Nuclear Fission Propulsion

Why Nuclear?

1 kg of fissionable material has

10,000,000 times

the energy of 1 kg of chemical fuel

Specific Impulse

- **English Definition**

$$I_{sp} = \frac{\text{thrust}}{\text{mass flow rate}} = \frac{lb_f}{\frac{lb_m}{s}}$$

Newton's 2nd Law

$$F = \frac{m \bullet a}{g_c}$$

Where g_c = universal dimensional constant,

$$\left(\frac{32.1739\ ft - lb_m}{lb_f - s^2} \right)$$

a = the acceleration due to gravity $\left(\frac{ft}{s^2} \right)$

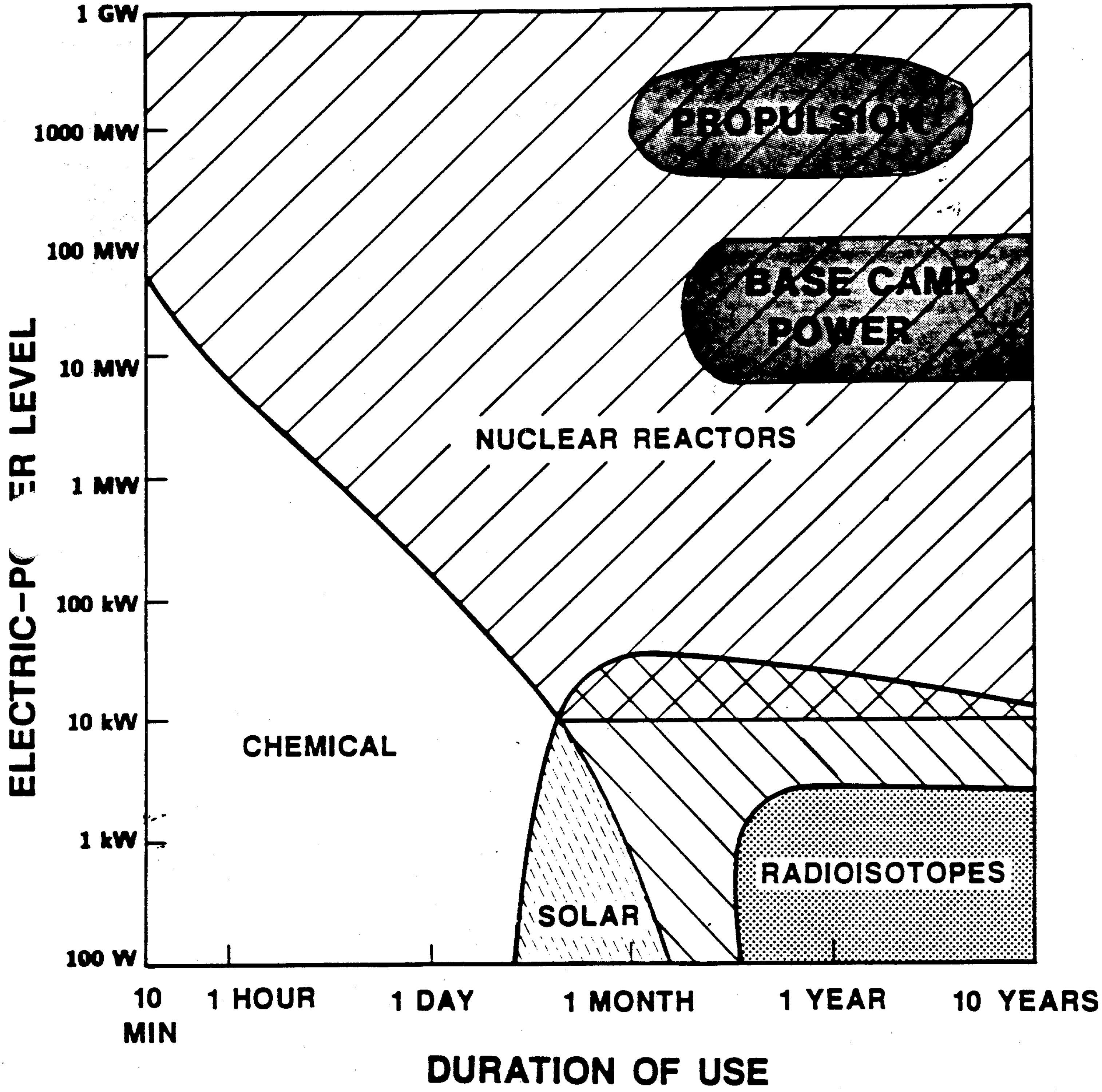
At sea level a= 32.1739 $\left(\frac{ft}{s^2} \right)$

So, At Sea Level, $lb_f = 1 lb_m$

Then I_{sp} has units of seconds, but only at sea level!

Relationship of I_{sp} to Rocket Parameters

REGIMES OF POSSIBLE SPACE POWER APPLICABILITY



$$I_{sp} = \frac{F}{m} = AC_f \sqrt{\frac{T_c}{M}}$$

Where;

I_{sp} = Specific Impulse, m/s
F = Thrust, Newtons
m = Propellant Mass Flow, kg/s
A = Performance Factor (nozzle)
C_f = Thrust Coefficient, (nozzle)
T_c = Chamber Temperature
M = Molecular Wt. of Exhaust Gas

NOTE DIFFERENCES WITH VARIOUS PROPELLANTS (FIGURES)

SPECIFIC IMPULSES FROM VARIOUS ENERGY SOURCES

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3 Videos:

- **“BNTR Program 1” (Nuclear Rocket Mission to Mars), Stan Borowski, NASA Lewis (2000)**

