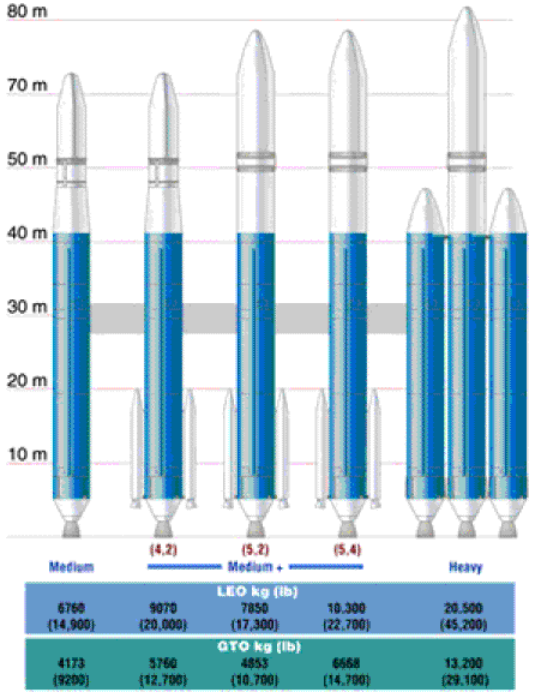
Rockets: Past, Present, and Future

Robert Goddard With his Original Rocket system



Delta IV … biggest commercial Rocket system currently in US arsenal

Material from Rockets into Space by Frank H. Winter, ISBN 0-674-77660-7

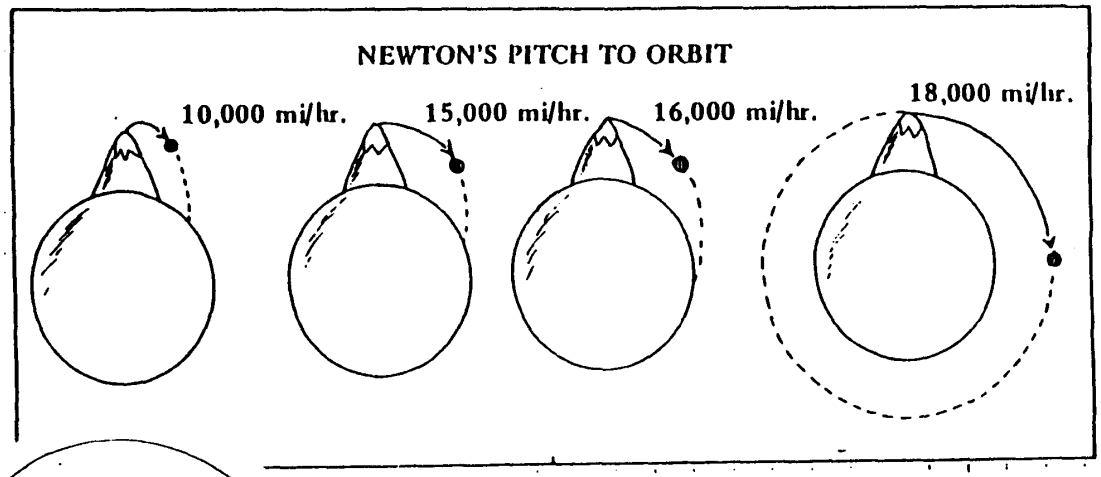
Earliest Rockets as weapons

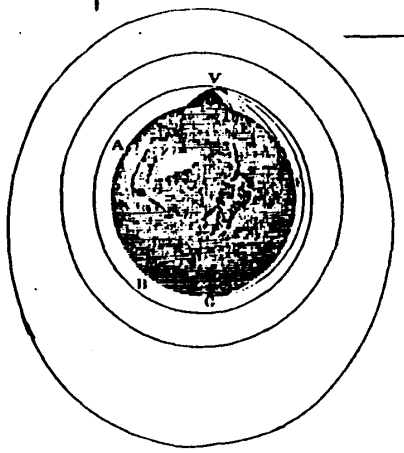
- Chinese development, Sung dynasty (A.D. 960-1279)
  - Primarily psychological
- William Congreve, England, 1804
  - thus “the rockets red glare” during the war of 1812.
  - 1.5 mile range, very poor accuracy.
- V2 in WWII

First Principle of Rocket Flight

- "For every action there is an equal and opposite reaction." Isaac Newton, 1687, following Archytas of Tarentum, 360 BC, and Hero of Alexandria, circa 50 AD.
- "Rockets move because the flame pushes against the surrounding air." Edme Mariotte, 1717
- *Which one is correct?*

Isaac Newton explains how to launch a Satellite





ACTUAL ILLUSTRATION FROM ISAAC NEWTON'S BOOK "SYSTEM OF THE WORLD", PUBLISHED IN 1687.

HIGHER SPEED CARRIES A BODY FURTHER BEFORE IT FALLS TO THE GROUND. IF THE SPEED IS GREAT ENOUGH, IT WILL NOT FALL AT ALL.

The Reaction-propelled Spaceship of Hermann Ganswindt (1890)

- The fuel for his spaceship consisted of heavy steel cartridges with dynamite charges. They were to be fed machine gun style into a reaction chamber where they would fire and be dropped away.

- "Shock absorbers protected the travelers"

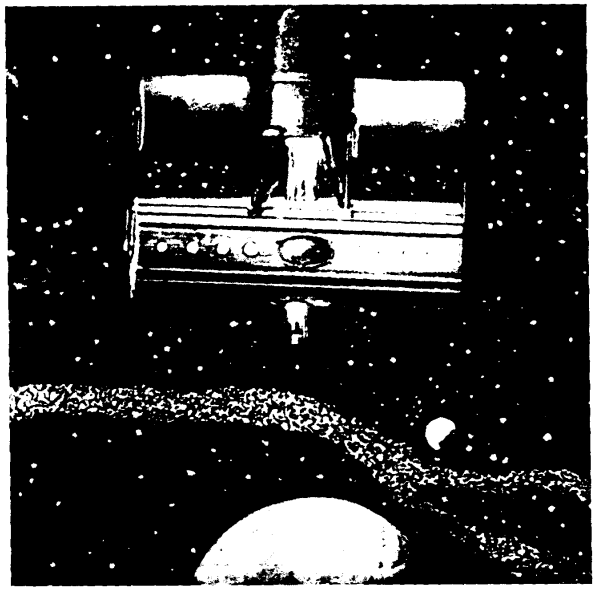
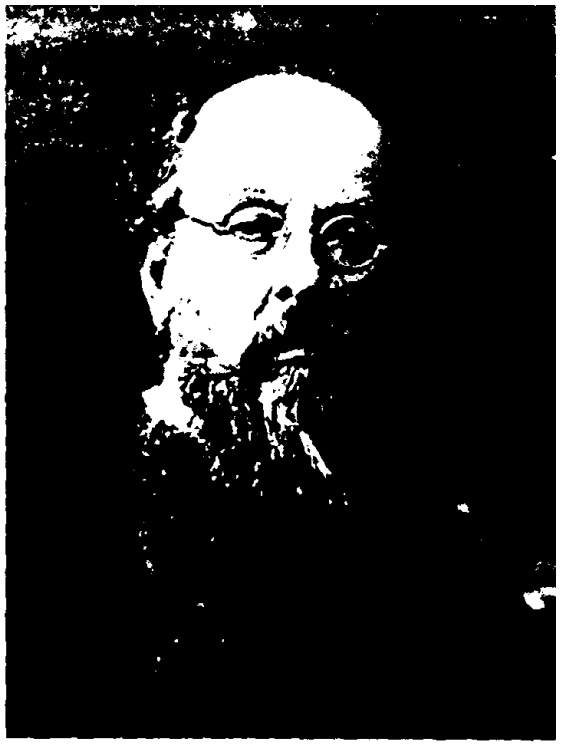


Figure 2. Hermann Ganswindt's reaction-propelled spaceship, 1891.

The Three Amigos of Spaceflight Theory

- Konstantin Tsiolkovsky
- Hermann Oberth
- Robert Goddard
- Independent and parallel development of Rocket theory

Three Amigos



•Tsiolkovsky

•Goddard

•Oberth

Konstantin Tsiolkovsky
1857 - 1935

- Deaf Russian School Teacher - fascinated with space flight, started by writing Science Fiction Novels
- Discovered that practical space flight depended on liquid fuel rockets in the 1890's, and developed the fundamental Rocket equation in 1897.
- Calculated escape velocity, minimum orbital velocity, benefit of equatorial launch, and benefit of multi-stage rockets
- Excellent theory, Not well published, not as important as he could have been.
- Famous for development of "Rocket Equation"

Robert H. Goddard
1882 - 1945

- Also a loner, developed rocket theory in 1909-1910,
- Forte was as an experimenter, actually building and testing liquid fuel rockets (first flight in 1926.)
- In a report to his sponsors (Smithsonian Institute) in 1920, he described a rocket trip to the moon. This subjected him to ridicule since the common belief was still that a rocket needed air to push against.
- Goddard ended with 214 patents covering details of rocket design

Goddard and his Rocket

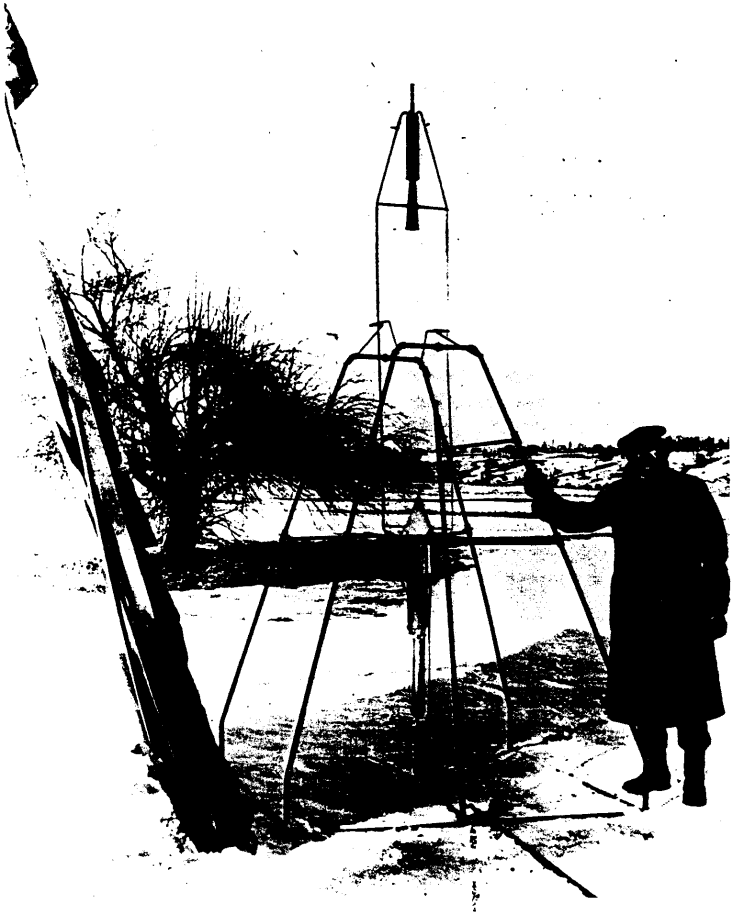


Figure 4. Robert Goddard standing beside the world's first successfully flown liquid-fuel rocket, which was launched on March 16, 1926. Note the rocket nozzle on the top. The asbestos-covered cone on the bottom directed exhaust gases away from the propellant tanks below. Goddard found this "nose-driven" design unstable and later shifted the rocket motor to the bottom. The "tail-driven" configuration was more stable and became standard in all rockets.

