The Road to Space.
The First Thousand Years

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Blazing the Trail. The Early History of Spacecraft and Rocketry
AIAA, Reston, Va., 2004

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Breakthrough to space

Photo credit: NASA NQ

- anniversary in October
- launch of Sputnik (October 4, 1957), followed by American launches

- Exciting achievements of space exploration that began in the late 1950s are very well known to many
- Not that many, however, are familiar with the beginning:
  - How we prepared for this breakthrough to space
  - What happened in the early days of rocketry and spacecraft
  - Who were those often unappreciated and forgotten visionaries, scientists, engineers, and political and military leaders who opened the way to space

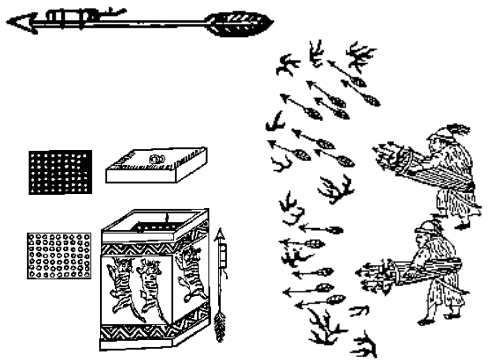
Ancient Greeks and Principle of Rocket Propulsion

- Ancient Greeks observed the principle of rocket propulsion.
- Hero (or *Heron*) of Alexandria (~ 65–125 AD) demonstrated the concept of reactive propulsion by his aeolipile.
- The phenomenon was neither understood nor explained in those times and considered as a curiosity not useful for any practical purpose.

Courtesy of *NASA, EG-1999-06-108-HQ*

First Rockets in China

- The earliest rockets were solid rockets.
- By the year **1045 AD** gunpowder and rockets had been used by the Chinese military.
- Rocket ***fire-arrows*** (hu-o chi-en) were certainly used to repel Mongol troops at the battle of K'ai-fung-fu in AD 1232.
- **Chinese rockets remained small and inefficient**
  - powder section: 1/3–1/2 ft. long
  - bamboo shaft: 1.5–2.0 ft. long
  - **range: 300–400 yards**
  - concentrated on **multiple launchers** carried and operated by one soldier
- **In contrast, India developed large rockets**



Right: rocket basket for launch of up to 20 arrows (dated 1621).
Left: launcher for launch of 100 rocket arrows (dated 1621).
(Courtesy of the *National Defense Industrial Association)*

Who Was the First?

Bragging rights important to many ...

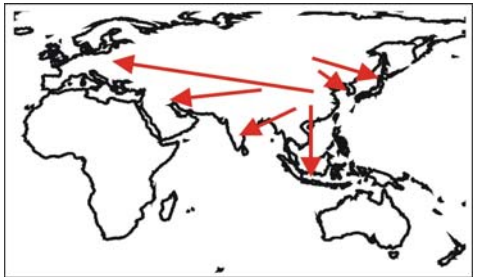
- **We do not know exactly when and where first rockets were built.**
- **First rockets** likely appeared **either in China or India**.
- The existing Chinese records are simply older.
- The earliest rockets used a form of gunpowder

  Strictly speaking, the term "gunpowder" is incorrect here since the guns appeared only in the early 14th century.

- Gunpowder consists of **charcoal**, **sulfur**, and **saltpeter**.
- Charcoal, sulfur (brimstone), and saltpeter (niter) were known since the times immemorial.
- Saltpeter is naturally abundant in China and India but rare in Europe
- Gunpowder likely appeared first in China and India

Proliferation of Rocket Technology

First wave: XII-XIII centuries



- **Japan**: 1274 and 1281
- **Java**
- **Iraq** – Baghdad in 1258 ? Probably not.
- **Korea**
- **India** – ?
- **Europe**: battle of Legnica, 1241

- The Mongols learned from the Chinese
- Did the Mongols bring gunpowder and rockets to the Near East and teach the Arabs and Europeans? – **Not necessarily**.

- The **Byzantine Empire** had independently developed and known incendiary and explosive weapons for several centuries by that time.
  - **Greek fire** appeared some time in the 6th or 7th centuries.
  - **Marcus Græcus** described gunpowder-like mixtures and incendiary and explosive projectiles as early as in the 9th century.

