1957 to usher in the third phase of the JUPITER missile program. That part of the program was well underway by the beginning of 1958, and the Army and AFMTC expended considerable money and effort in 1956 and 1957 at Cape Canaveral and the AMR stations downrange to make the program's success possible. Whereas Complex 5/6 and its launch pads had been built for the REDSTONE back in 1954 and 1955, Complex 26 and launch pads 26A and 26B were built expressly for the JUPITER program. The $6,808,000 'brick and mortar only' contract for Complex 26 was awarded in June 1956, and government officials accepted the facility from the contractor on 14 May 1957. In early October 1956, two more JUPITER-related facility contracts were awarded: 1) a $2,964,000 contract for Assembly Building "Y" and 2) a $562,000 contract for a calibration laboratory within Assembly Building "Y". Officials designated Assembly Building "R" and a new Laboratory Engineering Building for the program, and a JUPITER Spin Test Facility was completed at the Cape on 2 August 1956. Per an exchange of notes between the U.S. State Department and the British Embassy, the United States was given the right to enter the island of Antigua on 15 January 1957 to construct and operate a tracking station. The station was 1,227 nautical miles southeast of the Cape, and it was built mainly to support Project VANGUARD and the Air Force and Army IRBM programs.[139] A total of six FS-type picket ships were spaced between Antigua and the island of Ascension (4,109 nautical miles from Cape Canaveral) to provide continuous telemetry reception between the two stations. At least one of those vessels supported JUPITER launches initially, and two more modern and capable C-1-MAV-1 instrumentation ships[140] covered JUPITER flights later in the program.[141]

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[139] An addition the Bahamian Agreement (5th Addition to Addendum #3) was released on 28 May 1957. It permitted AFMTC to acquire about 535 additional acres of land on San Salvador, GBI, Mayaguana, and Eleuthera to build facilities and operate range instrumentation. Range support for JUPITER extended down through the instrumentation station on Mayaguana to Antigua.

[140] Each 178-foot-long FS vessel carried a crew of 20 men and seven range technicians. It cruised at 10 knots, and it could remain on station for three weeks before returning to base. Its range instruments included two helical antennas, two Raymond-Rosen receivers, four Clark crystal controller receivers, eight magnetic tape recorders, timing gear and communications equipment. The C-1-MAV-1 was 340 feet long, and it carried a crew of 39 men and 8-12 range technicians. Its range equipment included two helical telemetry antennas, two omni-directional telemetry antennas, eight crystal controller receivers, three magnetic tape records, direction-finding equipment, timing gear and communications equipment. Standard maritime practice limited the C-1-MAV-1 to three weeks at sea, but continuous coverage could be achieved by alternating

Before the Cape's JUPITER flights are addressed, we need to mention that a significant shift in the program's oversight occurred as those missions got underway. Following Secretary Wilson's decision in November 1955 to develop two types of IRBMs, the Defense Department entrusted JUPITER's development to the Army and Navy jointly. The Navy was reluctant to put liquid-fueled ballistic missiles aboard its submarines, and the 'silent service' managed to bow out of the JUPITER effort on 8 December 1956. The Navy subsequently refocused its ballistic missile procurement effort on the solid-propellant POLARIS. With proper funding, the Army could continue to pursue JUPITER development on its own, but budgetary constraints soon forced Secretary Wilson to set up an *ad hoc* committee in August 1957 to work out details for a *single* land-based IRBM program. The JUPITER program was saved from extinction when *Sputnik I* was launched in early October 1957. Put simply, the THOR had some flight failures in 1957, and the JUPITER provided insurance against total failure. But a significant shift occurred when the Defense Department directed the Air Force to assist the Army in the JUPITER program. By mid-December 1957, responsibility for *deployment* of the JUPITER shifted from the Army to the Air Force's Strategic Air Command (SAC).[142]

The Air Force's Air Materiel Command (AMC) became the executive agent for the JUPITER program, and AMC established the Air Force JUPITER Liaison Office at Redstone Arsenal early in 1958 to coordinate the program the Army Ballistic Missile Agency (ABMA) *already had underway*. In the interest of joint-service cooperation, ABMA created the JUPITER Support Management Office (JSMO) to provide plans for provisioning and deploying missile forces, maintaining them and identifying the necessary contractor support services. Funding cutbacks in Fiscal Year (FY) 1959 threatened the extent of the missile's deployment, and, by mid-November 1958, the Air Force notified the Army that "tactical mobility was no longer

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duty shifts. Two C-1-MAV-1s were based at Trinidad to provide telemetry support and nose cone recovery services for the THOR and JUPITER missiles landing in the Antigua and Broad Ocean Area (BOA) impact zones.

[141] AFTMC History, 1 January – 30 June 1956, Vol I, p 273; AFTMC History, 1 July – 31 December 1956, Vol I, p 323; AFTMC History, 1 January – 30 June 1957, Vol I, p 103; AFTMC History, 1 July – 31 December 1957, Vol I, pp 217, 218, 219; AFMTC History, January – June 1958, Vol I, p 186.

[142] Grimwood and Strowd, "History of the Jupiter Missile System," pp 12, 13, 34, 35, 47.

considered a part of the program." Thus, much of the time and effort spent on developing ground transport equipment for the JUPITER was wasted.[143]

The missile's radio guidance backup system and the inertial fuze were deleted during early development, but most of the principal features of the JUPITER remained intact. The proximity and impact fuzes and the all-inertial guidance system were retained throughout the program. The length of the missile increased from 58 to 60 feet, but the JUPITER's diameter remained 105 inches. As described in early 1959, the JUPITER weighed 108,804 pounds at lift-off (including 68,760 pounds of oxidizer and 30,415 pounds of RP-1 fuel). The total weight was within a ton of the missile proposed back in 1955. The nose cone weighed 3,000 pounds including a 1,600-pound nuclear warhead (a slight change from the 2,000-pound payload proposed earlier). The JUPITER was powered by a North American Aviation NAA-150-200-S-3D rocket engine rated at 150,000 pounds of thrust — unchanged from the original proposal. A solid-propellant vernier thrust system rated at 500 pounds of thrust was mounted on the aft section of the missile to control the JUPITER after main engine cut-off. (Two hydrogen peroxide-powered thrust nozzles had been suggested earlier.) Eight nitrogen-powered jet nozzles controlled pitch, yaw and roll (versus six nozzles proposed for the spatial attitude control in 1955).[144]

The missile was designed to strike targets as close as 300 nautical miles away, but its maximum range remained 1,500 nautical miles as agreed in 1955. Circular Error Probability (CEP) was 1,500 meters for all targets. The missile had to reach an altitude of 390 nautical miles to reach targets at maximum range, but the nearest targets only required an altitude of 85 nautical miles. The JUPITER could reach its most distant targets in 1,017 seconds, but the closest targets only required flights of 487 seconds. To reach maximum range, the JUPITER topped Mach 13 at main engine cut-off. It achieved Mach 15.45 during reentry but slowed down to less than half the speed of sound (Mach 0.49) on impact.[145]

The THOR, POLARIS, and ATLAS made their debut flights from Cape Canaveral on 25 January, 13 April, and 11 June 1957, so JUPITER #AM-1A was in good company when it

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[143] Grimwood and Strowd, "History of the Jupiter Missile System," pp 50, 51, 52.

[144] Grimwood and Strowd, "History of the Jupiter Missile System," pp 8, 55, 56, 58, 59, 148.

[145] Grimwood and Strowd, "History of the Jupiter Missile System," pp 8, 148.

inaugurated JUPITER flights from Pad 5 at 1651 hours on 1 March 1957. The primary objectives of this flight and other early JUPITER missions were to: 1) flight test North American's S-3D engine, 2) collect stability and vibration data on the guidance system, 3) test the vehicle's attitude, altitude and angle-of-attack control systems, 4) note propellant temperatures as the engine operated under flight conditions, 5) gather data on the missile's body and booster architecture, 6) flight test heat-protected components, and 7) test flame effects on the backup radio guidance system. Inertial guidance system components flew aboard the missile as "passengers" on the first mission, but the missile's North American S-3D main engine was only rated at 135,000 pounds of thrust (versus 150,000 pounds required by contract specification).[146] The first JUPITER flight appeared normal until the missile pitched upward and exploded about 74 seconds after lift-off. Mission failure was attributed to excessive heating in the missile's tail section. The missile managed to reach an altitude of 48,000 feet before it exploded, so some important data was gathered before the flight ended.[147]

The next flight displayed a different design problem, but the third JUPITER flight began to demonstrate the missile's real potential. The second JUPITER (#AM-1B) managed to last 93 seconds after its lift-off from Pad 5 at1512 hours on 26 April 1957. The missile reached an altitude of 60,000 feet before "sloshing" propellant destabilized the JUPITER and caused it to disintegrate. The mission was designed to test the airframe and rocket engine, so the data gathered suggested the flight was partially successful. The third flight was somewhat shorter than planned, but it was considered completely successful. JUPITER #AM-1 was launched from Pad 5 at 1308 hours on 31 May 1957, and it provided the first real test of the range, capability and performance of the S-3D engine and its control system. All aspects of the flight were normal, and

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[146] The first two flyable S-3D engines were received by the Army in September and November 1956, but static tests led ABMA to rate them both at 135,000 pounds of thrust due to deficiently designed turbo pumps. North American began modifying later series engines as soon as the deficiency was noted, but ABMA was forced to use lower-rated engines on the first seven JUPITER flights from the Cape due a critical shortage in S-3D engines in 1957. The main engines used on the first two flights were rated at 135,000 pounds of thrust each, and the other five engines were rated at 139,000 pounds of thrust each. JUPITER #AM-5 was the first of the series to use a 150,000-pound-thrust main engine.

[147] Grimwood and Strowd, "History of the Jupiter Missile System," pp 70, 149, 157; AFMTC History, 1 January – 30 June 1957, Vol I, pp 150, 221; AFMTC Monthly Test Status Report, March 1957.

the missile achieved an apogee of approximately 351 nautical miles before impacting about 1,150 nautical miles downrange. The flight was 253 nautical miles short of the intended target, but, considering the S-3D engine was only rated at 139,000 pounds of thrust, the Army was gratified by the results of the flight.[148]

Four more JUPITER missiles were launched from the Cape in the latter half of 1957, and the first two of them had the distinction of inaugurating launch operations on Complex 26. Missile #AM-2 lifted off Pad 26A on the fourth JUPITER mission at 1602 hours on 28 August 1957. That flight featured the first flight test of the thrust unit's separation from the missile body. The missile was guided by autopilot, and it carried the all-inertial guidance system and radio guidance system as passengers. Thrust unit separation occurred five seconds after burnout as planned, and the missile splashed down 1,490 nautical miles downrange. Though the missile impacted approximately 30 miles beyond the intended impact point, all phases of the JUPITER #AM-2 flight were successful.[149]

Missile #AM-3 was flown on the fifth JUPITER mission from the Cape, and it was launched from Pad 26B at 2007 hours on 22 October 1957. The missile carried a heat-shielded nose cone, and the flight featured the first use of an all-inertial guidance system on a JUPITER prototype missile. Missile #AM-3 followed its preplanned trajectory closely, but the flight went 9.5 seconds longer than anticipated. According to a monthly test report, the missile impacted nine miles short and eight miles east of the target about 1,100 nautical miles downrange. The nose cone survived reentry, and the flight was successful.[150]

The last two JUPITER flights in 1957 were only partially successful. Missile #AM-3A was launched from Pad 26B at 2110 hours on 26 November 1957. The flight followed its planned trajectory for about 100 seconds, but the missile's turbo pump failed abruptly and caused a complete loss of thrust. The JUPITER reached an altitude of 65,000 feet before

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[148] Grimwood and Strowd, "History of the Jupiter Missile System," pp 148, 157; AFMTC History, 1 January – 30 June 1957, Vol I, p 222; AFMTC Monthly Test Status Report, April 1957; AFMTC Monthly Test Status Report, May 1957.

[149] Grimwood and Strowd, "History of the Jupiter Missile System," p 157; AFMTC History, 1 July – 31 December 1957, Vol I, p 190.

[150] Grimwood and Strowd, "History of the Jupiter Missile System," p 157; AFMTC History, 1 July – 31 December 1957, Vol I, p 190; AFMTC Monthly Test Status Report, October 1957.

exploding in full view of the Cape above the horizon. JUPITER #AM-4 lifted off Pad 26B at 1907 hours on 18 December 1957. Once again, the main engine's thrust was cut off abruptly when the missile's turbo pump shut down about 117 seconds into the flight. Though both flights ended early, some primary and secondary objectives were accomplished during both missions. North American had been working on the turbo pump problem since at least the beginning of 1957, and later JUPITER missions would have better luck with their turbo pumps, as we shall see.[151]

The eighth JUPITER mission was launched from Complex 26 at 0005 hours on 18 May 1958. It featured the first flight and recovery of a full-scale JUPITER tactical nose cone. The missile (#AM-5) splashed down 1,257 nautical miles downrange, albeit 28.3 nautical miles short and 15.6 nautical miles to the right of the intended target. The nose cone was secured with a flotation buoy within two hours of impact, and it was recovered by U.S.S. *Escape* about two hours later. Its successful return to Redstone Arsenal permitted a detailed analysis of the nose cone's internal components and any 'wear and tear' due to high velocity reentry.[152]

The second full-scale tactical JUPITER nose cone was carried aboard JUPITER #AM-6B when it lifted off on the ninth JUPITER mission on 17 July 1958. About 100 pounds of explosives were carried in the nose cone to supply Sandia Corporation with practical evidence of any adverse effects on explosives during missile flight. The mission also featured the first flight test of the *complete* inertial guidance system. Four unscheduled holds added nearly four hours to the countdown, and they were required to check guidance equipment, replace a DOVAP transponder and verify a liquid oxygen control valve was positioned properly. The missile lifted off Pad 26B at 0404 EST, and it impacted just one nautical mile short and a mile and a half to the right of the target 1,241 nautical miles downrange. All systems functioned normally, and the nose cone was recovered about one hour and 21 minutes after launch.[153]

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[151] Grimwood and Strowd, "History of the Jupiter Missile System," pp 157, 158; AFMTC History, 1 July – 31 December 1957, Vol I, p 191; AFMTC Monthly Test Status Report, November 1957; AFMTC Monthly Test Status Report, December 1957.

