HUMANITY'S JOURNEY TO INTERSTELLAR SPACE

INTERSTELLAR

PROBE

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Planning for a Pragmatic Interstellar Probe: Requirements, Desirements, Realities

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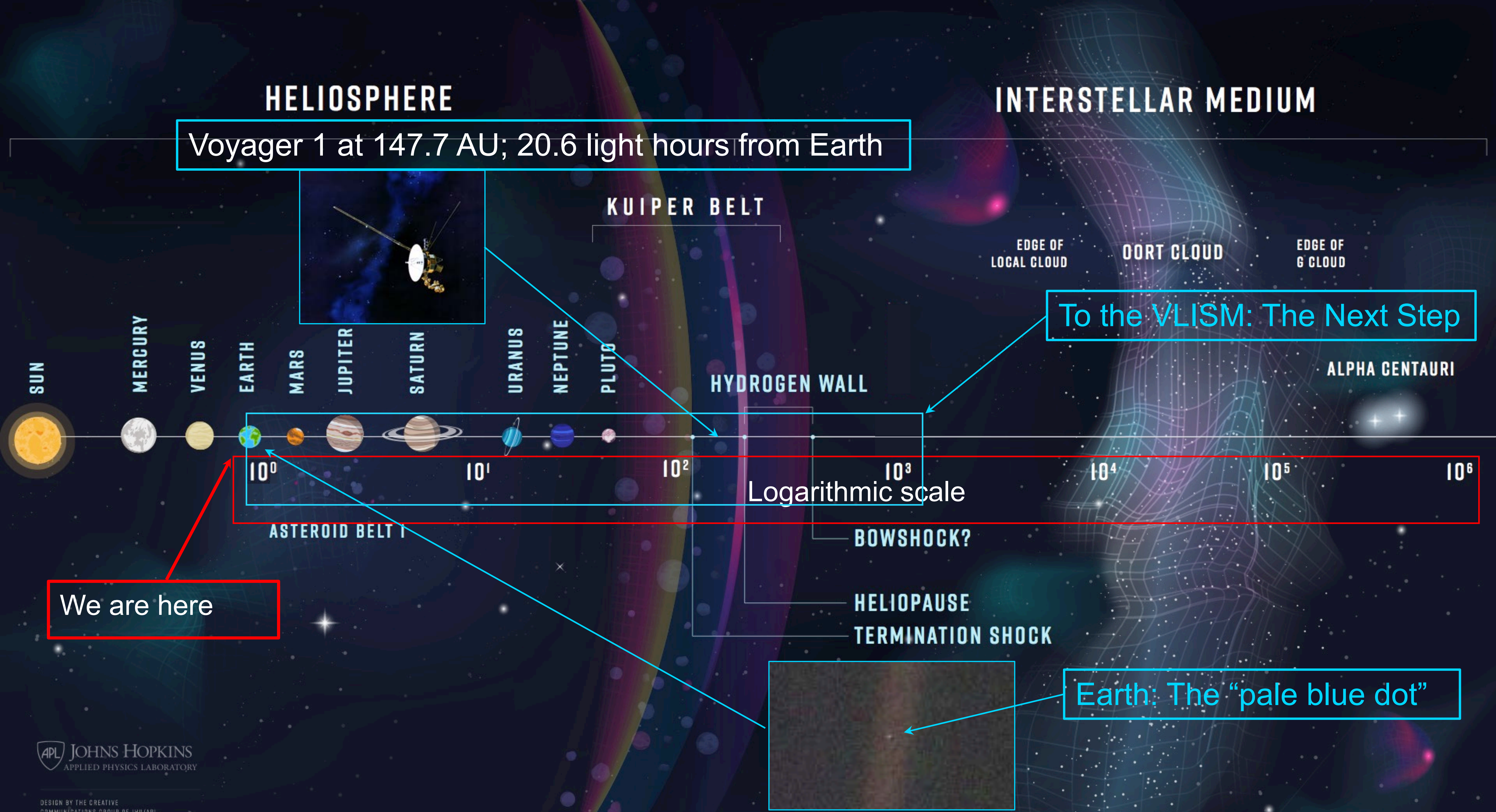
Interstellar Probe: At the Intersection of Heliophysics, Planetary Physics, and Astrophysics I

