ELECTRIC PROPULSION FOR SPS

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SPS TRANSPORTATION REQUIREMENT:

- CONSTRUCT TWO 50,984 MT SPS's IN GEO PER YEAR, PLUS SPARES
- ANNUAL CARGO REQUIREMENT:
  - SATELLITE: 101,968
  - SPARES (1%): 1,020

  102,988 MT

LEO TO GEO OTV SYSTEMS CONSIDERED

- LO_2/LH_2
  - PERMITS GEO CONSTRUCTION
  - SHORT TRIP TIME
  - SPS SOLAR ARRAY PROTECTED FROM VAN ALLEN RADIATION

  UP TO $1B PENALTY PER 5 GW SPS DUE TO GREATER PROPELLANT DELIVERY TO LEO.
- PAYLOAD POWERED ELECTRIC OTV
  - REQUIRES LEO CONSTRUCTION OF SOLAR ARRAY MODULES
  - LONG TRIP TIME - ECONOMIC PENALTY
  - EXPOSES SOLAR ARRAY TO VAN ALLEN RADIATION
  - LARGE DISTRIBUTED MASS PRESENTS CONTROL PENALTIES

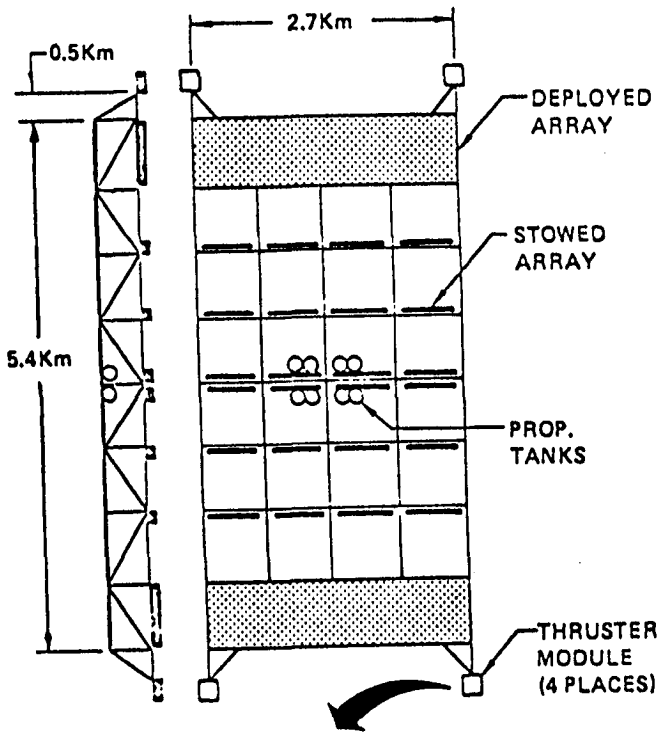
  CONTROL PENALTIES BECAME A DECISION FACTOR.
- INDEPENDENT POWERED ELECTRIC OTV
  - PERMITS GEO CONSTRUCTION
  - LONG TRIP TIME - ECONOMIC PENALTY
  - SPS SOLAR ARRAY PROTECTED FROM RADIATION
  - CONCENTRATED PAYLOAD MASS ALLEVIATES CONTROL PROBLEM

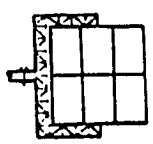
  BETTER MASS DISTRIBUTION DOMINATES PENALTY OF ADDED SOLAR ARRAY.

OTHER OTV POSSIBILITIES:

- SOLAR COLLECTOR, THERMAL CYCLE CONVERSION ELECTRIC PROPULSION
- SOLAR COLLECTOR HEATED HYDROGEN PROPULSION
- LASER HEATED PROPELLANT SYSTEM
- ELECTROMAGNETIC MASS DRIVER