[152] Grimwood and Strowd, "History of the Jupiter Missile System," p 158; AFMTC History, 1 January – 30 June 1958, Vol I, p 163.

[153] Grimwood and Strowd, "History of the Jupiter Missile System," p 158; AFMTC History, 1 July – 31 December 1958, Vol I, p 187.

Three more JUPITER missions were launched from Complex 26 on 27 August, 9 October and 13 December 1958 respectively. The first of those operations featured JUPITER #AM-7, and it included the first flight test of the missile's warhead and fuzing system. Missile #AM-7 lifted off Pad 26A at 1815 hours on August 27th following a 15-minute delay in the countdown for last-minute adjustments. The flight was normal, but early fuel depletion ended the mission short of its intended target. The missile splashed down about 39 nautical miles short and 15.7 nautical miles to the left of the predetermined impact point (i.e., impact was 1,207 nautical miles downrange).[154]

Missile #AM-9 was launched from Pad 26B at 2249 hours on 9 October 1958. The flight became erratic when the missile reached an altitude of about 7,000 feet, and the Range Safety Officer (RSO) destroyed the JUPITER about 49 seconds after lift-off. The missile impacted about 3,000 feet from the launch pad. Post-flight analysis suggested a pin-hole leak near the thrust transducer caused a fire that burned through the fuel and oxidizer lines in the tail section of the missile.[155]

Missile #AM-13 fared better than its predecessor when it flew the twelfth JUPITER mission on 13 December 1958. In addition to the routine flight objectives, a physiological study of space flight effects prompted officials to include a one-pound squirrel monkey named GORDO as a passenger on the mission. The missile lifted off Pad 26B at 0353 hours, and it splashed down about five miles farther than intended (i.e., about 1,307 nautical miles downrange). The missile reached an altitude of 300 miles, but (sadly) the capsule and its heroic little astronaut were not recovered. A leaky flotation mechanism was blamed for the loss of the spacecraft. The mission was considered a highly successful valuable contribution to space research.[156]

No fewer than 15 JUPITER missiles were launched from four different sites on Cape Canaveral during 1959. Highlights of the missions included: 1) the first Chrysler

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[154] Grimwood and Strowd, "History of the Jupiter Missile System," pp 158, 159; AFMTC History, 1 July – 31 December 1958, Vol I, p 188.

[155] Grimwood and Strowd, "History of the Jupiter Missile System," p159; AFMTC History, 1 July – 31 December 1958, Vol I, p 188.

[156] Grimwood and Strowd, "History of the Jupiter Missile System," p159; AFMTC History, 1 July – 31 December 1958, Vol I, p 188.

production/qualification missile flight (on 21 January 1959), 2) a flight to declare the JUPITER "operationally ready" (flown on 6 May 1959), and a space research flight for two monkeys (ABLE and BAKER) on 29 May 1959. Details of all 15 flights are listed below:[157]

VEHICLE # and Pad #	DATE/LOCAL TIME	OBJECTIVES	OUTCOME
CM-21 Pad 5	21 January 1959/1910 hours	1st Chrysler Production/ Qualification Flight – 1,302 NM downrange	Successful flight, but 3 NM over and 1 NM left due to long vernier burn.
CM-22 Pad 26B	27 February 1959/1850 hours	Nose Cone Test - 1,302 NM downrange	Successful, but 2.8 NM over due to long vernier burn.
CM-22A Pad 26B	3 April 1959/1934 hours	Nose Cone Test	Successful flight. 5.0 NM left due to drifting gyro.
AM-12 Pad 26B	6 May 1959/2047 hours	JUPITER declared "operationally ready"	Thrust controller dropped missile 69 NM short and 4.9 NM right, but primary objectives accomplished.
AM-17 Pad 5	14 May 1959/0052 hours	Missile Accuracy Test	0.26 NM over & 0.4 NM left. Highly successful.
AM-18 Pad 26B	28 May 1959/0235 hours	Primates ABLE and BAKER bioflight – 1,302 NM downrange	Successful. Primates recovered unharmed less than 0.5 NM from target.
AM-15 Pad 26B	9 July 1959/2001 hours	1,302 NM Accuracy Test	Impact well within 1 NM.
AM-19 Pad 5	26 August 1959/2030 hours	300 NM Accuracy – 1st short-range JUPITER Flt.	0.03 NM short & 0.22 NM right on intended target.
AM-23 Pad 26B	16 September 1959/0645 hours (per test activity report) G&S claim flight was 15 September 1959/1645 hours)	Missile Accuracy Test and Specimens (Mice & Frogs)	Missile destroyed itself 13 seconds after lift-off. (just before destruct command).
AM-24 Pad 6	30 September 1959/2028 hours	1,299.4 NM Accuracy Test	Impact within 1.25 NM of target. Successful Flight.
AM-31 Pad 26A	21 October 1959/2220 hours	1,600.448 NM Tactical Prototype Flight	Impacted 0.9 NM short and 0.6 NM right of target.
CM-33 Pad 6	4 November 1959/1938 hours	Chrysler Assembled Missile Accuracy Test– 1,299.4 NM.	Impacted 0.56 NM short and 0.09 NM right of target.
AM-25 Pad 26B	18 November 1959/2031 hours	664.8 NM Accuracy Test – 1st medium range flight.	Impacted 0.9 NM over and 1.0 NM left of target.
AM-32 Pad 6	9 December 1959/1908 hours	1,299.4 NM Accuracy Test	Impacted 0.3 NM over and 2.0 NM right of target.
AM-26 26B	16 December 1959/1903 hours	300 NM Accuracy Test	Impacted 0.1 NM right of target.

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[157] Grimwood and Strowd, "History of the Jupiter Missile System," pp 159, 160, 161, 162; AMR Test Activity Reports, January through December 1959.

With the exception of JUPITER #AM-23, all the JUPITER flights in 1959 were successful. The Army and Chrysler could take pride in this remarkable achievement, and greater successes were yet to come in the course of PERSHING flights from the Cape in the 1960s, 1970s and 1980s. In the meantime, the Research and Development (R&D) portion for the JUPITER program was closed out with two test flights on 25 January and 4 February 1960. There was also a “Live System Test” on 20 October 1960, and six Combat Training Launches (CTL) from Pad 26 between 22 April 1961 and 23 January 1963. A modified version of the JUPITER called the JUNO II[158] was employed on ten PIONEER, EXPLORER, and BEACON missions launched from Pad 5 and Pad 26B between 6 December 1958 and 25 May 1961. The first five JUNO II flights occurred before ABMA’s space missions were transferred to NASA on 14 March 1960. Since the formal transfer of personnel and facilities from ABMA to the Marshall Space Flight Center did not take place until 1 July 1960, it is only fitting that we mention the first five JUNO II missions before we close this chapter with the Army’s final JUPITER flights from Cape Canaveral in the early 1960s.[159]

The first two JUNO II vehicles were used to launch PIONEER payloads for NASA in December 1958 and March 1959. The first JUNO II vehicle (#AM-11) boosted the 15-pound PIONEER 3 lunar probe from Pad 5 at 0044 hours on 6 December 1958. Most of the mission’s objectives were accomplished, but the first stage burn ended 3.7 seconds early. Consequently, the probe did not reach the vicinity of the Moon as intended, but it managed to fly part of the way (e.g., 66,654 miles from Earth). The second JUNO II (#AM-14) was slightly more successful. The vehicle carried the 15-pound PIONEER 4 spacecraft into space from Pad 5 at 0011 hours on 3 March 1959. The payload managed to take photos as it flew past the Moon, but it was on the wrong trajectory and wound up orbiting the Sun. Despite the flawed trajectory the

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[158] The basic JUNO II was a JUPITER missile equipped with an elongated booster and at least one upper stage consisting of a cluster of scaled-down SERGEANT rockets. (Additional upper stages were added, depending on the mission.) The similarities between the JUNO II architecture and the modified REDSTONE/JUPITER-C configuration are obvious. The primary objectives of the JUNO II missions were to place satellites in Earth orbit or gather space data out to the Moon. Source: Atlantic Missile Range Test Activity Report, January 1959.

[159] 45 SW History Office, “Eastern Range Launch Database, July 1950 – Present” undated; “Marshall Space Flight Center (MSFC)” p 1, history.nasa.gov website, undated.)

booster performed satisfactorily, and NASA took some consolation in the fact that radio contact with America's "first solar satellite" continued out to a distance of 406,620 miles.[160]

Three more JUNO II vehicles were launched from Pad 5 before the end of 1959. Vehicle #AM-16 lifted off Pad 5 with a 94-pound EXPLORER payload at 1237 hours on 16 July 1959. An electrical malfunction caused the vehicle to heel over five seconds after lift-off, and the JUNO II crashed 250 feet from the launch table. The fourth JUNO II (#AM-19B) was launched from Pad 26B at 1931 hours on 14 August 1959. Its 25.5-pound BEACON payload included a 12-foot diameter inflatable sphere. The mission's primary objective was to gather data on the sphere's density characteristics while in orbit, but NASA never got the chance. The payload failed to orbit when an upper stage cluster fired in the wrong direction. The fifth JUNO II (#AM-19A) lifted off Pad 5 at 1030 hours on 13 October 1959. The principal goal of the mission was to orbit the 91.5-pound EXPLORER 7 payload successfully so it could transmit radiation data and weather information back to Earth. In this it succeeded admirably, and all transmitters carrying satellite information functioned properly once in orbit.[161]

Two JUPITER flights concluded the R&D series at Cape Canaveral shortly thereafter. The first of the two lifted off Pad 26B at 1948 hours on 25 January 1960. The flight tested the missile's two-way deflector launch table, and it provided data on high temperatures in the missile's tail section. It also reconfirmed all systems functioned properly out to a range of 1,299.4 nautical miles. The flight met all mission objectives, and the missile (#AM-28) impacted 0.04 nautical mile over and 3.27 nautical miles to the left of the target. The last JUPITER R&D mission featured JUPITER #AM-30, and it was launched from Pad 6 at 1919 hours on 4 February 1960. The range was 1,299.4 nautical miles, and the objectives included performance tests of: 1) DOFL and Picatinny Arsenal nose cone components, 2) the final production version of the Sandia warhead and dual radar fuze, 3) the complete inertial guidance system including its ST-90 stabilized platform and tactical guidance computers, and 4) the North American S-3D engine. Telemetry indicated all systems and components operated normally at the proper times.

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[160] Grimwood and Strowd, "History of the Jupiter Missile System," p 171; AMR Monthly Test Activity Report, December 1958; AFMTC History, 1 July – 31 December 1958, Vol I, p 189; AFMTC History, 1 January – 30 June 1959, Vol I, p 176.

[161] Grimwood and Strowd, "History of the Jupiter Missile System," p 171; AMR Monthly Test Activity Reports, July, August and October 1959.

The nose cone impacted two-thirds of a mile short and half a mile to the right of the intended target. All primary and secondary objectives were accomplished successfully, and the flight concluded the R&D series on a high note.[162]

An oddly numbered JUPITER missile (#217) was chosen for the Cape's only JUPITER Live System Test (LST) on 20 October 1960. The launch featured the first use of JUPITER tactical ground support equipment at the Cape, and the target was 962.5 nautical miles downrange. There were no technical holds during the countdown. The missile lifted off Pad 26A at 1102 hours under simulated tactical or "field" conditions. All primary and secondary mission objectives were accomplished successfully, and the nose cone splashed down about a mile over and a fifth of a mile to the right of the target.[163]

The LST was an encouraging forerunner to the six Combat Training Launch (CTL) operations conducted at Cape Canaveral for JUPITER crews in the early 1960s. As mentioned earlier, the responsibility for deployment of the JUPITER shifted from the Army to the Air Force's Strategic Air Command (SAC) in December 1957. Early plans suggested foreign (host nation) crews would work alongside Air Force personnel when the missiles were deployed to Europe, but the search for willing allies proved difficult. The Defense Department intended to deploy three squadrons of 15 JUPITER missiles each to France initially, but negotiations on a bilateral agreement that would allow French crews to operate JUPITER missiles led nowhere in 1958. Negotiations with Italy and Turkey proved more successful, but lengthy negotiations over funding and site construction delayed the conclusion of technical agreements with those countries until August 1959 and June 1960. Ultimately, ten missile emplacements of three JUPITER missiles each were turned over to the Italian Air Force crews between 11 July 1960 and 21 June 1961. As agreed, U.S. Air Force personnel continued to control the arming of the nuclear warheads associated with those emplacements after the transfer. By April 1962, a third squadron of 15 missiles was manned by U.S. Air Force personnel in Turkey. The Americans

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[162] Grimwood and Strowd, "History of the Jupiter Missile System," p 162; AFMTC, "Atlantic Missile Range Test Activity Reports," February and March 1960 (for tests in January and February 1960).

