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STUDY TO DETERMINE THE EFFECTIVENESS AND COST OF A LASER-PROPELLED "LIGHTCRAFT" VEHICLE SYSTEM - RESULTS TO GUIDE FUTURE DEVELOPMENTS

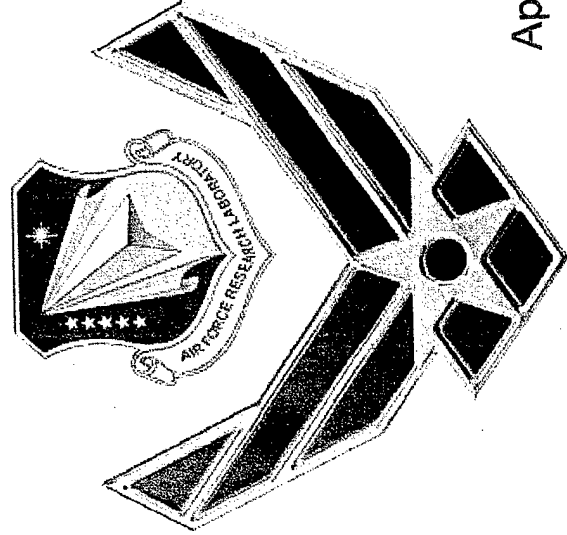
Second International Symposium

on

Beamed Energy Propulsion

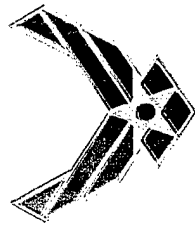
Sendai, Japan

20 - 23 Oct 2003

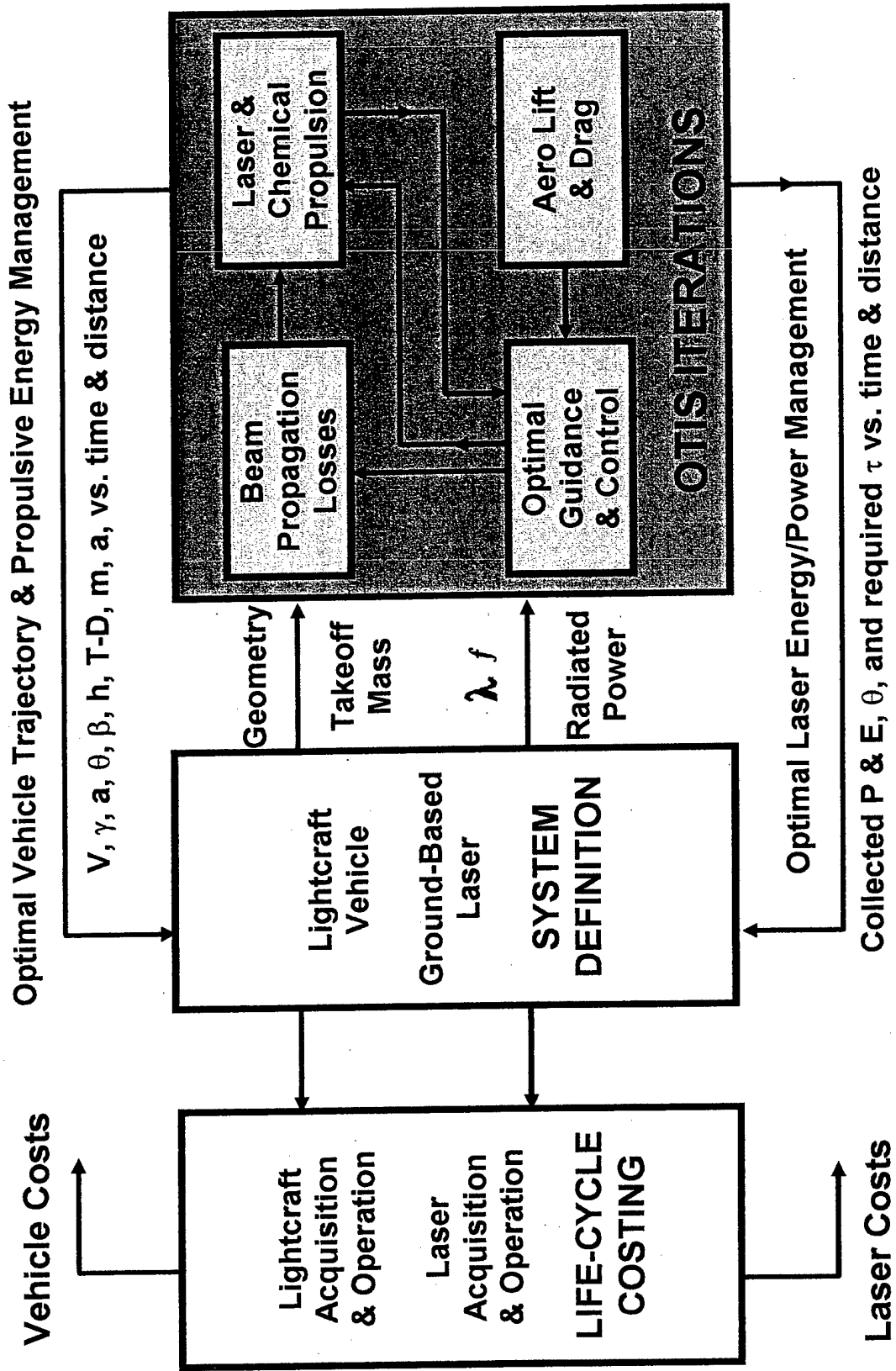
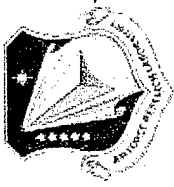


