LASER PROPULSION OPTION

Donald H. Humes

LEO TO LLO TRANSPORTATION VEHICLES

LUNAR TRANSFER VEHICLE

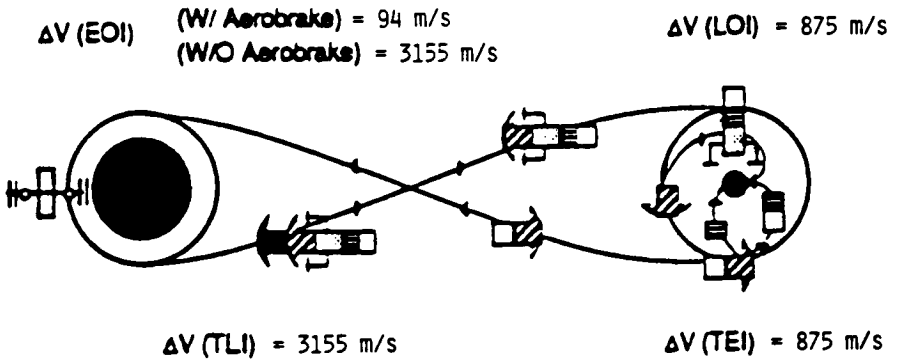
Dry Mass (engines, structure, etc.)	7.9 t
Propellant Type	LOX/LH2
Mixture Ratio	7/1
Specific Impulse	470 s
Payload Capacity (includes crew)	1.0 t
Crew Capacity	6
Propellant Capacity	18.5 t

ELECTRIC CARGO VEHICLE

Dry Mass		125.0 t
5 MWe Reactor, Engines	(75.0 t)	
Tanks, Propellant Reserves (10% Propellant)	(19.0 t)	
Payload Adaptor/Structure (5% Payload Capacity)	(31.0 t)	
Propellant Type		Argon
Mixture Ratio		NA
Specific Impulse		6000 s
Payload Capacity		620
Crew Capacity		Unmanned
Propellant Capacity		190

