Solar Gravity Lens for Exoplanet Imaging: Sail Architectures

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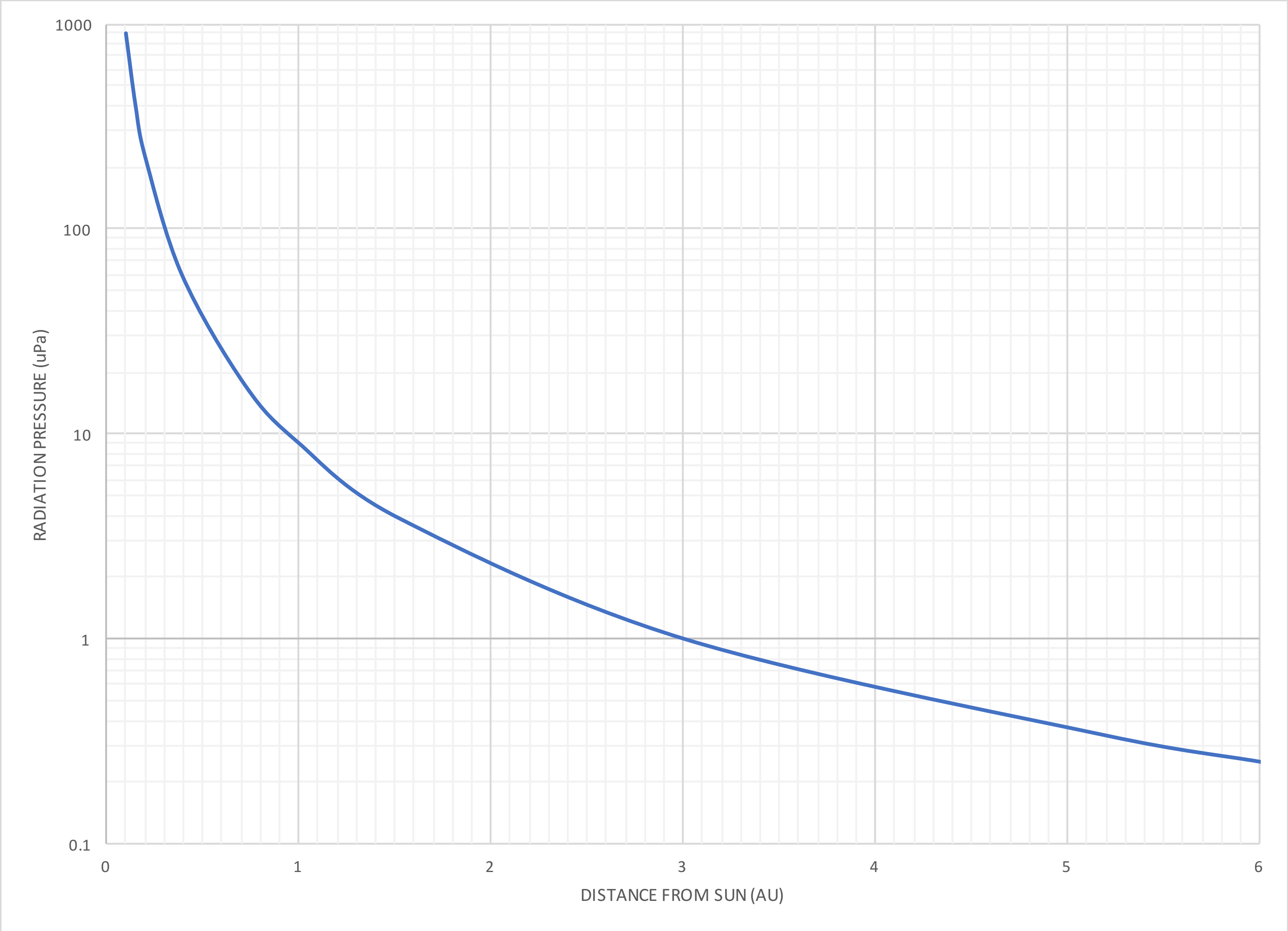
Overview

- Radiation Pressure
- Sail Trajectory Analysis
- Sail Velocity
- Sail Architectures