Rockets in Europe

- Facility "to research in saltpeter" was established in Paris in **1227**
- French Army of King Louis IX met with rocket-propelled devices at Damietta during the Seventh Crusade in **1249**
- Rich Italian cities, **Venice**, **Genoa**, and **Pisa**, led the European technology development, benefiting from constant contacts, in trade and war, with the Byzantine Empire and Oriental countries
- **First recorded use of rockets in European warfare: in 1379 in Italy**

Rocket firing in Europe ca. 1598

Rockets in India

Battle near Delhi on Dec. 17, 1399

Timur (Tamerlane) recounted that the opposing forces of Indian Sultan Mahmud included *"125 elephants covered with armor, most of them carrying howdahs in which were men to hurl grenades, fireworks, and rockets."*

- By the mid-18-th century, Indian warriors widely employed war rockets.
- Saltpeter was abundant and bamboo made excellent straight and light guiding sticks.
- Rockets did not require bullocks or elephants for transport, in contrast with artillery

Mysore Rulers Promote Rocketry

- Hyder Ali, the ruler of Mysore, established the 1200-man strong rocketeer force.
- Hyder Ali's son, Tippoo Sultan, later increased the force to 5,000 men.
- Major technological innovation: **metal cylinders** to contain the black powder
- Indian rockets developed into large devices with mass up to **12 lb** and range **1.5 miles**.

Figure: de la Tour, 1855

Hyder Ali (1722–1782)

Figure: Beatson, 1800

Tippoo Sultan (1749-53?–1799)

Rockets remain highly inaccurate and unpredictable — incendiary and terror weapon

William Congreve

The British were under particularly heavy rocket attacks during the two battles of Seringapatam in 1792 and 1799, where Tippoo Sultan used rockets on large scale. British troops captured almost 10,000 Indian war rockets in 1799.

- **Indian rockets fired at Seringapatam 'hit' an unintended target, a British inventor William Congreve**
- Congreve developed in the early 1800s a family of rockets for the army and the navy
- The first successful rocket attack conducted against Boulogne in 1806
- Copenhagen burned to the ground by rockets in 1807
- **The rockets became known as the Congreves**

William Congreve directing the discharge of his rockets into the Town of Copenhagen in 1807. Courtesy of the *Anne S.K. Brown Military Collection*.

Congreve Rocket

Figure courtesy of *Mike Gruntman*

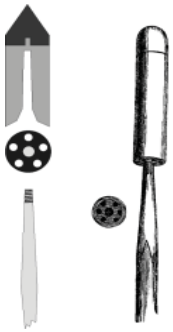
Typical rocket consisting of a **warhead**, **gunpowder grain** with conoidal chamber, **base plate** with the exhaust orifice, and **guiding stick**.

Congreve rocket family with rockets from 6 lb to 300 lb
Courtesy of the *Anne S.K. Brown Military Collection*

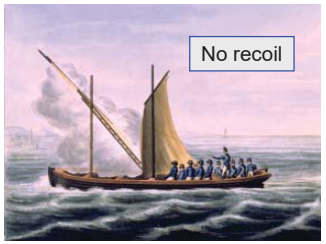
100-pd. Congreve rocket.
Photo courtesy of *Mike Gruntman*.

Rocket Launch

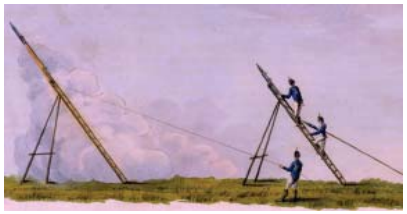
Major Innovation
Centrally-Mounted Guiding Sticks



Courtesy of the *Anne S.K. Brown Military Collection*



Recoilless launch allowed rocket use from small boats (later – 1916 – from airplanes).



