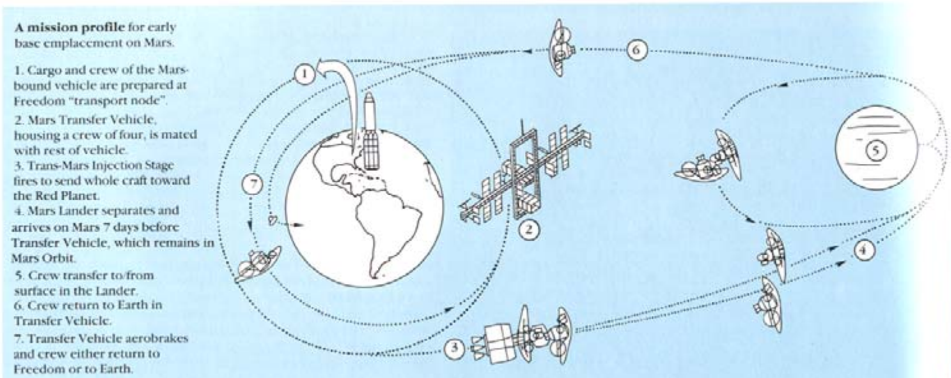
# The Greatest Engineering Race: Part 3
# Cheap Access to Space
# The New Race to Space &
# The Key to our Future in Space

By Glenn Chapman



## Why Go Into Space?

- Exploration of the Moon & Planets
- When you are in orbit you are half way to the planets
- Space Manufacturing in Low Earth Orbit
- Raw Materials: asteroids & planets
- Robot vs Human



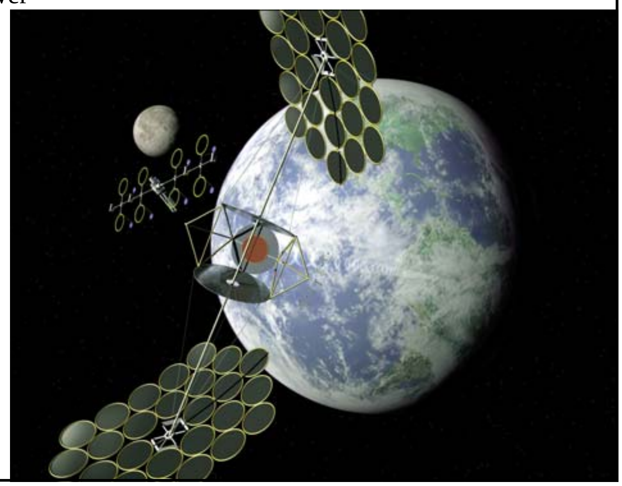
## Advantages of Space Processing

**Orbital Advantages**

- Lots of Sunlight for power
- Zero Gravity
- Vacuum
- Transportation costs lower

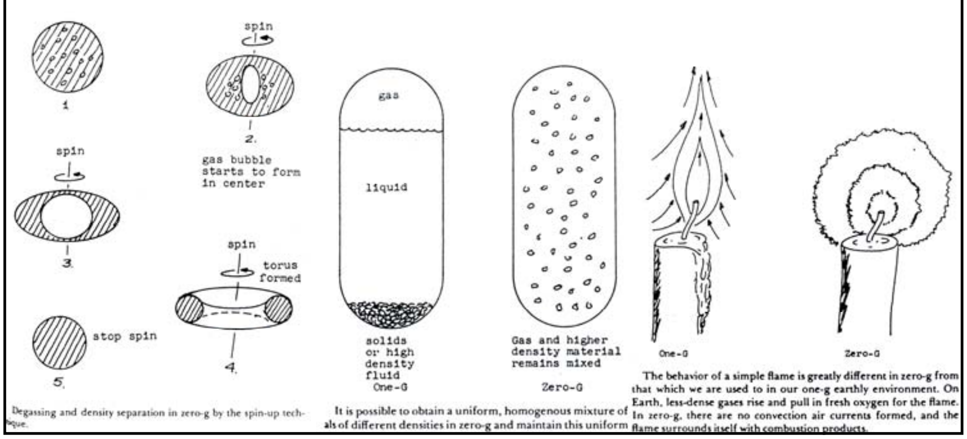
**Orbital Problems**

- Cooling: radiation only
- Stability



## Microgravity

- Allows us to do many things not possible on earth
- Convection absent so create materials not possible on earth
- Make perfect spheres:
- Spin molten metal to removes gas: surface tension creates perfect sphere
- No Convection: Flame Burns in interesting ways



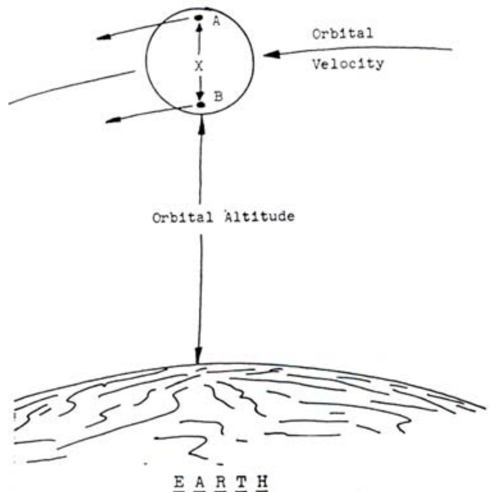

Degassing and density separation in zero-g by the spin-up tech- ique.

It is possible to obtain a uniform, homogenous mixture of als of different densities in zero-g and maintain this uniform

The behavior of a simple flame is greatly different in zero-g from that which we are used to in our one-g earthly environment. On Earth, less-dense gases rise and pull in fresh oxygen for the flame. In zero-g, there are no convection air currents formed, and the flame surrounds itself with combustion products.

