901

N91-28215

SPACE TRANSPORTATION PROPULSION TECHNOLOGY SYMPOSIUM

FUTURISTIC SYSTEMS

SOLAR & NUCLEAR ELECTRIC PROPULSION

DAVE BYERS

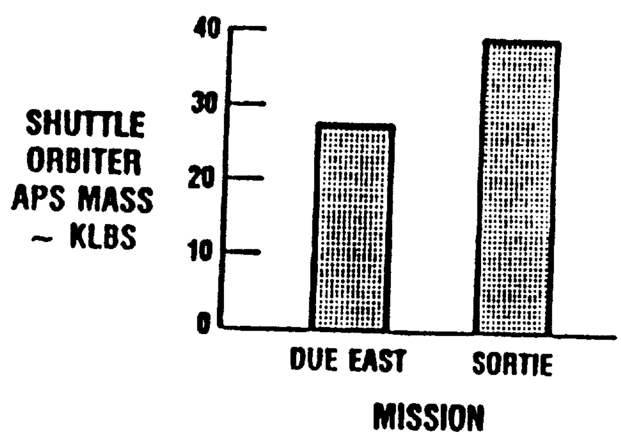
NASA LeRC

JUNE 27, 1990

AGENDA

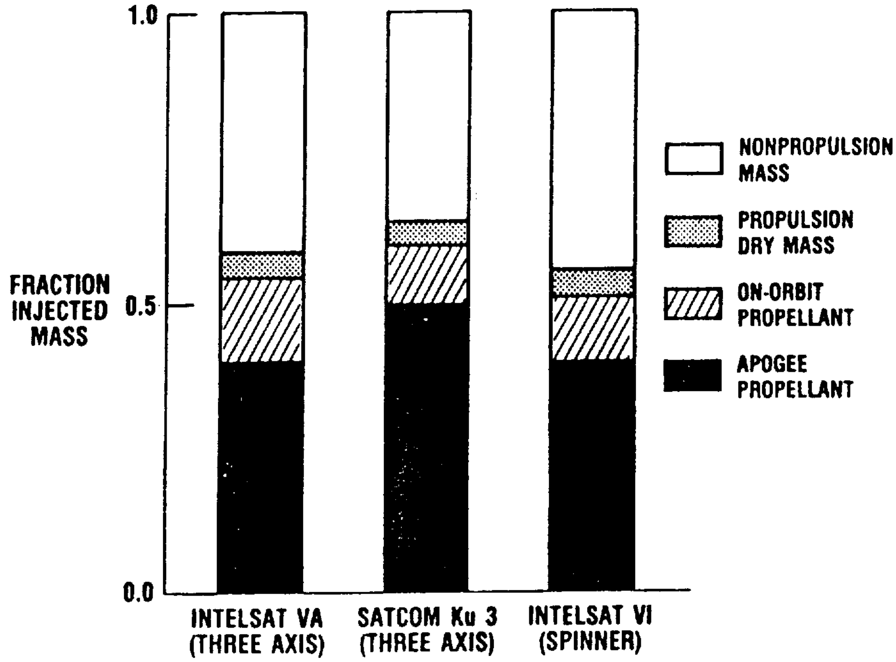
- IN-SPACE PROPULSION IMPACTS
- ELECTRIC PROPULSION
  - CHARACTERISTICS
  - CONSTRAINTS
  - CONCEPTS
  - STATUS
- MISSION IMPACTS OF ELECTRIC PROPULSION
- SUMMARY

