PROJECT ICARUS: CANDIDATE TECHNOLOGIES FOR INTERSTELLAR PROPULSION
Overview

- Why Interstellar Space
- Candidate Propulsion Technologies
  - Propellant Considerations
  - Hybrid Systems / Propulsion by Proxy
- More about Project Icarus
  - vIcarus
Why Study Interstellar Space

- Study Interstellar Medium
- Survey Oort Cloud Objects
- Study Heliopause

- Gravitational Lensing (550 AU)
- Pioneer Anomaly
- Galactic Cosmic Ray

We need 42.1 km/s to leave SS.
Progress Daedalus Project Study
Work towards in-situ Exoplanet study
Pave the path to Interstellar travel
Inspire (Pulsed Propulsion Prototype, Interstellar Internet, etc)
Interstellar Missions

V1 (115 AU)  V2 (93 AU)

P10 (102 AU)  P11 (82 AU)

NH (18 AU)

Innovative Interstellar Explorer
REP: 7.8 AU/yr@104 AU (2032)

Radioisotope Electric Propulsion

Dr. Andreas C. Tziolas | Deputy Project Leader

18th Advanced Space Propulsion Workshop | JPL/NASA
# High TRL Benchmark

<table>
<thead>
<tr>
<th></th>
<th>$V_{\text{exhaust}}$ (km/s)</th>
<th>$V_{\text{final}}$ (km/s)</th>
<th>$V_{\text{final}}$ (%c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Shuttle</td>
<td>4.5</td>
<td>21</td>
<td>0.00007</td>
</tr>
<tr>
<td>Electrostatic Ion Thruster</td>
<td>210</td>
<td>967</td>
<td>0.00322</td>
</tr>
<tr>
<td>VASIMR</td>
<td>300</td>
<td>1382</td>
<td>0.00461</td>
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</tbody>
</table>

R = 100
Mf = 10 kg
### Nuclear Powered Heat Exchange Methods

<table>
<thead>
<tr>
<th>Nuclear Thermal</th>
<th>Vexhaust (km/s)</th>
<th>Vfinal (km/s)</th>
<th>Vfinal (%c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid</td>
<td>10</td>
<td>46</td>
<td>0.00015</td>
</tr>
<tr>
<td>Liquid</td>
<td>15</td>
<td>69</td>
<td>0.00023</td>
</tr>
<tr>
<td>Gas</td>
<td>50</td>
<td>230</td>
<td>0.00077</td>
</tr>
</tbody>
</table>

![Diagram of nuclear propulsion system](image-url)
## Pulsed Propulsion Methods

<table>
<thead>
<tr>
<th>Vexhaust (km/s)</th>
<th>Vfinal (km/s)</th>
<th>Vfinal (%c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orion</td>
<td>3000</td>
<td>13816</td>
</tr>
<tr>
<td>Daedalus</td>
<td>10000</td>
<td>46052</td>
</tr>
<tr>
<td>Medusa</td>
<td>1000</td>
<td>4605</td>
</tr>
<tr>
<td>Longshot</td>
<td>5000</td>
<td>23026</td>
</tr>
<tr>
<td>Antimatter</td>
<td>4000</td>
<td>18421</td>
</tr>
</tbody>
</table>
Beamed Propulsion

MagBeam: Winglee

$V_{eff} = 200\text{km/s}$

$20\text{km/s in 4 hours of beaming}$

10 tonne S/C

Dyson-Harrop Satellite

$P_b = \frac{1}{2}Ma\left(V_b^3/V_s^2\right)$

$P_a = MV_a$
Project Icarus Documentation Flow

PHASE

1  2  3  4  5  6  7  8  9  10

- Concept Design
- Preliminary Design
- Detail Design
- Integration
- Certify Design
- Publish Design
- Executive Summary
- Final System Studies
- Final Review
- SRD
- SSRD
- PIEM
- Prelim-Review
- Preliminary Review
- Convergent Systems Research
- Divergent Research
- External Divergent Research
- Action response
Icarus Spacecraft Pathfinder Concepts

**satIcarus:**
- LEO
- Radiation Hard ENL Test
- On-Board Repair Test
- Magnetic Nozzle Test

**simIcarus:**
- Earth to Lunar Orbit
- Pulsed Propulsion Prototype
- Evolutionary Algorithms

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Credit: Adrian Mann
ARM05 reports Thermal Shunt RTG06/03 Override in effect.
ARM05 thermal transfer rate 6.41 Joules/sec to space.
SNR17 reports sector RTG06/03-RTG06-05 ambient temperature 47 K.
CPU09 dispatch request received. ARM02 to sector RTG06/03. Override.
ARM02 arrived at station RTG06/03...
Project Icarus is comprised of a select group of scientists donating their time and resources to research interstellar travel.