Radiation Pressure



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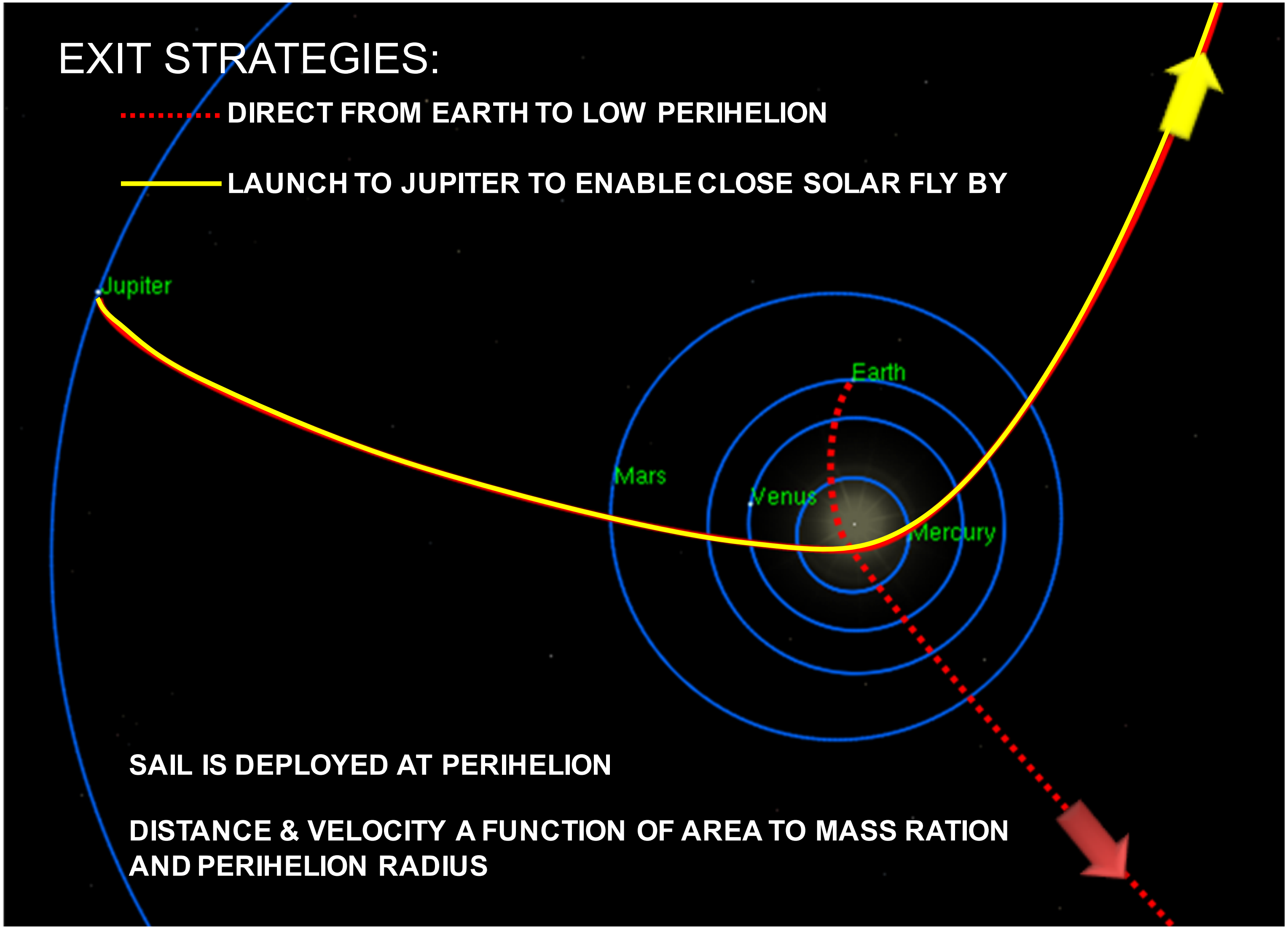
Sail Trajectory Analysis

