NIAC Fellows Meeting
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Hypersonic Airplane Space Tether Orbital Launch (HASTOL) System

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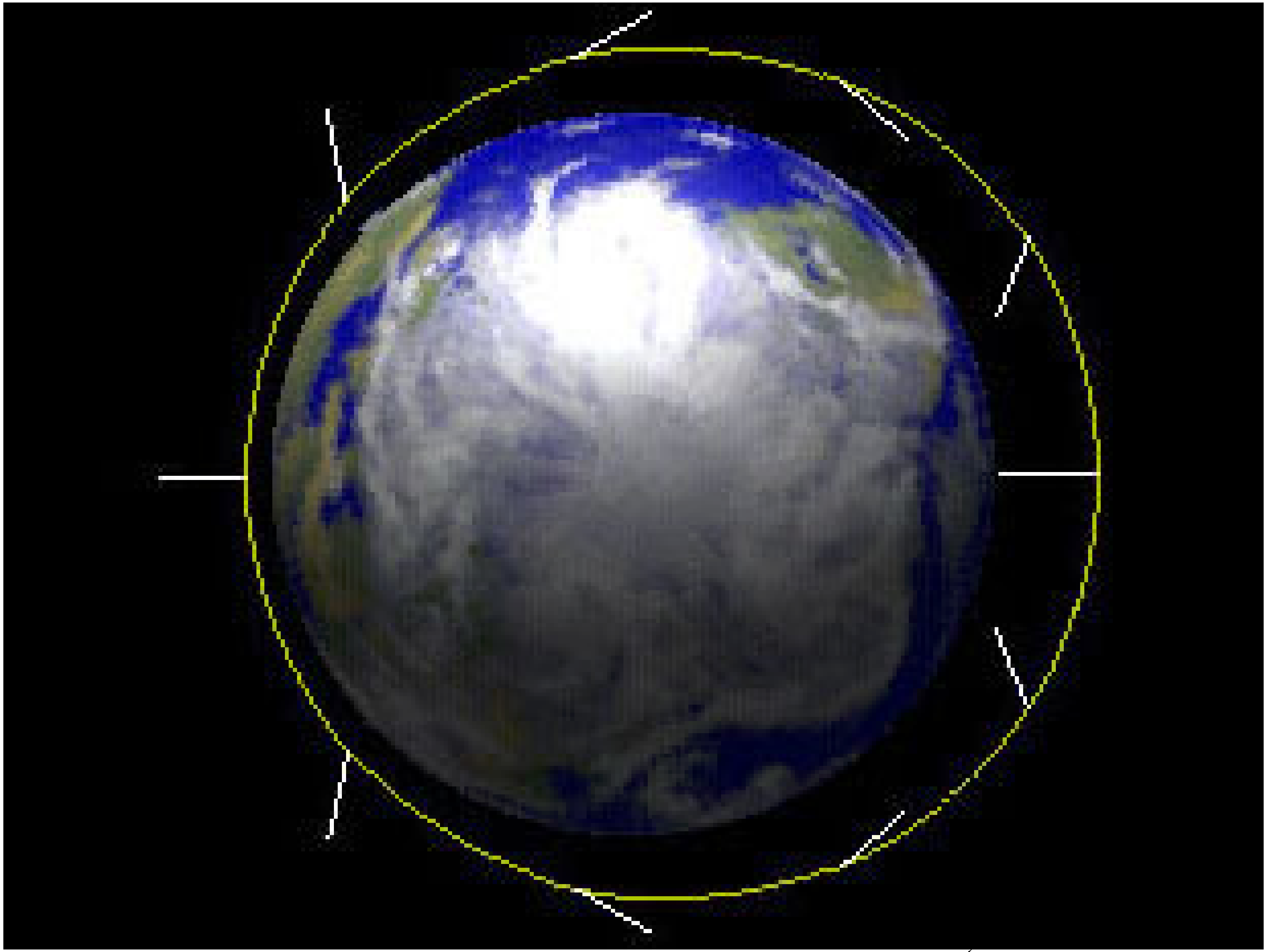
Discussion Topics

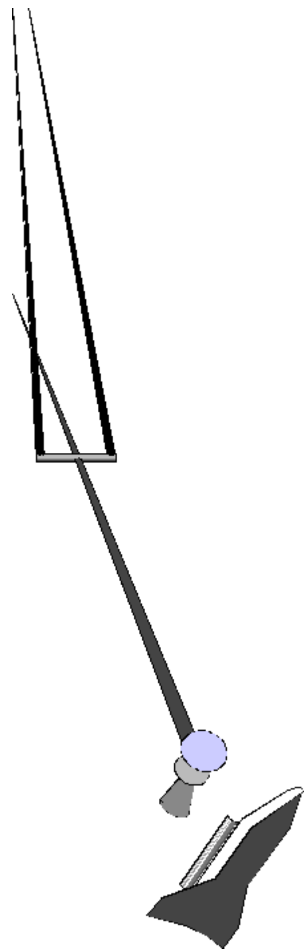
- **HASTOL Concept Overview**
- **Hypersonic Vehicle Description**
- **Trajectory Analysis Results**
- **Tether Design Considerations**