[163] Grimwood and Strowd, "History of the Jupiter Missile System," p 163; AFMTC, "Atlantic Missile Range Test Activity Reports," November 1960 (for test in October 1960).

turned over the first flight of three JUPITER missiles to the Turkish Air Force in late October 1962. Once again, the Americans retained control of the nuclear warheads.[164]

In February 1959, the Secretary of Defense issued a schedule indicating that the first JUPITER squadron would be manned by U.S. Air Force personnel and the second JUPITER squadron would be manned by the Italian Air Force. Consequently, SAC deactivated two of its tactical training squadrons (the 865th and 866th), and the Air Force relied on the recently-trained 864th Tactical Training Squadron to maintain its presence in the JUPITER program.[165] The first group of Italian crew members arrived at Lackland AFB, Texas, for language skills training in June 1959. Following completion of their studies there, the Italians transferred to Redstone Arsenal in September 1959 to begin JUPITER training. The Italian training program in the United States was completed by October 1960. The Turks received a total of 12 months of English instruction before beginning their individual technical training for JUPITER on 28 June 1961. Under the Rome Air Development Center's Liaison Office, the U.S. Air Forces Europe (USAFE) Liaison Officer exercised operational and administrative control over NATO troops participating in JUPITER CTL operations at Cape Canaveral. AFMTC provided billeting, office equipment, subsistence, and transportation in the local area. The initial complement for a CTL crew was five NATO officers and 36 NATO enlisted men. The training program continued into the following year, but the Cuban Missile Crisis in October 1962 finally precipitated the removal of all JUPITER missiles from service by April 1963. The last six JUPITER flights from Cape Canaveral were all CTL missions. Italian crews launched five of the missiles, and a Turkish crew launched one JUPITER on 18 April 1962. Details of the flights appear in the table on the next page.[166]

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[164] Grimwood and Strowd, "History of the Jupiter Missile System," pp 98, 100, 101, 103, 104.

[165] Under the terms of the August 1959 bilateral agreement, both squadrons destined for Italy could be manned by Italian crews. The 864th thus became a "floating training team" for the JUPITER force.

[166] Grimwood and Strowd, "History of the Jupiter Missile System," pp 92, 93, 95, 97 163; AFMTC History, 1 January – 31 December 1961, Vol I, p 17; AFMTC, "Atlantic Missile Range Test Activity Reports," May and September 1961 (for tests in April and August 1961; AFMTC, "Atlantic Missile Range Test Activity Report" January Report (for tests in December 1961); AFMTC, "Atlantic Missile Range Test Activity Reports" April and August 1962 (for tests in those months) and January 1963 (for tests in January 1963).

VEHICLE # and Pad #	DATE/LOCAL TIME	OBJECTIVES	OUTCOME
209 26A	22 April 1961/0907 hours	Test crew capabilities under operational alert conditions and confirm JUPITER weapon system reliability.	Scrubbed on 20 April 1961 but launched successfully on 22 April. Impact was .79 NM long & 2.19 NM right of 1,514 NM target.
218 26A	4 August 1961/1919 hours	Same as #209 plus airburst test of operational warhead (w/o nuclear component).	All objectives met. Early report indicated detonation occurred 1.24 NM long & 0.13 NM left of target.
115 26A	6 December 1961/1737 hours	Same as #209. No airburst.	Telemetry indicated missile flew well. First reports indicated impact was 0.62 NM long and 0.39 NM right of 1,516 NM target.
114 26A	18 April 1962/1317 hours	Same as #209 and #115	Flight was normal until early fuel depletion cut off thrust 155 seconds into the flight. Later staging events (separation, vernier engine ignition, etc.) were not achieved at the proper time. Fuel mixture was 19% too rich. Impact was 232.9 NM short of target.
111 26A	1 August 1962/1346 hours	Same as #209, #115 and #114	Completely successful. Nose cone impacted 0.26 NM short and 0.81 NM left of target.
106 26A	22 January 1963/1927 hours	Same as #209, #115, #114 and #111.	Slowly closing fuel and oxidizer valves prolonged thrust decay. The extra velocity prevented vernier engine ignition. Impact was 23 NM long and 0.3 NM left of target.

The JUPITER flight on 22 January 1963 marked the end of an era for Army liquid-fueled ballistic missiles at the Cape, but initial testing of the Army’s most significant solid-fueled ballistic missile — the PERSHING — was nearly complete by the time the JUPITER lifted off on the final CTL mission. In fact, PERSHING missiles had been flying from Complex 30 since late February 1960. Unlike the REDSTONE and JUPITER, the PERSHING and its successors (PERSHING 1A and PERSHING II) would have considerable longevity with the Army’s missile forces, and three generations of PERSHING missiles provided a considerable nuclear deterrent to Soviet aggression in Western Europe in the 1960s, 1970s and 1980s.[167]

The PERSHING offered greater mobility, reliability, flexibility and responsiveness than the REDSTONE and JUPITER. Together with the Air Force's MINUTEMAN and the Navy's POLARIS, the first-generation PERSHING was on the cutting edge of America's latest ballistic missile technology in the early 1960s. Complexes 16 and 31 would be pressed into service for PERSHING 1A and PERSHING II flight tests later on, but Complex 30 was purpose-built for the PERSHING program west and slightly south of Complex 5/6 between December 1958 and February 1960.[168] The site was occupied by the Army on 8 January 1960, and the complex was finally accepted on 21 March 1960. In the meantime, the first PERSHING was launched from Pad 30A on 25 February 1960. In the next chapter, we will look at the PERSHING era at Cape Canaveral, the program's successes and failures, and its connection with the Intermediate Nuclear Forces (INF) Treaty signed by the United States and the Soviet Union.[169]

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[167] 45th Space Wing History Office, "Eastern Range Launch Database," undated.

[168] The complex included: 1) a two-story blockhouse with an eight-foot-thick roof, 2) two launch pads with service towers, 3) a missile installation and checkout building and 4) a helicopter apron. The "brick and mortar" cost of Complex 30's blockhouse and two launch pads (30A and 30B) was either $2,460,000 or $4,824,000 depending on the source cited. The facility was completed on 22 January 1960, and the Corps of Engineers inspected it on 10 February 1960 before transferring it to AFMTC for use by the Army.

[169] 45th Space Wing History Office, "Eastern Range Launch Database," undated; AFMTC History, 1 January – 30 June 1960, Vol I, p 40.

PERSHING

On 31 October 1956, the Chief of the Army's Research and Development Department asked the Army Chief of Ordnance to undertake a feasibility study for a solid-fueled ballistic missile to replace the liquid-fueled REDSTONE tactical missile system.[170] The request was transferred to the Army Ballistic Missile Agency (ABMA) on 14 November 1956. The study was successful, and its subsequent endorsement by the Joint Chiefs of Staff prompted the Secretary of Defense to authorize development of the missile on 7 January 1958. The Defense Department informed the public on 16 January 1958 that the new solid-fueled missile would be named the PERSHING in honor of General John J. Pershing, Commander of the American Expeditionary Force (AEF) in France in World War I. The Army Secretary gave ABMA responsibility for the PERSHING development project on 19 February 1958, and a cost-plus-fixed-fee contract was awarded to the Martin Company (Orlando, Florida) on 28 March 1958 to research, develop and produce the missile under the U.S. Government's technical supervision. The Army's Ordnance Technical Committee gave the project "1A" priority in April 1958, and the Committee approved the basic military features of the PERSHING on 9 October 1958. Construction of Complex 30 for the PERSHING program was underway at Cape Canaveral in December 1958.[171]

Touted as having "the field worthiness and accuracy of the Army's REDSTONE missile" yet lighter, smaller and more mobile than its predecessor, the two-stage PERSHING was 34 feet 7 inches long and 40 inches in diameter. The missile weighed approximately 10,000 pounds, and both its stages burned solid Polybutadiene Acrylic Acid (PBAA) to provide thrust.[172] The PERSHING was designed to carry an 800-pound warhead up to 300 nautical miles, and it was

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[170] The REDSTONE was not deployed until 1958, but an arms race with the Soviet Union spurred rapid advancements in "nuclear-capable" missile technology in the latter half of the 1950s. The Army wisely chose to plan aggressively to ensure a follow-on missile system was available for deployment before emerging technologies rendered the REDSTONE completely obsolete.

[171] "The Pershing Weapon System and Its Elimination," pp 1, 3, redstone.army.mil website, undated; AFMTC History, 1 January – 30 June 1960, Vol I, p 40.

[172] The first stage developed approximately 27,500 pounds of thrust, and the second stage delivered about 18,000 pounds of thrust. The first six PERSHING missiles launched from the Cape weighed about 12,700 pounds each and developed more than 31,000 pounds of thrust at lift-off. Each of those "Group I" test missiles carried an *unpowered* second stage, and (except for #105 that flew about 20 miles) their target areas were about 30 nautical miles downrange.

equipped with an inertial guidance system to limit its Circular Error Probability (CEP) to 400 meters. The missile could be fired from an unprepared launch site in a matter of minutes. The missile was carried on a newly designed erector-launcher featuring a 20-foot-long erector boom mounted on a tracked M-474 vehicle.[173] The Martin Company (later known as Martin Marietta) was the prime contractor for the PERSHING. Thiokol Chemical Corporation (Huntsville, Alabama) was the subcontractor for design and development of the propulsion system. Bendix's Eclipse-Pioneer Division (Teterboro, New Jersey) provided the inertial guidance stable platform, and the Bulova Watch Company (Long Island, New York) delivered the fuzing and arming system. Thompson Ramo Woolridge (TRW) Inc. developed the mobile erector-launcher initially, but the Unidynamics Division of Universal Match Company (St. Louis, Missouri) manufactured the erector-launcher in the early 1960s.[174]

The PERSHING test program was divided into four groups of missiles initially, but it progressed through three groups of developmental missiles and two groups of prototype production missiles before test flights ended at the Cape in 1963. Six Group I missiles were assembled, each with a powered first stage, an unpowered second stage, a dummy warhead, and an LEV-3 autopilot. Tactical guidance components flew as 'passengers' onboard the "100" series missiles. Group I flights were designed to prove the rocket motor could deliver enough thrust to fly the missile through the desired trajectory at the proper velocity. Other objectives included: 1) confirmation of the missile's structural integrity, 2) successful demonstration of the flight control system and its ability to respond correctly to the control computer's commands, and 3) collection

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[173] The M-474 was built by FMC Corporation, and it was based on the M-113 light armored personnel carrier. Four M-474 tracked vehicles were required to transport: 1) the PERSHING minus its warhead section, 2) the warhead section, 3) the programmer-test station/power station, and 4) the tropospheric-scatter radio terminal set. The M-474 was 18 feet long and 8 feet wide, and it weighed 12 tons. It had a range of 200 miles and a top speed of 40 miles per hour on improved roads. The basic PERSHING firing unit only needed four tracked vehicles versus 20 vehicles required for a REDSTONE firing unit.

[174] AFMTC, "Atlantic Missile Range Test Activity Reports," for February, May, September and November 1960; AFMTC Office of Information Fact Sheet, "PERSHING FACT SHEET," January 1962; AFMTC Office of Information Fact Sheet, "PERSHING FACT SHEET," 1 April 1963; Andreas Parsch, "Martin Marietta M14/MGM-31 *Pershing*," p 2, 2002.

of data on the missile's aerodynamic characteristics and rocket motor performance during flight.[175]

The next eight PERSHING test missiles were assigned to Group II and given "200"series serial numbers. They featured a 'live' first stage, a 'high energy' second stage, an LEV-3 guidance system, and an instrumented warhead. Stable platform (i.e., guidance) components were carried as passengers. Group II flights tested the second stage's performance, first/second stage 'in-flight' separation, proper operation of the engine cut-off (thrust termination) system, and performance of the warhead during the flight.[176]

The Army expected to launch 47 missiles under Group III, but only 32 of those "300" series missiles were launched before the Group IV and Group V prototype production missiles were introduced to the Cape in early 1963. The Group III missiles had high energy first and second stages. The series started with LEV-3 autopilots and progressed to the "open loop" stable platform guidance system. Group III missions tested the PERSHING's first and second stages, its open and closed loop guidance computers, adaptation kits, the missile's warhead and reentry bodies. The flights could be of short, medium or long duration, but all Group III missions provided an opportunity to explore various tactical procedures.[177]

Eight PERSHING missiles were set aside for Group IV flights initially, but those prototype production operations were cut back to six "400" series missions. A batch of four "500" series missiles were allocated to a new group — Group V — in February 1963. Both groups of prototype production flights tested the complete tactical weapon system and its final tactical procedures. The missile and all its ground handling equipment (e.g., tactical computer, power station, handling equipment and erector-launcher) were evaluated during those operations.[178]

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[175] AFMTC, "Atlantic Missile Range Test Activity Reports," for February, May, September and November 1960.

[176] AFMTC, "Atlantic Missile Range Test Activity Reports," for February, May, September and November 1960.

[177] *Ibid.*

[178] AFMTC, "Atlantic Missile Range Test Activity Reports" for February, March and April 1963.

