Rockets for War . . . And Peace: A History of the U.S. Intercontinental Ballistic Missile Force

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“Scientists and scientifically trained officers will be just as important to the Air Force as the operators who currently run it” Hap Arnold

A meeting in January 1946 in General Arnold’s Pentagon office with then Col. Schriever would lead to the creation of the Scientific Liaison Branch of the Research & Engineering Division and an officer core trained in engineering and science
New Technologies for War
The V-2 Rocket: The World’s First Ballistic Missile

- Developed by the rocket engineering genius Wernher von Braun and his rocket team at Peenemünde during WWII

- 46 feet long by 11½ feet in diameter, weighing 34,000 pounds when fueled, and producing 69,100 pounds of thrust from a single engine consuming liquid oxygen and a mixture of alcohol and water

- Carried a 2000 pound payload for a range of 200 miles

- First deployed in 1944, 3,745 V-2s fired at targets on the European Continent and at England
The V-2’s Impact

• On the continent the V-2 caused 5,400 deaths and wounded 22,000 people and destroyed 90,000 homes

• In England, in which most of the rockets hit London and it suburbs, there were 2,754 deaths and 6,500 serious injuries

• Very advanced rocket technology, but it did not change the outcome of the war for Germany

• The V-2 would usher in a new era of long-range weaponry
US Rocket Efforts: Pre-war and WWII

- Robert Goddard’s work in Roswell, New Mexico . . . Most successful rocket achieved and altitude of 7500 feet
- The US Government showed little interest
- Professional engineers and scientists formed the American Rocket Society in the 30’s. (Became the AIAA and Reaction Motors)
- Cal Tech – Theodore von Karman- studied high-altitude sounding rockets, the principles of reaction, fuels, and nozzle shapes. – his work led to the Jet Propulsion Laboratory and the firm of Aerojet General.
- Military research on JATO (Jet Assisted Take-off) during WWII
The Atomic Bomb

• **Little Boy** – Dropped on Hiroshima
  – Weighed 9,700 pounds
  – Gun Type – used a cordite explosive to fire a bullet of enriched uranium (U-235) into three larger rings of the same isotope. The U-235 is so fissionable when the bullet hit the rings it set off the nuclear explosion

• **Fat Man** – Dropped on Nagasaki
  – Weighed 10,000 pounds
  – Used a plutonium core surrounded by conventional explosives
  – The explosives compressed the core so quickly that the plutonium became supercritical and the nuclear explosion occurred
Post-War
The Quest for Rocket Technology
Operation Paperclip

• It was clear rockets had the potential to become formidable weapons

• As the Germany military collapsed, the Allies advanced from the West and the Soviets from the East in an effort to get a hold of the German rocket technology

• In Feb 1945, the US Army dispatched Captain Robert Staver to track down the V-2 rocket team and get them into US custody

• von Braun and his team had moved south from Peenemünde and surrendered to the US Army on 2 May 1945

• Von Braun had 14 tons of rocket development materials, including 4 million pages of documents stored in a cave to protect them.
Operation Paperclip (2)

• The US reached the V-2 Mettlework assembly site inside the Harz Mountains and was able to collect and ship the parts of 100 V-2s to the US

• In the end, more than 100 rocket team members, including von Braun signed contracts to work for the US Army

• While most of von Braun’s team went the US, the Soviets were able to acquire many V-2 components and several key rockets team members, including most of the guidance control team

• It might have been considered a draw as to whether the US or the Soviet Union was able to collect the most assets, but the US had von Braun.
Rocket Testing in the US

• von Braun and a group of seven of his rocket team arrived at Ft. Bliss, Texas on 29 Sept 1945 as part of Operation Paperclip

• Since his surrender in May, von Braun had been interviewed extensively about the German rocket program and he aided the US Army in tracking down more of his team

• In all, 642 rocket specialists, ranging from scientists, engineers and technicians were brought to US between May 1945 and Dec 1952

• Less than a year after the war ended, the first V-2 was ready to be launched. On 16 April 1946 – a reconstructed V-2 was launched at White Sands and over the next six years 64 more V-2s would be tested
The Rocket Debate Begins
The Question of Rockets and Demobilization

• Even though the Army started testing V-2 rockets in New Mexico, the future of rockets was still up for debate.

• The V-2 demonstrated that a rocket could deliver a payload over a long distance.

• With the advent of atomic bombs, would it be possible to deliver a nuclear bomb over thousands of miles with the required precision?

• While the debate started, the US military branches were facing the reality of rapid demobilization.
Reliance on Strategic Bombers (but What About Rockets?)