Hypersonic Airplane – Space Tether Orbital Launch System

CardioRotovator Concept



Tillotson Two-Tier Tether (T4) Concept



- Two-Stage Rotovator
- Reduces Ratio Of Tether System Mass To Payload Mass

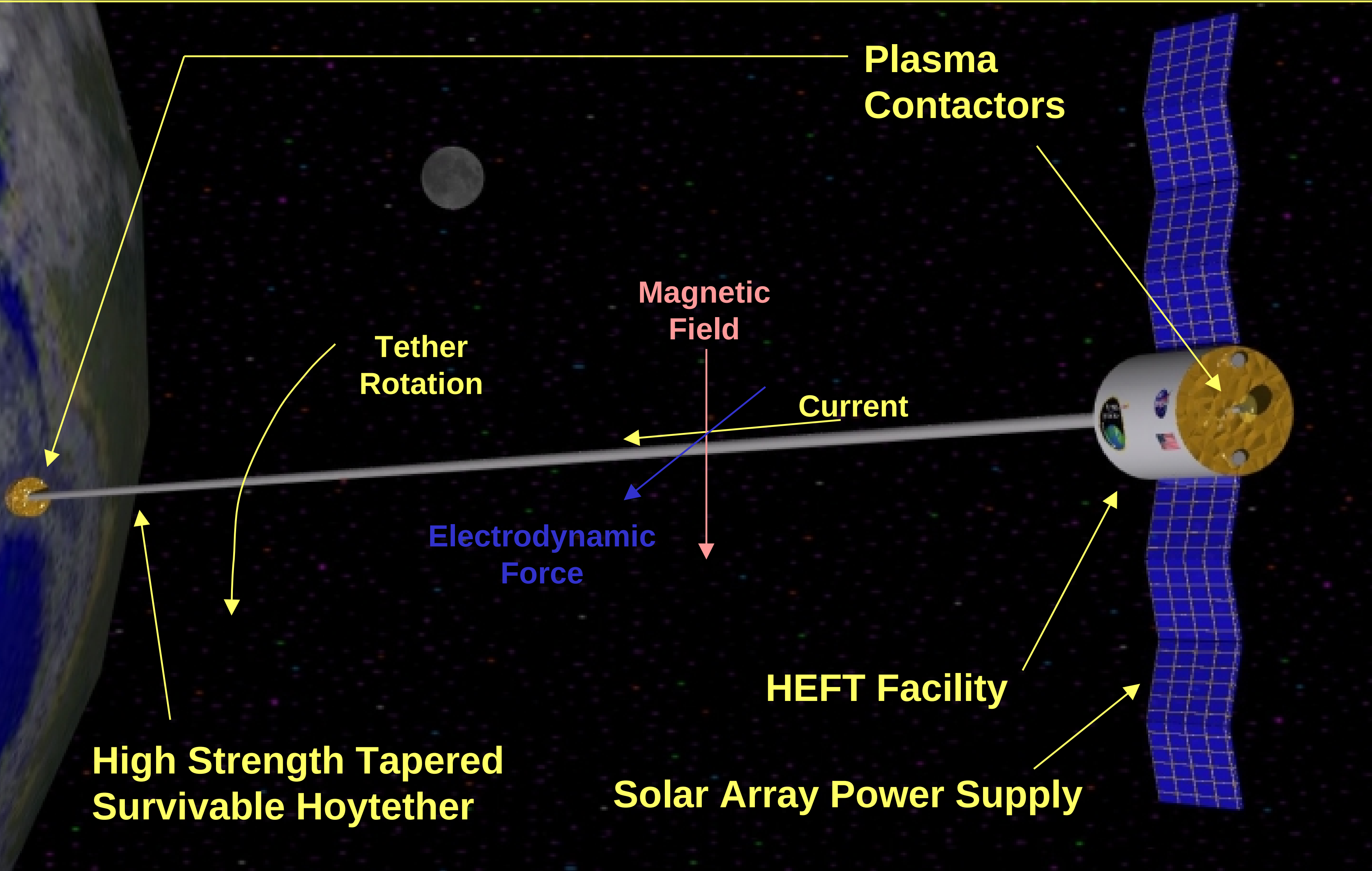
Rotovator Tether Mass Ratios

Tether Length	Orbital Radius	Orbital Velocity	Tip Velocity	Hypersonic Airplane Velocity		Tether to Payload Mass Ratio		
L	R_O	V_O	V_T	$V_H = V_O - V_T - 470$ m/s		M_T/M_P		
(km)	(km)	(m/s)	(m/s)	(m/s)	Mach	Spectra ™	2x	10x
400	6878	7614	2494	4650	15.0	10.4	2.4	0.37
500	6978	7559	2749	4340	14.0	16.7	4.2	0.56
600	7078	7506	3006	4030	13.0	27.1	5.9	0.65
700	7178	7453	3263	3720	12.0	44.0	8.2	0.73
800	7278	7402	3522	3410	11.0	71.8	11.6	0.90
900	7378	7352	3782	3100	10.0	117.6	16.3	1.07

