

Interstellar Propulsion Research: Realistic Possibilities and Idealistic Dreams

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Though physically possible, interstellar travel will be exceedingly difficult. Both the known laws of physics and the limits of our current understanding of engineering place extreme limits on what may actually be possible.

Our remote ancestors looked at the night sky and assumed those tiny points of light were campfires around which other tribes were gathered – and they dreamed of someday making the trip to visit them. In our modern era, we've grown accustomed to humans regularly traveling into space and our robots voyaging ever-deeper into the outer edges of our solar system. Traveling to those distant campfires (stars) has been made to look easy by the likes of Captains Kirk and Picard as well as Han Solo and Commander Adama.

Our understanding of physics and engineering has not kept up with our imaginations and many are becoming frustrated with the current pace at which we are exploring the universe. Fortunately, there are ideas that may one day lead to new physical theories about how the universe works and thus potentially make rapid interstellar travel possible – but many of these are just ideas and are not even close to being considered a scientific theory or hypothesis.

Absent any scientific breakthroughs, we should not give up hope. Nature does allow for interstellar travel, albeit slowly and requiring an engineering capability far beyond what we now possess. Antimatter, fusion and photon sail propulsion are all candidates for relatively near-term interstellar missions.

The plenary lecture will discuss the dreams and challenges of interstellar travel, our current understanding of what may be possible and some of the “out of the box” ideas that may allow us to become an interstellar species someday in the future.



Interstellar Propulsion Research Realistic Possibilities & Idealistic Dreams

Les Johnson

**Deputy Manager, Advanced Concepts Office
NASA George C. Marshall Space Flight Center**



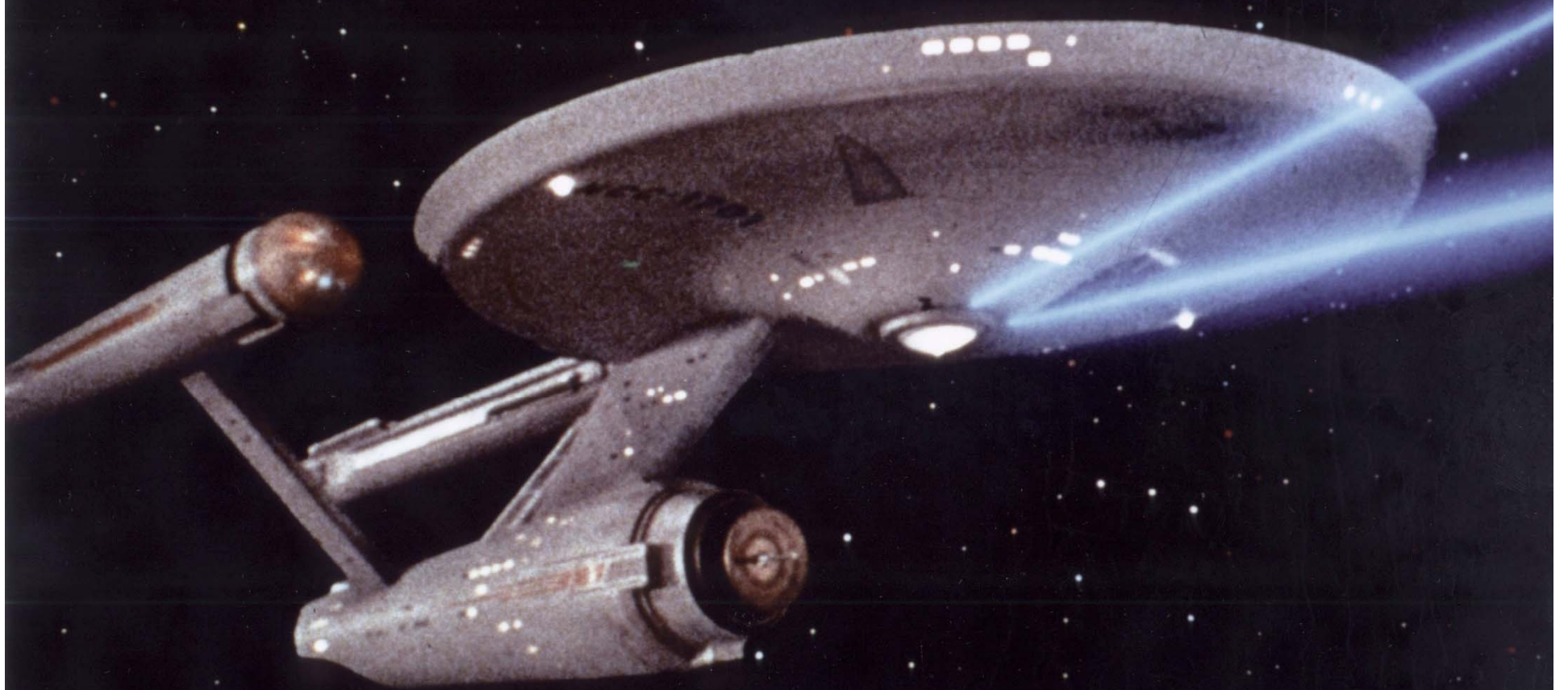
Who am I to talk about Interstellar Propulsion?



- Managed Interstellar Propulsion Research Project in the late 1990's and early 2000's for NASA
- Managed In-Space Propulsion Technology Project which included technologies that might one day enable us to reach the stars
- Deputy Manager for Advanced Concepts Office
- Advocate of solar sails as a propulsion system – and believe they have the potential to take us to the stars
- And

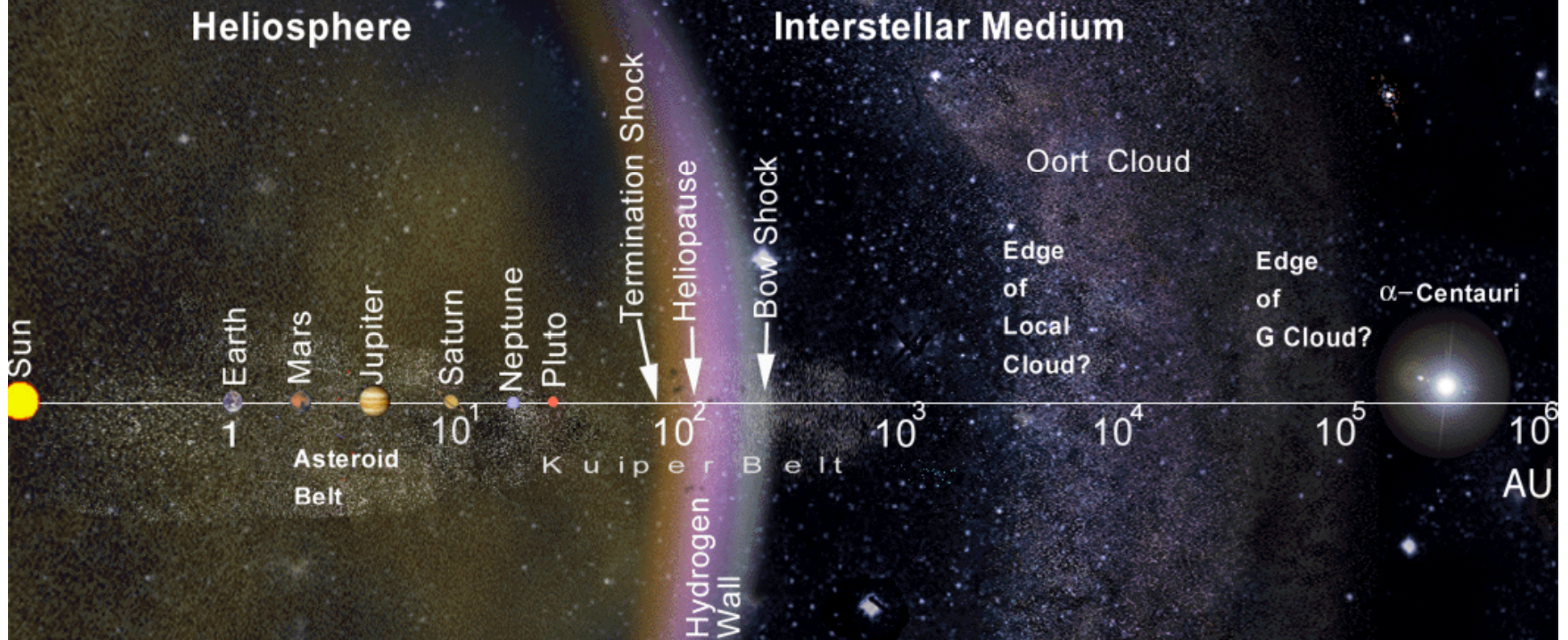
Adva
Co

I watched Star Trek ...



And I believe it is a future open to us

The challenge is great (distance!!!)



Today

**Voyager I (launched April
1977)**

(Launch + 32 Years)

Distance:

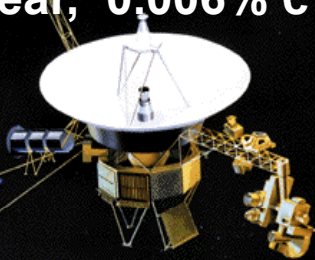
10 billion miles

**108 Astronomical Units
(AU)**

Speed:

17 km/sec

(3.7 AU/Year, 0.0006% c)



Time to Travel

150 AU: 40 Years

4.3 Light Years: 74,000 Yrs

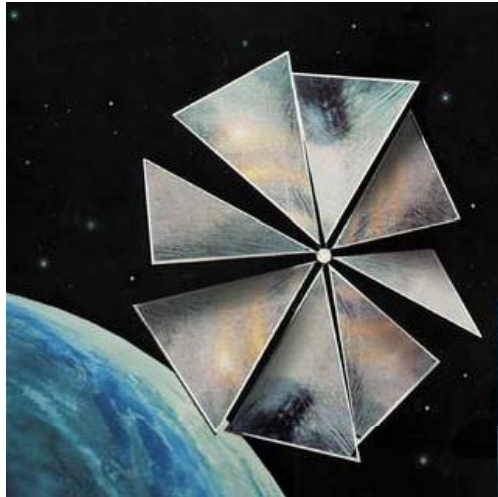
Today plus 74,000 years

Alpha & Beta Centauri will be ours!
(If Voyager were going in the right direction...)