PAYLOAD POWERED OTV





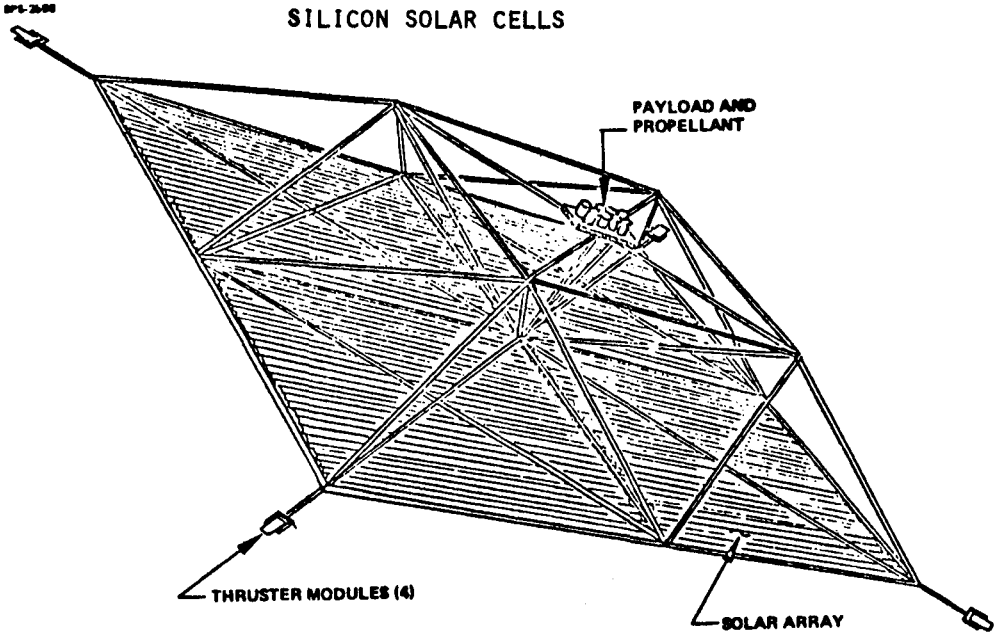
	NO ANTENNA	WITH ANTENNA
PANEL SIZE:	24x38m	48x57m
NO. THRUSTERS:	560	1680

GENERAL CHARACTERISTICS

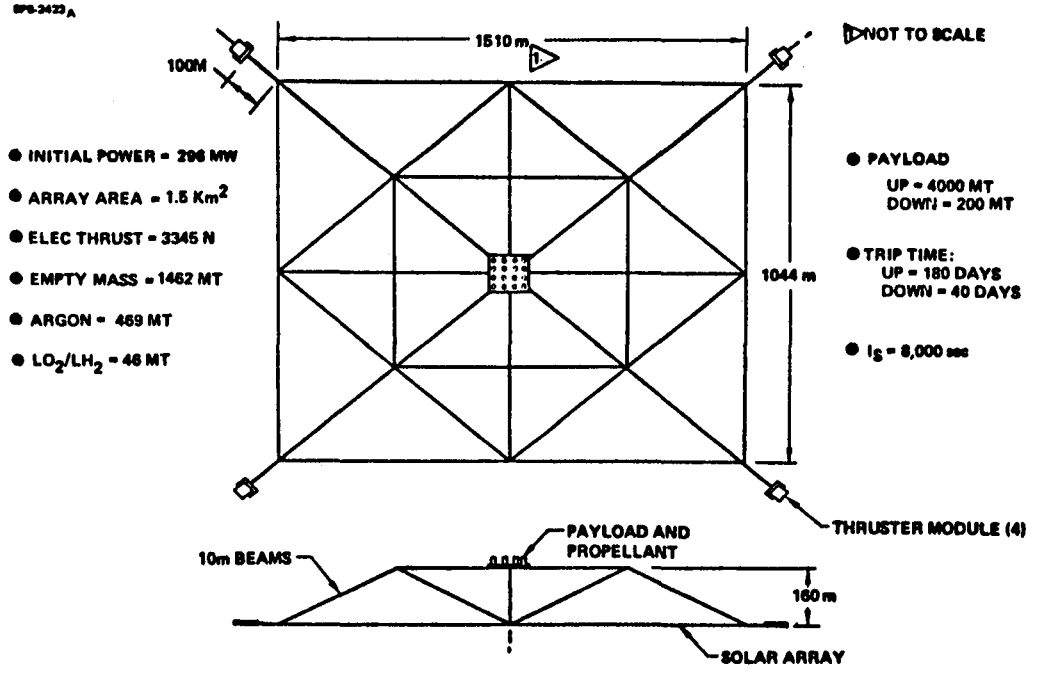
- 5% OVERSIZING (RADIATION)
- TRIP TIME = 180 DAYS
- ISP = 7000 SEC

