Propulsion Needs for Lunar/Mars Missions

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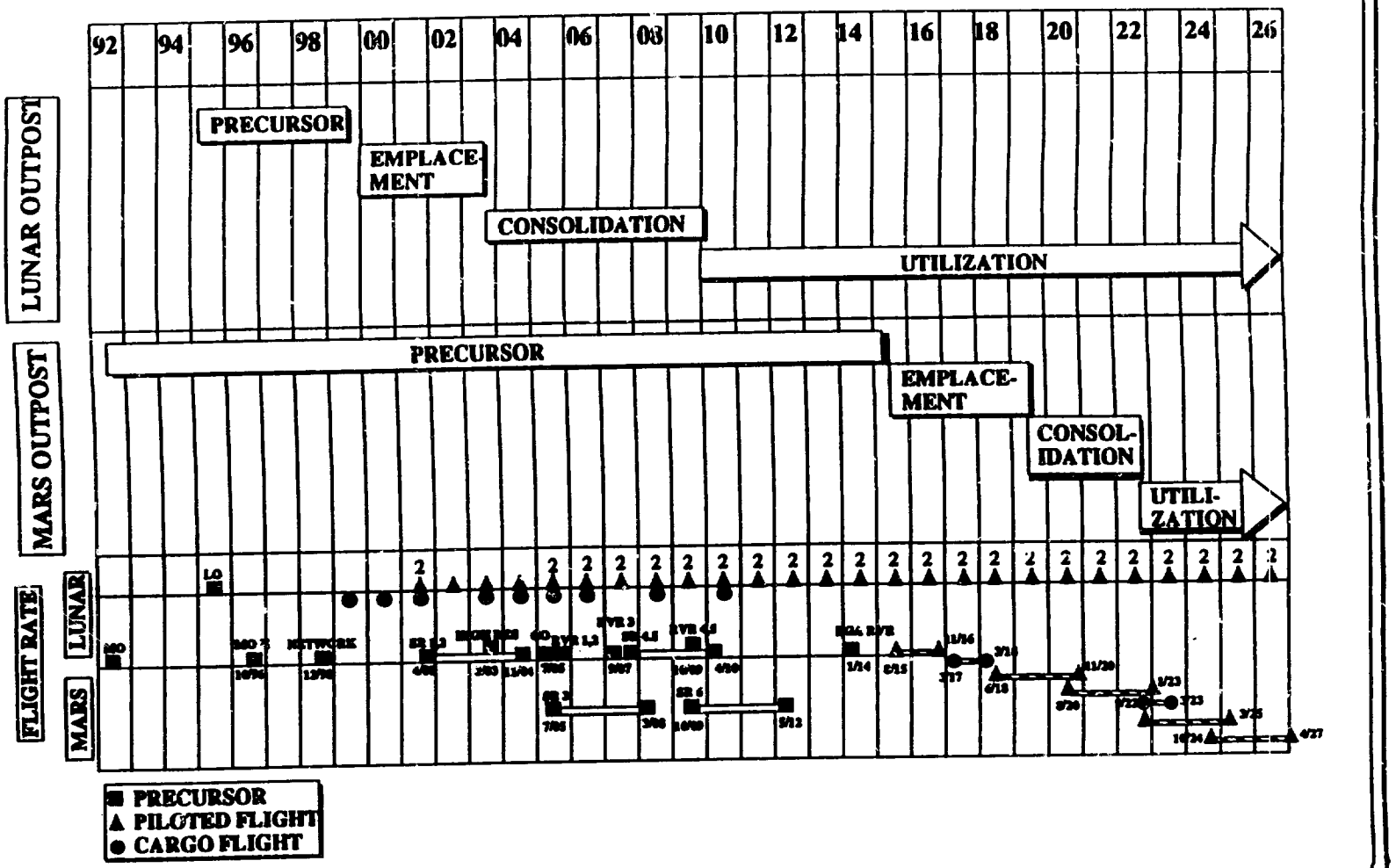
NASA LEVEL II

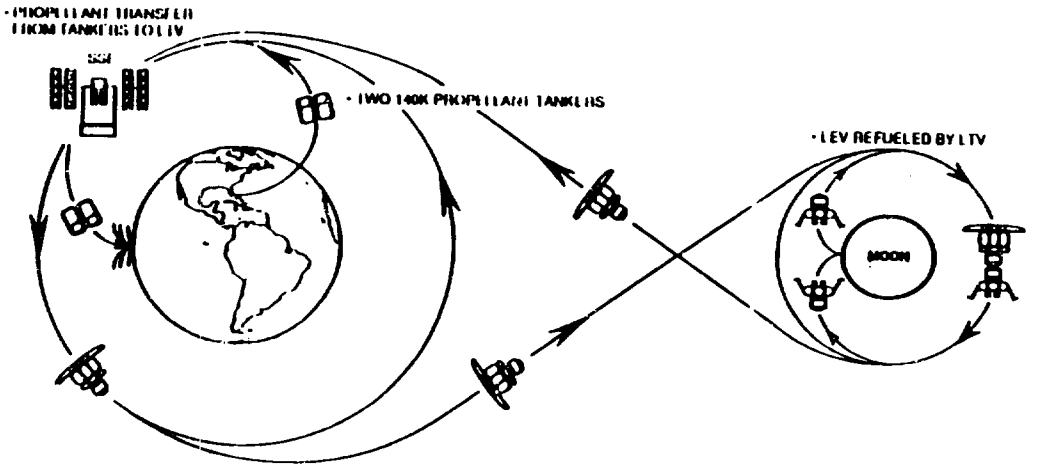
Baseline Missions Sequence



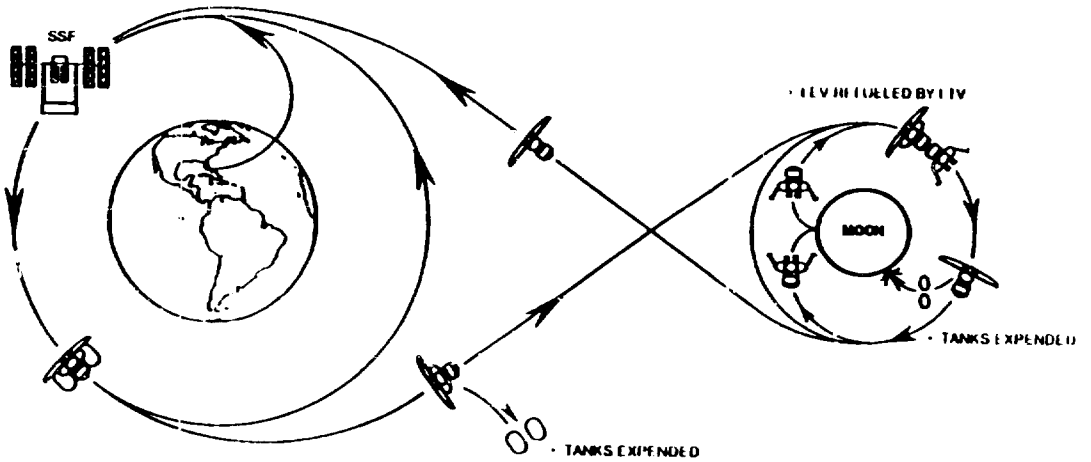
LTV/LEV LUNAR MISSION PROFILE

(STEADY - STATE MODE)