CHEMICAL PROPULSION ΔV SUMMARY

from T.D. HOY LBS-88-233



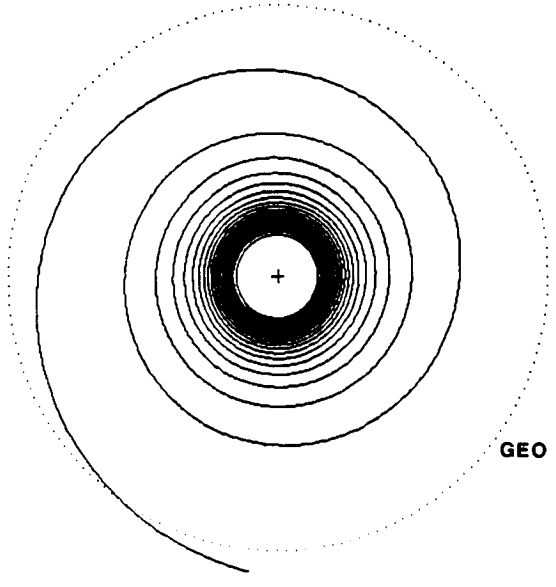
EOI - Earth Orbit Insertion

LOI - Lunar Orbit Insertion

TLI - Trans Lunar Burn

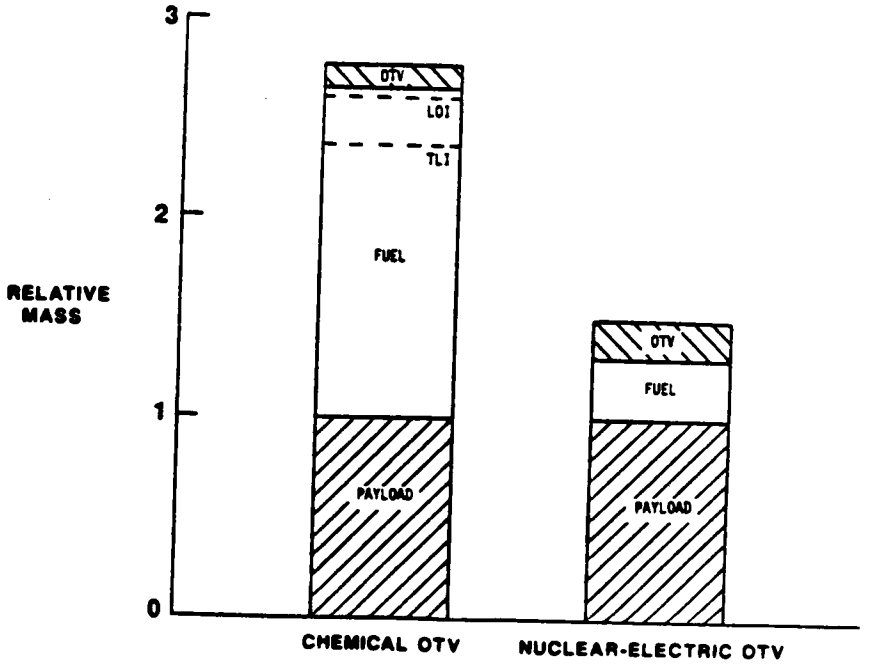
TEI - Trans Earth Injection Burn

LOW-THRUST EARTH-ESCAPE TRAJECTORY



COMPARISON OF CHEMICAL OTV AND ELECTRIC OTV

FOR LEO-LLO OPERATIONS



COMPARISON OF CHEMICAL OTV AND ELECTRIC OTV

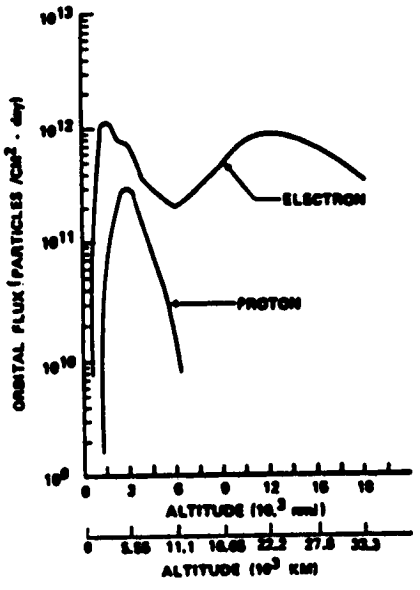
FOR LEO-LLO OPERATIONS

OTV	TIME, days (OUTGOING) LEO-GEO	LEO-LLO
CHEMICAL	.091	2.3
NUCLEAR-ELECTRIC	277.	401.
NUCLEAR-ELECTRIC *	90.	130.

* with 144000 kg payload (oneway)

RADIATION FLUX VERSUS ALTITUDE

NASA CONTRACTOR REPORT 3536



COMPARISON OF CHEMICAL OTV AND ELECTRIC OTV

FOR LEO-LLO OPERATIONS

OTV	RELATIVE RADIATION FLUENCE	
	ELECTRONS	PROTONS
CHEMICAL	1	1
NUCLEAR-ELECTRIC	2970	6570
NUCLEAR-ELECTRIC *	958	2120

* with 144000 kg payload (oneway)

NASA EVOLUTIONARY EXPANSION TRANSPORTATION PLAN

TWO OTVs ARE REQUIRED BECAUSE

- CHEMICAL OTVs ARE TOO EXPENSIVE TO DELIVER CARGO (IN TERMS OF FUEL MASS DELIVERED TO LEO)
- NUCLEAR-ELECTRIC OTVs ARE TOO SLOW FOR MANNED FLIGHTS