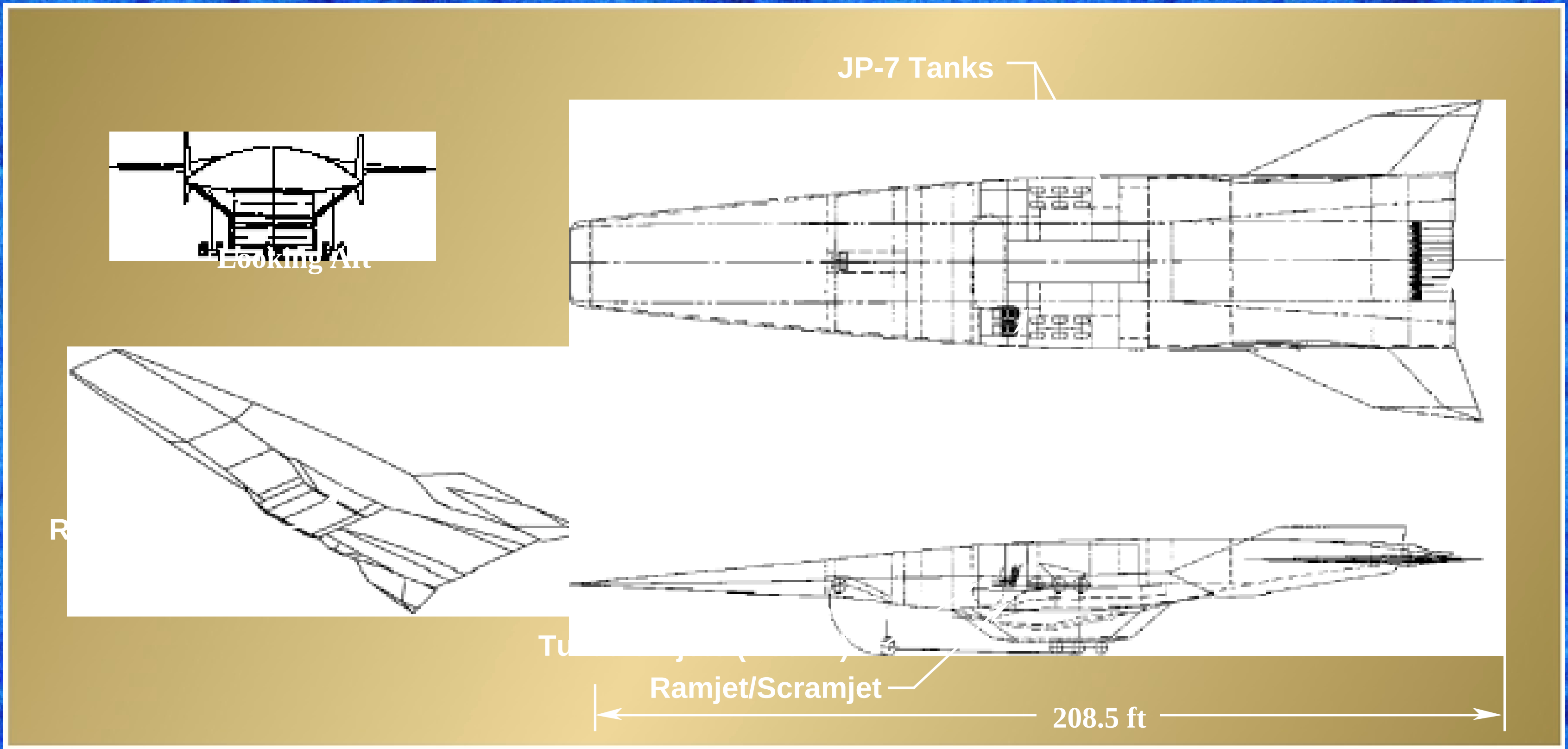
CardioRotovator Tether Mass Ratios

Tether Length	Orbital Radius	Orbital Velocity	Tip Velocity	Tip Accel.	Hypersonic Airplane Velocity		Tether to Payload Mass Ratio		
L	R_O	V_O	V_T	a	$V_H = V_O - V_T - 470$ m/s		M_T/M_P		
(km)	(km)	(m/s)	(m/s)	(m/s^2)	(m/s)	Mach	Spectra	2x	10x
1000	7478	7147	2076	0.43	4601	14.8	10.8	3.1	0.39
1200	7678	7004	2440	0.50	4094	13.2	22.2	5.2	0.55
1400	7878	6868	2789	0.56	3608	11.6	44.7	8.4	0.75
1600	8078	6737	3124	0.61	3143	10.1	87.8	13.4	0.97
1800	8278	6611	3445	0.66	2695	8.7	168.5	21.0	1.24

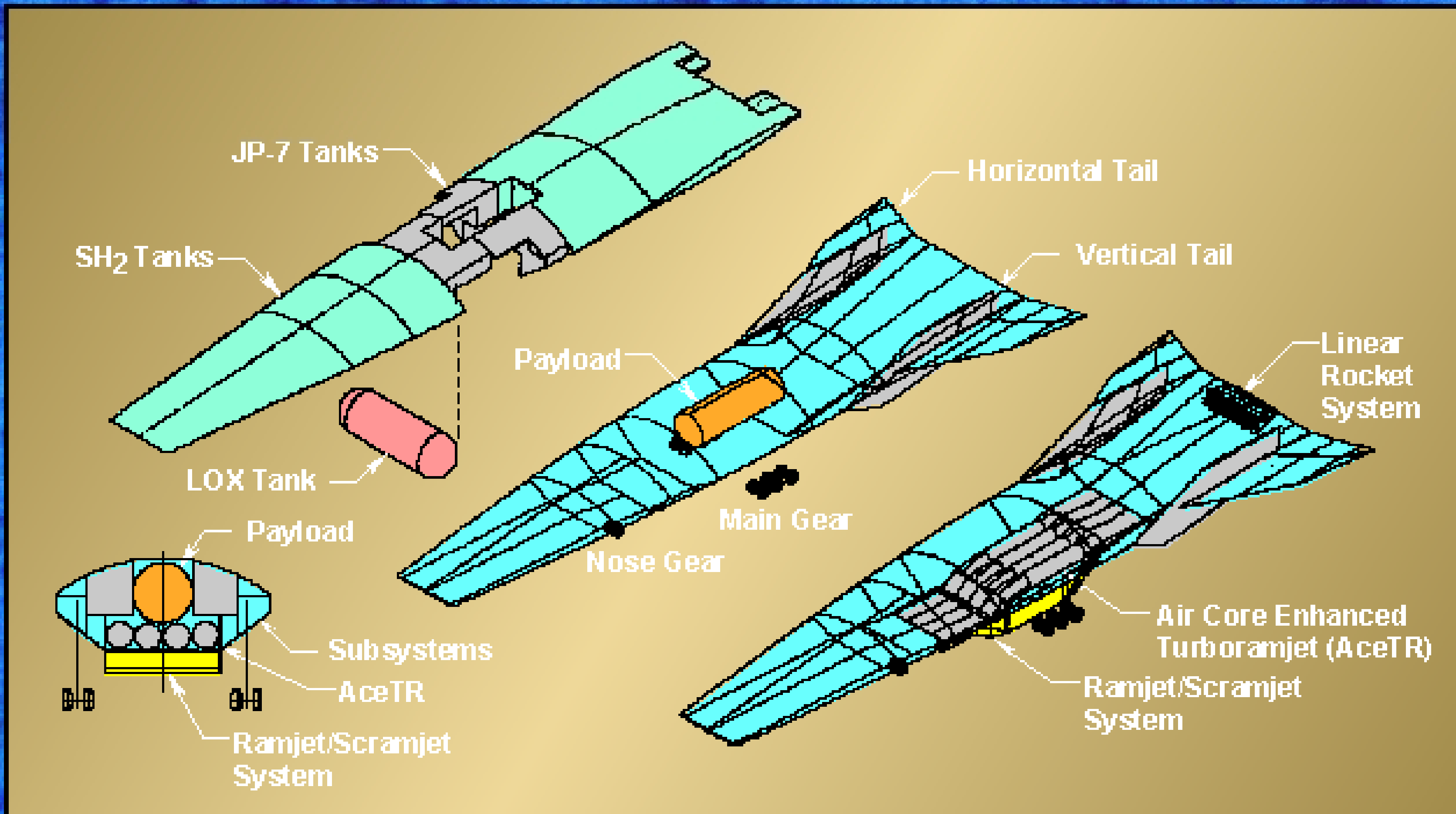
High-strength Electrodynamic Force Tether (HEFT) Facility