- Since 1815, the sticks were mounted axially.
- The base plate has a threaded socket in the center and several exhaust orifices ("nozzles") on the periphery.
  - ➢ enables launch from tube launchers

Rockets Come to America – War of 1812

- British Congreves fired from Hampden in Main to Lower (Quebec) and Upper (Ontario) Canada to New Orleans
- Royal Marine Artillery and a few naval vessels specially outfitted for rocket warfare

Figures: Lossing, 1869

Battle of Bladensburg near Washington
August 24, 1814

- By a blunder, three Baltimore regiments were moved into entirely uncovered positions
- Two militia regiments broke and fled in the wildest confusion under the flight of hissing Congreve rockets
- The battle was lost, the British troops later the same day occupied Washington and burned the Capitol and the President's House.

Remains of the Capitol building after the fire.

Fort McHenry – … And the rockets' red glare …

- On September 13 and 14, 1814, British bomb vessels and the rocket-ship H.M.S. *Erebus* poured heavy fire on Ft. McHenry that guarded Baltimore
- American fire injured the *Erebus* and small boats had to tow it to safety

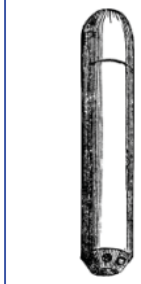
Francis Scott Key (1780–1843)

Bombardment of Fort McHenry.
Courtesy of the *Anne S.K. Brown Military Collection*

- Francis Scott Key observed bombardment of Ft. McHenry
- It was these Congreve rockets that inspired his famous lines that later became the National Anthem of the United States

First American Rockets

- The U.S. Army Ordnance department experimented with rockets on a small scale after the War of 1812
- A war and an invention brought the rockets into focus of the Army
- The **War with Mexico** broke in 1846
- William Hale, a British inventor from London, found a way to stabilize rocket flight without a guiding stick **by using oblique exits ("nozzles") at the baseplate to spin the rocket**
- **The new rockets became known as the Hales**



Hale rocket. Contemporary drawing (1840s)

Washington Arsenal ca. 1860
Courtesy of
National Defense University

- Hale's invention purchased by the Ordnance Department
- New rockets built and successfully tested at the Washington Arsenal in Jan.1847
- More than 2000 rockets were made at the Washington Arsenal by June 30, 1847

First American Missile Units – Rockets in Combat

- A special ***Howitzer and Rocket Battery*** (100+ men) was formed in December of 1846
- The Battery landed near **Vera Cruz** with the Army in March 1847
- **The Mexican Army was the first to fire its Congreves at the besieging Americans**
- **On the night of the 24th of March, the American rockets were fired for the first time in a military operation**; many times later during the campaign.
- The experience with rockets was not exceedingly impressive (eccentricity in flight, instability, premature explosion, deterioration in storage).

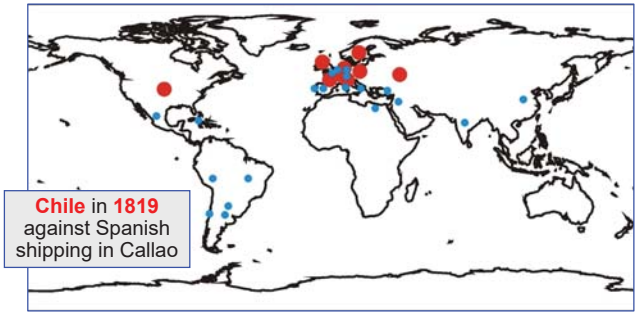
Figure: Lossing, 1889

Bombardment of Vera Cruz

Rockets were rarely used in the Civil War, 1861–1865

Proliferation of Rocket Technology

Second Wave: XIX Century



Countries with **major** and **minor** rocket establishments

Chile in **1819** against Spanish shipping in Callao

Great Britain and Russia employed rockets in their colonial wars until the end of the 19th century

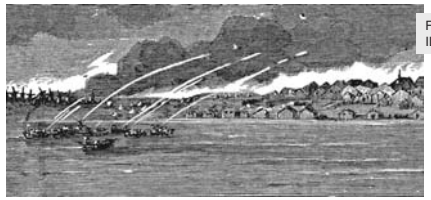


Figure: ILN, 1855

British rocket attack from small gun boats on the town of Gheisk in the Sea of Azov on November 5th, 1855, during the Crimean War, 1853–1856.