APS OFFERS MAJOR LEVERAGE

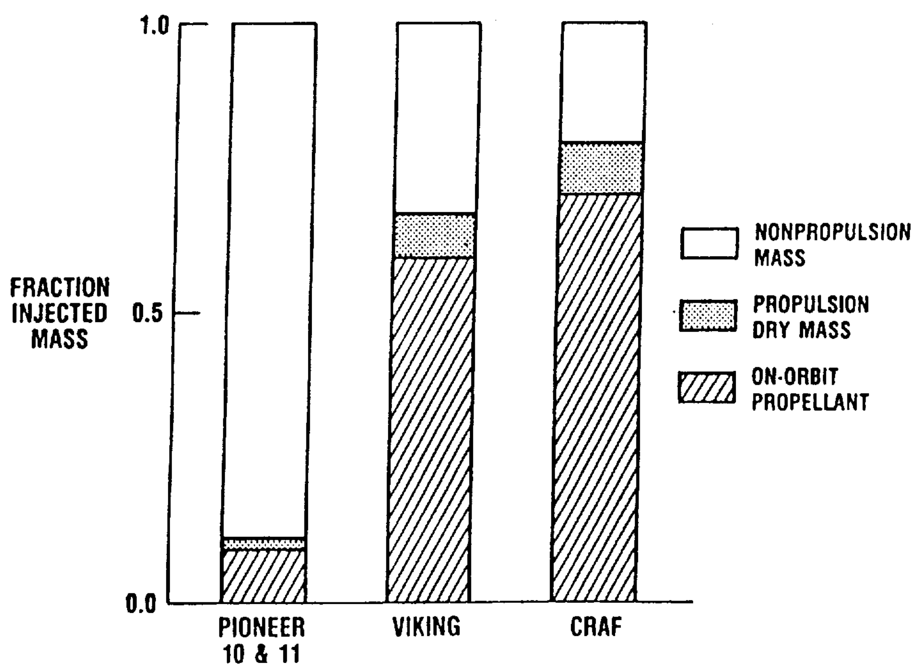


- APS MASS IS 11.4% TO 18.6% OF ORBITER

GEOSYNCHRONOUS TRANSFER ORBIT MASS FRACTIONS FOR RECENT COMMUNICATIONS SATELLITES



PLANETARY SPACECRAFT INJECTED MASS FRACTIONS



IN-SPACE PROPULSION IMPACTS

- PREDOMINANT MASS OF PAYLOADS NOW DELIVERED BY ETO AND ST VEHICLES

  - 12-19% OF ORBITER
  - 55-65% OF GTO
  - 70-80% OF PLANETARY

- IN-SPACE PROPULSION FRACTIONAL IMPACTS WILL INCREASE WITH INCREASED MISSION OBJECTIVES:

  - "DELTA V"
  - DURATIONS
  - PAYLOADS

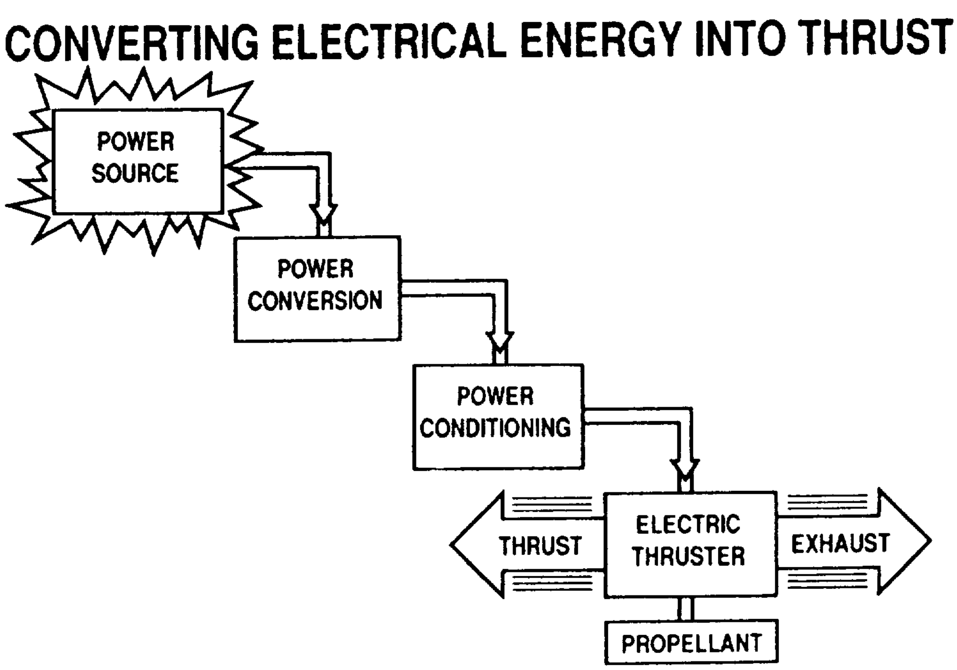
IN-SPACE PROPULSION IMPACTS

NON-INCREMENTAL IMPROVEMENTS IN FRACTIONAL

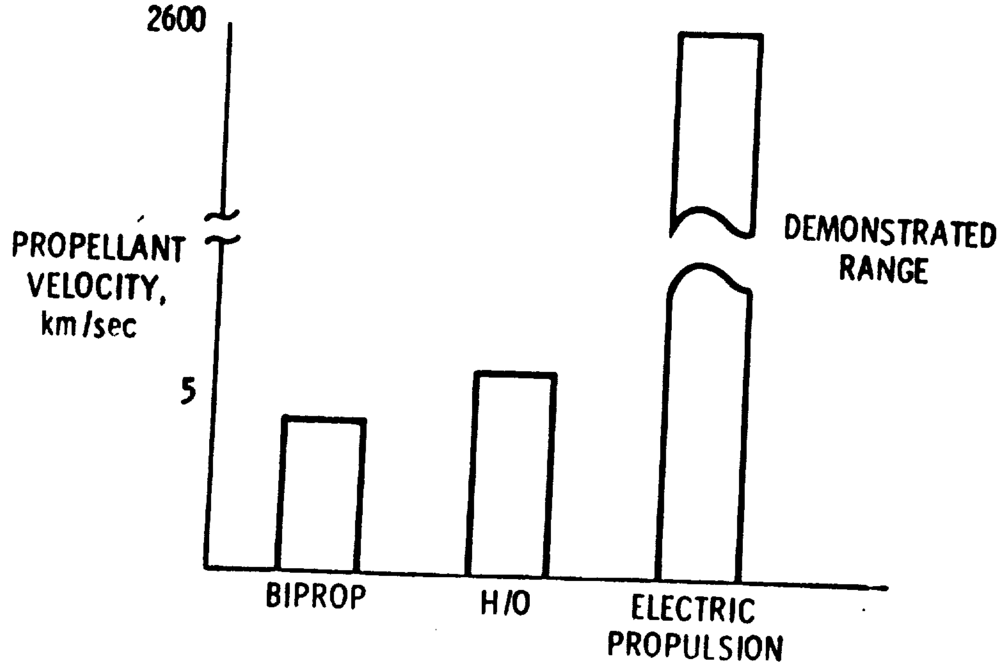
IMPACT OF IN-SPACE PROPULSION WILL

REQUIRE MAJOR TECHNOLOGY DELTA'S

ELECTRIC PROPULSION



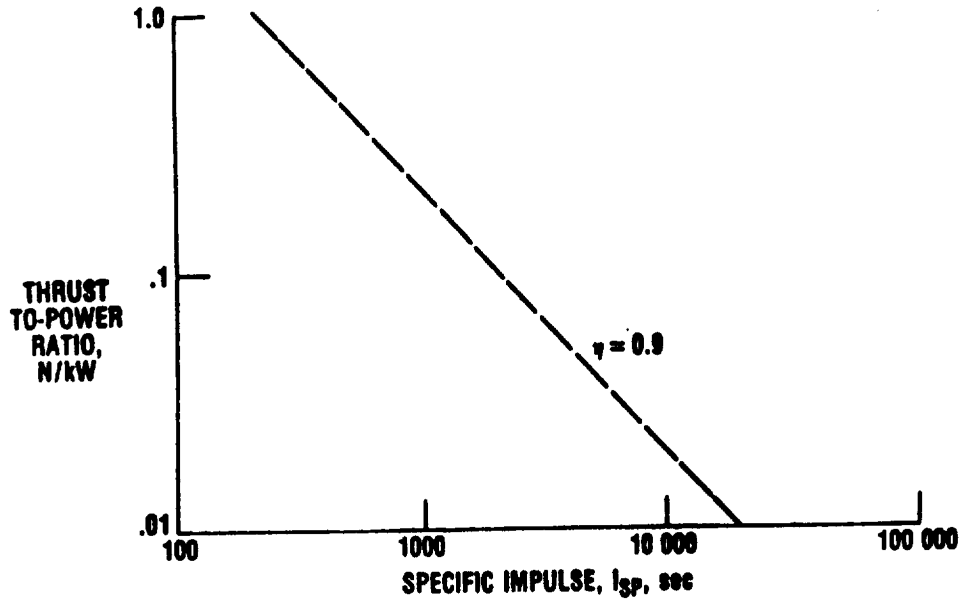
ELECTRIC PROPULSION ENABLES PROPELLANT VELOCITIES BEYOND FUNDAMENTAL LIMITS OF CHEMICAL SYSTEMS



