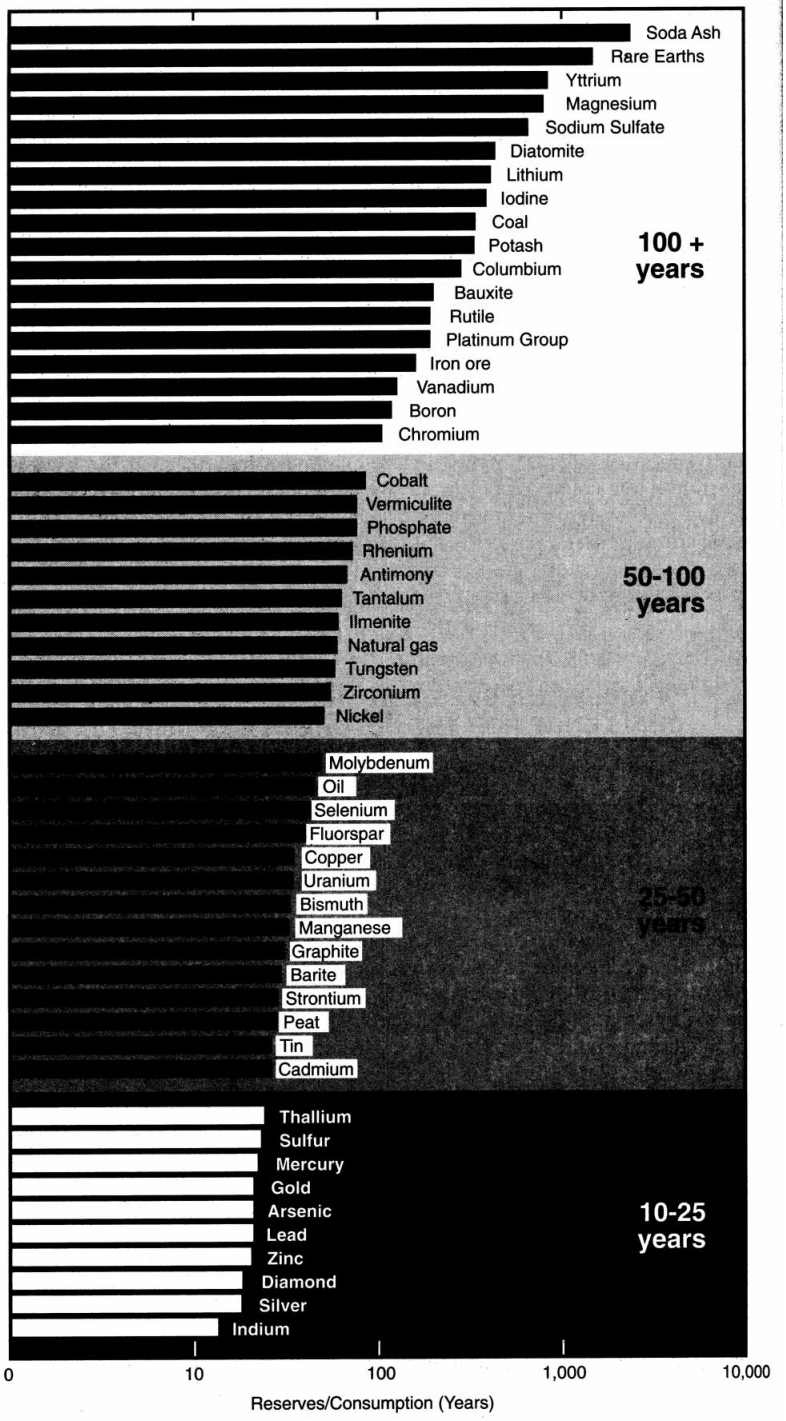
What We Hope You Will Remember in 2010

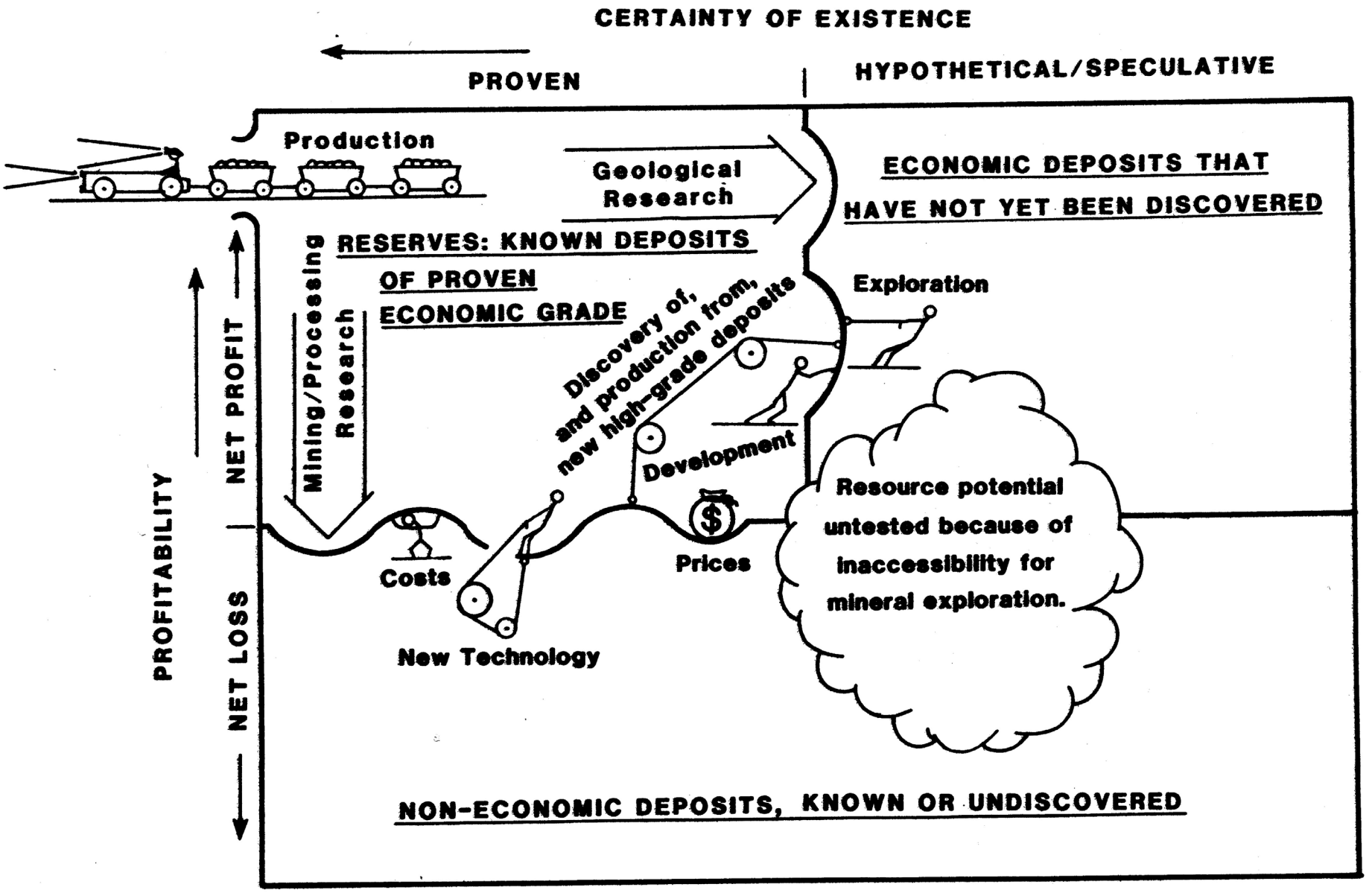
Professors Brown, Santarius, Kulcinski, and Schmitt