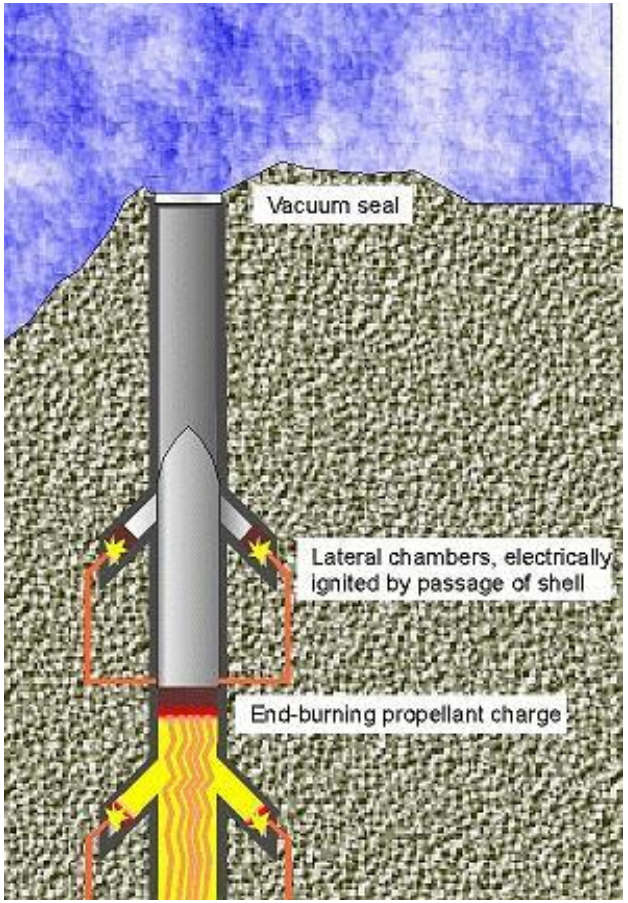
Hermann Oberth
1894 - ??

- His 1923 book: Die Rakete zu den Planetenraumen (The Rocket into Planetary Space) covered the entire spectrum of manned and unmanned rocket flight.

- Because it was published and widely read, he had more influence on the growth of rocket concepts then either of the others. His book spawned several rocket societies in Germany, significantly the German Rocket society, out of which the German army recruited Werner Von Braun in 1932 and started the project which produced the V2.

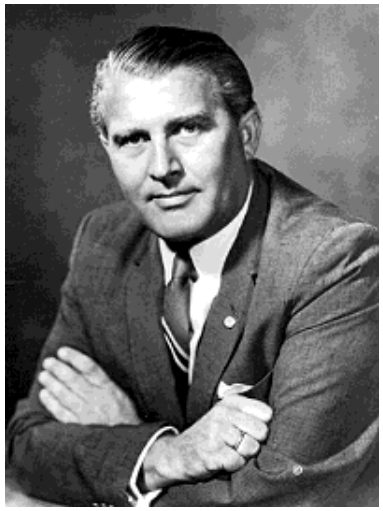
Valier-Oberth Moon Gun *Nation*: Germany.

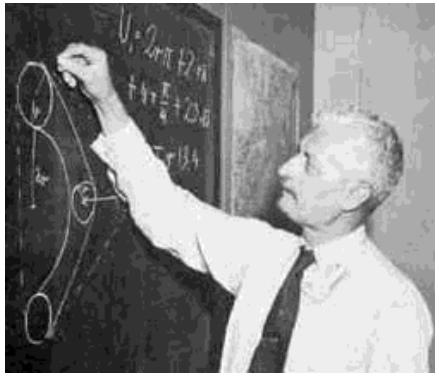
In the 1920's members of the German VfR (Society for Space Travel) amused themselves by redesigning Verne's moon gun. In 1926 rocket pioneers Max Valier and Hermann Oberth designed a gun that would rectify Verne's technical mistakes and be actually capable of firing a projectile to the moon.

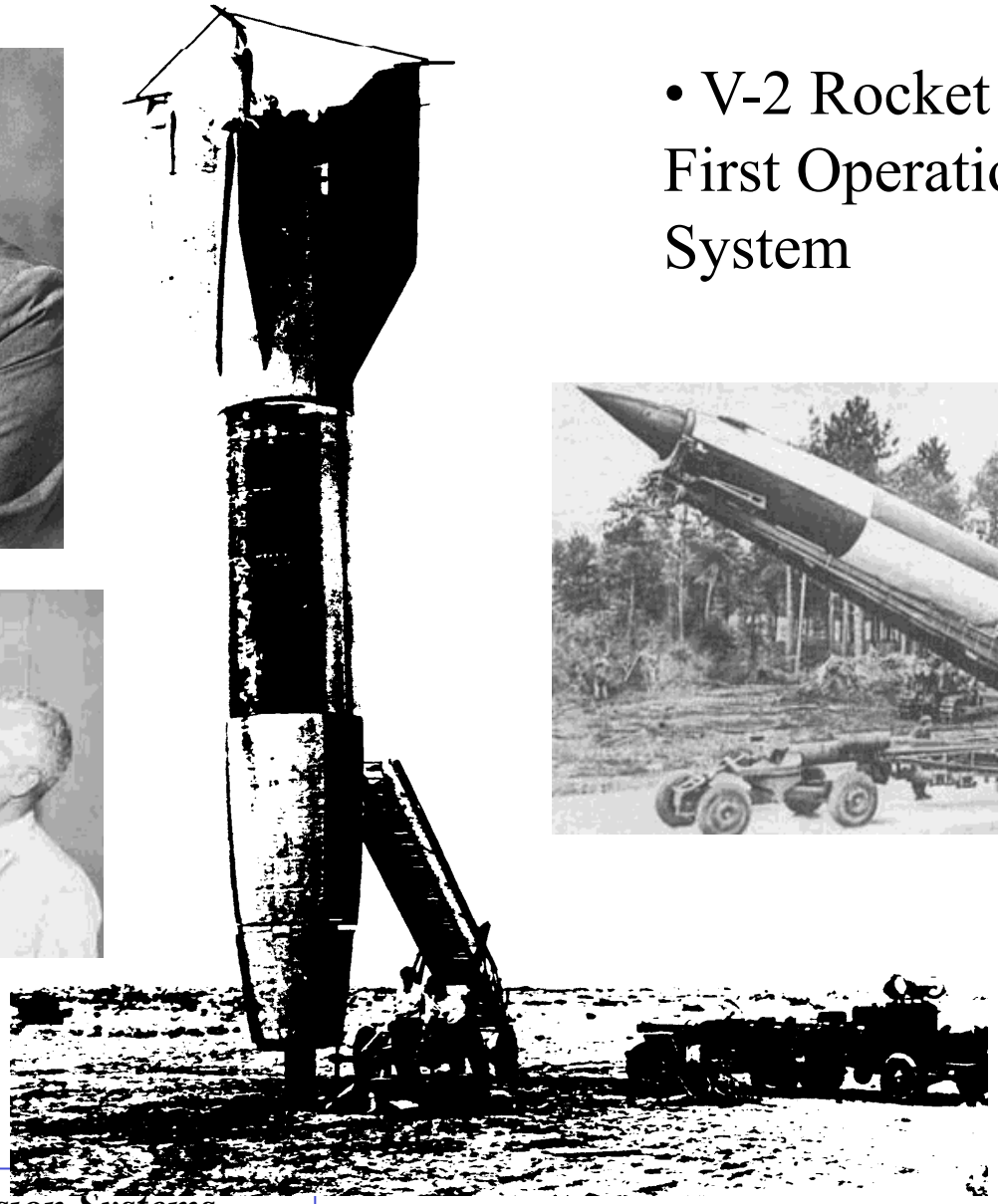


The V2

- Challenge was to deliver a one ton warhead, 180 nm range.
- Final design: 2300 lb warhead, 190 nm range. 47 ft long, 5.4 ft diameter, 28,229 lb takeoff weight. 59,500 lb thrust for 68 seconds.
- 6400 weapon launches
- The Americans got Von Braun and 117 other scientists, and about 100 rockets. The Soviets got the facilities and about the same number of rockets.
- 60 plus V2's and V2 mods were launched in the late 40's in US. All were sub-orbital, highest altitude was 244 miles



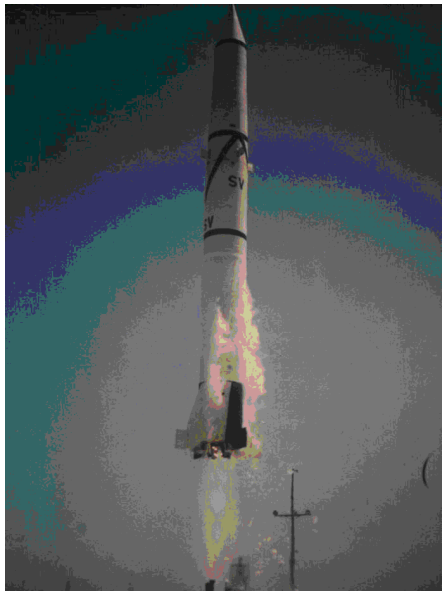




- V-2 Rocket
First Operational System

Sounding Rockets

- Both the Soviets and the US built sub-orbital rockets in the late 1940's, 50's and 60's
  - WAC-Corporal - 1500 lbs thrust
  - Aerobee - 2600 lbs thrust and up
- Viking -developed by NRL to replace the V-2's - 20,600 lbs thrust
- Redstone Missile … suborbital nuke weapons delivery system



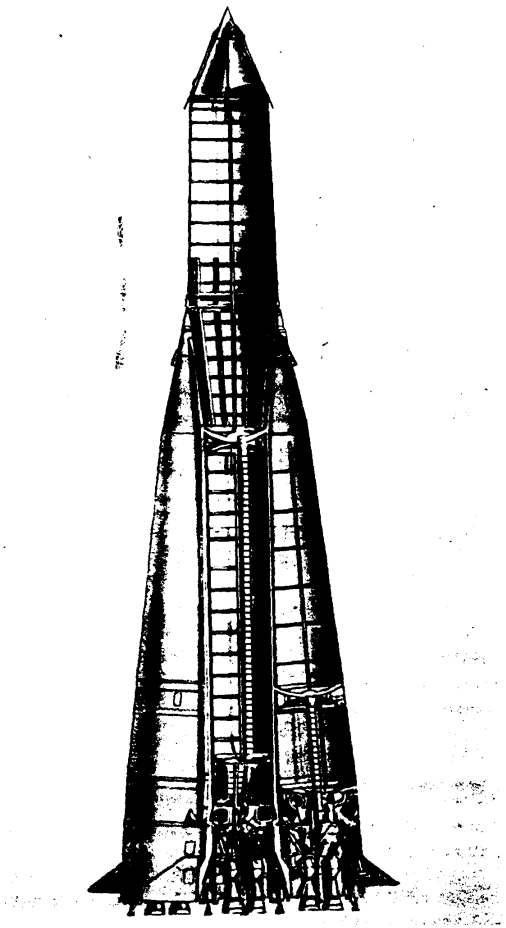
First Satellite Launchers

Russia (Soviet Union)