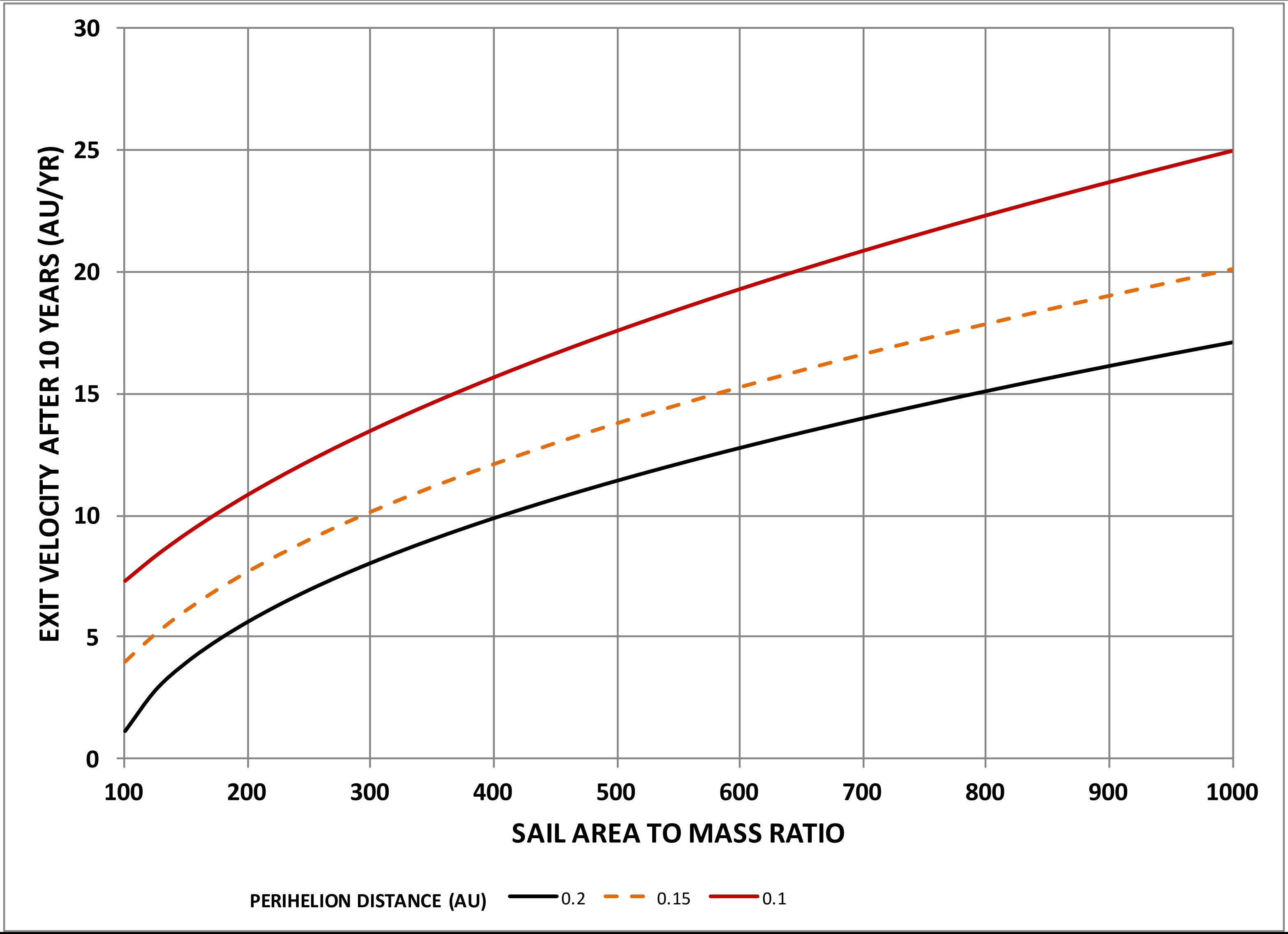
- Objective: investigate performance of simple solar sail trajectories over a 10 year period
  - Determine baseline (“inefficient”) performance
  - Simple example for comparison

- Simulation Parameters
  - Solar Sail Area to Mass Ratio: 100 to 1000
  - Reflectivity of 0.9
  - Perihelion: 0.1, 0.15 & 0.2 AU
  - Mission CONOPS:
    - Earth direct to perihelion
    - Jupiter encounter to perihelion
    - Deploy sail at perihelion and align sail with velocity vector
  - No fly-bys or gravity assists
  - No additional propulsion employed