“Interstellar Probe”

INTERSTELLAR PROBE

- … is a mission through the outer heliosphere and to the interstellar medium
- … uses today’s technology
- … can pave the way for more ambitious future journeys (and more ambitious science goals)


HELIOSPHERE
INTERSTELLAR MEDIUM
Voyager 1 at 147.7 AU; 20.6 light hours from Earth
KUIPER BELT
EDGE OF LOCAL CLOUD
OORT CLOUD
EDGE OF G CLOUD
To the VLISM: The Next Step
ALPHA CENTAURI
SUN
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
URANUS
NEPTUNE
PLUTO
HYDROGEN WALL
10^0
10^1
10^2
10^3
10^4
10^5
10^6
Logarithmic scale
ASTEROID BELT
BOWSHOCK?
HELIOPAUSE
TERMINATION SHOCK
We are here
Earth: The "pale blue dot"
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DESIGN BY THE CREATIVE COMMUNICATIONS GROUP OF JHU/APL

Neither the Questions…nor the Answers… are new – but they have evolved

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JPL study of 1976 – 1977:

Science Aspects of a Mission Beyond the Planets

LEONARD D. JAFFE AND CHARLES V. IVIE

Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, California 91103

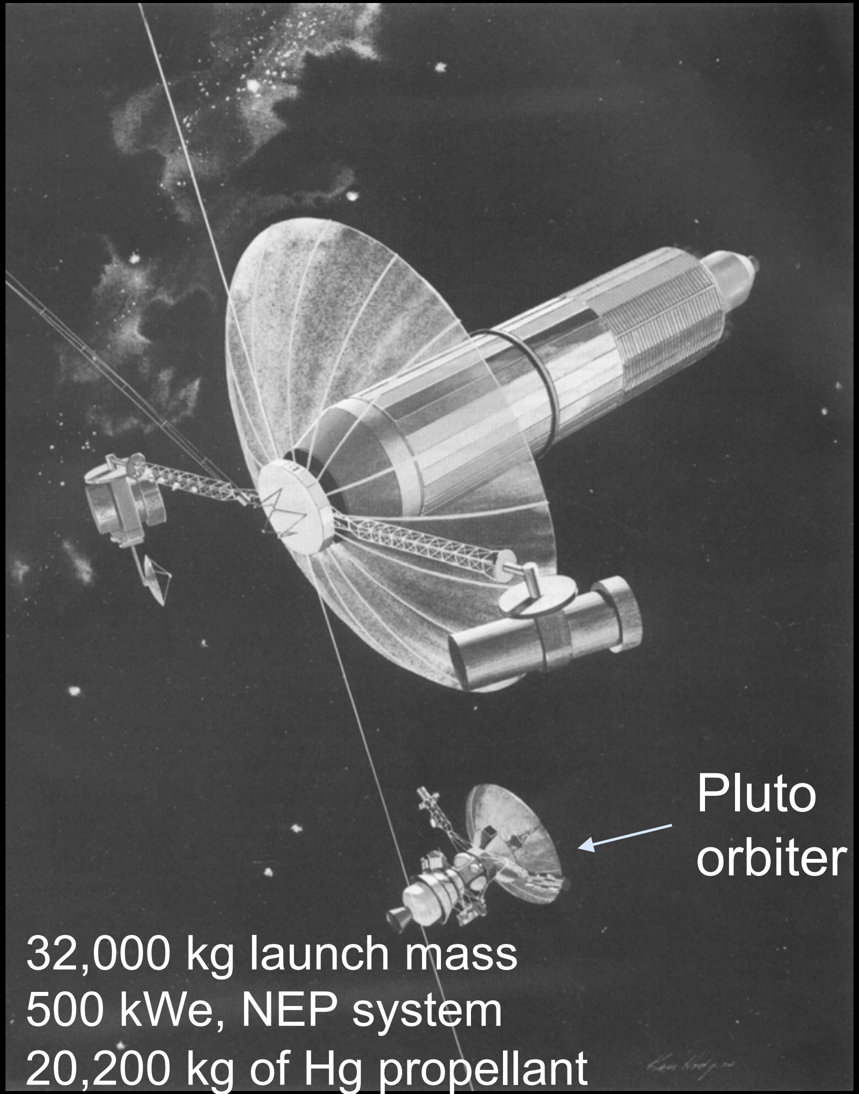
Received July 26, 1978; revised April 10, 1979