- **“Gaseous Core Nuclear Rockets”, Steve Howe, LANL, (1998)**

- **“A Space Vision for the next 100 Years”, Harris Corporation, (≈ 1996)**

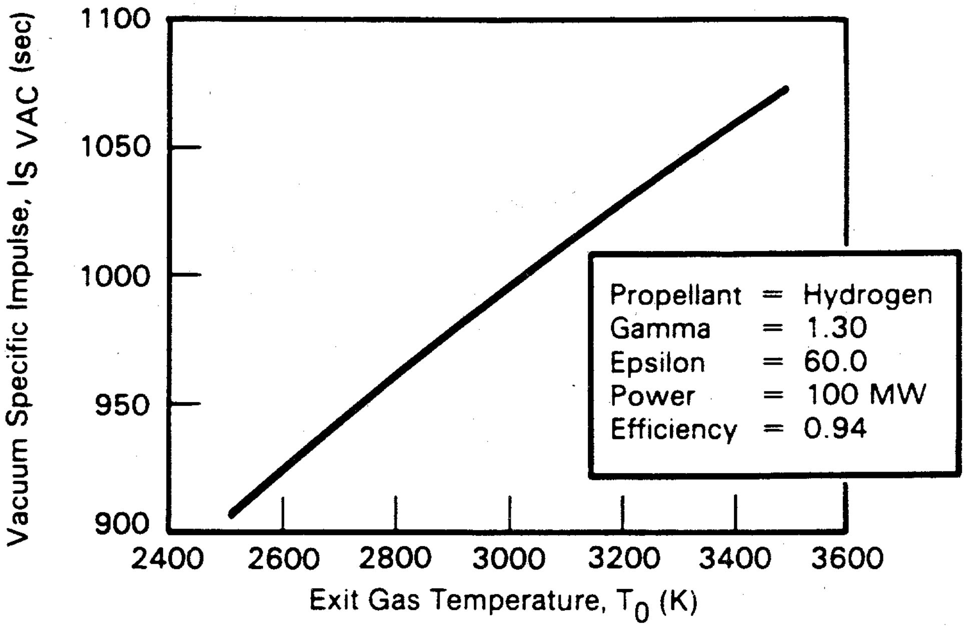