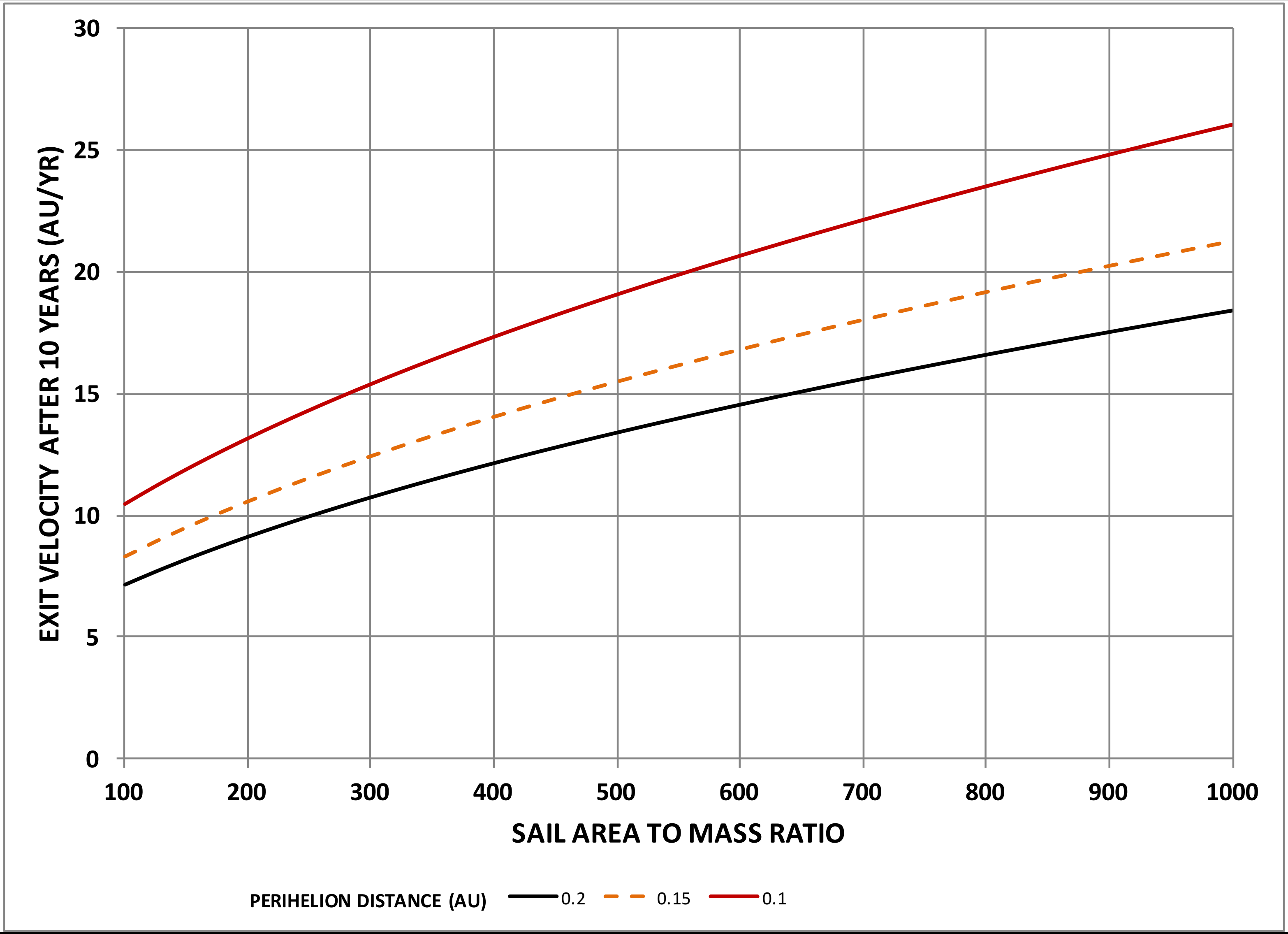
Sail Trajectories to Exit the Solar System