PURPOSE OF TALK

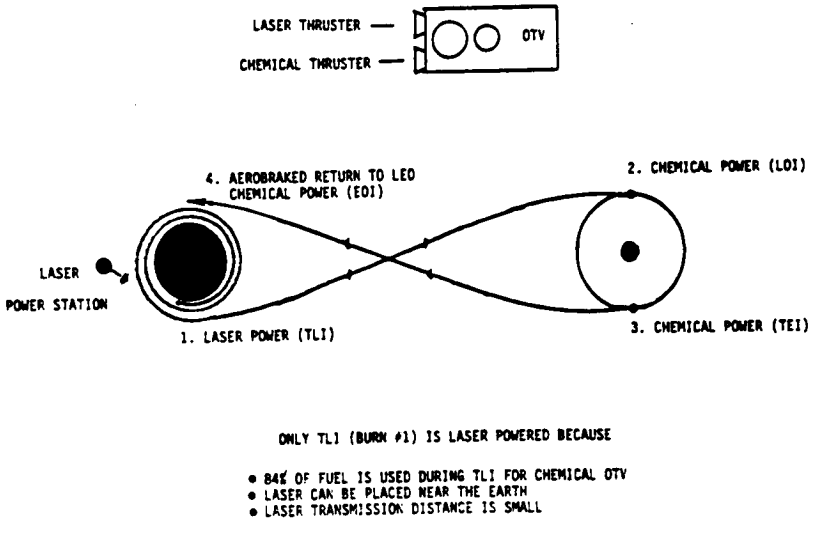
THE PURPOSE OF THIS TALK IS TO SHOW THAT THE ADDITION OF A LASER THRUSTER TO A CHEMICAL OTV, MAKING IT A HYBRID LASER/CHEMICAL OTV, WOULD RESULT IN THE FUEL SAVINGS NEEDED WHILE STILL PROVIDING FAST TRIP TIMES, THUS ELIMINATING THE NEED FOR NUCLEAR-ELECTRIC OTVs IN THE EARTH/MOON REGION

ADVANTAGES OF LASER PROPULSION

- FUEL EFFICIENT COMPARED TO CHEMICAL THRUSTERS BECAUSE LASER THRUSTERS HAVE A SPECIFIC IMPULSE OF ABOUT 1500 s COMPARED TO ABOUT 480 s FOR CHEMICAL THRUSTERS
- HIGH THRUST COMPARED TO NUCLEAR-ELECTRIC THRUSTERS MAKING TRIP TIMES MUCH SHORTER, ESPECIALLY THROUGH THE VAN ALLEN RADIATION BELTS
- LASER PROPULSION IS A HAPPY COMPROMISE BETWEEN CHEMICAL AND NUCLEAR-ELECTRIC PROPULSION HAVING THE ADVANTAGES OF BOTH

HYBRID LASER/CHEMICAL OTV

FOR LEO-LLO OPERATIONS



ONLY TLI (BURN #1) IS LASER POWERED BECAUSE

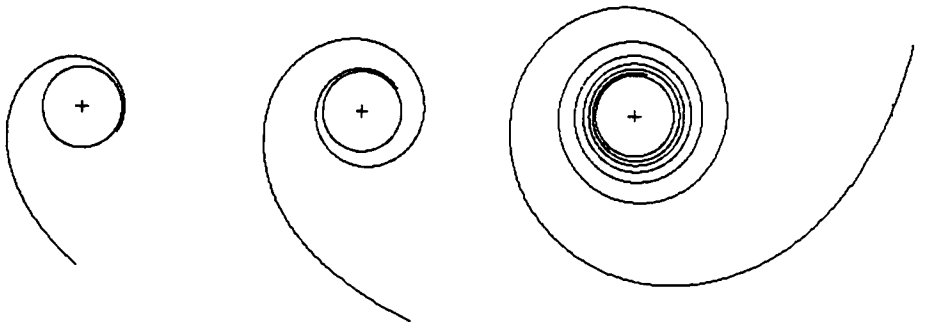
- 84% OF FUEL IS USED DURING TLI FOR CHEMICAL OTV
- LASER CAN BE PLACED NEAR THE EARTH
- LASER TRANSMISSION DISTANCE IS SMALL