Primary Objectives

(1) Characterize the heliopause
(2) Determine characteristics of the interstellar medium
(3) Improve the stellar and galactic distance scale
(4) Determine characteristics of cosmic rays
(5) Determine characteristics of the solar system as a whole

Secondary Objectives

(1) Determine characteristics of Pluto and its satellites and rings, if any.
(2) Determine characteristics of distant galactic and extragalactic objects
(3) Evaluate problems of scientific observations of another solar system from a spacecraft



Reiterated in the 1980's and the 1990's

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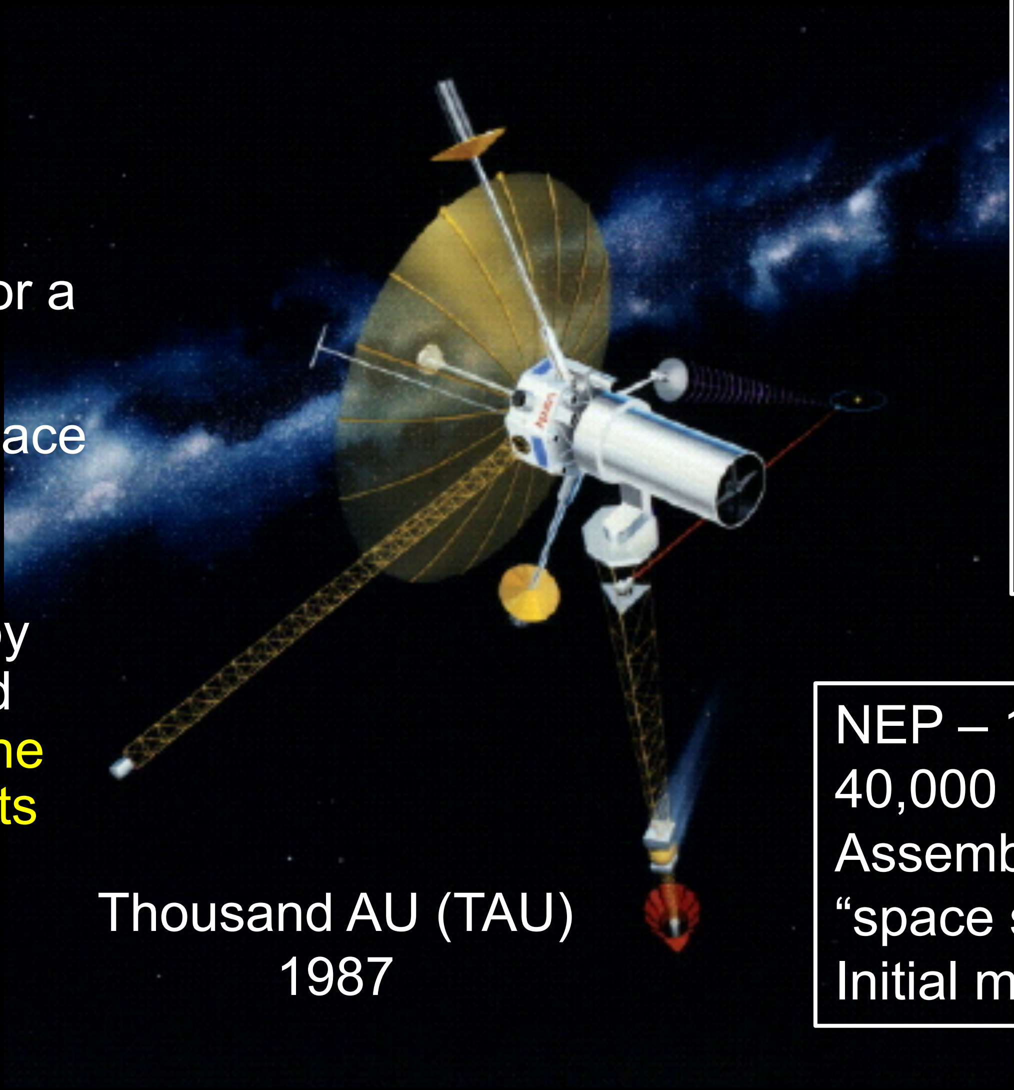
- From Holzer et al (1990) – transition to smaller spacecraft and more limited science