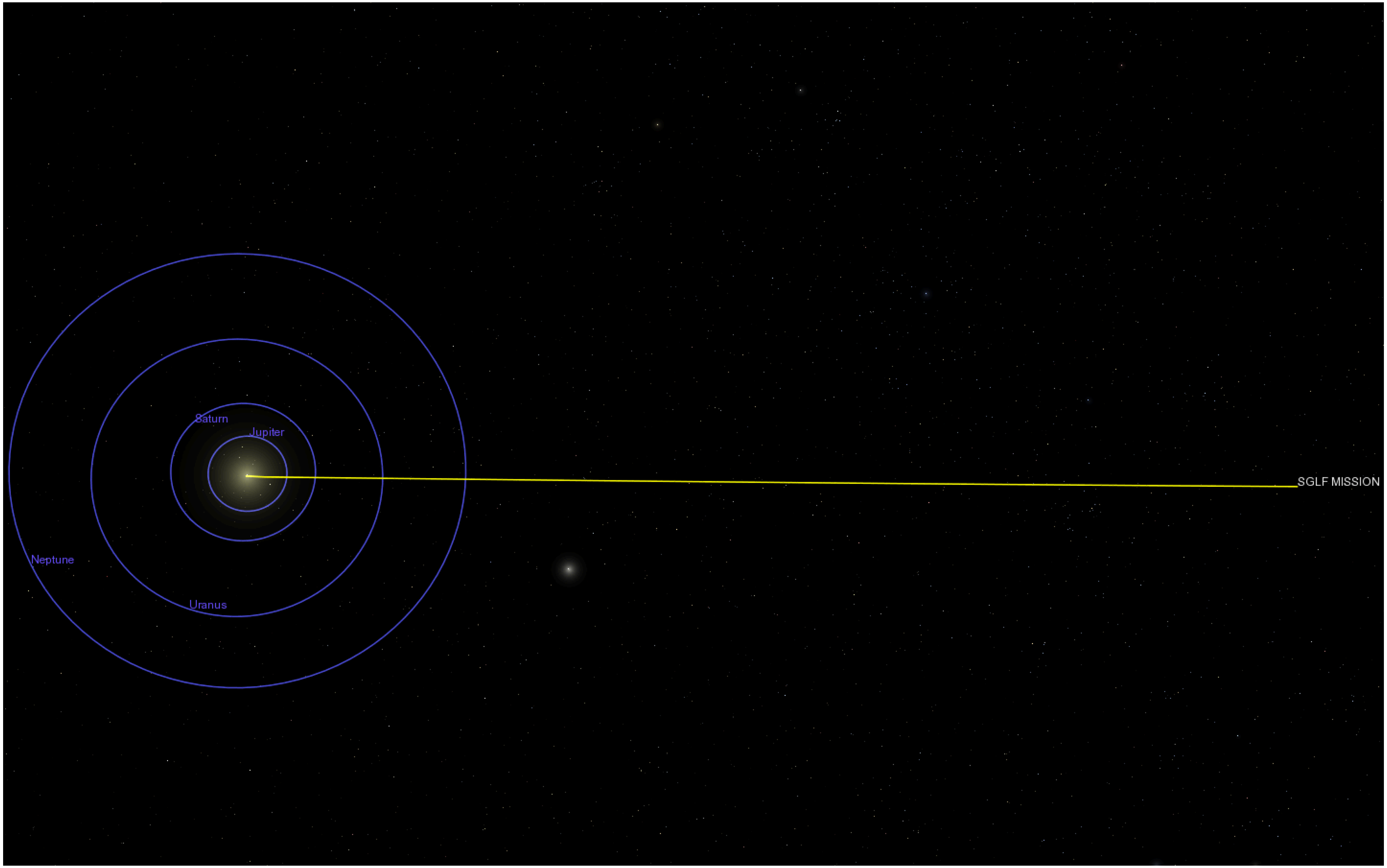
Sail Velocity: Earth Departure



Sail Velocity: Jupiter Encounter



10 years post 0.1 AU Perihelion 500A/m: 125 AU

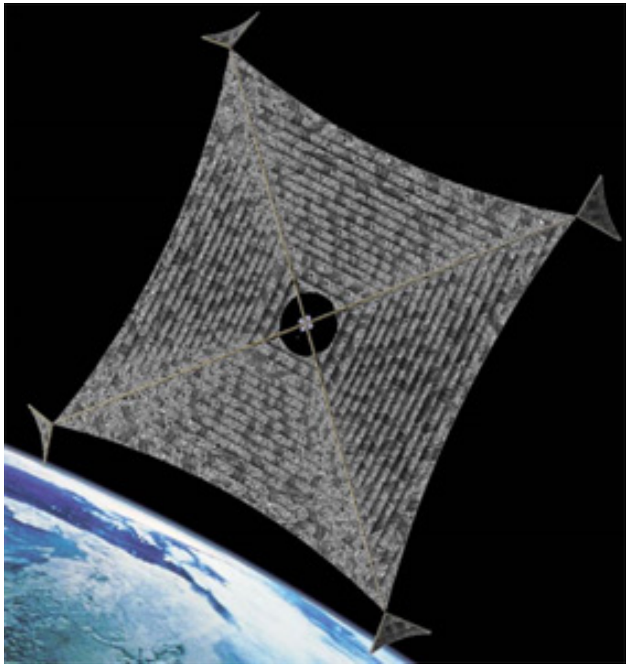


Challenge of Solar Sails

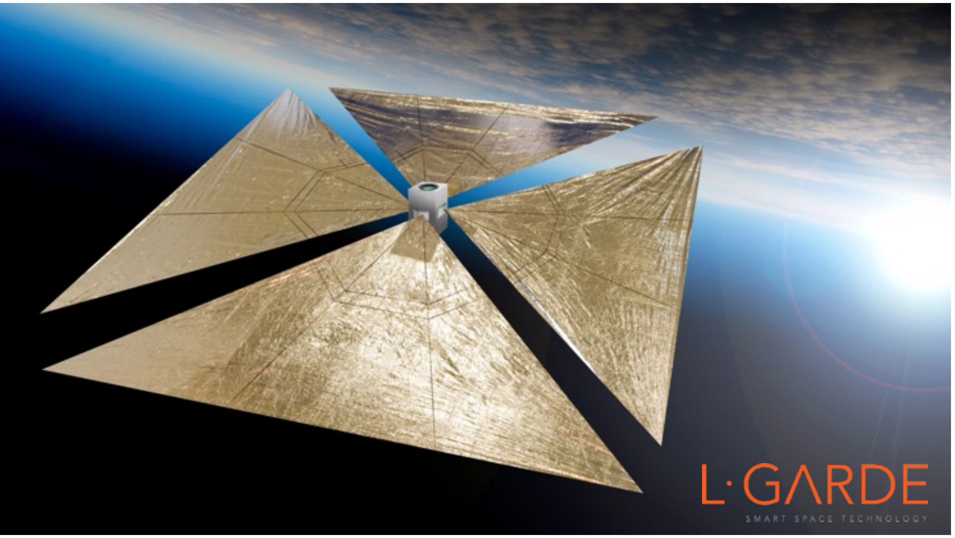
- Solar sail challenges:
  - Packaging and deployment
  - Control
    - Center of Pressure vs Center of Gravity
    - Constrained & conflicting dynamics
      - Power vs Comm vs Trajectory vs Payload
