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LOW THRUST PROPULSION

INTEGRATED TECHNOLOGY PLAN

EXTERNAL REVIEW

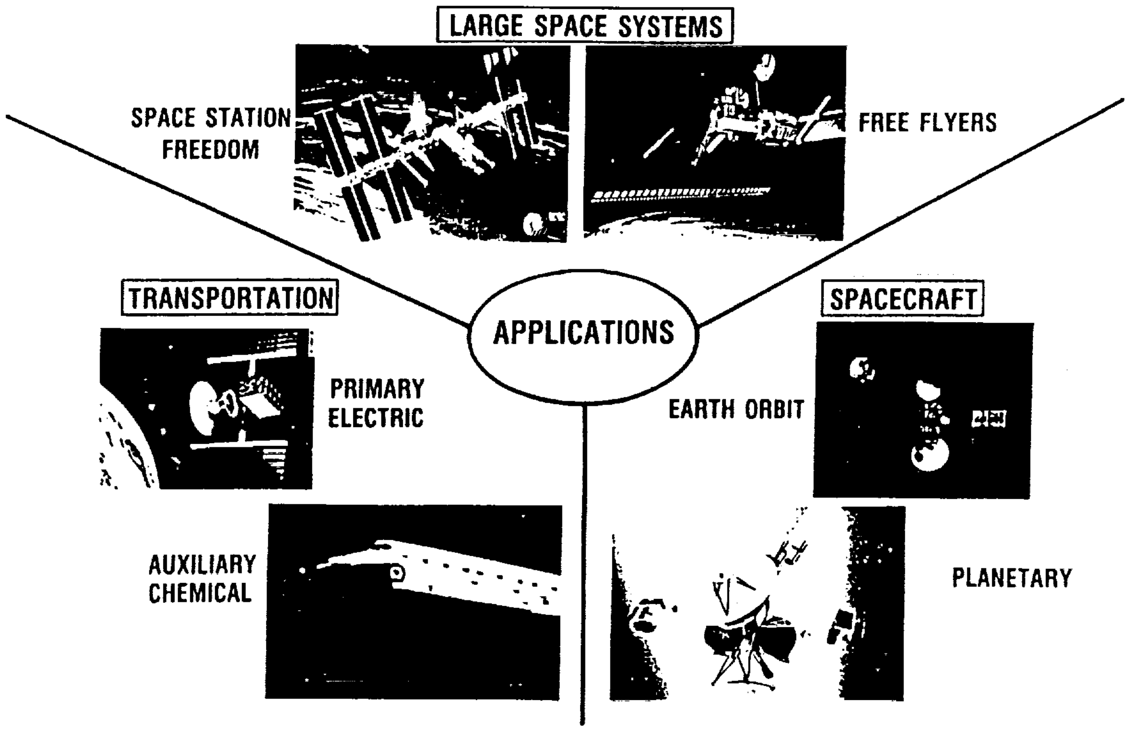
JUNE 26, 1991

LOW THRUST PROPULSION

AGENDA

- APPLICATIONS
- OBJECTIVE
- STATE-OF-ART MISSION IMPACTS
  - EARTH SPACE
  - PLANETARY
- PROGRAM
  - APPROACH
  - CONTENT
    - = "STRATEGIC"
    - = "CURRENT"
- ADVANCED TECHNOLOGY BENEFITS
- SUMMARY

LOW THRUST PROPULSION



SPACE PROPULSION TECHNOLOGY DIVISION

NASA Lewis Research Center

LOW THRUST PROPULSION

OBJECTIVE

PROVIDE TECHNOLOGIES FOR A BROAD RANGE OF FUTURE SPACE SYSTEMS

- SPACECRAFT
  - —PLANETARY
  - —EARTH-ORBITAL
- LARGE SPACE SYSTEMS
  - —SPACE STATION
  - —TENDED
- VEHICLES
  - —EARTH-TO-ORBIT
  - —ORBIT TRANSFER

CD-90-47460

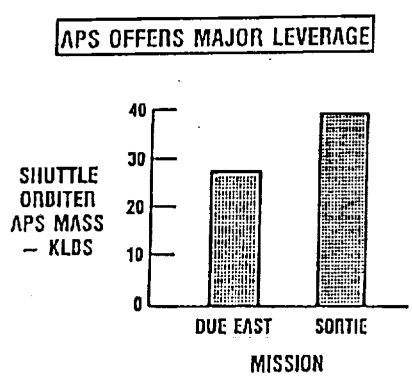
STATE-OF-ART

LOW THRUST PROPULSION

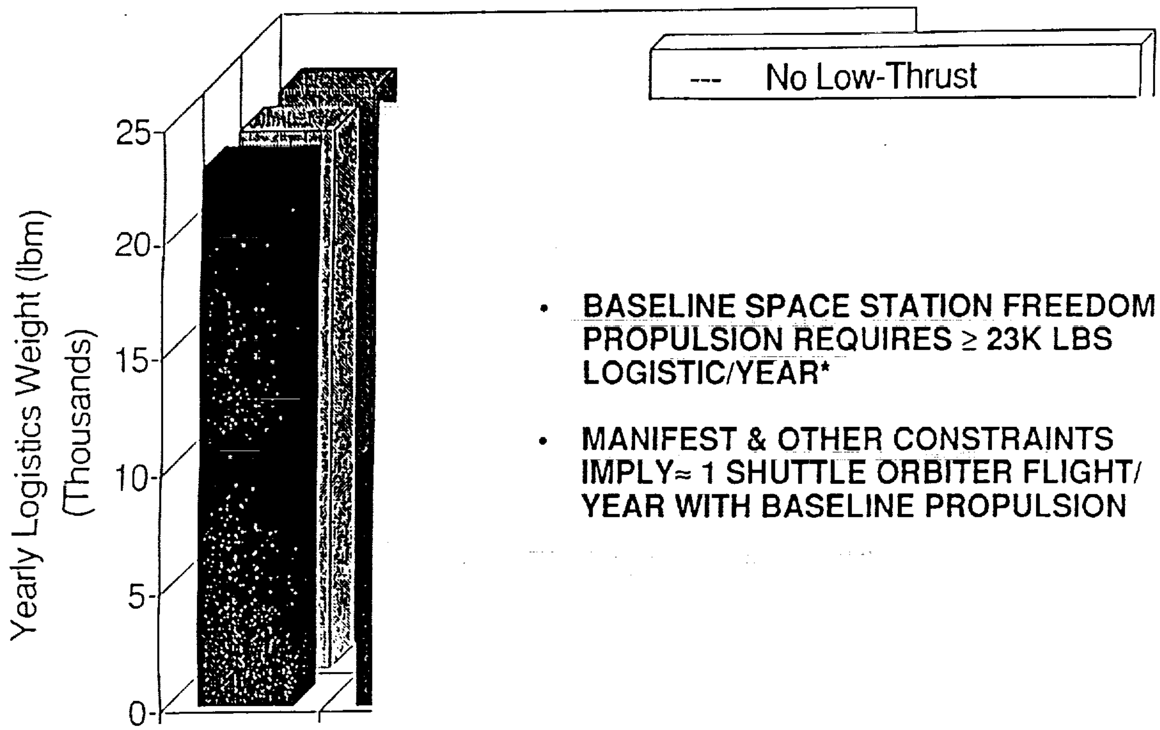
MISSION IMPACTS

- LOW EARTH ORBIT (LEO):
    - ORBITER APS
    - SPACE STATION
- GEOSYNCHRONOUS (GEO):
    - TRANSFER ORBIT (GTO)
    - SATELLITES
- PLANETARY