SINGLE STAGE REUSEABLE



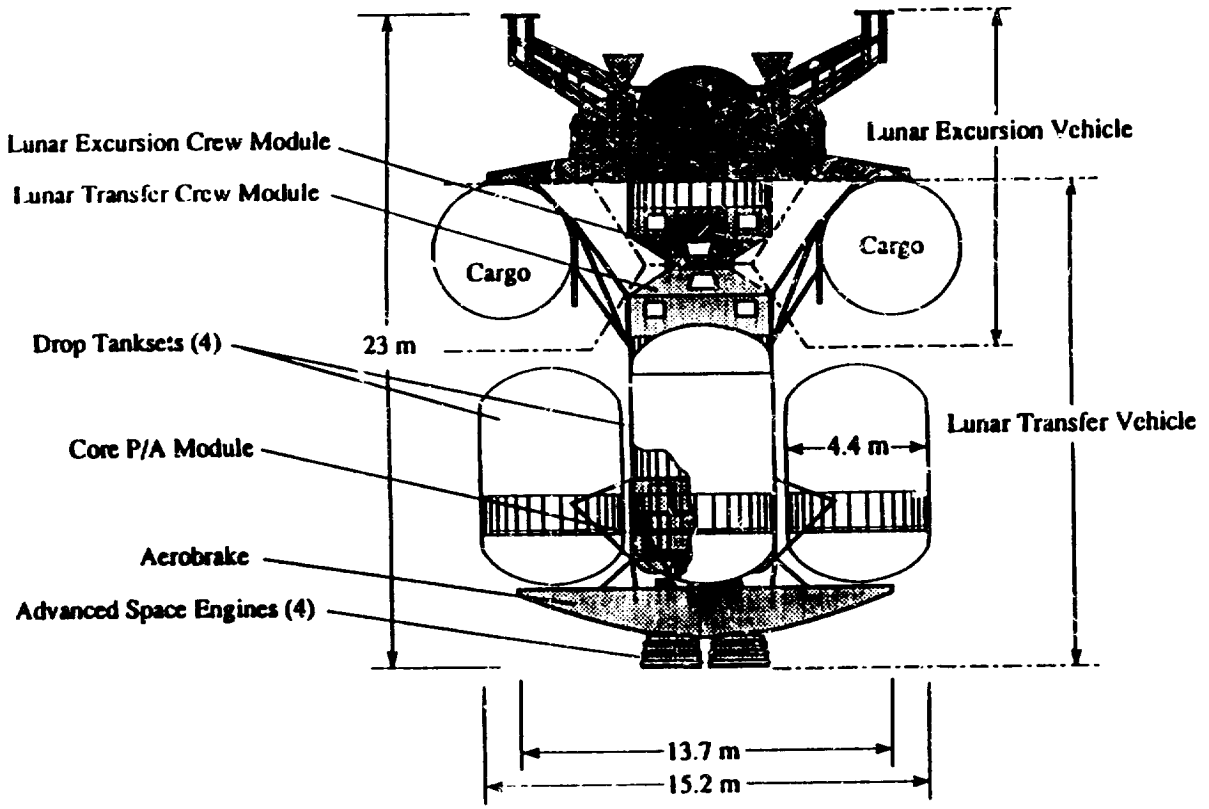
1 1/2 STAGE (REFERENCE)



CURRENT REFERENCE IS 1 1/2 STAGE

- SMALLER AEROBRAKE
- BETTER PERFORMANCE
- CORE STORAGE
- CORE APPLICATIONS
- LTV SIZE/ASSEMBLY IMPROVED

Lunar Transfer Vehicle/Lunar Excursion Vehicle Option 1



LEV	
• Mass	5.6t
• Propellant	23t
• Crew Module	3.6t *
LTV Tanksets (4)	
• Mass	5.8t
• Propellant	100t **
LTV Core	
• Mass	8.1t
• Propellant	6.4t
• Crew Module	7.6t *

* Excludes Crew, LTV Crew Module Includes 1.8t H_2O Radiation Shield

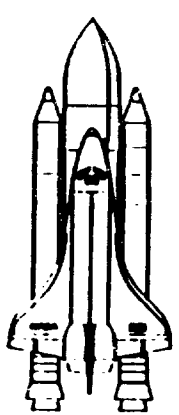
** Capacity 129.8t

NASA *Exploration Initiative*

Launch Vehicles for Lunar Missions

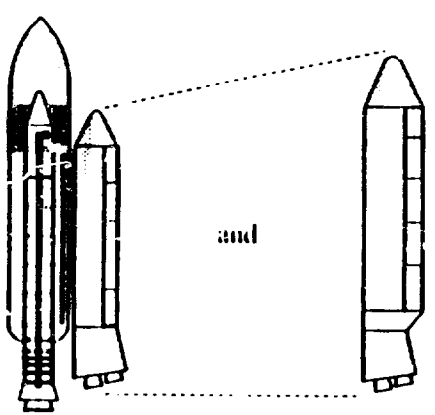
- **Requirements**
  - Shuttle for Manned Launches
  - HLLV for Cargo + Propellant
  - 2-6 HLLV Flights/Year
  - Lunar Vehicle/Aerobrake Requires 7.6m dia x 27m Payload Envelope

Shuttle



- 2 ASRMs
- Std ET
- 3 x 104% SSMEs
- 22t P/L Capability to SSF
- 4.6m x 18.2m P/L Envelope

Shuttle-C

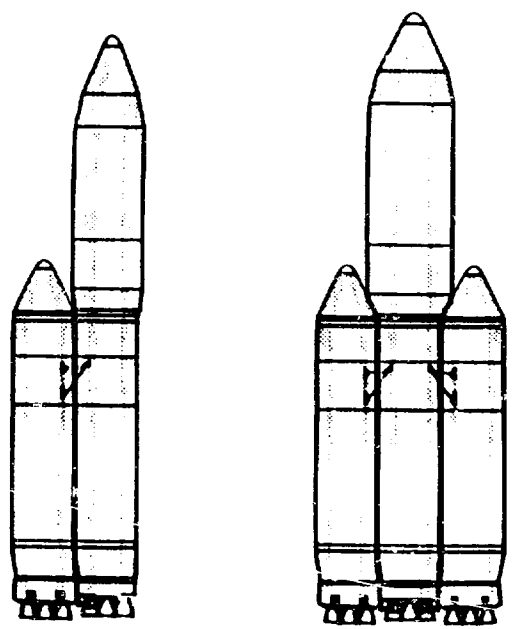


- 2 ASRMs
- Std ET
- 3 x 104% SSMEs
- 71t P/L Capability to SSF
- 4.6m x 25m P/L Envelope

- 2 ASRMs
- Mod. ET
- 3 x 104% SSMEs
- 61t P/L Capability to SSF
- 7.6m x 27m P/L Envelope

or

ALS.