MODULE CHARACTERISTICS	NO ANTENNA	WITH ANTENNA
• NO. MODULES	6	2
• MODULE MASS (10^6KG)	8.7	23.7
• POWER REQ'D (10^6Kw)	0.3	0.81
• ARRAY %	13	36
• OTS DRY (10^6KG)	1.1	2.9
• ARGON (10^6KG)	2.0	5.6
• LO_2/LH_2 (10^6KG)	1.0	2.8
• ELEC THRUST (10^3N)	4.5	12.2
• CHEM THRUST (10^3N)	12.0	5.0

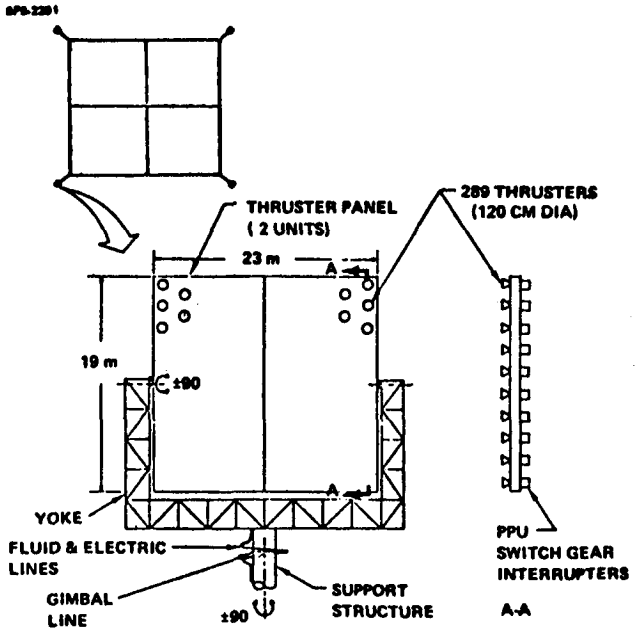
INDEPENDENT POWER EOTV CONFIGURATION CONCEPT - BOEING



INDEPENDENT POWER EOTV CONFIGURATION

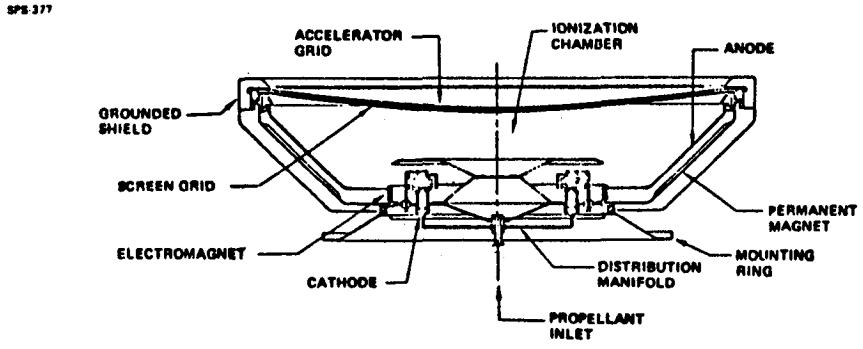


EOTV PROPULSION SYSTEM



- THRUSTER POWER SUPPLY
  - DIRECTLY FROM ARRAY
    - NO PROCESSING
    - NO REGULATION
  - NO PROCESSING
    - ARRAY REGULATION
  - ✓ PROCESS ALL POWER
- TYPE OF PROCESSING
  - MOTOR/GENERATOR
  - ✓ SOLID STATE
- PROCESSING THERMAL CONTROL
  - ACTIVE RADIATOR
  - 915 M^2
  - LIMIT ELECTRONICS TO 200°C