THE INTERSTELLAR PROBE:

Scientific Objectives and Requirements for a Frontier Mission to the

Heliospheric Boundary and Interstellar Space

- Missions to interstellar space have been studied in the past, including the TAU (Thousand AU) mission recently studied by JPL. Whereas the TAU study was directed mainly towards astronomical objectives, the present Interstellar Probe would have as its prime focus in situ particles and fields measurements at the boundary of the heliosphere and in interstellar space,…



Thousand AU (TAU)
1987

The primary scientific objective of the TAU mission is to establish an accurate cosmic distance scale throughout our Galaxy and perhaps beyond.

NEP – 1 $MW_{electric}$ +
40,000 kg Xe propellant
Assembly in LEO at "space station"
Initial mass 61,500 kg

Mentions in the Last Two Heliophysics Decadals

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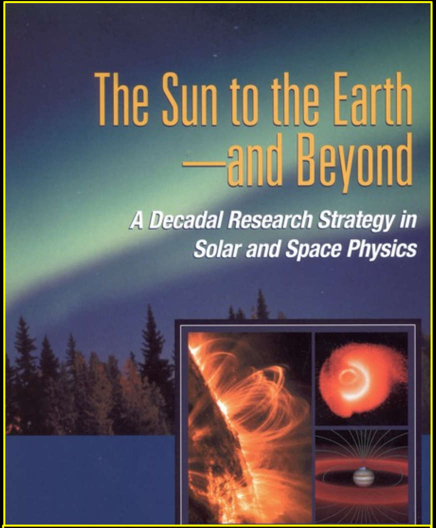
- **Propulsion for a compelling mission has been the issue**

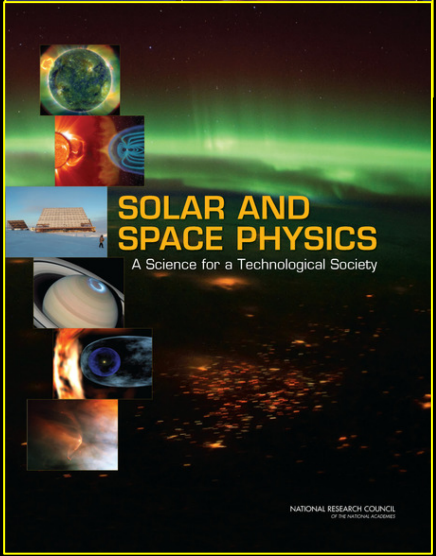
In 2003 – "Missions to the outer planets and beyond, including an Interstellar Probe, require propulsion capabilities that significantly exceed those of the present fleet of launch vehicles. – **Near-term realities of NEP eliminated by Prometheus effort findings**

78 THE SUN TO THE EARTH—AND BEYOND

TABLE 2.4 Deferred High-Priority Flight Missions (Listed Alphabetically)