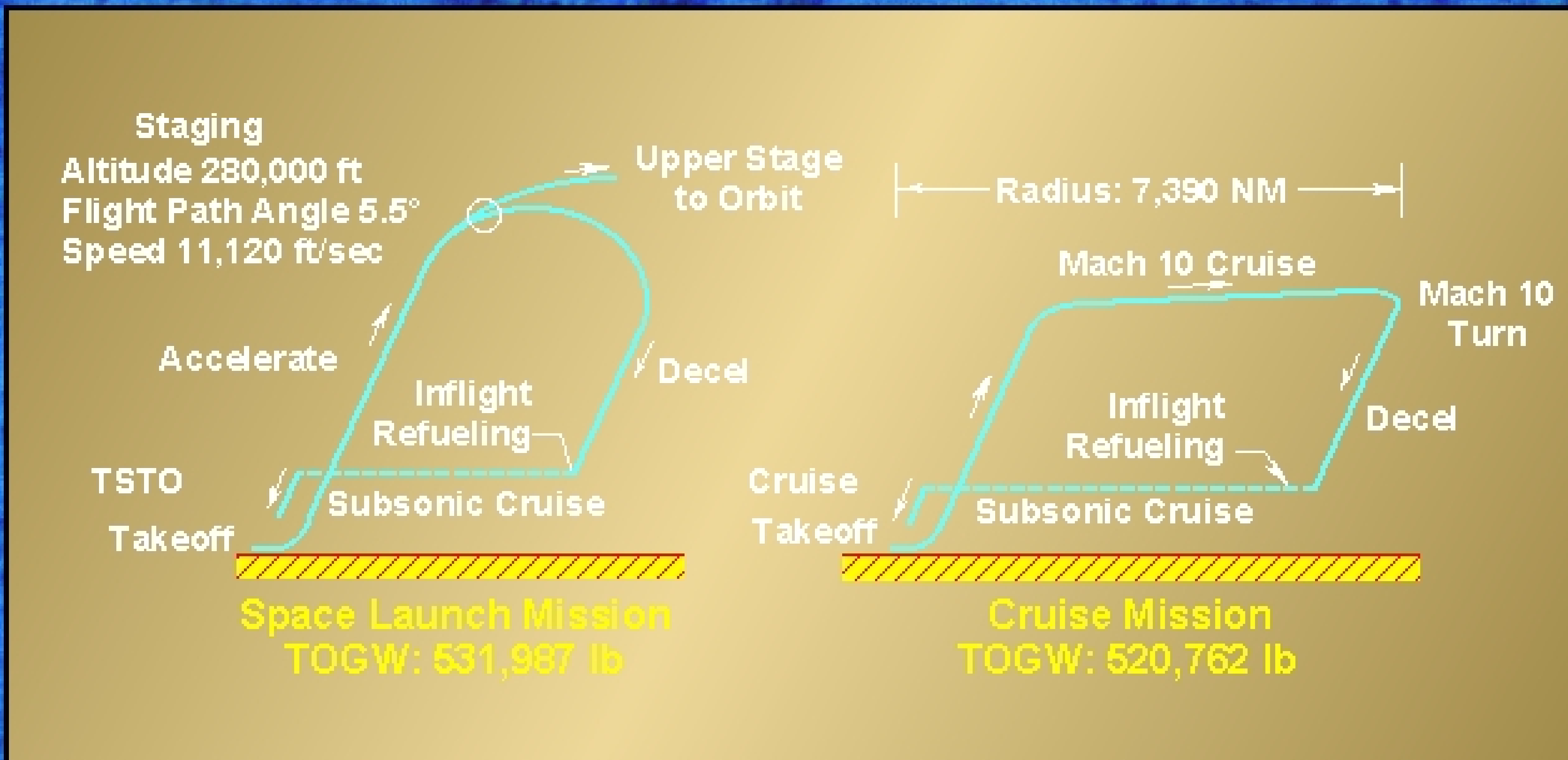
Dual-Fuel DF-9 Dual Role Vehicle



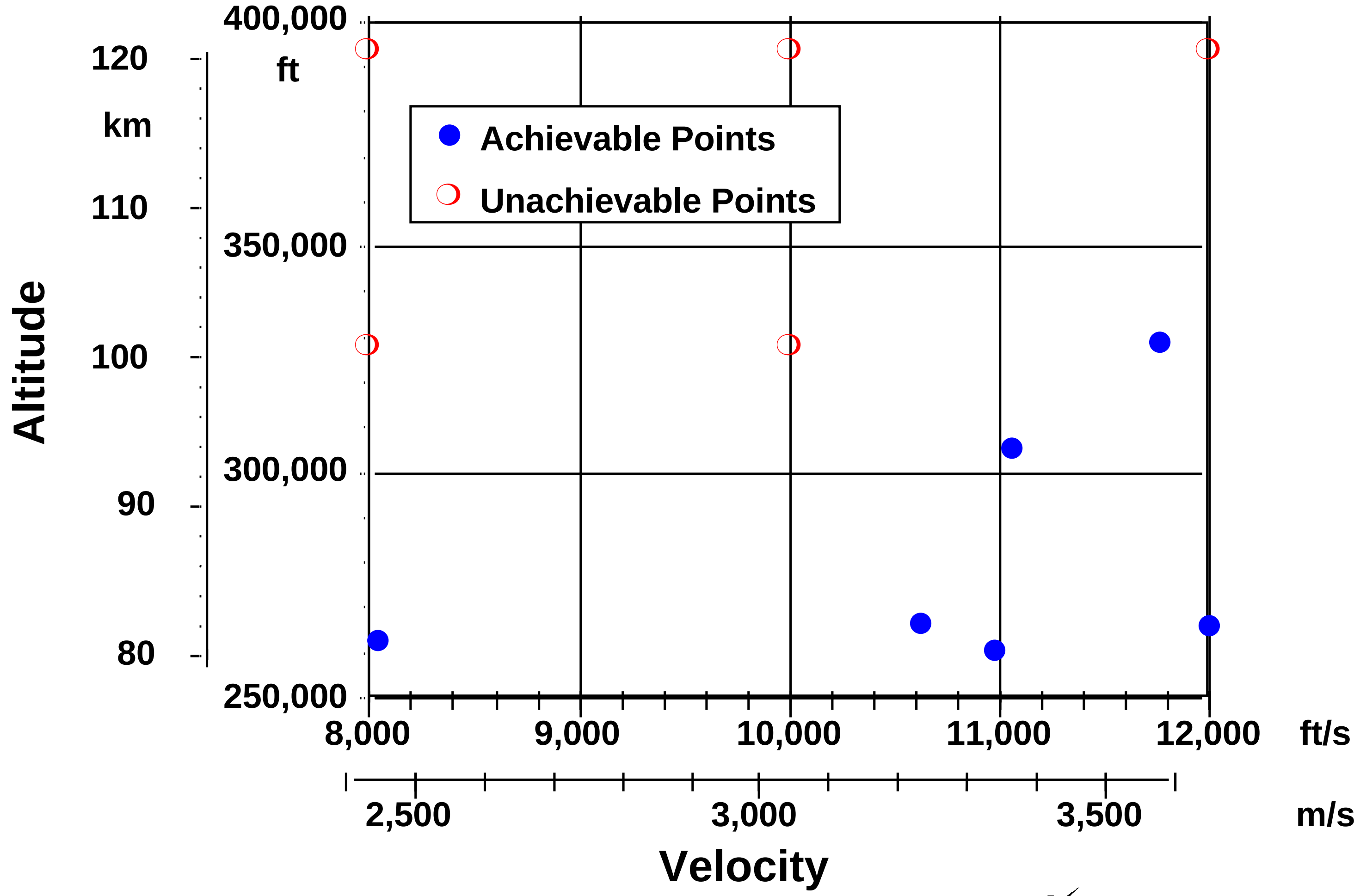