Figure 13. Hydrogen Specific Impulse Variations With Exit Gas Temperature

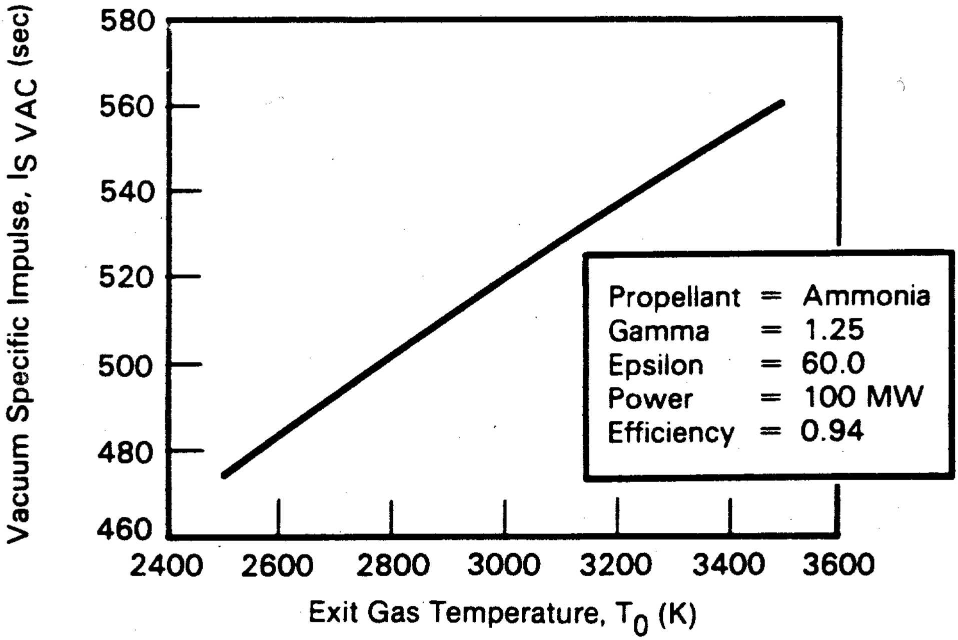


Figure 15. Ammonia Specific Impulse Variations With Exit Gas Temperature

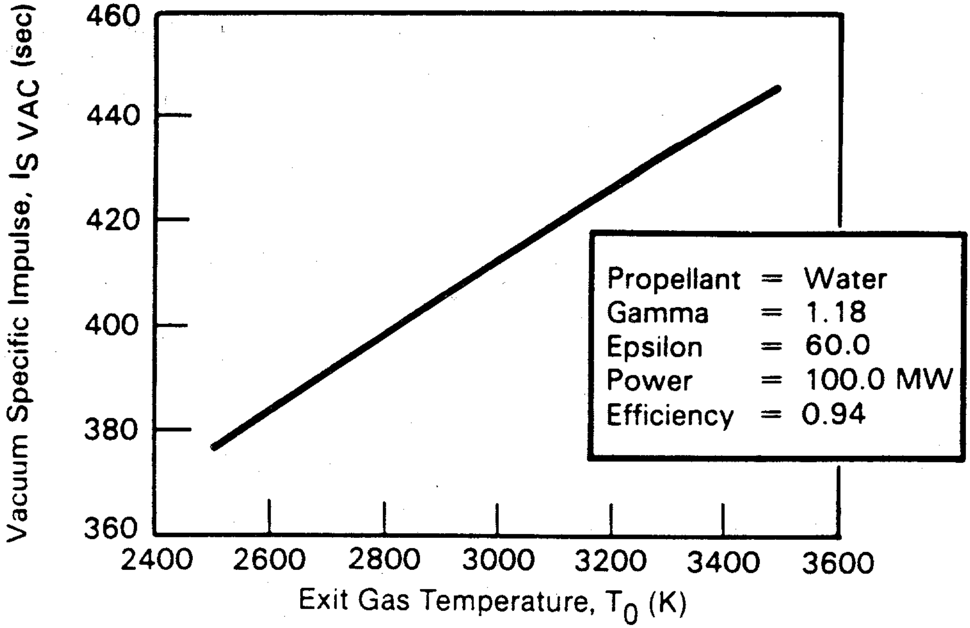