Interstellar Propulsion Research: Near Term, Far Term & Beyond



- **Near-Term**

- Several “do-able” missions have been proposed
 - Interstellar Probe (250 AU)
 - Gravity Lens Mission (550 AU)
 - TAU Mission (1000 AU)

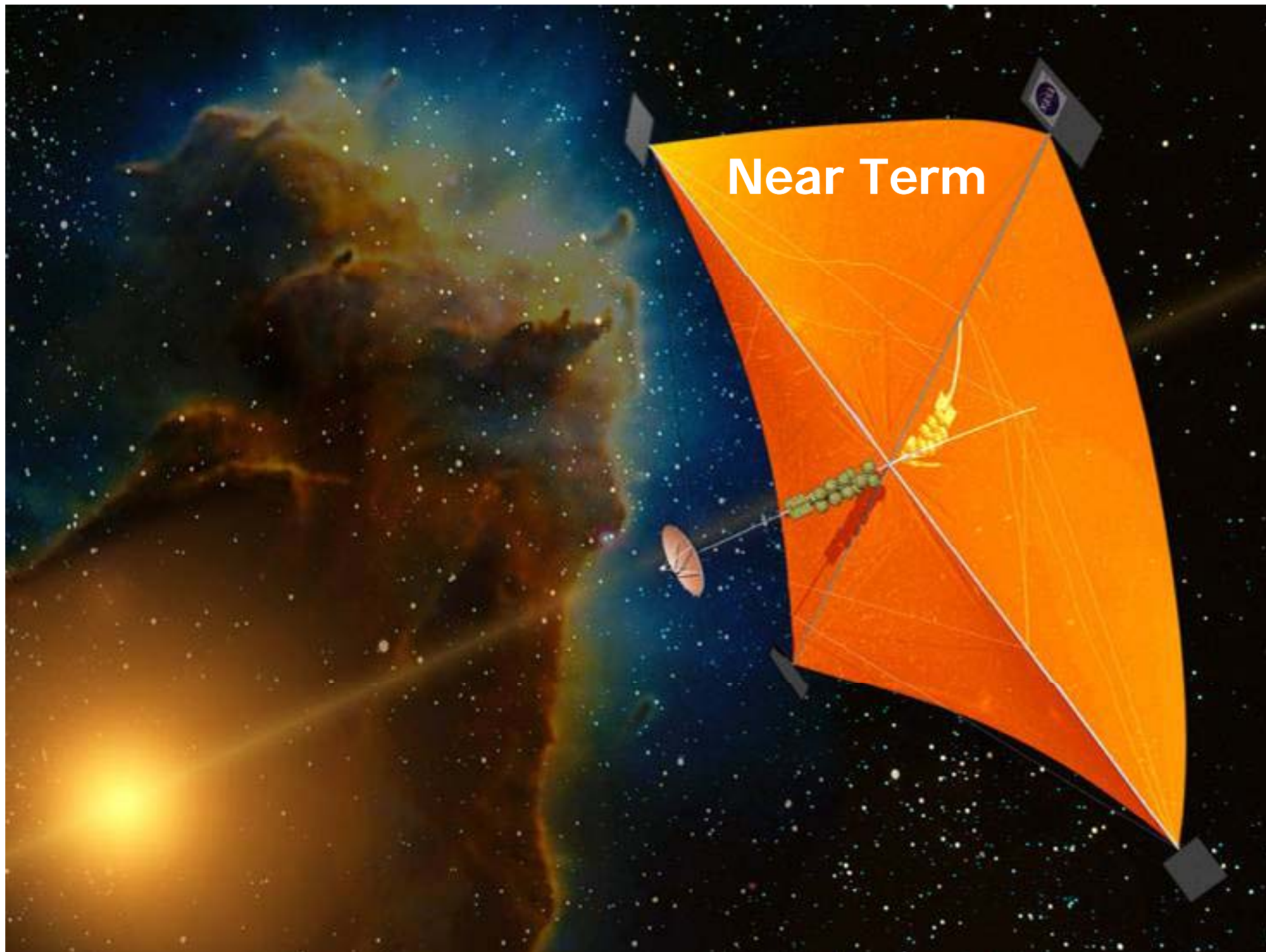
- **Far-Term**

- Technologies that might enable missions to another star (4.3 LY min.)

- **Beyond**

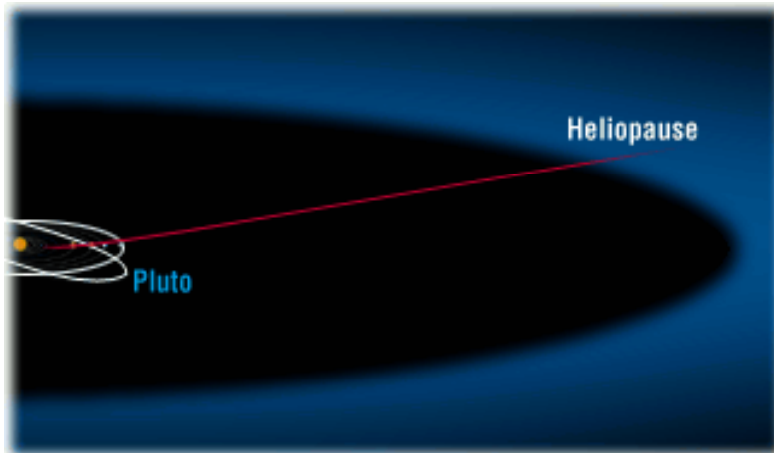
- Will physics allow us to build a warp drive?







Interstellar Probe Mission



The Heliopause is a barrier where charged particles from the sun cannot go beyond because cosmic rays from deep space force them back.

- **The first mission to beyond the Heliopause**

- 250 AU minimum (500 AU desired)
- Reach 250 AU within 20 years from launch
- 15-20 AU/year target velocity

- **Three propulsion approaches appear to be possible in the “near” term**

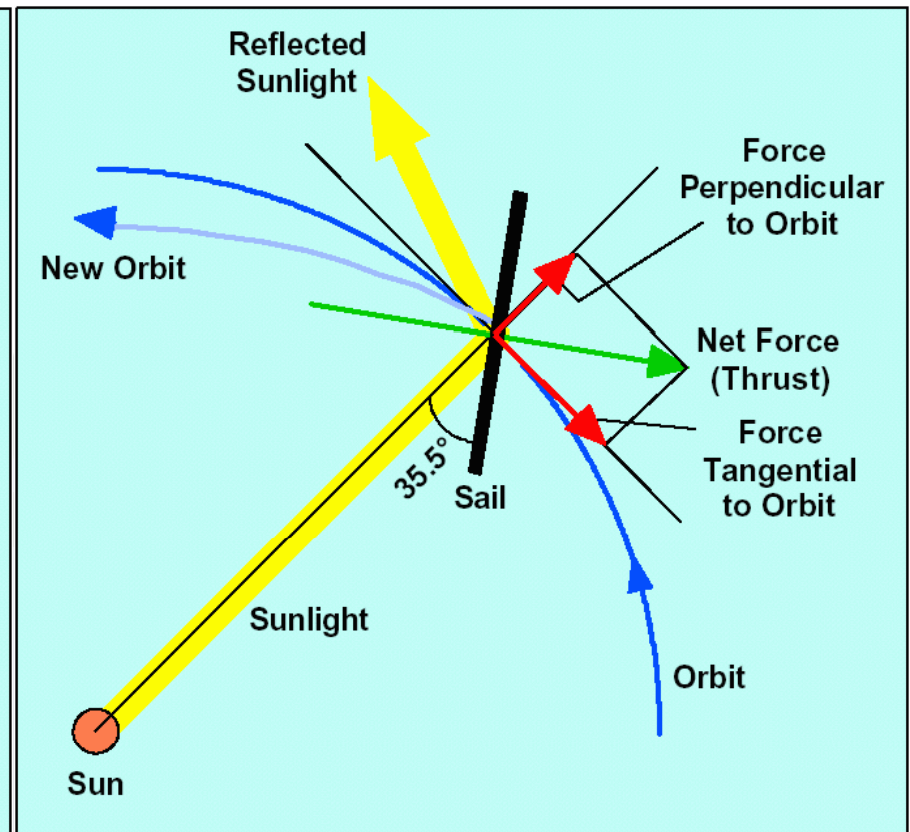
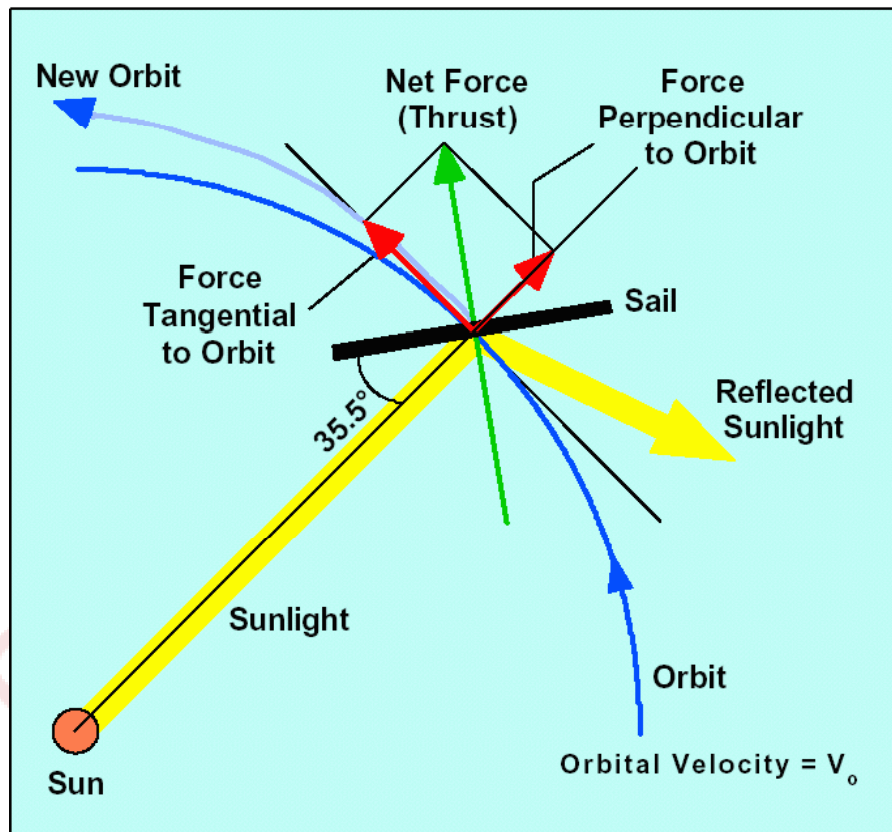
- Chemical with Jovian and Solar Close Approaches (25 – 30 years required)
- Solar Sails (via close solar approach)
- Nuclear Electric (fission reactor)