Rocket Technology Marches On

- Rocket design and manufacturing technology improved
- Centrally-mounted stick
- Rocket spin for stabilization
- Stabilization by fins was tried
- Hydrostatic press (William Hale) instead of ramming gunpowder by mallets and monkeys
  – safety improved

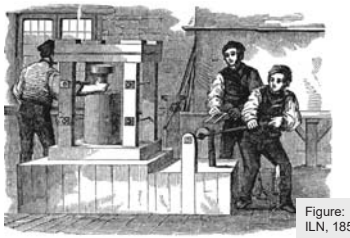
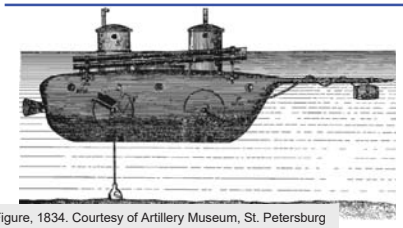


Figure: ILN, 1855

Making war rockets by hydrostatic-driven process



Figure, 1834. Courtesy of Artillery Museum, St. Petersburg

Submarine secretly built and tested by the Russian Karl Shil'der in 1834.

The iron-clad submarine was 20 ft. long and carried the crew of 10 men. Two rocket stands could fire three rockets each from a submerged position.

Artillery Wins the Competition

- **Important advancements in artillery sealed the fate of rockets in the middle of the 19-th century**
- **Rifled barrels**
  Superior accuracy
- **Breach loading**
  Higher firing rate
- **Bessemer's steel process**
  Stronger barrels – increased range
- New steam-powered ironclad ships were protected by **armor** that made **rockets ineffective**

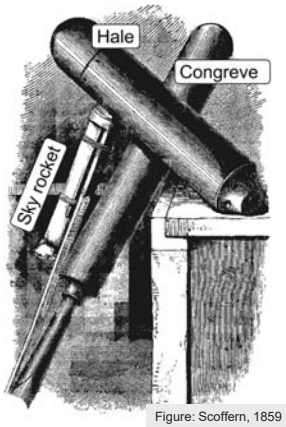


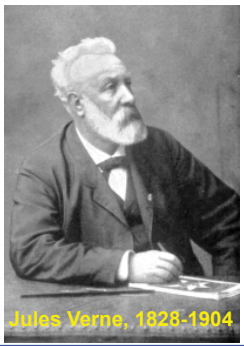
Figure: Scoffern, 1859

Rockets remained in the entertainment (fireworks) and the whaling industry

Public Imagination on Fire

- Interest to rockets among the military dramatically diminished
- **The writers replaced the men of sword as the keepers of public interest in rocketry and spaceflight.**
- Space travel could be found in (science) fiction writings for many centuries: Lucian, Firdausi, Kepler, Wilkins, de Bergerac, Defoe, Poe, and many others

- The second part of the 19th century: writers set public imagination on fire
- Nobody captured the imagination of the public more than **Jules Verne**
- His classic novel *De la Terre à la Lune* (*From the Earth to the Moon*) was a seminal work on spaceflight



Jules Verne, 1828-1904

Jules Verne motivated those special kids who would later become visionaries of the space age: **Tsiolkovsky, Goddard, Oberth, Esnault-Pelterie, Von Braun, Glushko, and Korolev**.

Fire!
From the Earth to the Moon

First "Application" Satellite

- The characters in science fiction novels attempted space travel for fun, curiosity, as a bet, escaping debts and wives, but never with a practically useful goal
- In 1870, **Edward Everett Hale**, a most inventive author, published a story ***The Brick Moon*** in the *Atlantic Monthly*.
- A huge water-powered flywheel flung an artificial satellite into orbit along the Greenwich meridian. This new moon was visible from earth and helped in **determination of longitude**, a tremendous aid in navigation.

Edward Everett Hale at the Boston Common.
Photo courtesy of *Mike Gruntman*.

Four Great Space Pioneers

Konstantin E. Tsiolkovsky
1857–1935

Photo courtesy of *K.E. Tsiolkovsky Museum of Cosmonautics, Kaluga*

Visionary writings inspired new generations of space enthusiasts.