The first six PERSHING missiles (#105 through #110) were launched successfully from Pad 30A on 25 February, 20 April, 10 May, 9 June, 30 June and 26 July 1960. The first missile in the series splashed down about 20 miles from the launch pad, but the other missiles impacted in a target area about 30 nautical miles downrange (as planned). All six flights met their primary mission objectives, and only one unplanned hold (to adjust a high-power air supply) was noted in the test activity reports for the missions. The mission on 26 July 1960 featured the first use of the experimental transporter-erector-launcher (XM-474). The program was off to a good start.[179]

Before we discuss the Group II launches, we need to mention the principal Army organizations that supported PERSHING operations at the Cape in the early 1960s. The U.S. Army Element, AFMTC began representing the Army's interests on the Atlantic Missile Range in January 1957, but it was replaced by the Atlantic Missile Range Army Field Office (AMRAFO) on 1 March 1962. The AMRAFO Chief was given a new title, "the Department of Army Representative at the Atlantic Missile Range." Detachment A, Army Ordnance Missile Command (AOMC) was organized on 15 December 1960, and it was placed under AMRAFO for administration and operational control *more than a year before* AMRAFO absorbed the U.S. Army Element's responsibilities. Detachment "A" became Detachment A, USAMICOM (TD69-7877) when AOMC was redesignated U.S. Army Missile Command (USAMICOM) on 1 August 1962. The Detachment remained on station, but it was attached to Headquarters USAMICOM (Redstone Arsenal) for logistical support and training effective 25 March 1963.[180] While the Martin Company and its subcontractors were involved in PERSHING throughout the flight test program, it appears AMRAFO and Detachment A participated in PERSHING activities at the Cape at least from early 1961 onward. In addition to those stationed units, a contingent of the 2nd Missile Battalion, 44th Artillery arrived at Patrick AFB on 21 March 1963 for PERSHING

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[179] AFMTC, "Atlantic Missile Range Test Activity Reports," for February, April, May, June and July 1960.

[180] Detachment "A" had 3 officers and 25 enlisted troops on its rolls by the end of 1960, but it had 19 civilians and *no* military members by December 1961. AMRAFO had 6 officers 21 enlisted troops, and 6 civilians assigned to its activities at Patrick AFB at the end of 1962. The office's assigned strength was listed as 10 officers, 22 enlisted troops, and 4 civilians at the end of 1963.

training. The contingent launched the final three Group V PERSHING missiles in April 1963 before returning to Fort Sill, Oklahoma to train other Army personnel.[181]

The Martin Company launched the first Group II PERSHING missile (#205) from Pad 30A on 28 September 1960. The mission went well through first stage separation, but the flight became erratic about 56 seconds after lift-off. Consequently, the Range Safety Officer (RSO) sent destruct signals to the missile to terminate the mission about 69 seconds into the flight. Range telemetry indicated the second stage's engine chamber pressure had been normal following second stage ignition, so the flight anomaly was probably caused by some other system. The next two PERSHINGs (#206 and #207) flew well on 16 November and 12 December 1960. Both missiles splashed down 145 nautical miles downrange as planned, and all primary mission objectives were accomplished.[182]

Missile #208 was scheduled to fly 145 nautical miles downrange on the next PERSHING mission. That flight occurred on 5 January 1961 as planned, but the missile experienced abnormal pitch, yaw and roll about 22.5 seconds after lift-off. The PERSHING broke up about three seconds later. Since the first stage rocket motor continued to fire normally after the break-up, engineers concluded the anomaly was caused by a control system failure. The last four Group II missiles (#209 through # 212) experienced no control problems during their flights on 25 January, 15 February, 2 March, and 15 March 1961 respectively. They met all of their primary mission objectives, and the final Group II flight featured a complete test of the ST-120 stable platform and its associated guidance system.[183]

As mentioned earlier in this chapter, 32 PERSHING missile flights were launched from Complex 30 to complete Group III testing for the PERSHING program. Group III missions

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[181] Mary S. Touchstone, "AFETR/(AFMTC) Index of Military Units Assigned and Attached, 1963 – 1964," p 65, AFETR Historical Division, 10 May 1965; AFMTC History, 1 July – 31 December 1960, Vol I, pp 19, 35; AFMTC History, 1 January – 31 December 1961, Vol I, p 37; AFMTC History, 1 January – 31 December 1962, Vol I, pp 39, 42, 67; AFMTC History, 1 January – 31 December 1963, Vol I, pp 21, 42; AFMTC, "Atlantic Missile Range Test Activity Reports," for April 1963.

[182] AFTMC, "Atlantic Missile Range Test Activity Report for September 1960," October 1960; Marven R. Whipple, "Index of Missile Launchings by Missile Program, July 1960 – June 1961," 10 October 1961.

[183] AFTMC, "Atlantic Missile Range Test Activity Reports" February, March and April 1960.

tested the PERSHING's first and second stages, its open and closed loop guidance computers, adaptation kits, the missile's warhead and reentry bodies. The flights could be of short, medium or long duration, but all Group III missions provided opportunities to explore various tactical procedures. The results of those flights appear in the table below:[184]

VEHICLE # and Pad #	DATE	MISSION HIGHLIGHTS	OUTCOME
308 Pad 30A	21 April 1961	First Group III launch. Flew 220 nautical miles downrange. All objectives were met.	Successful Mission.
310 Pad 30A	18 May 1961	Erratic flight beginning 56.2 seconds after lift-off.	RSO send destruct command ending flight.
311 Pad 30A	9 June 1961	Fired from Transporter-Erector-Launcher (TEL) mounted on XM-474 tracked vehicle. All primary objectives were met.	Preliminary data showed impact was 0.2 NM long & 0.18 NM left of target.
312 Pad 30A	30 June 1961	Fired from TEL on XM-474. All primary and secondary objectives were met.	Successful Mission.
313 Pad 30A	19 July 1961	Less damage to TEL used for this launch than previous missions. All objectives met.	Impact was "within allowable tolerance."
315 Pad 30A	10 August 1961	TEL launch. Missile went into auto-destruct ~55 seconds after lift-off. RSO destruct at T + 76 seconds as a safety measure.	Upper level winds. Control computer filter network failed to dampen violent roll, pitch & yaw.
316 Pad 30A	22 August 1961	First launch from newest TEL. All primary and secondary objectives were met.	Successful Mission.
318 Pad 30A	13 September 1961	All primary and secondary objectives met. Missile impact "well within" target area.	Successful Mission.
319 Pad 30A	26 September 1961	Results identical to PERSHING mission on 13 September 1961.	Successful Mission.
320 Pad 30A	10 October 1961	Same results as #318 and #319.	Successful Mission.
322 Pad 30A	2 November 1961	Same results as #318, #319 and #320.	Successful Mission.
323 Pad 30A	15 November 1961	Same results as #318, #319, #320 and #322.	Successful Mission
324 Pad 30A	30 November 1961	All objectives were achieved.	Successful Mission
327 Pad 30A	28 December 1961	Scheduled for 20 December, then 21 December. Weather delay until the 28th.	Flight normal. All objectives met.
334 Pad 30A	16 January 1962	No holds during countdown. Flew 385 NM. All objectives were met.	Successful Mission.
332 Pad 30A	24 January 1962	100-minute hold for technical troubles at T-5 seconds. Count recycled and lift-off occurred without further incident.	All mission objectives were accomplished.

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[184] 45 SW History Office, "Eastern Range Launch Database," undated; AFMTC, "Atlantic Missile Range Test Activity Reports" May 1961 through January 1963.

335 Pad 30A	19 February 1962	300 NM flight. Officials scrubbed the launch on 13 February for telemetry trouble and rescheduled it for 14, 15 and 16 February 1962. Bad weather downrange delayed mission until the 19th.	All mission objectives were accomplished.
328 Pad 30A	15 March 1962	Ground Support Equipment (GSE) failure during pre-firing delayed pick-up of countdown for 165 minutes. Bad weather caused an additional delay of 106 minutes.	Flight was normal. All objectives were met.
326 Pad 30A	4 April 1962	One 33-minute hold to investigate an ST-120 (stable platform) problem. Ship in second stage's impact area delayed launch an additional 14 minutes.	All mission objectives were met.
337 Pad 30A	24 April 1962	Missile yaw after lift-off prompted RSO destruct command 28 seconds into the flight.	Missile destroyed. No objectives met.
329 Pad 30A	27 April 1962	Small craft in danger area prompted 13-minute hold. Weather delayed launch 12 minutes. All systems performed normally.	All objectives were accomplished.
330 Pad 30A	9 May 1962	Violent roll, pitch and yaw after second stage ignition. Missile broke up 107 seconds into the flight following RSO action.	Unsuccessful.
339 Pad 30A	4 June 1962	Four-minute hold for clouds at T-4 minutes. Count resumed without further incident.	All objectives met.
342 Pad 30A	14 June 1962	Missile performance was normal until second stage ignition. Abnormal increase in flame size preceded second stage explosion two seconds later.	Unsuccessful.
338 Pad 30A	21 August 1962	No holds. Remarkable accuracy reported: 88.3 *yards* short & 16.5 *yards* right of target.	Highly successful mission.
347 Pad 30A	26 September 1962	Scheduled for 28 June 1962 but cancelled for ~two months for additional R&D testing. Scrubbed on 18 September due to a guidance computer malfunction. Scrubbed on the 25th for a telemetry dropout. Held up for 66 minutes on the 26th for a power station problem and 10 minutes for cloud cover over a camera site.	Nose cone splashed down in planned target area. The mission was successful.
351 Pad 30A	22 October 1962	Scheduled for 11 October 1962 but rescheduled for 15, 17, 18 and 19 October before final countdown on 22 October. Aircraft telemetry equipment trouble held up launch for 195 minutes.	Successful flight. All objectives were met.
348 Pad 30A	15 November 1962	Rescheduled from 6 to 8 to 14 November due to technical difficulties. Launch on 14th was scrubbed due to heavy cloud cover over camera sites. Uneventful launch on the 15th.	Impact in target area. All objectives were met.
354 Pad 30A	27 November 1962	83-minute hold due to weather ceiling violation. Azimuth alignment took another 16 minutes.	Impact in target area. All objectives were achieved.

353 Pad 30A	10 December 1962	Technical difficulties pushed countdown from 6 to 7 December. Launch scrubbed on 7 December for heavy clouds over camera sites. Flight on 10 December was normal.	Impact “very near” impact point. All objectives were accomplished.
358 Pad 30A	17 January 1963	“Hang fire” on 19 December and failed ignition on 21 December led to scrubs until 16 January 1963. Countdown cancelled on 16th to complete modifications of first stage ignition circuitry. TEL launch on 17th went well. 200 NM range.	‘Quick Look’ radar indicated impact was ~148 yards right and 585 yards short of target. All objectives were met.
363 Pad 30A	30 January 1963	Rescheduled from 29 January due to bad weather downrange. 200 NM flight.	‘Quick Look’ indicated impact 105 yards right and 14 yards short of target. All objectives were met.

On the heels of the last Group III flight, the first Group IV prototype production PERSHING missile lifted off Pad 30A on 14 February 1963. The missile was supposed to fly 200 nautical miles downrange, but the second stage cut-off failed to terminate thrust at the proper time. Consequently, only a few mission objectives were achieved during the flight, and the PERSHING (#403) splashed down about 110 nautical miles farther than planned. The remaining five missiles in the Group IV series did much better. They met all of their mission objectives, and all but the final one (#408) splashed down fairly close to the target.[185]

The first of four Group V prototype production flights occurred just two days after the last Group IV mission was launched from Complex 30 in early April 1963. Group V flights were designed to transition the PERSHING program from R&D testing to service testing by incorporating all previous program changes and closely simulating service tests. Army artillery personnel and Martin Company contractors monitored all four missions, and Army personnel actually launched the last three Group V PERSHING missiles themselves. Martin personnel launched PERSHING #511 from a sandy area near Pad 30A on 5 April 1963. Despite nearly eight hours of delays for PERSHING power station and guidance and control problems, the

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[185] PERSHING #406 flew 145 nautical miles on 25 February 1963 and impacted 62 yard over and 81 yards left of the target. PERSHING #405 flew 300 nautical miles on 4 March 1963 and splashed down in the target area. PERSHING #407 flew 110 nautical miles on 13 March 1963 and impacted 462 yards short and 170 yards left of the target. PERSHING #410 flew a duplicate of the #405 mission on 21 March 1963 and had similar results. The final Group IV missile (#408) flew 203 nautical miles on 3 April 1963 and splashed down 1,867 yards left and 660 yards short of the target. It still managed to accomplish its assigned mission objectives. (Source: AFMTC. “Atlantic Missile Range Test Activity Reports” for February, March and April 1963.)

missile flew 326 nautical miles downrange and accomplished all its essential objectives. Members of the 2nd Battalion, 44th Artillery launched PERSHING #515 successfully on 12 April 1963. The missile flew 220 nautical miles and splashed down 182 yards short and 363 yards to the right of the target. The 2nd Battalion completed two more successful launches near Pad 30A on 17 April and 24 April 1963. Both missiles (#520 and #521) achieved their essential objectives, and #521 impacted just 170 yards left and 123 yards short of the target center.[186]

In September 1963, the Federal Republic of Germany (West Germany) accepted an offer from the United States for joint maintenance and support of PERSHING missiles on German soil. The first German PERSHING unit began training at Fort Sill, Oklahoma, in March 1964. The first American PERSHING unit to deploy — the 4th Battalion, 41st Artillery — became operational in June 1964. The REDSTONE was declared obsolete on 25 June 1964. Within six months of the PERSHING's activation, the Secretary of Defense asked the Army to establish a list of changes needed to give the new missile system a "Quick Reaction Alert" (QRA) capability. New solid-state electronics and a faster Transporter-Erector-Launch (TEL) system were needed, and the Army awarded a contract to Martin Marietta in January 1966 to deliver those improvements and upgrade the weapon system to the PERSHING 1A.[187] Under "Project SWAP," the 4th Battalion, 41st Artillery upgraded to PERSHING 1A missiles in September 1969. Deliveries of PERSHING 1A equipment in July 1970 signaled the completion of the project. In 1976, the system was upgraded with a sequential launch adapter to allow a battery to fire three PERSHING missiles in rapid succession. An automatic reference system was introduced at the same time to eliminate the need for a launch site survey before the missiles were launched. Though the PERSHING 1A 'production run' was completed in 1975, Martin Marietta reopened the line in 1977 to replace missiles fired on training missions. Ultimately,

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[186] 45 SW History Office, "Eastern Range Launch Database," undated; AFMTC, "Atlantic Missile Range Test Activity Report" for April 1963.