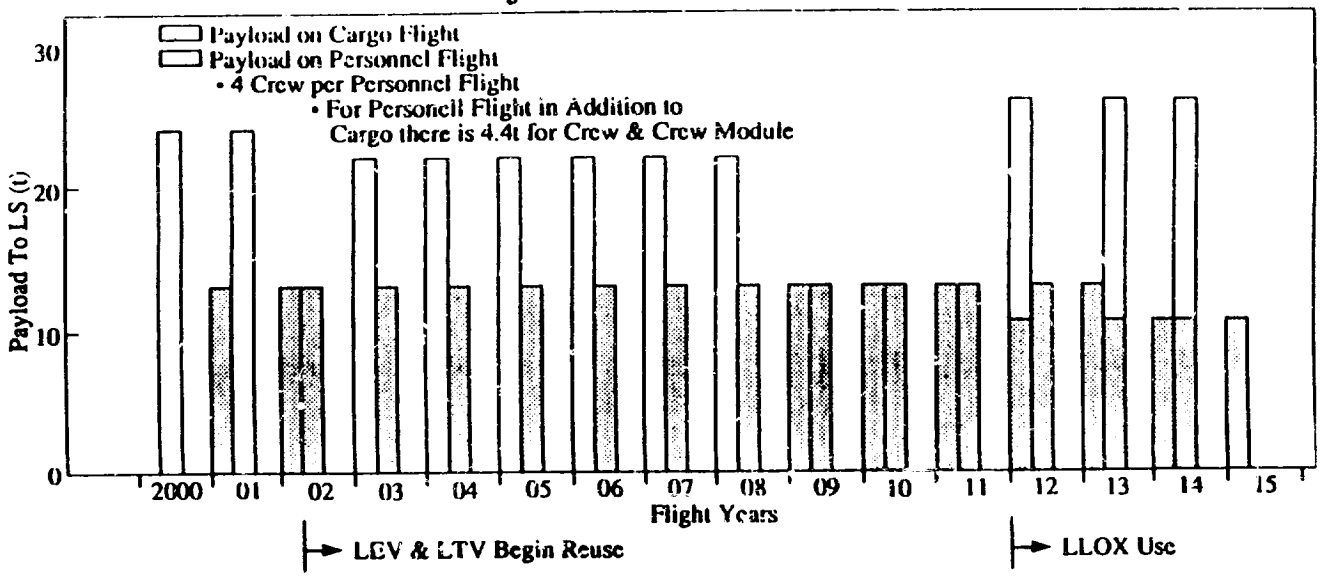
- 1 LOX/LH_2 Booster w/6 STMEs
- LOX/LH_2 Core w/3 STMEs
- 52.3t P/L Capability to SSF
- 7.6m D x 30m L P/L Envelope

- 2 LOX/LH_2 Booster w/6 STMEs
- LOX/LH_2 Core w/3 STMEs
- 98.2t P/L Capability to SSF
- 10m D x 30m L P/L Envelope