Robert Esnault-Pelterie (REP)
1881–1957

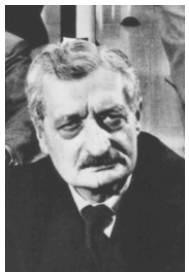
Photo courtesy of *Musee de l'Air* and *CNES*

Aviation pioneer.
Theoretical and experimental work; acceptance by "mainstream" science.
Introduced the word *Astronautics*.

Robert H. Goddard
1882–1945

Photo courtesy of *NASA*

Theoretical and experimental work.
First liquid rocket.



Hermann Oberth
1894–1989

Photo courtesy of *NASA*

Influential book in 1923.
Many important concepts in propulsion and rocketry.

First Liquid Rocket
Robert H. Goddard

- first liquid-propellant (gasoline and liquid oxygen) rocket
- first flight on **16 March 1926** in Mass: **184 ft** to a maximum altitude of **41 ft**

- Experimentally proved that rocket would work in vacuum
- Viciously ridiculed by *The New York Times*, 1920

  ... That Professor Goddard with his 'chair' in Clark College … does not know the relation of action and reaction, and of the need to have something better than a vacuum against which to react – to say that would be absurd. Of course he only seems to lack the knowledge ladled out daily in high schools ...

  Major impact on life and work of Goddard

  The New York Times (sort of) "apologized" in 1969 (when Apollo 11 was on the way to the first Moon landing),

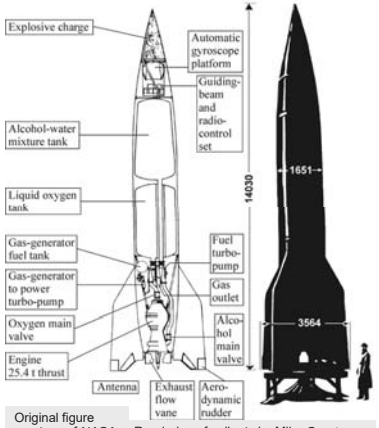
  … Further investigation and experimentation have confirmed the findings of Isaac Newton in the 17th Century and it is now definitely established that a rocket can function in a vacuum as well as in an atmosphere.
- By 1937, Goddard's rockets reached 9000 ft
- 214 rocket patents

Robert H. Goddard. Photo courtesy of *NASA*.

First Modern Rocket A-4 (V-2)

Wernher von Braun in 1937. Photo courtesy of U.S. Army

Mass (fueled) – 12 700 kg (28 000 lb)
Length – 14 m (46 ft)



Original figure courtesy of *NASA*. Rendering of callouts by Mike *Gruntman*.

- Development of long-range liquid-propellant rockets started by the *German Army* in 1930
- Major effort in National-Socialist Germany led by **Walter Dornberger** and **Wernher von Braun**
- A-4 or V-2 (*Vergeltung* ≡*Vengeance*)

Technological marvel
- warhead – **2000 lb**
- range – up to **180 miles**
- specific imp. (sea level) – **210 s**
- 5800 V-2s manufactured
  – slave labor (concentration camps)
- 3000 operationally fired

A-4 (V-2) engine. Photo courtesy of Mike Gruntman

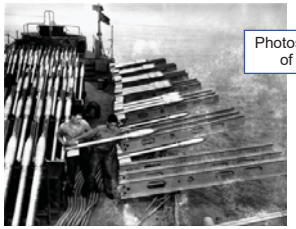
American Rockets in WWII

- rocket technology development since late 1930s by Theodore von Kármán's group at California Institute of Technology, supported by Gen. Henry H. "Hap" Arnold
  – Jet-Assisted Take-Off (JATO)
  – solid and liquid-propellant propulsion
  – composite propellants
  – JPL formed in 1943–1944
- groups at the East Coast (ARS, Navy, …)
- **first private rocket enterprises**
  – Reaction Motors, Inc. (RMI), Dec. 1941
  – Aerojet Engineering Corp., March 1942

Photo courtesy of *NARA*

Takeoff of the first rocket-assisted airplane from March Field, Calif., on 12 August 1941. Photo courtesy of *NASA*.