Solar Sail Propulsion



- Solar sails use photon “pressure” of force on thin, lightweight reflective sheet to produce thrust; ideal reflection of sunlight from surface produces **9 Newtons/km²** at 1 AU
 - Net force on solar sail perpendicular to surface
 - One component of force always directed radially outward
 - Other component of force tangential to orbit (add/subtract V_o)
- [<0.2 oz per football field]





Candidate Solar Sail Trajectory

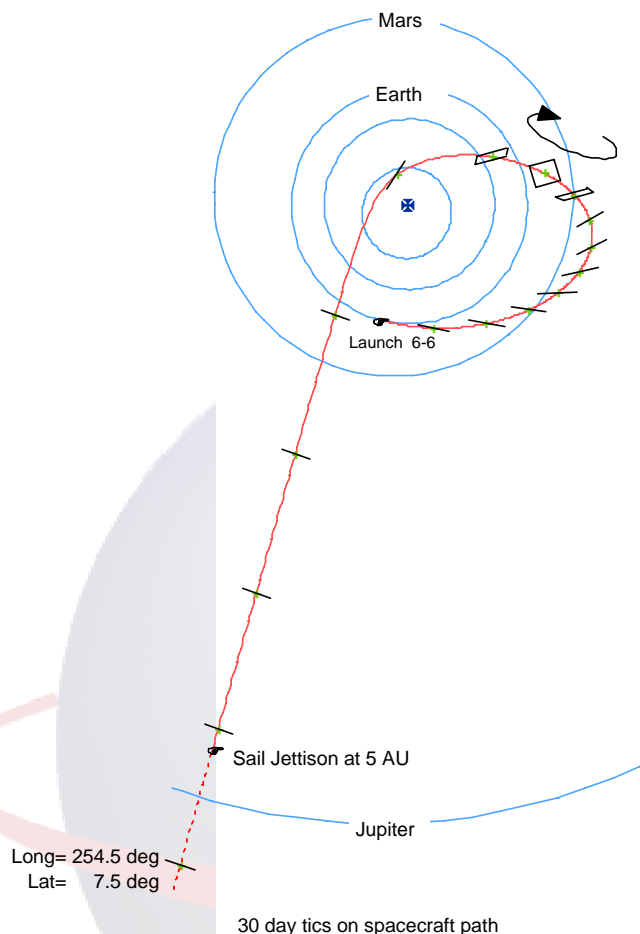


J

15 Year Solar Sail to 200 AU

$$a_c = 3.039 \text{ mm/s}^2$$

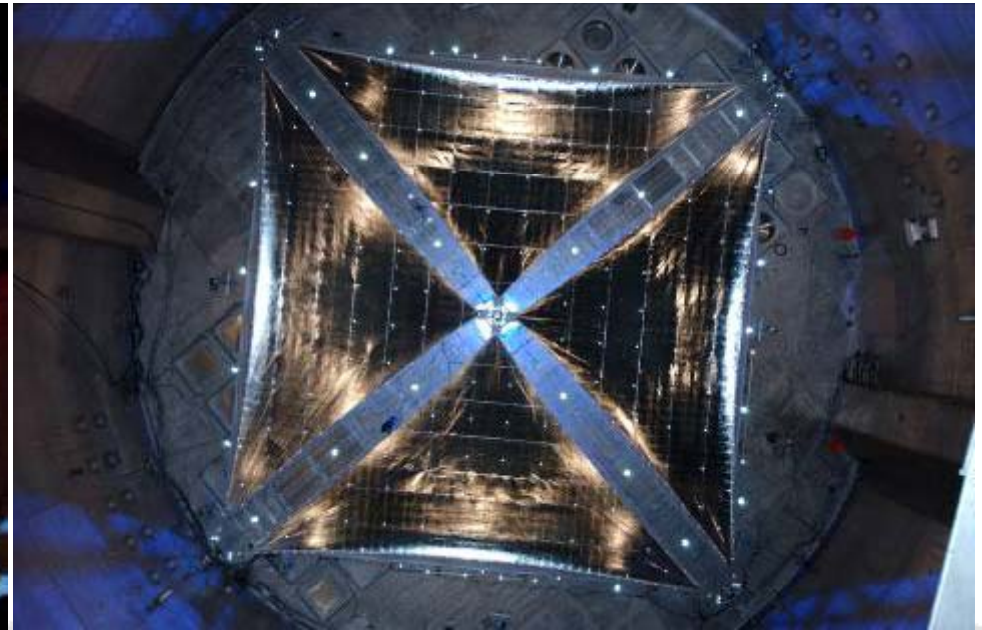
$$V_H = 14.127 \text{ au/y} \quad R_{\min} = .25 \text{ AU}$$



- Delta-II class launch to Earth escape
- Sail unfurled with 1800 N-sec impulse for spin up to 12 rpm
 - ◆ Final spin rate of 0.3 rpm (after deployment)
- Heliocentric trajectory inbound to 0.25 AU for maximized solar photon pressure
- Sail jettisoned on outbound near 5 AU (low solar pressure beyond this point)
 - ◆ 14 AU/year final coast velocity achieved

Sauer 4-8-99
escape69

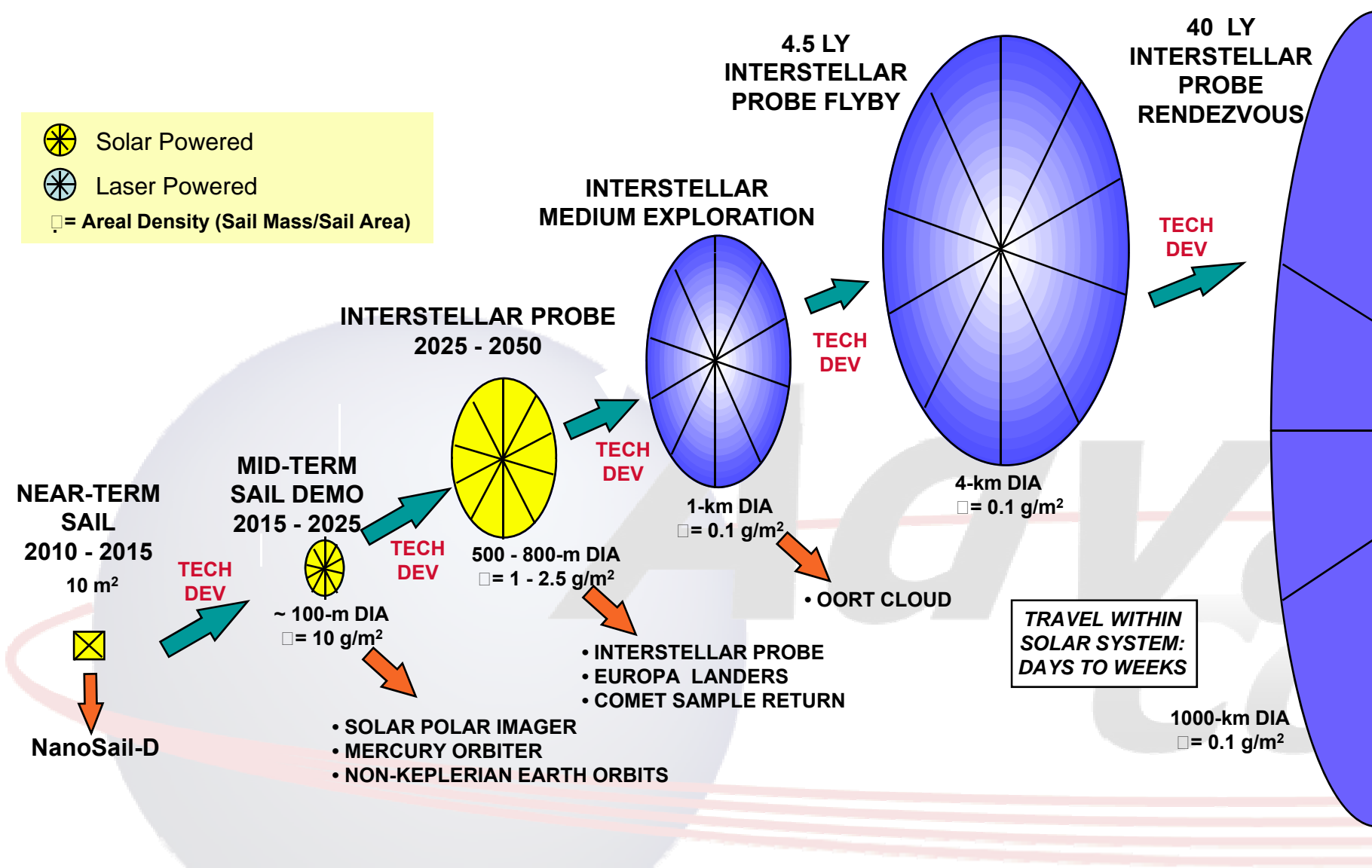
Figure 1: Spacecraft Trajectory, Baseline Option
Minimum Perihelion 0.25 AU—15 yr to 200 AU