May 7, 2004

Reserves/Resources

- Ore deposits result from over-exuberant or fortuitous geochemical processes
- Reserves and Resources on Earth are limited
- Remaining years production
  - Varies with commodity
- ‘Reserves’ are a moving target depending on:




CERTAINTY OF EXISTENCE
PROVEN
HYPOTHETICAL/SPECULATIVE
Production
Geological Research
ECONOMIC DEPOSITS THAT HAVE NOT YET BEEN DISCOVERED
RESERVES: KNOWN DEPOSITS OF PROVEN ECONOMIC GRADE
Mining/Processing Research
Discovery of, and production from, new high-grade deposits
Exploration
Development
Resource potential untested because of inaccessibility for mineral exploration.
Costs
Prices
New Technology
NET PROFIT
PROFITABILITY
NET LOSS
NON-ECONOMIC DEPOSITS, KNOWN OR UNDISCOVERED

Earth-Moon Trade?

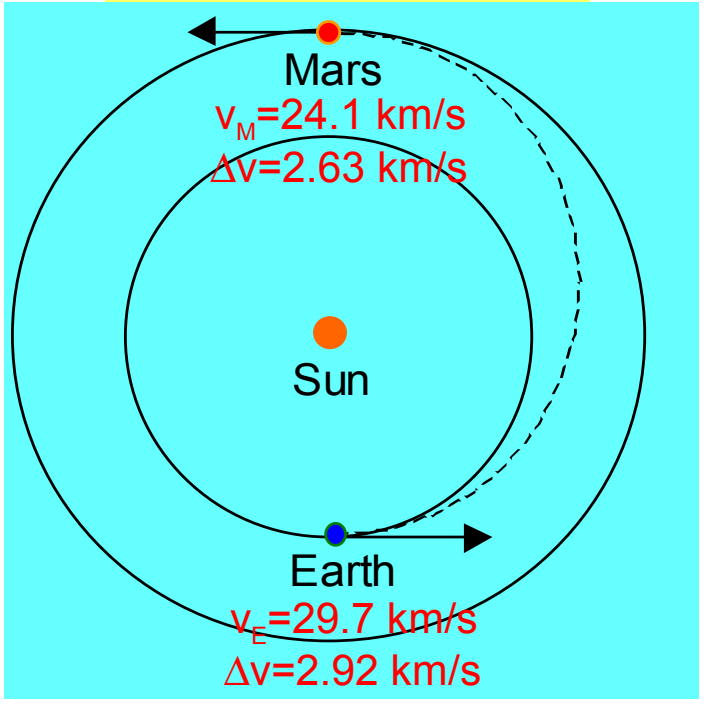
- Except for exotics like ^{3}He, nothing on the moon is economically worth bringing back to Earth
- Obviously must send processed materials to moon for a period of time to get started
- The variables that control the definition of ‘reserves’ on Earth will apply in different degrees on Moon and Mars

Efficient Solar-System Travel Requires High-Exhaust-Velocity Propulsion

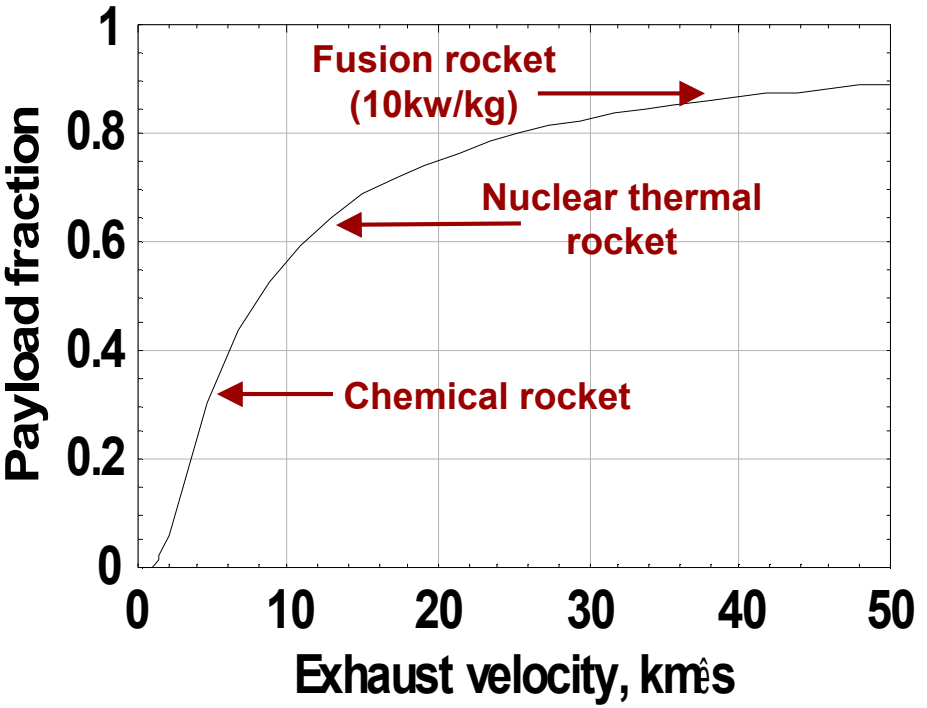
Rocket Equation

$$\frac{m_f}{m_i} = \exp\left(\frac{-\Delta v}{v_{ex}}\right)$$

Hohmann Transfer

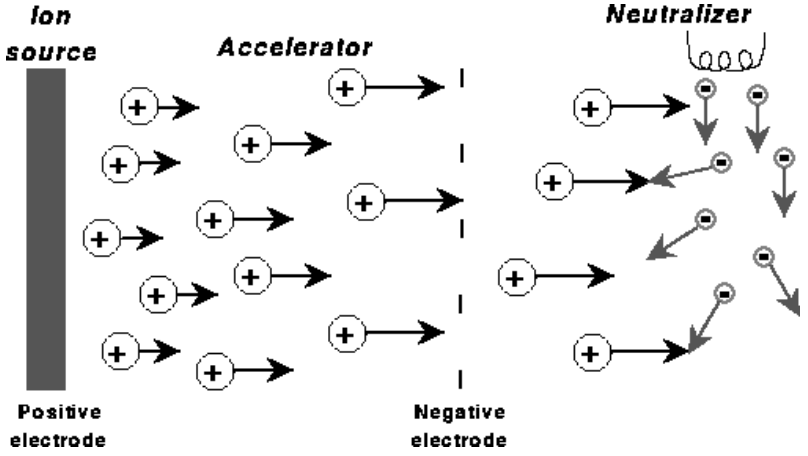


Earth-Mars 260-day, one-way trip: Δv~5.6 km/s (Hohmann)