General Henry H. "Hap" Arnold



Photos courtesy of *NARA*

Theodore von Kármán, Jan. 1943 Photo courtesy of *Aerojet-General*

Successful Artificial Satellite Requires:

- **Launch systems**
- communications subsystem
  - radio telemetry for data transmission (**1932**)
- electric power subsystem
  - solar cells (**1953**)
- on-board propulsion subsystem
  - cold-jets and hydrazine monopropellant (**1962**)
- attitude control and guidance and navigation
  - aviation and guided missiles
- ground-based facilities (testing range and launching sites)
  - Cape Canaveral (**1949**)
  - Tyuratam (Baikonur) (**1955**)

Launch of Convair's **MX-774** in 1948. Courtesy of U.S. Air Force.

International Geophysical Year (IGY)

- **July 1957 to December 1958**
- broad synoptic study of geophysical phenomena
- period of solar activity maximum (11-year cycle)
- 70 countries participated in IGY
- both USA and USSR announced intention (**and succeeded**) to launch artificial satellites

Soviet Union and *United States* developing ballistic missiles with the increasing capabilities in

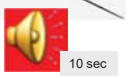
- accuracy
- range
- payload (warhead) weight

Soviet *Sputnik*

Intercontinental Ballistic Missile (ICBM) R-7

- **December 1950**
  feasibility study authorized
  - warhead 5500 kg (12,200 lb)
- **20 May 1954**
  top national priority
- **21 August 1957**
  first ICBM R-7 successful launch on full range (6300 km)
- **4 October 1957**
  modified R-7 launched the first artificial satellite Sputnik

APL's engineers William Guier and George Weiffenbach determined the Sputnik orbit from Doppler measurements – this would lead to space-based navigational system *Transit*



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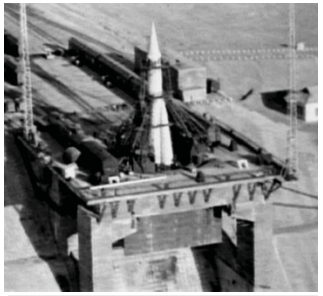
Sergei P. Korolev, the leader of the early Soviet rocket and space program. His Design Bureau (the predecessor of *RKK Energia*) built the first ICBM R-7, first space launcher, and first satellite Sputnik. Courtesy of *S.P. Korolev Memorial House-Museum*.

Valentin P. Glushko, the leading Soviet designer of rocket engines. Courtesy of *Energomash*.



ICBM R-7 readied for launch in May-June 1957. Photo courtesy of *Videocosmos*.

First American Satellite(s)

Program Vanguard

- **August 1955**
  - civilian (= not weapon) under **Navy** direction
  - authorized as part of *International Geophysical Year* IGY
  - new space launcher
  - satellites
- Naval Research Laboratory (NRL) – technical direction
- Glenn L. Martin Co. – prime contractor
- heritage: NRL-Martin Viking sounding rockets (early 1950s)

U.S. Army (Huntsville, Ala.) proposed to launch a satellite by a modified **IRBM Redstone** rocket (Gen. John B. Medaris and Dr. Wernher von Braun)

U.S. Air Force was developing a highly-capable **ICBM Atlas** (Convair) that could be modified for space launch

Policy of President Dwight D. Eisenhower

- **top priority – satellite reconnaissance** to prevent a surprise attack by the USSR (closed society)
  - launch of the American scientific satellite to assert the principle of freedom of space
  - deliberately played down future role of satellites
- development of a new "pure space launcher" *Vanguard* for IGY not linked to ballistic missile military weapon programs
  - to protect high-priority *Atlas* ICBM development (rushed to counter the anticipated *missile gap* with the aggressive Soviet Union) from distractions
  - *Vanguard* to assert freedom of space

Sequence of Events

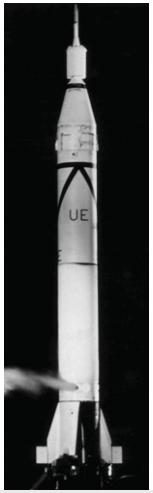
- **20 September 1956**
  Test launch of the U.S. Army's *Jupiter C* that **could have placed a satellite into orbit**. U.S. Army's Medaris and von Braun were specifically ordered not to deploy a satellite.