Dual-Fuel DF-9 Dual Role Vehicle



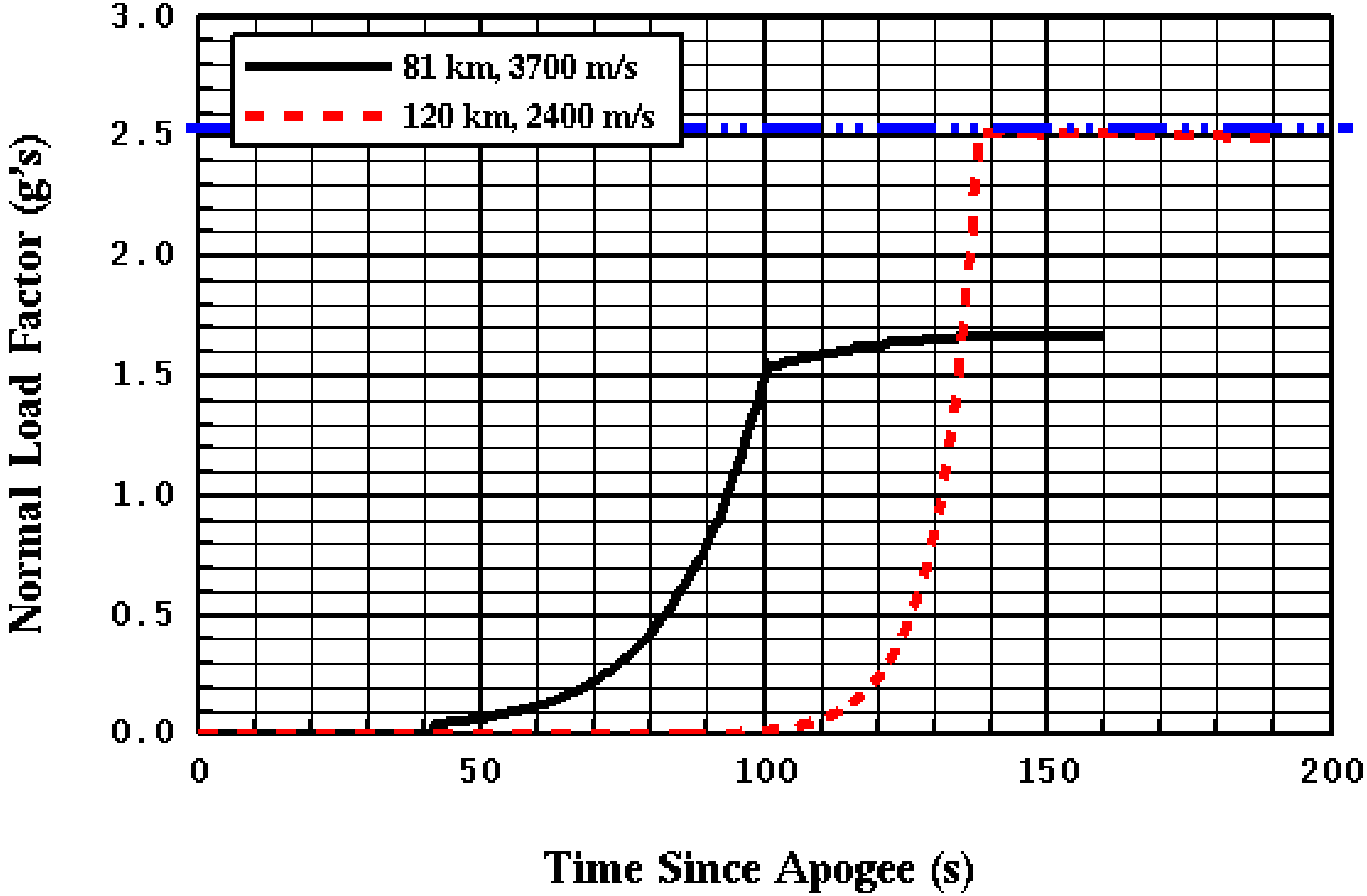