    - Limited degrees of freedom for active illumination
  - Scalability
    - Materials
    - Non-linearity between mass and area
  - Durability

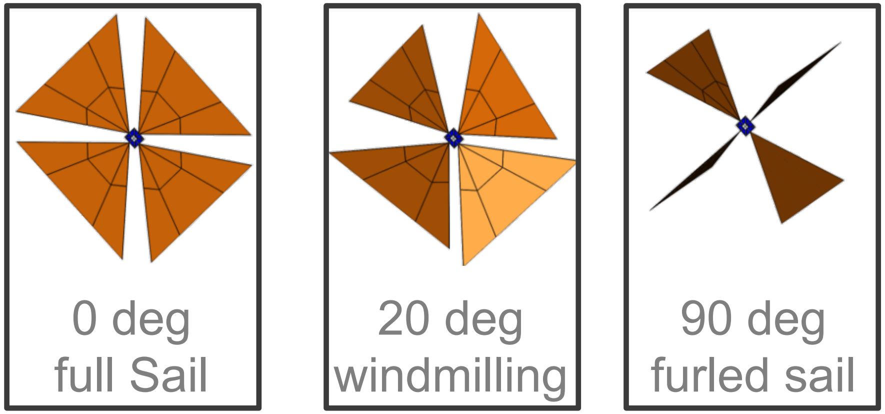
- Despite significant research largest A/m developed was Sunjammer at 22 m^2/kg
  - Vane technology provides key to advancing sail architectures
  - SunDrake & SunVane

Spacecraft	A/m
IKAROS	1.3
Nanosail-D	2.2
Cosmos-1	5.7
LightSail	7.0
Lunar Flashlight/NEA Scout	8.0
Sunjammer	22.3