- Sputnik - SS-6/R7

•217,000 lbs thrust -

•2900 lbs to LEO

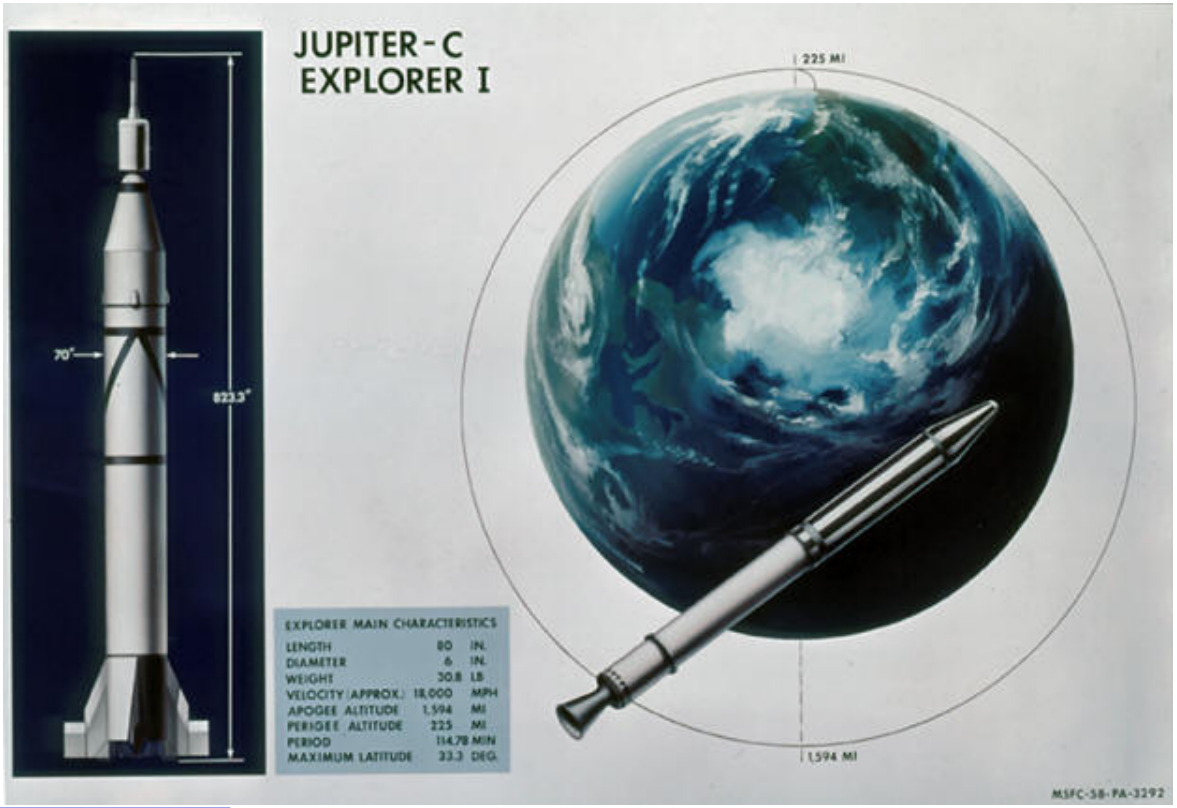


R7 Semiorka Rocket

First Satellite Launchers (cont'd)

USA

- Explorer I - Jupiter C - 75000 lbs thrust - 20 lbs to LEO



First Satellite Launchers (cont'd)

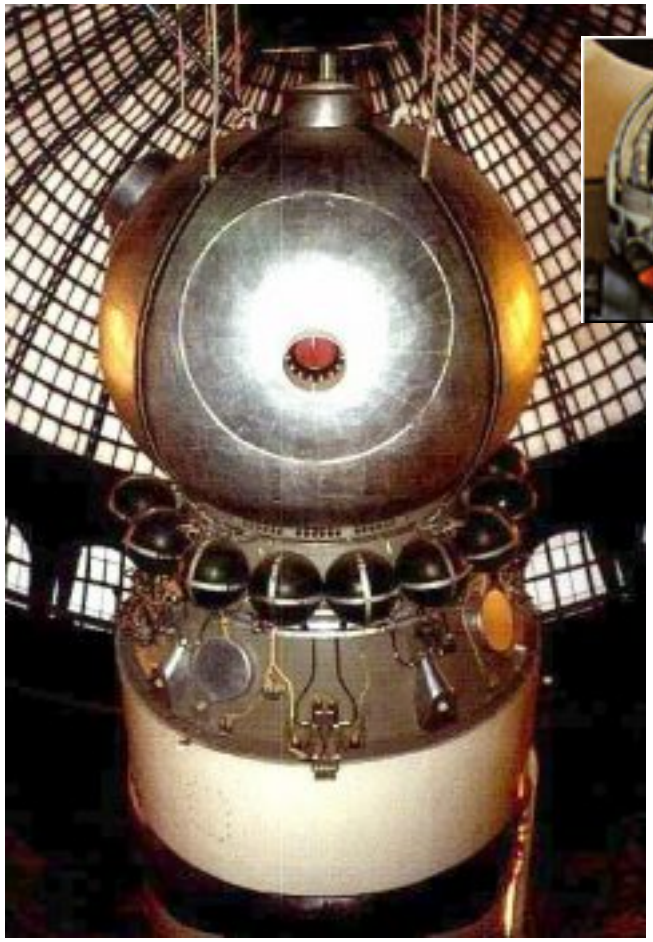
Comparison of R-7 and Jupiter C

- Russians started out with a BIG lead

- Sergi Korolev

Manned Space Flight

- Yuri Gagarin, April 12, 1961 …



- Modified R-7 Launcher

- Liftoff Thrust: 870,000 lbf
- Payload to LEO: 10,000 lbm

Manned Space flight (cont'd)

- Alan Shepard, Mercury 3 … May 5, 1961

Redstone missile sub-orbital …

- Liftoff Thrust: 80,000 lbf
- Payload to LEO : 0
- USA is still Way behind

Manned Space flight (cont'd)

- John Glenn, Mercury 6 … Feb. 20, 1962

Launch vehicle, Atlas-D

- Liftoff Thrust: 360,000 lbf
- Payload to LEO : 3100 lbm
- USA starting to catch up

Manned Space flight (cont'd)

- Gemini 3 - Titan II

- First Flight March 23 1965

- Liftoff Thrust: 430,000 lbf
- Payload to LEO : 7000 lbm
- Still behind R-7

Manned Space flight (cont'd)

- Apollo Saturn 1-B

- First Flight October 11, 1968

- Liftoff Thrust: 1.64 M lbf
- Payload to LEO : 41,000 lbm
- Third Most Powerful Rocket ever flown

Manned Space flight (cont'd)

- Apollo Saturn V

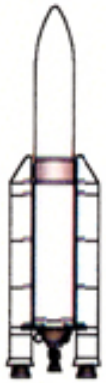
- First Flight December 21, 1968

- Liftoff Thrust: 7.7 M lbf
- Payload to LEO : 260,000 lbm
- Lunar payload capable
- Most Powerful Rocket ever flown

Modern Launchers

- European
- Indian
- Japanese
- Russian
- Chinese
- American

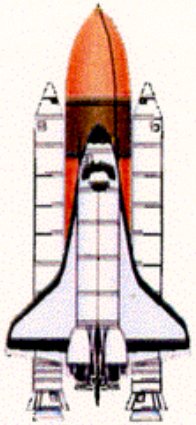
European, Chinese, Indian, and Japanese (2001)

	Europe		India		China	Japan
						
Vehicle	Ariane 4	Ariane 5	PSLV	GSLV	LM- 2F	H 2A 202
2001 Total Launches	6	2	1	1	1	1
Reliability 2001	6/6	1/2	1/1	1/1	1/1	1/1
	100.0%	50.0%	100.0%	100.0%	100.0%	100.0%
Last 10 Years	92/95	8/10	2/2	1/1	2/2	1/1
	96.8%	80.0%	100.0%	100.0%	100.0%	100.0%
First Launch	1988	1996	2000	2001	1999	2001
Launch Sites	Kourou	Kourou	Sriharikota	Sriharikota	Jiuquan	Tanegashima
LEO kg (lb)	9,191 (20,220)	17,250 (37,950)	3,700 (8,140)	5,000 (11,000)	9,500 (20,900)	9,940 (21,868)
GTO kg (lb)	4,748 (10,446)	6,534 (14,375)	800 (1,760)	2,500 (5,500)	3,500 (7,700)	4,100 (9,020)

Russian and Ukrainian Vehicle Performance(2001)

Vehicle	START	Cosmos	Cyclone 2	Cyclone 3	Molniya	Soyuz	Zenit 2	Proton	Proton M
2001 Total Launches	1	1	1	2	2	9	1	5	1
Reliability 2001	1/1	1/1	1/1	2/2	2/2	9/9	1/1	5/5	1/1
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Last 10 Years	5/5	47/49	12/12	29/31	41/41	150/153	16/20	89/95	1/1
	100.0%	95.9%	100.0%	93.5%	100.0%	98.0%	80.0%	93.6%	100.0%
First Launch	1993	1964	1977	1977	1960	1963	1985	1967	2001
Launch Sites	Svobodny	Plesetsk	Plesetsk, Baikonur	Plesetsk	Plesetsk	Baikonur, Plesetsk	Baikonur	Baikonur	Baikonur
LEO kg (lb)	607 (1,335)	1,350 (2,970)	2,820 (6,204)	3,929 (8,644)	1,800 (3,960)	6,708 (14,758)	13,199 (29,038)	19,254 (42359)	21,000 (4,620)
GTO kg (lb)	--	--	--	--	1,600 (3,520)	--	--	4,421 (9,726)	2,920 (6,424)

U.S. and FAA-Licensed Launch Vehicle Performance in 2001

	USA						Multinational (Sea Launch)
							
Vehicle	Athena 1	Taurus	Delta 2	Atlas 2	Shuttle	Titan 4	Zenit 3SL
2001 Total Launches	1	1	7	4	6	3	2
2001 Licensed Launches	0	1	1	1	0	0	2
Reliability	1/1	0/1	7/7	4/4	6/6	3/3	2/2
2001	100.0%	0%	100.0%	100.0%	100.0%	100.0%	100.0%
Last 10 Years	4/5	5/6	84/85	55/55	70/70	27/31	6/7
	80.0%	83.3%	98.8%	100.0%	100.0%	87.1%	85.7%
First Launch	1995	1994	1990	1991	1981	1989	1999
Launch Sites	Wallops, Kodiak, VAFB	VAFB	CCAFS, VAFB	CCAFS, VAFB	KSC	CCAFS, VAFB	Odyssey Pacific Ocean Platform
LEO kg (lb)	360 (792)	1,437 (3,161)	4,887 (10,751)	8,298 (18,256)	23,435 (51,557)	20,822 (45,808)	15,246 (33,541)
GTO kg (lb)	--	562 (1,236)	1,769 (3,892)	3,833 (8,433)	5,663 (12,459)	8,276 (18,207)	5,700 (12,540)