## Microgravity Problems

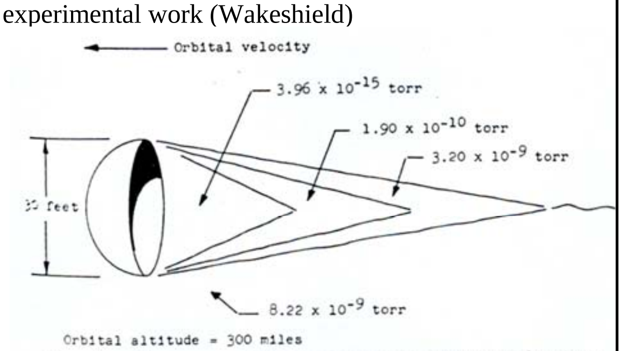
- Not perfect in orbit due to Tidal Effect
- Problem with shaking of structure



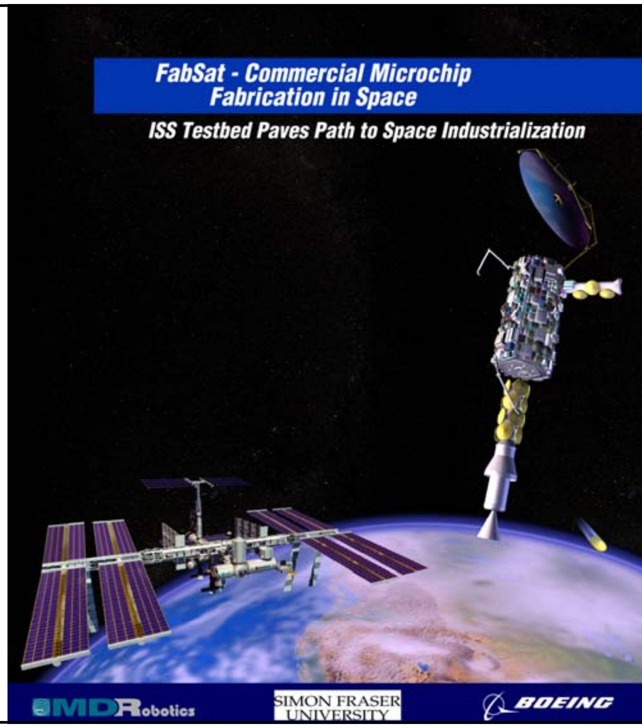

## Potential Orbital Space Processes: Vacuum

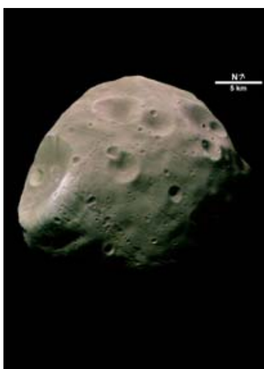
**Historical: Microgravity Material Processing**
- Growth of high quality crystals
- Superior separation of materials
- Near perfect spheres (ball bearings etc)

**Newer Area: Vacuum Based Space Processing**
- Ultra high vacuum for experimental work (Wakeshield)
- Microchip fabrication

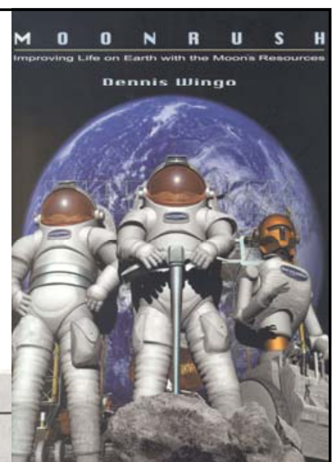



Even though a very good vacuum exists at orbital altitudes, even higher vacuums exist in the wake of a satellite.



Raw Materials from Space
High Value Metals in Asteroid/Meteors




| *Metal* | *LL Chondrite* | *$90^{th}$ % Ni/Fe* | *$98^{th}$ % Ni/Fe* |
|---|---|---|---|
| Germanium | 1020 | 70 | 35 |
| Gallium* | N/A | N/A | 87 |
| Platinum | 30.9 | 28.8 | 63.8 |
| Ruthenium | 22.2 | 20.7 | 45.9 |
| Rhodium | 4.2 | 3.9 | 8.6 |
| Palladium | 17.5 | 2.6 | 1.2 |
| Osmium | 15.2 | 14.1 | 31.3 |
| Iridium | 15.0 | 14.0 | 31.0 |
| Gold | 4.4 | 0.7 | 0.6 |

**Table 13.1:** PGM and Other Valuable Metals Concentrations in Grams Per Ton[ii]

Lunar or Asteroid Profits

| *Resource* | *Price 2004 (Kg)* | *Value Per 1 Million Kg Today's mkt* | *Lunar Discounted* | *Value Per 1 Million Kg* | *Percent Global Supply/yr* |
|---|---|---|---|---|---|
| Platinum | $20,811 | $20.81 billion | $10,405 0.3 x | $10.4 billion | 5X |
| Palladium | $10,226 | $10.23 billion | $2556 0.25 x | $2.56 billion | 5X |
| Ruthenium | $1961 | $1.96 billion | $490 0.25 x | $490 million | 12X |
| Rhodium | $26,464 | $26.46 billion | $6616 0.25 x | $6.62 billion | 15 X |
| Gold | $14,109 | $14. 11 billion | $3527 0.25 x | $3.53 billion | .19 X |
| Iridium | N/A | | N/A | | |
| Osmium | N/A | | N/A | | |
| Germanium | $470 | $470 million | $117.5 | $117 million | 22 X |
| Gallium | $530 | $530 million | $132 | $132 million | 18 X |
| *Total* | | *$74.57 billion* | | *$23.85 billion* | |

