



The Road to SpaceMike Gruntman


The Road to Space

The First Thousand Years

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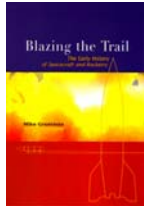
Year 2007

- The year of the 50th anniversary of the breakthrough to space
 - Launch of **Sputnik** on 4 October 1957, followed by American launches

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Presentation based on




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

Book received the Luigi Napolitano Award (2006) from the International Academy of Astronautics.

Source for more information, details, references, etc.
<http://astronauticsnow.com/blazingthetrail/>


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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

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First Rockets. China.

- The earliest rockets were **solid rockets**.
- Certainly by the year **1045 AD** gunpowder and rockets were 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)

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Who Was the First?

- We do not know exactly when and where the first rockets were built.
- It is likely that the first rockets 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
- The gunpowder likely appeared first in China and India

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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 the 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.

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Rockets in Europe

- Facility “to research in saltpeter” was established in Paris in **1227**
- French Army of King Louis IX during the Seventh Crusade in **1249** met with rocket-propelled devices at Damietta
- Rich Italian cities, **Venice**, **Genoa**, and **Pisa**, led the European technology development, benefiting from their 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**.

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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, **Tipu Sultan**, later increased the force to **5,000 men**.
- Major 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**.

Hyder Ali (1722–1782) Tipu Sultan (1749-53?–1799)

Rockets remain highly inaccurate and unpredictable – incendiary and terror weapon

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The British were under particularly heavy rocket attack 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 attack was against Boulogne in **1806**
- Copenhagen was burned to the ground by rockets in **1807**
- The rockets became known as the Congreves**

William Congreve

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

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

Congreve rocket family with rockets from 6 lbs. to 300 lbs.


Courtesy of the Anne S.K. Brown Military Collection

Congreve Rocket

100-pd. Congreve rocket.

Photo courtesy of Mike Gruntman.

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Major Innovation
Centrally-Mounted Guiding Sticks



- 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

Rocket Launch



Courtesy of the Anne S.K. Brown Military Collection

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




No recoil



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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



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.

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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
- The *Erebus* was injured by the American fire and had to be towed by small boats 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

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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**

Washington Arsenal ca. 1860
Courtesy of
National Defense University





Hale rocket.
Contemporary
drawing (1840s)

- 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

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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).



Bombardment of Vera Cruz

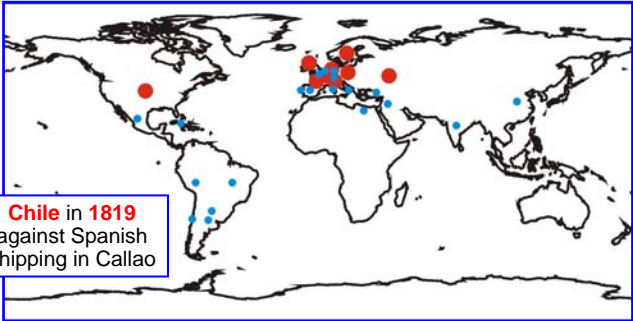
Rockets were rarely used in the Civil War, 1861-1865

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Proliferation of Rocket Technology.

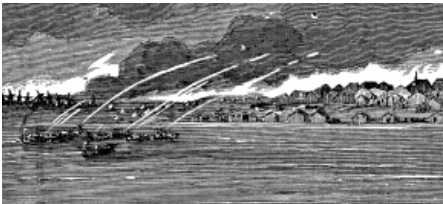
Second Wave: XIX Century



Chile in 1819 against Spanish shipping in Callao


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

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




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**.

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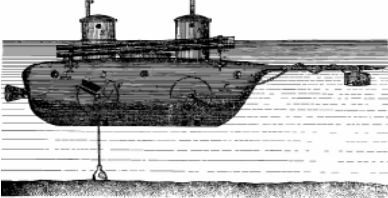
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Rocket Technology Marches On

- 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



Making war rockets by hydrostatic-driven process



Submarine secretly built and tested by 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.**

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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 – improved range
- New steam-powered ironclad ships were protected by **armor** that made **rockets** ineffective



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

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Public Imagination on Fire

- The interest to rockets among the military dramatically diminished
- The men of plume replaced the men of sword as the keepers of the 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

**Jules Verne, 1828-1904**

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

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First “Application” Satellite

- The characters in science fiction novels attempted space travel for fun, curiosity, as a bet, escaping debts, 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.

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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 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.

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First Liquid Rocket

Robert H. Goddard


- Experimentally proved that rocket work would work in vacuum
- Viciously ridiculed by *The New York Times* ... **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**
- NYT sort-of "apologized" in 1969, spinning the story
- By 1937, Goddard's rockets reached 9000 ft
- 214 rocket patents

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



Robert H. Goddard. Photo courtesy of NASA.