[187] The PERSHING M-474 tracked ground vehicle system was replaced with wheeled vehicles for all PERSHING 1A ground support equipment. A modified version of Ford's M-656 truck — the M-757 tractor — was used to tow the complete PERSHING 1A missile and its erector-launcher on a transporter or semi-trailer.

Martin Marietta manufactured about 750 PERSHING and PERSHING 1A missiles to meet training requirements and maintain 108 missiles on alert in Western Europe.[188]

The PERSHING 1A was introduced without any developmental flight tests at Cape Canaveral, but follow-on launches for the new missile began at the Cape in late February 1973. Army units launched PERSHING 1A missiles in batches of four missiles from that time onward, and those operations overlapped PERSHING II missile launches at the Cape in September and October 1983. In light of the overlap and changes in the PERSHING program in the latter half of the 1970s, it might be a good idea to mention the rationale for the PERSHING II program and how the newer missile differed from the PERSHING 1A.[189]

Deployment of the PERSHING 1A did not end competition between the United States and the Soviet Union in theater nuclear weapons. Rather, it prompted both sides to field new systems including the Soviet SS-20 and the American PERSHING II. On 7 March 1974, the Deputy Secretary of Defense gave the Army permission to begin development of the PERSHING II. Martin Marietta was given the contract for the PERSHING II, and the company began firing modified versions of the PERSHING 1A in late November 1977 to support the new program. But the introduction of the Soviet SS-20 prompted American officials to change the direction of the new missile's development in 1978. To counter the SS-20, the new PERSHING II needed a range of more than 740 kilometers. While the missile's dimensions remained virtually unchanged from the PERSHING 1A (e.g., 415 inches long and 40 inches in diameter), lightweight Kevlar was substituted to add strength and save weight that could be used for fuel. The overall weight of the PERSHING II grew to 16,842 pounds (versus 10,244 pounds for the PERSHING 1A). The PERSHING II was equipped with a new inertial guidance system that continually computed vehicle velocity and compared it with the velocity needed to impact the target.[190] Martin Marietta touted the new system as having "ten times the accuracy of the [PERSHING] 1A."[191]

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[188] Martin Marietta, "FACT SHEET Pershing 1-A," July 1972; The Pershing Weapon System and Its Elimination," pp 4, 5, redstone.army.mil website, undated; AFETR History, CY 1976, Vol I, Part II, p 2-62; Andreas Parsch, "Martin Marietta M14/MGM-31 *Pershing*," p 3, 2002.

[189] 45 SW History Office, "Eastern Range Launch Database," undated.

[190] Upon reentry, a pull-up/pull-down maneuver was executed for velocity control. As the reentry vehicle approached the target its terminal guidance system compared the live radar scene with a

On 2 November 1972, the Army announced its PERSHING 1A field artillery units would begin launching Follow-on Operational Tests (FOT) at Cape Canaveral. The Cape's first four PERSHING 1A flights lifted off Pad 31A on 21 February 1973.[192] They were fired by members of Battery A, 3rd Battalion, 84th Field Artillery, which was stationed in Germany as part of U.S. Seventh Army. Captain Joseph Siraco commanded the Battery "A" test cadre which included approximately 110 officers and men. Two more sets of four missiles each were fired from Pad 31A on 6 March and 19 March 1973 as part of the 1973 series of FOTs. They were launched by similar-sized cadres from Battery C, 41st Field Artillery and Battery C, 84th Field Artillery under the command of Major Thomas Fitzgerald and Captain Paul Savidge respectively.[193]

To support all 12 PERSHING 1A firings in 1973, the Army sent the Pershing Range Support Battery (Provisional), 3rd Battalion, 9th Field Artillery from Fort Sill, Oklahoma, to Patrick AFB in January 1973. The support battery provided four officers, one warrant officer, and 60 men for the mission. As installation host, the Air Force Eastern Test Range (AFETR)[194] provided messing and billeting for all participants at Patrick AFB. The PERSHING 1A flights were conducted under the technical direction of Lieutenant Colonel Donald M. Opel, who served

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stored reference scene. Positional errors were corrected with air vanes, and the reentry vehicle was steered into the target.

[191] The Pershing Weapon System and Its Elimination," p 6, redstone.army.mil website, undated; ESMC History, 1 October 1981 – 30 September 1982, Vol I, pp 264, 266; ESMC History, 1 October 1982 – 30 September 1984, Vol I, p 253; Pan American World Airways, Inc. and RCA International Service Corporation, "Range Pretest Briefing, Pershing II Engineering Development (ED) Firings 1982," undated; Pan American World Airways, Inc. and RCA International Service Corporation, "Range Pretest Briefing, Pershing II Engineering Development (ED) 1983, ED-9/ED-8," undated; Pan American World Services, Inc. and RCA International Services Corporation, "PERSHING II, Artillery Ordnance [A-O] Firing," September 1984, p3, undated.

[192] Complex 31 had been built to support MINUTEMAN launch operations in the 1960s, but its flat-surfaced launch pad (Pad 31A) became an interim launch site for 12 PERSHING 1A missiles before the Army moved its PERSHING 1A operations to an abandoned TITAN II missile site (Complex 16) on 29 June 1963.

[193] AFETR History, FY 1973, Vol I, Pt 1, pp, 14, 15, 8 March 1974.

[194] Following the organization of the National Range Division within Air Force Systems Command on 2 January 1964 to establish a "global range capability," the Air Force Missile Test Center (AFMTC) was redesignated the Air Force Eastern Test Range (AFETR) on 15 May 1964.

as Chief, PERSHING Operational Test Unit. As Director of Army Tests, Department of the Army Field Office, Patrick AFB, Colonel Edward L. Ramsey coordinated the PERSHING 1A operations with AFMTC.[195] One PERSHING 1A malfunctioned during its flight on 6 March 1973, but all the other FOT flights in February and March 1973 were successful. The launch cadres returned to their duty stations about a week after their FOTs, and the Pershing Range Support Battery (Provisional) returned to Fort Sill, Oklahoma, on 29 March 1973.[196]

Following the transfer of PERSHING 1A launch operations from Pad 31A to Complex 16 in June 1973, the next series of 12 FOTs was launched in May 1974. Under the command of Major Donald M. Lyman, Battery A, 1st Battalion, 81st Field Artillery fired three PERSHING 1A missiles successfully on 7 May 1974. The unit's fourth PERSHING 1A misfired on the 7th, but Battery "A" fired it successfully the following day. Major Robert J. Bruce, Jr. commanded Battery D, 3rd Battalion, 84th Field Artillery when it fired the next four PERSHING 1A missiles from Complex 16 on 21 May 1974. Three of the four flew properly, but the third missile in the firing sequence veered off-course, and the RSO destroyed it at T plus 99 seconds. The last four missiles in the series were fired on 31 May 1974 by Battery C, 1st Battalion, 81st Field Artillery under the command of Major Martin Kedra, Jr. Three of the four missiles flew normally, but the first missile in the firing sequence faltered when its second stage failed to ignite. Consequently, the RSO destroyed the missile at T plus 82 seconds. In summary, 10 of the 12 PERSHING 1As launched from the Cape in May 1974 were fired successfully, and the Army requested recovery of the warheads from the two PERSHING 1A missiles that malfunctioned. Though initial attempts to find the warheads were unsuccessful, both were recovered in June 1974.[197]

In January 1975, the Army notified the Army Field Office at Patrick AFB that the next series of FOT launches would be delayed by budgetary constraints until early Fiscal Year (FY)

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[195] Lieutenant Colonel Ramsey became Director of Army Tests at Patrick AFB on 27 April 1971. He was one of four test agency directors on the AFETR Special Staff. The other three officials were the Director for NASA Test Support and the commanders of the 6555th Aerospace Test Group and the Naval Ordnance Test Unit (NOTU). The Army Field Office was authorized two officers, eight enlisted people, and one civilian in December 1973. During the same period, the 6555th had 148 officers and airmen and NOTU had 246 personnel.

[196] AFETR History, FY 1973, Vol II, Pt 1, pp 358, 8 March 1974; AFETR History, FY 1974, Vol I, Pt 1, pp 24, 197, January 1975; AFETR History, FY 1974, Vol I, Pt 2, pp 311, 399, Jan 1975.

[197] AFETR History, FY 1974, Vol I, Pt 2, pp 311, 398, 399, 400, January 1975.

1976. Consequently, the next series of PERSHING 1A missiles was fired from the Cape in July and August 1975 instead of February and March (as planned earlier). A cadre of 32 troops arrived from Fort Sill in early July 1975 to support the launches. The tests were conducted under the technical direction of Lt. Colonel Gerald D. Curbow. Under the command of Major Joseph F. Weedel, Battery D, 3rd Battalion, 84th Field Artillery fired three PERSHING 1A missiles on 23 July 1975 and one PERSHING 1A on 24 July 1975. All four launches were successful. Under Major Wayne R. Williams, Batteries "C" and "D," 1st Battalion, 81st Field Artillery fired the next four FOT missiles on 5 August 1975. Three of the four flights were successful, but the second PERSHING 1A in the firing sequence experienced a guidance control malfunction, and it had to be destroyed about 92 seconds after lift-off. The third set of four FOTs was launched on 25 and 26 August 1975 by Battery C, 1st Battalion, 41st Field Artillery under the command of a captain named Kresge (first name unavailable). The first missile in that set had to be destroyed by the RSO destruct command about 72 seconds after lift-off when it experienced a second stage "burn through." The second and third PERSHING 1A firings on 25 and 26 August was successful, but another RSO destruct command was required when the second stage of the fourth PERSHING 1A did not fire during the flight on 26 August 1975. In summary, nine of the 12 FOTs launched from the Cape in 1975 successful, but the other three experienced guidance control or second stage malfunctions that required RSO destruct actions.[198]

Only four PERSHING 1As were launched from the Cape in 1976, but Battery C, 3rd Battalion, 84th Field Artillery brought along two more missiles as 'back-ups' for the firings on 26 October 1976. All six missiles were "counted down" by the troops for training purposes. Major Earl Robinson commanded Battery "C" and Lieutenant Colonel Donald Lyman served as Technical Director for the FOTs. Two new improvements — the Sequential Launch Adapter (SLA) and the Automatic Reference System (ARS) — were used during the firing missions in 1976. All four flights were successful. Earlier in the year the Army Field Office asked AFETR to reconsider supporting PERSHING II launches at the Cape, and range officials agreed to accommodate the new program on 12 August 1976.[199] While a somewhat different PERSHING

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[198] AFETR History, 1 July – 31 December 1975, Vol I, Pt II, pp 280, 281, 282.

[199] Initially, the Army asked AFETR to support two short-range and four long-range flight tests that required the recovery of earth-penetrating payloads after each test. AFETR demurred on 22 January 1976 by indicating it could not support the physical requirements of the program (e.g., launch distances to target, payload recovery services and impact area instrumentation demands).

II than the one proposed in 1976 would emerge in the early 1980s, Air Force officials were aware the new third-generation PERSHING would be coming to the Cape eventually. In the meantime, PERSHING 1A launches continued at the Cape. Details concerning those missions appear in the table below:[200]

UNIT & NUMBER FIRED	DATE	MISSION HIGHLIGHTS	OUTCOME
Battery D, 3rd Battalion, 84th Field Artillery 1 Missile.	17 February 1977	.Missile was fired from a mobile launcher on Complex 16.	Successful mission.
Battery B, 1st Battalion, 41st Field Artillery 4 Missiles	2 March 1977	The first missile deviated from planned trajectory prompting RSO destruct ~100 seconds after lift-off. The second missile was destroyed 8 seconds after launch, and it impacted near Complex 16 causing brush fires.	Two of four missiles flights were successful.
"D" Battery, 1st Battalion, 81st F.A. 3 Missiles	13 July 1978	All three flights were successful. The missiles' inert warheads impact in the target area ~400 NM downrange. (Note: Battery D became "D" Battery with change in nomenclature in 1978.)	Successful mission.
"A" Battery, 3rd Battalion, 84th F.A. 3 Missiles	25 July 1978	All three flights were successful, and the warheads impacted 400 NM downrange.	Successful mission.
"C" Battery, 1st Battalion, 41st F.A. 3 Missiles	25 August 1978	Six missiles were positioned on six launch points, and all six were 'counted down.' The three not launched were available to cover for any 'problem' missile that failed to fire.	Three successful flights and three simulated launches. Warhead impacted on target.
No Firing Unit #s listed for this and later firings. 3 Missiles	22 February 1979	The first and third missiles flew successfully, but the second missile was fired on an incorrect azimuth due to an azimuth laying set malfunction. No RSO action required, but warhead impacted right of the intended target.	Partially successful mission.

The Army Field Office appealed to AFETR to reevaluate its position on 3 June 1976, and range officials agreed in August 1976 to accommodate the PERSHING II program.

[200] AFETR History, CY 1976, Vol I, Pt I, pp 2-58, 2-61, 2-62, 2-63, undated; Kathryn A. Lansdowne, "Eastern Test Range Index of Missile Launchings, CY 1977," p 12, undated; Detachment 1, SAMTEC History, 1 January – 31 December 1978, Vol I, p 118; Kathryn A. Lansdowne, "Eastern Test Range Index of Missile Launchings, CY 1978," pp 12, 13, undated; Detachment 1, SAMTEC History, 1 January – 30 September 1979, Vol I, pp 160, 161; ESMC History, 1 October 1979 - 30 September 1981, Vol I, pp 426, 428, 430, 432, 433, 434, 435, undated; ESMC History, 1 October 1981 30 September 1982 Vol I, pp 262, 263.