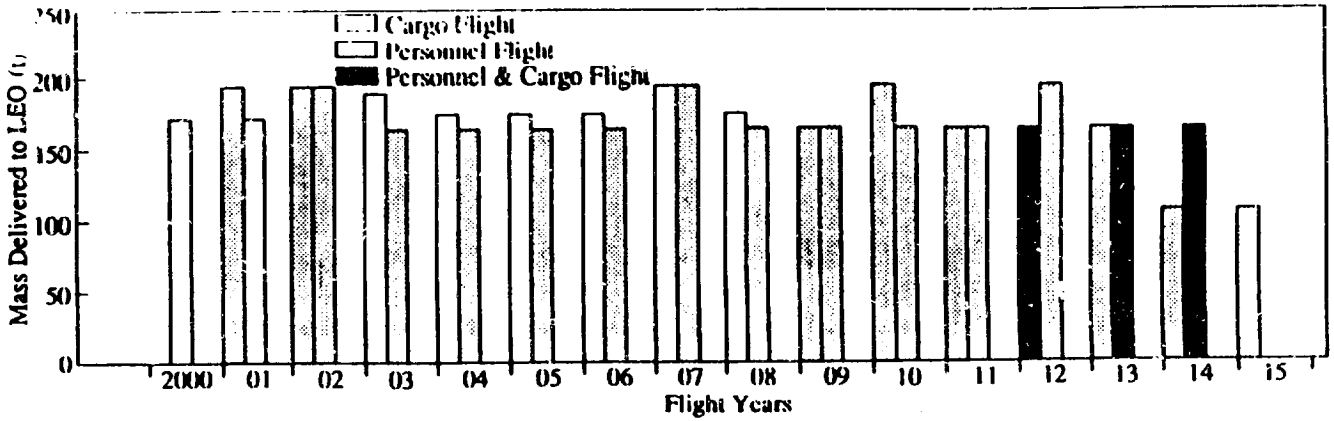
Technical Study Group

Lunar Outpost

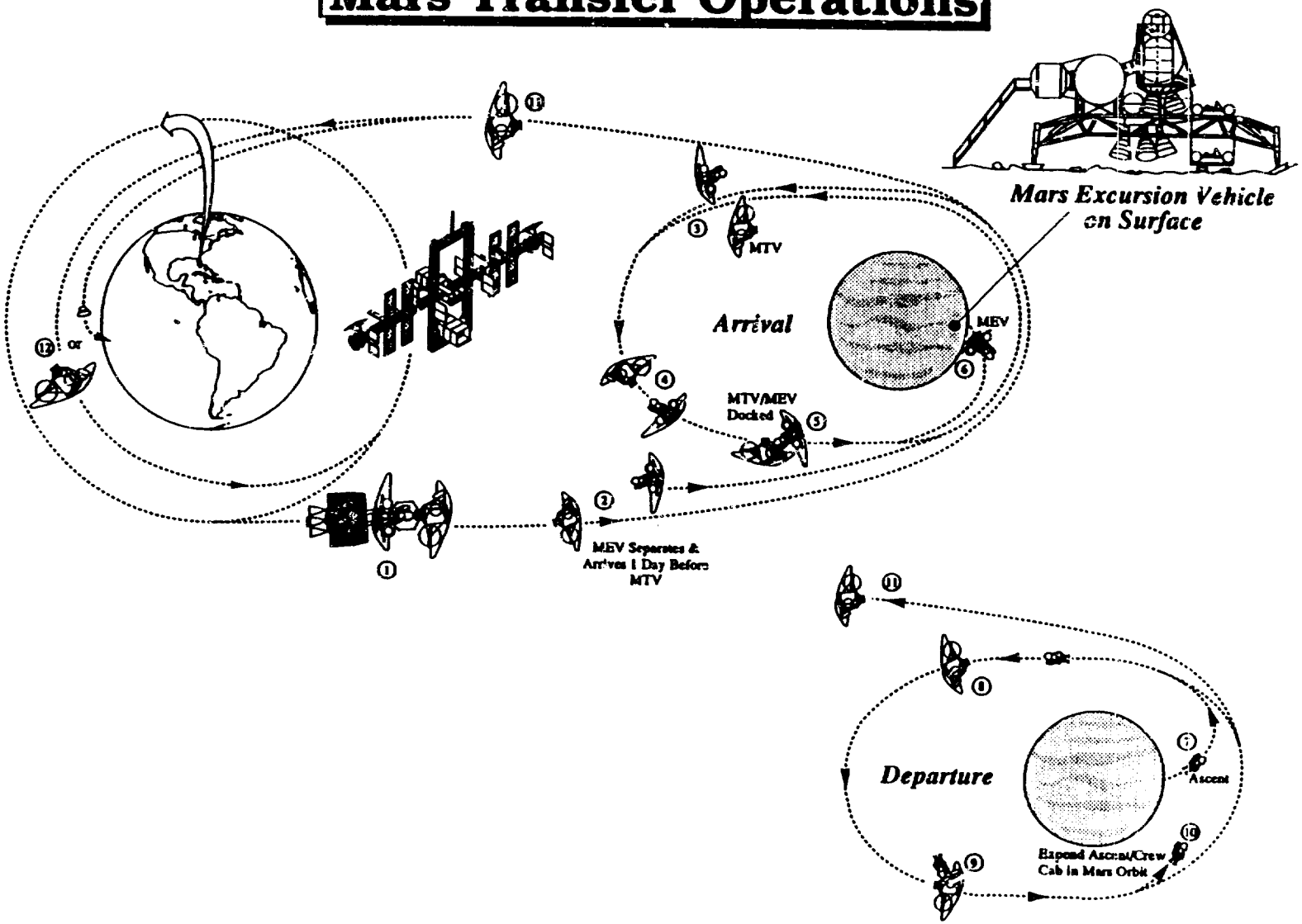
Payload To Lunar Surface



Mass Delivered To LEO



Mars Transfer Operations



Mars Mission Vehicle in LEO

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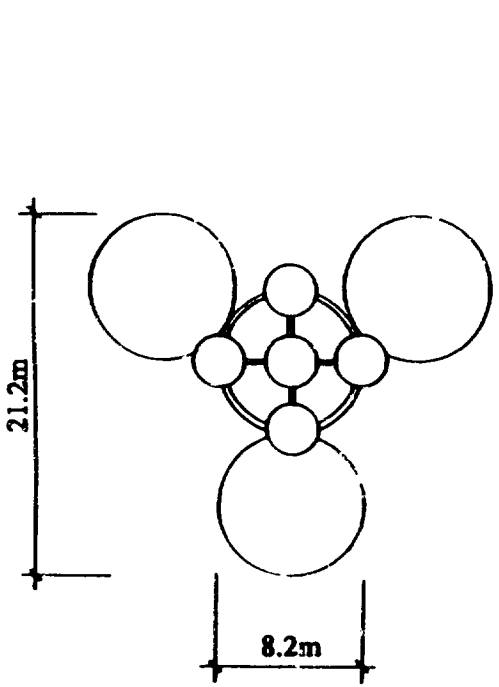

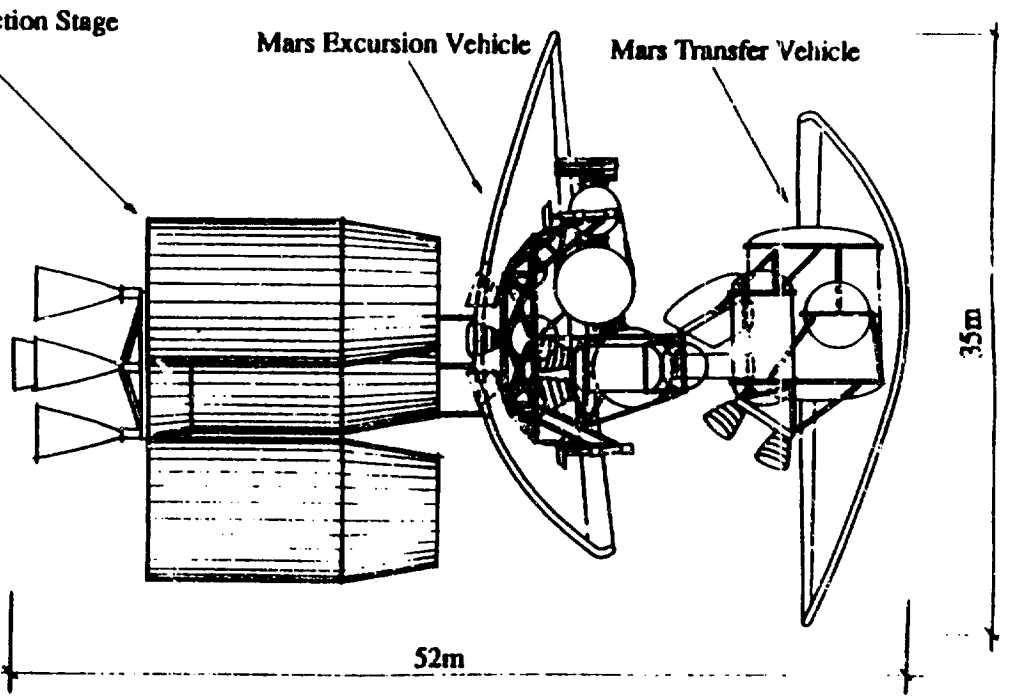

Mass for Option 1	
MTV	138.7 t
MEV	79.0 t
TMIS	509.8 t
Total IMEO	727.5 t

Mass for Option 5	
MTV	138.7
MEV	83.6 t
TMIS	517.1 t
Total IMEO	739.4 t

Mission Vehicle Commonality

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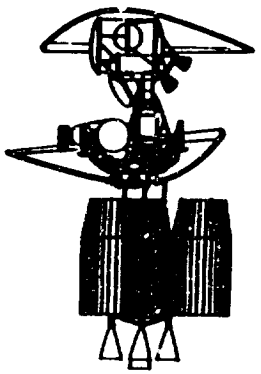

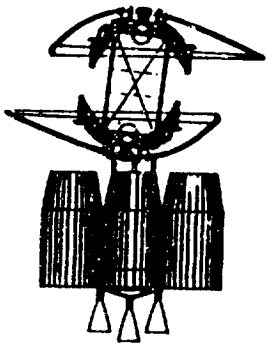

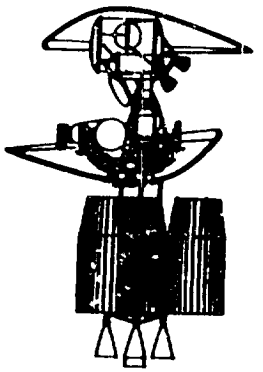

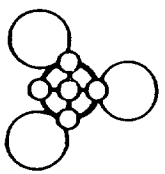

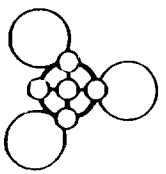

2015 Crew (Opposition)

- Reference configuration
- (4) tank sets, (5) engines

MEV	81
ECCV	7
Crew System	36
TEIS	89
MTV Aerobrake	21
TMIS	490
Total IMEO	**724t**

2017 Cargo

- (2) 59t capacity cargo landers
- No MTV, no TEIS
- (3) tank sets, (3) engines

MEV's	163
Nav-kit	10
TMIS	360
Total IMEO	**533t**

2018 Crew (Conjunction)

- Extra provisions
- (4) tank sets (offloaded), (5) engines
- Aeroshell reused at Earth

MEV	90
ECCV	7
Crew System	48
TEIS	70
MTV Aerobrake (1 re-use)	21
TMIS	340
Total IMEO	**576t**