Europe's Ariane 5

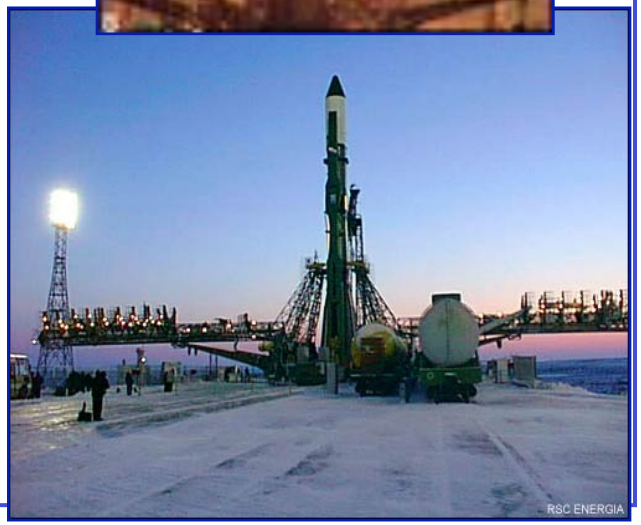
- The European Space Agency Was Set up in 1975 With the Express Mission of Helping Europe "Catch Up"with the U.S. And Soviet Space Programs
- European Leaders Are Pushing Ahead With Commercial Ventures to Exploit Space
- Shared Half the Global Market for Commercial Space Launches
- Europe Is Set to Give the Go-ahead for a $3 Billion Rival to the U.S.-Run Global Positioning System (GPS)

Russia's Proton

- The Heavy-lift Proton Has Been the Cash Cow for the Russian Space Industry Receiving Tens of Millions of Dollars for Each Launch
- Russia Has Put Commercial Satellites, Mostly Foreign, Into High, Geostationary Orbits Throughout the 1990's
- Russia Has Blamed the Sluggish Global Market for the Drop in Proton Launches
- Russia Invested Part of the Earnings From Commercial Launches Into Research and Development for Rockot, Proton-M and the Next Generation Angara Rocket

Russian's Soyuz

- The Vehicle Is Used to Launch Commercial and Government Satellites. It Also Launches Humans to Orbiting Space Stations
- The Russian Soyuz Rocket Is One of the Oldest and Most Reliable in the World
- The Soyuz U Was Adopted for Military Use Some 25 Years Ago in May 1976. Rockets in the Series Have Been Launched About 400 Times From Both the Baikonur and Plesetsk Cosmodromes



Russia's Angara

- Angara Has Been Developed by the Khrunichev Center
- Destined to Replace the Proton, the Main Workhorse of the Russian Space Program
- Overall the Russian Aerospace Industry Output Has Increased by 18-20%, at the Same Time, About 30-40% of the Industry Has Not Been in Use
- The Future of the Russian Aerospace Industry May Further Integrate With the European Aerospace Enterprise

Russian Engine Development

- Seven Russian and European Companies Have Signed a Memorandum of Intent to Develop a Powerful Reusable Rocket Engine Propelled by Methane and Liquid Oxygen

- The Companies, Whose Representatives Were Present at a Signing Ceremony in Moscow, Are: NPO Energomash; The Chemical Automation Design Bureau; The Keldysh Research Center; Astrium GMBH Snecma Motors; Volvo Aero Corp.; And Techspace Aero, a Division of the Snecma Group

China

- Before Realignment of World Diplomacy That Followed the Sept. 11 Terrorist Attacks, China's Participation in the $60 Billion-plus International Space Station Was Generally Considered Unlikely

- Now, Both Through Face-to-Face Negotiations, and Through the Space Testing of Impressive New Hardware, China Seems to Be Knocking on the Door of the Orbital Outpost

China's Long March Rockets

- Chart Depicts the Nation's Family of Long March Rockets (Chinese National Space Administration)

- China Has Developed Its Own Spaceship, the Shenzhou, or "Sacred Vessel," Whose Round Body and Wing-like Solar Panels Resemble Russia's Venerable Soyuz Space Capsule

- Yet to Fly Chinese Booster, Long March 2EA, Will Lift 12-14 Metric Tons into Low Earth Orbit
  - Will Be Used to Launch Shenzhou to Future Space Stations

China's Commercial Space Concerns

- January 1995 - The Chinese-designed Long March 2E Rocket Carrying Tele-communications Satellite Explodes After Blast-off From Xichang in the Southwestern Province of Sichuan, Killing a Family of Six People

- February 1996 - A Rocket Carrying an Intelsat 708 Communications Satellite Explodes Soon After Take-off From China's Launch Site in Xichang

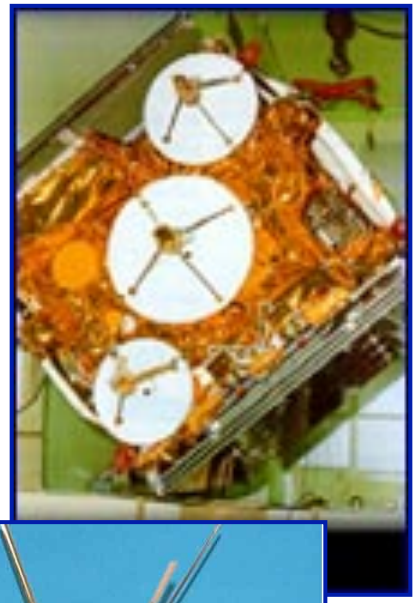
- August 1996 - A Long March Rocket Places a $120 Million Chinese Satellite in the Wrong Orbit, Leaving It Drifting Hopelessly in Space

China's Commercial Space

- Space Systems/Loral, Palo Alto, Calif., Will Design and Build a Telecommunications Satellite to Be Launched Aboard a Chinese-built Long March Rocket

- The Number of U.S.-Built Satellites Exported for Launch Aboard Chinese-built Rockets Marketed by China Great Wall Industry Corp., Beijing Has Dropped to Zero Since Allegations Surfaced in 1998 That U.S. Satellite Manufacturers Were Giving Technical Assistance to China's Missile Industry

- Great Wall Appealing to Be Allowed to Continue Launching U.S. Satellites, Impacting Business
- Long March Vehicles Will Be Retained in the World Market, Protected by Chinese Government



China's Shenzhou

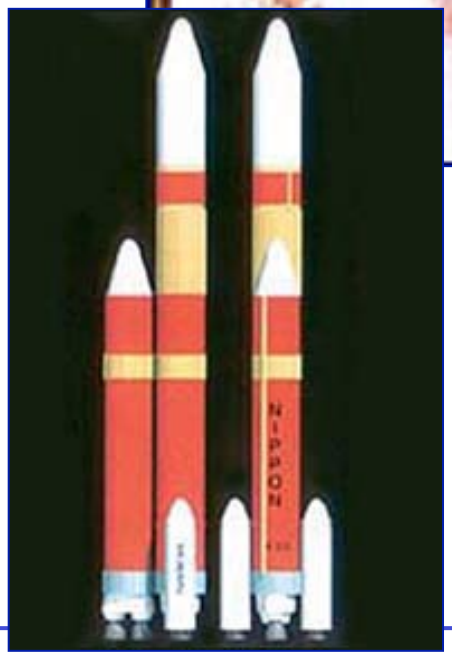
- The Shenzhou Flights Started With Its Maiden Voyage in November 1999. Shenzhou 2 Followed in January 2001
- Each Mission Has Expanded the Capabilities of the Spacecraft, Furthering China's Goal of Launching a Piloted Vehicle by 2003
- Shenzhou 5 launched on October 15, 2003 first manned flight
- Shenzhou 6 launched on October 12, 2005 second manned flight
  - Destination for Future Manned Flights May Be a Chinese Space Station
- Lunar Orbiter Mission Planned for 2006

The First Unmanned Shenzhou Space Capsule Lies on the Inner Mongolian Desert After Its Successful Re-entry in November 1999

Japan's H-IIA Rocket

- The H-IIA Lift-Off on August 29, 2001, Breaks Years of Embarrassing Failures for Japan's Space Agency (NASDA): Six Major Setbacks in Just Seven Years

- Prior to 1994, Japan's Space Dreams Seemed to Be Going Well. It Had Launched Many Satellites and Developed the Impressive H-II Rocket With American Help. Comparable in Size and Performance to an Early European Ariane Rocket, Japan Was Poised to Be a Serious Contender in the Lucrative Global Satellite Launching Market



Japan's J-II Rocket

- The J-II Rocket Program, Aimed at Development of a Medium Lift Cargo Rocket, Will Now Include Demonstrations of Advanced Technology That Could Be Applied to Other Japanese Space Vehicles

- Chief Among These Will Be Tests of a New Liquid Oxygen Fueling System and Development of a Completely Automated Ground Processing System to Check Out, Countdown, and Launch Space Vehicles

- The Automated System Is Aimed at Reducing the Cost of Conducting NASDA Launches

Japan's Small Rockets

- Japan's IHI Aerospace Co. Ltd. Is Considering Developing a Low-cost, Small-satellite Launcher Based on Components From ISAS's Current Solid-propellant M-5

- The Proposed Rocket, Dubbed M-5 Lite, Would Be Capable of Launching 1,100 lbs. Payloads to Low Earth Orbit; Cost Roughly $35 Million to Develop and About $13 Million Per Launch

- Galaxy Express Under Development. First Fully Commercial Venture. Using Liquid Natural Gas As the Second Stage Using a Lockheed Martin Atlas Tank and Russian Engine

- Plan to Launch From Christmas Island Due to Limited Launches Allowed From Tanegashima Launch Center (Fishing Ind.)