3 Missiles	25 April 1979	All three missiles flew successfully.	Successful mission.
3 Missiles	9 May 1979	Second missile had a power failure, but a back-up missile was launched in its place.	Three missiles were fired, and all flew properly. Successful mission.
2 Missiles	12 February 1980	Two Advanced Range Instrumentation Aircraft (ARIA) provided additional telemetry support for all PERSHING 1A flights in 1980.	Both missile flights were successful.
4 Missiles	23 April 1980	All four missiles flew properly.	Successful mission.
3 Missiles	7 May 1980	The first flight was successful. The second missile failed shortly after second stage ignition, prompting an RSO destruct command at T plus 113 seconds. The third missile had a longer-than-planned second stage burn.	Partially successful mission.
1 Missile	15 May 1980	This was the first missile in a new production series, but it was identical to PERSHING 1As fired earlier in the FOT program. Termed an "Artillery Ordnance Round," the flight was used to assess the quality had reliability of the first new production missile.	Successful mission. U.S. Army was gratified by the result.
3 Missiles	4 February 1981	All range support requirements were met except ARIA support in the terminal area.	Three successful flights.
3 Missiles	17 February 1981	Missile anomalies and misfires occurred during the countdown, but three missiles were fired successfully and all range support requirements were met.	Three successful flights.
3 Missiles	7 April 1981	The Chief of the Pershing Operation Test Unit (Europe) cited the operation as "one of the smoothest series of launch countdowns in a number of years." Three successful flights.	Successful mission.
3 Missiles	20 January 1982	First and third missile flew successfully, but second missile had to be destroyed by RSO.	Partially successful mission.
3 Missiles	24 February 1982	First two missiles misfired, but all three flights were successful.	Successful mission.
3 Missiles	10 March 1982	All three flights were successful.	Successful mission.

The PERSHING II made its debut on the Eastern Range on 22 July 1982. It was launched from Complex 16 on what might have been the first of *only three* Engineering Development (ED) flights from the Cape.[201] Its test objectives included: 1) a proper assessment of the safety

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[201] Additional PERSHING II test flights were scheduled to take place at White Sands, New Mexico, but the engineering development flight schedule at the Cape was supposed to be short because the production contract had been signed and officials expected to field the new missile in 1983. The engineering development schedule lengthened after the disappointing PERSHING II debut flight in July 1982. The first mission was relegated to the status of a 'prototype' launch, and engineering development missions began thereafter.

features and technical performance of PERSHING II ground equipment, missile systems and subsystems, 2) detection of any equipment failures and procedural problems that had not surfaced in earlier tests, 3) confirmation that the missile met the necessary reliability, maintainability and range requirements, 4) a thorough test the missile's new telemetry system, and 5) verification of the successful development on the entire PERSHING II weapon system. Because the PERSHING II flew farther downrange than the PERSHING 1A, additional instrumentation support was required from the range stations on Antigua, Grand Turk and (for more northerly flight azimuths) Wallops Island and Bermuda.[202]

The Cape's first PERSHING II flight did not go well. The missile failed about 14 seconds into the flight, and the RSO sent a destruct command at T plus 17 seconds. Debris fell on the Cape's shoreline and into the Atlantic Ocean. Divers recovered the PERSHING II reentry vehicle and dummy warhead about 1,000 feet offshore on 30 July 1982. Analysis of the flight data revealed the missile's first stage band liner caused erosion of the first stage thrust termination pads. Engineers concluded that gases and flames had entered the inner stage liner and activated the missile's auto-destruct system. Obviously, some redesign work was in order. More engineering development flights would have to be scheduled on the Eastern Range in 1983 and 1984.[203]

Ten Engineering Development flights and two Artillery Ordnance (AO) flights were conducted as single missile missions from Complex 16 between 21 January 1983 and 4 October 1984. In the meantime, Army troops fired five PERSHING 1A missiles from Complex 16 on 28 September 1983, and they launched four more PERSHING 1As on 13 October 1983. Six missiles were set up in six different launch points on Complex 16 on September 28th. All six missiles were counted down in a simulated launch, but the second missile experienced a 'hang fire' and the back-up missile (one of the six missiles set up that day) was fired as a replacement. Two unscheduled holds were required on the 28th to clear onlookers who had strayed inside the Impact Limit Lines (ILL) and vessels that floated into an off-shore surveillance area, but all five missile flights were successful. The final four PERSHING 1As also flew well on October 13th.

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[202] ESMC History, 1 October 1981 30 September 1982 Vol I, pp 264, 267; ESMC History, 1 October 1983 – 30 September 1984, Vol I, pp 257, 260, 261.

[203] ESMC History, 1 October 1981 30 September 1982 Vol I, pp 267, 268.

Those FOTs completed the PERSHING 1A's run at Cape Canaveral, and they brought the Eastern Range's final tally to 100 PERSHING 1A missiles fired.[204]

The Cape's second PERSHING II mission (ED-10) was launched from Complex 16 on 21 January 1983. The flight had been scheduled for January 20th, but a range computer problem caused a lengthy hold during the countdown. Deteriorating weather forced officials to scrub the launch later in the day. Fortunately, there was a break in the weather on the 21st, and the missile was launched successfully. The next five PERSHING II missions were launched from Complex 16 on 9 February, 28 March, 10 April, 27 May and 2 June 1983 respectively. Brief unscheduled holds were required during the countdowns on 27 May and 2 June, but all five flights (ED-2, ED-9, ED-8, ED-11 and ED-14) were completed successfully.[205]

Unfortunately, the string of successes was interrupted when the next PERSHING II (ED-17) malfunctioned during its flight from Complex 16 on 27 July 1983. One of the thrust reversal ports on the missile's second stage failed mechanically, and the RSO was forced to end the flight about 90 seconds after lift-off. Post-flight analysis revealed the failure was caused by a misalignment of an explosive sector that held the thrust reversal port retaining ring in place. To avoid a reoccurrence of the problem, engineers sent the next PERSHING II missile's second stage motors back to their manufacturer (Hercules) for inspection and analysis. All explosive sectors were replaced at the factory as a precaution, and the next PERSHING II (ED-18) flew well. Though the countdown on 7 September 1983 was delayed for about two hours to repair some ground support equipment, the mission was successful.[206]

On 15 December 1983, the U.S. Army declared the PERSHING II weapon system operational. The announcement coincided with the 56th Field Artillery Brigade's receipt of PERSHING II ordnance and ground equipment. Activation notwithstanding, the last two PERSHING II engineering development flights were launched from the Cape on 16 May 1984 and 7 August 1984 respectively. The lateness of those operations can be explained by the unusual nature of both missions. The missiles had been deliberately dropped, rattled, and frozen

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[204] ESMC History, 1 October 1982 – 30 September 1984, Vol I, pp 263, 264, 265, 266.

[205] ESMC History, 1 October 1982 – 30 September 1984, Vol I, pp 254, 255, 256, 257, 258, 259, 261.

[206] ESMC History, 1 October 1982 – 30 September 1984, Vol I, pp 262, 263.

to provide "worst case conditions" long before launch operations got underway. Consequently, Army officials did not expect to be alarmed by the results, nor did they consider a flight failure particularly serious under such constraints. As events turned out, the first of the two missiles (ED-21) went out of control *only* during the last few seconds of its flight on 16 May. The second missile (ED-22) completed its mission successfully on 7 August without any guidance failure whatsoever. Army officials were not disturbed by the results of the first flight, and they were completely satisfied with the outcome of the second flight.[207]

Two PERSHING II Artillery Ordnance (A-O) missions were launched from Complex 16 on 20 September 1984 and 3 October 1984 respectively.[208] The flight on the 20th was held up for about 30 minutes when an Advanced Range Instrumentation Aircraft (ARIA) encountered mechanical trouble and arrived on station late. The second A-O mission was scrubbed a week later, but it was completed on 3 October 1984 after unscheduled holds for bad weather and the somewhat delayed removal of the missile's shroud. Delays aside, both A-O missions were successful.[209]

The first U. S. Army battalion equipped with PERSHING II missiles deployed to Western Europe at the end of June 1984, and the Army considered the PERSHING II weapon system fully operational on 13 December 1985. U.S. Army troops conducted three PERSHING II firings at the Cape as a single System Shakedown Operation (SSO) on 16 and 17 December 1985. An important goal of the flights was a test demonstration of the PERSHING II's "Quick Reaction Alert" capability. The flights also provided missile firing training for soldiers deployed in Western Europe, and they confirmed the correctness of operating procedures, safety measures

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[207] ESMC History, 1 October 1982 – 30 September 1984, Vol I, pp 267, 286, 269; "The Pershing Weapon System and Its Elimination," pp 1, 3, redstone.army.mil website, undated.

[208] The A-O operations were designed to demonstrate the PERSHING II could fulfill its tactical mission. The flights provided firing crews opportunities to develop and maintain their combat proficiency while displaying the capabilities and limitations of the weapon system in a "pre-conditioned hot environment." Those (and later PERSHING II) flights revealed potential problem areas, and they allowed the Army to hone its operating procedures under realistic conditions.

[209] ESMC History, 1 October 1982 – 30 September 1984, Vol I, pp 269, 271; ESMC History, 1 October 1984 – 30 September 1986, Vol I, p 321; Pan American World Services, Inc. and RCA International Services Corporation, "PERSHING II, Artillery Ordnance [A-O] Firing, September 1984," p3, undated.

and service/maintenance techniques. Soldiers launched the first SSO missile on 16 December, and they fired the other two missiles on the 17 December 1985. There was an 85-minute delay between the second and third firings due to radio frequency interference on the 17th, but all three flights were successful.[210]

Troops launched the next five PERSHING II missiles from Complex 16 as a Demonstration and Shakedown Operation (DASO) on 24 and 26 June 1986.[211] The first of three missiles launched on the 24th was fired at 1356Z (Greenwich Mean Time) following one unscheduled hold for stray vessels in the first stage impact area and another unscheduled hold for a support van checkout problem. The second and third missiles launched on the 24th were fired at 1523Z and 1633Z respectively. The fourth and fifth missiles were fired at 1305Z and 1647Z on the 26th. All five launches were successful.[212]

Following the tragic loss of the Space Shuttle Challenger in January 1986 and flight failures involving space vehicles launched from Vandenberg AFB and the Cape, the vast majority of flights on the Eastern Range in 1987 were ballistic missile test operations. Taken together, the U.S. Army, U.S. Navy, and British Navy sponsored 41 of the 46 major launches requiring Eastern Range instrumentation support in FY 1987. Regarding the Army missions, members of the 56th Field Artillery fired 16 PERSHING II missiles from Complex 16 on 24 March, 21 May, and 27 July 1987. The first six missiles were launched individually at roughly 20-minute intervals beginning at 1333Z on March 24th. The next six missiles were launched on between 0200Z and 0500Z on May 21st. Six more missiles were supposed to lift off on 27 July 1987, but officials scrubbed the last two launches of the day at 1600Z due to bad weather in the ARIA support area. Follow-up flights were scheduled for the 'tail-end charlies,' but they were cancelled on the morning of 28 July 1987. Though the cancelled flights were a disappointment, the 16 flights that were completed appeared to be successful from the Eastern Range standpoint.[213]

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[210] ESMC History, 1 October 1984 – 30 September 1986, Vol I, pp 322, 323, 324; Pan American World Services, Inc. and RCA International Services Corporation, "PERSHING II, System Shakedown Operation (SSO), December 1985," p 2, undated.

[211] As the name suggested, DASO and SSO objectives were virtually identical.

[212] ESMC History, 1 October 1984 – 30 September 1986, Vol I, pp 324, 325.

[213] ESMC History, 1 October 1986 – 30 September 1987, Vol I, pp 395, 396, 429, 430, 431.

In September 1987, the United States and the Soviet Union were close to signing an agreement on the reduction and eventual elimination of their intermediate-range and shorter-range nuclear-tipped missiles.[214] The Intermediate Nuclear Forces (INF) Treaty was signed on 8 December 1987, but it was not ratified by the United States Senate until 27 May 1988. Consequently, PERSHING II launches continued at the Cape, and 12 more PERSHING II missiles were fired there in January, February, and March 1988 before the program ended.[215]

The first of those last 12 missiles was an Artillery Ordnance round, and it was fired from Complex 16 on 13 January 1988 by soldiers of the 3rd Battalion, 9th Field Artillery. (Two more PERSHING II missiles were supposed to be launched as part of the A-O operation on the 13th, but officials scrubbed both firings for missile shutdown indications.) Members of the 56th Field Artillery Command fired the next six missiles on 15 February 1988 between 1300Z and 1602Z. The fourth missile in the firing order had to be recycled to the end of the line on the 15th, but all six missiles were fired successfully. The Army conducted its final five PERSHING II firings from the Cape with a mixture of FOT and A-O rounds on 21 March 1988. The day was eventful — it included a missile hang fire, and range officials ordered two unscheduled holds to get vessels out of the impact area before two of the five missiles were launched —but the operation was a successful firing mission. The five launches concluded the Army's firing program at the Cape on a solid note.[216]

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[214] As later signed and ratified, the INF Treaty addressed the speedy elimination of the PERSHING 1A, PERSHING II and BGM-109G cruise missile (on the American side) and the Soviet SS-20, SS-4, SS-5, SS-12 and SS-23 nuclear-capable missiles. Under Article V the Americans and Soviets agreed to eliminate the shorter range PERSHING 1A, SS-12, and SS-23 within 18 months of the treaty's effective date. Under Article IV the SS-20, SS-4, SS-5, and PERSHING II would follow not later than three years after the effective date. Article XI provided guidelines for verifying the elimination of the weapons, and each 'superpower' gave the other the right to conduct escorted inspections of all intermediate and short range missile operating bases and support facilities 30 days after the effective date.