Figure 17. Water (Steam) Specific Impulse Variations With Exit Gas Temperature

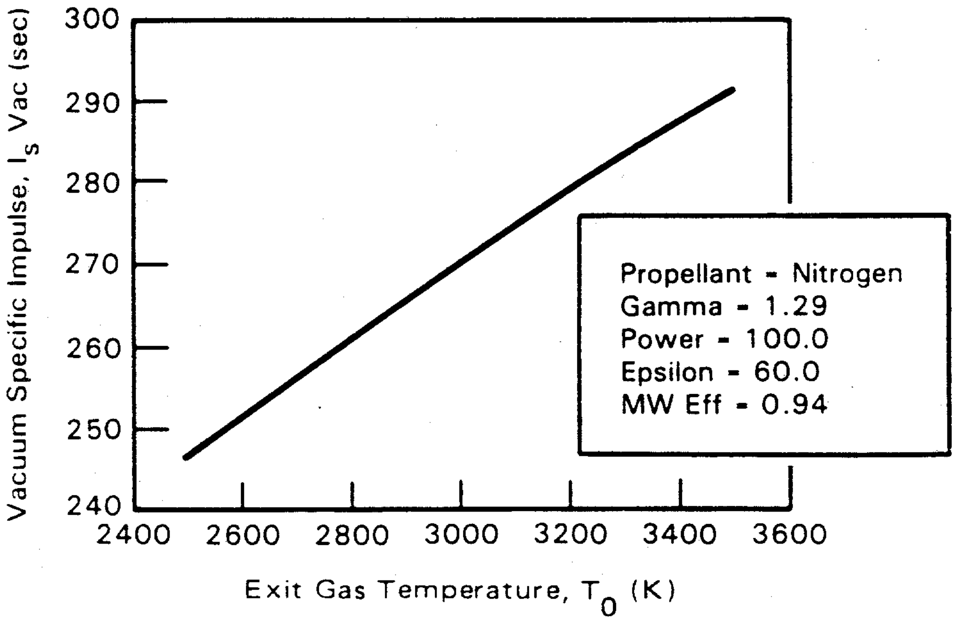
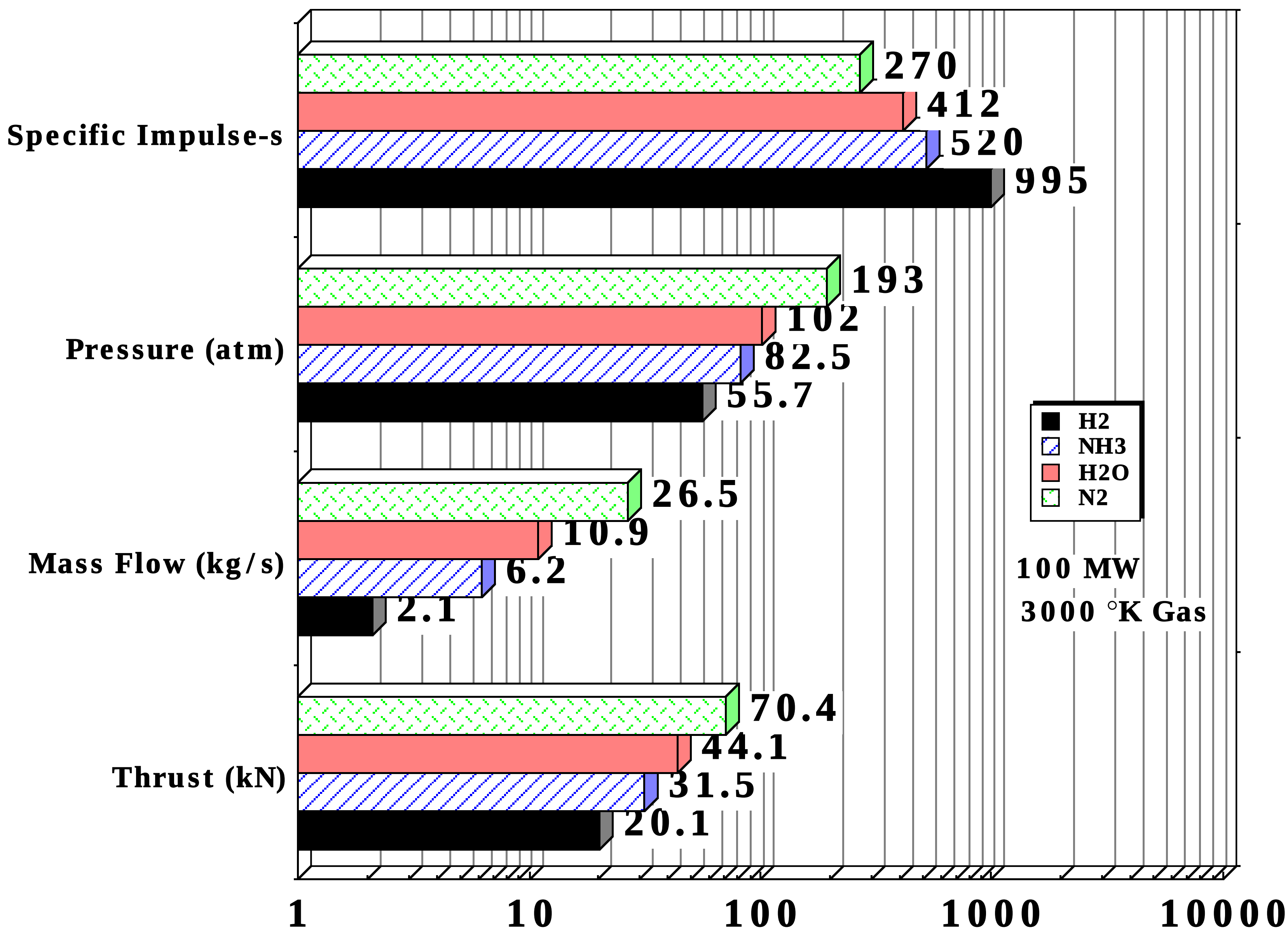
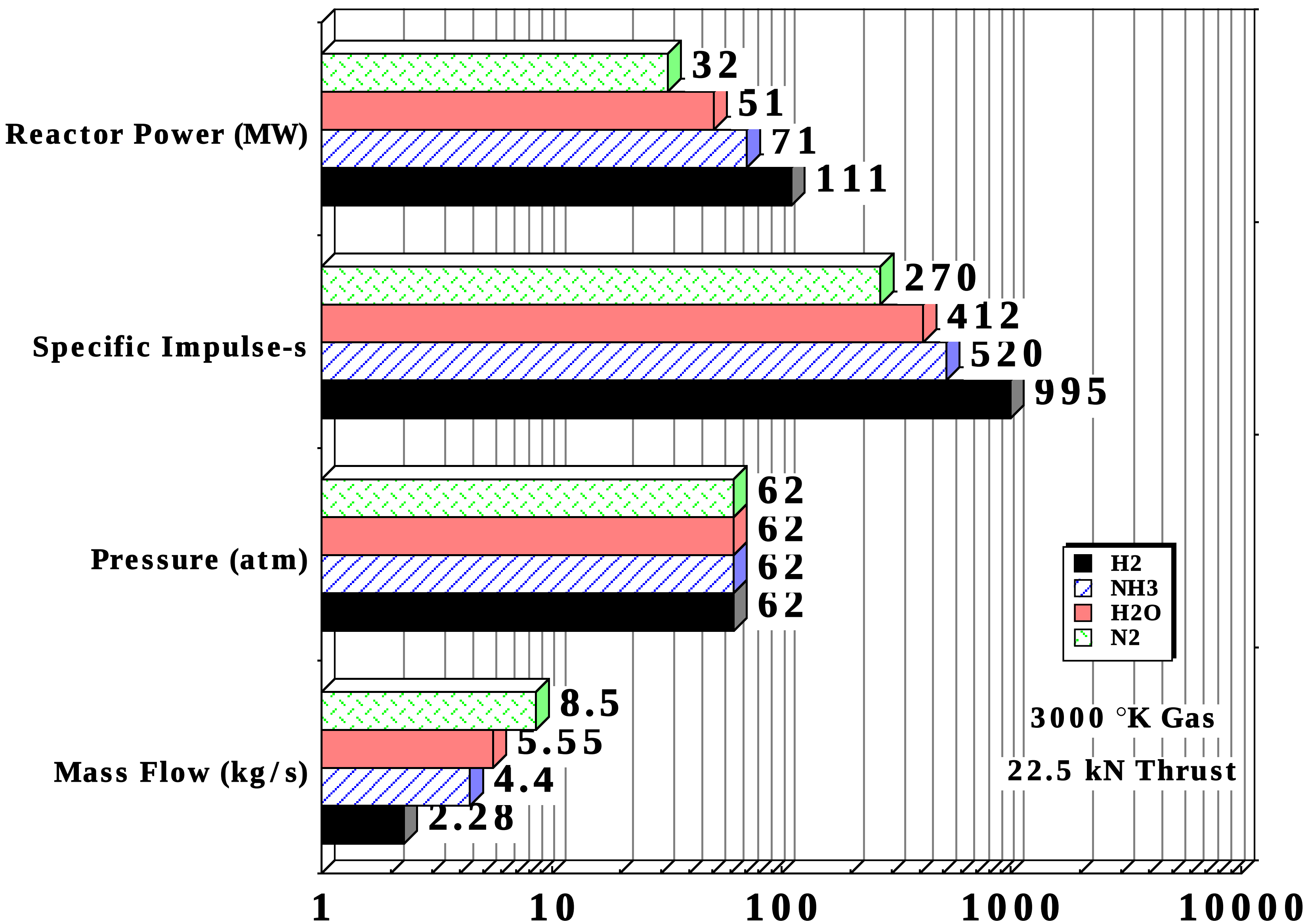