LOW THRUST PRIMARY AND AUXILIARY PROPULSION



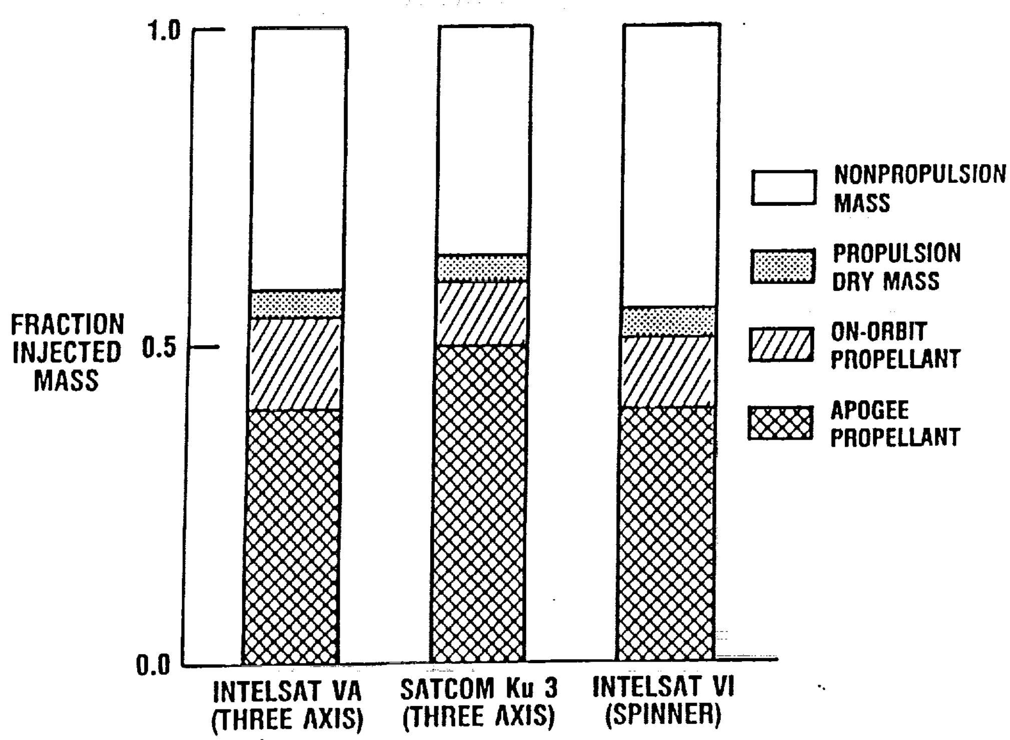
- APS MASS IS 11.4% TO 10.6% OF ORBITER



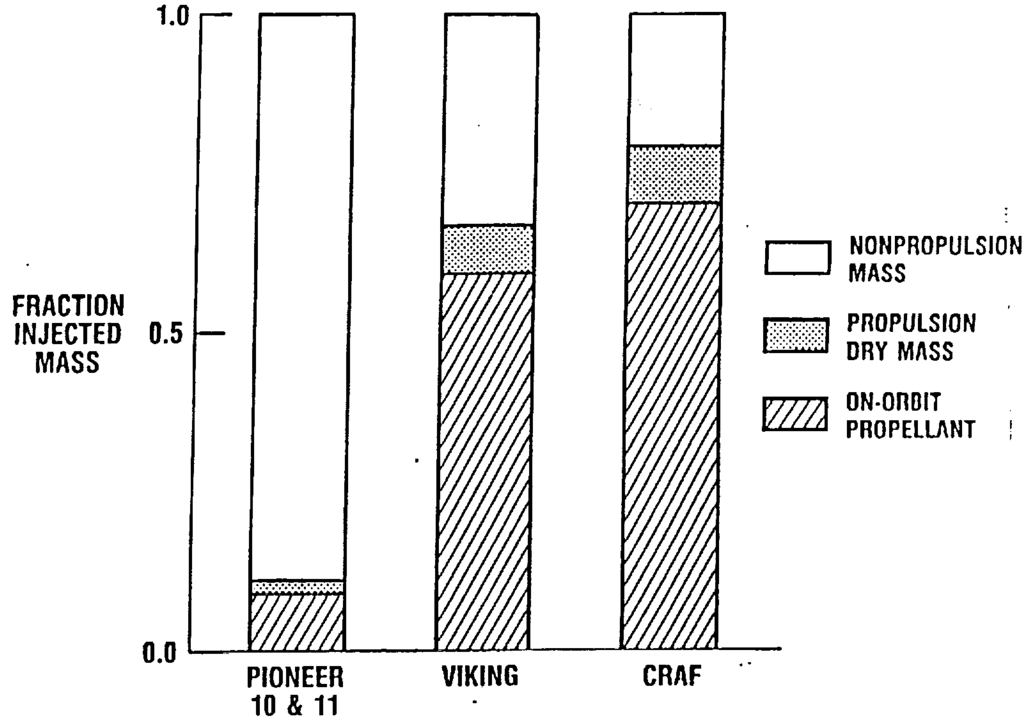
- BASELINE SPACE STATION FREEDOM PROPULSION REQUIRES ≥ 23K LBS LOGISTIC/YEAR*
- MANIFEST & OTHER CONSTRAINTS IMPLY≈ 1 SHUTTLE ORBITER FLIGHT/ YEAR WITH BASELINE PROPULSION