**By Froning, Pike, McKinney, Mead, & Larson
Work Performed by Flight Unlimited, Flagstaff, AZ
Under the Direction of the Propulsion Directorate
Air Force Research Laboratory, Edwards AFB, CA**

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Flow Diagram of Laser Lightcraft System Study





Lightcraft Vehicle Concept



Shroud (Cowl):
within which Laser
Heating of Airflow
and Propellant
Occurs

Laser Airbreathing Flight
from Zero Velocity to
Hypersonic Speed

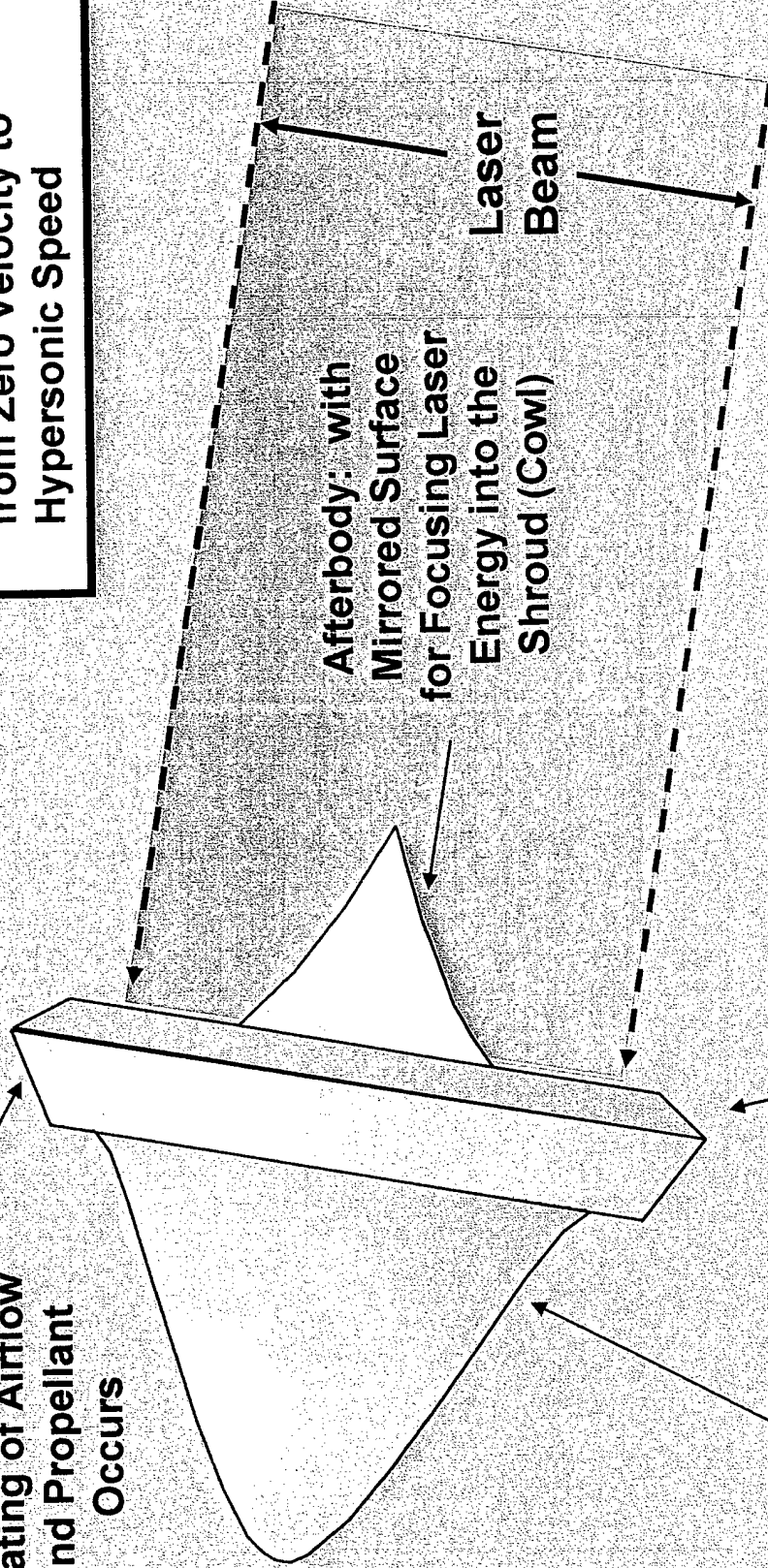
Afterbody: with
Mirrored Surface
for Focusing Laser
Energy into the
Shroud (Cowl)