Figure 19. Nitrogen Specific Impulse Variations with Exit Temperature

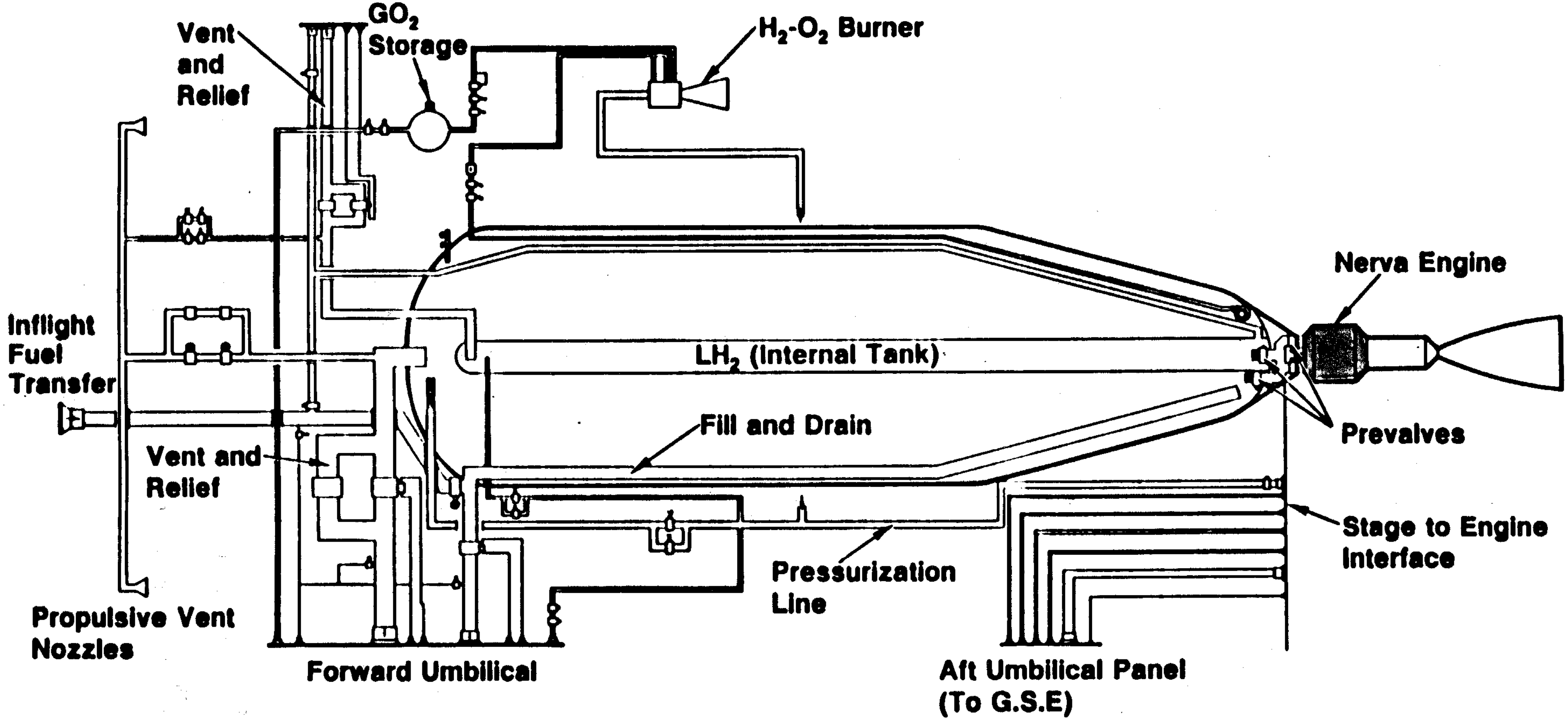
Comparison of Propellant Parameters for Nuclear Rockets



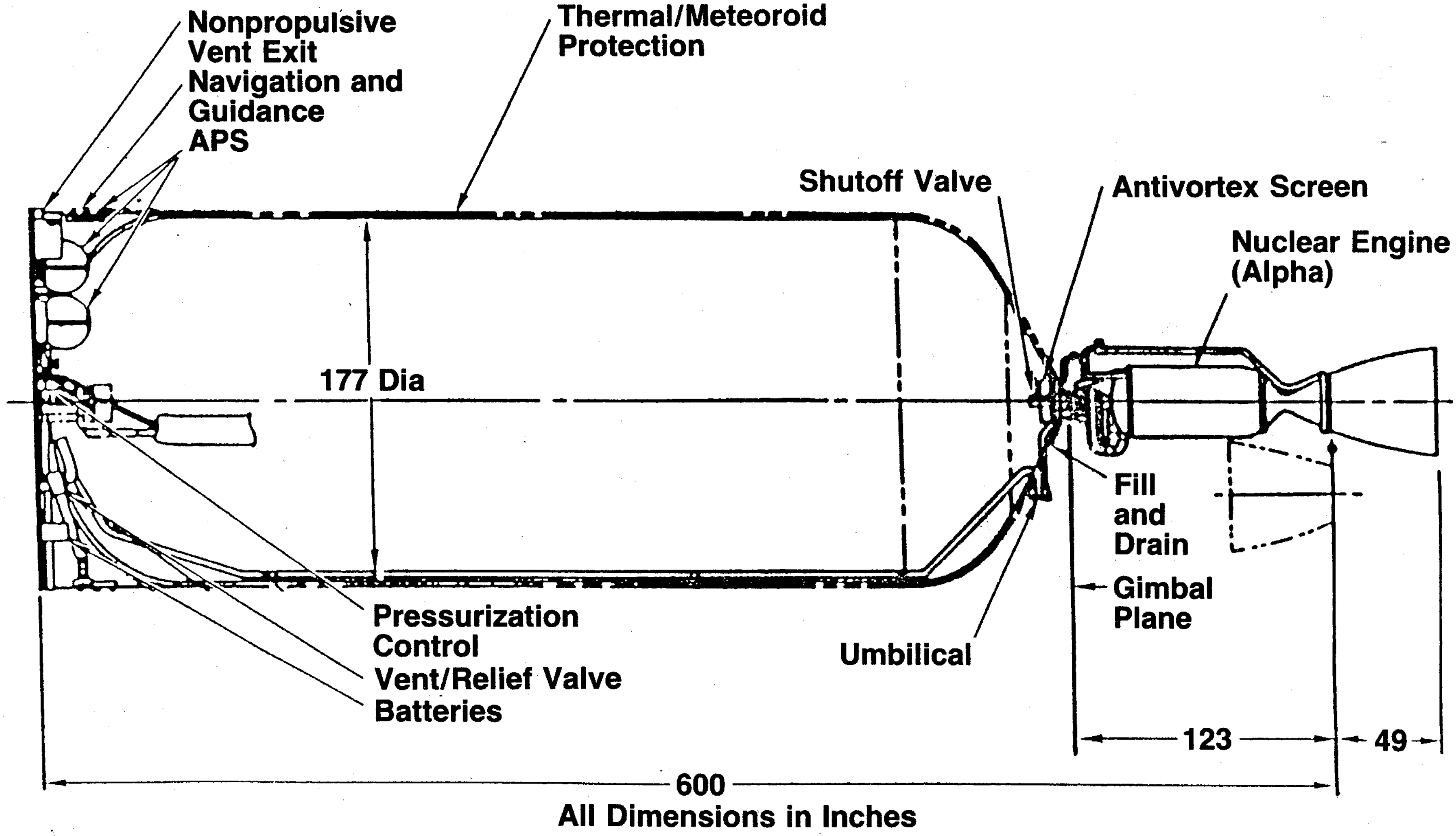
Comparison of Propellant Parameters for Nuclear Rockets