Mission	Reason for Deferral
Large	
Interstellar Probe	Advanced propulsion technology needed
Moderate	





In 2013 – only mention was in Solar and Heliospheric Physics Panel report: "…the principal technical hurdle is propulsion…Advanced propulsion options, which could be pursued with international cooperation, should aim to reach the heliopause considerably faster than Voyager 1 (3.6 AU/year)." – **No near-term solutions have emerged.**

Status of This Study

- Contract with NASA Heliophysics Division added funding 25 July 2019
- Period of performance extended to 30 April 2022
  - Allows for final report to be delivered late Fall 2021 to help inform next Heliophysics Decadal Survey
- Effort comparable to pre-phase A study effort at APL 2002–2006 on Solar Probe
  - Focus on engineering design and trades as informed by cross-disciplinary science community
- Based upon SLS Block 1B/2B and upper stages as enablers for the mission – no other existing, credible alternatives

A “Menu” Approach

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- Look widely across the science and technical communities
- Assemble a “Menu” of what has been done and what can be done
- By its nature this is a “superset” of what might be implemented
- “Ordering” from the menu will we a charge to a future Science Definition Team – at NASA’s discretion
- But one always would like the assurance about what orders can be placed – and delivered – and what they would cost
- This approach has been adopted successfully in the past in providing input to the Decadal Surveys

Engineering Requirements

- Engineering requirements are needed to frame the engineering study
  - "Bound the box" – but allow for trades
  - Still evolving

(1) Enable a mission that can be launched no later than 1 January 2030.

(2) Have the capability to operate from a maximum range of not less than (NLT) 1000 astronomical units (AU) from the Sun.

(3) Require no more than 400 Watts of electrical power (We) at the beginning of mission (BOM) and be able to operate at no less than half of the BOM amount at the end of mission (EOM).

(4) Achieve a mission lifetime of not less than (NLT) 50 years with a probability of success of NLT 85%.

Critical Trade-Offs Are Not New

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- **Mass: Driven by flyout speed and payload capability**
- **Communication:** Solid, near-term, tested engineering