Electric Propulsion

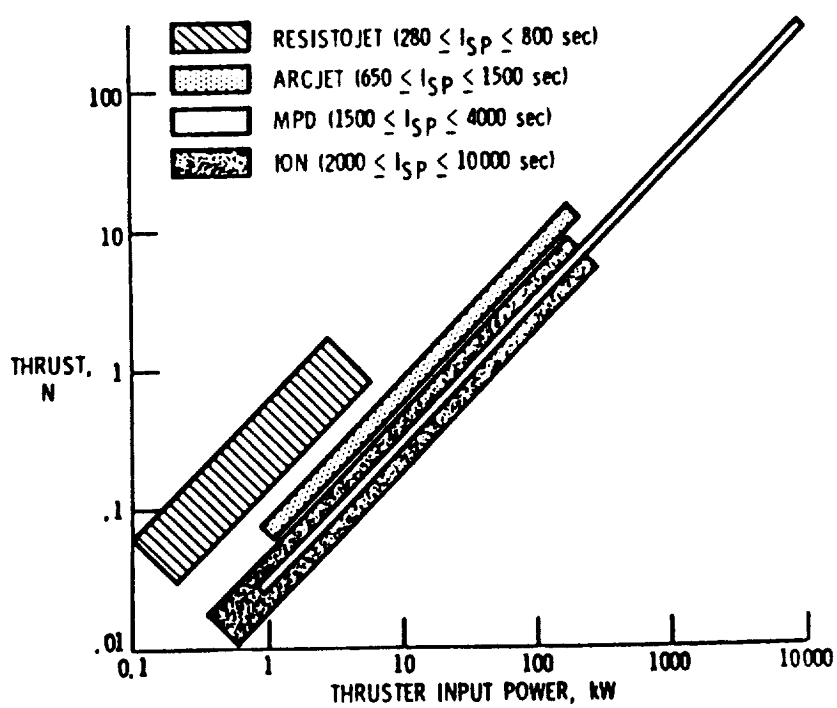
The limits of achievable propellant velocity of chemical propulsion systems are shown along with the range of propellent velocities demonstrated with electric propulsion. With storable and H/O propellant the achievable upper values of propellant velocities are about 3700 and 5000 m/sec, respectively. The upper limit electric propulsion reflects tests in 1970 of a hydrogen ion thruster operated at about 70 KV. There is no fundamental subrelativistic propellant velocity with electric propulsion. The ability to achieve high propellant velocities is the fundamental charateristic of electric propulsion which has led to extensive R&T programs in a number of countries. Other key characteristics, which can potentially be of extreme benefit, are low thrust, precise impulse bit control (a quality exploited on the Navy NOVA satellites for precise ephemeris control (orbit constant to 0.01 seconds) and many propellant options including earth storables and inert gases.

THRUST-TO-POWER RATIO VS SPECIFIC IMPULSE



THRUST VS POWER FOR ELECTRIC PROPULSION

η_{PPU} = 0.9



ELECTRIC PROPULSION

AFTER EQUATIONS ARE MASSAGED

$$\frac{\text{THRUST}}{\text{POWER}} = \frac{2\eta}{gI_{sp}}$$

THEREFORE!

- INCREASED FUEL EFFICIENCY (Isp) GAINED AT EXPENSE OF REDUCED THRUST FOR A GIVEN POWER

- ELECTRIC PROPULSION INHERENTLY RESULTS IN LOW ACCELERATIONS AND IS USEFUL ONLY FOR IN-SPACE APPLICATIONS

ELECTRIC PROPULSION

POWER OPTIONS

SEPS

- PHOTOVOLTAIC
  - SPACE STATION FREEDOM
    = 40W/KG (@ 1AV)
  - APSA
    = 130w/kg (@ 1AV)

NEPS

- SP-100 REACTOR + CONVERSION
  - STATIC (TO 100 KW)
    = 30W/KG
  - DYNAMIC (GROWTH)
    = $\geqslant$ 100 W/KG

- SPACE STATION FREEDOM PROGRAM PROVIDING LARGE ARRAY EXPERIENCE AND INFRASTRUCTURES
- APSA PROJECT DEVELOPING LIGHTWEIGHT ARRAYS
- SP-100 REACTOR ONLY ACTIVE POWER REACTOR PROGRAM
  - STATIC & DYNAMIC CONVERSION TECHNOLOGIES UNDER DEVELOPMENT