**Table 13.2:** USGS Metal Prices, Lunar Discount and Total Export Value

**The New Race for Space**

USA

Russia

China

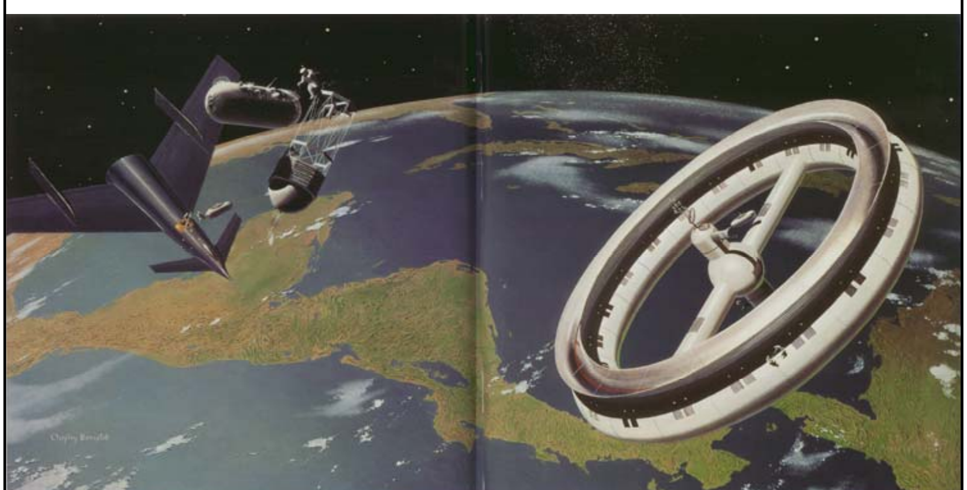
Europe

India

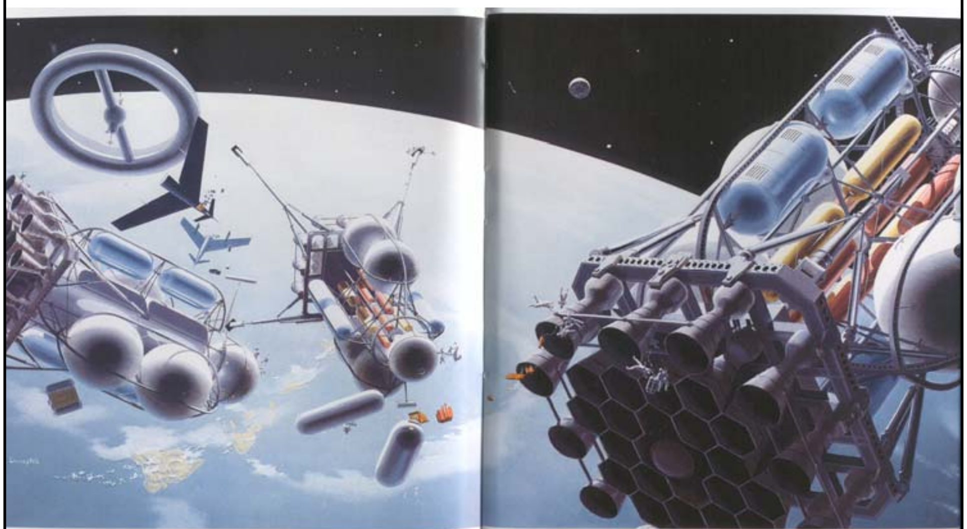
Commercial

Reliable Access to Orbit
Von Braun’s Shuttle
1952


Space Station Assembled in Low Earth Orbit
Von Braun’s 1952 station

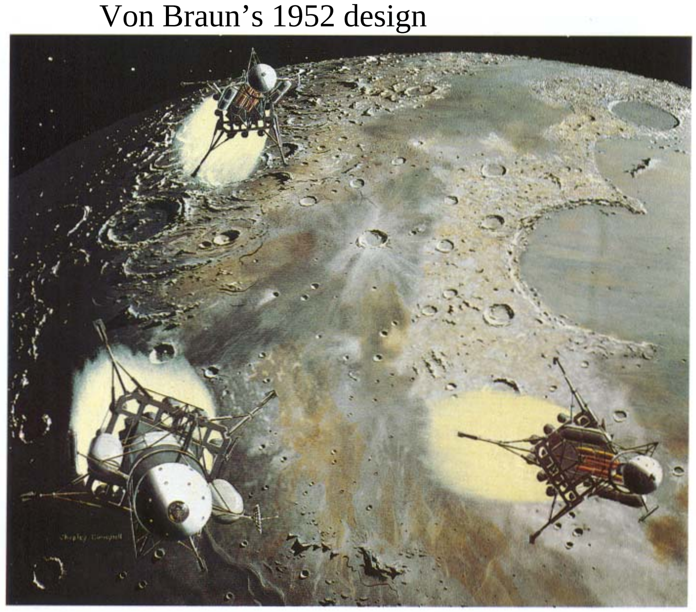


Moon Ships Built & Fueled at Space Station
Von Braun's 1952 design



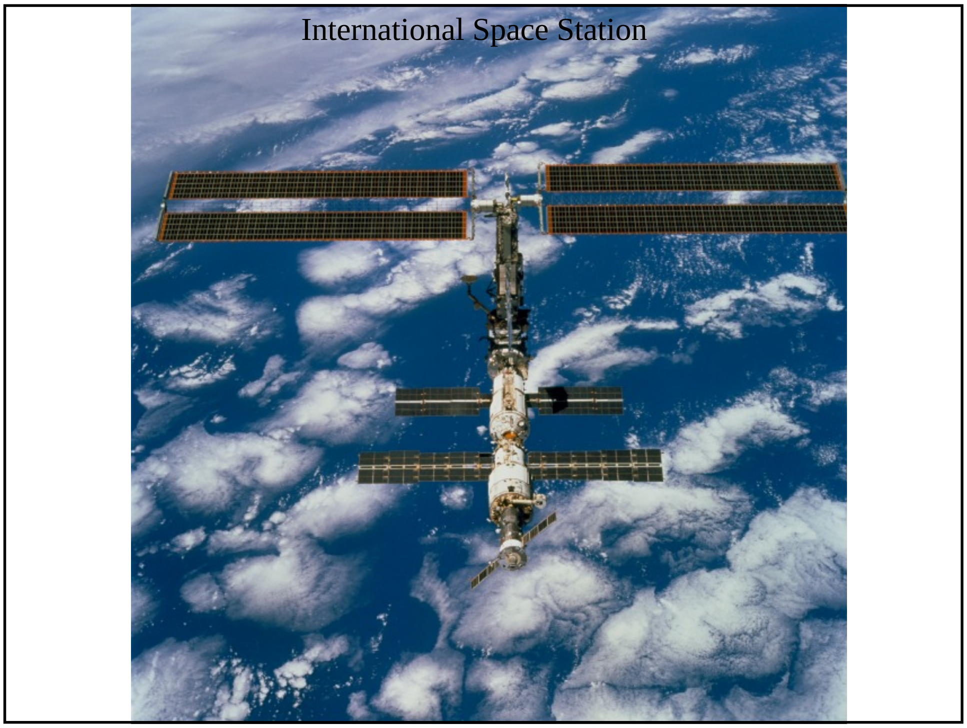
Moon Ships Returning from the Moon to Space Station
Von Braun's 1952 design