India in Space

- The India Space Research Organization's (ISRO) GSLV Project Was Initiated in 1990 at an Initial Cost of 756 Crores ($157 Million) to Achieve Self Reliance in Satellite Launching. Successful Maiden Flight on April 18, 2001
- The Indian Space Program Has Announced Plans to Launch an Un-piloted Spacecraft to the Moon in 2008
- The Mission Will Be Submitted to the Country's Space Council, Which Oversees the Space Program, in the Coming Months
- India Would Be the Fourth Country to Send a Spacecraft to the Moon, Joining Russia, the United States and Japan

U.S. LAUNCH

Systems

Space Shuttle

- First Flight April 12, 1981

- Liftoff Thrust: 6.7 M lbf
- Payload to LEO : 54,000 lbm
- Only man rated US Launch System
- Aged fleet of orbiters due for retirement by 2010

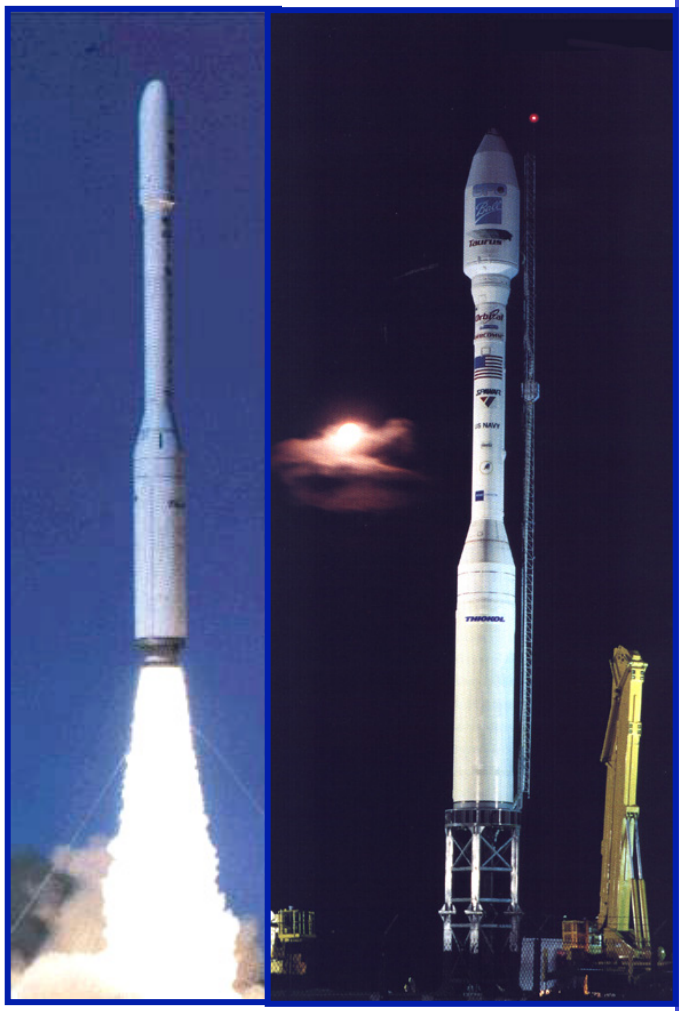
Orbital Sciences Pegasus

- 3-Stage Winged, SRM Booster for Small Payload Class
- First Commercial Air-Launched System
  - ❖ Started Service in 1990
    - ❖ Lifts 975 lbs. To LEO, 730 lbs. to Polar
- Air-Launched From L-1011
  Permits Launches from Different Facilities
  - ❖ Launch Sites - VAFB, CCAFS, Wallops, Kwajalein, Grando AFB (Canary Is.)
- 31 Launches to Date, 12 Commercial
- All Stage/Payload Integration at VAFB
  - ❖ Irrespective of Launch Site

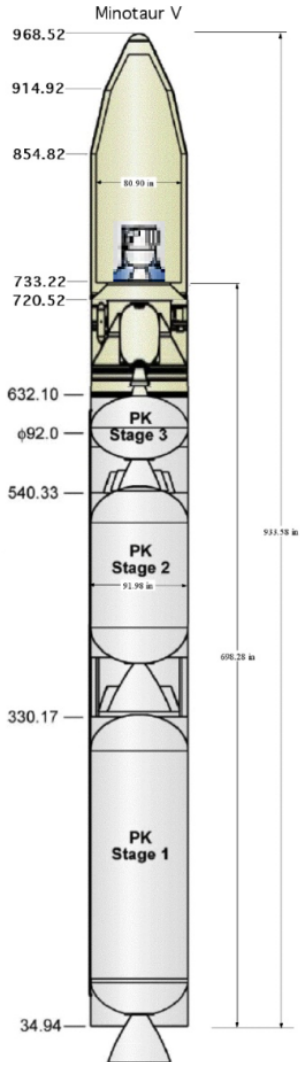

STARGAZER
Orbital Sciences' Pegasus

Orbital Sciences Taurus

- Ground-Launched Taurus Is Comprised of a Standard Pegasus (w/o wings) With a Castor 120 SRM First Stage
- Developed to Launch from Austere Launch Sites
  - ❖ Set Up in Ten Days; Mobile Launch Control/ Support
- Small Vehicle Payload Class
  - ❖ Started Service in 1994
    - ❖ Lifts 2,360 lbs. to Polar
  - ❖ Launch Site - VAFB
- 3 Commercial Launches to Date
  - ❖ ROCSAT-2 Planned for 2003



Minotaur IV-V (1)



Heavy Lift OSC Launch Vehicle Configuration

Uses legacy Government Furnished Equipment (GFE) for Stages 1-3

Peacekeeper 1st stage (Motor TU-903)

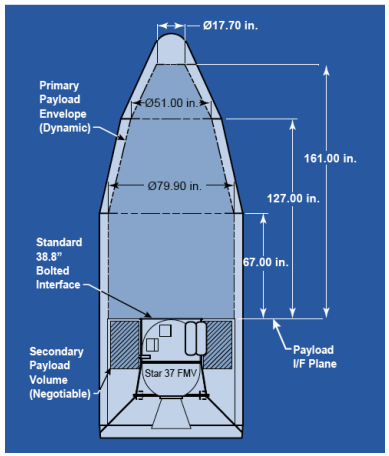
Peacekeeper 2nd stage (Motor SR-119)

Peacekeeper 3nd stage (Motor SR-120)

4th Stage – Star 48B long

5th Stage – Star 37FM (spin stabilized)

or Star 37 FMV (3 axis)

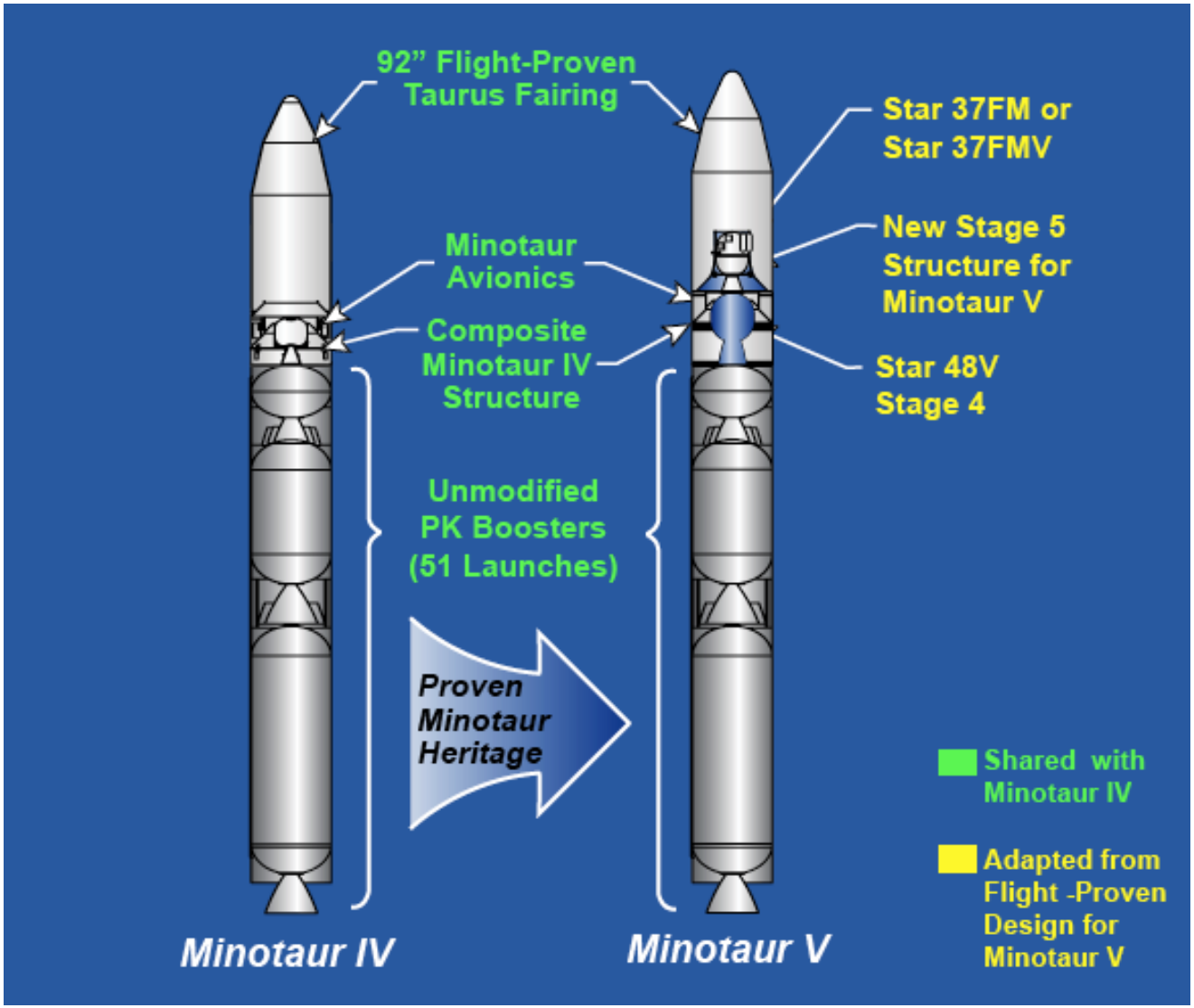


- ***Star 37 FM motor designed for GEO Final Orbit kick***

- **ATK Star 48V Replaces (Minotaur IV)**

Orion -38 4th Stage for Hi-Energy Trajectory

Minotaur IV-V (2)



- First Flight Scheduled for Minotaur IV in late 2009

- USAF payload -- Space Based Surveillance (SSBS) mission.

Lockheed Martin Athena Vehicle

- Athena I Uses One Castor 120; Athena II Uses Two Castor 120's. Uses Orbus 21 As a 2nd or 3rd Stage and a Liquid Propelled Orbit Assist Module
- Renamed From Lockheed Launch Vehicle to Athena in 1997 (After Merger of Lockheed and Martin Marietta)
- Small Launch Vehicle Payload Class
  - ❖ Started Service in 1993
  - ❖ Total of 7 Com'l Launches - 4 From VAFB, 2 From CCAFS, 1 From Kodiak
  - ❖ Lifts 1,750 Lbs. To LEO, 1,200 Lbs. To Polar; II – 4,350 Lbs. To LEO; 3,470 Lbs. To Polar
- Launch Sites - VAFB, CCAFS, & Kodiak
- 1 Vehicle in Inventory, Launch Date: TBD