* AVERAGED OVER 11 YEAR CYCLE

GEOSYNCHRONOUS TRANSFER ORBIT MASS FRACTIONS FOR RECENT COMMUNICATIONS SATELLITES



PLANETARY SPACECRAFT INJECTED MASS FRACTIONS



STATE -OF-ART

LOW THRUST PROPULSION

MISSION IMPACTS

LEO

- 12-19% OF ORBITER DELVERED MASS (> 50% OF PAYLOAD)
- ~ ORBITER/YEAR FOR SPACE STATION LOGISTICS

GEO

- 55-65% OF MASS DELIVERED TO GTO
- ON-ORBIT LIFE LIMITER

PLANETARY

- OVER 80% OF INJECTED MASS FOR PLANNED MMII MISSIONS

IN-SPACE FRACTIONAL MISSION PENALTIES REDUCED ONLY BY IMPROVED IN-SPACE PROPULSION

LOW THRUST PRIMARY & AUXILIARY PROPULSION

MANAGEMENT STRUCTURE

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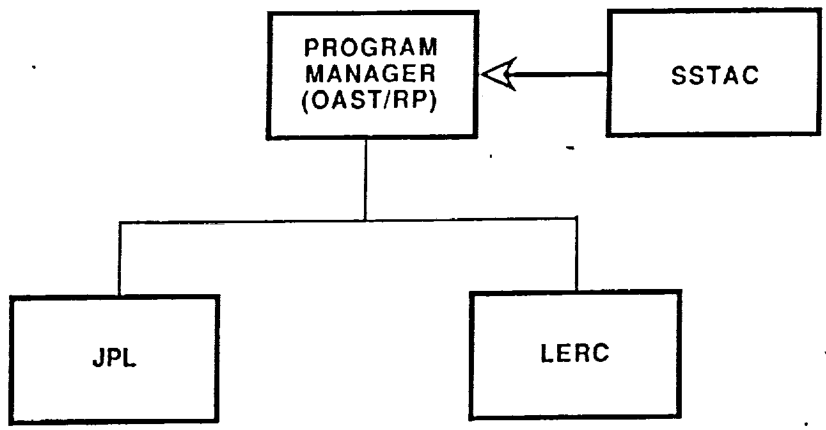
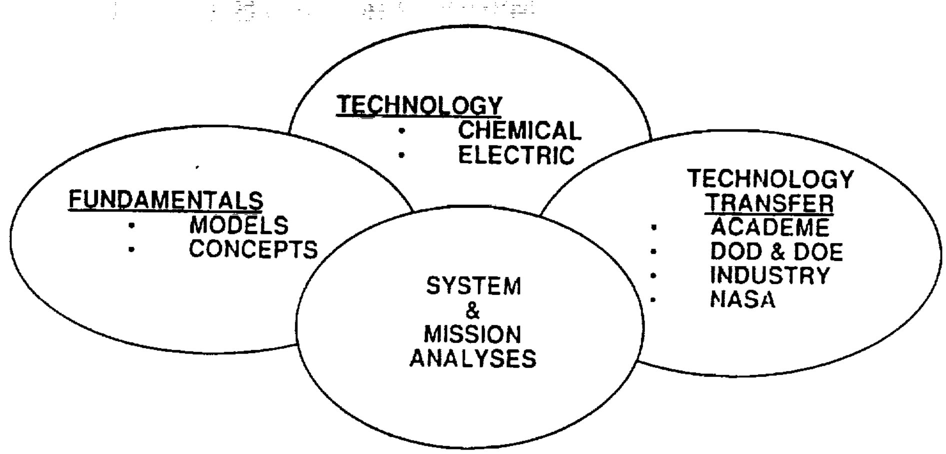