- The US defense budget shrunk from $81 billion in 1945 to $13.1 billion in 1947
- There were a lot of new technologies including high speed jets and atomic weapons
- As the US military shrunk its conventional forces, the decision was made to rely on long range bombers and atomic weapons as the main deterrent
- The result was initial efforts to develop long range ballistic missiles were small
- There were still technological obstacles such as accuracy and weight. Yet, the three services (Army, Navy and Air Force) all embarked on exploratory rocket programs – with intense inter-service competitions.
Rocket Opposition

• Between 1945 – 53 the army, navy and air force initiated 110 separate missile projects. But funding was minimal.

• General Hap Arnold, the Air Force Chief of staff pushed for development of long range missiles. He ran up against strong opposition from the Director of the Office of Scientific Research and Development, Vannevar Bush.

• Bush had expressed the prevailing mood in a much-quoted piece of testimony before a Congressional committee:
  
  • "There has been a great deal said about a 3,000-mile high-angle rocket. In my opinion, such a thing is impossible today and will be impossible for many years .... I wish the American public would leave that out of their thinking."
The Soviet Program
The Soviet Quest for German Technology

- In September 1945, a Red Army Col named Sergei Korolev, who was trained in aeronautical engineering at the Kiev Polytechnic Institute, was sent to Germany to study the V-2.
- He was ultimately part of a Soviet team responsible for transferring the remaining V-2 production and testing facilities to the Soviet Union.
- The Soviets were first to grasp the potential of putting a nuclear weapon on a ballistic missile even before they had successfully developed an atomic bomb.
The Soviet Quest for German Technology

• In 1947, a State Commission looked at the feasibility of a ballistic rocket and recommended using an improved V-2.

• Following his time working with the German rocket team members captured by the Soviets, Korolev rebuilt about a dozen V-2s and conducted test launches just like what was occurring at White Sands.

• Korolev even designed his own improved V-2 rocket called R-1, which had a range of 500 miles.
Soviet Rockets Mature

• Korolev was put in charge of a design team at the Scientific Research Institute 88 with the goal to develop a true ballistic missile.

• Korolev also realized that the V-2 technology, while advanced for its time was limiting and started on a path to develop his own rocket the R-2, which doubled the range of the V-2, and was the first design to utilize a separate warhead.

• The R-2 in 1947 was a technological jump, it was a 20 ton vehicle and used its own skin, rather than internal tanks to store the fuel, which saved weight.

• This was followed by the R-3, developed between 1947 and 1949, which had a range of 3,000 kilometers (1,900 mi), and thus could target England.
Developing the First Intercontinental Ballistic Missile

• The R-3 was cancelled in 1952 and work began on the R-5 which had a more modest 1,200 kilometers (750 mi) range. It was the first true Soviet designed missile and it completed its first successful flight in 1953.

• This would lead to the development of the world’s first intercontinental ballistic missile the R-7, in 1953, designed to carry a 5 ton warhead 4300 miles.

• The Soviets detonated their first atomic bomb in 1949, but even in the mid to late 1950’s the Soviet nuclear warheads were heavy and bulky.

• A powerful rocket was needed to deliver these payloads.
The R-7: The Soviet Answer

- The R-7 was 34 m (112 ft) long, 3.02 m (9.9 ft) in diameter and weighed 280 metric tons; the rocket had one central stage and four side sections attached to the central core, which is sometimes referred to as 1 ½ stages.
- It used 5 OKB-456 liquid oxygen-kerosene engines which produced about 890,000 lbs of thrust.
- The first successful long flight, of 3,700 miles was made on 21 August 1957.
- The R-7 required a complex pre-launch and ground testing operation that could take up to 12 hours, which in the end would render it ineffective as a ballistic missile.
The US Ballistic Missile Program – The First Real Steps
Inter-Service Conflicts

- While the Soviets made a commitment to ballistic missiles, at play in the US was the inter-service competitions and no direction from the political leadership on missile development.

- **But throughout these conflicts, the Air Force demonstrated more interest in preserving the strategic bomber role than in moving ahead with a missile program.**

- Just as curiously, as the Air Force’s commitment to develop an intercontinental range missile diminished, its determination to be the service with final authority for long-range missiles increased... Meaning, they didn’t want the army working on long-range missiles either.