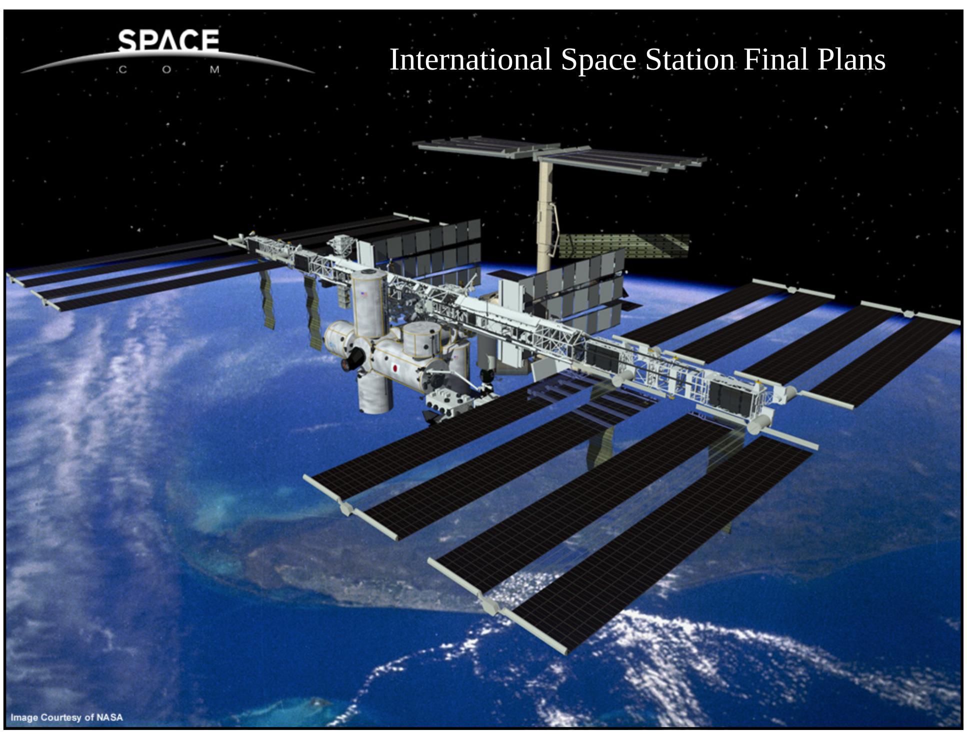
RIGHT:
Landing on the Moon. From *Conquest of the Moon* (1953). In order to paint the Moon correctly Chesley had a sculptor, Nishan Tour, create a 20in (51cm) lunar globe, which he photographed. He then enlarged and painted over the photograph. Finally the three ships were painted on top of this.
*Oil on board, 22 x 36½in (56 x 93cm).*



Mars Ships
Built at Station
Von Braun 1954

Russian Mir Final form: 1986-2001 (15 years operation):
20 Soyuz missions, 7 Shuttle dockings, 54 Cosmonauts 6 Astronauts:
53 Progress tankers; 5 expansion modules; 61 space walks