- **Technology Status:**
 - Two competing teams designed, fabricated, and tested solar sails and performed system level ground demonstrations:
 - 10 m system ground demonstrators were developed and tested in 2004.
 - 20 m system ground demonstrators designed, fabricated, and tested under thermal vacuum conditions in 2005.
 - Developed and tested high-fidelity computational models, tools, and diagnostics.
 - Multiple efforts completed: materials evaluation, optical properties, long-term environmental effects, charging issues, and assessment of smart adaptive structures.

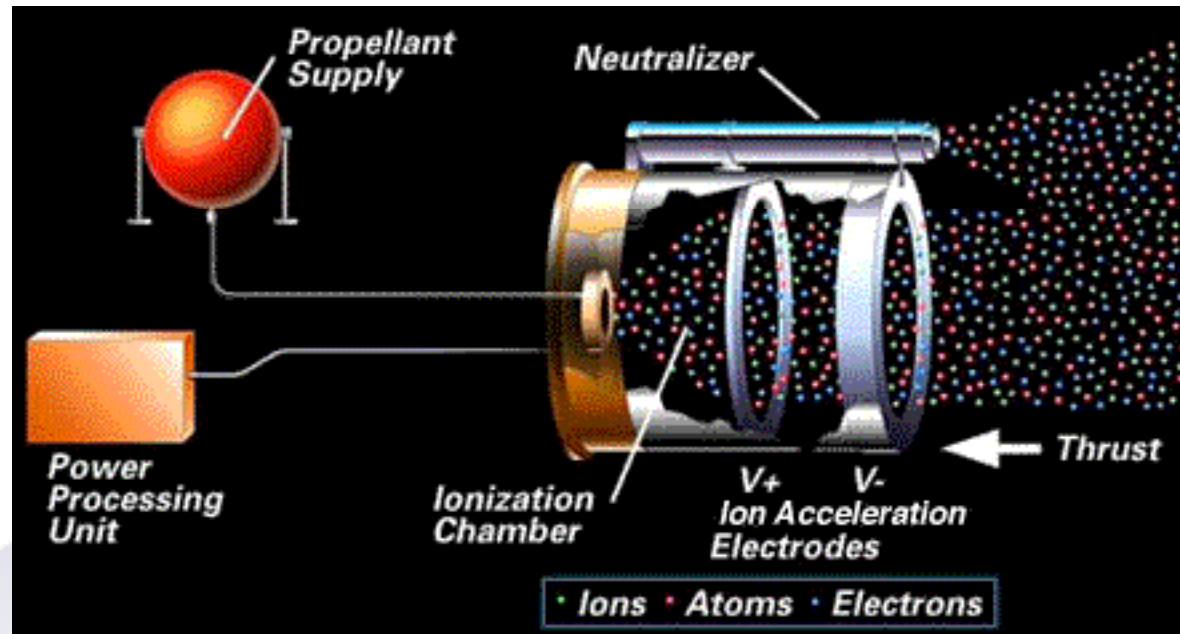


Near-Term Solar Sail Applications Lead to Interstellar Capability with Laser Sails



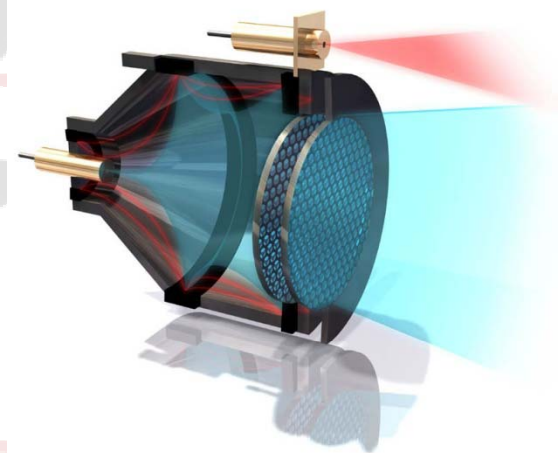


Electric Propulsion



Electric Propulsion

Is an In Space Propulsion technology that utilizes electrical energy to produce an electrostatic reaction (with a propellant) to obtain thrust. May utilize Solar or Nuclear generated power.

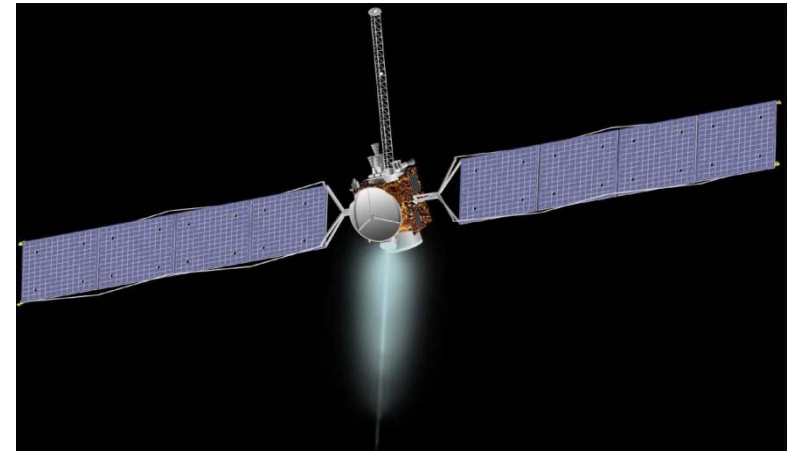
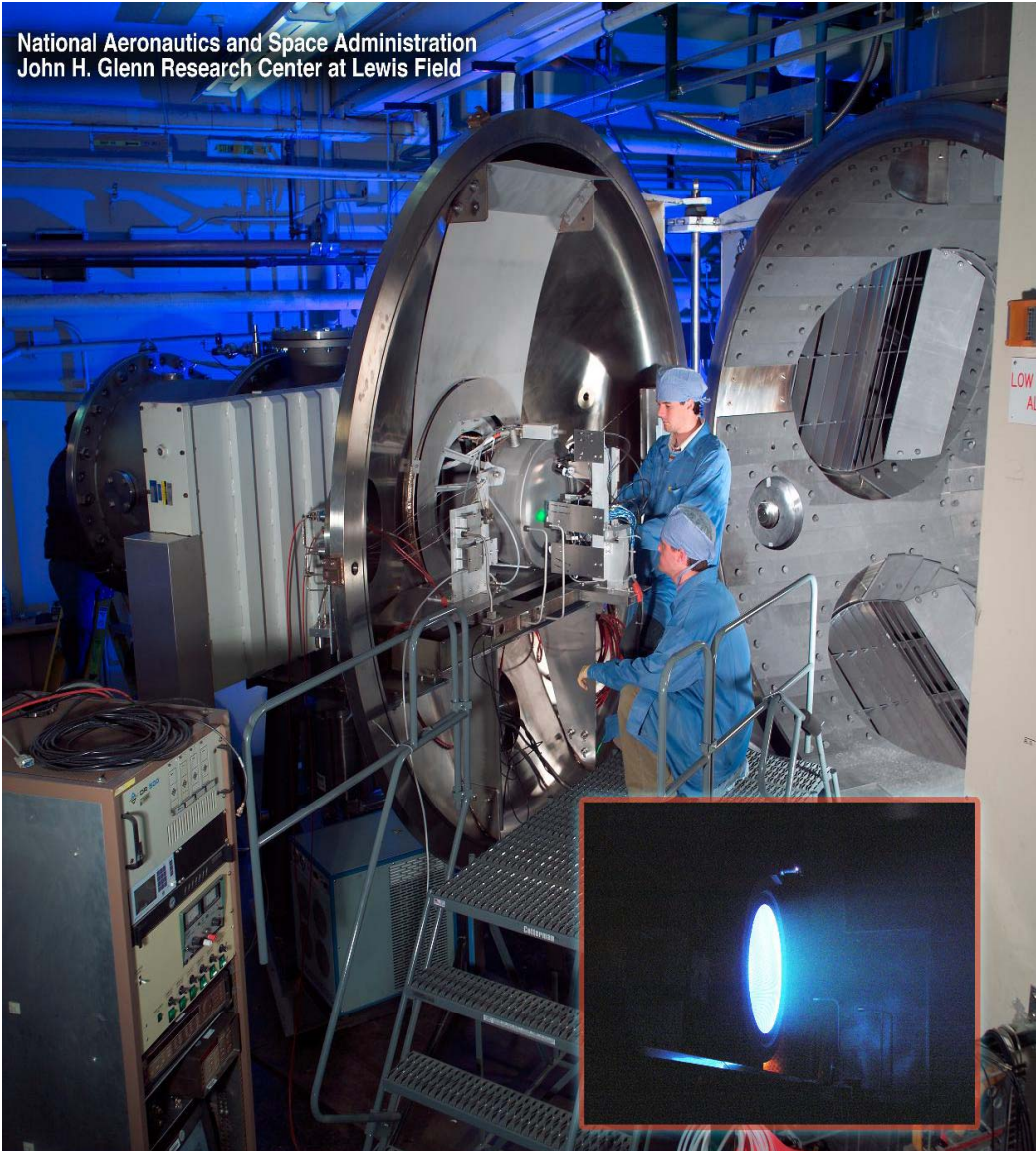