PROPULSION SCHEMATIC



SPACE SHUTTLE LAUNCHED REUSABLE ORBIT TRANSFER



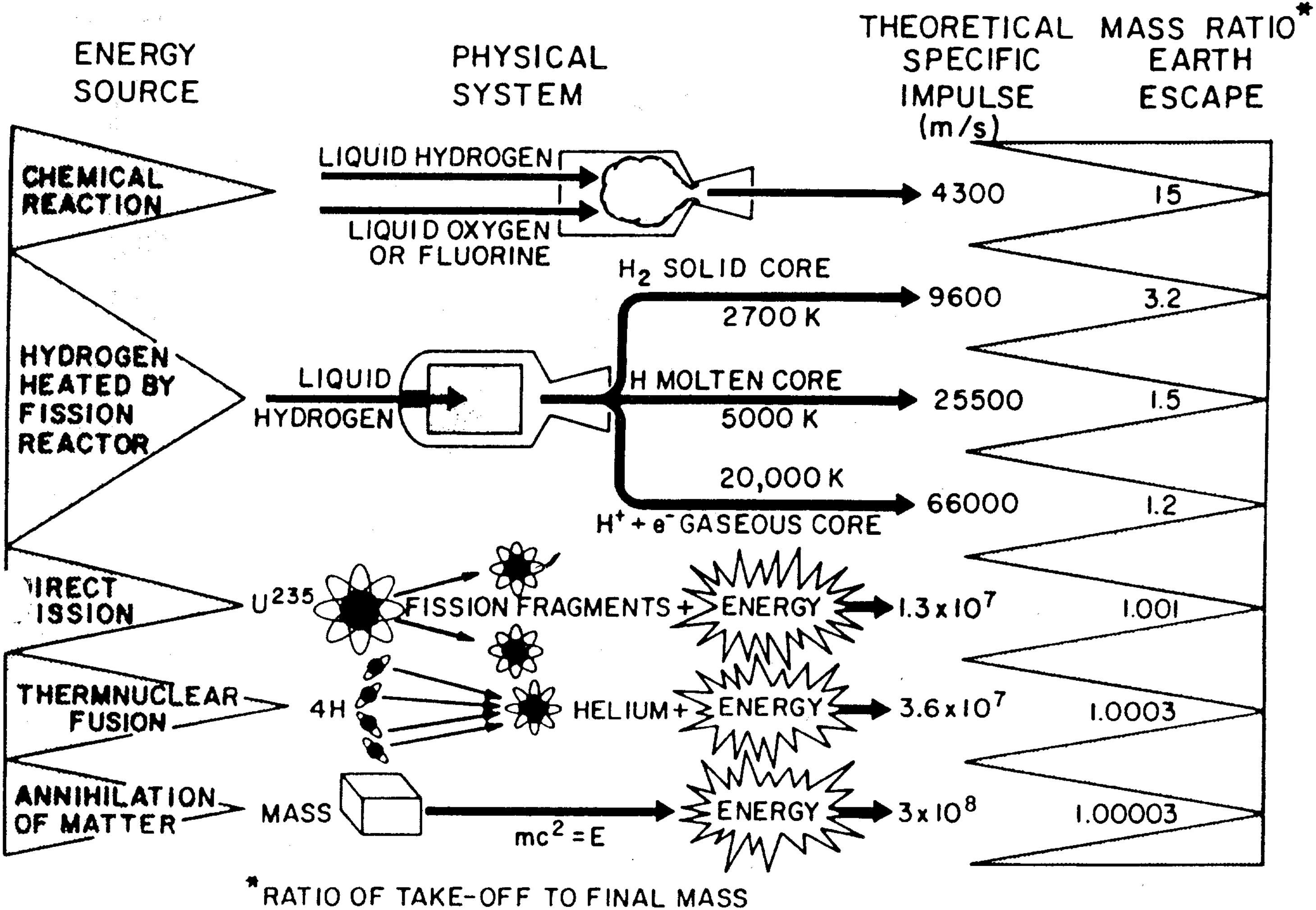
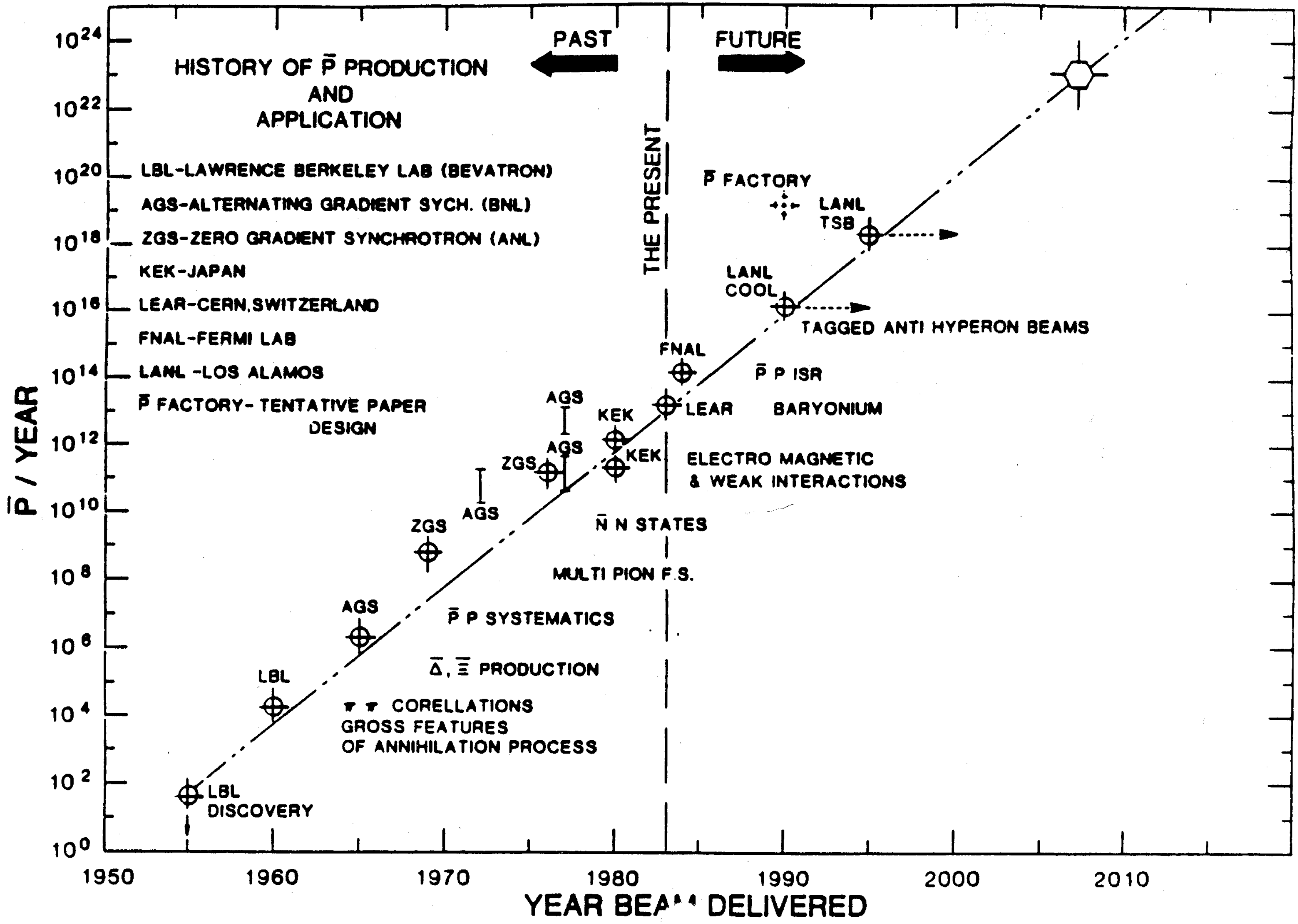


