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Icarus Project Leader
Talk Outline

• Introduction to Project Icarus
• Project Daedalus Overview
• Engine Configuration
• Choice of Fuel
• Pellet Design
• Reaction Chamber
Introduction to Project Icarus

Terms of Reference

1. To design an unmanned probe that is capable of delivering useful scientific data about the target star, associated planetary bodies, solar environment and the interstellar medium.

2. The spacecraft must use current or near future technology and be designed to be launched as soon as is credibly determined.

3. The spacecraft must reach its stellar destination within as fast a time as possible, not exceeding a century and ideally much sooner.

4. The spacecraft must be designed to allow for a variety of target stars.

5. The spacecraft propulsion must be mainly fusion based (i.e. Daedalus).

6. The spacecraft mission must be designed so as to allow some deceleration for increased encounter time at the destination.
Introduction to Project Icarus

Modules
Introduction to Project Icarus

Design Team

Consultants

Students

Dr. Richard Obousy | Icarus Project Leader

Advanced Space Propulsion Workshop 2010
Introduction to Project Icarus

Publications


**Project Icarus: A review of local interstellar medium properties of relevance for space missions to the nearest stars.** I.A.Crawford. Accepted for publication in *Acta Astronautica*.


**Project Icarus: Exploring the interstellar roadmap using the icarus pathfinder probe and icarus starfinder probe - a level on (concept builder) trade study report.** K.F.Long, A.Hein, P.Galea, R.Swinney, A.Mann, M.Millis. INTERNAL PAPER.
Project Daedalus Overview

- 1973-1978 BIS Team
- Internal Fusion Pulse Propulsion
- Barnard’s star
- 12.2% c
- 3.8 Year Acceleration phase
- 45 Year Coast Phase
- $I_{sp}$ about $10^6$ s
Engine Configuration
Choice of Fuel

\[ ^2\text{D} + ^3\text{T} \rightarrow ^4\text{He}(3.5) + ^1\text{n}(14.1) \quad \alpha = 0.0038 \]

\[ ^2\text{D} + ^2\text{D} \rightarrow ^3\text{T}(1.01) + ^1\text{p}(3.03) \quad \alpha = 0.0011 \]

\[ ^2\text{D} + ^2\text{D} \rightarrow ^3\text{He}(0.82) + ^1\text{n}(2.45) \quad \alpha = 0.0009 \]

\[ ^2\text{D} + ^3\text{He} \rightarrow ^4\text{He}(3.6) + ^1\text{p}(14.7) \quad \alpha = 0.0039 \]
Pellet Design

- Stored at Cryogenic Temperatures at 3K and 0.813 atm
Pellet Ignition

- Magnetic gun
- Field Strength 15T
- 1st stage acceleration $3.83 \times 10^7$ m/s$^2$
- 2nd stage acceleration $8.21 \times 10^7$ m/s$^2$
- Fired at 250 Hz
Pellet Performance

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>2.84g</td>
<td>0.288g</td>
</tr>
<tr>
<td>Radius</td>
<td>1.97 cm</td>
<td>0.916 cm</td>
</tr>
<tr>
<td>Exhaust Velocity</td>
<td>1.1 E7</td>
<td>0.96 E7</td>
</tr>
<tr>
<td>Driver Energy</td>
<td>2.7 GW</td>
<td>0.4 GW</td>
</tr>
<tr>
<td>Burn up Fraction</td>
<td>0.175</td>
<td>0.133</td>
</tr>
<tr>
<td>Power Output</td>
<td>136 PW</td>
<td>64.3 PW</td>
</tr>
</tbody>
</table>

Radiation Output

Stage 1: $1.5 \times 10^{24}$ n/s
Stage 2: $1.1 \times 10^{23}$ n/s

X-rays and Gammas believed to be
Less than 1%.
Reaction Chamber

Functionality:

• Hemispherical thin-wall is surrounded by superconducting field coils.
• After pellet igniton the plasma ball expands and is compressed by the field against the shell. The field strength is momentarily raised to several tens of Tesla.
• The Plasma KE is temporarily stored in the field, and is then received by the shell as an impulse.
• The reaction chamber is in constant oscillatory motion with an almost steady thrust.
Reaction Chamber

Chamber Design

Desirable Properties:

i. Low Density
ii. High Temperature Capability
iii. High Electrical Conductivity

Molybdenum meets these needs

Chamber Dimensions

i. Stage 1: 50m
ii. Stage 2: 20m

Chamber Mass

i. Stage 1: 218.7 Tonnes
ii. Stage 2: 22.1 Tonnes

Excitation Field Coils

Main Features:

i. Two large counter coils near chamber exit.
ii. High Fields reflects most of the plasma and prevents wall damage.