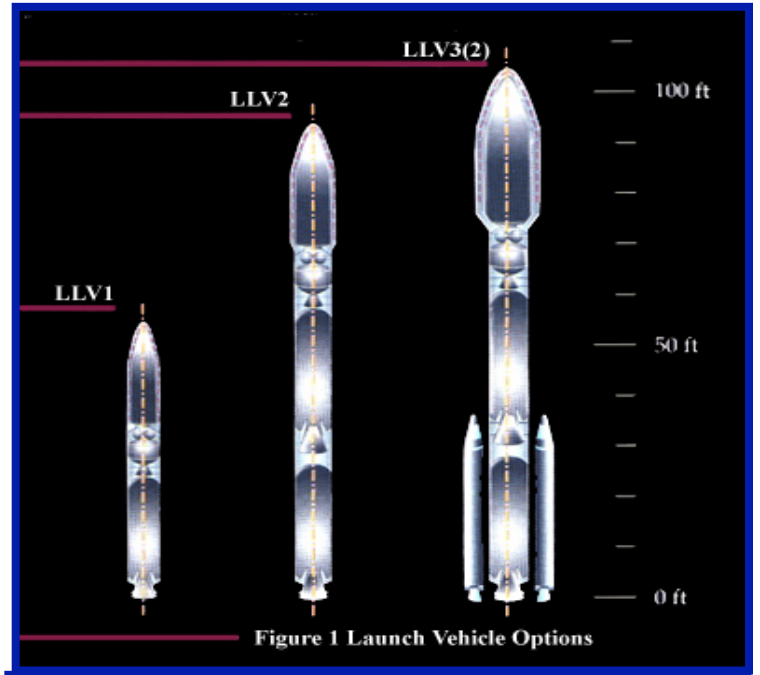


Figure 1 Launch Vehicle Options

Boeing Delta II/III

- Based on Thor Vehicle Technology Developed in the 1950's
  - ❖ Com'l Launch - 1989
- LOX-Kerosene First Stage, Nitrogen Tetroxide-Aerozine Second Stage, and Optional SRM Strap-ons
- Delta II - Medium Class Delta III - Intermediate Class
  - ❖ Lifts 11,300 lbs. to LEO, 8,590 lbs. to Polar; III – 18,280 lbs. to LEO
  - ❖ Launch Sites – II – VAFB, CCAFS III – CCAFS
- Will Be Replaced by Delta IV

Lockheed/Martin Atlas II/III

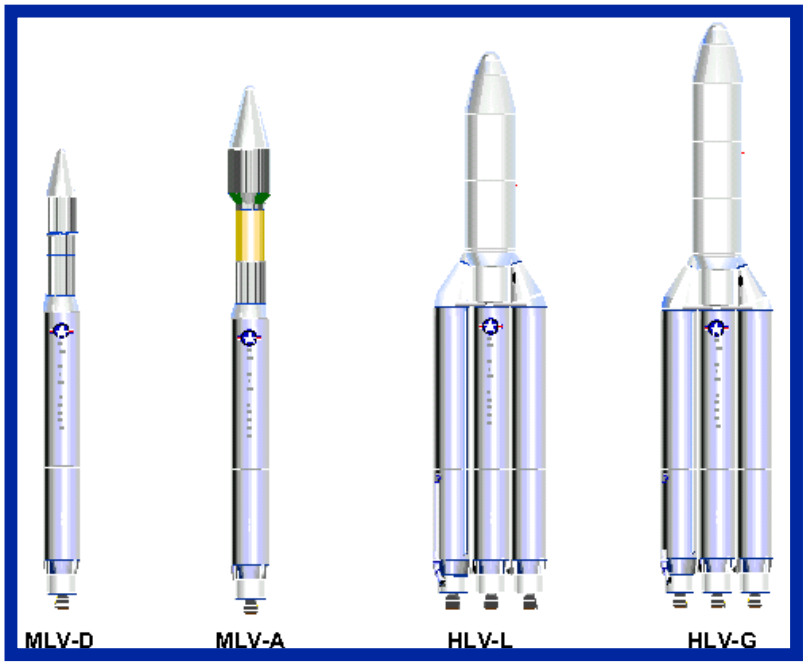
- Stage and a Half Design Based on 1950's Atlas ICBM Technology; Com'l Launch 1990
  - ❖ Atlas IIAS Has Four SRM Strap-Ons
- Atlas III is Transition Between Atlas II and Atlas V (EELV); Launched 2000
  - ❖ RD-180 Main Engine Developed by Russia Under Russian-American Partnership
  - ❖ Flight Tested 85% of Atlas V Hardware
- Atlas IIAS/III – Intermediate Class
  - ❖ Lifts 19,000 lbs. to LEO, 15,900 lbs. to Polar; III – 23,600 lbs. to LEO
  - ❖ Launch Sites – II – VAFB, CCAFS III - CCAFS

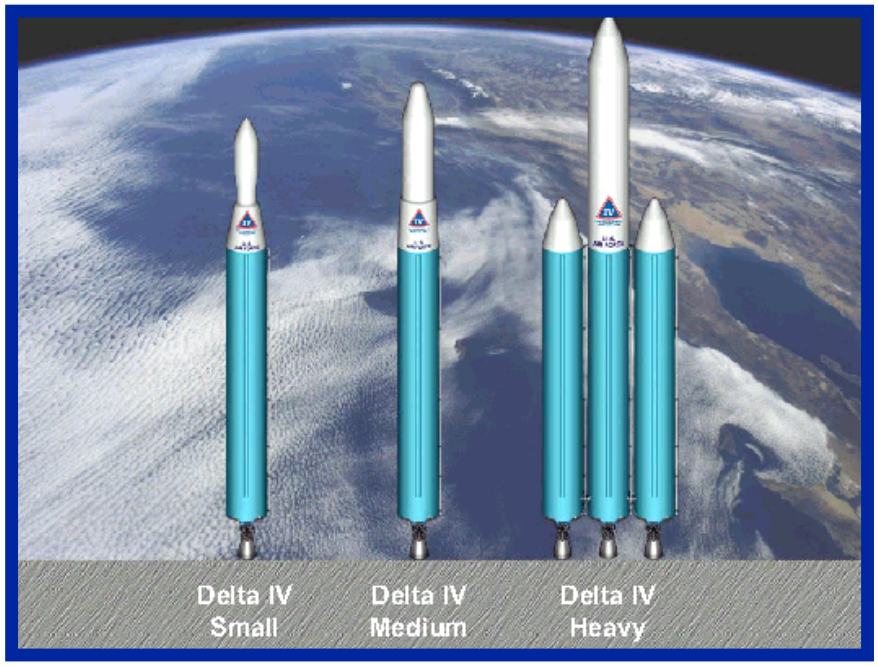
EELV Development

- National Space Transportation Policy, Signed by President Clinton on August 5, 1994
  - NASA Responsible for Reusable Launch Vehicle (RLV) Development
  - DoD Responsible for Expendable Launch Vehicle (ELV) Development and Improving Launch Infrastructure
- Partnership With Industry to Develop National Launch Capability
  - AF Provided $500M for Technology Development
- Lockheed Martin and Boeing Awarded Production Contracts for Eastern and Western Range
- Competes with Ariane Class Vehicles on World Market

EELV Baseline

Develop a Family of Launch Vehicles to Support Government and Commercial Needs



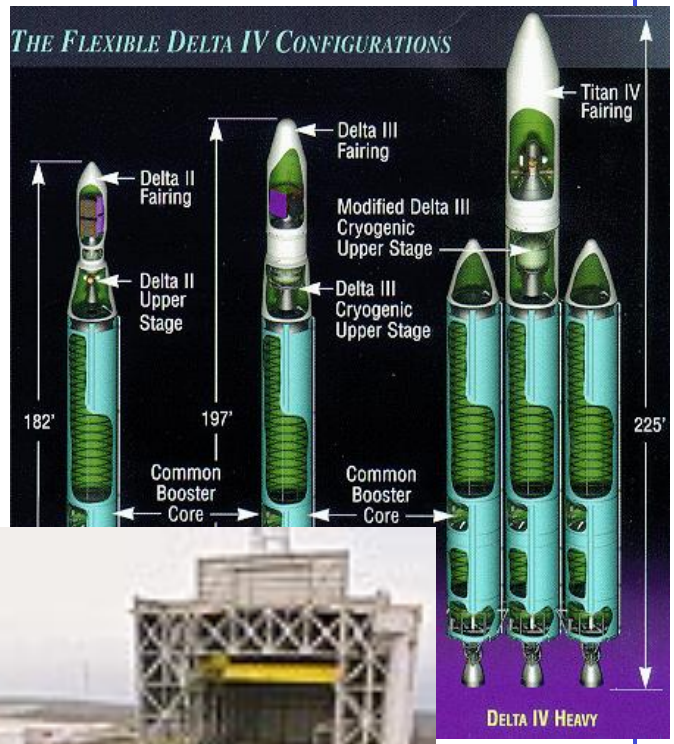


Lockheed Martin **Boeing**

Commercial Services Replacing Military Heritage Systems – Titan, Atlas, and Delta. Reduce Launch Costs by 25%

Boeing Delta IV

- Oxygen/Hydrogen Common Booster Core
  - ❖ First New Liquid Rocket Engine Developed in U.S. Since Space Shuttle
- Two – Four SRMs, Two Types of Upper Stages and Three Payload Fairings
  - ❖ Five Versions Depending on Payload
- Horizontal Processing Away From Pad
  - ❖ Launch Pad Time Reduced from 24 Days (DII) to 7 Days
- Medium to Heavy Class
  - ❖ First Launch – 2002
    - ❖ Lifts 8,120 – 23,040 lbs. to LEO
    - ❖ Lifts 9,285 – 28,950 lbs. to GTO
    - ❖ Heavy Lifts up to 56889 lbs to LEO
  - ❖ Launch Sites - VAFB, CCAFS



Lockheed/Martin Atlas V

- Common Core Booster First Stage
  - ❖ Eliminates Pressure-Stabilized Fuel Tanks; Load Payload Without Rocket Being Fueled
  - ❖ RD-180 Main Engine Developed by Russia For Atlas III; Pratt & Whitney Build for Gov. Launches
- Vertical Processing Away From Pad
  - ❖ Transported to Pad on Mobile Launcher
- 400 and 500 Series has Variety of SRMS and Three Payload Fairings
- Medium Class (No Heavy Lift)
  - ❖ First Launch – 2002
    - ❖ 400 Lifts 10,910 – 16,843 lbs. to GTO
    - ❖ 500 Lifts 8,750 – 19,110 lbs. to GTO
    - ❖ 500 Lifts up to 45202.5 lbs to LEO
  - ❖ Launch Site - CCAFS

Sea Launch Company, LLC

- Multinational Joint Venture
  - ❖ Boeing (USA), RSC-Energia (Russia), Kvaerner A.S. (Norway) and NPO-Yuzhnoye (Ukraine)
- Sea-Going Launch Platform
  - ❖ Ukrainian/Russian Zenit 3SL
    - ❖ Liquid Oxygen and Kerosene
  - ❖ Transport to International Waters, Avoids Safety Restrictions
- Assembly and Command Ship; 10-12 Day Sail To Location
- Heavy Class
  - ❖ First Launch – 1999
    - ❖ Lifts 12,566 lbs. to GTO
  - ❖ Launch Site – Pacific Equator

Space-X Falcon 1

- Privately Funded Endeavor … Started by Pay Pal Founder Elon Musk

- Liftoff of the SpaceX Falcon 1 Flight 4, from Omelek Island in the Kwajalein Atoll, at 4:15 p.m. (PDT) / 23:15 (UTC).

- Acheived elliptical orbit of 621x643 km, 9.3 degrees inclination, and carried a payload mass simulator of approximately 165 kg (364 lbs).

Space-X Falcon 1 (2)

• Falcon 1 is a two stage, liquid oxygen and rocket grade kerosene (RP-1) powered launch vehicle.

• Designed in-house from the ground up by SpaceX for cost efficient and reliable transport of satellites to low Earth orbit.