LOW THRUST PROPULSION

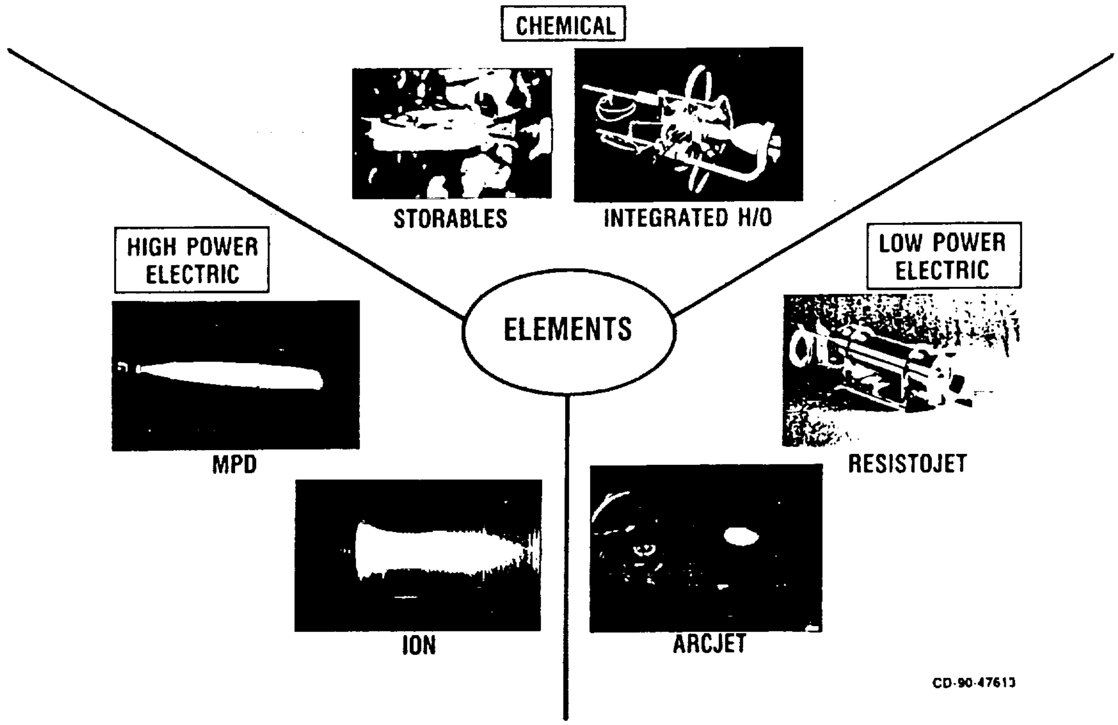
PROGRAMMATIC APPROACH



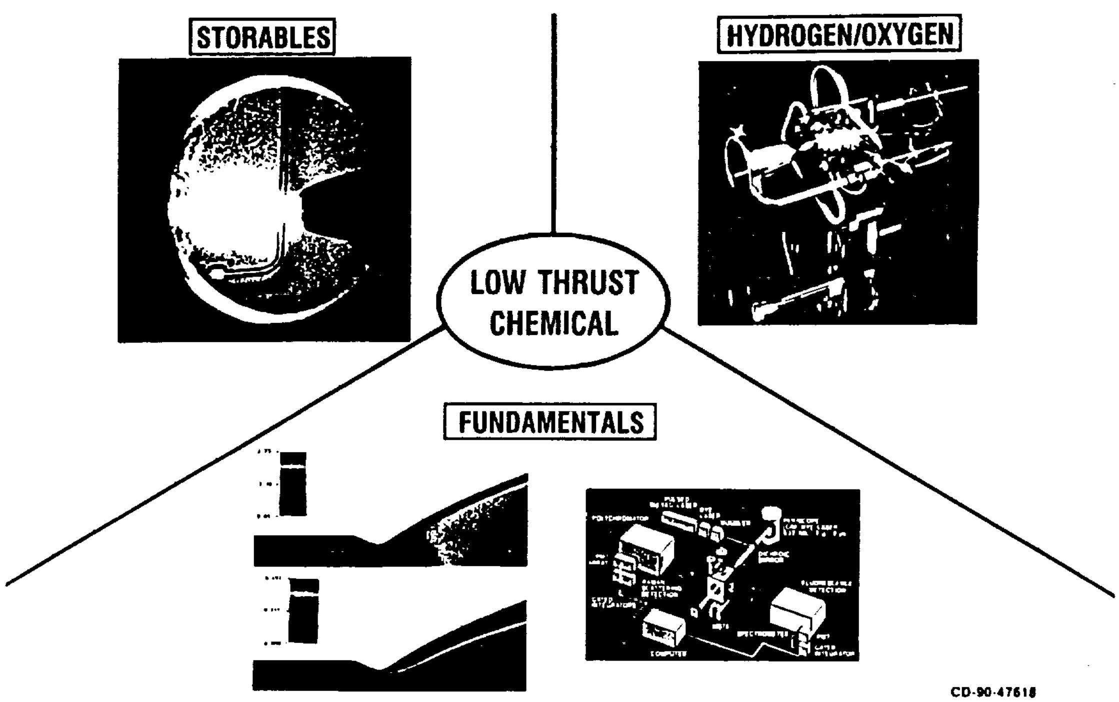
PROGRAM STRUCTURED TO SUPPORT:

- TECH TRANSFER & APPLICATIONS VERSUS TIME
- MAJOR BENEFITS FOR FUTURE MISSIONS

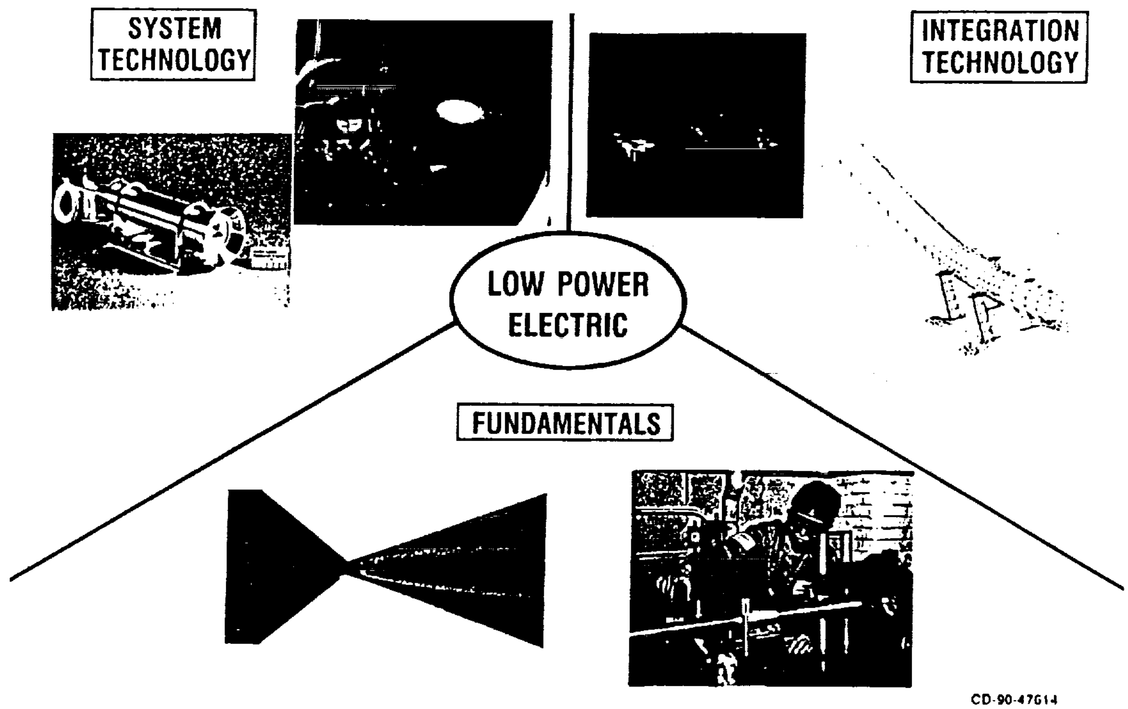
LOW THRUST PROPULSION



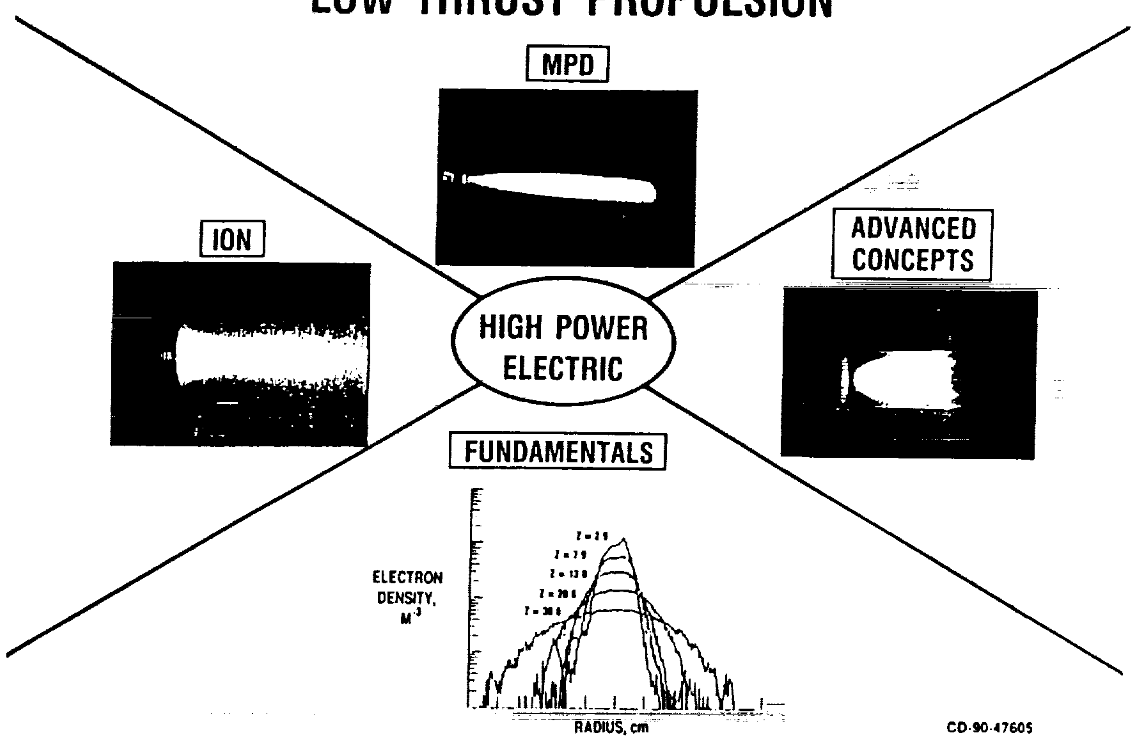
LOW THRUST PROPULSION



LOW THRUST PROPULSION



LOW THRUST PROPULSION

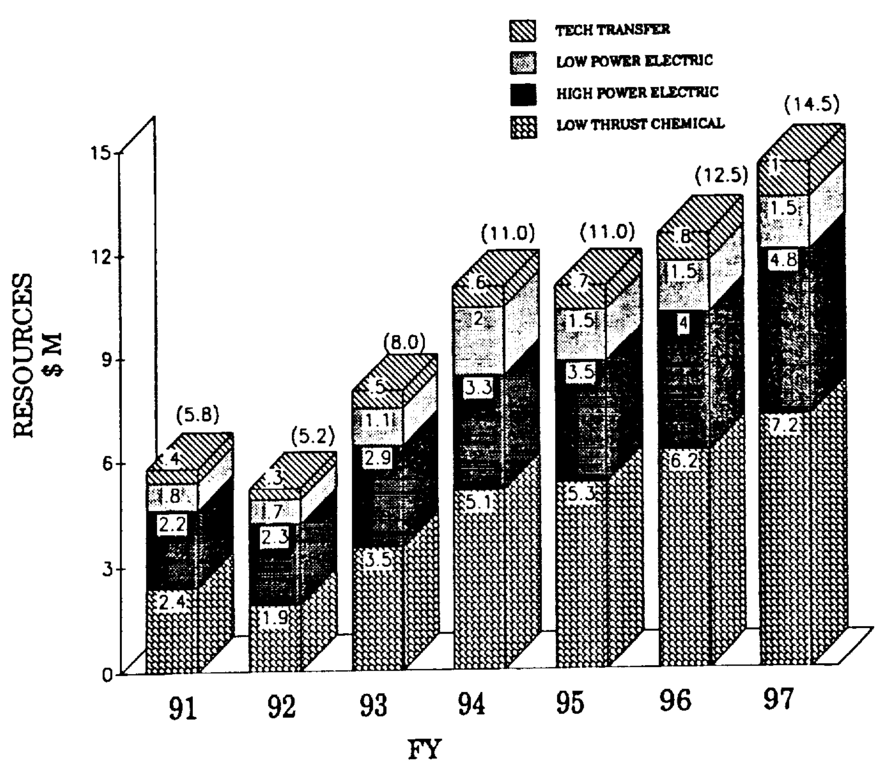


TECHNOLOGY TRANSFER

MECHANISMS/EFFORTS

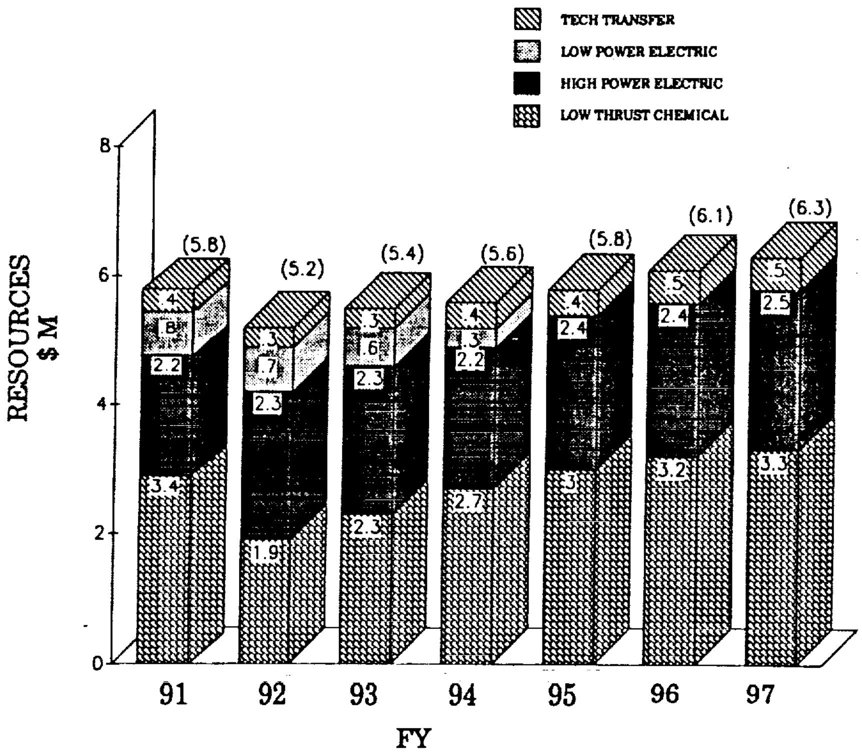
- SPACE ACT AGREEMENT (NASA/INDUSTRY)
  - FOUR IN PLACE
  - THREE IN NEGOTIATION
- BAILMENT AGREEMENT (NASA/INDUSTRY)
  - ONE IN PLACE
- MOA (INTRA AGENCY)
  - TWO IN PLACE
- "OUTREACH" (ACADEME & DOE)
  - FIVE ARCJET SYSTEMS PROVIDED
  - ION SYSTEMS IN FAB

LOW THRUST PROPULSION
" STRATEGIC " PROGRAM (1)



(1) ASSUMES PROPOSED NEP & DEEP SPACE PLATFORM PROPULSION FOCUSED PROGRAMS

LOW THRUST PROPULSION
" CURRENT " PROGRAM (1)



(1) ASSUMES PROPOSED NEP & DEEP SPACE PLATFORM PROPULSION FOCUSED PROGRAMS

LOW THRUST PROPULSION

"STRATEGIC" VERSUS "CURRENT" PROGRAM

LOW THRUST CHEMICAL

TECHNOLOGIES	PROGRAM "CURRENT"	PROGRAM "STRATEGIC"
EARTH-STORABLE		
NTO/MMH NTO/N_2H_4	• VALIDATE 100LBF ROCKET FOR MMII (1)	• VALIDATE 100LBF ROCKET FOR MMII • COMPLETE 15LBF ROCKET VALIDATION • APOGEE VERSION DEMO (1)
SPACE STORABLE LOX/N2H4 LOX/HC	• ROCKET DEMO	• ROCKET VALIDATION • VEHICLE APS ROCKET DEMO
INTEGRATED H/O		• RAD-COOLED ROCKET VALIDATION • VEHICLE APS PROGRAM INITIATED