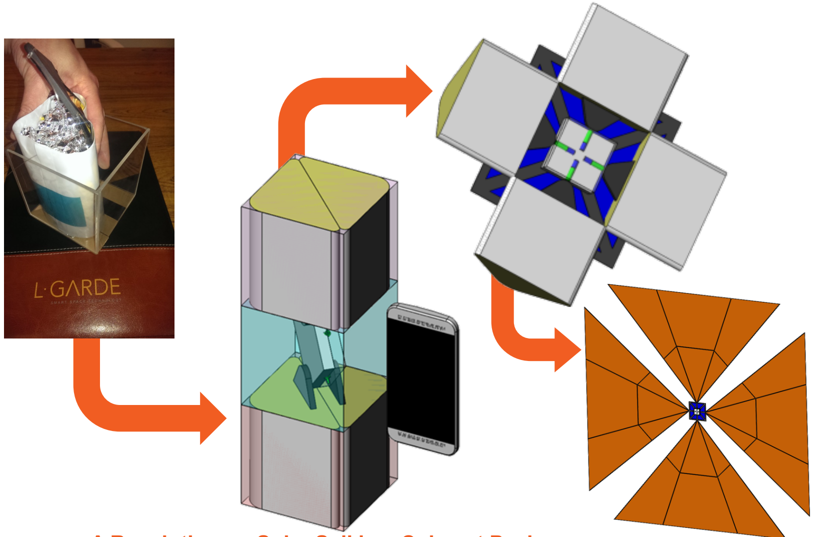


SunDrake: Vanes Enable Dynamic Missions



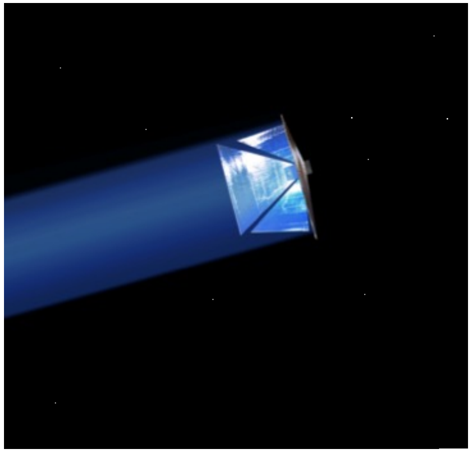


Fully Articulated Vanes Allow for Orbital Operations of Propellantless Solar Sail



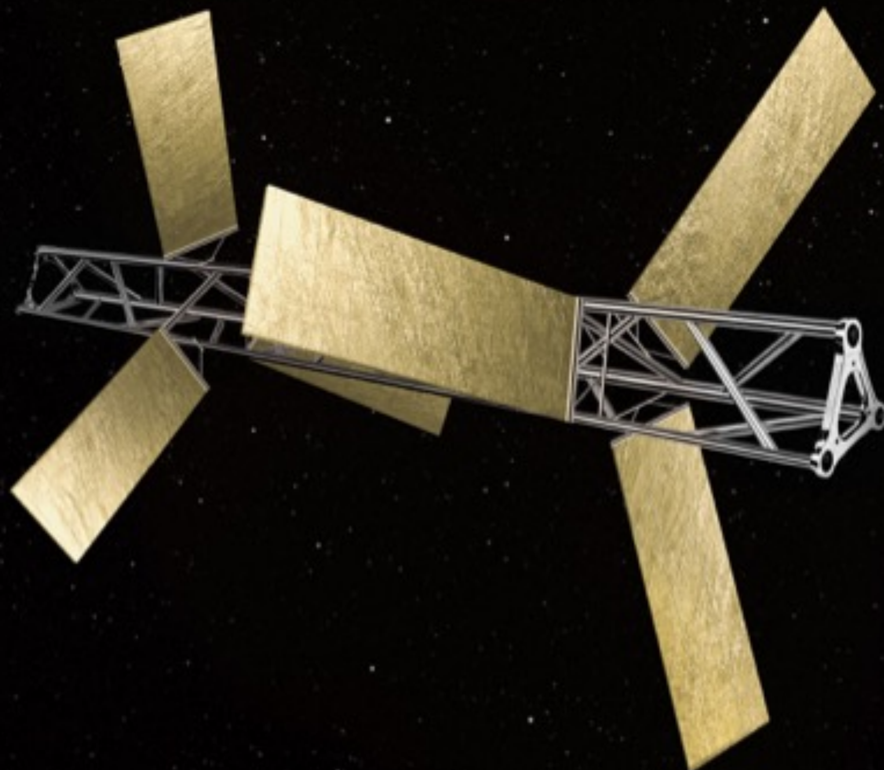
A Revolutionary Solar Sail in a Cubesat Package