Nor Are Enabling Technologies

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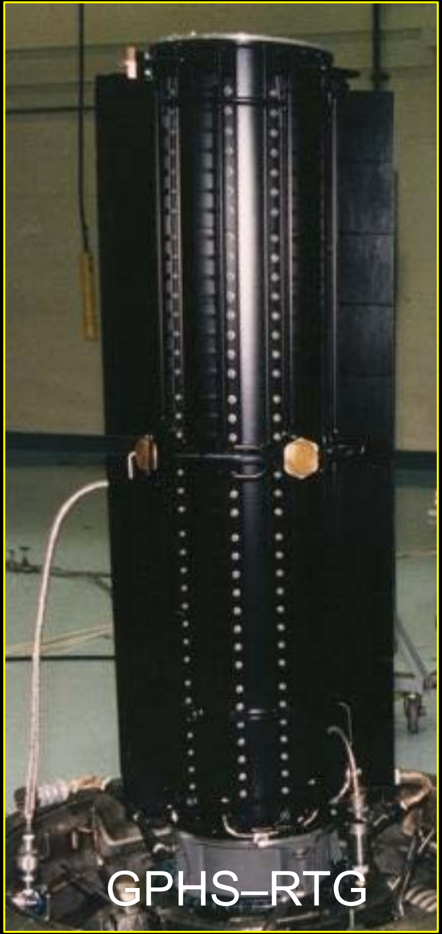
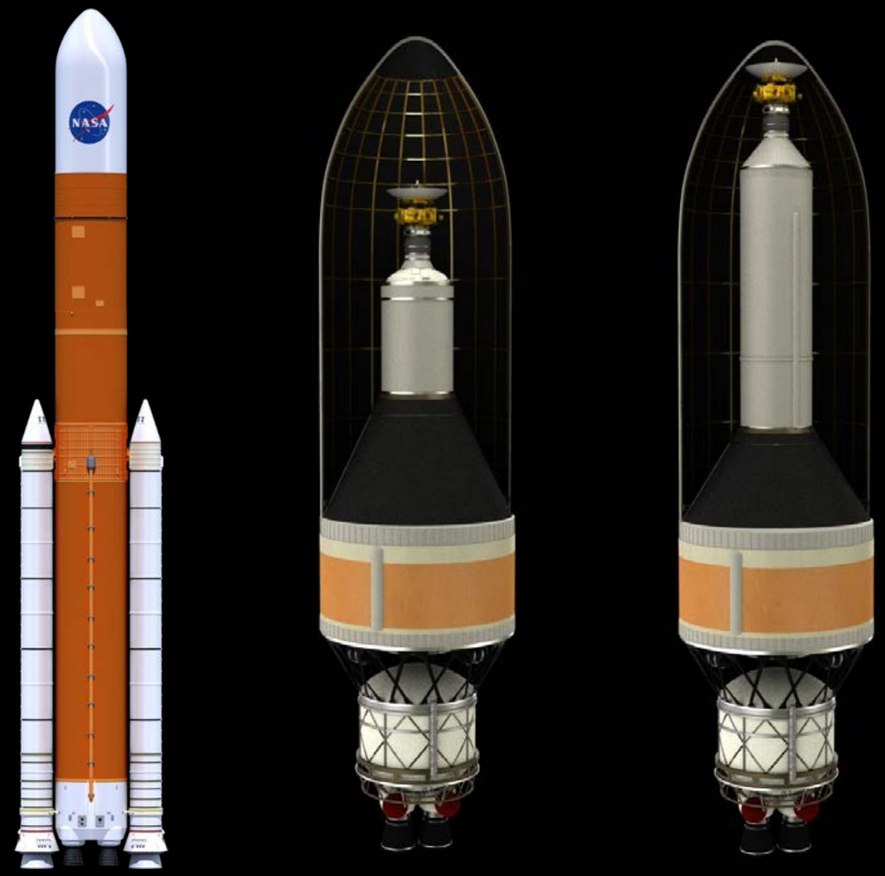
- **Power:** GPHS/MHW derivative RTG – efficiency and lifetime for use *in vacuo*



- **Propulsion/Launch Vehicle:** Keys for implementation



The Issue is a System that "Closes"

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- **Three trajectory options considered**
  1) Unpowered Jupiter Gravity Assist optimized for speed
  2) Powered Jupiter Gravity Assist
  3) Powered Solar Gravity Assist ("Oberth Maneuver")
- **Determine best performance for buildable systems**
- **95 configurations studied to provide ~5 downselects for additional consideration**

…	Oct 19	Nov 19	Dec 19	Jan 20	Feb 20	Mar 20	Apr 20	May 20	Jun 20	July 20	Aug 20	Sep 20	Oct 20	…	Sep 21
	Wksp 2019								Prelim Results	ACE Run		Interim Report	Wksp 2020		Final Report

Science

ConOps

Longevity
- SC lifetimes/failures, long-lasting systems, failure modes

- Develop process of failure modes and accelerated testing

- Symposium to discuss results;

- Report and papers

Instruments
- Candidate payload components with parameters + operating requirements