Solar Electric Propulsion Status



National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field



Solar powered DAWN mission is flying to Asteroids Ceres & Vesta



National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field

Hall thrusters are in use on multiple orbital spacecraft



Nuclear Electric Propulsion For the Interstellar Probe Mission



Small Reactor:
180 kWe, 335 kg
32 cm x 35 cm core

Radiation
Shield

Power
Conversion

Electric
Thrusters
(13,300 s Isp)

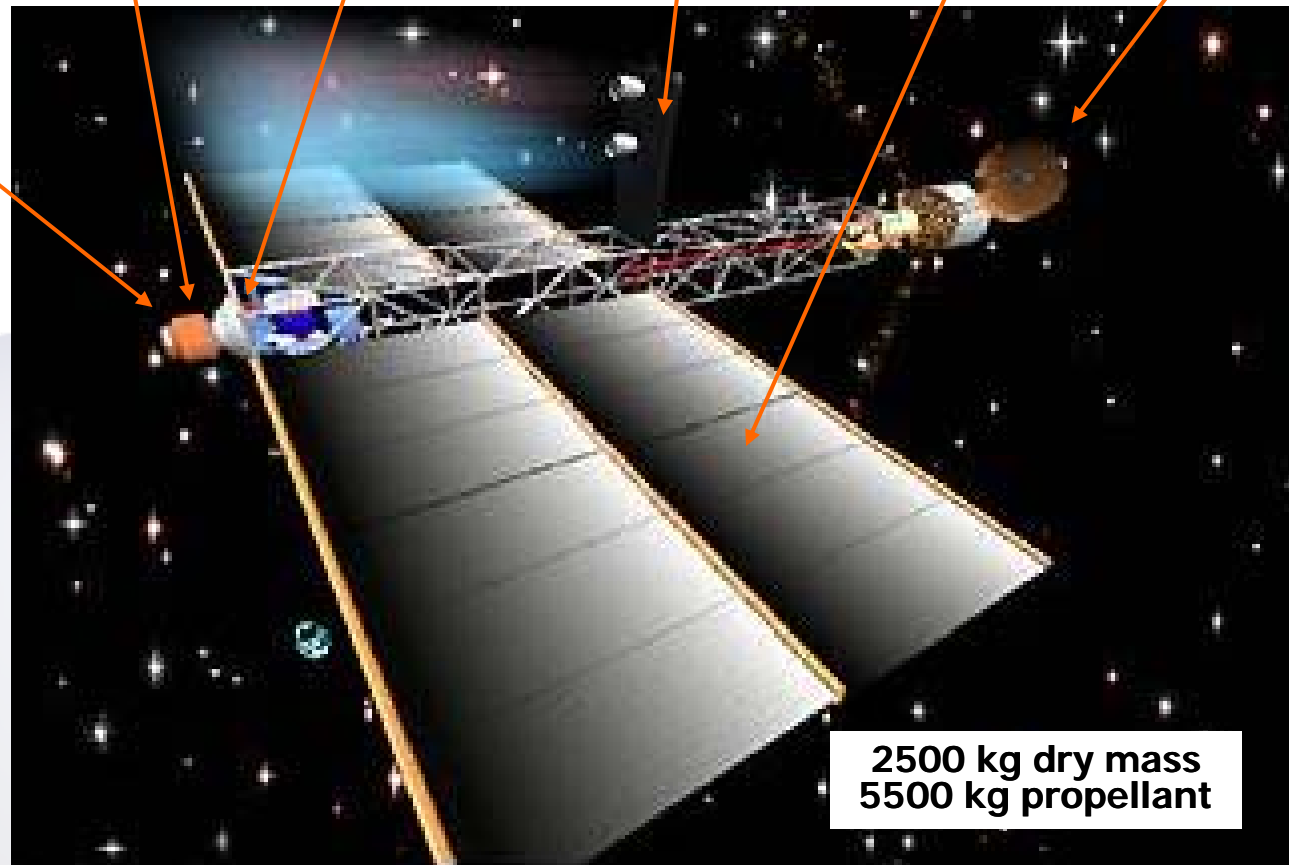
Thermal
Radiators

Payload
(250 kg)