Mass Comparison for Reference Missions

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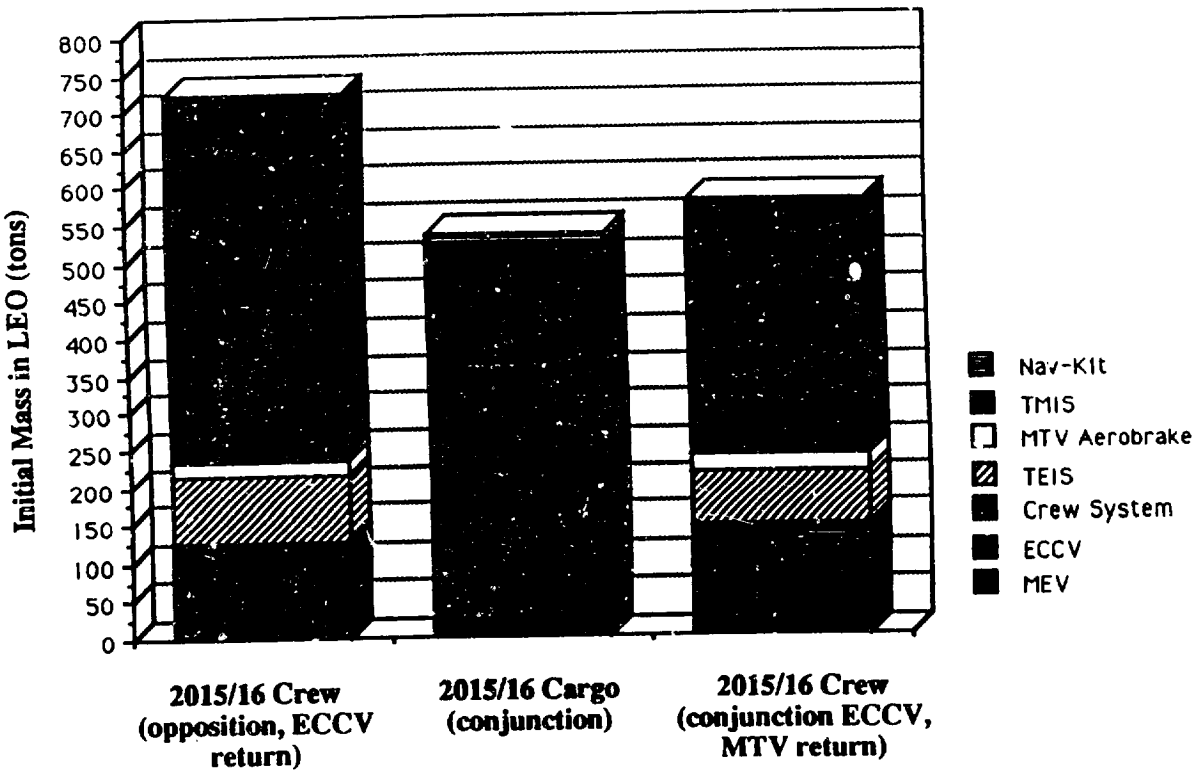

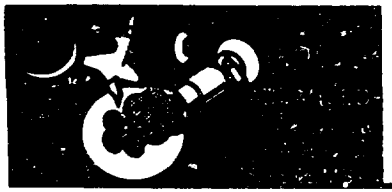

Advanced Propulsion

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Advanced propulsion options exist that could provide benefits in terms of reduced mass requirements, trip times, or both, relative to chemical propulsion.

Options considered:

Solar Electric Propulsion (SEP)
Nuclear Electric Propulsion (NEP)
Solid Core Nuclear Thermal Rockets (NTR)
Gas Core Nuclear Thermal Rockets (GCR)

The impact of these options upon a single Mars mission has been assessed; However, a fully integrated mission scenario must be developed to most effectively utilize these systems over the Lunar/Mars initiative.

Propulsion Option Size Comparison

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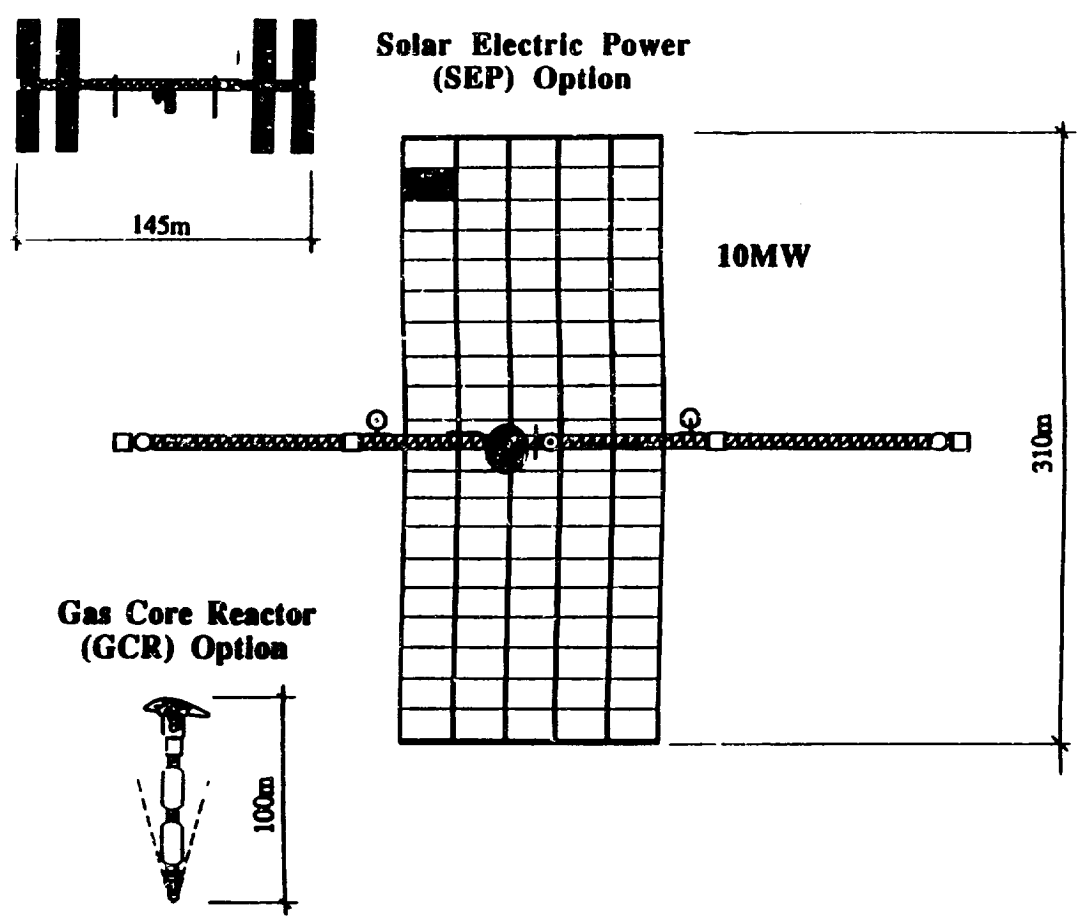