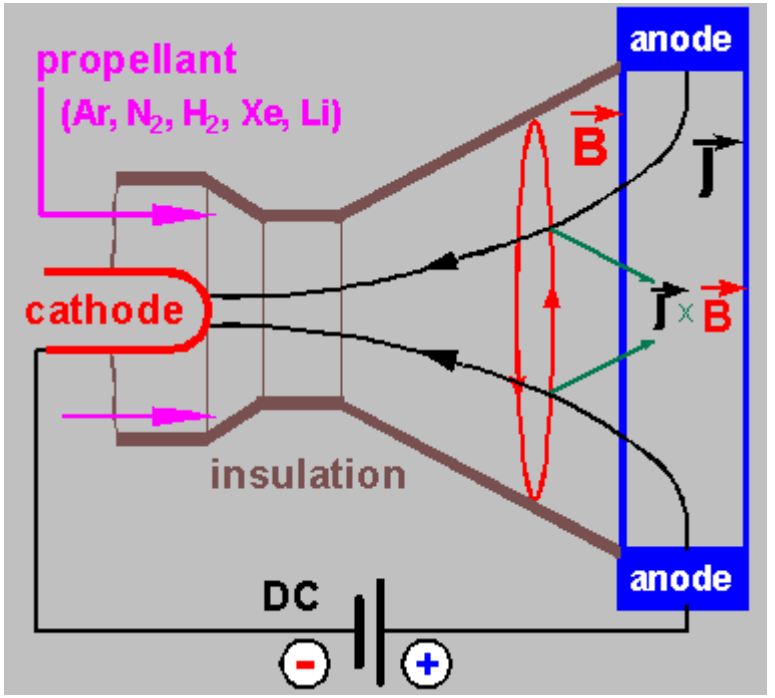


Plasma Thrusters Give High Exhaust Velocity

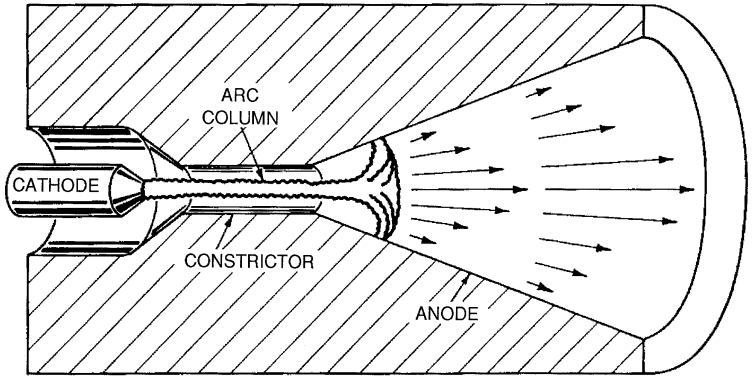
Electrostatic thruster



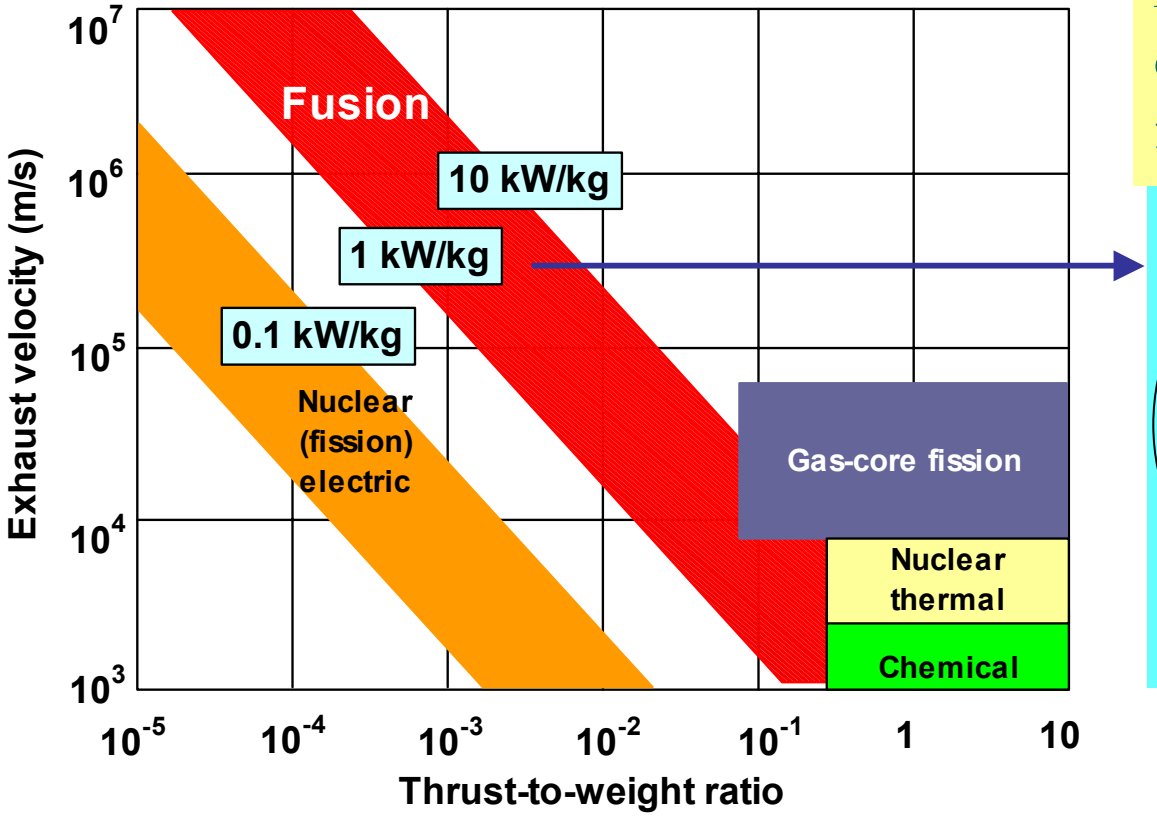
Electrodynamic thruster



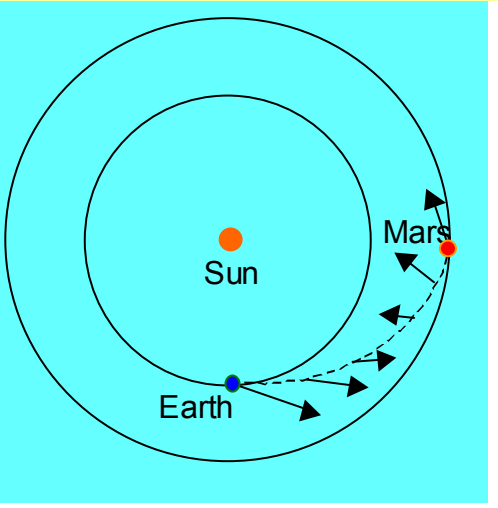
Electrothermal thruster



D-^{3}He Fusion Will Provide Capabilities Not Available from Other Propulsion Options