International Space Station


SPACE
C O M
International Space Station Final Plans
Image Courtesy of NASA

US Space Shuttle


US Shuttle Landing


US Atlas
U.S.A.F.
NASA

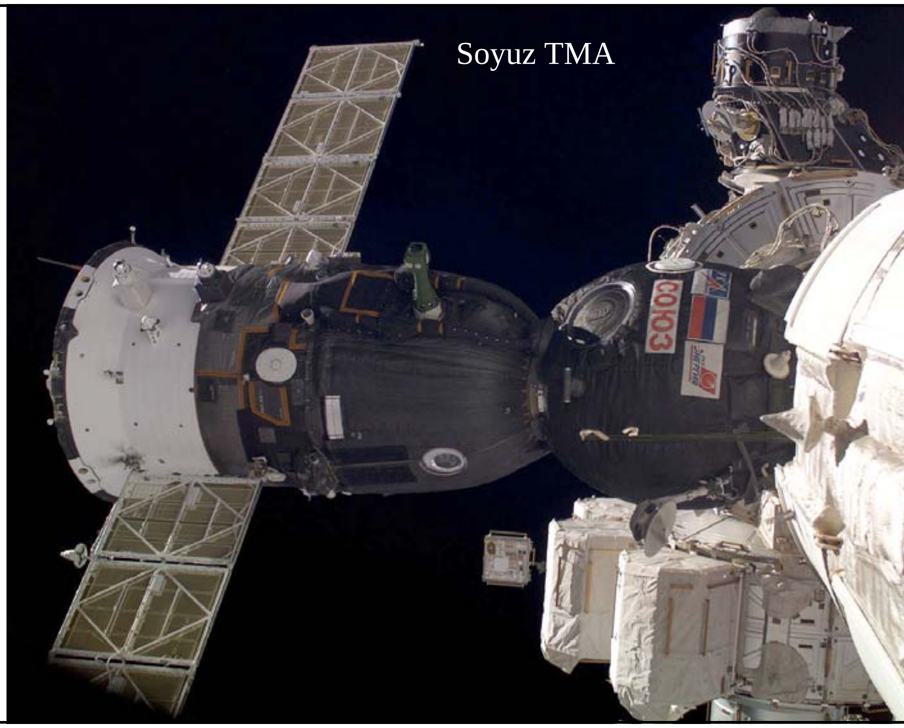

Delta 4 Heavy

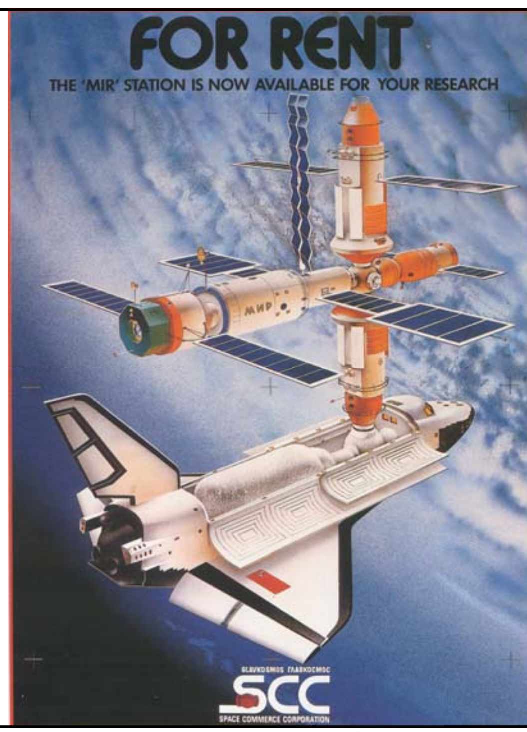

Advance Soyuz Launcher

Proton Launcher


Zenit Booster

USSR’s Buran Shuttle
Energia Booster


Soyuz TMA


FOR RENT
THE 'MIR' STATION IS NOW AVAILABLE FOR YOUR RESEARCH
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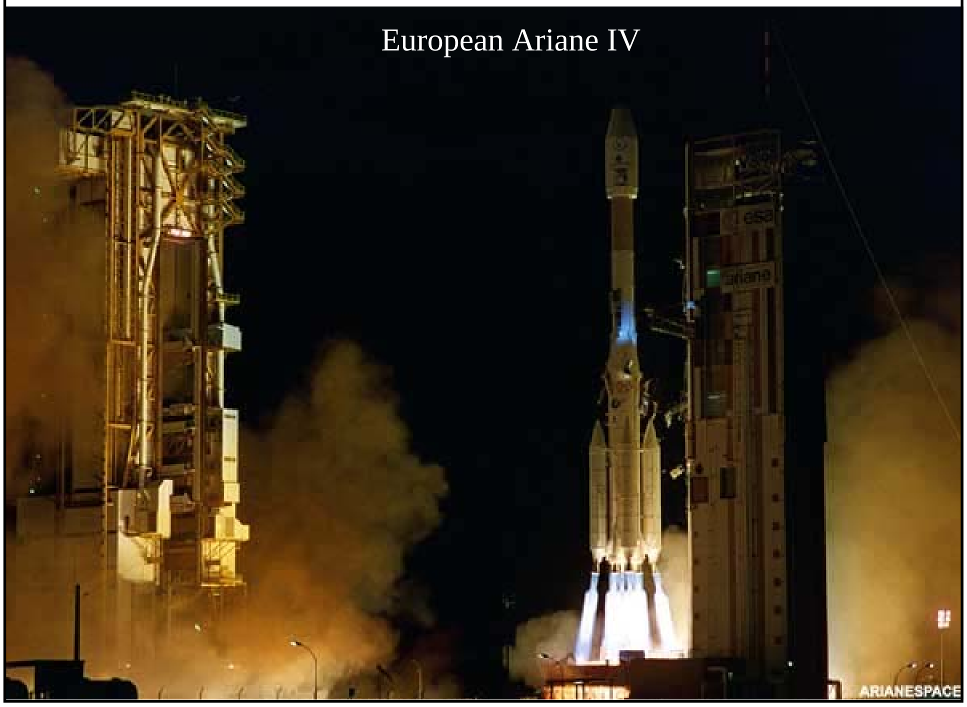
Russian Kliper Return Vehicle


European Ariane IV




European Ariane V

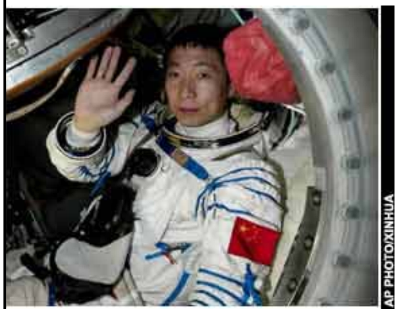
Japanese H2 (11T to orbit)


Indian GLSV: 10T to orbit


China’s Long March Boosters

Shenzhou 5
Oct. 2003


# China's Taikonauts

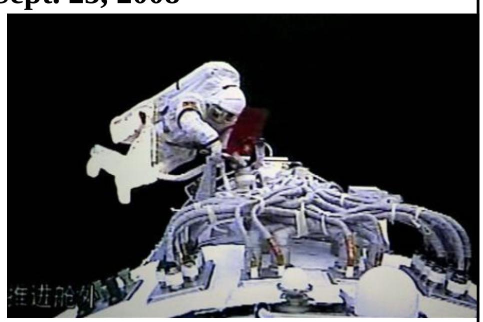



Yang Liwei Shenzhou 5 2003

Shenzhou 6
Oct. 11, 2005
Fei Junlong &
Nie Haisheng

# Shenzhou 7, Sept. 25, 2008

Zhigang, Boming, Haipeng

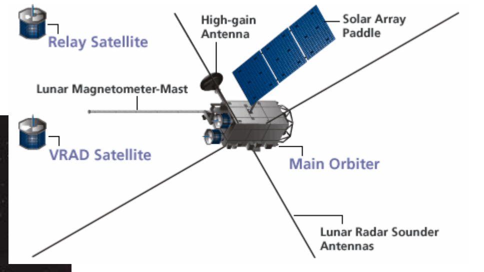


Zhigang 1st spacewalk  Sept 27

Zhigang, Boming Spacewalk

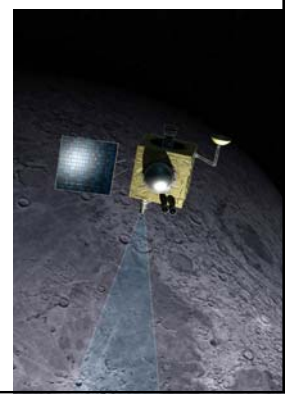
## Japan & China's Lunar Orbiters (2007)