"STRATEGIC" PROGRAM ENABLES AGGRESSIVE SPACE STORABLE AND INTEGRATED H/O LOW THRUST CHEMICAL PROGRAMS

(1) ASSUMED FOCUSED PROGRAM

LOW THRUST PROPULSION

"STRATEGIC" VERSUS "CURRENT" PROGRAM

LOW POWER ELECTRIC

TECHNOLOGIES	PROGRAM "CURRENT"	PROGRAM "STRATEGIC"
ARCJET >600s, 1-2kW <1KW & 2-5KW	• ROCKET VALIDATION	• ROCKET, PPU, & GASSIFIER VALIDATION • SYSTEM TECHNOLOGY VALIDATIONS
DERATED" ION	• THRUSTER DEMO	• THRUSTER/PPU DEVELOPMENT
"HALL THRUSTER"	• TECHNOLOGY EVALUATION	• TECHNOLOGY EVALUATION

"STRATEGIC" PROGRAM ENABLES SECOND GENERATION ARCJET AND STATIONKEEPING ION OPTIONS

LOW THRUST PROPULSION

"STRATEGIC" VERSUS "CURRENT" PROGRAM

HIGH POWER ELECTRIC (1)

TECHNOLOGIES	PROGRAM "CURRENT"	PROGRAM "STRATEGIC"
SEPS	• THRUSTER VALIDATION	• SYSTEM VALIDATIONS - THRUSTER - PPU - THERMAL & PROP. MGT. - INTERFACES • SYSTEM INTEGRATION INITIATED
NEPS (ROBOTIC)	• THRUSTER DEMO'S	• SYSTEM R&T INITIATED

"STRATEGIC" PROGRAM ENABLES SEP & ROBOTIC NEPS SYSTEM R&T

(1) MW CLASS NEPS FOCUSED PROGRAM ASSUMED

SPACECRAFT ON-BOARD PROPULSION (LERC, JPL)

- GOAL: PROVIDE DUAL-MODE (NTO/N_2H_4) PROPULSION FOR PLANETARY MISSIONS
- AUGMENTATION OBJECTIVE: [ASSURE DUAL MODE PROPULSION READINESS]
  - DEVELOP DUAL MODE HOT ROCKET
  - DEVELOP ADVANCED TANKAGE

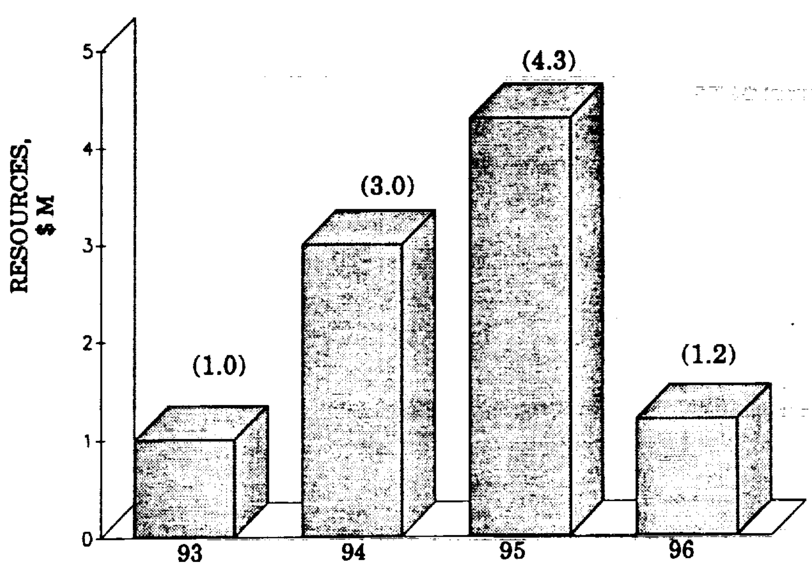
STATIONKEEPING PROPULSION (LERC, JSC)

- GOAL: PROVIDE INTEGRATED H/O & RESISTOJET SPACE STATION PROPULSION
- AUGMENTATION: [ENABLE LOGISTICS OPERATIONS BENEFITS FOR SPACE STATION]
  - DEVELOP H/O ROCKETS
  - DEVELOP LOW PRESSURE ELECTROLYSIS
  - DEVELOP SINGLE RESISTOJET FOR H_2O & WASTE GAS

AUXILIARY PROPULSION (JSC, LERC)

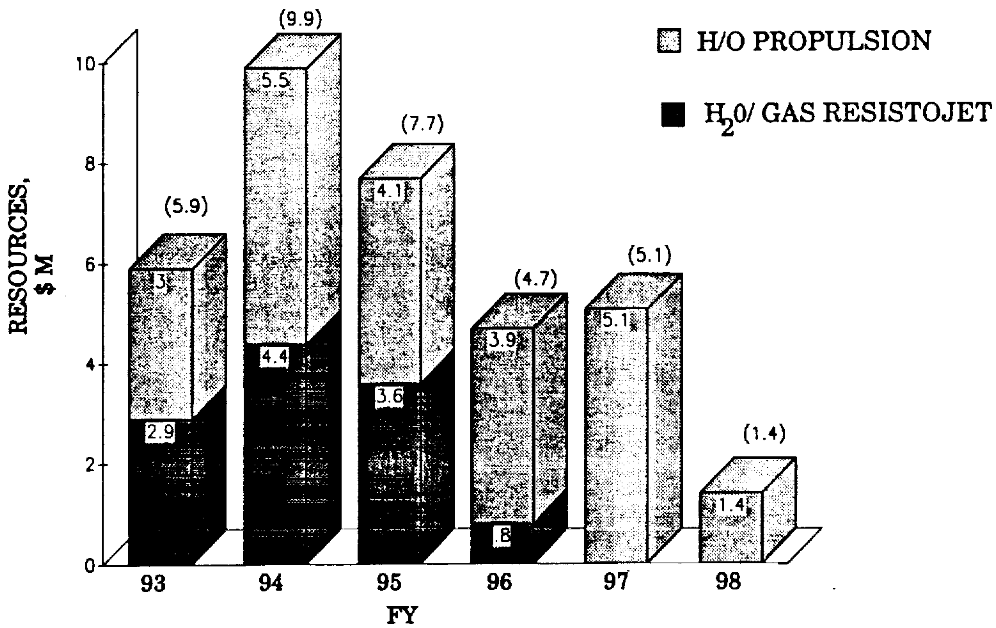
- GOAL: PROVIDE ADVANCED AUXILIARY PROPULSION FOR EARTH LAUNCH VEHICLES
- AUGMENTATION GOAL: [PROVIDE EVOLUTIONARY HI PERFORMANCE OPERATIONALLY EFFICIENT AUXILIARY VEHICLE PROPULSION]
  - PROVIDE RAD COOLED EARTH & SPACE STORABLE PROPULSION
  - PROVIDE INTEGRATED H/O PROPULSION