Dual-Fuel DF-9 Performance



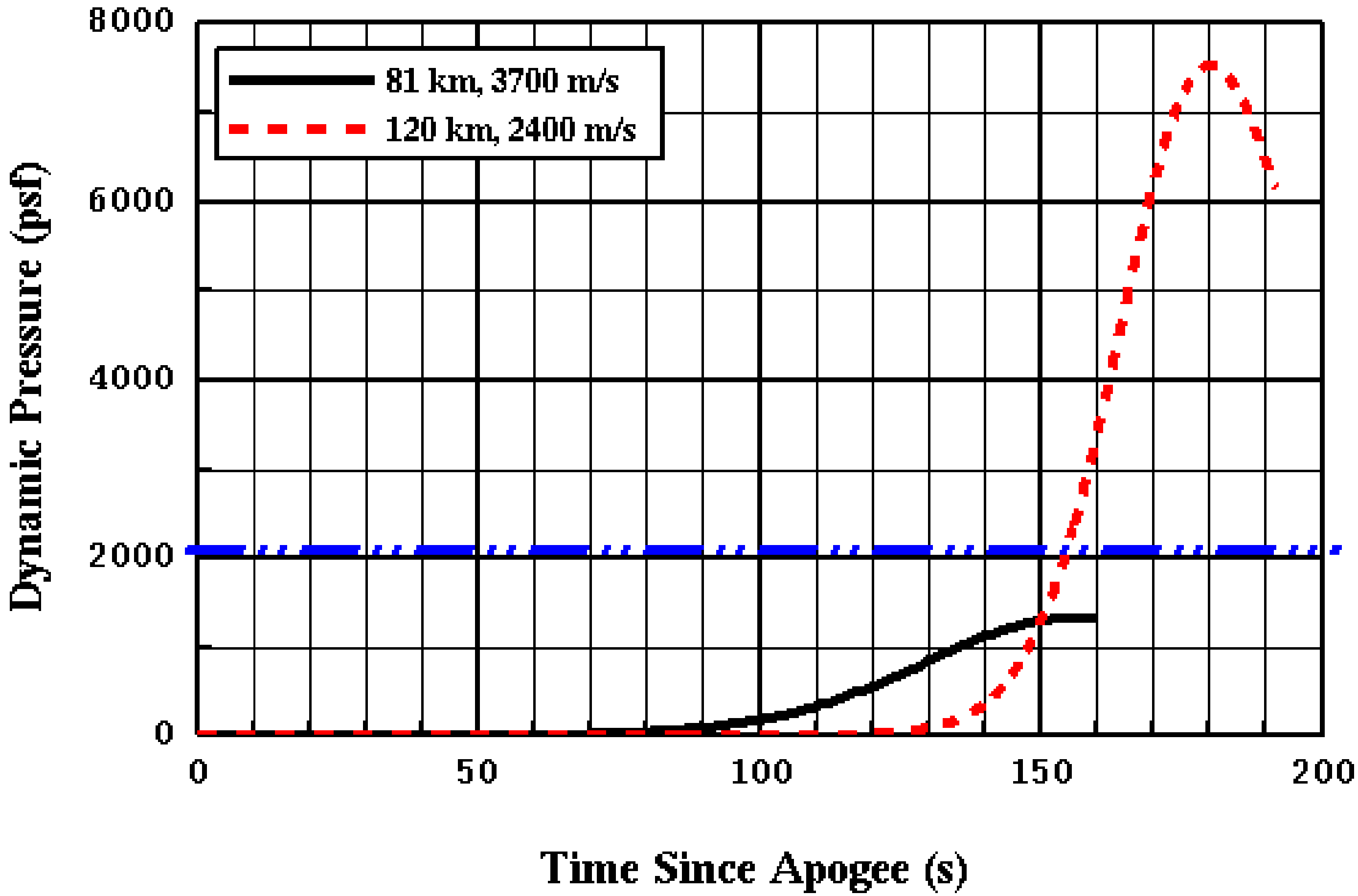
Matrix Of Payload Transfer Points Analyzed