ELECTRIC PROPULSION

CONCEPT SUMMARY

ELECTRIC PROPULSION

THREE CLASSES OF CONCEPTS

<u>ELECTROTHERMAL</u>

- GAS-HEATED BY RESISTORS AND/OR ARCS AND EXPANDED THROUGH A NOZZLE
  - RESISTOJETS
  - ARCJETS
  - PULSED

<u>ELECTROSTATIC</u>

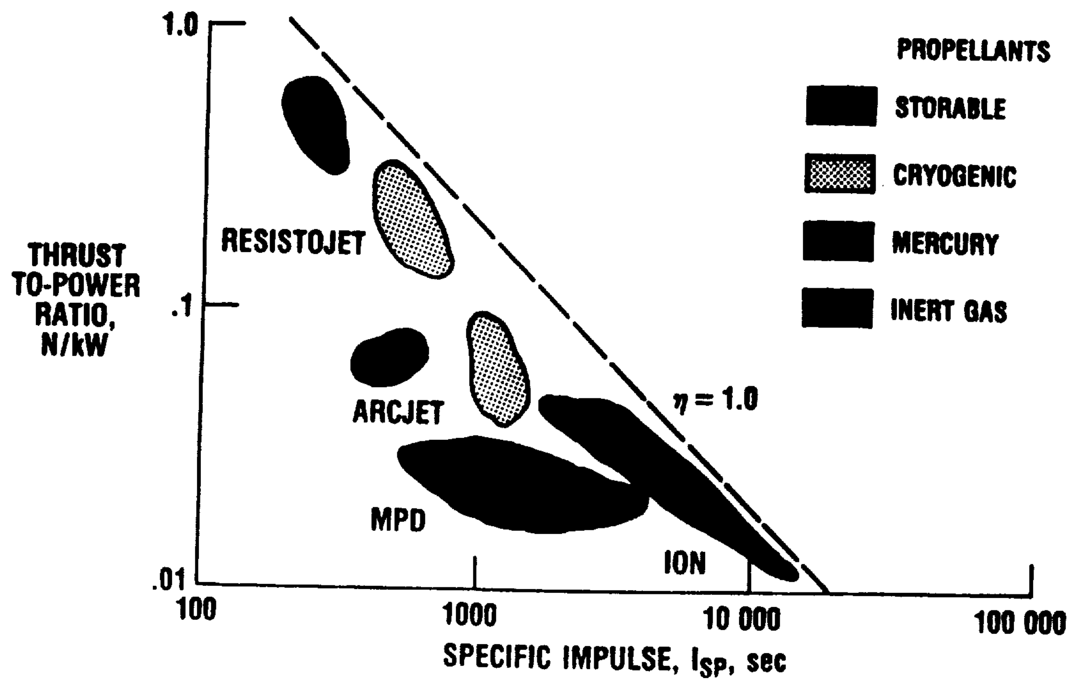
- IONS ELECTROSTATICALLY ACCELERATED
  - ION

<u>ELECTROMAGNETIC</u>

- PLASMAS ACCELERATED BY ELECTRIC AND MAGNETIC FIELDS
  - MPD
  - PULSED PLASMA

THRUST-TO-POWER RATIO VS SPECIFIC IMPULSE

$\eta_{PPU} = 0.9$



ELECTRIC PROPULSION

STATUS

ELECTRIC PROPULSION

STATUS

77 SPACE TESTS CONDUCTED

TYPE		ORIGIN	
ELECTROTHERMAL	33	CHINA	1
ELECTROSTATIC	16	JAPAN	7
ELECTROMAGNETIC	28	USSR	21
		USA	48
	77		77

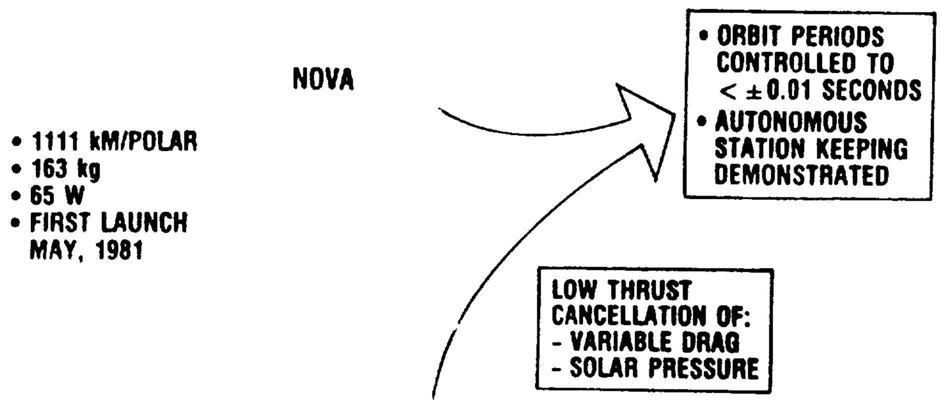
(1) SCHREIB, R., AIAA PAPER NO. 88-0777, MARCH 1988