Fig. 10.3 Propulsion performance for various energy sources. *After J. M. Taub, UC-33.*



PAST
FUTURE
HISTORY OF P̄ PRODUCTION
AND
APPLICATION
LBL-LAWRENCE BERKELEY LAB (BEVATRON)
AGS-ALTERNATING GRADIENT SYCH. (BNL)
ZGS-ZERO GRADIENT SYNCHROTRON (ANL)
KEK-JAPAN
LEAR-CERN, SWITZERLAND
FNAL-FERMI LAB
LANL -LOS ALAMOS
P̄ FACTORY- TENTATIVE PAPER
DESIGN
THE PRESENT
P̄ FACTORY
LANL
TSB
LANL
COOL
TAGGED ANTI HYPERON BEAMS
FNAL
P̄ P ISR
LEAR
BARYONIUM
AGS
KEK
AGS
KEK
ZGS
ELECTRO MAGNETIC
& WEAK INTERACTIONS
AGS
N̄ N STATES
ZGS
MULTI PION F.S.
AGS
P̄ P SYSTEMATICS
Δ̄, Ξ̄ PRODUCTION
LBL
π π CORELLATIONS
GROSS FEATURES
OF ANNIHILATION PROCESS
LBL
DISCOVERY
P̄ / YEAR
10^0
10^2
10^4
10^6
10^8
10^10
10^12
10^14
10^16
10^18
10^20
10^22
10^24
1950
1960
1970
1980
1990
2000
2010
YEAR BEAM DELIVERED

Dual Mode Nuclear Power System
(LANL Version)