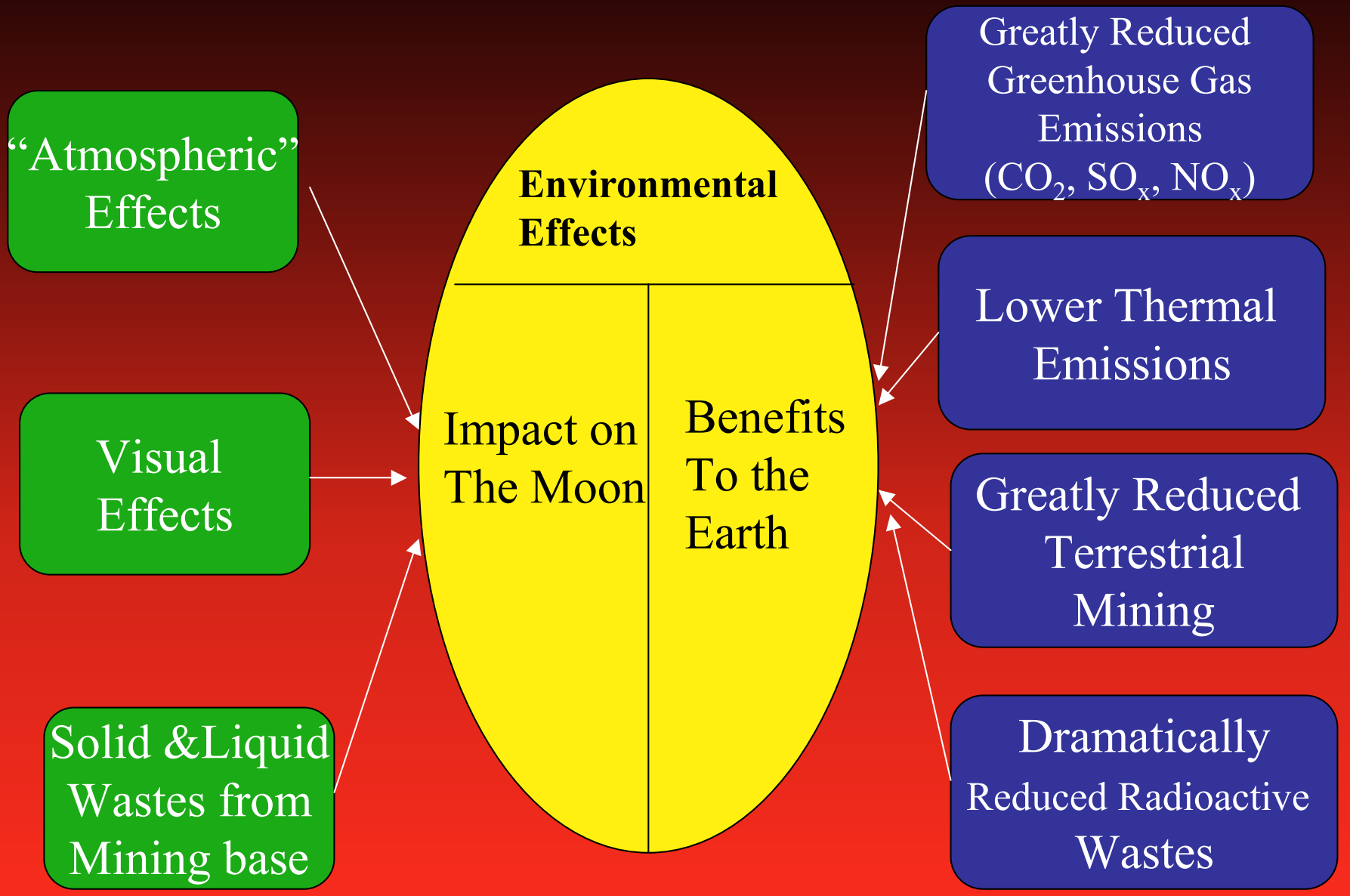
Low-thrust trajectories differ fundamentally from high-thrust ones.

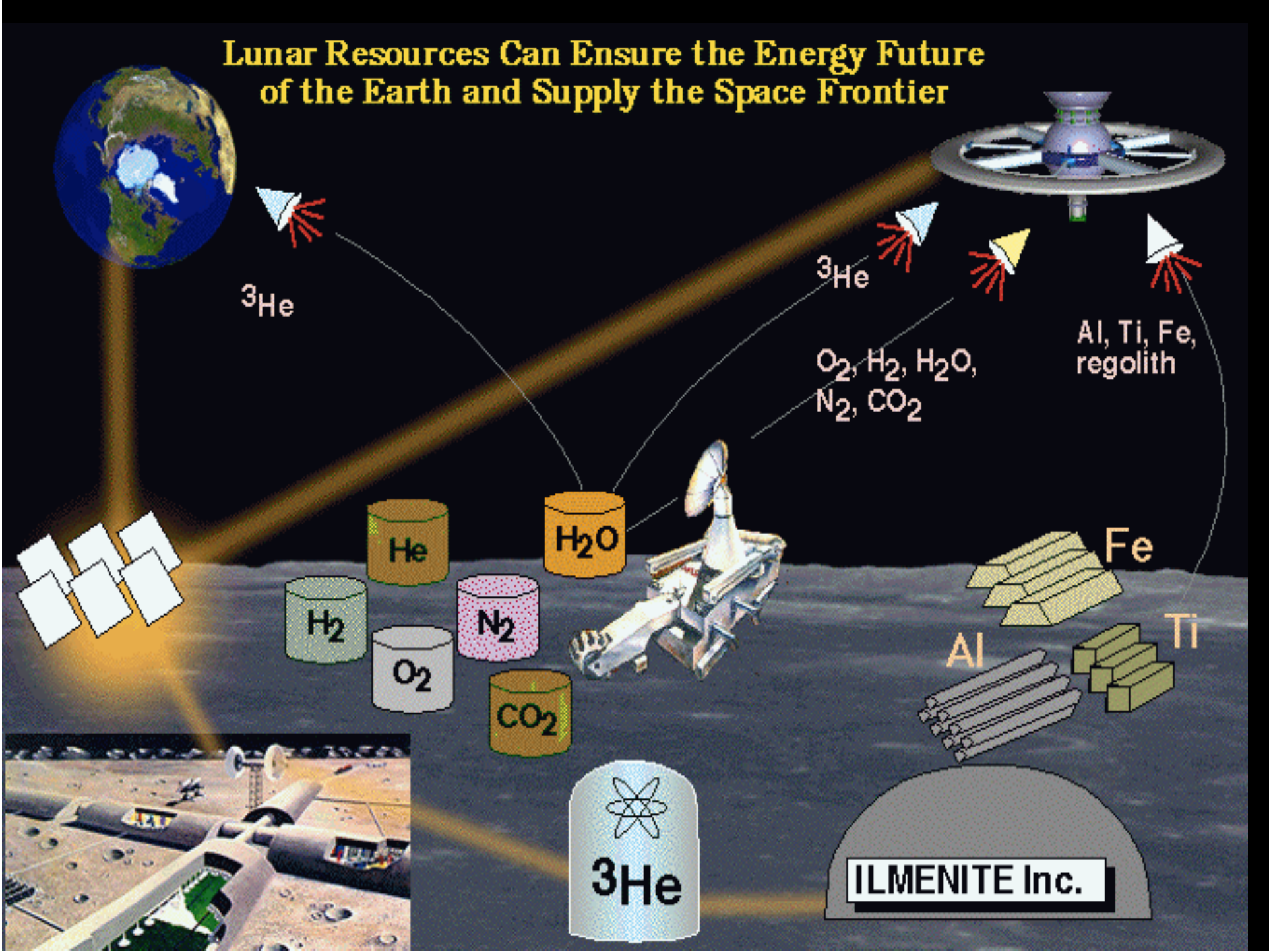


What Resources from the Moon Can Have a Major Impact on Future Generations?