	Falcon 1	Falcon 1e
Length:	**21.3 m** (70 ft)	**27.4 m** (90 ft)
Width:	**1.7 m** (5.5 ft)	**1.7 m** (5.5 ft)
Mass:	**27,670 kg** (61 klbs)	**46,760 kg** (103 klbs)
Thrust on liftoff:	**347 kN** (78 klbf)	**556 kN** (125 klbf)

Falcon 1e vehicle available starting in 2010.

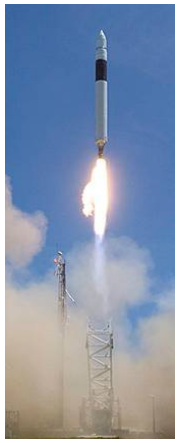
The Future?

Emerging USA Emphasis on Commercial Launch Services after Space Shuttle Decommission

… **COTS** ***(Commercial Orbital Transportation Services)***
… ***CCDEV (*****Commercial Crew Development)**

Emerging Commercial Spaceflight Industry

- NASA is contracting with commercial space hardware and launch service companies to fill the void left by the retirement of the Space Shuttle fleet.
- Well funded firms like Virgin Galactic, SpaceX, Blue Origin, Sierra Nevada Corp, Bigelow Aerospace, and others are pioneering a new era in spaceflight and space exploration.



Space X Falcon 9 Medium Lift Launcher

SNC Dream Chaser Powered by SNC Hybrid Rocket Motor

Masten Engineering's Winning Lunar X-prize Entry

Danish Suborbital's Tycho Brahe Spacecraft powered by Hybrid HEAT Rocket

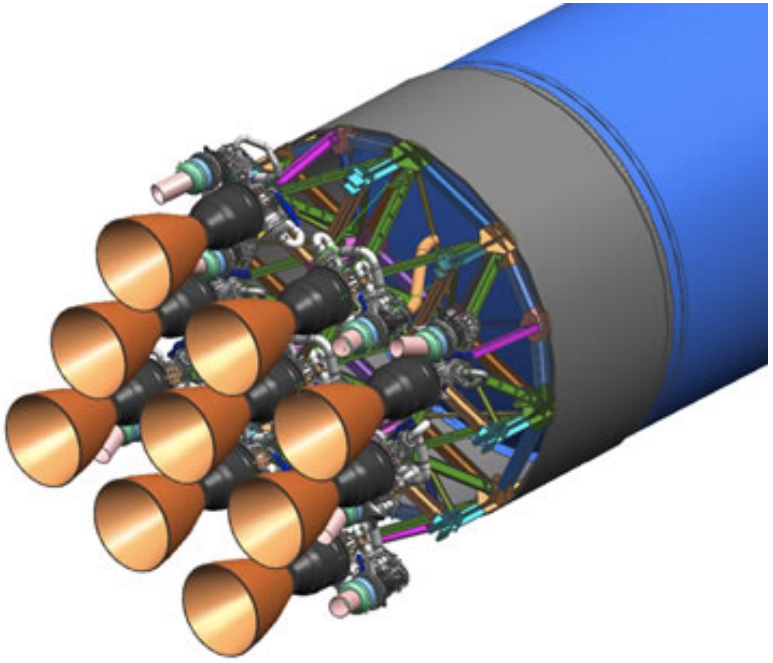
Bigelow Aerospace Space Station Module

Spaceship One™ Hybrid Rocket Firing During Ansari X-prize Flight

Virgin Galactic VSS Enterprise Powered by SNC Hybrid Rocket Motor

Space-X Falcon 9 (COTS)

- Medium/Heavy Lift Option from Space-X



Space-X Falcon 9 (2)

• Falcon 9 is a two stage, liquid oxygen and rocket grade kerosene (RP-1) powered launch vehicle.

• Uses the same engines, structural architecture (with a wider diameter), avionics and launch system.

• First Launch Scheduled for Early 2009.

Length:	**54.9 m** (180 ft)
Width:	**3.6 m** (12 ft)
Mass (LEO, 5.2m fairing):	**333,400 kg** (735,000 lb)
Mass (GTO, 5.2m fairing):	**332,800 kg** (733,800 lb)
Thrust (vacuum):	**5.56 MN** (1.25 M lb)

Data reflects the Falcon 9 Block 2 design.

Space-X Falcon 9 (3)

- Falcon 9 Heavy

Length:	**54.9 m** (180 ft)
Width:	**3.6 m** (12 ft)
Mass:	**885,000 kg** (1,950 klb)
Thrust on liftoff:	**15 MN** (3,375 klbf)

Space-X Dragon

Successful Launch and Recovery, December 8, 2010.

- Fully Automates ISS re-supply Spacecraft
- Funded under NASA COTS Contract
- Potential Manned ISS Option? Using Falcon 9 as launcher

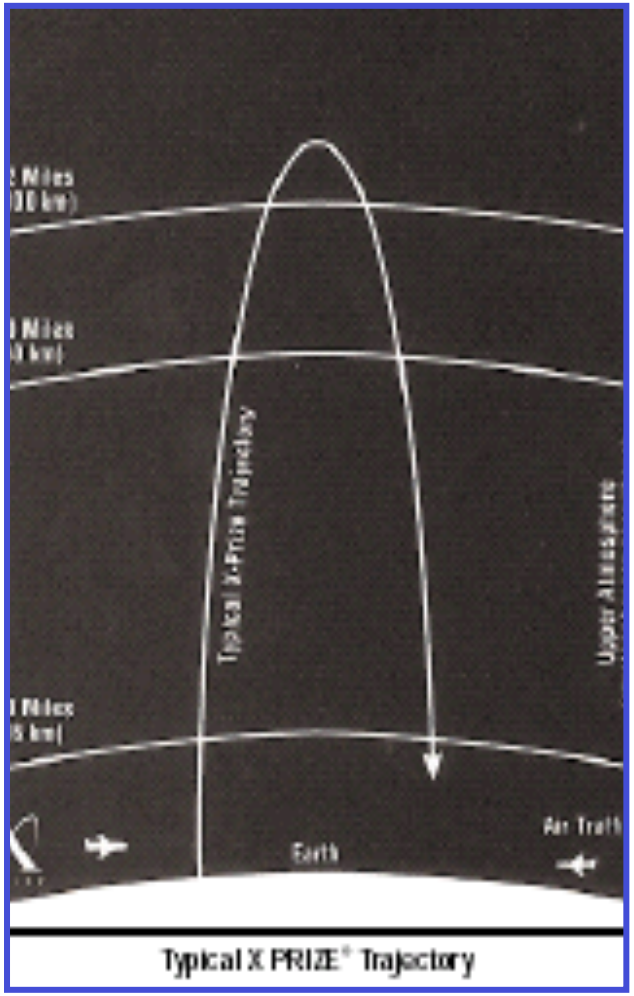
On the "Fringe" no More


X PRIZE® Trophy

- ❖ The Ansari® X PRIZE Foundation Was Established in 1994 As A Non-profit Corporation Dedicated to Inspiring Private, Entrepreneurial Advancements in Space Travel

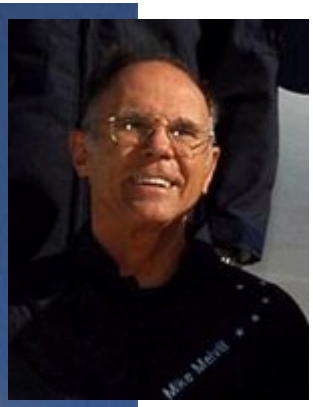
- Help Speed Development of Space Vehicle Concepts Will Reduce the Cost of Access to Space and Allow Human Space Flight to Be Routine

- X PRIZE Foundation Is Offering a $10 Million Prize to the First Team That Launches a Vehicle Capable of Carrying Three People to a 100 Kilometer (62-miles) Sub-orbital Altitude and Repeating the Flight Within Two Weeks



Typical X PRIZE® Trajectory

On the "Fringe" no More (cont'd)



• Built by Burt Rutan (Scaled Composites®) with Paul Allen's (Apple co founder) Money in Mojave CA SS1 wrote history, when the first private suborbital spaceflight was conducted on June 21, 2004 (with pilot Mike Melvill).

• SS1 won the X-Prize with flights on 29.09.2004 (Melville) and a follow up flight on 04.10.2004. (Brian Binneie)

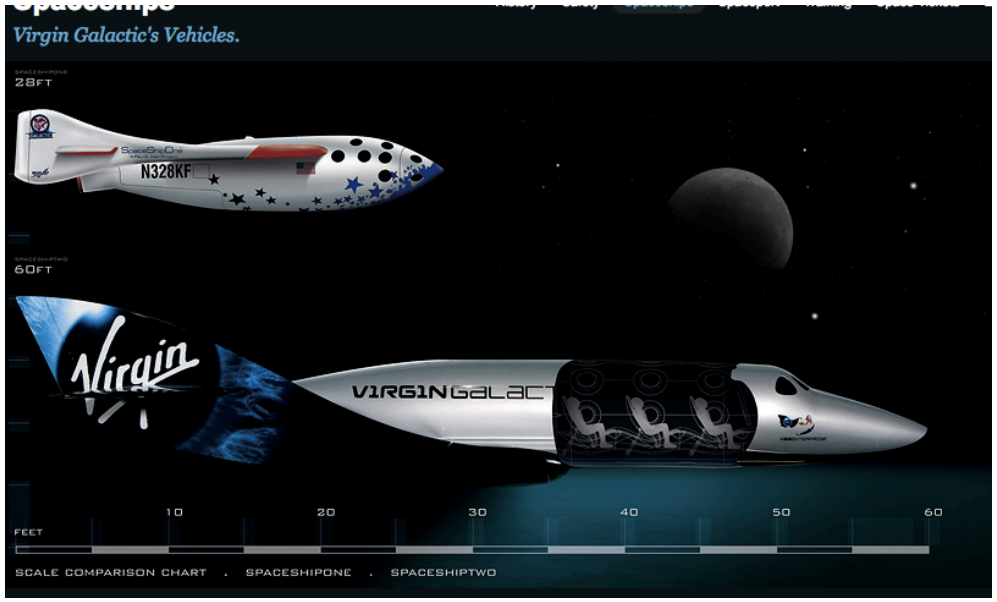
• Powered by a 16700 lbf thrust Hybrid Motor (SpaceDev)

A New Era?

"Virgin Galactic, the British company created by entrepreneur Richard Branson to send tourists into space, and New Mexico announced an agreement Tuesday for the state to build a $225 million spaceport. Virgin Galactic also revealed that up to 38,000 people from 126 countries have paid a deposit for a seat on one of its manned commercial flights, including a core group of 100 "founders" who have paid the initial $200,000 cost of a flight upfront. Virgin Galactic is planning to begin flights in late 2008 or early 2009."

Virgin Galactic has a deal with Rutan to build five spacecraft, licensing technology from Paul Allen's company, Mojave Aerospace Ventures.

A New Era?