MTV Propulsion Option Weights For Mission Favorable Opportunities

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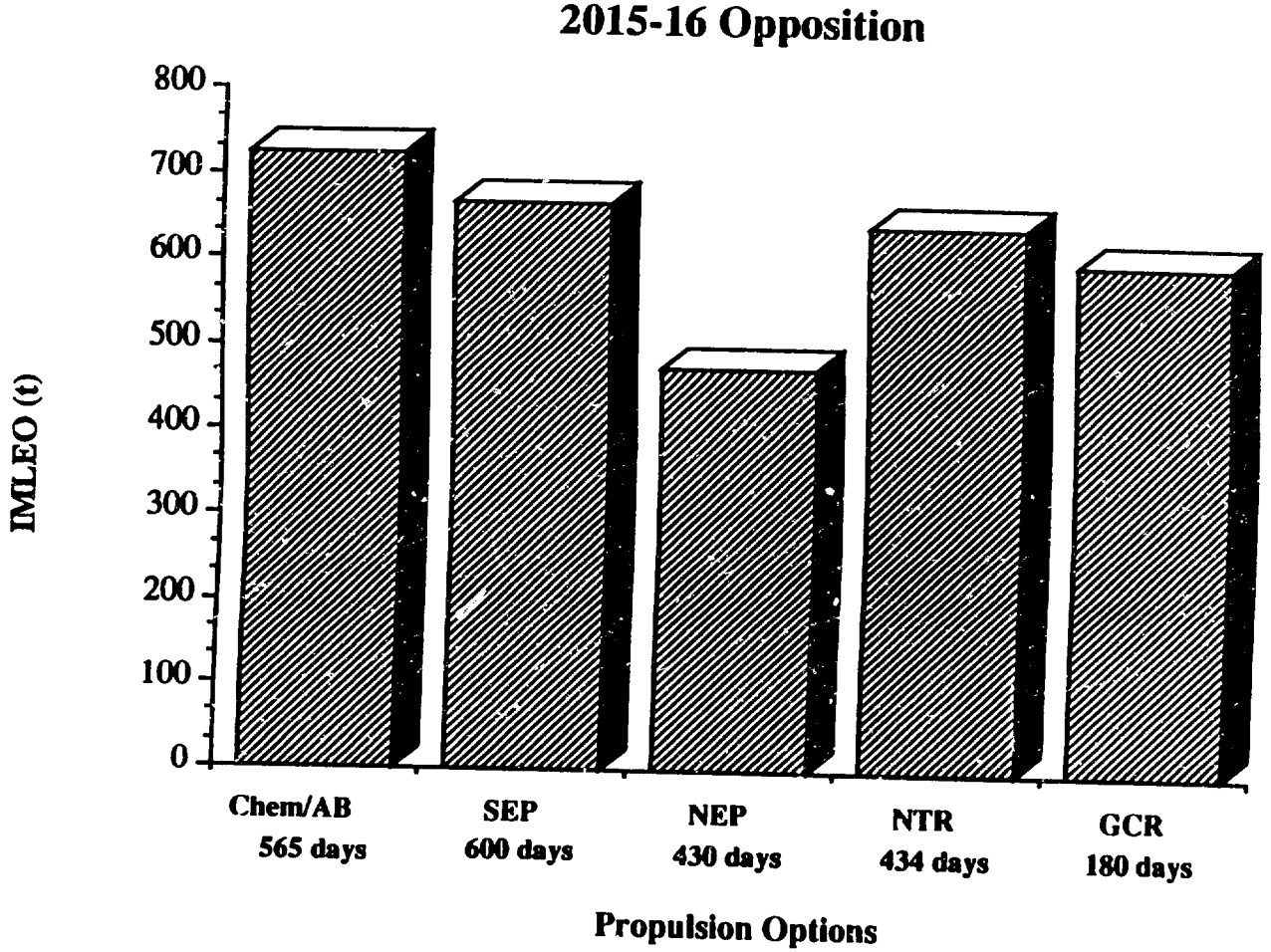

Propulsion Options Comparison - LeRC

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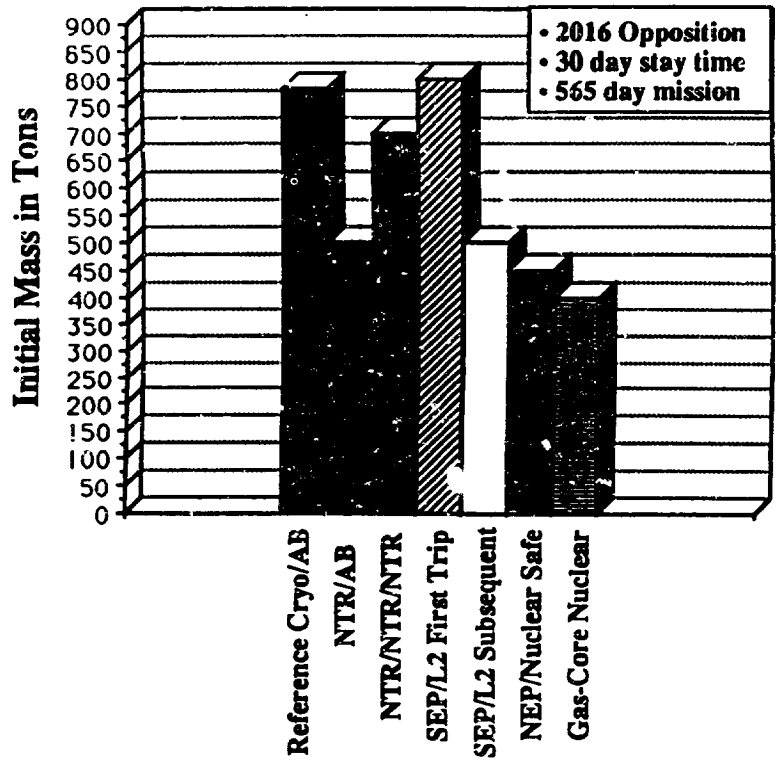
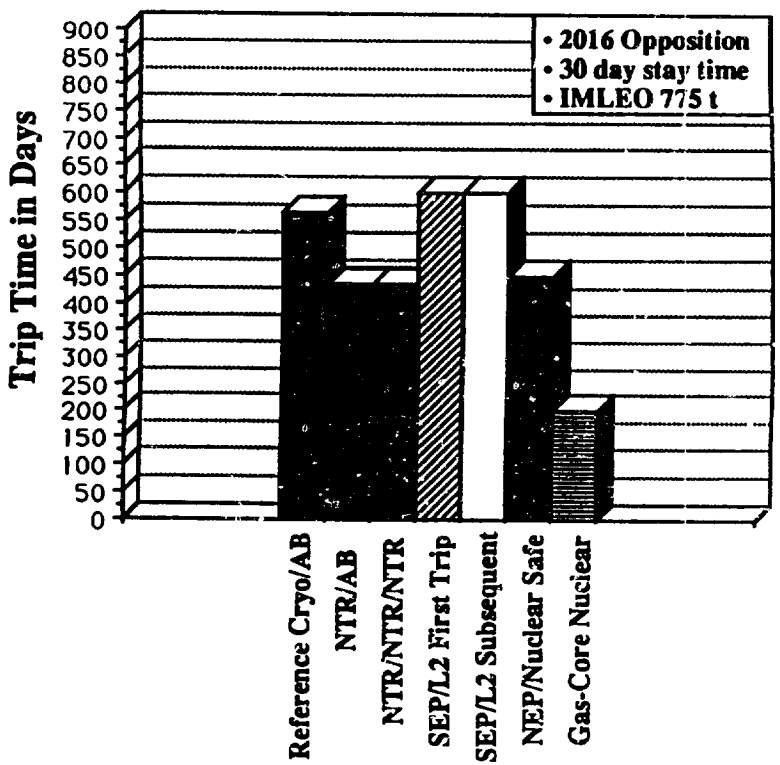
Propulsion Options Mass Comparison
Reference Mission

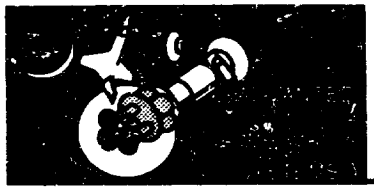


Trip Times at Constant IMLEO
Propulsion Options Mass Comparison



Mars Transportation Architecture Options

Propulsion/ Vehicle Type	NODE(S)				FUELING/REFUELING		
	Assy at SSF	Assy off SSF	HEO/L2 Node	SSF Support	Launch Loaded	Tankers Direct	Tankers to Depot to Vehicle
Cryo/Aerobrake Partially Reusable (Reference)	(1)	(2)		(2)	(1 & 2)		
Cryo/Aerobrake Fully Reusable	(3 &5)		(4	(4)		(3 & 4)	(5)
NTR 900 Isp Staged Tanks & Engines	(6)				(6)		
NTR 1250 Isp Staged Tanks & Engines	(7)				(7)		
NTR 1250 Isp Fully Reusable		(8)	(8)	(8)		(8)	
GCR Isp 2500 Fully Reusable		(9)	(9)	(9)		(9)	
SEP Operated from L2	(10 &12)	(11)	(11)	(11)	(12)	(10 & 11)	
NEP Operated from SSF Orbit	(13)				(13)		
NEP Operated from High Orbit/L2	(14)	(15)	(15)	(15)	(14)	(15)	