Laser
Beam

Forebody: for Lift
and Compression
of Airflow during
Atmospheric Flight

Axi-Symmetric Body

Laser Rocket Flight from
Hypersonic to Orbital
Speed

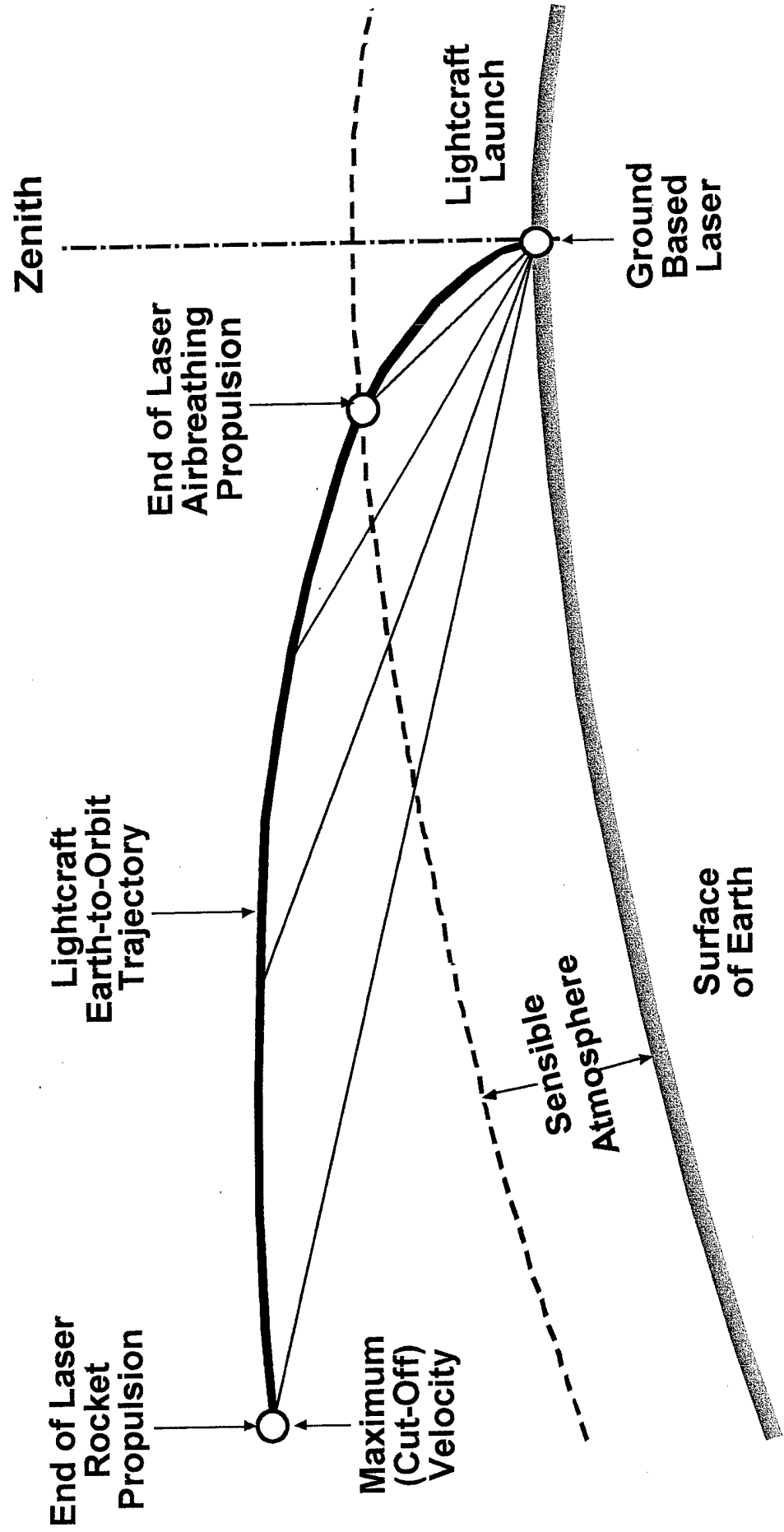


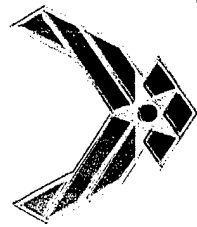


Lightcraft Earth-to-Orbit Trajectory and Associated Pointing Direction of Laser Beam

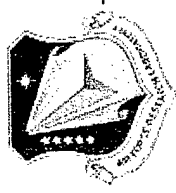


(Not to Scale)





Laser Beam Power Loss Mechanisms



Diffraction:

Reduces Vacuum Propagation Intensity of Power P and wavelength λ , through an aperture of diameter D at a range of R to : $PD^2/R^2\lambda^2$

Thermal Blooming:

Laser Heating of Air Distorts Far Field Beam:

- Aggravated by low wind, low slew rate, high absorption, high power density

Turbulence:

Fluctuates Day-to-Day & Seasonally:

- Aggravated by low altitude targets, short wavelength, large diameter beams

Extinction:

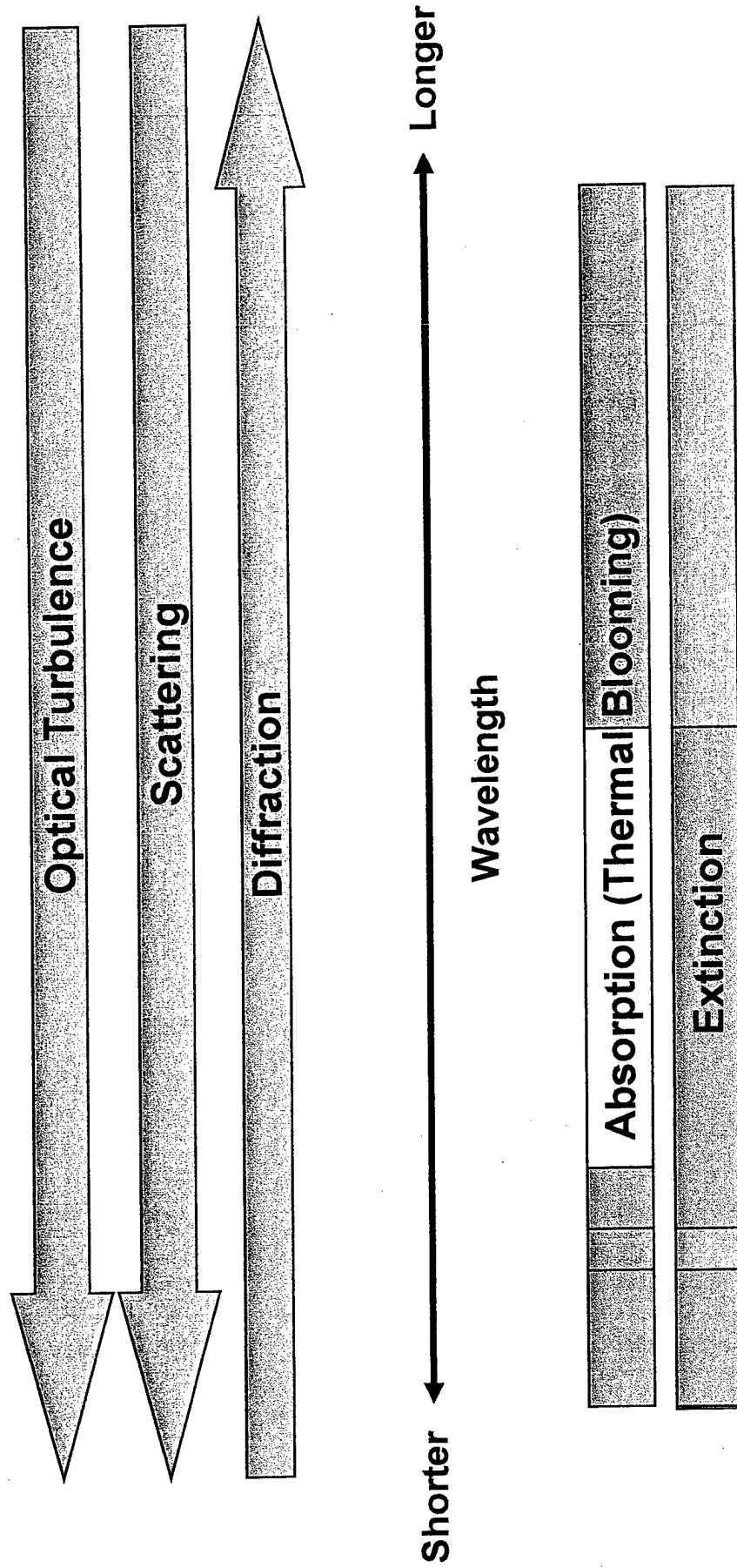
Varies Seasonally, Daily if Fog/Rain, & by Detailed Laser Wavelength(s):

- Aggravated by higher temperature, long ranges, rain
- Devastated by fog, clouds