- One factor that likely contributed to the Air Force reluctance to move ahead was a culture wedded to pilots in the cockpit.
Technical Concerns

• The other issue was clearly technical. The only payload for an intercontinental ballistic missile was a nuclear weapon, and the atomic weapons of that time were large and heavy.
• Plus there was concern for accuracy.
• Those things combined placed ballistic missiles on a low priority for the Air Force.
• The Air Force did not even want to invest funds in solving the technical problems.
• Signs of change started happening in 1949, as the Air Force leadership created new commands to highlight research and development. .. And external forces changed the priorities.
External Influences Drive the Need

- News that the Soviets exploded their first atomic bomb in 1949, the communist triumph in China, the Korean War and reports of Soviet progress in missile development called for a reassessment of US military preparedness.
- The first step was President Harry Truman’s authorization of the development of the hydrogen bomb.
- And there were calls for an enhanced missile program. One program that drew interest was the Convair Corporation’s MX-774 ballistic missile project.
Convair MX-774

• Started in the late 1940’s to study the V-2 and other long-range missiles, the program aimed to study various vehicles with a range of 5000 miles (8200 km)

• The program was canceled in 1947, but Convair convinced the Air Force to continue funding several test missiles that helped advance the technology needed for these missiles

• With the global situation changing, the MX-774 program was revised in 1951, this time with a new name – Atlas

• The Air Force called for a missile that could carry an 8000 pound warhead 5000 miles.
The Army – Air Force Battle
The Battle Between the Air Force and the Army

• As the debates continued at the highest levels of the US government, the US Army wanted to move ahead and build on the work von Braun and his team conducted at White Sands on the V-2.

• The army saw ballistic missiles as an extension of artillery and they wanted to develop a tactical ballistic missile based on the V-2 technology that could carry existing nuclear weapons.

• The rocket that von Braun and the army proposed was the Redstone rocket, which was actually a super V-2.
The Redstone Rocket

- The Redstone weighed about 62,000 pounds, was 69 feet in length, 5.83 feet in diameter and carried a 6300 pound payload for a range of 57 miles to 201 miles.
- The Redstone used a North American Aviation 75-110 A-7 engine that produced 78,000 pounds of thrust.
- Redstone burned a fuel mixture of 25 percent water–75 percent ethyl alcohol with liquid oxygen (LOX) used as the oxidizer.
- First flight was 20 August 1953 and went into service in 1958 and was retired in 1961. But like the Atlas, the Redstone would also find other duties.
- In the end, the Air Force won the battle and the army was limited to developing only battlefield and short-range missiles.
The First American Intercontinental Ballistic Missiles
The Birth of Atlas

• There were still many who thought that the technological challenges were too much to overcome when a breakthrough in weapons design changed the game

• Informed by the nation’s top weapons scientist Edward Teller that it would be possible to downsize a hydrogen bomb to less than a ton in weight, it made building a practical and smaller intercontinental ballistic missile possible

• That led to the go-ahead for the development of an operational Atlas in 1953, which was a follow-on to Convair’s MX-774
The Atlas

• The first successful flight occurred on 17 December 1957
• It would become the America’s first intercontinental ballistic missile
• The Atlas, which would become operational in 1959, measured 110 feet in length, 12 feet in diameter with a total weight of 440,000 pounds
• The missile generated 656,100 pounds of thrust from its 4 booster engines and could carry a 3000 pound warhead 5,500 nautical miles
• Used Liquid Oxygen (oxidizer) and the fuel was RP-1 (kerosene)
• The Atlas would have a short operational life as a ballistic missile, but would prove its usefulness in other ways
Titan I: A Back-up to Atlas

- General Schriever, who was leading the ballistic missile project, was concerned that Atlas’ design was too radical and he wanted a conservative back-up.

- Schriever also felt having a second contractor was a hedge against placing too much work with one company.

- The Air Force approved the Titan program on 2 May 1955 and the Glenn Martin Company was selected as the prime contractor.

- Titan I was a two-stage, liquid-fueled, rocket-powered missile.

- The first stage delivered 300,000 pounds of thrust; the second stage 80,000 pounds. The missile utilized both radio and all-inertial guidance.
Titan I: The Primary ICBM

- First Flight 6 February 1959
- The 97 foot tall rocket was designed to deliver a four-megaton nuclear warhead to targets in the Soviet Union more than 8,000 km (5,000 miles) away
- Deployed from 1962 to 1965 (replaced by Titan II)
- The Titan II carried double the payload of the Titan I
- Unlike the Titan I, it used hydrazine-based hypergolic propellant which was storable and reliably ignited. This reduced time to launch and permitted it to be launched from its silo.
- At the time, the Titan II carried the largest single warhead of any American ICBM
- In service from 1963 to 1987
The Rocket Developers
Karel Bossart: The Atlas Engineer