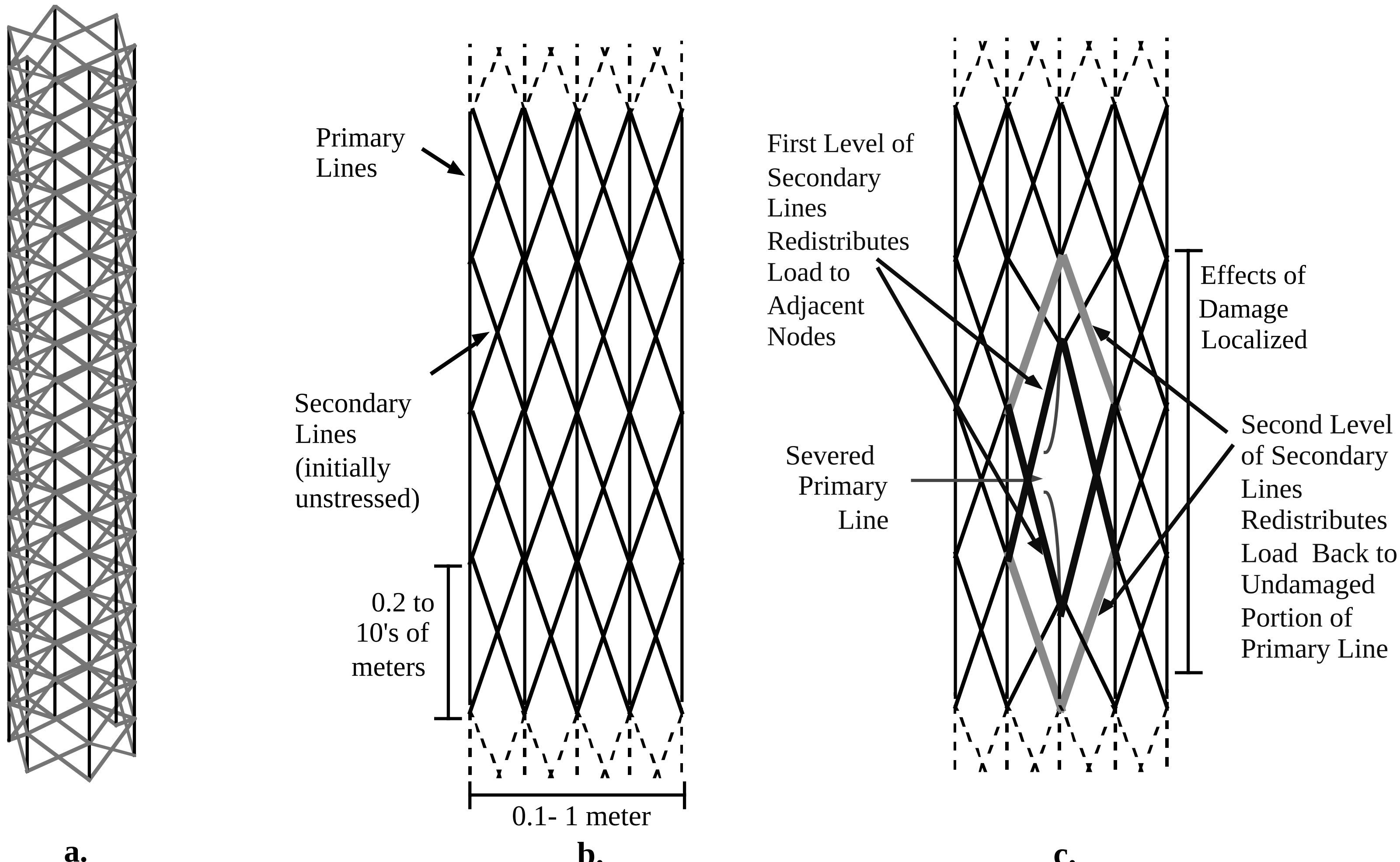
Normal Load Factor Along Descent Trajectory