	Energy	Volatiles, Metals, and Minerals
On Earth	• ^3He • Microwaves from Solar Power	Probably None
In Space	• ^3He • Microwaves from Solar Power • H_2-O_2 fuel cells	• Volatiles (H_2, N_2, O_2, CO_2, etc.) • Al, Fe, Ti, etc. • Regolith
On the Moon	• ^3He • Solar Power • H_2-O_2 fuel cells	• Volatiles (H_2, N_2, O_2, CO_2, etc.) • Al, Fe, Ti, etc. • Regolith

"Net" Environmental Considerations for Energy from Space




Lunar Resources Can Ensure the Energy Future
of the Earth and Supply the Space Frontier
3He
3He
O2, H2, H2O,
N2, CO2
Al, Ti, Fe,
regolith
He
H2O
H2
N2
O2
CO2
Fe
Al
Ti
3He
ILMENITE Inc.

Points to Remember!

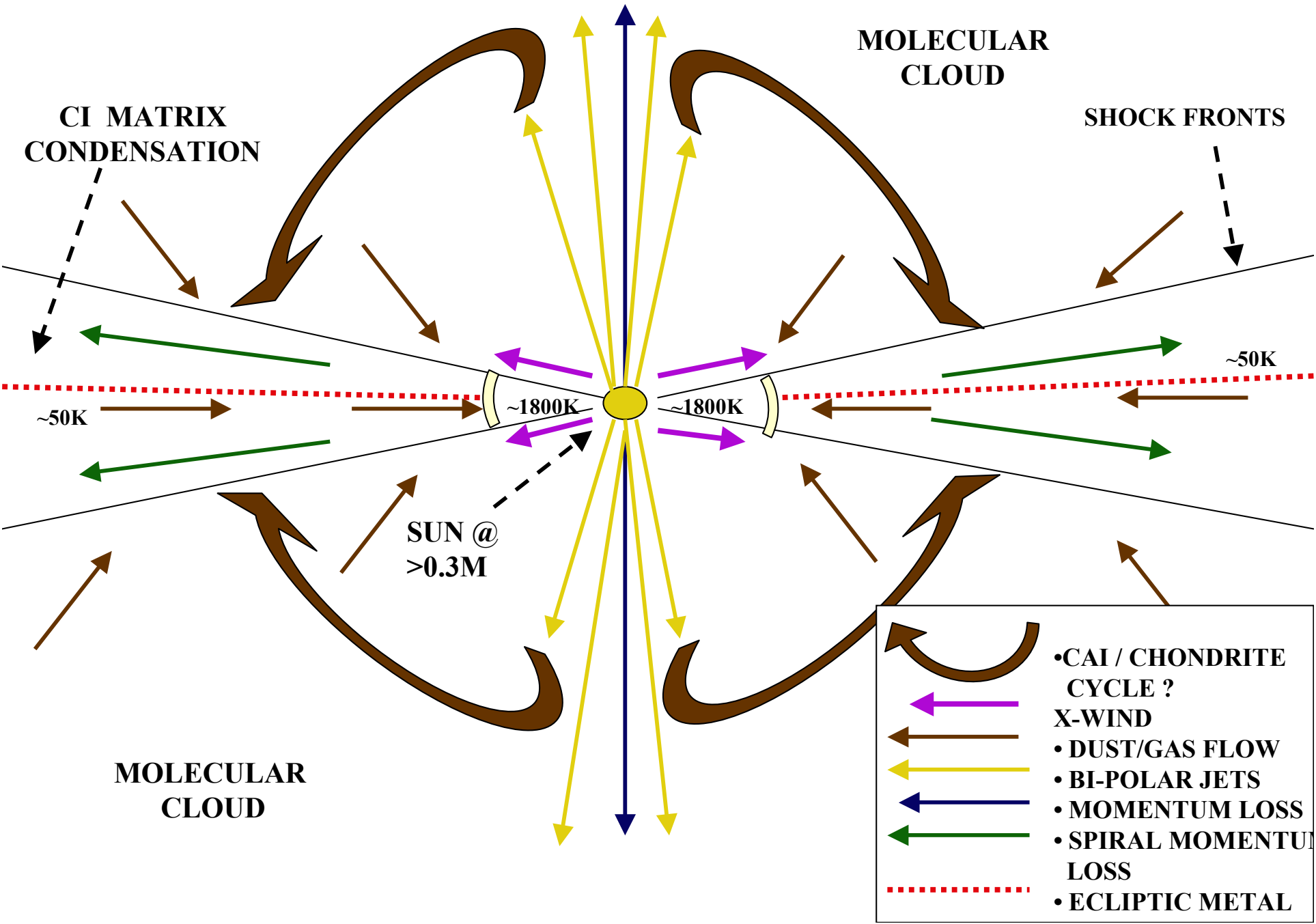
- Expand Your Time Horizons
  - *Serious worldwide energy problems will be encountered when you are 45-50 (when your children are in college or starting their careers)*
- "There's Gold in Them Thar Hills!"
  - *The existence of 1 million tonnes of ^{3}He on the Moon has been established (and we know how to get it!)*
- Solar Wind Volatiles Will Be Enabling Resources for Future Space Exploration
- It is Possible to Think About Nuclear Energy Without Nuclear Waste!
- Consider the "Net" Environmental Impact of Your Actions
  - *Will the use of a resource produce more benefits than the environmental cost of obtaining it?*