[215] 45 SW History, 1 October 1987 – 30 September 1988, Vol I, pp 325, 326, 327, 30 May 1989; "Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Elimination of their Intermediate-Range and Shorter-Range Missiles," signed 8 December 1987; 45 SW History Office, "Eastern Range Launch Database," undated; The Pershing Weapon System and Its Elimination," p 7, redstone.army.mil website, undated; 45 SW History, 1 January – 31 December 2001, Vol I, p 50, 30 May 2002.

[216] ESMC History, 1 October 1987 – 30 September 1988, Vol I, pp 301, 321, 323, 324.

Following the Senate's ratification of the INF Treaty on 27 May, the agreement became effective on 1 June 1988. The Army awarded a contract to the Thiokol Corporation the next day (2 June 1988) to eliminate PERSHING 1A and PERSHING II rocket motors. The Army started removing the motors in accordance with the INF Treaty on 8 September 1988. Thiokol began destroying the missiles in October 1988. The rocket motors were taken to the Army's Longhorn Ammunition Plant in Texas where they were fired statically to eliminate their solid fuel. Once the fuel was exhausted and the motors cooled, the contractor retrieved the motor cases and nozzles and flattened them in a hydraulic crusher. Thiokol completed the process by disposing of the debris that remained. Approximately 48 first- and second-stage motors were destroyed each month, and a Soviet inspection team (together with members of the U.S. On-Site Inspection Agency) witnessed the elimination process. The last of 343 PERSHING 1A rocket motor stages were destroyed at the Longhorn Ammunition Plant in early July 1989. The last PERSHING II missiles (minus a few inert leftovers reserved for displays at the Smithsonian, the Central Armed Forces Museum, and various other locations) were destroyed in Texas in May 1991. The last SS-20s (minus a few inert display leftovers) were destroyed at Kapustin Yar in 1991.[217]

American and Russian inspectors conducted hundreds of INF Treaty compliance inspections between 1 June 1988 and 13 May 2001. They visited 32 American installations and 117 sites in Russia, Ukraine, Belarus, and Kazakhstan.[218] During the first three years of the treaty, nearly 2,700 missiles (including launchers and support equipment) were destroyed with INF Treaty inspectors present. Inspections continued, and the atmosphere of mutual respect engendered by the success of the treaty formed a foundation for the Strategic Arms Reductions

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[217] "The Pershing Weapon System and Its Elimination," p 7, redstone.army.mil website, undated; 45 SW History, 1 January – 31 December 2001, Vol I, pp 50, 51, 30 May 2002.

[218] INF inspections at the Cape included visits to Complex 16, the ERI Building, the NAVSTAR Processing Facility (NPF), and Missile Assembly Building 3. There was also some PERSHING II hardware in Hangar F at the start of the inspection campaign. The Eastern Space and Missile Center and (later) the 45th Space Wing provided transportation, billeting and messing support for the Russian inspectors and their On-Site Inspection Agency (OSIA) escorts. The first 10-member inspection team and its OSIA escort landed at Cape Canaveral's 'Skid Strip' on 3 August 1988. The ESMC Commander and his Air Base Group and Eastern Range commanders met the visitors at Base Operations where several members of the press took down brief statements by the OSIA and Soviet team chiefs. The first INF Treaty compliance inspection also served as the closeout inspection for PERSHING at the Cape since no more PERSHING missiles were launched from that location after 21 March 1988.

Treaty (START) that followed. The INF Treaty was a turning point in U.S. and Soviet efforts to reduce the threat of nuclear war. For the first time in history, the U.S. and the Soviet Union agreed to reduce a portion of their respective nuclear arsenals and let each other verify the elimination of nuclear weapons by on-site inspection. Over a period of 13 years, 15,000 American and 7,000 Russian personnel were involved in treaty compliance inspections under START and the INF Treaty.[219]

The final INF inspection held in the United States was completed at Cape Canaveral Air Force Station on 12 May 2001. Worldwide, the INF inspection effort ended on 31 May 2001. To commemorate the end of inspection responsibilities the Russian Federation hosted a dedication ceremony for INF participants on 21 May 2001. Following a speech by Lieutenant General Vyacheslav Romanov thanking all participants for their efforts, U.S. Ambassador Steven Steiner noted:[220]

> ….This treaty has demonstrated that former adversaries can work together in the spirit of cooperation to achieve a common purpose. Our success together in negotiating and implementing INF paved the way to deep strategic arms reductions….I want to express my gratitude to all our colleagues, military and civilian, in the Russian Federation, Belarus, Kazakhstan, Ukraine and the United States for having worked together to make this treaty a resounding success.

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[219] 45 SW History, 1 October 1987 – 30 September 1988, Vol I, pp 328, 329, 331; 45 SW History, 1 January – 31 December 2001, Vol I, p 51, 30 May 2002.

[220] Transcript, Erin Sornberger, ANSER, "Statement by US and RF Officials Regarding Completion of Inspection & Monitoring Activities under the Intermediate-Range Nuclear Forces Treaty," 21 May 01; 45 SW History, 1 January – 31 December 2001, Vol I, p 50, 30 May 2002.

CONCLUSION

Historians often cite the transfer of German rocket scientists to the United States as one of the most important steps in the development of America's ballistic missile programs, yet most people remain unaware that the U.S. Army Ordnance Department sponsored a project involving the California Institute of Technology to design and launch small rockets in 1936. Few know that the Army expanded the project in 1944 to develop the PRIVATE and WAC CORPORAL instrumented rockets to conduct atmospheric research up to and (later) above 100,000 feet in altitude. Under Army sponsorship, General Electric (GE) began work in 1944 on a series of Hermes guided missile projects. Within a decade, GE developed better rocket fuels, more rugged and efficient rocket motors, and America's first inertial guidance system. No one can deny the importance of Dr. Wernher von Braun's 'hand-picked' team to America's first missile and space programs, but the contributions of the U.S. Army, American universities, government-sponsored commercial "think tanks," civil servants, veteran industrial contractors and subcontractors deserve the lion's share of the credit for America's REDSTONE, JUPITER, and PERSHING ballistic missile programs. The same can be said of U.S. Air Force and U.S. Navy ballistic missile programs, since both those military branches relied heavily on similar resources for their missiles' development.

Army ballistic missile programs were an important part of Cape Canaveral's history from the early 1950s through the early 1960s, and the PERSHING 1A and PERSHING II programs contributed mightily to the Eastern Range's operations in the 1970 and 1980s. Following years of tactical missile studies, reevaluations and updates, the Korean War (among other international developments) prompted the Army to develop a ballistic missile weapon system in the early 1950s that could carry a 6,900-pound nuclear warhead and attack ground targets as far as 175 nautical miles away. The Chrysler Corporation received a letter order contract for the liquid-fueled REDSTONE ballistic missile system in October 1952, and the Army's Guided Missile Center conducted the first REDSTONE launch at Cape Canaveral on 20 August 1953. Such rapid development was only possible thanks to concurrent development of the missile's various components and the realization that contractors had to begin building major assemblies of those components as soon as the designs were completed. In one instance, the Guided Missile Development Division completed only 85 percent of the REDSTONE's prototype guidance and control systems in December 1951 before it gave the Ford Instrument Company a contract to simplify the design and build the complete prototype guidance and control system. Continuity was preserved by ensuring that the selection of Chrysler as the missile's prime contractor came with the understanding that important subcontractors — North American Aviation, the Ford Instrument Company, and Reynolds Metals Company — would continue to support the REDSTONE effort as the program evolved.

The REDSTONE program was successful, and the missile was deployed under Army auspices. Redstone Arsenal also managed to complete its JUPITER effort gracefully when that program was turned over to the Air Force in December 1957. As events soon proved, the liquid-fueled REDSTONE and JUPITER would be eclipsed by the more successful solid-fueled PERSHING within a few years. The Army was preparing for that eventuality even before the REDSTONE was deployed.

Early Army missile launches at Cape Canaveral were rather modest affairs — only a small group of maintenance and liaison personnel were sent to Patrick AFB initially. They coordinated the efforts of larger groups sent to Patrick periodically to fire missiles at the Cape as the launch schedule dictated. In March 1955, a larger and more permanent party (Detachment B, 9330th Technical Unit) began sending people to Patrick to assist in the REDSTONE effort on a more permanent basis. Detachment "B" was eliminated in January 1956, but its people were transferred to Detachment A, 9377th Technical Unit, and the latter supported the JUPITER program for nearly a year. It was replaced by Detachment "C" in the fall of 1956, and that unit (redesignated twice in 1958 and 1959) had as many as 346 personnel assigned before it was discontinued on 15 December 1960.

Only 33 REDSTONE missiles (not counting JUPITER-A versions) were launched from Cape Canaveral, but 25 additional REDSTONEs were fired at White Sands between 2 June 1958 and 6 October 1963 to qualify units initially or meet annual practice firing requirements.[221] The 40th and 46th Field Artillery Groups were deployed overseas in 1958 and 1959 respectively, and the two units exhibited the REDSTONE in operational demonstrations for the U.S. Seventh Army in Europe. Though the REDSTONE was a viable weapon system in 1959, its heavy, liquid-fueled propulsion system made it cumbersome to operate, and the Army replaced it with

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[221] The Army established the 209th Field Artillery Missile Group at Fort Sill, Oklahoma, to support approximately four REDSTONE practice firings per year at White Sands. Members of the 40th accomplished the first annual practice firing at White Sands in March 1959.

the smaller and more mobile PERSHING in June 1964. The JUPITER (under Air Force auspices) also made it to Europe in1960, but all JUPITER missiles were removed from service by April 1963. A Turkish crew and five Italian crews fired a total of six JUPITER missiles from Cape Canaveral between 22 April 1961 and 23 January 1963, but those Combat Training Launches marked the end of the Army's liquid-fueled ballistic missile operations at the Cape. The future (at least for ballistic missiles) belonged to solid-propellant missiles including the Air Force MINUTEMAN, Navy POLARIS and Army PERSHING.

In passing, it is only fair that we consider the fortunes of the contractors most responsible for the missile systems presented earlier in this work. The early liquid-fueled rocket engines for REDSTONE and JUPITER were developed by North American Aviation and its Rocketdyne division. North American created Rocketdyne after World War II to adapt V-2 rocket engine technology for the NAVAHO winged missile. Though the Air Force cancelled the NAVAHO's development on 12 July 1957, Rocketdyne developed a more advanced version of the NAVAHO liquid-fueled rocket engine — the S-3D. That engine was used on the REDSTONE, JUPITER and THOR. A later and larger version of the S-3D — the LR89/LR105 —was used on the ATLAS ballistic missile, and the Rocketdyne RS-27 found its way onto the DELTA line of space launch vehicles. The RS-27 and RS-27A provided yeoman service on DELTA, DELTA II, and DELTA III space missions for decades. Rocketdyne manufactured H-1, F-1, and J-2 engines for the APOLLO manned space program. The company also built the Space Shuttle Main Engines (SSMEs) used on Space Shuttle orbiters. North American merged with the Rockwell Corporation in March 1967 to become North American Rockwell. Renamed Rockwell International, the corporation sold many of its former North American holdings including Rocketdyne to Boeing in 1996. Rocketdyne was sold to Pratt & Whitney in August 2005.

Chrysler remained a diversified supplier of military products following the closeout of the REDSTONE and JUPITER programs, but Martin Marietta reaped even greater rewards in the missile business due to Martin's long-term involvement in the PERSHING and TITAN ballistic missile programs. The Glenn L Martin Company received an Air Force contract for the liquid-fueled TITAN I in 1958, and the company launched its first liquid-fueled TITAN I from Cape Canaveral on 6 February 1959. Following Martin's merger with the American Marietta Corporation in 1961, Martin Marietta launched the first TITAN II ballistic missile from the Cape on 16 March 1962. The TITAN family progressed from TITAN ballistic missiles and the TITAN

IIIC space booster to the more powerful TITAN 34D and TITAN IV space vehicles of the 1980s and 1990s. Martin Marietta merged with the Lockheed Corporation to form Lockheed Martin Corporation on 2 January 1995. By the time the TITAN era ended in 2005, more than 360 TITANs of all types had been built. Some of the later TITANs — most notably the TITAN IVA and TITAN IVB heavy launch vehicles launched from Complexes 40 and 41 — were extremely large, powerful and costly. The U.S. Government spent several hundred million dollars on each TITAN IV mission, not including the cost of the payload. Today, Lockheed Martin remains one of the largest defense contractors in the world. It manufactures the liquid-fueled ATLAS V space launch vehicle and operates it from Complex 41 on Cape Canaveral.

PERSHING, PERSHING 1A, and PERSHING II missions at the Cape were presented in the previous chapter, but a few facts about the missile and its solid fuel contractor should be added before we close. A grand total of 56 PERSHINGs, 100 PERSHING 1As and 49 PERSHING IIs were launched from Cape Canaveral between 25 February 1960 and 22 March 1988. The Thiokol Company built both of the PERSHING rocket stages (first and second stage), and it got into the solid rocket business almost by accident. The Thiokol Chemical Company was founded in 1929, and it was a major supplier of liquid polymer sealants for the Allies in World War II. After the war, the Jet Propulsion Laboratory's scientists discovered Thiokol's products made excellent rocket fuel. The company opened facilities in Maryland and at Redstone Arsenal, and it delivered POLLUX, FALCON, and NIKE-ZEUS missiles before winning a contract in 1958 to build the MINUTEMAN Intercontinental Ballistic Missile's first stage. The latter proved to be a very lucrative and important contract indeed: 1,000 MINUTEMAN missiles were deployed in the Western United States in the 1960s, and 92 MINUTEMAN I, MINUTEMAN II, and MINUTEMAN III missiles were launched from Cape Canaveral between 1 February 1961 and 15 December 1970. A grand total of 740 MINUTEMAN missiles of all types have been launched from Vandenberg AFB, California, through November 2005. The MINUTEMAN program remains a vital part of America's strategic missile deterrent force. Thiokol won the contract to build solid rocket boosters for the Space Shuttle in 1974, and the company was awarded a contract in 2006 to build the ARIES I launch vehicle for NASA's Constellation project. Thiokol (currently ATK Launch Systems) maintains a workforce of more that 4,000 people worldwide.