Stage 1 Coil Masses

Coil 1: 25.9 Tonnes
Coil 2: 3.2 Tonnes
Coil 3: 42.6 Tonnes
Coil 4: 53.0 Tonnes

Stage 2 Coil Masses

Coil 1: 8.9 Tonnes
Coil 2: 1.2 Tonnes
Coil 3: 14.9 Tonnes
Coil 4: 18.6 Tonnes
<table>
<thead>
<tr>
<th>Parameter</th>
<th>1st Stage value</th>
<th>2nd Stage value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propellant mass (tonnes)</td>
<td>46,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Staging mass (tonnes)</td>
<td>1,690</td>
<td>980</td>
</tr>
<tr>
<td>Boost duration (years)</td>
<td>2.05</td>
<td>1.76</td>
</tr>
<tr>
<td>Number tanks</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Propellant mass per tank (tonnes)</td>
<td>7666.6</td>
<td>1000</td>
</tr>
<tr>
<td>Exhaust velocity (km/s)</td>
<td>$1.06 \times 10^4$</td>
<td>$0.921 \times 10^4$</td>
</tr>
<tr>
<td>Specific impulse (million s)</td>
<td>1.08</td>
<td>0.94</td>
</tr>
<tr>
<td>Stage velocity increment (km/s)</td>
<td>$2.13 \times 10^4$ (0.071c)</td>
<td>$1.53 \times 10^4$ (0.051c)</td>
</tr>
<tr>
<td>Thrust (N)</td>
<td>$7.54 \times 10^6$</td>
<td>$6.63 \times 10^5$</td>
</tr>
<tr>
<td>Pellet pulse frequency (Hz)</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Pellet mass (kg)</td>
<td>0.00284</td>
<td>0.000288</td>
</tr>
<tr>
<td>Number pellets</td>
<td>$1.6197 \times 10^{10}$</td>
<td>$1.3888 \times 10^{10}$</td>
</tr>
<tr>
<td>Number pellets per tank</td>
<td>$2.6995 \times 10^9$</td>
<td>$7.5213 \times 10^9$</td>
</tr>
<tr>
<td>Pellet outer radius (cm)</td>
<td>1.97</td>
<td>0.916</td>
</tr>
<tr>
<td>Blow-off fraction</td>
<td>0.237</td>
<td>0.261</td>
</tr>
<tr>
<td>Burn-up fraction</td>
<td>0.175</td>
<td>0.133</td>
</tr>
<tr>
<td>Pellet mean density (kg/m³)</td>
<td>89.1</td>
<td>89.1</td>
</tr>
<tr>
<td>Pellet mass flow rate (kg/s)</td>
<td>0.711</td>
<td>0.072</td>
</tr>
<tr>
<td>Driver energy (J)</td>
<td>$2.7 \times 10^9$</td>
<td>$4 \times 10^8$</td>
</tr>
<tr>
<td>Average debris velocity (km/s)</td>
<td>$1.1 \times 10^4$</td>
<td>$0.96 \times 10^4$</td>
</tr>
<tr>
<td>Neutron production rate (n/pulse)</td>
<td>$6 \times 10^{21}$</td>
<td>$4.5 \times 10^{20}$</td>
</tr>
<tr>
<td>Neutron production rate (n/s)</td>
<td>$1.5 \times 10^{24}$</td>
<td>$1.1 \times 10^{23}$</td>
</tr>
<tr>
<td>Energy release (GJ)</td>
<td>171.82</td>
<td>13.271</td>
</tr>
<tr>
<td>Q-value</td>
<td>66.6</td>
<td>33.2</td>
</tr>
</tbody>
</table>
From Imagination to reality

Ad Astra Incrementis