IMPLICATIONS

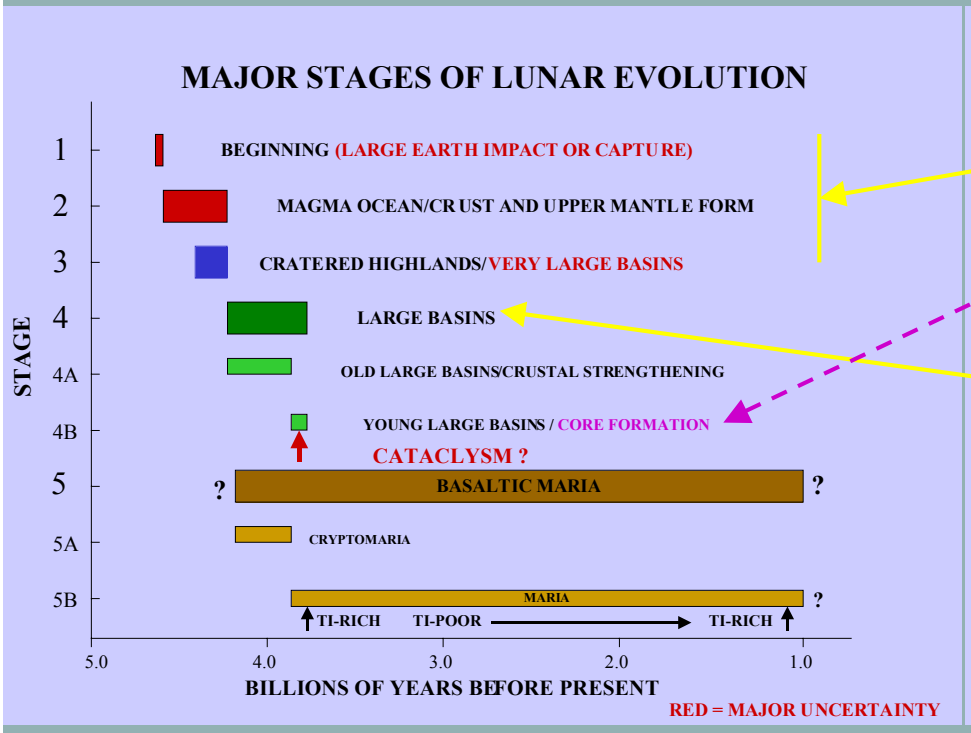
- RETURNING TO THE MOON TO STAY
  - COMPARABLE TO THE FIRST MOVEMENT OF HUMANS OUT OF AFRICA ~150,000 YEARS AGO
    - OR TO THE FIRST MIGRATION OF HUMANS TO NORTH AMERICA IN SEARCH OF FREEDOM ~400 YEARS AGO