30 a.u. in 6 yrs
250 a.u. in 15 yrs
500 a.u. in 26 yrs

123 km/s;
26 au/yr;
0.4 milli-c

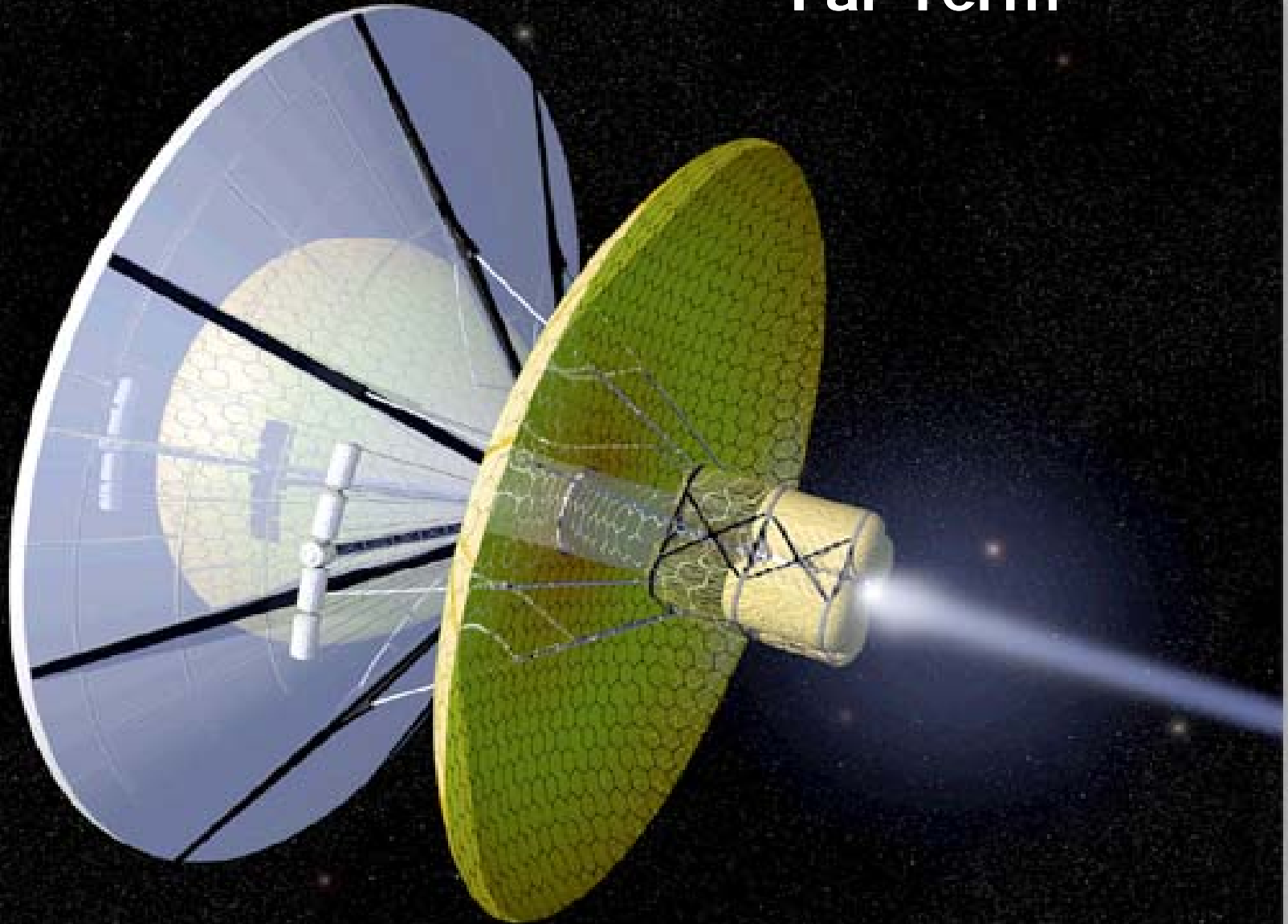
Mid-course
maneuvering



2500 kg dry mass
5500 kg propellant

Sandia National Laboratories

Far Term



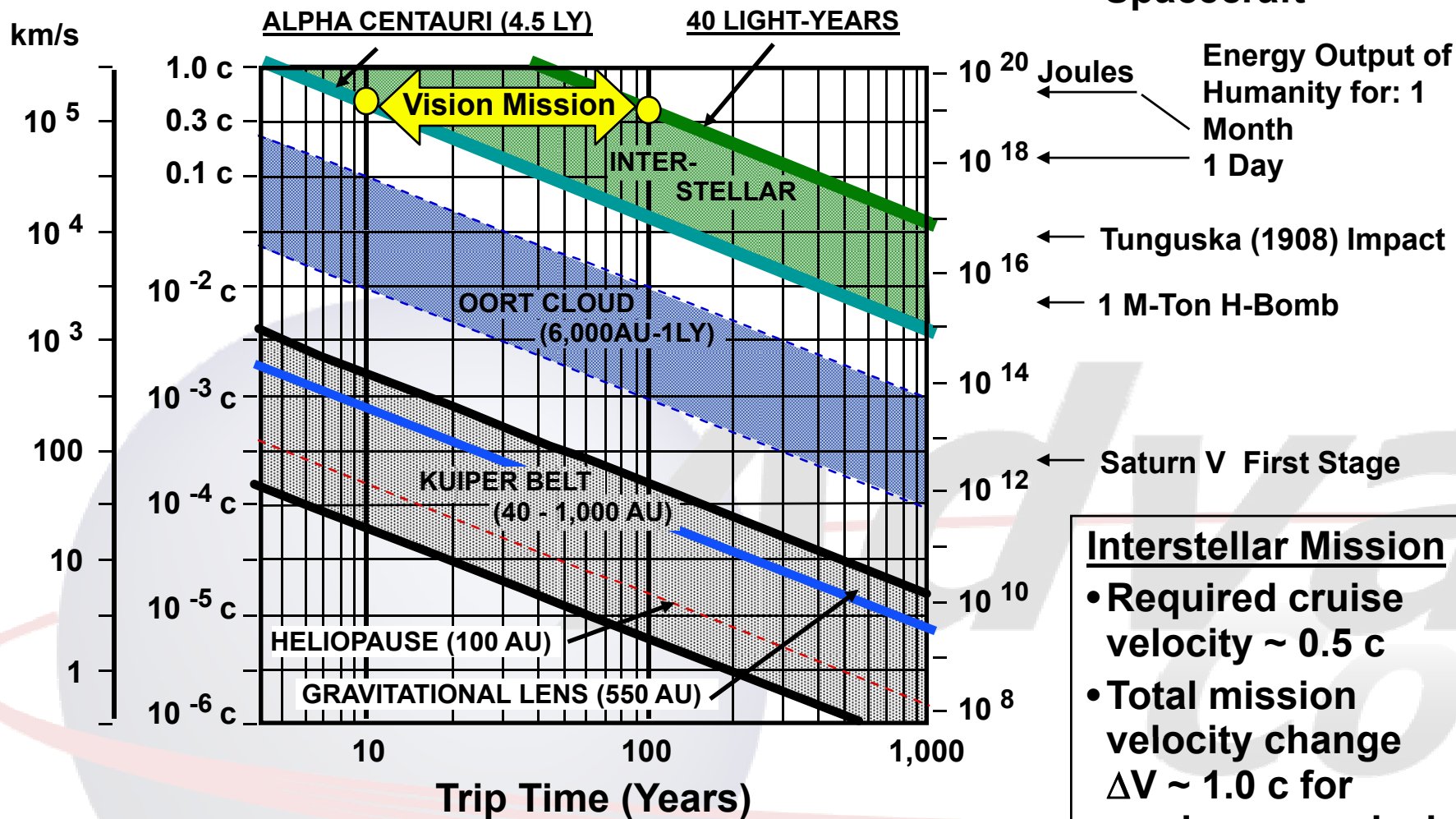


INTERSTELLAR & PRECURSOR MISSION CRUISE VELOCITY & ENERGY ROTTS



Cruise Velocity

Kinetic Energy of 1,000 kg Spacecraft



Interstellar Mission

- Required cruise velocity $\sim 0.5 c$
- Total mission velocity change $\Delta V \sim 1.0 c$ for rendezvous mission (start & stop)

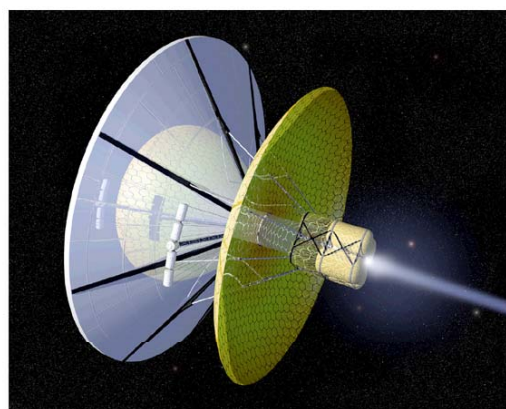


Far Term: Extending Our Reach Demands Extraordinary Methods of Propulsion



- **Matter-Antimatter (Highest Energy Density Propellant)**

- Production, handling and storage
- Converting energy to exhaust



- **Fusion Ramjet
(Refueling on the Road)**

- H-H fusion
- Large area magnetic scoops
- “Drag-free” fusion

- **Beamed Energy (Propellantless Propulsion)**

- Very high power lasers with large apertures
- Precision pointing
- Large, low density sails