- Define baseline payloads

Trajectory / Launch Vehicle

Comm and GNC trades

Heat Shield
- Attitude control at burn
- High temp coating

- If yes, define ConOps parameters

Mechanical
- Design spacecraft layout

Power
- Compare NG-RTG, GPHS-RTG and MHW-RTG using GPHS components

ACE Run

Interim Report

Work -shop Input

Revise Report

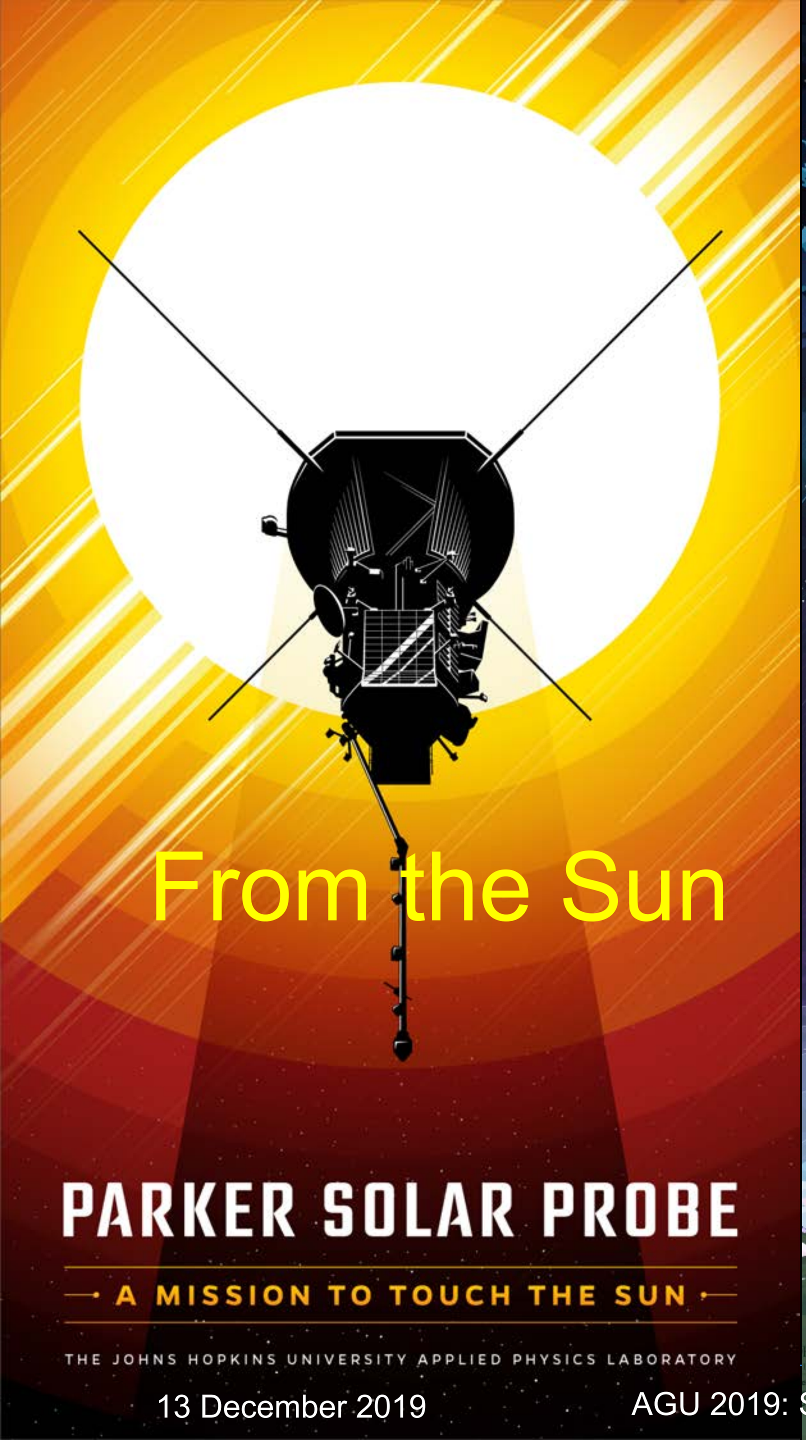