Harry Diamond Laboratories (formerly Diamond Ordnance Fuze Laboratory, the maker of the DOFL fuze) moved its operations to Adelphi, Maryland, in the mid-1970s. The firm continued to develop fuzes for the Army for a few more years, but officials decided to reallocate much of that work to Picatinny Arsenal and Redstone Arsenal. Consequently, Harry Diamond Laboratories (HDL) refocused its efforts into research in battlefield electronics, high-power microwave systems, sensors and signal processing. HDL was renamed the Adelphi Laboratory Center, and it became a major component of the U.S. Army Research Laboratory (ARL) in 1992.

The Ford Instrument Company (maker of the REDSTONE guidance system) continued to operate as a division of Sperry after the latter was renamed the Sperry Rand Corporation in 1955. Sperry Rand remained a major U.S. military contractor, but Sperry sold off the Ford Instrument Company, Remington Rand Systems, Remington Rand Machines, Sperry Aerospace and Sperry Vickers in 1978 so it could concentrate on its computer business. The Burroughs Corporation — Sperry's rival — eventually engineered a hostile takeover of Sperry in 1986, and Sperry merged with Burroughs to become Unisys.

The Reynolds Metals Company (manufacturer of the REDSTONE fuselage) grew in the 1960s, but financial set-backs in the mid-1960s led to a highly significant reorganization of Reynolds' interests into separate operating divisions. Each division was responsible for its own financial performance thereafter. Around the end of the 1960s, Reynolds began receiving widespread praise for its pervasive aluminum recycling efforts. By 1990, Reynolds was recycling about 210,000 tons of aluminum consumer products each year. As of this writing, Reynolds Metals Company is the third largest aluminum and packaging company in the world.

The Army's arsenals continued to prosper following the demise of REDSTONE, JUPITER and PERSHING missile programs. Picatinny Arsenal remained committed to developing and manufacturing munitions and propellants for the U.S. Army through the early 1970s, but it shifted its operations to the development of smaller caliber weapons and munitions in later years. Army officials kept the Arsenal's traditional name, but they renamed the operating agency in 1986. The agency became the United States Army Armament Research, Development and Engineering Center (ARDEC), and it joined the Army's Tank Automotive and Armaments Command (TACOM) in 1994. In May 2005 the Defense Department announced the creation of "a center of excellence for guns and ammunition at Picatinny." As of this writing, the Arsenal employs about 3,000 soldiers and civil servants and 1,000 contract employees. The Arsenal celebrated its 126th anniversary on 6 September 2006.

Redstone Arsenal remains an important center for the development, testing, maintenance and repair of U.S. Army missile systems. In October 1997, the U.S. Army Missile Command at the Arsenal merged with U.S. Army Aviation Command in St. Louis, Missouri, to form the U.S. Army Aviation and Missile Command (AMCOM). The Space and Missile Defense Command also has its headquarters at the Arsenal. The Arsenal hosts the Tactical UAV (Unmanned Air Vehicle) Project Office, the Missile Munitions Center, and the Redstone Technical Test Center (RTTC) School. In addition to those tenants, the Arsenal continues to support NASA's Marshall Space Flight Center. The Arsenal maintains a working population of about 17,000, and it continues to break new ground in the areas of aviation and missile research.

White Sands Proving Ground was renamed White Sands Missile Range (WSMR) in 1958. It remains an active Army installation with a wide range of customers including the Army, the Air Force, the Navy, NASA, American universities, commercial companies and allied military forces. The range became a test site for Hawk interceptor and Nike Hercules missile defense systems in the early 1960s, and it supported laser weapon system testing in the 1970s. White Sands was the U.S. Army's main test site for the PATRIOT missile defense system in the 1980s and 1990s. White Sands remains an important site for advanced PATRIOT missile testing, and it provides a test bed for the new Terminal High Altitude Area Defense (THAAD) program and the Mobile Tactical High-Energy Laser (MTHEL) program. Farther to the south at Fort Bliss, Texas, the U.S. Army Air Defense Artillery Center hosts the Army's Air Defense Artillery School and four combat air defense artillery brigades. Fort Bliss supports a number of tenant agencies, but its main mission is the training, mobilization and deployment of air defense artillery forces. Consequently, the Army continues to maintain its ballistic missile battery traditions from the old REDSTONE days to the present time.

Army missile programs left a considerable footprint on Cape Canaveral over the years. In addition to launch pads built for other missile programs but pressed into service for REDSTONE and PERSHING launch operations, Complex 5/6 was built expressly for the REDSTONE program. Similarly, Complex 26 was built for the JUPITER program, and Complex 30 was built for PERSHING. Twenty-three REDSTONE, JUPITER A, JUPITER-C, JUPITER, and JUNO II missiles and space vehicles were launched from Pad 5. Forty-three REDSTONE, JUPITER-A, and JUPITER missiles were launched from Pad 6. Thirty-six REDSTONE, JUPITER-C, JUPITER, and JUNO II missiles and space vehicles were launched from Complex 26. Slightly southwest of complexes 5/6 and 26, Complex 30 supported 56 PERSHING missile firings. Northeast of those sites, Pad 31A (formerly a MINUTEMAN facility) was used to fire 12 PERSHING 1A missiles. A grand total of 88 PERSHING 1A and 49 PERSHING II missiles were fired from Complex 16 (formerly a TITAN facility) not far from Complex 19, where manned GEMINI missions were launched in the mid-1960s.

The Army programs also impacted the Cape and the Eastern Range in other ways. Pad 4 (formerly a BOMARC facility) was used to launch the first six REDSTONE missiles at the Cape, and the Army shared space with the Air Force in a BOMARC hangar at the Cape until Hangar “D” was finished for the REDSTONE program in 1955. Officials set aside Assembly Building “R” for the JUPITER program, and several other facilities —Assembly Building “Y” with its calibration laboratory, a spin test facility and a laboratory engineering building — were built expressly for JUPITER operations. JUPITER and other long-range missile programs prompted a lengthening of the Eastern Range via instrumentation ships and new range stations in the mid-to-late 1950s. Ballistic missile testing required the application and integration of more advanced range systems, notably the Army’s DOVAP optical system and the Air Force’s AZUSA radar system. Engineers introduced Ultra High Frequency (UHF) command/destruct transmitters and MOD II radars in 1955, and long-range optical systems arrived a few years later. Though the Air Force and its contractors deserve much of the credit for those innovations, Army missile programs provided a significant demand for better range tracking technology in the 1950s. In many instances, the new tracking systems were field-tested on REDSTONE and JUPITER missions.

From 1949 through September 1986, the Army Field Office (a.k.a., the Directorate for Army Tests) promoted cooperation with its Air Force host at Patrick AFB. The Field Office was never very large — it had 10 officers, 22 enlisted people, and 4 civilians at the end of 1963, and its authorizations dwindled to only 2 officers, 4 enlisted people, and 2 civilians by December 1975. Nevertheless, the Field Office administered support for much larger visiting Army units, and it arranged billeting and messing for missile firing batteries and support troops coming to Patrick on a rotating basis. The Field Office Chief (more typically identified as either the “Director for Army Tests” or the “Director of Army Tests”) was the Army’s senior representative on the Eastern Range. As such, he was one of four test agency directors (i.e., Air Force, Army, Navy, and NASA) with direct access to AFMTC, AFETR, and (later) Eastern Space and Missile Center commanders.

Not all of the Army Test directors are listed in the early AFMTC histories, but the record shows Colonel Leonard M. Orman was in charge of the Directorate for Army Tests at Patrick AFB as of 15 February 1956. He was succeeded by Colonel James D. Sams on 1 August 1958. Colonel Sams remained Director until his retirement on 31 December 1960, and Lieutenant Colonel Curtis L. Ferrell became Acting Director the following day. Colonel Arthur L. MacKusick succeeded Lieutenant Colonel Ferrell on 15 February 1961, and the Director's position passed to Lieutenant Colonel (later Colonel) Melvin D. Clark on 1 September 1962. Colonel Clark was in charge of the Directorate when the last JUPITER Combat Training Launch (CTL) operation was completed at the Cape on 22 January 1963. Troops from the 2nd Battalion, 44th Artillery fired the Cape's final 'first-generation' PERSHING on 24 April 1963.

No more Army missiles were launched from the Cape until late February 1973, but the Directorate of Army Tests remained active in the interim. Colonel Ferrell succeeded Colonel Clark on 4 December 1964, and Colonel William R. Parr became the next Director on 1 December 1966. Colonel Parr continued as Director until 27 April 1971, whereupon Colonel Edward L. Ramsey became the new Director of Army Tests. Colonel Ramsey remained in that post at least through the end of 1976, but there is a gap in the official history in 1977. There may have been another director after Colonel Ramsey in 1977, but Lieutenant. Colonel Joseph F. Weedel became the Director of the Army Field Office on 26 April 1978.

Colonel Weedel and his tiny staff (e.g., one soldier and one civilian) coordinated PERSHING 1A launches and the first PERSHING II firing at the Cape, but operations test units accompanied the missile batteries to provide technical oversight for the firings. Lieutenant Colonel Ralph E. Lancaster succeeded Lieutenant Colonel Weedel on 1 December 1982, and Lancaster continued as Director of Army Tests at least through September 1986. The Army Field Office dropped off the books in FY 1987 only to be replaced by the Pershing Project Manager's Office. As Pershing Project Manager, Mr. A. L. Powers became the local point of contact for PERSHING matters at the Cape.

The evolution of the United States Army's ballistic missile programs from 1936 through the late 1980s was really quite remarkable. The early REDSTONE and JUPITER programs prompted broad-based and far-reaching improvements in rocketry, missile guidance and control systems, and reentry vehicle technology. That effort was largely successful, and it proved enormously valuable to all branches of the military for their ballistic missile programs, to NASA, and to space launch contractors who would (eventually) launch more modern liquid-fueled rockets for commercial, civil and military customers. As a weapon system, the Air Force's MATADOR was deployed earlier than the REDSTONE, but the latter provided the first significant 'all-weather' nuclear-tipped *ballistic* missile capability in Western Europe in the late 1950s. The JUPITER and REDSTONE were eclipsed by the PERSHING rather quickly, but NASA found uses for both of those obsolete missiles in the BEACON, EXPLORER, and early manned MERCURY programs. Three generations of PERSHING missiles remained at the ready in Western Europe for the better part of three decades. They were so worrisome to the Soviet Union that the latter eventually agreed to liquidate five classes of intermediate-range and shorter-range ballistics missiles just to eliminate the PERSHINGs once and for all. Admittedly, American BGM-109G cruise missiles were also part of the INF Treaty deal.

A few REDSTONE, JUPITER, and PERSHING missiles survive as displays and exhibits in various locations around the world. The INF Treaty permitted the retention of 15 inert PERSHING II missiles for display purposes, and the White Sands Missile Range, Redstone Arsenal, the Air Force Space & Missile Museum at Cape Canaveral, and the Smithsonian National Air and Space Museum in Washington D.C. each have a PERSHING II. The National Museum of the Air Force at Wright-Patterson, Ohio, maintains a REDSTONE and a JUPITER locally, and it has loaned out additional missiles to Air Force Space & Missile Museum in Florida and the Kansas Cosmosphere and Space Center in Kansas. NASA also retains at least one REDSTONE and one JUPITER for display purposes, and the USAF Space & Missile Museum has a CORPORAL, a REDSTONE, a JUPITER, and a PERSHING I in its 'rocket garden' at Complex 5/6. Several PERSHING and PERSHING 1A missiles are displayed elsewhere in the United States and Germany, and the Central Armed Forces Museum in Moscow had an exhibit featuring an inert PERSHING II alongside an inert Soviet SS-20. A similar exhibit is displayed at the National Air and Space Museum in Washington, D.C.

As of this writing, nuclear-tipped ballistic missiles continue "on alert" in the United States and the Russian Federation, but tensions between the two great nations have lessen considerably. The Cold War, which endured from the late 1940s through the 1980s, is over. The

Peoples Republic of China, India, Pakistan and (most recently) North Korea have joined the 'nuclear club' but world attention appears to be shifting to the more palpable threat of global terrorism, Middle Eastern insurgencies, Iranian nuclear enrichment efforts, and the potential threat of Islamic fanatics with weapons of mass destruction. Fortunately, the nightmare of even a limited nuclear exchange between the Soviet Union and the United States — which would have made all the Middle Eastern conflicts of the past half century look like no more than neighborhood squabbles — has receded. When confronted with the prospect of mutually assured destruction, deterrence was achieved and sanity prevailed. The prospect of nearly certain extinction in retaliation — not only for the attacker but for all he holds near and dear — had a chilling affect that could not be ignored by the superpowers.

Though incredibly expensive, the nuclear arms race between the United States and the Soviet Union led to vastly destructive weapons that curbed the tendency to attack in the first place. Put simply, land-based deployable nuclear-tipped missiles were an important part of that deterrent, and the United States Army deserves its fair share of credit for the role it played with the REDSTONE, JUPITER, and PERSHING. The fact that the Soviet Union and the United States came to terms to eliminate an entire class of nuclear weapons reflects well on the wisdom of both nations. But deterrence was the key. I'm sure the great Chinese military strategist Sun Tzu would approve. To achieve one's aims without a major battle is one of the hallmarks of good generalship.