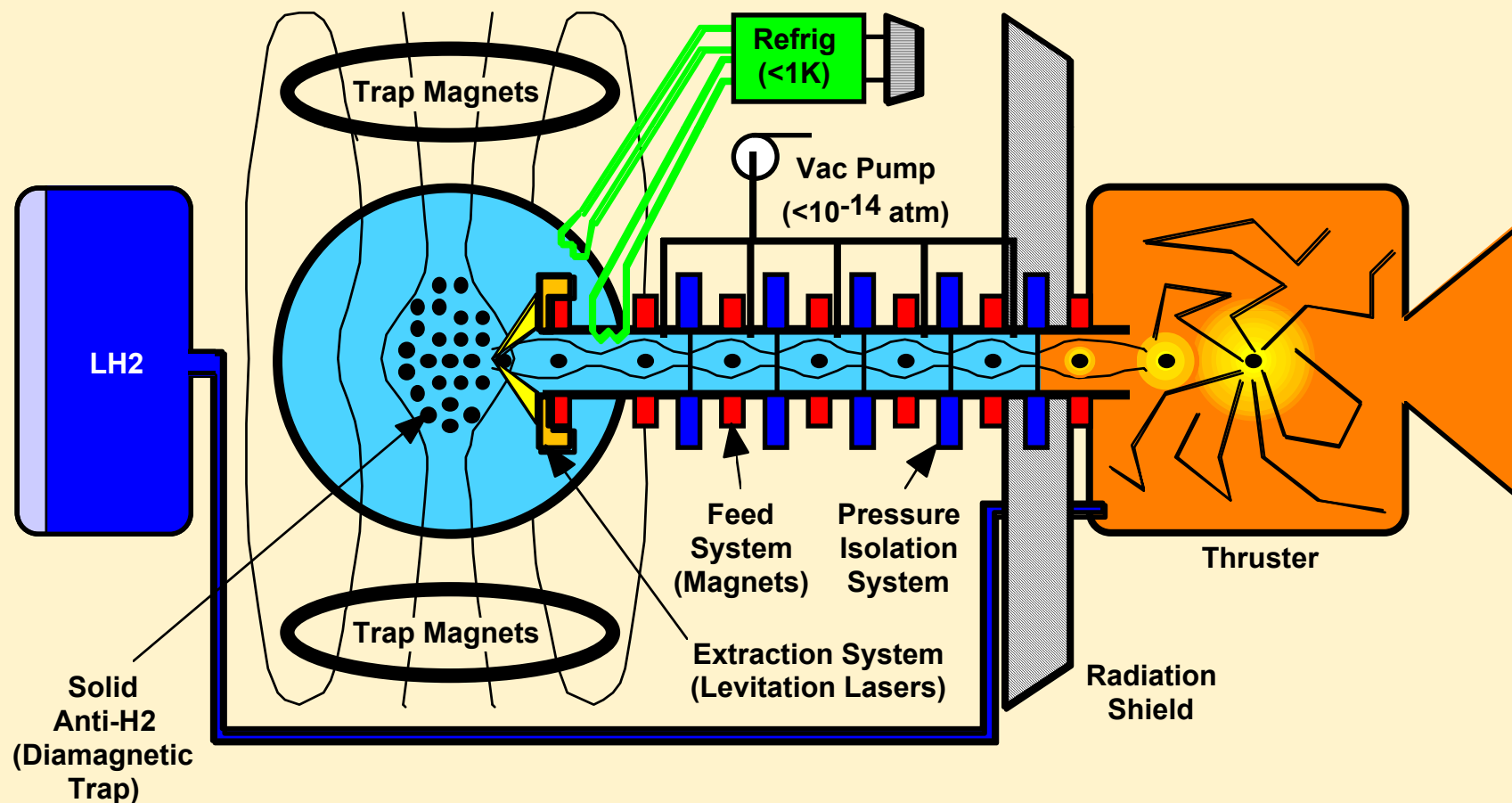
Antimatter Propulsion Concept



Propellant
Tanks

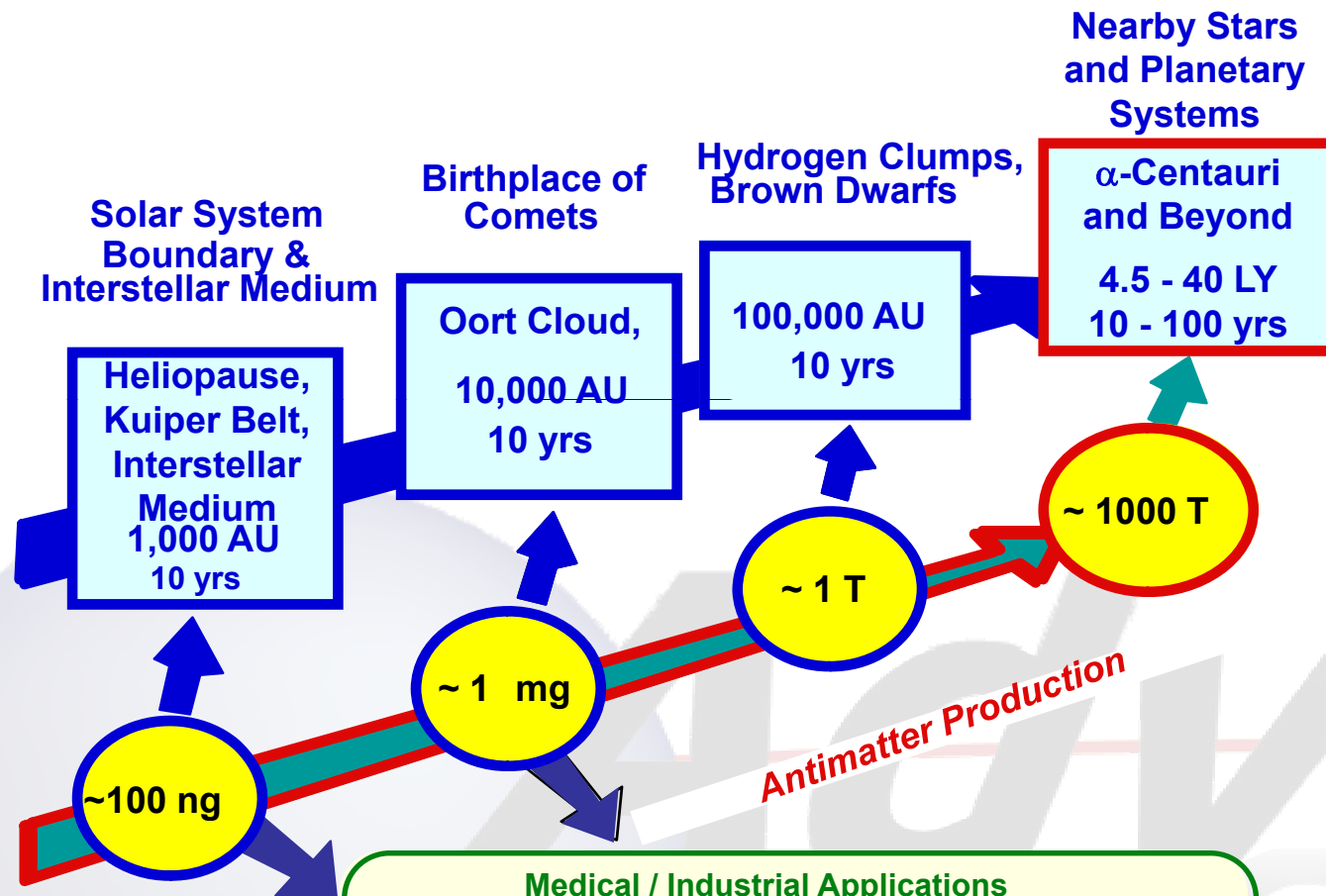
Antimatter Storage and Feed System

Engine
System





Intermediate Returns on Antimatter Infrastructure And Propulsion Investment



Medical / Industrial Applications

- Imaging & Treatment - e.g., Detect & Destroy Cancer Tumors
- Basic research

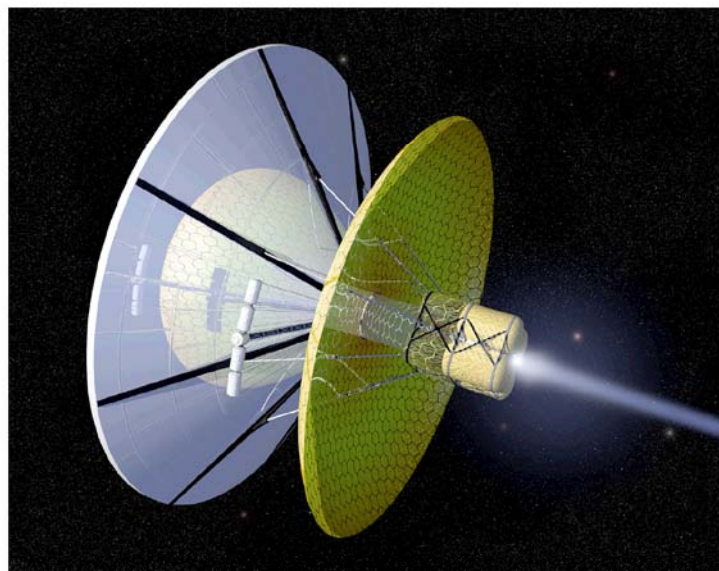
Additional Space Applications

- 4-Month R/T to Mars - Deliver/Retrieve 100 M-tons (TAU)
- < 4-Weeks travel to any place in the Solar System (TTAU)

Basic Science Return



Nuclear Fusion Propulsion

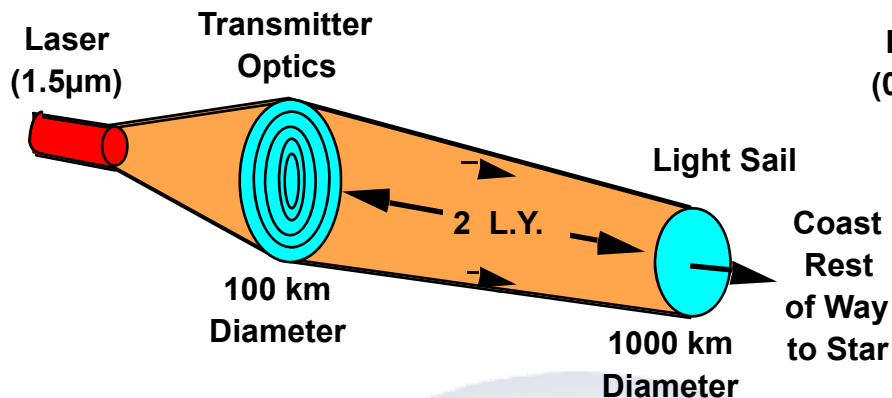


- Fusion concepts will enable human exploration beyond Mars to the moons of the outer planets.
- Antimatter-catalyzed fusion looks promising for space applications
 - Might be the first real application of fusion technology
- **Insufficient energy density to enable true interstellar travel -- unless Bussard ramjet proves feasible**
 - Must collect enough interstellar hydrogen to work ($v > 0.6c$ required)
 - Most interstellar hydrogen is not the correct isotope and therefore will not likely work at all!

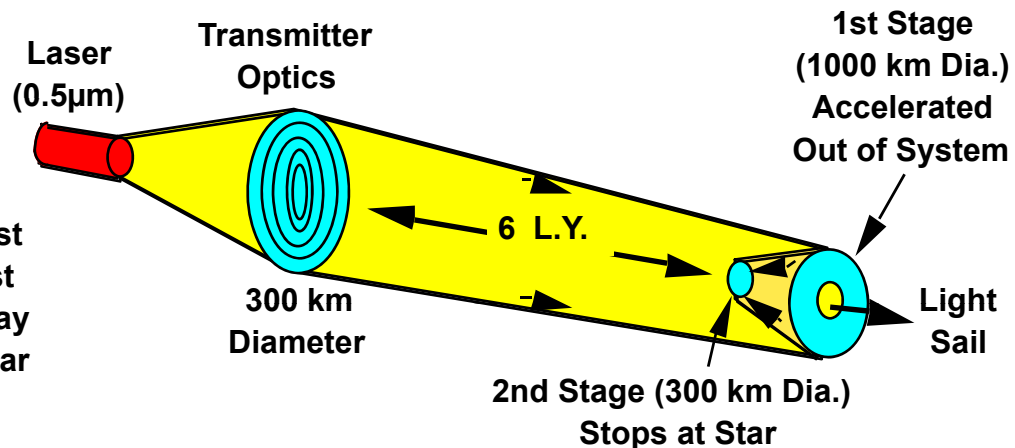


Interstellar Light Sail Concept

INTERSTELLAR FLYBY



INTERSTELLAR RENDEZVOUS



- **Advantages**
 - Perform interstellar missions in 50 - 100 years
 - Only competitor is antimatter
 - Use as a solar sail once in orbit about target
 - Use solar power satellite as driver for robotic flybys
- **Disadvantages**
 - Very high laser / microwave powers (0.1-1,000 TW)
 - Very large optics (100-1,000 km)
- Far-term concept, but one of the few ways to do "fast" interstellar missions