FOCUSED TECHNOLOGY
SPACECRAFT ON-BOARD PROPULSION
PLANETARY DUAL-MODE PROPULSION
"3X" PROJECT

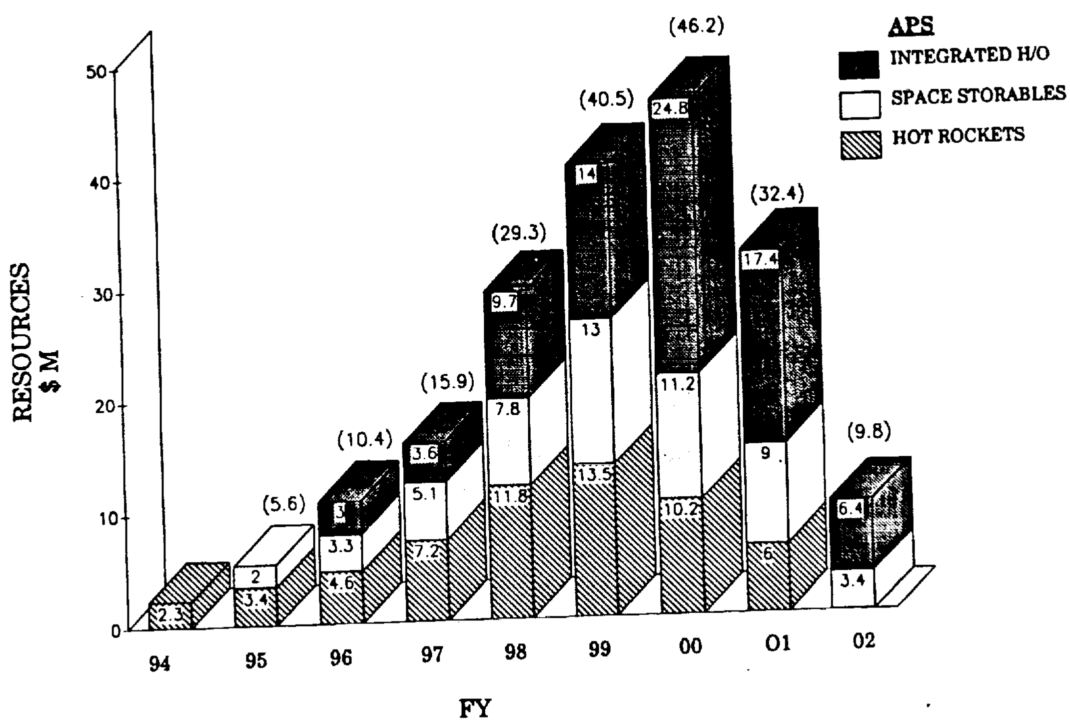


JOINT JPL/NASA LeRC PROJECT PROPOSED

FOCUSED TECHNOLOGY
SPACECRAFT ON-BOARD PROPULSION
SPACE STATION FREEDOM
"STRATEGIC"

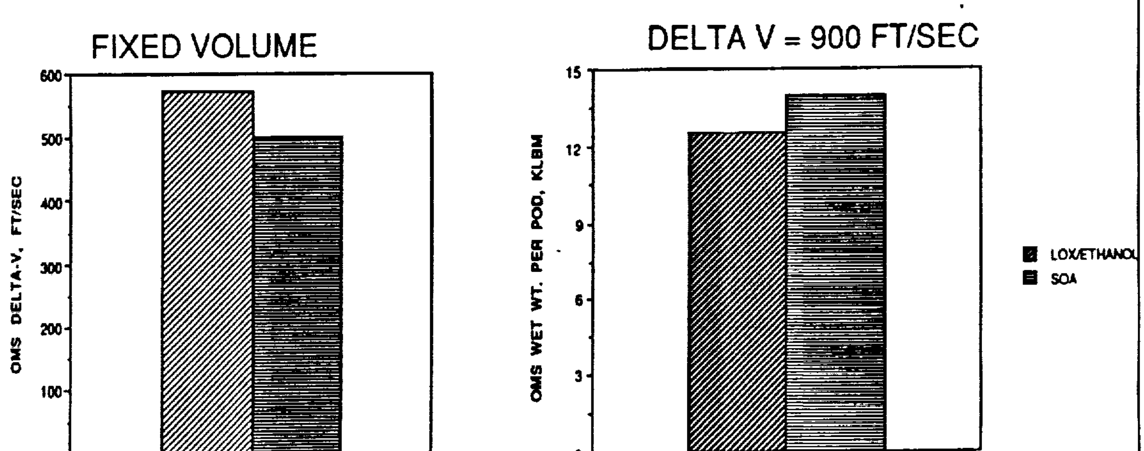


FOCUSED TECHNOLOGY
TRANSPORTATION
AUXILIARY PROPULSION
"STRATEGIC"



	Current Baseline	Potential Baseline
Propulsion Element Upmass	1 flight per year	1 flight per 5 years
Ground Processing (Man-Hours)	$200 K/Year	$200 K/ 5 Years
Dedicated SSF Hazardous Processing Facility	$50 Million	N/A

SPACE STORABLE IMPACT (1)

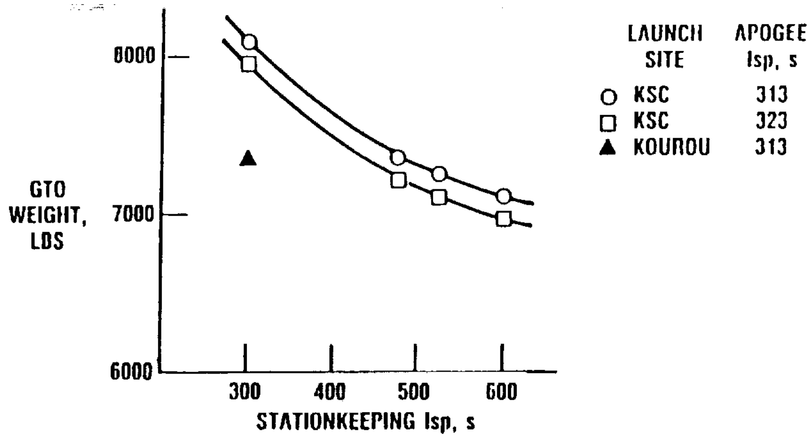


SPACE STORABLES

- OFFER SIGNIFICANT BENEFITS FOR FUTURE ETO VEHICLES

(1) REF: McDONNEL DOUGLAS STUDY FOR JSC (MDC E0713)

ON-BOARD PROPULSION IMPACTS(1)