STATUS

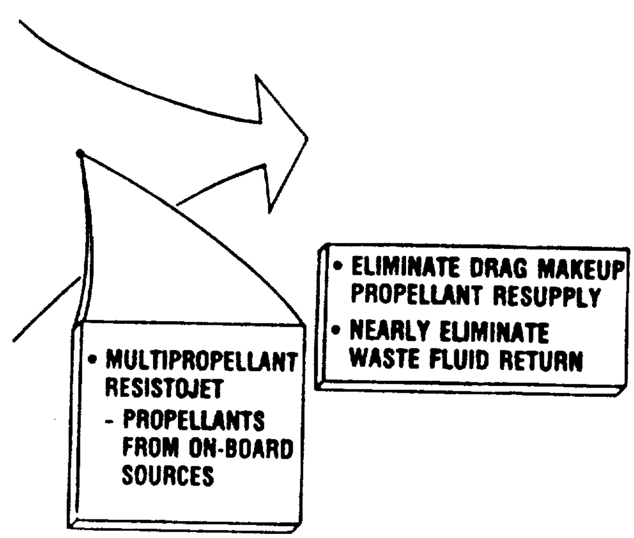
LOW POWER (ORBIT ADJUST) SYSTEM OPERATIONAL/BASELINED

- NOVA
- US COMMUNICATION SATELLITES
- SPACE STATION

ELECTRIC PROPULSION PROVIDES PRECISION ORBITS FOR NOVA SATELLITES



ELECTRIC PROPULSION SELECTED FOR IOC SPACE STATION DRAG MAKEUP PROPULSION



ELECTRIC PROPULSION STATUS SUMMARY

PROPULSION

- MANY CONCEPTS EVALUATED AND FLIGHT TESTED
  - ONLY TWO SPACE TESTS OVER 1KW
- LOW POWER SYSTEMS OPERATIONAL AND BASELINED
- PRIMARY PROPULSION CONCEPTS IN R&T PHASES

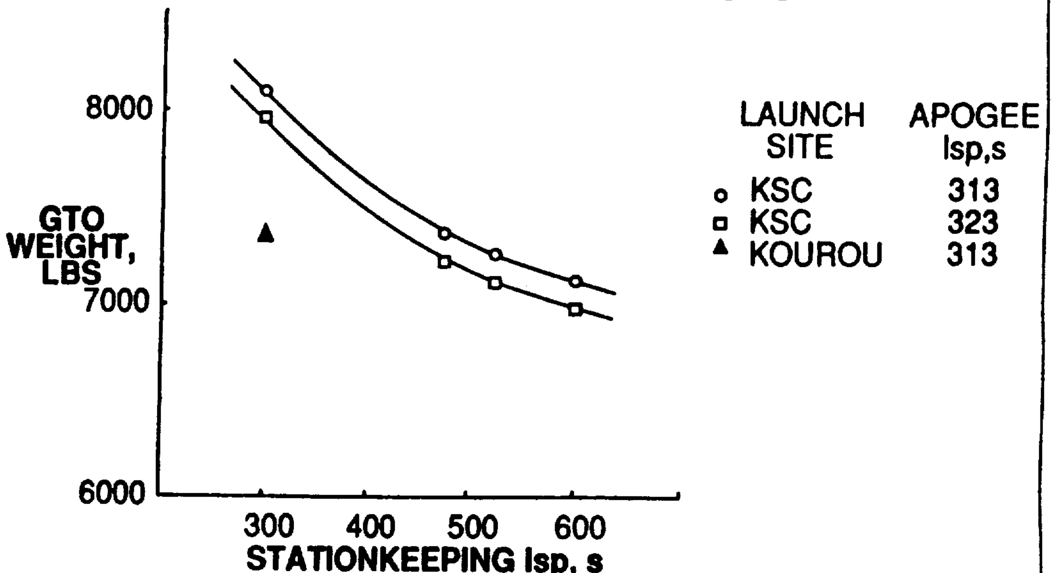
POWER

- SAFE ARRAY STRUCTURE DEMONSTRATED IN SPACE
- LIGHTWEIGHT ARRAYS UNDER DEVELOPMENT
- SP-100 REACTOR PROGRAM ON-GOING
- MULTI-MEGAWATT REACTORS UNDER STUDY