Tanker Options for Fully Reusable Systems

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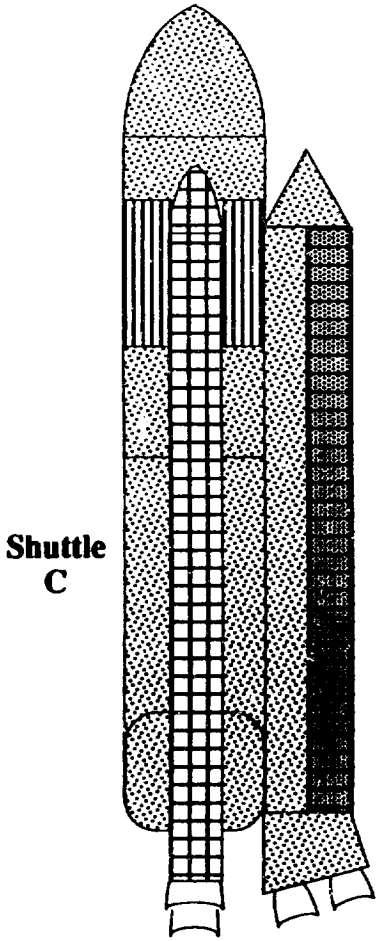
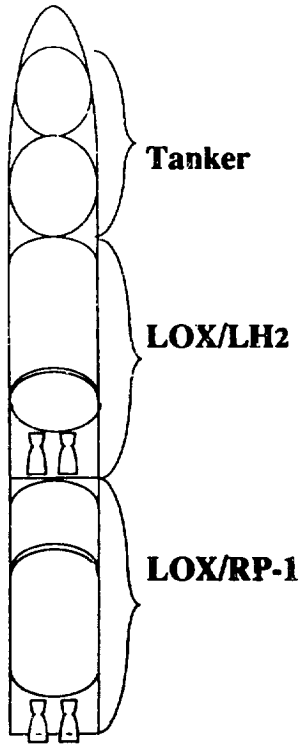
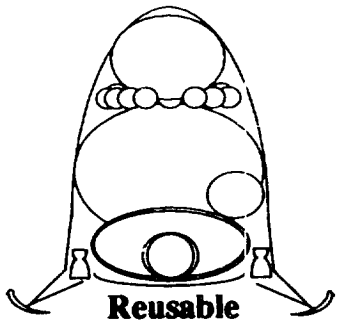


Shuttle C



Expendable Tanker



Reusable Tanker "SSX"

NTR 900 Isp Staged Tanks and Engines, Mode 6

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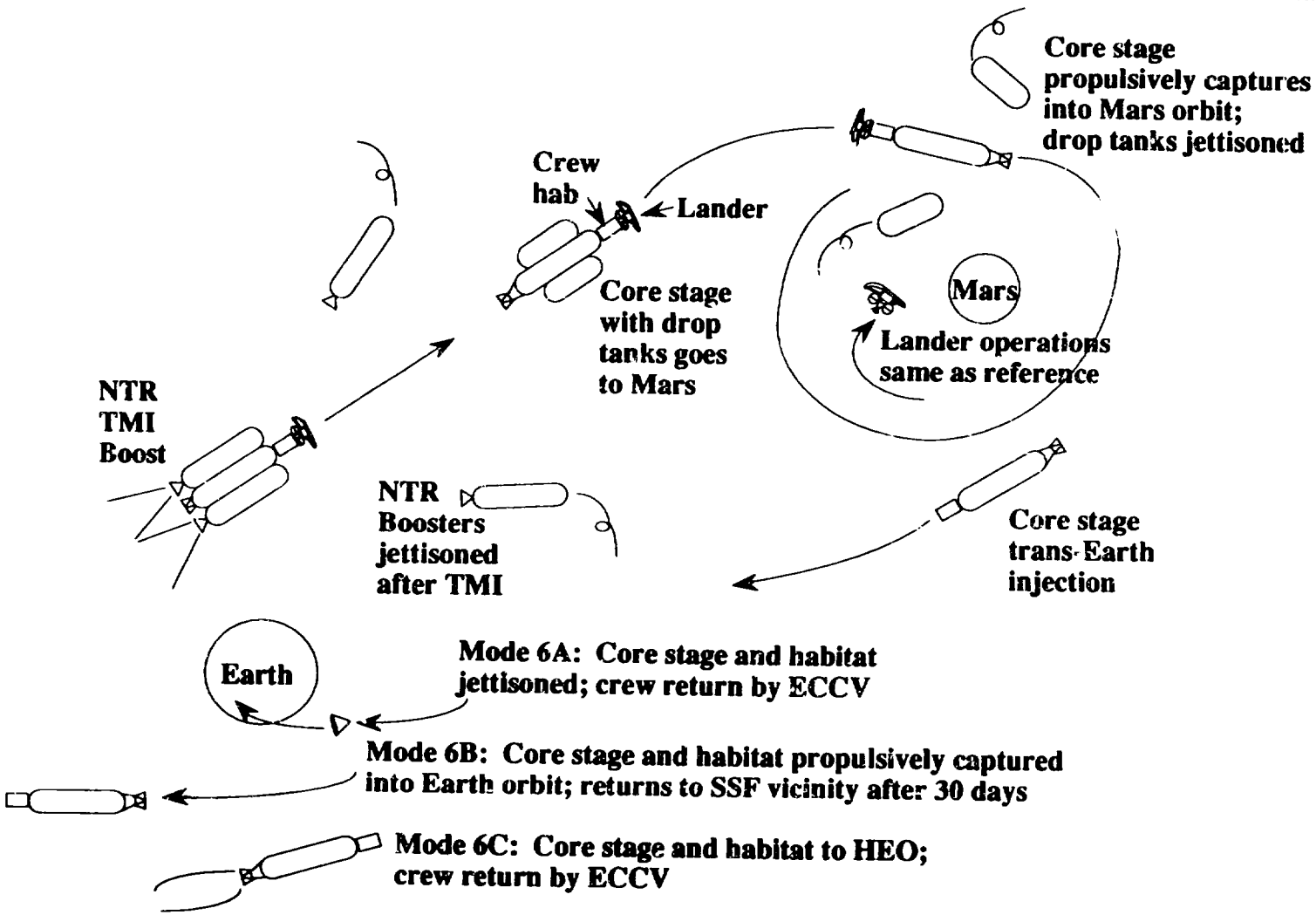

Fully Reusable Cryogenic Aerobraked System, Split TMI Burn (Modes 3 and 5)