Virgin Galactic's Vehicles.
28FT
N328KF
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VIRGIN GALACTIC
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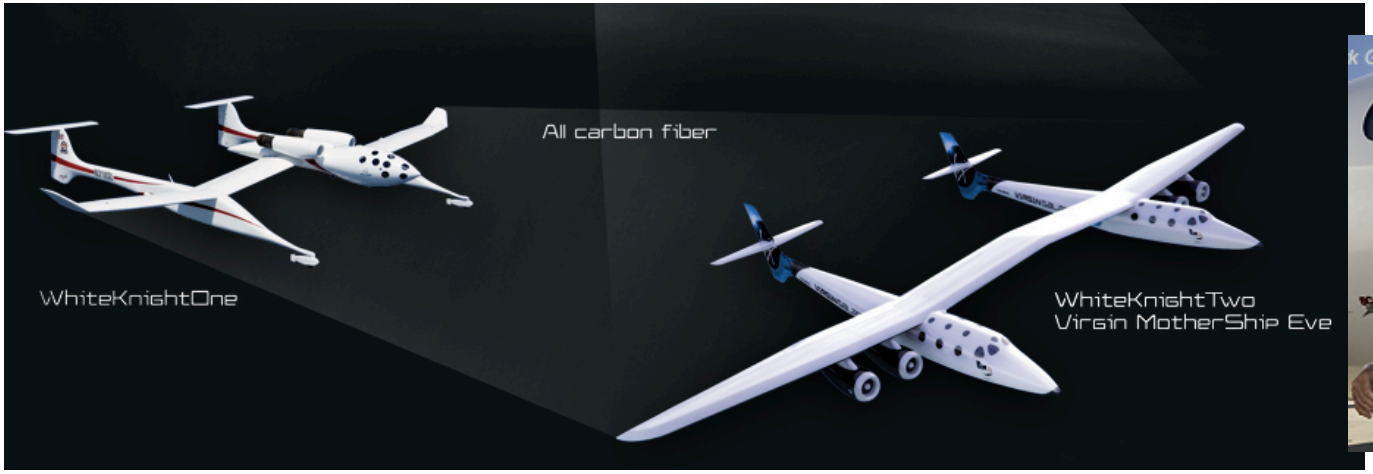
FEET
SCALE COMPARISON CHART . SPACESHIPONE . SPACESHIPTWO


Virgin
VIRGIN GALACTIC


All carbon fiber
WhiteKnightOne
WhiteKnightTwo
Virgin MotherShip Eve


k Greenberg
VMSEVE

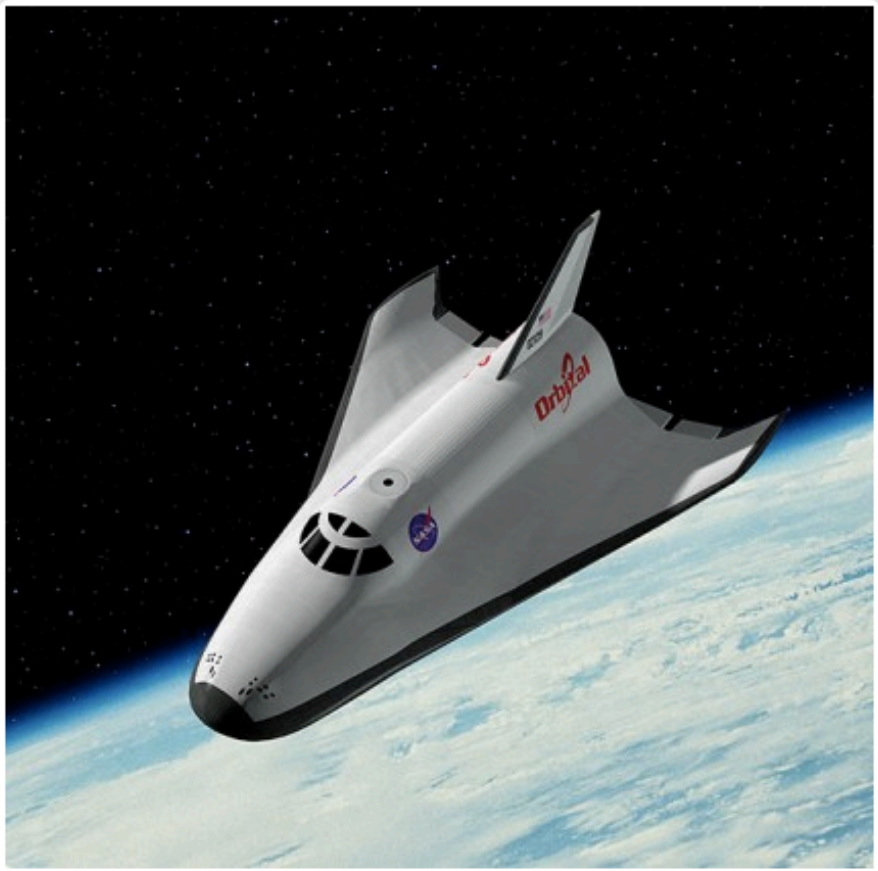
UtahState UNIVERSITY

Mechanical & Aerospace Engineering

CCDEV

CCDev 2 has 'Space Taxis' popping up all over

Jason Rhian, December 23rd, 2010



Orbital Sciences is one of many companies proposing a 'space-taxi.' Image Credit: Orbital Sciences Corporation

Virgin joins forces with two companies on CCDev

In a press release Virgin Galactic announced that it is teaming with Orbital Sciences Corporation and Sierra Nevada Corporation on their second round CCDev (CCDev-2) proposals.

CCDEV (2)

Already operators of the oft-used Atlas V and Delta IV rockets, this partnership between Boeing and Lockheed was awarded $6.7 million to develop an Emergency Detection System to help make the Atlas and Delta rockets become human-rated launch vehicles.

Space In Our Daily Lives

- Satellites are Used For:
  - Weather Forecasting
  - Relay of Television Broadcasting
  - Radio Traffic Reporting
  - Urban Planning
  - Research on the Internet
  - Credit Card Verification
  - Gas Station Point of Sale Terminals
  - Pagers, Phone Calls, Long Distance
  - Direct to Home Television

Interest of Entities

Military Space Activities

- Communications
- Missile Warning
- Launch Operations
- Meteorology & Geodesy
- Navigation
- Imaging & Signal Intelligence
- Satellite Tracking
- Anti-Satellite Weapons
- Wide Area/Ocean Surveillance

Civil Space Activities

- Science
- Launch Operations
- Disaster Relief/Monitoring
- Astrophysics
- Human Space Flight
- Meteorology
- Microgravity Research
- Environmental Modeling

Commercial Space Activities

- Design, Development, and Operation of Launch Vehicles/Facilities, Satellites/ Spacecraft, Ground Stations, and Sensors
- Telecomm. (including Personal Communications, Television/Cable, Radio, etc.)
- Support Services (including standards/allocations, insurance, consulting, etc.)
- Emerging Applications & Technologies (including remote sensing, geodesy, navigation, microgravity, broadband, etc.)

Emerging Applications

- Remote Sensing of the Environment
- Geographic Information Systems
- Global Positioning System (Real-time Tracking of Vehicles and Equipment)
- Microgravity (R&D for Biomedical, Semiconductors, etc.)

Remote Sensing Image Use

Oil and Gas	Disaster Management
Forestry	Government (All Levels)
Environ. Monitor	Civil Planning
Agriculture	Tax Mapping
Mining	Zoning
Transportation	Defense
Utilities	

Near-Term GPS Markets

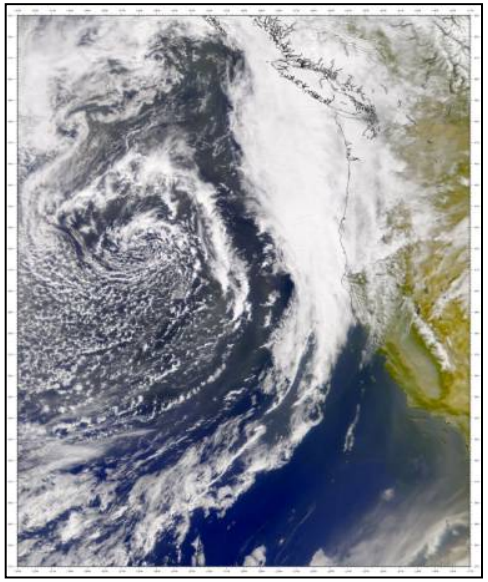
Aircraft Tracking and Control
Direction Assistance
Automobile Theft Prevention
Emergency Assistance
Electronic Maps

Other Emerging Applications

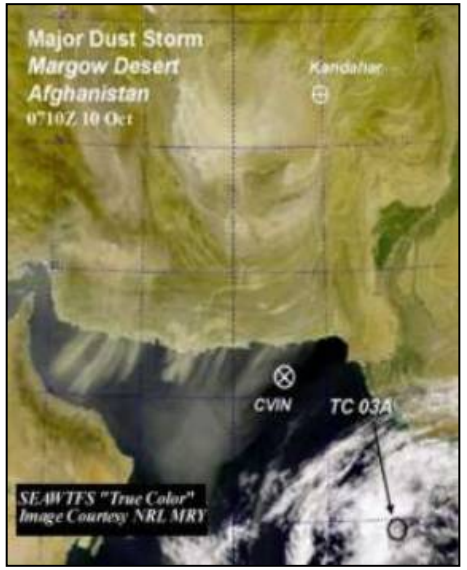
Space Power Stations
Waste Disposal
Tourism and Human Activities
XM Radio (Satellite Radio Broadcasting)

Eyes in Space

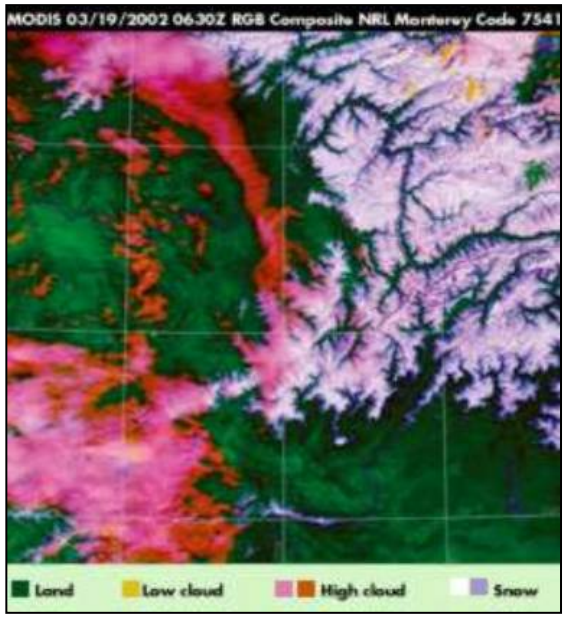
Sept. 15, 2001: World Trace Center & Pentagon Damage (spaceimage.com)



CA Dust Storms from Mongolia & China



Weather Determines GPS or Laser Weapons



Cloud/Fog Evaluation in Afghanistan

Suspected Oil Spill Determined to be Algae

Global Comm - IRIDIUM

Summary

- Commercial Space Launch Industry is of Great Importance and National interest to the U.S.
- Federal Government is Actively Working to Facilitate, Encourage, and Support the Commercial Space Launch Industry
- In spite of current problems with NASA and Commercial Launch industry
- Rockets have a long and bright future