Final Rprt

ACE = **A**PL **C**oncurrent **E**ngineering Laboratory

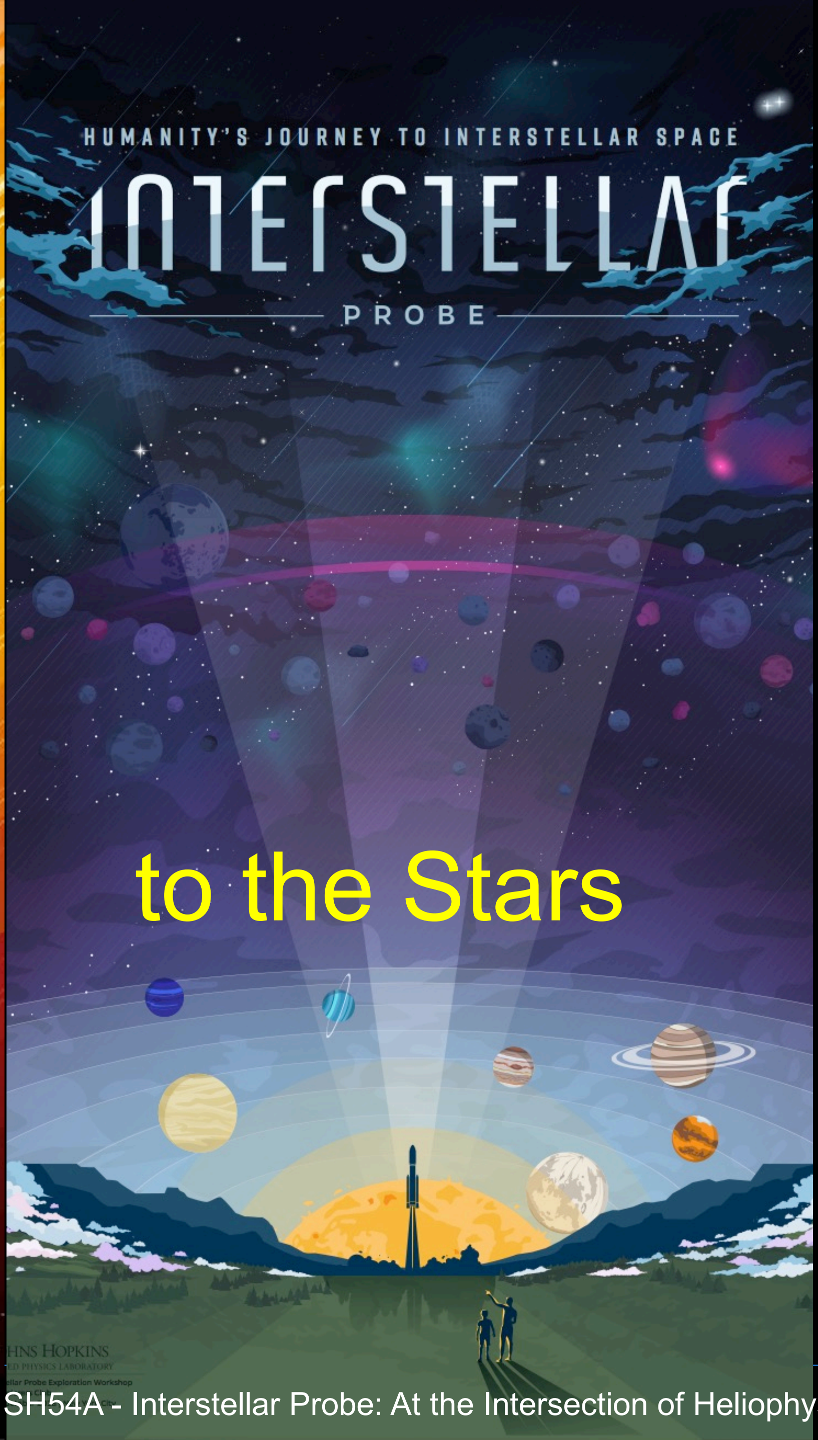
Engineering requirements:
- 400 W
- Launch-able 1/1/30
- >50 years
- >1000 AU

One scenario: 24 February 2030…

… Faster and Onward !



From the Sun



to the Stars

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The real journey has only just begun…