LEO DEBRIS INSPECTION



DIRECTED ENERGY PROPULSION

SunVane: A New Approach to Sail Architectures



SIMPLIFIED DEPLOYMENT

ARTICULATED VANES ENABLE CONTROL

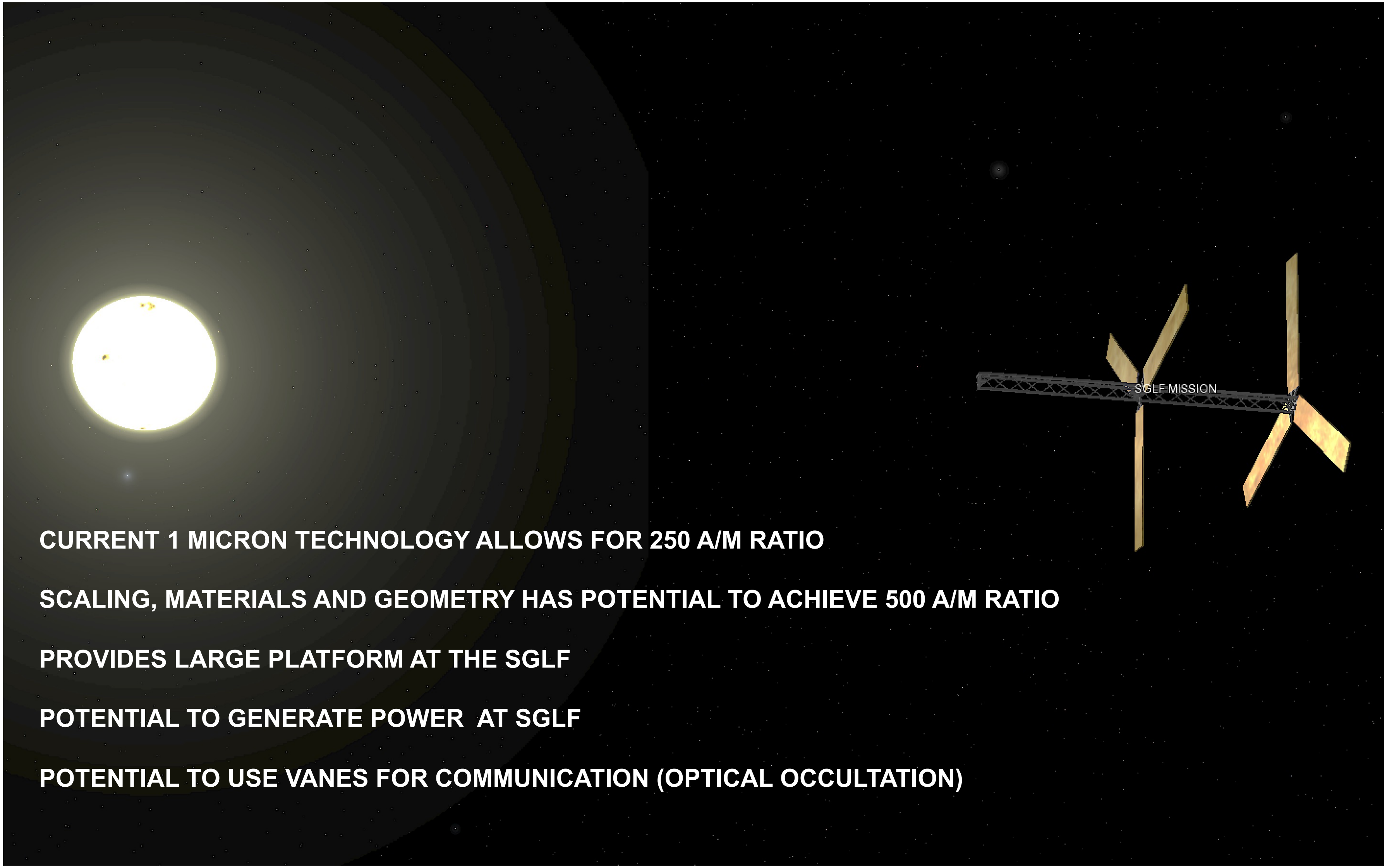
SIGNIFICANT POWER GENERATION

SCALES TO 250 A/M RATIO WITH CURRENT TECHNOLOGY

LEVERAGES TRUSS ADVANCES (< 30 g/m)

VANES PROVIDE MULTIFUNCTIONAL CABILITIES FOR COMMUNICATION AND POWER GENERATION

SunVane & SGLF Mission



- CURRENT 1 MICRON TECHNOLOGY ALLOWS FOR 250 A/M RATIO
- SCALING, MATERIALS AND GEOMETRY HAS POTENTIAL TO ACHIEVE 500 A/M RATIO
- PROVIDES LARGE PLATFORM AT THE SGLF
- POTENTIAL TO GENERATE POWER AT SGLF
- POTENTIAL TO USE VANES FOR COMMUNICATION (OPTICAL OCCULTATION)

Next Steps

- Design parameters
  - Truss mass per length
  - Sail material
  - Sail area
  - Sail geometry

- Current Designs
  - 100 A/m
    - Truss – 100m at 38 g/m
    - 2 micron Kapton
    - Vane area – 6 at 200m^2
  - 200 A/m
    - 1 micron sail
    - Double sail area
  - Advanced >500 A/m
    - Vanes transform to disk
    - Sub-micron sail