LOW-THRUST EARTH-ESCAPE TRAJECTORIES

HYBRID LASER/CHEMICAL OTV

MASS (OTV) = 8790 kg

I_{sp} = 1500 s



$P_{exhaust}$ = 250 MW
Payload = 36000 kg

$P_{exhaust}$ = 100 MW
Payload = 28800 kg

$P_{exhaust}$ = 25 MW
Payload = 24000 kg

PERFORMANCE OF HYBRID LASER /CHEMICAL OTV

FOR DELIVERY OF 144000 kg TO LLO FROM LEO

MASS (OTV) = 8790 kg

I_{sp} = 1500 s (laser)
I_{sp} = 465 s (chemical)

POWER (exhaust)	THRUST	PAYLOAD/TRIP	TRIPS	MASS FUEL*	LASER	
					ON TIME	MAXIMUM RANGE*
250 MW	34000 N	36000 kg	4	133600 kg	2.55 hr	24700 km
150	20400	28800	5	147800	3.81	27200
100	13600	28800	5	154000	6.05	34500
50	6800	28800	5	163400	13.2	47300
25	3400	24000	6	181600	24.7	63400

* Total fuel required to deliver 144000 kg to LLO (all four burns, all trips) with return to LEO

* Range of OTV from center of Earth when laser power discontinued

PERFORMANCE OF HYBRID LASER/CHEMICAL OTV

FOR LEO-LLO OPERATIONS

MASS (OTV) = 8790 kg

I_{sp} = 1500 s (laser)

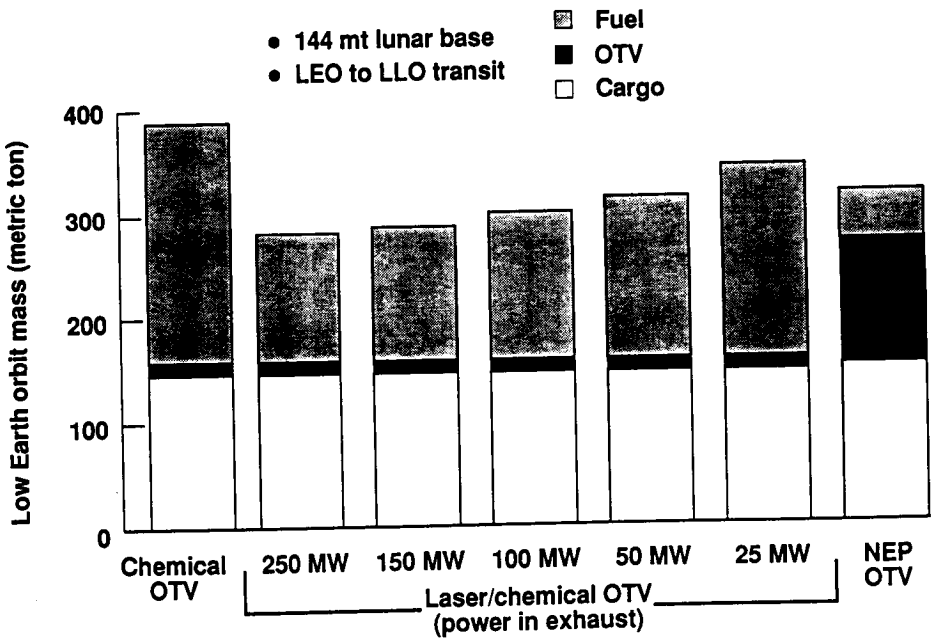
I_{sp} = 465 s (chemical)

POWER(exhaust)	RELATIVE* RADIATION FLUENCE PER TRIP	
	ELECTRON FLUENCE	PROTON FLUENCE
250 MW	1.61	2.54
150	2.08	4.10
100	3.04	6.65
50	5.43	11.6
25	9.27	20.5
Chemical	1.	1.
NEP	2970.	6570.
NEP*	958.	2120.