ELECTRIC PROPULSION

MISSION IMPACTS

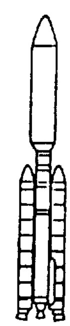
ON-BOARD PROPULSION IMPACTS(1)



ADVANCED STATIONKEEPING AND APOGEE PROPULSION
- **REDUCED GTO REQUIREMENTS**
- **MITIGATED LAUNCH SITE IMPACTS**
- **INCREASED LEVERAGE FOR LONG LIFE SATELLITES**

(1) 15 YEAR GEO LIFE, 3500 LBS EOL WEIGHT

ADVANCED ORBIT TRANSFER PROPULSION IMPACTS(1)

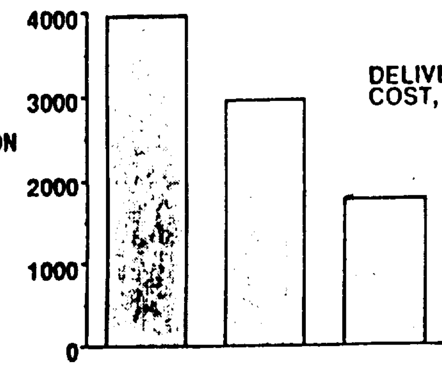


	ELECTRIC	CHEMICAL
MLEO, Lbs	10307	37782
TRIP TIME, DAYS	180	1
LAUNCHER	DELTA II	TITAN IV
OTV	SEPS	IUS

ELECTRIC PROPULSION OFFERS 3X MLEO REDUCTION

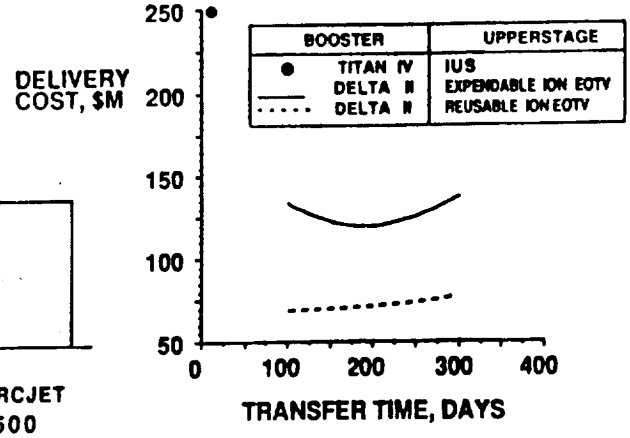
(1) AIAA 89-2496 "Electric Orbit Transfer Vehicle - A Military Perspective", S. Rosen and J. Sloan /AFSD. 5250 Lbs to GEO

LEO→MEO→LEO (1)



PROPULSION	N_2H_4	NTO/N_2H_4	ARCJET
ISP,S	220	310	500
TRANSFER TIME,DAYS	0.2	0.2	40
POWER,KW	–	–	5

LEO TO GEO (2)



ADVANCED PROPULSION OFFERS GREAT BENEFITS FOR E-O FREE FLYERS

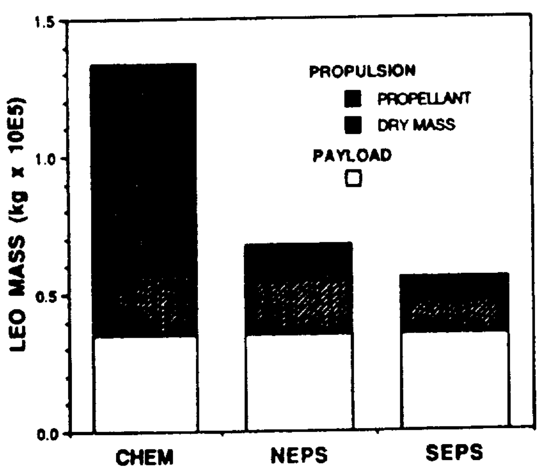
(1) EARTH OBSERVATION SYSTEM
(DRY MASS, 9x10³ KG)
(POWER, 8 kW)