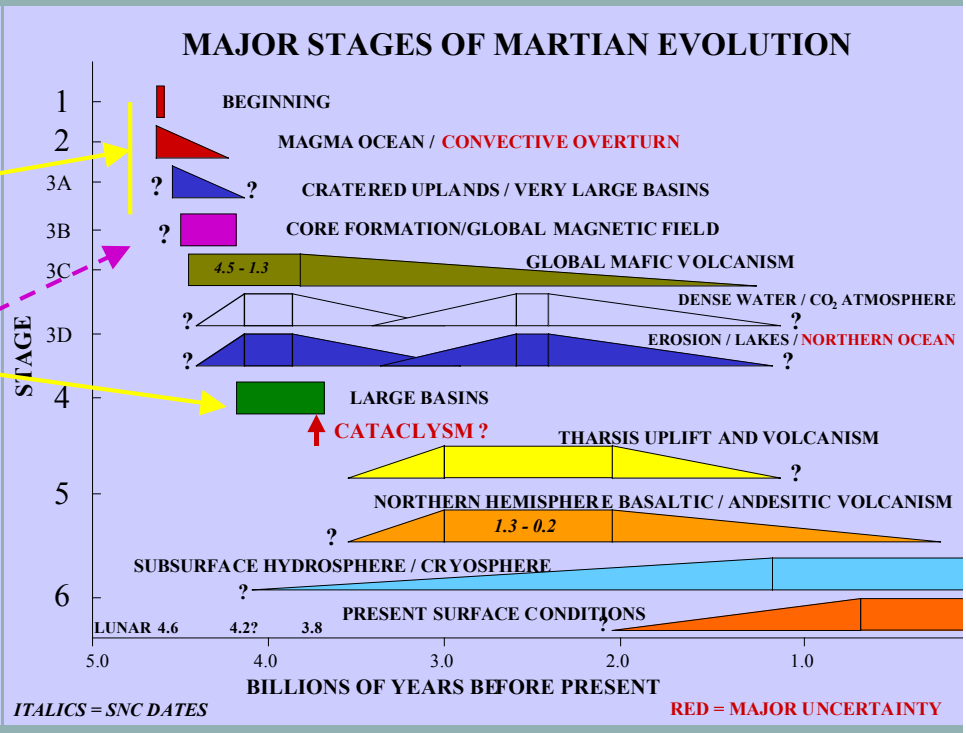
- A LOT RESTS ON YOUR SHOULDERS TO MAKE THIS HAPPEN……

NEBULAR DYNAMICS AT T_0 ±50,000 YEARS



COMPARISON OF LUNAR AND MARTIAN EVOLUTION WITH INSIGHTS ABOUT EARTH





CRATERING HISTORY CORRELATION

CORE FORMATION DIFFERENCE

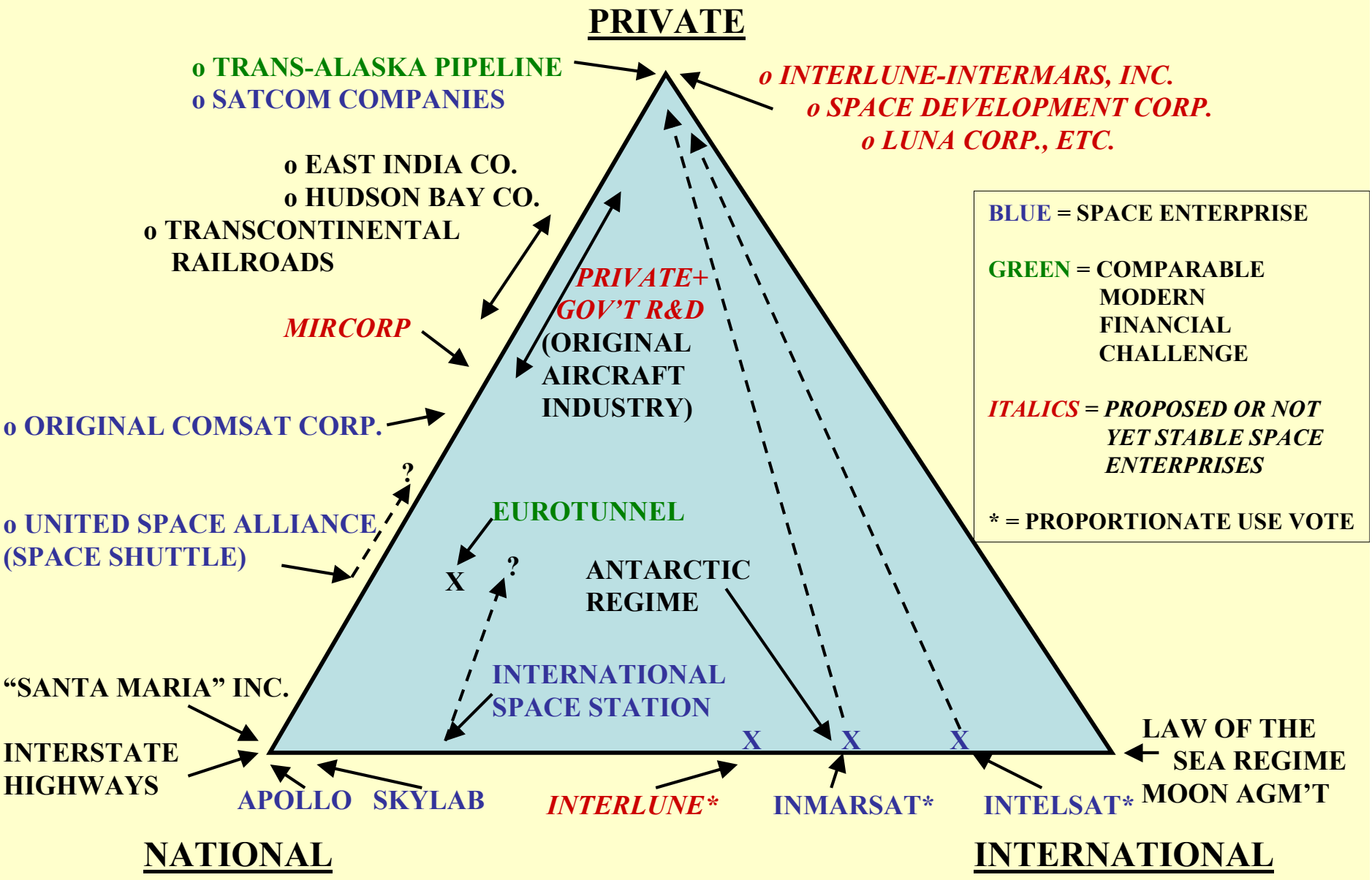
BASE ACTIVATION SCENARIOS

FUTURE SUIT DESIGN GOALS:

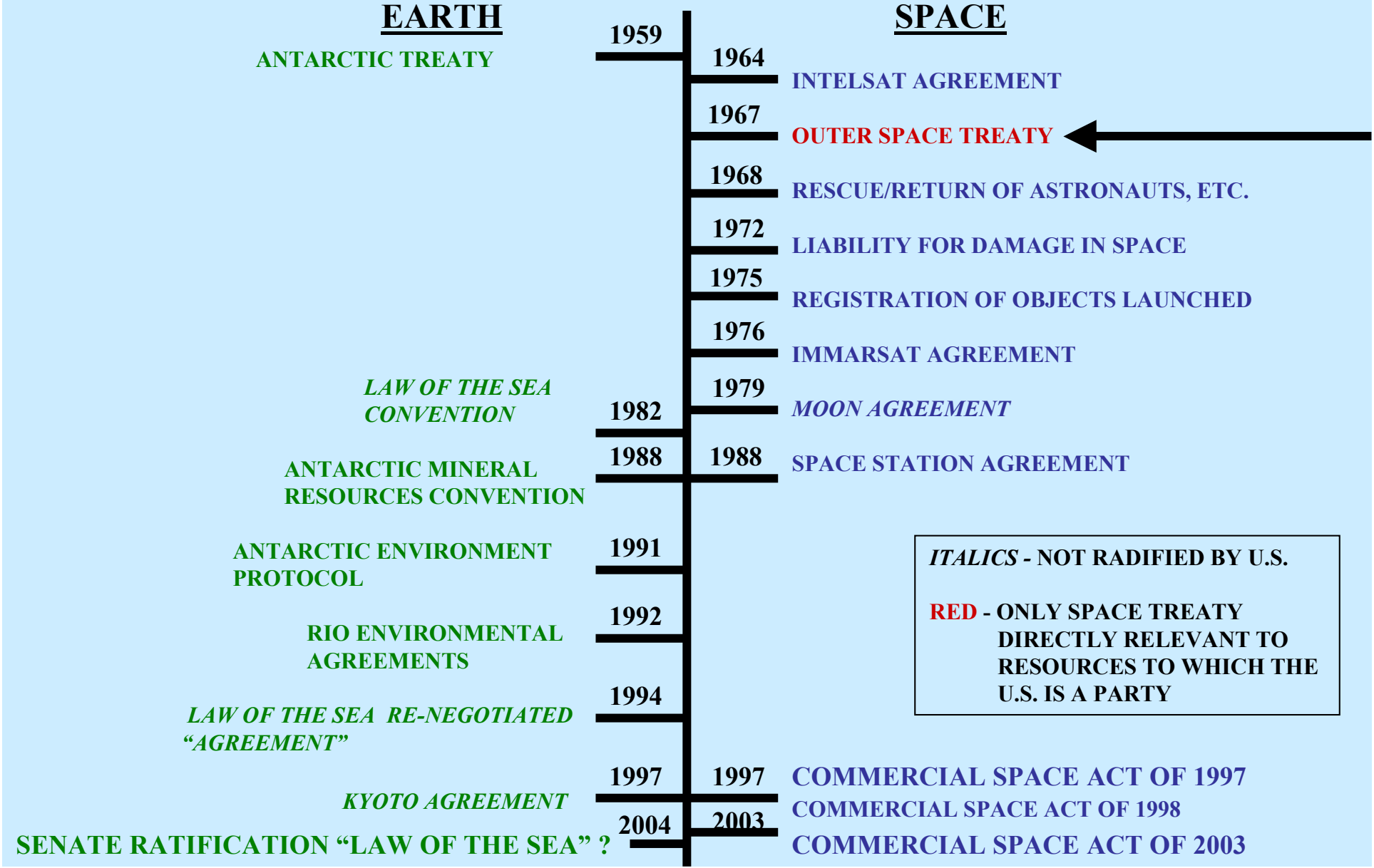
- >1/2 THE MASS
- >4 TIMES THE MOBILITY
- HAND DEXTERITY = NORMAL
- ASSISTED GRIP GLOVES
- >100 CYCLES BEFORE REFURBISHMENT
- VACUUM CONNECT / DISCONNECT

NASA PHOTO

"PURE" MANAGEMENT CONTROL COMPONENTS: LARGE ENTERPRISES



CHRONOLOGY OF INTERNATIONAL AGREEMENTS RELEVANT TO SPACE



SPACE LAW: GENERAL STATUS

THE CURRENT INTERNATIONAL TREATY ENVIRONMENT

FOR A PRIVATE, GOVERNMENT, GOVERNMENT / PRIVATE,

MULTILATERAL, OR AN INTERNATIONAL INITIATIVE

TO DEVELOP AND UTILIZE LUNAR RESOURCES

IS CURRENTLY PERMISSIVE

IF THE U.S. GOVERNMENT IS SUPPORTIVE

* **THAT IS, NO TREATIES TO WHICH THE UNITED STATES IS A PARTY WOULD, ON THEIR FACE, PREVENT SUCH AN INITIATIVE.**

* **POLITICAL PRESSURES, HOWEVER, MIGHT BE FELT, DEPENDING ON THE NATURE OF THE INITIATIVE.**

PRIVATE INITIATIVE

NEW SATURN ROCKET

"FACTOR OF 19 COST REDUCTION?"