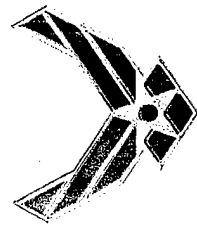


Optimization Considerations

Balancing Loss Mechanisms



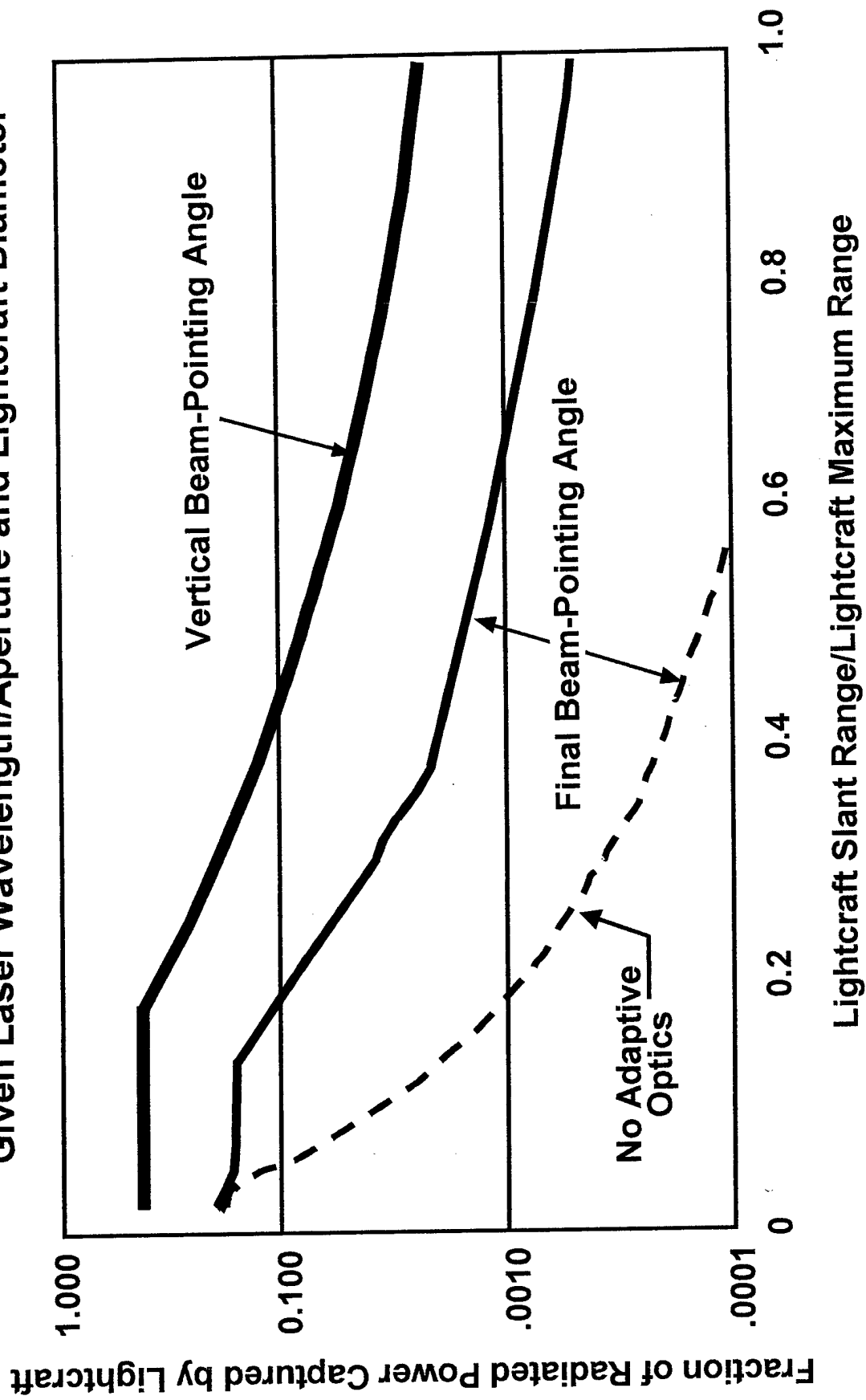
Selecting the Appropriate wavelength is a Delicate Balancing Act



Influence of Lightcraft Range and Laser Pointing Angle on Laser Power Captured by Lightcraft