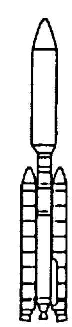


ADVANCED STATIONKEEPING AND APOGEE PROPULSION
- REDUCE GTO REQUIREMENTS
- MITIGATE LAUNCH SITE IMPACTS

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

CD 90 47467

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

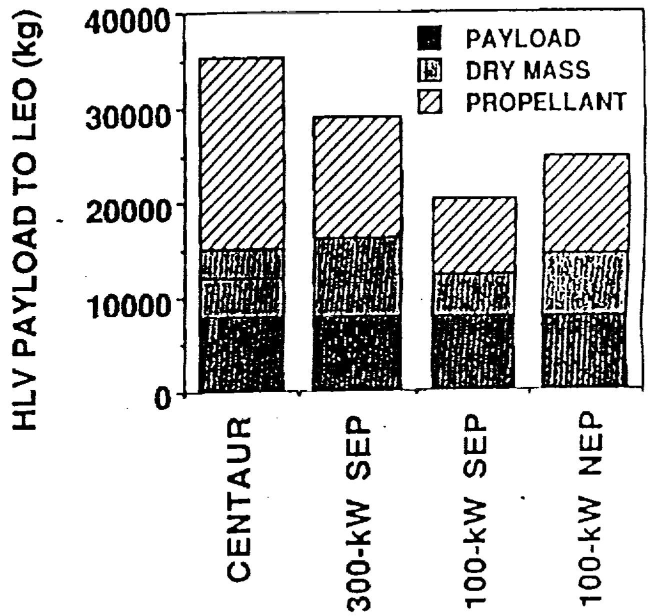
ELECTRIC PROPULSION OFFERS 3X MLEO REDUCTION

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

ADVANCED PROPULSION
FOR THE
MARS ROVER SAMPLE RETURN MISSION

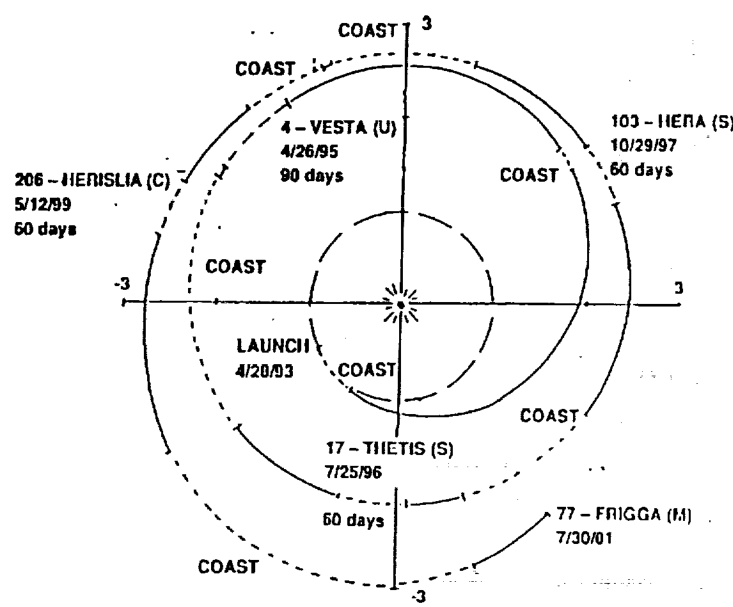
Significant Launch Mass Reductions Are Possible Using Electric Propulsion

- Electric Propulsion Reduces the LEO Launch Mass by 18 to 42 Percent
- A 300-kW SEP System Provides the Best Trip Time Performance
- Centaur Injection Is Replaced With Low-Thrust Escape



MBAR TRAJECTORY WITH SOLAR ELECTRIC PROPULSION ENABLES FIVE ASTEROID RENDEZVOUS PER MISSION

- FIVE ASTEROIDS CAN BE VISITED ON THE SAME MISSION WITH ELECTRIC PROPULSION; ONLY ONE ENABLED WITH NTO/MMH
- EXAMPLE ASTEROID TOUR INCLUDES:
  - 4 – VESTA (90 days)
  - 17 – THETIS (60 days)
  - 103 – HERA (60 days)
  - 206 – HERISLIA (60 days)
  - 77 – FRIGGA (TO EOM)



NEP MISSION VS BALLISTIC - KEY EXPECTED IMPROVEMENTS

FLIGHT TIME PAYLOAD MASS SCIENCE

1) NEPTUNE ORBITER/PROBE

- SHORTER FLIGHT TIME - 11 YRS VS > 18 YRS
- TRITON SCIENCE - ORBITER MISSION VS 41 FAST FLYBYS (4-5 KM/S)
- RING SCIENCE - POSSIBLE TO SPIRAL INWARD TO RING ZONE
- ATMOSPHERE SCIENCE - OBSERVATION FROM CLOSE (E.G. 3 R_N) ORBIT

2) PLUTO ORBITER/PROBE

- ORBITER MISSION VS FAST (13 KM/S) FLYBY FOR BALLISTIC MISSION
- SPIRAL INWARD AS LOW AS DESIRED
- RENDEZVOUS WITH CHARON
- DEPLOY NEPTUNE LANDER OR PROBE
- SHORTER FLIGHT TIME, 10.5 YEARS
- NEP IS ENABLING (BALLISTIC MODE TAKES > 36 YRS TO DO ORBITER)

3) JUPITER GRAND TOUR

- ORBITER MISSION FOR CALLISTO, GANYMEDE, EUROPA AND IO (IF RADIATION PROBLEM CAN BE TACKLED)
- DEPLOYMENT OF SOME LANDERS OR PENETRATORS

NEP MISSION VS BALLISTIC - KEY EXPECTED IMPROVEMENTS (CONTINUED)

3) MULTIPLE ASTEROID RENDEZVOUS

- MINIMUM OF SIX RENDEZVOUS WITH PREFERRED ASTEROIDS (SIZE, TYPE) VS ONE MAJOR TARGET PLUS ONE OR TWO SMALL TARGETS OF OPPORTUNITY
- ON AN AVERAGE OF ONE RENDEZVOUS EVERY TWO YEARS VS ~ ONE EVERY 4 YEARS

4) JUPITER POLAR ORBITER

- ADVANTAGE EXISTS IN LARGE PAYLOAD - POTENTIAL FOR MULTI-SPACECRAFT FIELDS AND PARTICLES EXPERIMENTS

5) COMET NUCLEUS SAMPLE RETURN

- BETTER PERFORMANCE AND ACCESSIBILITY TO LARGER NO. OF COMETS (MORE OPPORTUNITIES)
- PRESERVATION OF SAMPLE
- LOWER APPROACH SPEED WHEN RETURNING TO EARTH (V_∞=0 km/s)
- IF ALLOWED TO SPIRAL BACK INTO EARTH THEN ORBITAL SAMPLE RECOVERY INSTEAD OF HIGH VELOCITY (V_∞=15km/s) DIRECT ENTRY

LOW THRUST PROPULSION

- ESSENTIAL FOR SPACE MISSIONS
  - EARTH SPACE
  - PLANETARY
- PREDOMINANT LAUNCH & SPACE VEHICLE "PAYLOAD"
- HI LEVERAGE TECHNOLOGIES DEFINED
  - INITIAL TRANSFERS ACHIEVED
- BROAD & MAJOR BENEFITS ASSURED WITH SUPPORT:
  - SPACECRAFT
  - PLATFORMS
  - TRANSPORTATION