1. DESIGN SPECS ARE CLEAR DUE TO APOLLO SUCCESS
2. NEW, PROVEN TECHNOLOGIES
3. LONG-TERM PRODUCTION CONTRACTS
4. COMPUTER-BASED DESIGN, MANUFACTURING, AND MANAGEMENT SYSTEMS
5. DESIGN TO MINIMUM COST AS WELL AS MAX RELIABILITY AND LONGEVITY
6. EARTH RETURN CAPABILITY TIED TO TOURISM
7. DOUBLING OF PAYLOAD OVER APOLLO SATURN V

- AVERAGE FACTOR OF <1.5 REDUCTION FROM EACH SUFFICIENT TO MEET TARGET OF 19 TOTAL

FUSION POWER DEMO A MUST!

PRIVATE INITIATIVE

DEVELOPMENT PLAN AND MILESTONES

BASED ON ~18* YEARS FROM INITIAL FINANCING TO DELIVERY OF FIRST 100 KG HE-3 TO FIRST OPERATING

1000 MEGAWATT (e) FUSION PLANT

* **INCREASED RATE AND AMOUNT OF FINANCING COULD MAKE THIS TIME AS SHORT AS 10 YEARS BUT NOT MUCH LESS.**

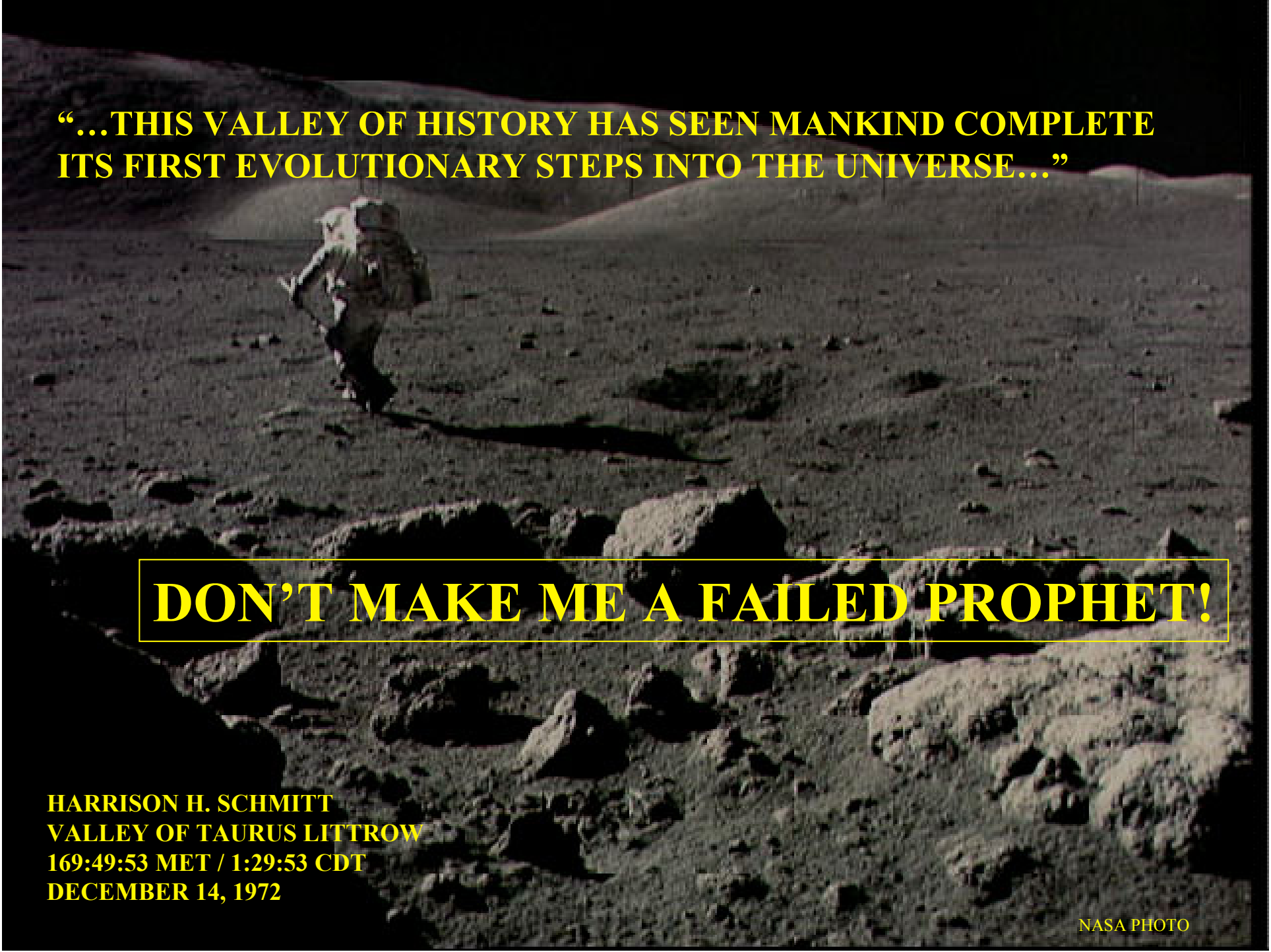
RETURN TO THE MOON
COMPARISON OF TWO PATHS - 1

GOVERNMENT

- HUMAN TENDED BASE
- POLICY DRIVEN IMPLEMENTATION
- OVERSIGHT BY PRESIDENTIAL COMMISSION ?
- HEADQUARTERS PROGRAM & PROJECT MANAGEMENT
- HIGH OVERHEAD, DIVERSE FUNCTION POLITICAL "CENTERS"
- MID-CAREER TO RETIREMENT WORKFORCE
- CURRENT STABLE OF ELVs
  - 25-30 TONNES TO LE0
  - 5-6 TONNES TO MOON

PRIVATE

- PERMANENT SETTLEMENT
- RETURN ON INVESTMENT DRIVEN IMPLEMENTATION
- OVERSIGHT BY INDEPENDENT BOARD OF DIRECTORS
- CENTRALIZED PROGRAM / DELEGATED PROJECT MGT.
- FOCUSED CENTERS OF EXCELLENCE
- YOUNG WORKFORCE / MID-CAREER MANAGERS
- NEW HEAVY LIFT ROCKET
  - 250-500 TONNES TO LEO
  - 50-100 TONNES TO MOON


"…THIS VALLEY OF HISTORY HAS SEEN MANKIND COMPLETE ITS FIRST EVOLUTIONARY STEPS INTO THE UNIVERSE…"
DON'T MAKE ME A FAILED PROPHET!
HARRISON H. SCHMITT
VALLEY OF TAURUS LITTROW
169:49:53 MET / 1:29:53 CDT
DECEMBER 14, 1972
NASA PHOTO

RETURN TO THE MOON

THIS TIME WE STAY

Second Annual Lunar Development Conference July 20-21, 2000 SPACE FRONTIER FOUNDATION Artwork Created for Space Frontier Foundation by Mark Maxwell


The Crew: Resources
from Space, Spring-2004