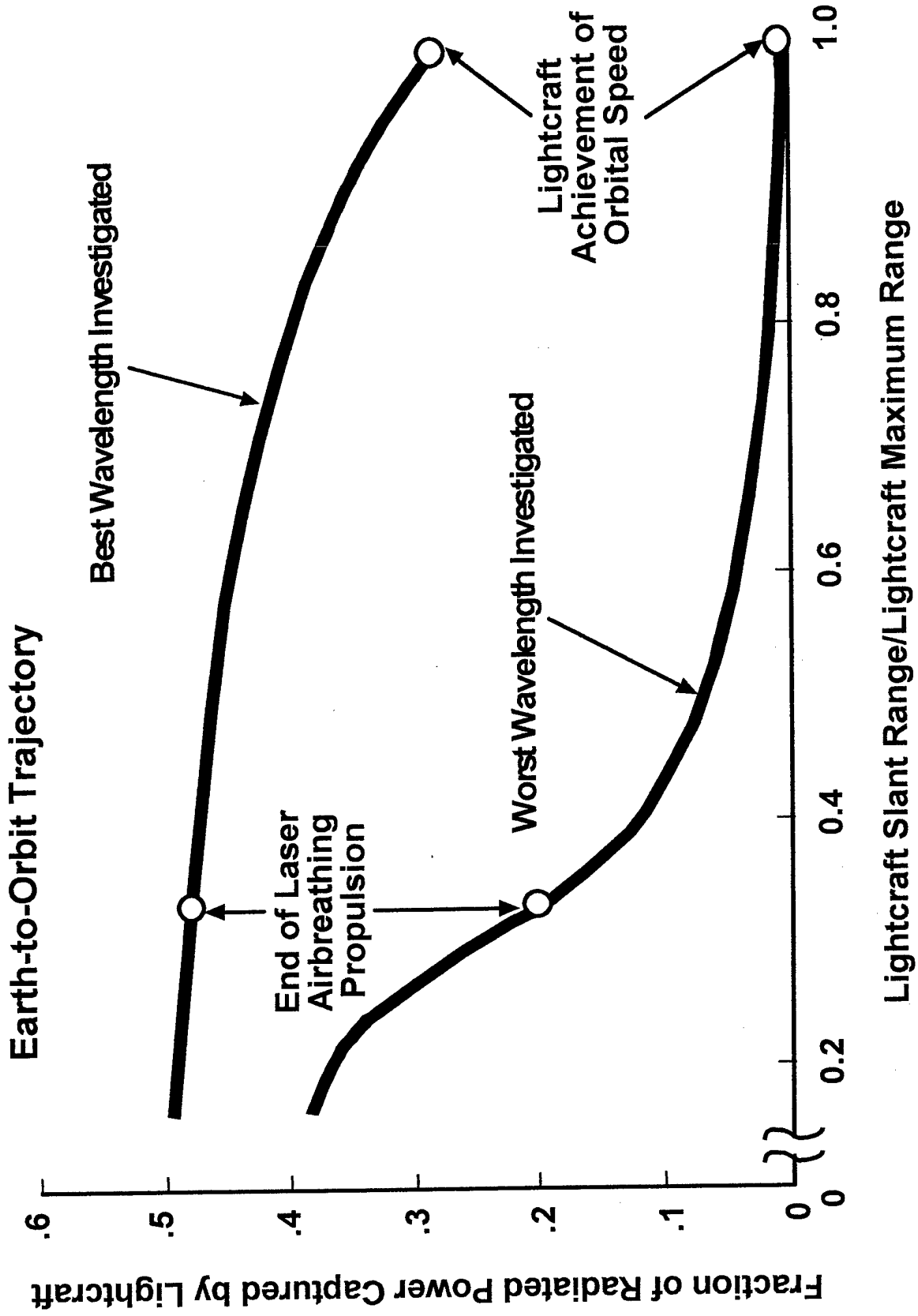


Given Laser Wavelength/Aperture and Lightcraft Diameter



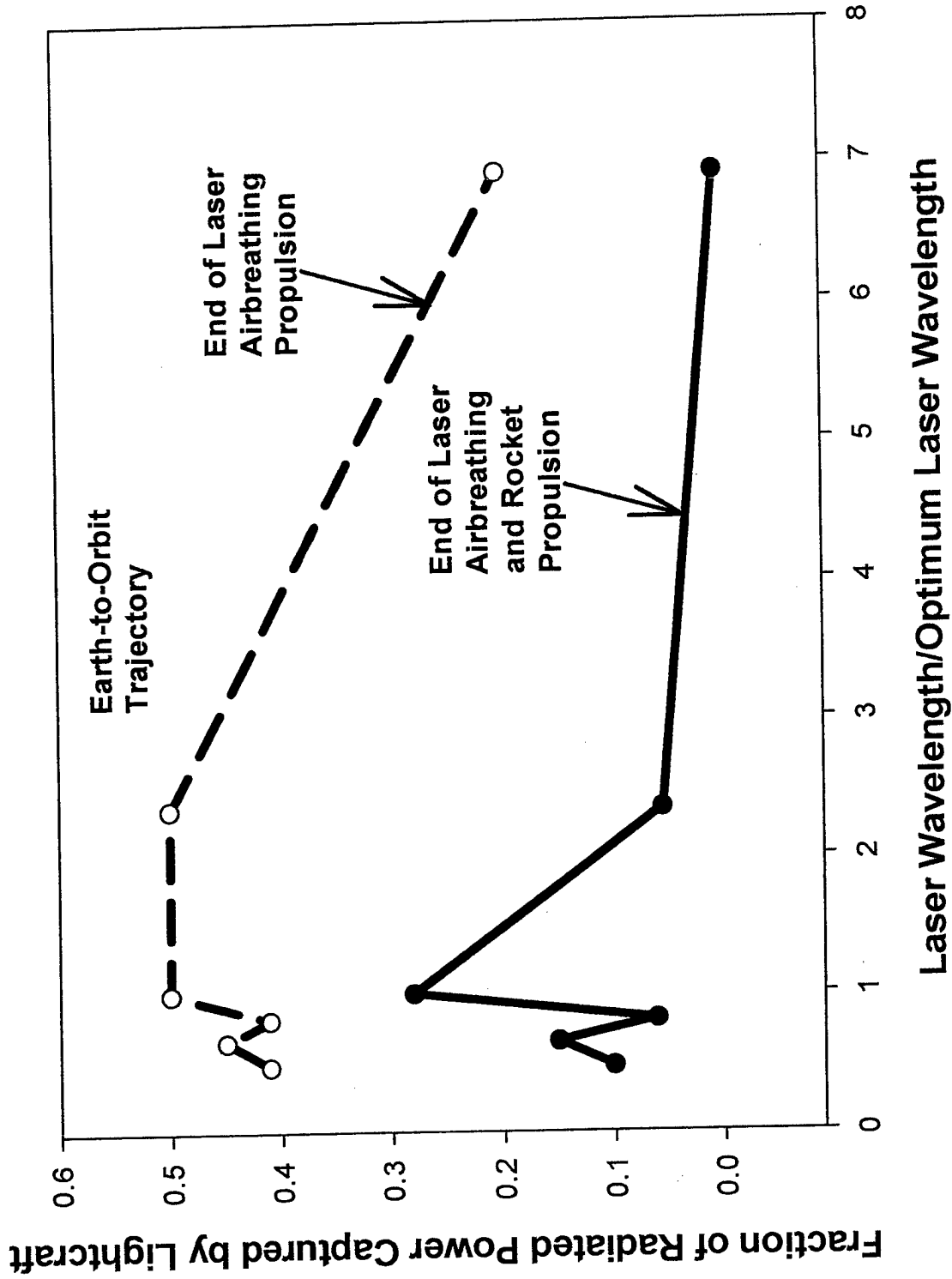


Influence on Laser Wavelength