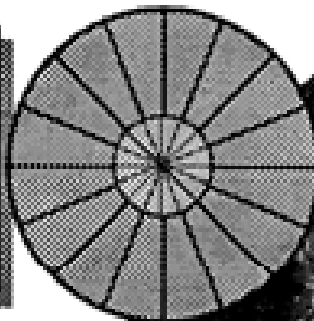


Laser Sails Are BIG



LightSail for 40 LY Rendezvous Mission

- 100 Year Trip Time
- 0.2 gees Max Accel.
- 936 km Dia
- 3,000 TW Beam



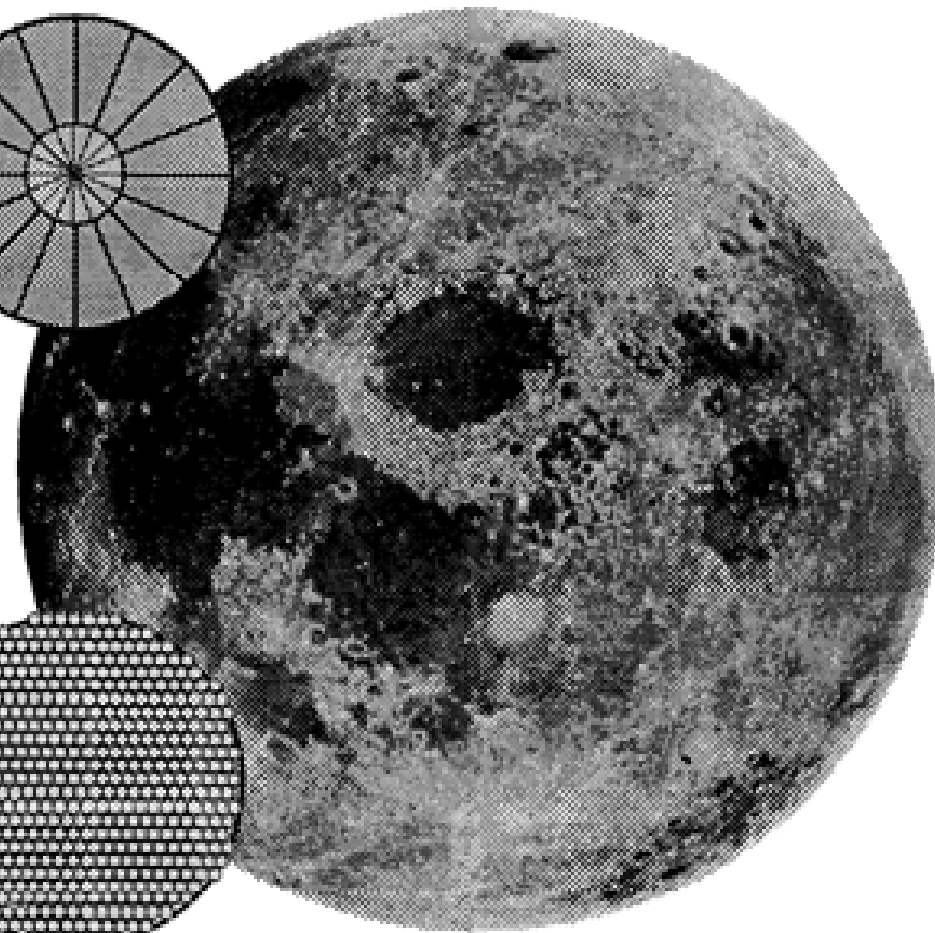
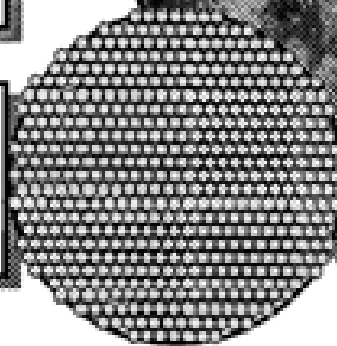
LightSail for 4.5 LY Rendezvous Mission

- 20 Year Trip Time
- 0.2 gees Max Accel.
- 117 km Dia
- 47 TW Beam



Beamed-Energy Transmitter Array

- 1,000 km Dia
- 1 μm Wavelength



Courtesy: Robert Frisbee

Cue Breakthrough Inspirations

- 1880, P. Grec, "*Antigravity*"
- 1928, E.E. Smith, "*FTL*"
- 1931, J. Campbell, "*Hyperspace*"
- 1935, N. Schachner, "*Space Warp*"
- 1951, M. Gibbs, "*Warp Drive*"



1956, *Forbidden Planet*



1966, *Star Trek*



1999, *Galaxy Quest*



Perry Rhodan



1993, *Babylon 5*



1984, *Buckaroo Banzai*



1978, Douglas Adams
Infinite Improbability Drive



1977, *Star Wars*

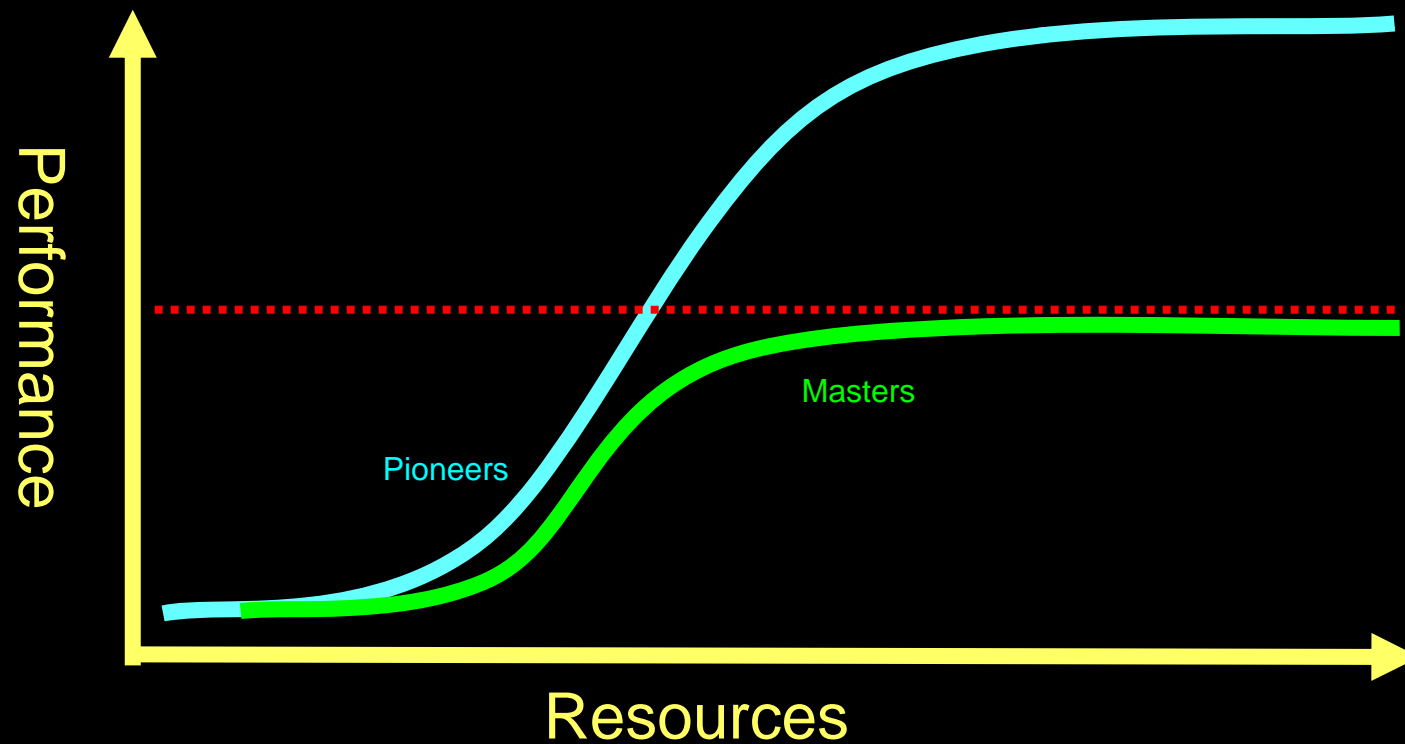
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Ingoing Premise - History Repeats Itself

limits prior technology

different technology

(Foster, *Innovation - The Attacker's Advantage*, 1986)



Propulsion's Next S-Curve

- Propulsion *technology*, even when at its upper limit, is inadequate for *timely* interstellar flight
- Since *Science* is the progenitor of *technology*...
- Seek new *physics* to circumvent *technological* limits
 - Even if impossible, spaceflight introduces new perspectives toward solving the lingering mysteries of physics
 - More optimistically, if new propulsion physics *is* discovered, a breakthrough class of technologies would result, revolutionizing spaceflight and enabling humanity to reach other habitable planets

Stages of Progress





Complications of Pursuing These Topics

- **The Good**
 - Intellectually stimulating topic
 - Easy to be a pioneer while others shy away –
by simply doing an honest, competent job
 - Coworkers offer encouragement (*to watch the arrows in your back*)
- **The Bad**
 - Virtually no funding
 - Difficult on your management (*"It doesn't fit our plan!"*)
 - Revolutionary work is disruptive
- **And The Ugly**
 - Attracts the *Lunatic Fringe*
 - Pedantic reactions



Great Researchers & Important Problems

1986 lecture, Richard Hamming, distinctions between *good* and *great* researchers

- Have courage to tackle Important Problems
 - Grand challenges that will make a real difference, not just "safe" research
 - Attackable; there is a way to begin solving the problem
- Start with independent thoughts and then collaborate
- Make steady progress, driven and focused
- Learn things beyond own work; "Knowledge is like compound interest"
- Redirect what is difficult to something easier (convert liabilities to assets)
- Honest with personal flaws & work to overcome (convert liabilities into assets)
- Tolerate ambiguity
 - Believe in self enough to proceed
 - Doubt self enough to honestly see flaws

Overall Status

- Subjective Assessment
 - **State of Art** spans defining problems to testing hypotheses - pieces of the puzzle
 - Nothing yet at **TRL-1** (Basic principles observed and reported)
 - Numerous research options remain unexplored
- Facts
 - NASA “Breakthrough Propulsion Physics Project” ran 1996-2002
 - More than 16 approaches explored by NASA and others
 - Private \$ exceeded NASA \$, but with undisclosed results
 - Progress continues in small, isolated efforts, with publications in peer-reviewed journals
 - No funding currently exists to seek out and support the best prospects
- Hype Warning: “antigravity” and “free energy” claims

Book: *Frontiers of Propulsion Science*

- **AIAA Progress in Aeronautics and Astronautics Series**
- **Editors:**
 - Marc Millis (NASA GRC)
 - Eric Davis (Inst. Adv. Studies, Austin TX)
- **18 Authors**
- **22 Chapters**
 - Gravity control
 - Faster-than-light
 - Energy conversion
 - How to's
- **Publication Date:**

2009-Feb-2



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Today

Voyager I (launched April 1977)

(Launch + 32 Years)

Distance:

10 billion miles

108 Astronomical Units (AU)

Speed:

17 km/sec

(3.7 AU/Year, 0.0006% c)



Time to Travel

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4.3 Light Years: 74,000 Yrs

Tomorrow



A Galactic Empire!