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

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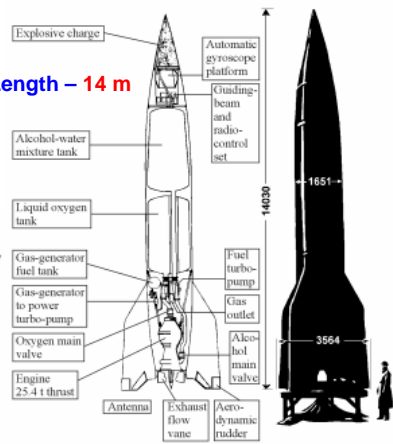
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First Modern Rocket A-4 (V-2)

- Development of long-range liquid-propellant rockets started by the *German Army Ordnance* 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**
- Spec. imp. (sea level) – **210 s**
- 5800 V-2s manufactured
 - slave labor from concentration camps
- 2000 operationally fired



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



Mass (fueled) – 12,700 kg

Length – 14 m

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

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American Rockets in WWII

- Rocket technology development since late 1930s by **Theodore von Kármán's** group at California Institute of Technology, supported by **Henry H. "Hap" Arnold**
 - Jet-Assisted Take-Off (JATO)
 - Solid and liquid-propellant propulsion
 - Composite propellants
 - JPL formed, 1943-1944
- **First private rocket enterprises**
 - Reaction Motors, Inc. (RMI), Dec. 1941
 - Aerojet Engineering Corp., March 1942



Courtesy of NARA



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



Courtesy of NARA



General Henry H. "Hap" Arnold




Theodore von Kármán, Jan. 1943
Courtesy of Aerojet-General

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Successful Artificial Satellite Requires


- **Launch systems**
- Communications subsystem
 - radio telemetry for data transmission (**1932**)
- Power supply subsystem
 - solar cells (**1953**)
- On-board propulsion subsystem
 - cold-jets and hydrazine monopropellant (**1962**)
- Attitude control and guidance and navigation
 - aviation and guided missiles
- Earth-based facilities (testing range and launching sites)
 - Cape Canaveral (**1949**)
 - Tyuratam (Baikonur) (**1955**)



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 were developing ballistic missiles with the increasing capabilities in
 - accuracy
 - range
 - payload (warhead) weight

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




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Soviet Sputnik

Intercontinental Ballistic Missile (ICBM) R-7


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



Sergei P. Korolev, the leader of the early Soviet rocket and space program. His Design Bureau (predecessor of Energia) build the **first ICBM R-7**, the **first space launcher**, and the **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. Courtesy of Videocosmos.

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First American Satellite

Program Vanguard

- August 1955**
 - 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 (General John B. Medaris and Wernher von Braun)

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


Policy of President Dwight D. Eisenhower

- Top priority – satellite reconnaissance** to prevent a surprise attack by the USSR (closed society)
 - launch of American scientific satellite **to assert the principle of freedom of space**
 - deliberately played down the role of satellites in the future
- 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 from distractions (Atlas was rushed to counter the anticipated **missile gap** with the aggressive Soviet Union)
 - Vanguard to assert freedom of space

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American Response

- 20 September 1956**
Test launch of the U.S. Army's Jupiter C that **could have placed a satellite into orbit**. The U.S. Army (Medaris and von Braun) were specifically **ordered not to** deploy a satellite.
- 4 October 1957**
Sputnik-1 launched, followed (on 3 Nov) by *Sputnik-2* with a dog *Laika* onboard (**asserting freedom of space!**)
- 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 public was shocked (fueled by media and politicians – anything new here?)
- U.S. Army permitted to try its launcher – Navy (*Vanguard*) and Army (*Explorer*) programs compete
- 6 December 1957**
spectacular explosion of experimental Vanguard on launch pad



Courtesy of NASA



31 January 1958
Explorer-1 launched

17 March 1958
Vanguard-1 launched

18 December 1958
Atlas launches a satellite

For the record (to correct popular perception created by enlightened media)
The Vanguard program demonstrated a record fast development of an entirely new space launcher, with only 30 months from vehicle authorization to first successful launch.

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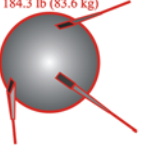
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First Satellites – Space Age Begins

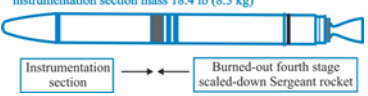
Vanguard I
6.44" (16.4 cm) diameter
3.25 lb (1.5 kg)



Sputnik I
22.8" (58 cm) diameter
184.3 lb (83.6 kg)



Explorer I
6.5" (16.5 cm) diameter
80.75" (2.05 m) long
total mass 30.7 lb (13.9 kg)
instrumentation section mass 18.4 lb (8.3 kg)



Instrumentation section → Burned-out fourth stage scaled-down Sergeant rocket

First three satellites (in scale)

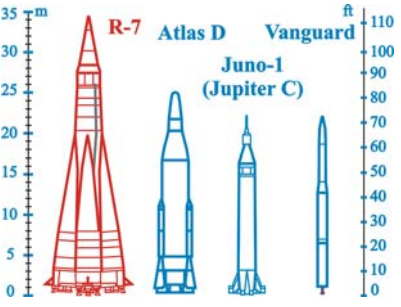
Was there a **technological gap**?

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 is much larger first American launchers, including first American ICBM Atlas

R-7 designed for much heavier nuclear warheads



R-7 evolved in a successful, still operational space launcher Soyuz

Atlas launched many space vehicles

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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
- **Brazil** – 1997, 1999, ...
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!*

More details



*Blazing the Trail.
The Early History of
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