- Bossart, born in Belgium, he was a mining engineer that became interested in aeronautics and got a fellowship from MIT.
- Went to work to improve on the V-2.
- Is contributions to the Atlas led to great advancements in missile designs:
  - An independent re-entry warhead that separates from the lifting booster.
  - Created a missile body that was simply a tank for the propellants.
  - No internal structure, the missile body was filled with inert gas until the propellant was loaded.
  - Gimbaled rocket nozzles for steering.
Bernard Schriever: Missileman

• B.S. in Architectural Engineering from Texas A & M in 1931
• Entered the Army Air Corp Flying School and earned his wings in 1933
• Earned a Master’s in Aeronautical Engineering from Stanford in 1942
• By the end of WWII, achieved rank of Colonel and was the commander of the Advanced Headquarters, Far East Service Command
• In June 1954, then a Brigadier General, he was asked to take over command of the Air Research and Development Command (now the AFSC) and lead the creation of the US Ballistic Missile Force
• Thor intermediate range missile developed in 3 ½ years; Atlas 5 years, Titan 6 years and the Minuteman 4 years and 8 months
Lt Col Edward Hall: The Guru of Rockets

- Earned undergraduate and master's degrees in chemical engineering from City College of NY and later, while in the Air Force, he earned a master's degree in aeronautical engineering (propulsion option) from the California Institute of Technology.

- In September 1939, as war was beginning in Europe, he joined the Army Air Corps as an enlisted man and later made 2nd Lt after Pearl Harbor.

- His introduction to missiles came near the end of the war, when he was assigned to acquire intelligence on Germany's wartime propulsion work.

- His work on the V-2 engine and Rocketdyne vastly improved the performance and it was used on the von Braun’s Redstone rocket.
In 1957, Schriever tasked Hall with developing a new kind of rocket using solid fuel.

Hall’s team began experimenting with a mixture of ammonium perchlorate, which provided oxygen for the rocket's internal fire, and aluminum, which served as a fuel. The two were mixed and encased in a rubber-like polymer that also burned upon ignition.

To provide even thrust without damaging the rocket, the team built upon a technique developed in a small British laboratory. Instead of having the fuel burn at one end, as early rockets had, they cast a star-shaped opening all the way through the solid fuel, allowing the propellant to burn from the inside out.

In this fashion, the propellant had a constant surface size, which provided even power output throughout the burn, and the remaining propellant also served to insulate the sides of the craft from the intense heat generated by the motor.
The Minuteman

• They even developed a way to shut the rocket down, a feat that many engineers had not believed possible, but one that was necessary for an ICBM to be able to hit its target accurately. To achieve this, they installed precision shutdown ports on the rocket chamber that, when opened in flight, reduced the chamber pressure so abruptly that the propellant was snuffed out.

• The first 10 Minuteman ICBMs using this technology were installed in underground launching silos in October 1962, during the Cuban missile crisis.

• Eventually, more than 1,000 were installed in silos throughout the country, but disarmament agreements have scaled the number back to 500.

• Each of the third-generation Minutemen now in place, however, carries three independently targeted warheads, in effect making them three ICBMs in one.
Closing Thoughts
The Missile Gap

- The launch of Sputnik in Oct 1957 sent shockwaves of fear through the America public. If the Soviets could launch a satellite, they could rain nuclear weapons down on the US.

- The US leadership in technology was questioned.

- And it spurred a “fairy tale” of the so called “missile gap” which had the US far behind the Soviet Union in ICBM capability. There were political and institutional motives and it became a center stone of JFK’s 1960 presidential campaign.

- The truth was that by 1959 there was a missile gap, all in favor of the US.

- While the Soviets had an advantage in heavy lift capabilities, the rockets were impractical as ICBMs.

- The small size of the US nuclear warheads gave the advantage to Gen Schriever’s team and the Thor, Atlas and Titan would provide an advantage for many years to come.
The R-7 was used to launch Sputnik and derivatives of the rocket became the Vostok, Voskhod and Soyuz rockets.

A variant of the Redstone, the Jupiter launched Explorer and the Redstone launched the first two Mercury missions.

The Atlas launched the last four Mercury missions.

The Titan II launched every Gemini Mission.
Legacy

• Why did the US win the Cold War?
• The blanket of protection provided by the US Ballistic Missile fleet served as a strong deterrence to an enemy attack
• The dedicated Air Force officers and industry contractors who developed these rockets are not known to the public, but it was their brilliance, innovation and commitment to the all of the ideals of the US that contributed to our safety and protection.

“They were cold warriors, but they were engineers first.”

Titan Missile Museum - Sahuarita, Arizona
For More Information

If you would like a copy of this presentation, send an email to b.dicht@ieee.org