on Lightcraft Power Capture



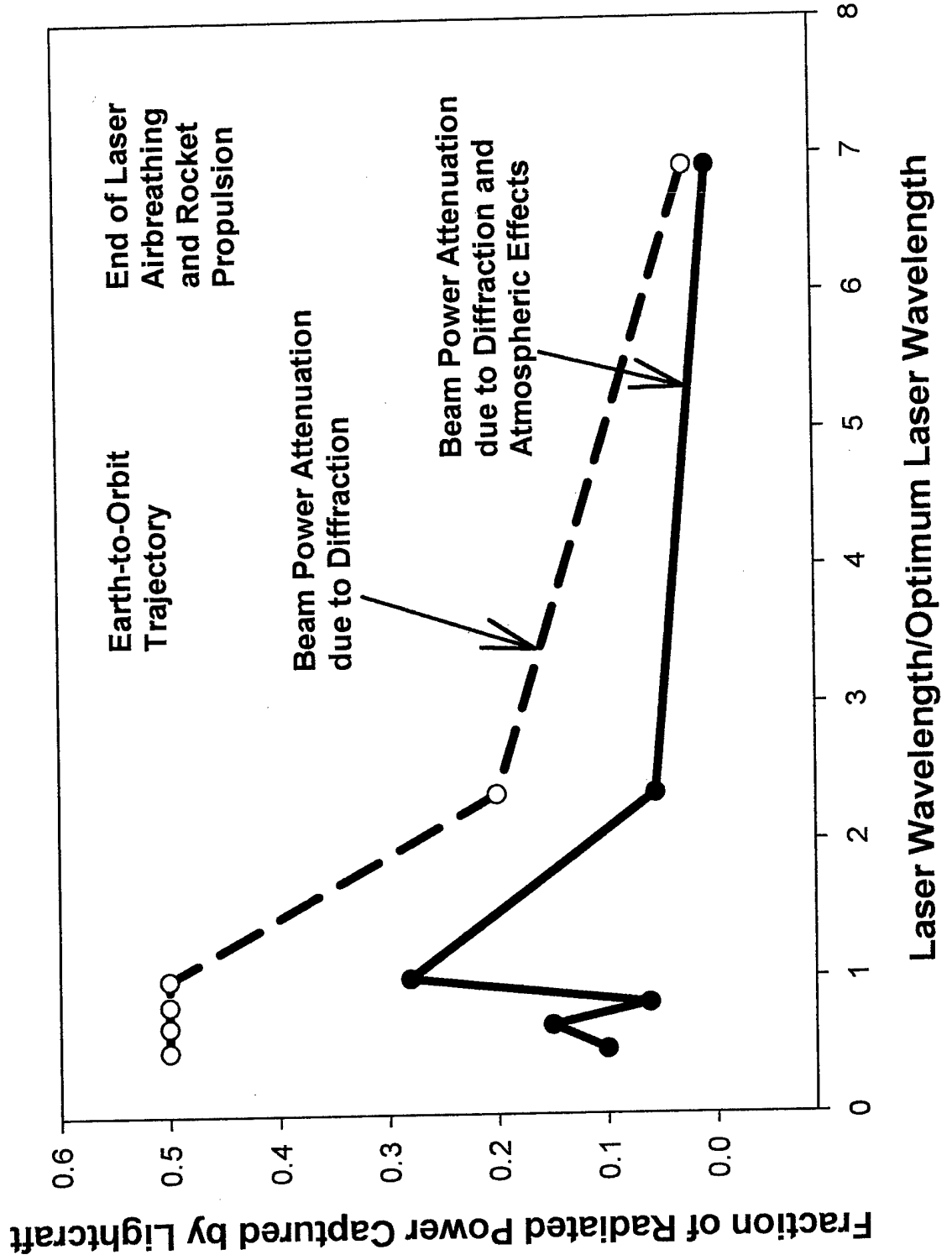


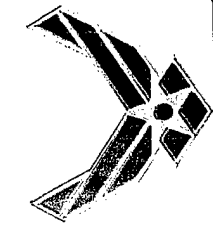
Influence of Wavelength on Lightcraft Power Captured