- **Open Cycle-**

  Provides high thrust, high I_{sp} propulsion for fast human transport

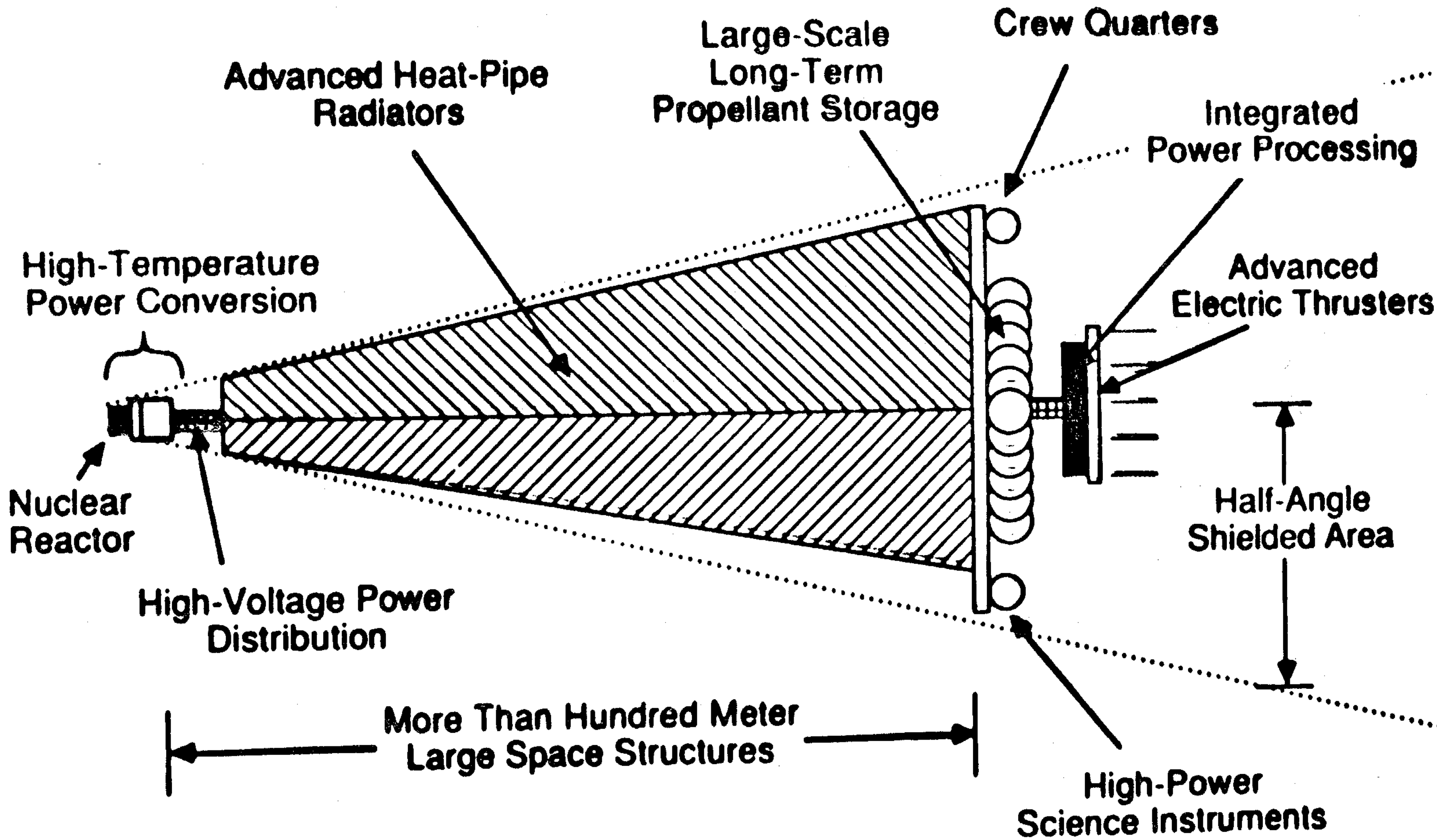
- **Closed Cycle-**

  Provides electric power for thrusters for slower cargo transport, for vehicle house keeping power, and the electric thrusters can be used with the open cycle for even faster human missions

- **Utilizes tested, proven technology from the ROVER/NERVA programs**

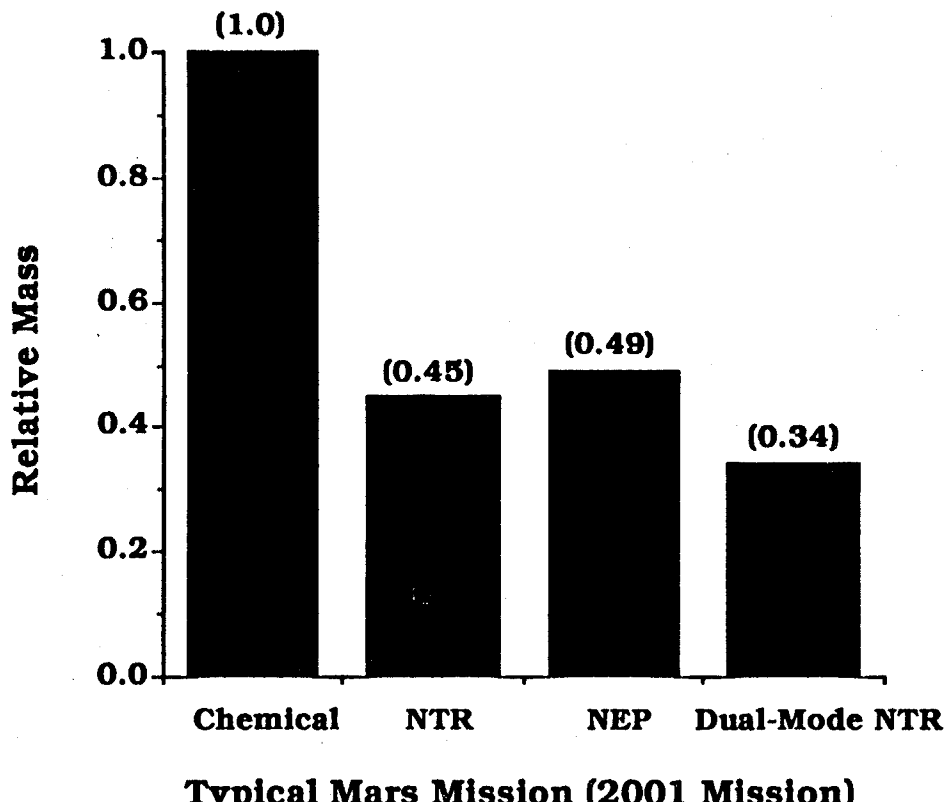
Principal Technologies

Odyssey: A Vision of Human Exploration



(Concept Drawing Only)

Propulsion System Comparison
(all propulsive braking)



Extracted from Manned Mars Mission Workshop Proceedings, 1985

1. **report by Eagle Engineering, p.37, vol.1**
2. **report by Los Alamos National Laboratory, p. 129, vol. 1**

Propulsion System Performance May Be Characterized by Specific Power and Specific Energy

University of Wisconsin