(2) DATA FROM AEROSPACE CORP.
(PAYLOAD, 2380 KG)

SPACE PROPULSION TECHNOLOGY DIVISION NASA Lewis Research Center

CARGO VEHICLE PROPULSION

LUNAR MISSION (1)
(LEO → LMO → LEO)

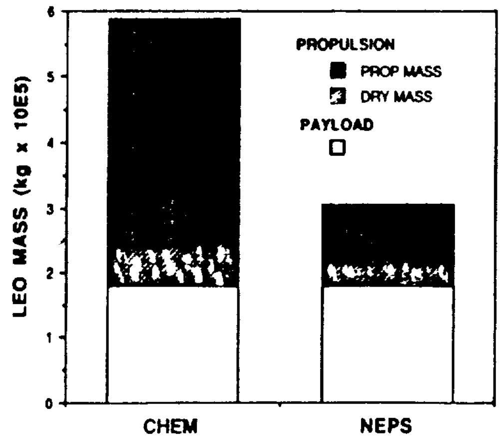


PROPULSION	CHEM	NEPS	SEPS
o Power, MW	–	1	0.3
o Trip Time, Days	10	257	769
o Aerobraking	Yes	No	No

ELECTRIC PROPULSION PROMISES SIGNIFICANT LEO MASS REDUCTIONS

CARGO VEHICLE PROPULSION

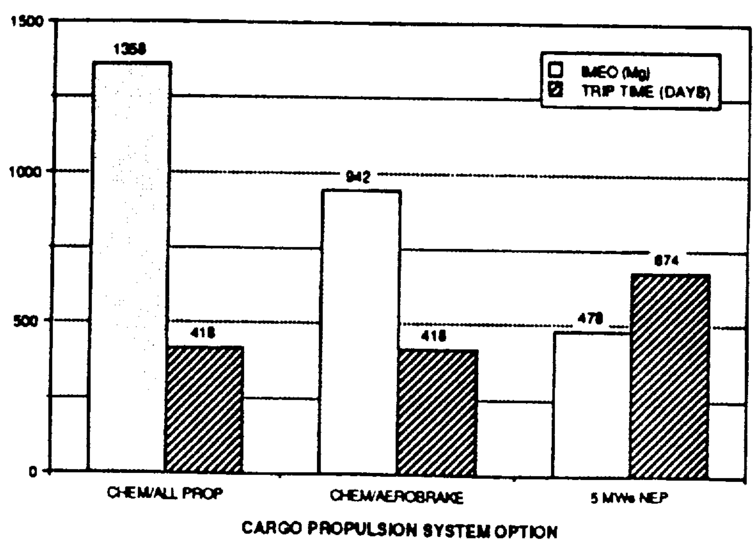
MARS MISSION
(LEO → LMO)



PROPULSION	CHEM	NEPS
o Power, MW	-	4
o Trip Time, Days	210	700
o Aerobraking	Yes	No

ELECTRIC PROPULSION PROMISES SIGNIFICANT LEO MASS REDUCTIONS

NASA LEWIS RESEARCH CENTER



IMEO and One Way Trip Time Comparison of Potential Transportation Systems for Mars Cargo Delivery. Vehicles Deliver 222 Mg from LEO to Phobos.

HUMAN EXPLORATION INITIATIVE OFFICE

SOLAR & NUCLEAR PROPULSION

SUMMARY

ETO & ST VEHICLE PAYLOADS OFTEN PREDOMINATELY IN-SPACE PROPULSION

- MITIGATED SIGNIFICANTLY ONLY BY NEW IN-SPACE PROPULSION

ELECTRIC PROPULSION STATUS

- LOW POWER APPLICATIONS IN PLACE AND GROWING
- HIGH POWER APPLICATIONS REQUIRE PROPULSION AND POWER DEVELOPMENTS

ELECTRIC PROPULSION IMPACTS:

- 1000 LBS GTO REDUCTIONS
- 2 TO 3X REDUCTIONS IN MLEO FOR MAJOR MISSIONS
- TRIP TIME PENALTY/BENEFITS VERY MISSION SPECIFIC
- GREAT EXPANSIONS OF LAUNCH WINDOWS

PRESENTATION 1.4.2

NUCLEAR THERMAL PROPULSION