Japan's Selene (Kaguya)
HDTV camera on orbit (main orbiter & 2 probes)




China's Chang'e 1 Nov 2007

India's Chandrayaan-1
Launched Oct. 23, 2008
Lunar orbit Nov 8
Moon Impact Probe Nov 14



## Cheap Access to Space

- Requires a fully reuseable space ship
- Fuel costs are low
- Most cost in building booster
- Throwaway Rockets: like destroying aircraft after each flight
- Boeing 747 costs $200 million, 400 passengers
- Current cost of ticket to Japan $1500
- If destroy plane after flight: $500,000
- Cost about $5000 /kg
- Orbital costs: about $2000-$10.000 / kg

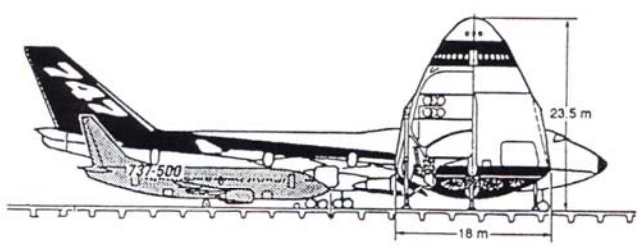
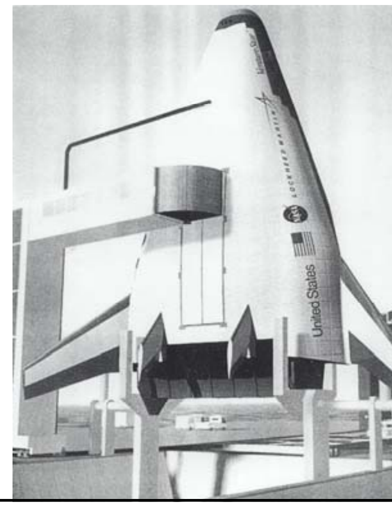



FIGURE 24-3: *The proposed Japanese "Kankoh-maru" passenger-carrying SSTO compared in size to a Boeing 747-400 and a Boeing 737-500. (From Nagatomo et al, paper before 6th International Space Conference on Pacific-Basin Societies, December 1995.)*

## Single Stage To Orbit (SSTO)

- Launch & reuse like aircraft
- Use High Specific Impulse Liquid oxygen/Hydrogen fuels
- Must use very light airframe
- Advanced materials Carbon fiber/epoxy
- Reuseable reentry shield




## 50 Minutes from Anywhere

- Hypersonic vehicles could cover globe in 50 minutes
- Current half world flights 18 hours!
- Orient Express planes for free with SSTO or orbital vehicle

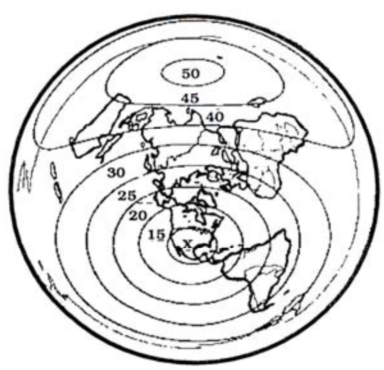
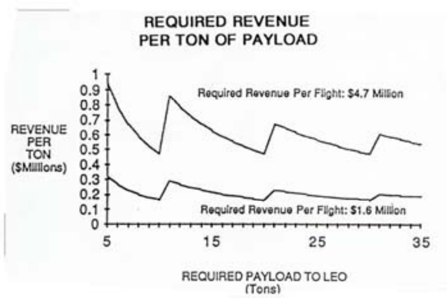



FIGURE 23-1: *A polar projection of the world centered on a hypothetical Southwest Regional Spaceport in the United States. Circular areas containing numbers indicate the number of minutes of flight time required to fly there from the Southwest Regional Spaceport with Global Express. (Drawing from an SDIO/BMDO briefing paper.)*

## It's Economics Time

- Can a SSTO pay for itself?
- Even with high capital for 1 vehicle $1-2 Billion
- Fuel costs have little effect
- Assume 100 flights per year, 5 year lifetime
- Cost per flight $1.5 - 5 million
- Current Expendable costs $50-$700 million
- SSTO Lower by 10-100 times!
- SSTO cost per Kg $1000 - $100
- Problem is the high development cost



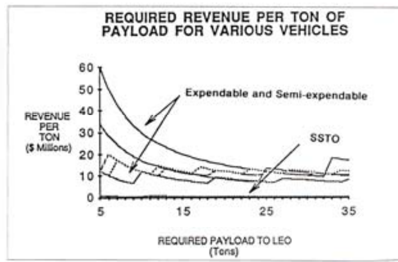




FIGURE 21-4: *When the required revenue per ton and required payload to orbit are compared against existing expendable and semi-expandable (the space shuttle) vehicles, the SSTO has such drastically lower costs that they can hardly be seen on this chart. (Courtesy Paul C. Hans and The Enterprise Institute, Inc.)*

## Mass Fraction: Problem with Single Stage to Orbit

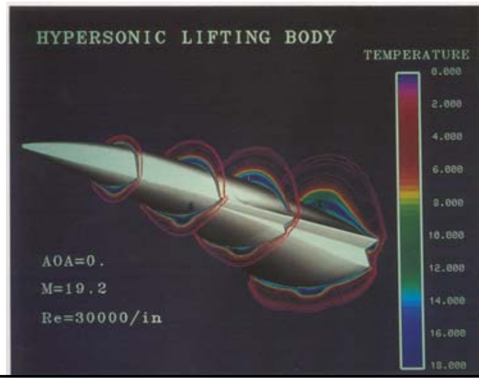
- Mass of rocket must be low compared to fuel
- Want mass fraction fuel/launcher nearly one
- Lower the mass fraction, poorer the launcher
- Typical 0.9-0.94