Dynamic Pressure Along Descent Trajectory



Hoytether™ Failsafe Tether Design

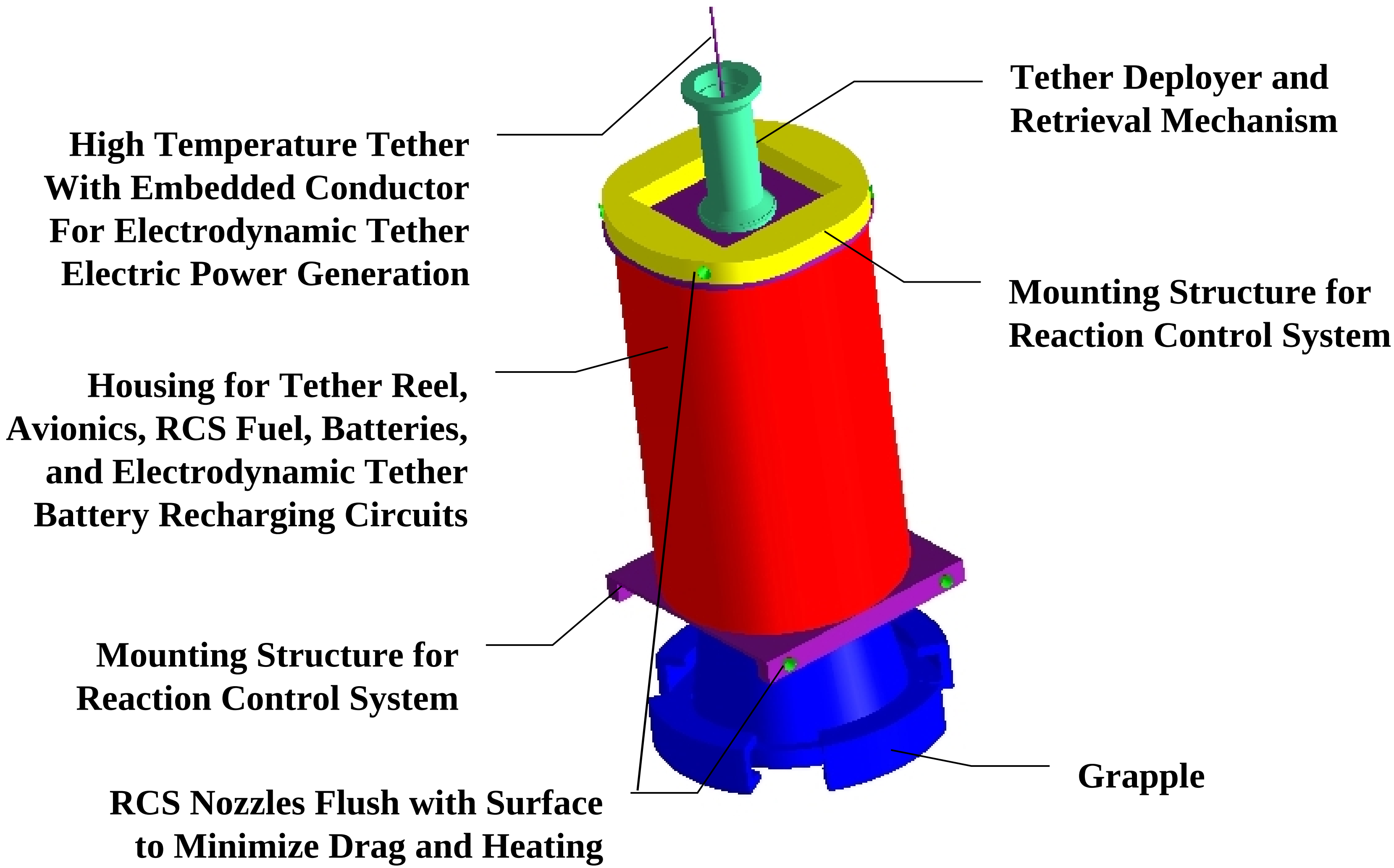


High Temperature Tether Materials

Tensile Strength (GPa) vs. Temperature

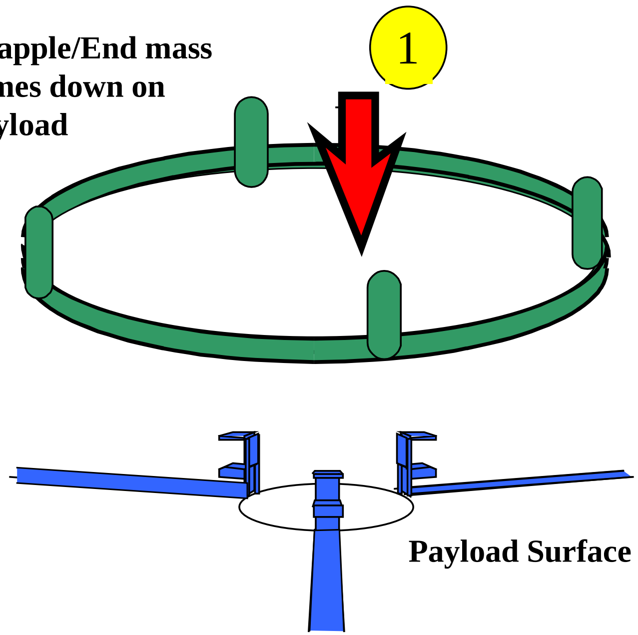
Material	V_C (km/s)	Density d (g/cc)	20 C	300 C	600 C	800 C	1000 C	1200 C
Spectra 2000	2.87	0.97	4.0	-	-	-	-	-
Zylon (PBO)	2.73	1.56	5.8	3.7	-	-	-	-
Quartz Glass (SiO_2)	1.81	2.20	3.6	3.6	3.6	3.6	3.6	?
S-glass	1.94	2.50	4.7	?	?	?	?	?
Carbon	2.77	1.80	6.9	?	?	?	?	?
Carbon/Ni-coated	2.12	2.68	6.0	?	?	?	?	?
Tyranno (SiTiCO)	1.66	2.55	3.5	3.5	3.5	3.5	3.5	3.5
Textron β-SiC	2.19	2.93	7.0	6.6	6.0	5.6	5.2	4.5
0.72 β-SiC/Ti-coated	1.72	3.37	5.0	4.8	4.3	4.0	3.7	3.2
Altex (Al_2O_3/SiO_2)	1.21	3.30	2.4	2.4	2.4	2.4	2.4	1.5
Nextel (α-Al_2O_3)	1.30	3.88	3.3	?	?	?	?	?
0.65 Nextel/Al-coated	0.97	3.40	1.6	1.4	?	?	?	?
Tungsten Wire	0.55	19.35	2.9	2.9	2.9	2.9	2.9	2.9

HASTOL GRAPPLE ASSEMBLY

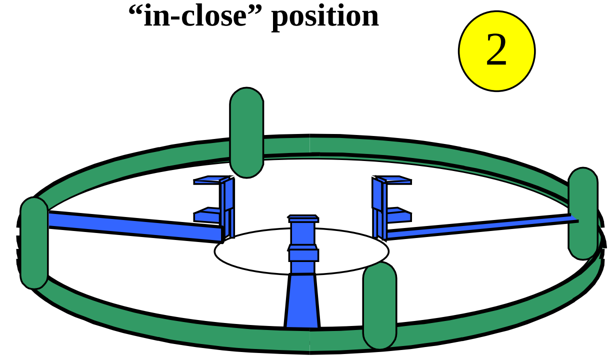


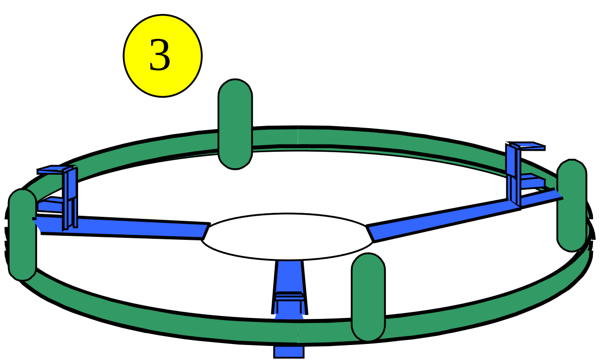
Grapple to Payload Attachment Option

Grapple/End mass comes down on Payload

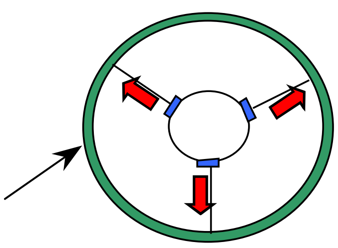


Grapple stops on Payload, levers on payload are in "in-close" position





**Attach Levers then move radially outward toward ring; sliding on rails. Once contact with ring is made,
they latch to the ring securing the payload to the grapple.**



Grapple Ring

Conclusions

- The HASTOL System provides a system to deliver payloads to space with minimal reliance on rocket propulsion
- Tether designs using existing materials can provide required strength at required thermal loads
- The Hoytether™ design provides a survivable tether concept for long duration operation
- Issues to be addressed in future work include Grapple design refinement and payload transfer logisitics