Photo courtesy of novayagazeta.ru

- **4 October 1957**
  Sputnik-1 launched, followed (3 November) by *Sputnik-2* with a dog *Laika* onboard
  asserting freedom of space! – no country protested overflights
- ***Sputnik*** – tremendous effect on the world and powerful weapon in a sharp ideological confrontation of the Cold War
- U.S. Government anticipated Soviet launch but the public eventually "shocked" (fueled by "uninformed" media and politicians – anything new here?)
- U.S. Army permitted to try its launcher – now, Navy (*Vanguard*) and Army (*Explorer*) programs compete
- **6 December 1957**
  spectacular explosion of experimental Vanguard on launch pad

Photo courtesy of NASA

First U.S. Launches



Explorer 1 on launch pad on 31 January 1958. Photo courtesy of *NASA*

William H. Pickering (left), **James A. Van Allen** (center), and **Wernher von Braun** (right) with a model of Explorer 1. Photo courtesy of *NASA*

Perfect launch of **Vanguard 1** from Cape Canaveral on 17 March 1958. Photo courtesy of *Naval Research Laboratory*.

31 January 1958
Explorer-1 launched

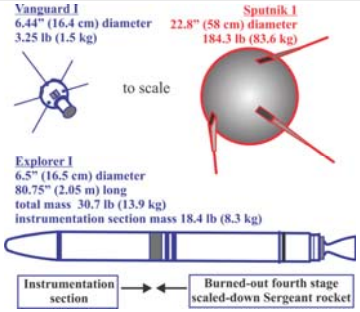
17 March 1958
Vanguard-1 launched

18 December 1958
Atlas launches a satellite

For the record (to correct the false popular perception created by enlightened media)

The Vanguard program demonstrated a record fast development of a new space launcher, with only 30 months from vehicle authorization to first successful launch.

First Satellites and Space Launchers – Space Age Begins

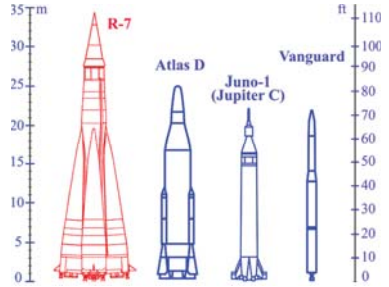


First three satellites (to scale)

Was there a **technological gap**? Soviet Union was first to place a satellite in orbit in October 1957. By December 1958, United States launched satellites by three entirely different launch systems.

First Soviet ICBM and space launcher much larger and heavier than first American launchers, including first American ICBM *Atlas*

R-7 designed for much heavier nuclear warheads



The R-7 evolved into a successful, still operational space launcher *Soyuz*. *Atlas* launched many space vehicles

Difficult Road

Titan 1 (24 sec video)
Cape Canaveral, December 12, 1959
Credit: Air Force

Success/failure of early U.S. space launches.
Figure: M. Gruntman, *Blazing the Trail*, 2004.

SS-7 (8K64, R-16) (21 sec video)
Tyuratam TTMTR (Baikonur), October 24, 1960
74 killed in fire (total: 92 died)
Credit: Min. of Def., Russia; Roscosmos; Yuzhnoe

The First Thousand Years

Other Nations Followed

- France – 26 November 1965
- Japan – 11 February 1970
- China – 24 April 1970
- United Kingdom – 28 October 1971
- ESA – 24 December 1979
- India – 18 July 1980
- Israel – 19 September 1988
- Iran – 2 February 2009
- North Korea – 12 December 2012
- South Korea – 30 January 2013
- Brazil – 1997, 1999, 2003 (21 killed) … Unsuccessful attempts but determined to succeed …

The **First Thousand Years** of rocketry brought us spectacular successes, and **we reached the cosmos**.

The next 1000 years will be even more exciting.

Who said that the road to *Alpha Centauri* would be easy?

Per Aspera ad Astra!

Through Difficulties to the Stars!