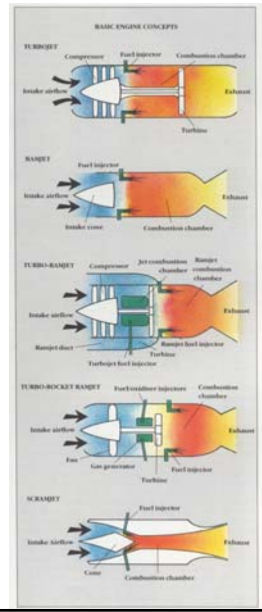
(Mass fraction = Propellant Weight/Gross Weight)

| Vehicle | Propellant Weight (lb) | Gross Weight (lb) | Mass Fraction |
|---|---|---|---|
| Titan II Stage 1 | 260.0 | 269.0 | 0.966 |
| Black Arrow Stage 1 | 28.7 | 31.1 | 0.922 |
| Saturn V Stage 1 | 4584.0 | 4872.0 | 0.941 |
| Titan III Stage 1 | 294.0 | 310.0 | 0.948 |
| Titan IV Stage 1 | 340.0 | 359.0 | 0.947 |
| Delta 6925 Stage 1 | 211.3 | 223.8 | 0.944 |
| Atlas E | 248.8 | 266.7 | 0.933 |
| Saturn V Stage 2 | 993.0 | 1071.0 | 0.927 |
| Zenith Stage 1 | 703.0 | 778.0 | 0.903 |
| Titan III Stage 2 | 77.2 | 83.6 | 0.923 |
| Saturn Ib Stage 2 | 233.0 | 255.0 | 0.913 |
| Titan II Stage 2 | 59.0 | 65.0 | 0.908 |
| Saturn Ib Stage 1 | 889.0 | 980.0 | 0.907 |
| Ariane 5 Stage 1 | 342.0 | 375.0 | 0.912 |
| Saturn V Stage 3 | 238.0 | 263.0 | 0.905 |
| Energia core | 1810.0 | 1995.0 | 0.907 |

## Aircraft/Rocket combinations

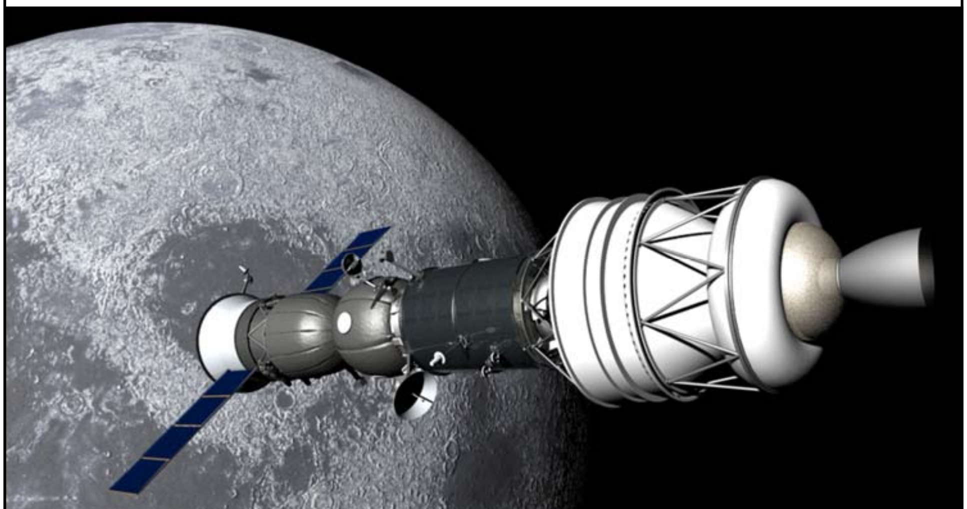
- Use air for oxidizer when possible
- Problem: need Supersonic Ram Jet engines
- work only Mach 3 - 6
- Jet engines before, Rockets after
- Use Hydrogen fuel
- Aircraft body must be integral with engines!