Influence of Wavelength on Lightcraft Power Captured



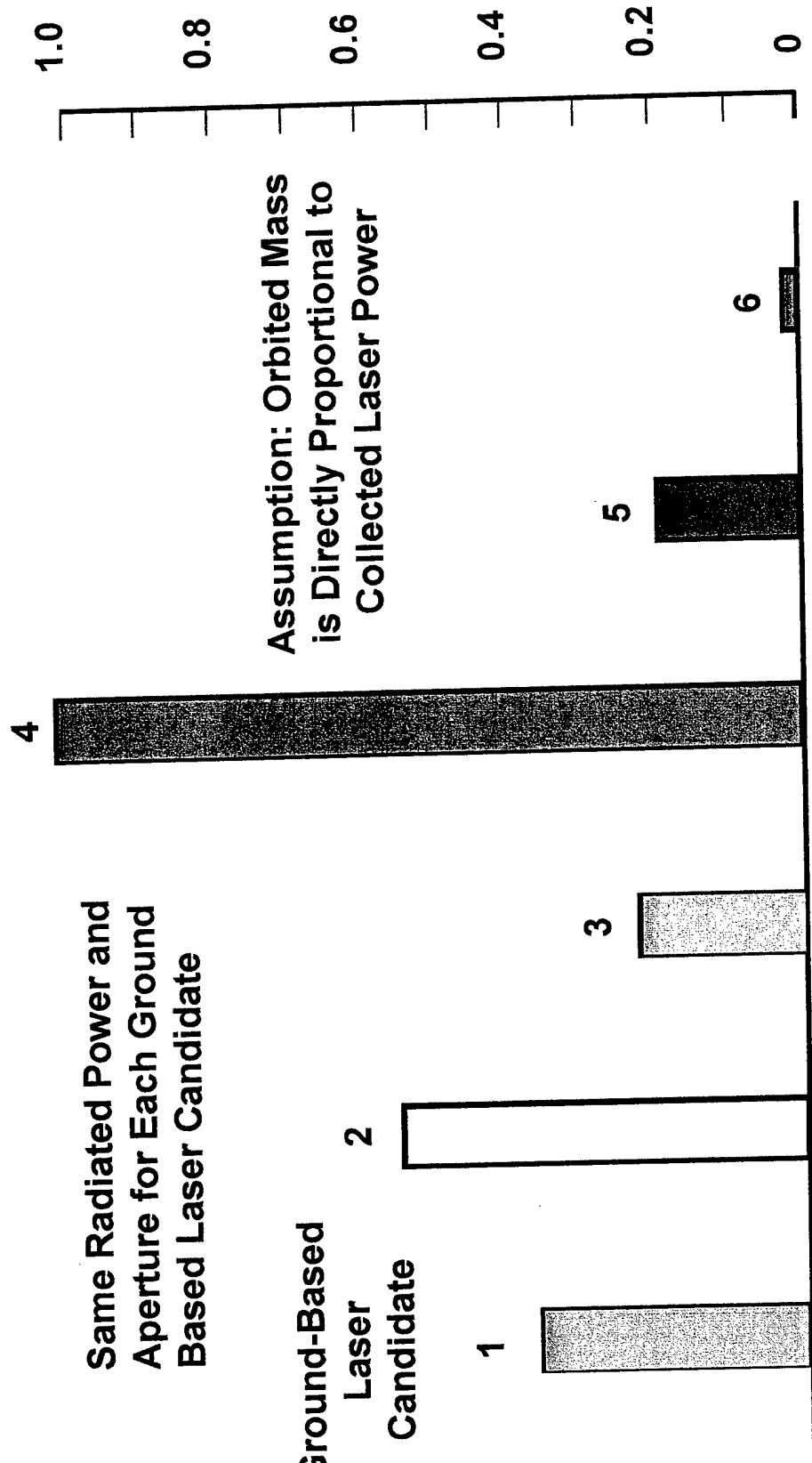


Influence of Wavelength on Orbited Mass



Same Radiated Power and Aperture for Each Ground Based Laser Candidate

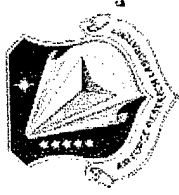
Ground-Based Laser Candidate



Shorter Wavelength ← Best Wavelength → Longer Wavelength



Summary and Conclusions



- Laser-powered lightcraft systems that deliver microsattelites to low-earth-orbit (LEO) have been studied for the Air Force Research Laboratory
- The many iterations needed for design of such an earth-to-orbit (ETO) system requires a multi-disciplinary optimization (MDO) for definition of the ground-based laser and lightcraft vehicle elements
- An example is the influence of laser wavelength on the energy and power lost during laser beam propagation through Earth's atmosphere and space, and the resulting effect on mass delivered by lightcraft to orbit
- Here, energy and power losses in the laser beam are very significant for ETO missions, and losses are highly dependent on laser wavelength
- Thus, wavelength (together with other laser technical, operational, and cost issues) is an important consideration in laser selection for lightcraft