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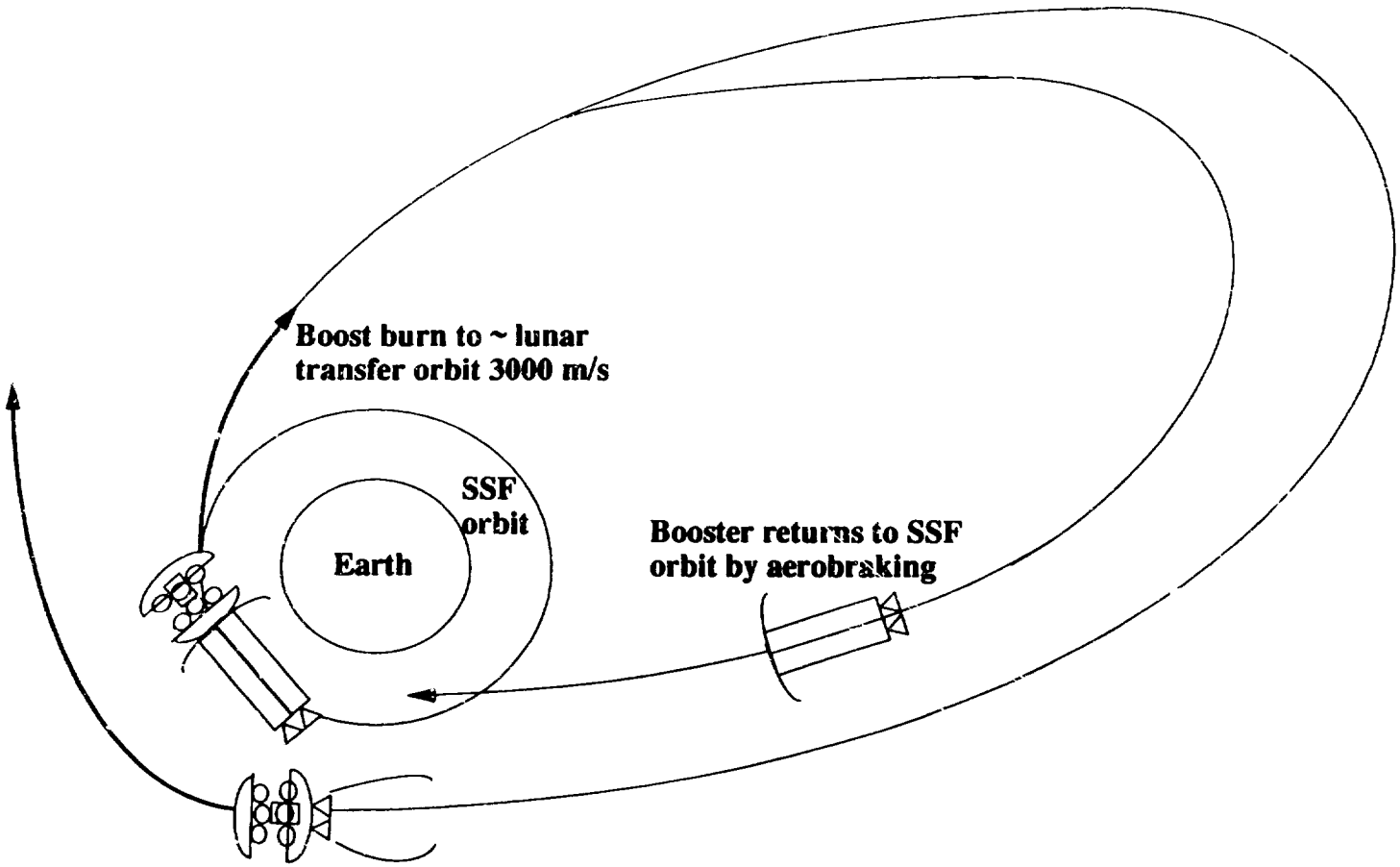

TMI burn ~ 1200 m/s, uses MTV propulsion with extra tanks.
MEV delivered to Mars and reused there; MTV returns to SSF orbit

NEP Operated from High Orbit,Modes 14 and 15

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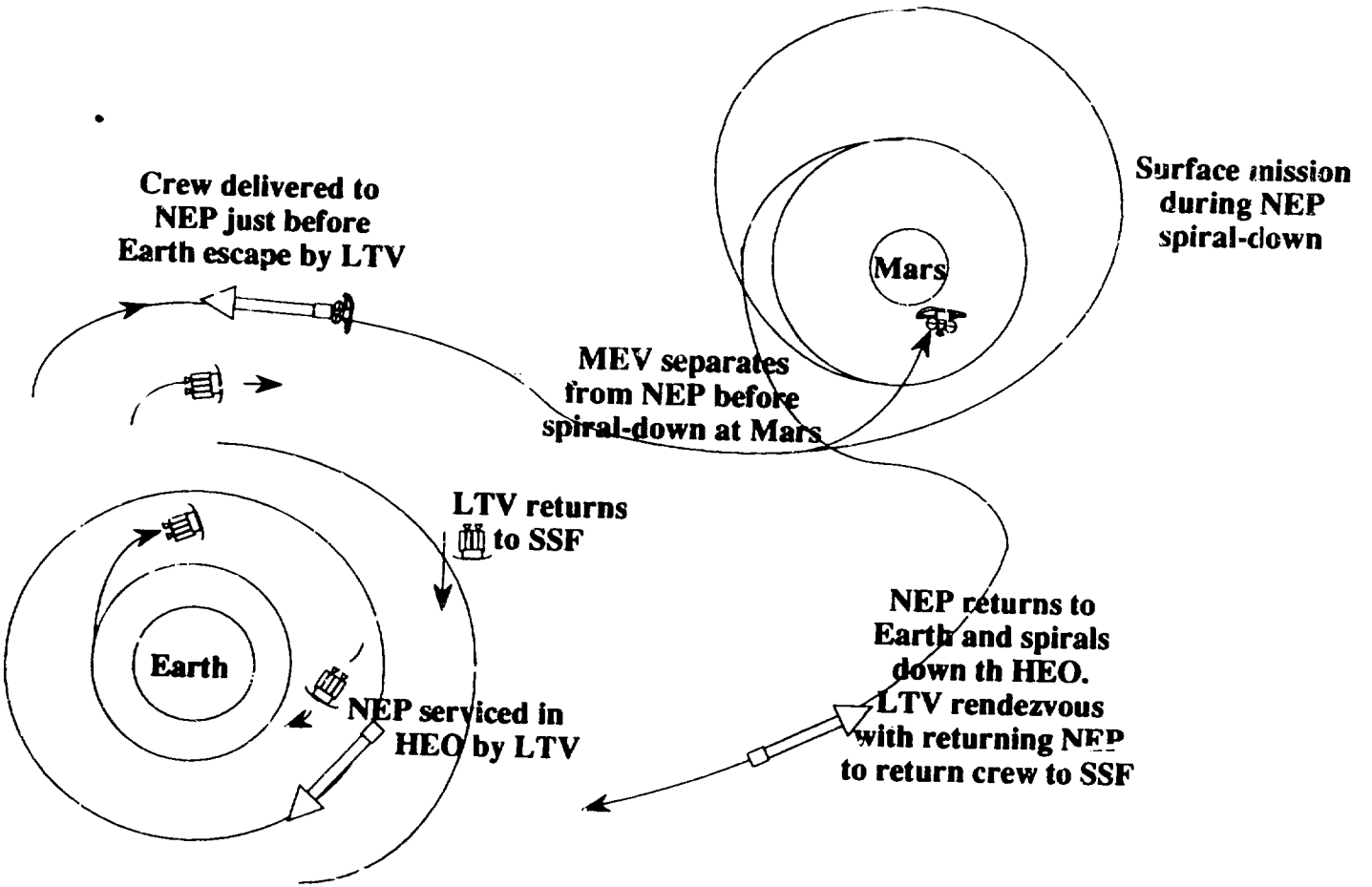

Nuclear Safe Orbit Considerations

- Nuclear safe altitude customarily set at ~ 800 km. for 300-year lifetime.
- This is close to worst possible debris altitude & therefore not acceptable.
- Options:

  (1) Operate nuclear system from SSF orbit, or
  (2) Operate nuclear system from a high orbit, above
  (a) debris environment,
  (b) High-radiation part of van Allen belt (>5000 km)

- High orbit can be at zero inclination with continuous access, or at SSF inclination, where it suffers differential nodal regression and therefore only occasional accessibility at low ΔV. ~ 1 year at 800 km; ~ 2-3 months at >5000 km.
- While this issue is not resolved, indications are that the high orbit may as well be GEO or L2.