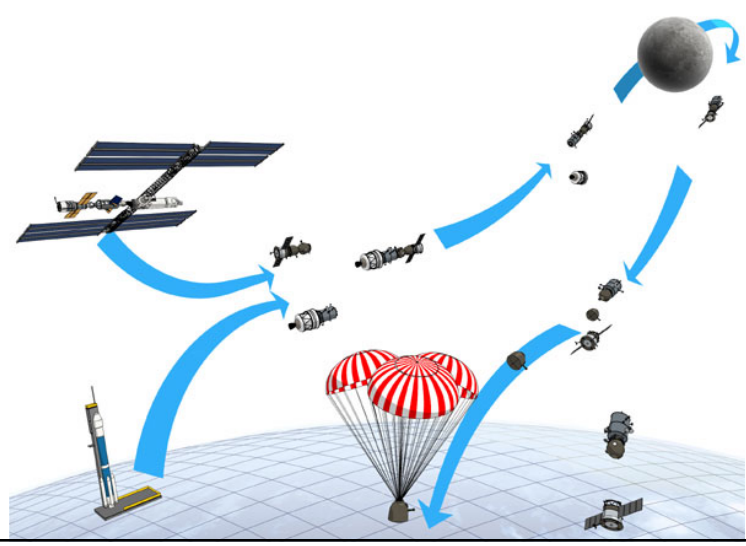



## Economic Driver to Orbit: Space Tourism
First by Dennis Tito May 16, 2001

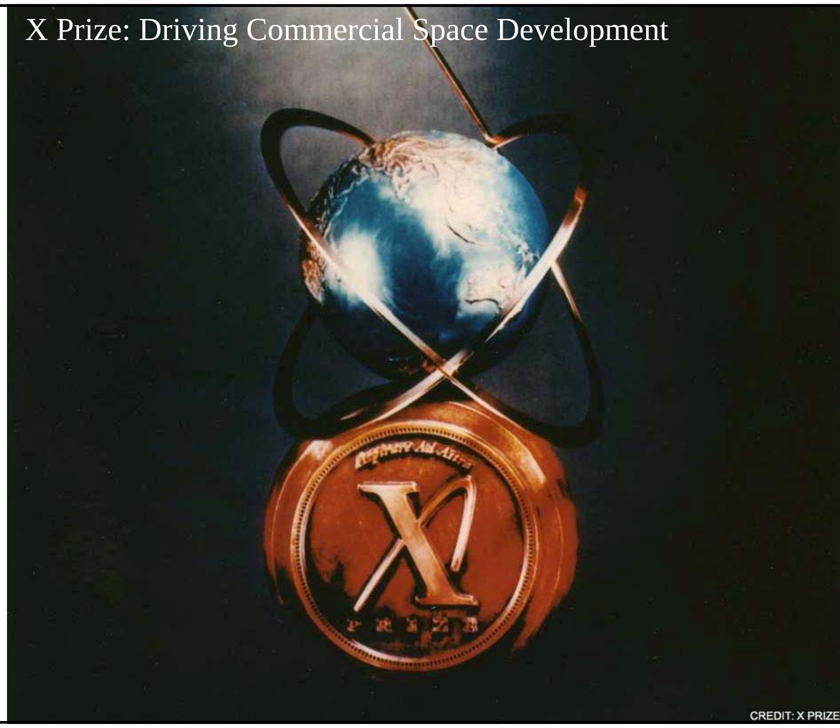
Russian Soyuz Tourist Trip Around the Moon



Russian Soyuz Tourist Mission Around the Moon



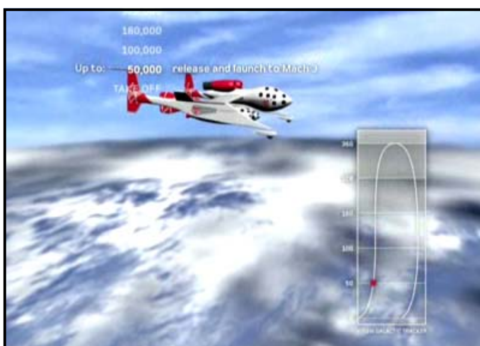
X Prize: Driving Commercial Space Development




Space Ship One & White Knight Carrier

## Space Ship One Oct. 4, 2004 Win's X prize

June 21, 2004: 100.1 Km
Sept. 29, 2004: 102.9 Km
Oct. 4, 2004: 112.0 Km

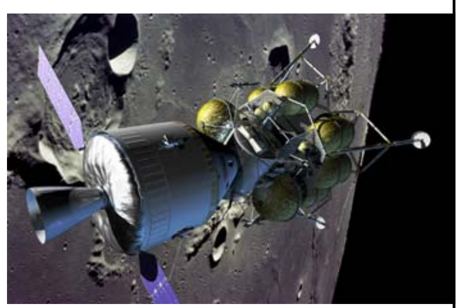


Virgin Galactic Space Ship 2
Pilot + 7 passengers

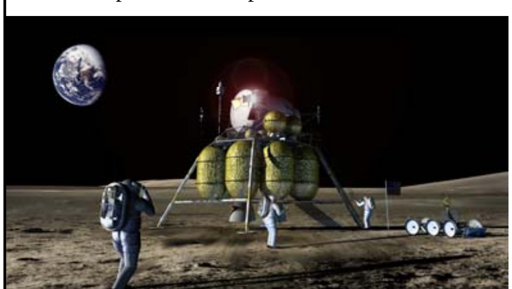
## White Knight 2 Shown 2008

## NASA’s Back to the Future: New Apollo Like Capsule

New Apollo Like Capsule



Apollo/LEM Lunar orbit flight



Larger/longer stay LEM

Same return capsule but on land

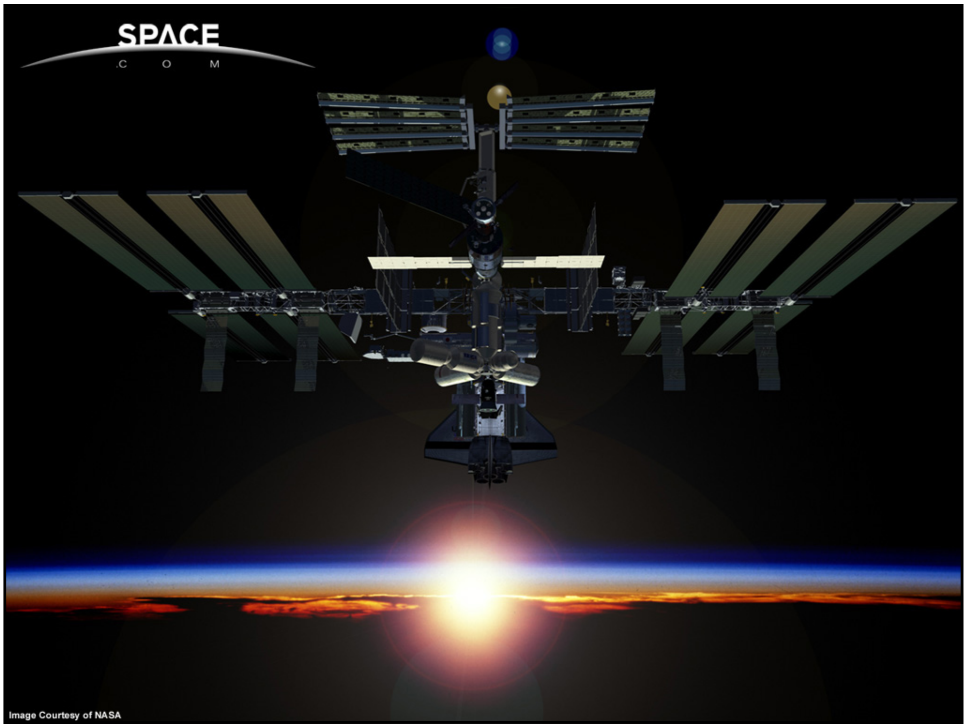

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Image Courtesy of NASA