120 cm ION THRUSTER



SELECTED 120 cm ARGON ION THRUSTER CHARACTERISTICS

FIXED CHARACTERISTICS	
BEAM CURRENT:	80.0 AMPS.
ACCEL. VOLTAGE:	500.0 V.
DISCHARGE VOLTAGE:	30.0 V. (FLOATING)
COUPLING VOLTAGE:	11.0 V.
DBL. ION RATES:	0.16 (J2/J1)
NEUTRAL EFFLUX:	4.8384 AMP. EQUIV.
DIVERGENCE:	0.98
DISCHARGE LOSS:	187.3 EV/ION
OTHER LOSS:	1758.0 W.
UTILIZATION:	0.892 W.
LIFE:	8000 HR.
*WEIGHT:	50. KG.
SELECTED CHARACTERISTICS	
SCREEN (BEAM) VOLTAGE:	1700 V.
INPUT POWER:	130 KW
THRUST:	2.9 N
EFFICIENCY:	78

*WEIGHT PREDICTION COURTESY OF T. MASEK OF HRL.

EOTV MASS STATEMENT

POWER GENERATION AND DISTRIBUTION		951,000	
SOLAR ARRAY-SILICON	780,000		
STRUCTURE	122,000		
POWER DISTRIBUTION	42,000		
ENERGY STORAGE	7,000		
ELECTRIC PROPULSION		496,000	
THRUSTERS	79,000		
POWER CONDITIONING	219,000		
THERMAL CONTROL	88,000		
STRUCTURES & MECHANISM	61,000		
PROPELLANT FEED	49,000		
AUXILIARY SYSTEMS		15,000	
DRY WEIGHT			1,462,000
PROPELLANT			515,000
ARGON	469,000		
HYDROGEN	6,600		
OXYGEN	39,400		
PAYLOAD (GROSS)			4,000,000
TOTAL START BURN MASS.			5,977,000

EOTV AVERAGE COST PER UNIT

FLIGHT UNIT			247.0 M
• POWER GENERATION & DISTRIBUTION		99.7	
SOLAR ARRAY	79.6		
STRUCTURE	12.2		
POWER DISTRIBUTION	1.6		
ENERGY STORAGE	6.4		
• ELECTRIC PROPULSION		141.0	
THRUSTERS	15.4		
POWER CONDITIONING	87.2		
THERMAL CONTROL	22.1		
STRUCTURES & MECHANISMS	11.3		
PROPELLANT SYSTEM	5.0		
• AVIONICS		6.5	
PROGRAMMATICS			36.6
TOTAL			$283.6 M

EOTV - PER FLIGHT COST

HARDWARE

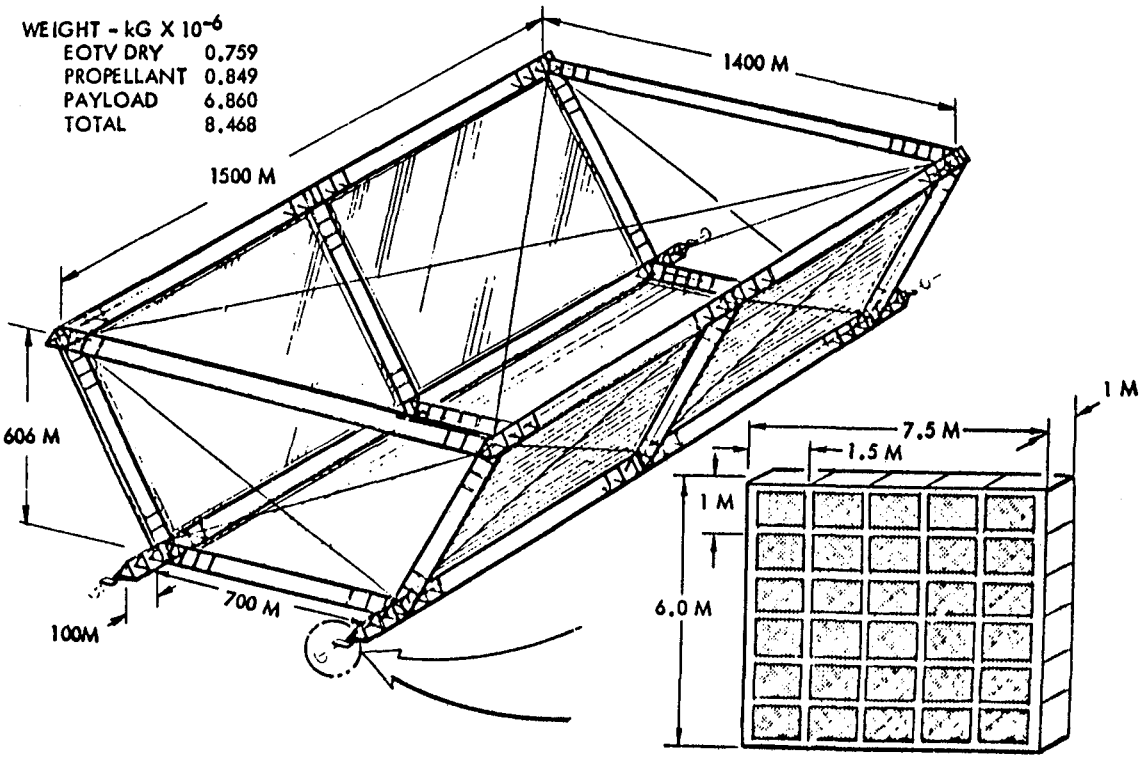
$$\frac{\text{AVERAGE VEHICLE COST}}{\text{FLIGHTS PER VEHICLE}} = \frac{283,600}{10} = \$28,400K$$