* With 144000 kg payload

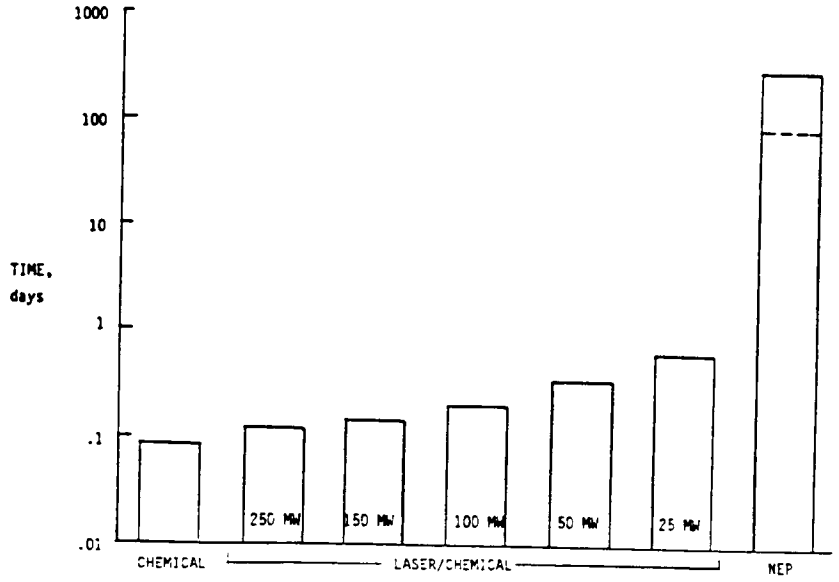
* Relative to that of chemical OTV

LEO MASS TO DELIVER LUNAR BASE

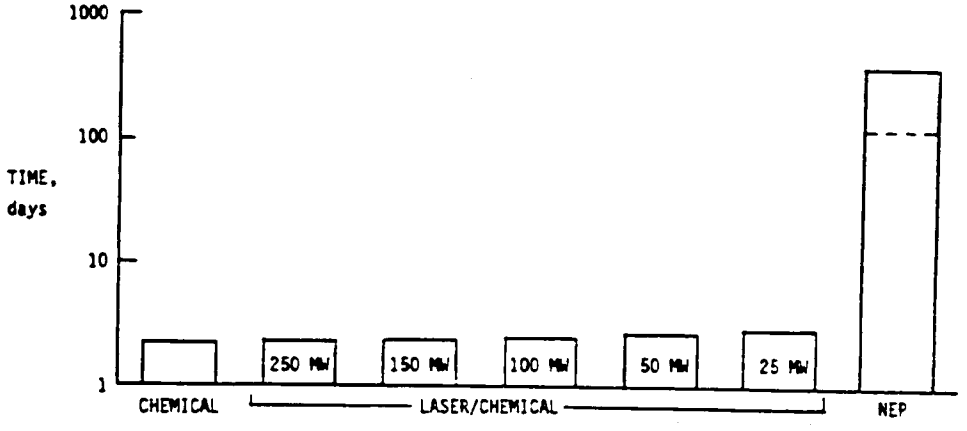


TIME IN VAN ALLEN RADIATION BELTS

(LEO-GEO)



TIME FOR LEO TO LLO TRANSFER



SUMMARY

THE USE OF LASER THRUSTERS WITH EXHAUST POWERS IN THE 25 MW TO 250 MW RANGE CAN REDUCE THE FUEL THAT WOULD BE NEEDED TO TRANSPORT THE LUNAR OUTPOST EQUIPMENT TO LOW-LUNAR ORBIT WITH A CHEMICAL OTV BY 57000 KG TO 105000 KG WITH NO SIGNIFICANT PENALTY IN TRIP TIME. THIS WOULD SAVE ONE OR TWO LAUNCHES OF THE HEAVY-LOAD LAUNCH VEHICLE.

NUCLEAR-ELECTRIC OTVs WOULD TAKE 40 TO 120 TIMES AS LONG TO GET TO THE MOON AND WOULD SPEND 100 TO 1700 TIMES AS LONG IN THE VAN ALLEN RADIATION BELTS AS OTVs THAT HAVE LASER THRUSTERS.