PROPELLANT

ARGON	470 MT @ $1/KG	470
O_2	39 MT @ $.037/KG	1
H_2	7 MT @ $1.53/KG	11

REFURBISHMENT	11,300
PROGRAM SUPPORT	500
TOTAL COST PER FLIGHT.	$40,682K

INDEPENDENT POWER EOTV CONCEPT - ROCKWELL
(GALLIUM ARSENIDE)



ARGON ION THRUSTER CHARACTERISTICS - ROCKWELL

MAXIMUM TOTAL VOLTAGE, VOLT	4405
MAXIMUM OPERATING TEMP, °K	1330
SCREEN GRID VOLTAGE, VOLT	1880
ACCELERATOR GRID VOLTAGE, VOLT	-2525
BEAM CURRENT, AMP	1500
BEAM POWER, WATT	2.8×10^6
SPECIFIC IMPULSE, SEC	7963
THRUST, NEWTON	56.26

BEAM CURRENT VS. THRUSTER LIFE ASSUMPTIONS

BEAM CURRENT -	80 AMPS/M^2	1500 AMPS/M^2
THRUSTER LIFE -	8000 HOURS	4000 HOURS

EOTV KEY ISSUE TECHNOLOGY NEEDS - GENERAL:

- CAPABILITY FOR COMPREHENSIVE ANALYSES OF COMPLEX, EXTREMELY LARGE STRUCTURES UNDER GRAVITY GRADIENT LOADS, NON-CONSTANT APPLIED FORCES, AND THERMAL TRANSIENTS. (STRUCTURAL CANNOT BE TESTED UNTIL IT IS CONSTRUCTED IN SPACE.)
- SELECTION OF STRUCTURAL MATERIALS FOR THER THERMAL, VACUUM, AND RADIATION ENVIRONMENT OF LEO-GEO FLIGHT. MEASUREMENT OF REQUIRED PROPERTIES FOR DESIGN.
- ANNEALING OF RADIATION DAMAGE IN SOLAR CELLS.
- HIGHLY RELIABLE, REDUNDANT ATTITUDE-CONTROL SYSTEM WHICH GUARANTEES STABILITY DURING OCCULATION OF THE SUN.
- AUTONOMOUS NAVIGATION, GUIDANCE, AND CONTROL SYSTEM.
- MEANS TO ASSURE AGAINST RE-ENTRY FROM LOW-EARTH ORBIT.

ELECTRIC PROPULSION - KEY ISSUES

- TECHNOLOGY FOR SCALING ION THRUSTERS FROM 30 CM TO 100 CM AND ABOVE.
  - GRID STABILITY
  - MULTIPLE CATHODE DESIGN
- REPLACEMENT OF MERCURY BY ARGON AS PROPELLANT.
- IONOSPHERIC EFFECTS OF ARGON.
- SYSTEMS DESIGN TRADE DATA TO SELECT:
  - THRUSTER LIFE
  - POWER
  - THRUST
  - I_{SP}