Project Icarus: A Technical Review of the Daedalus Propulsion Configuration and Some Engineering Considerations for the Icarus Vehicle.

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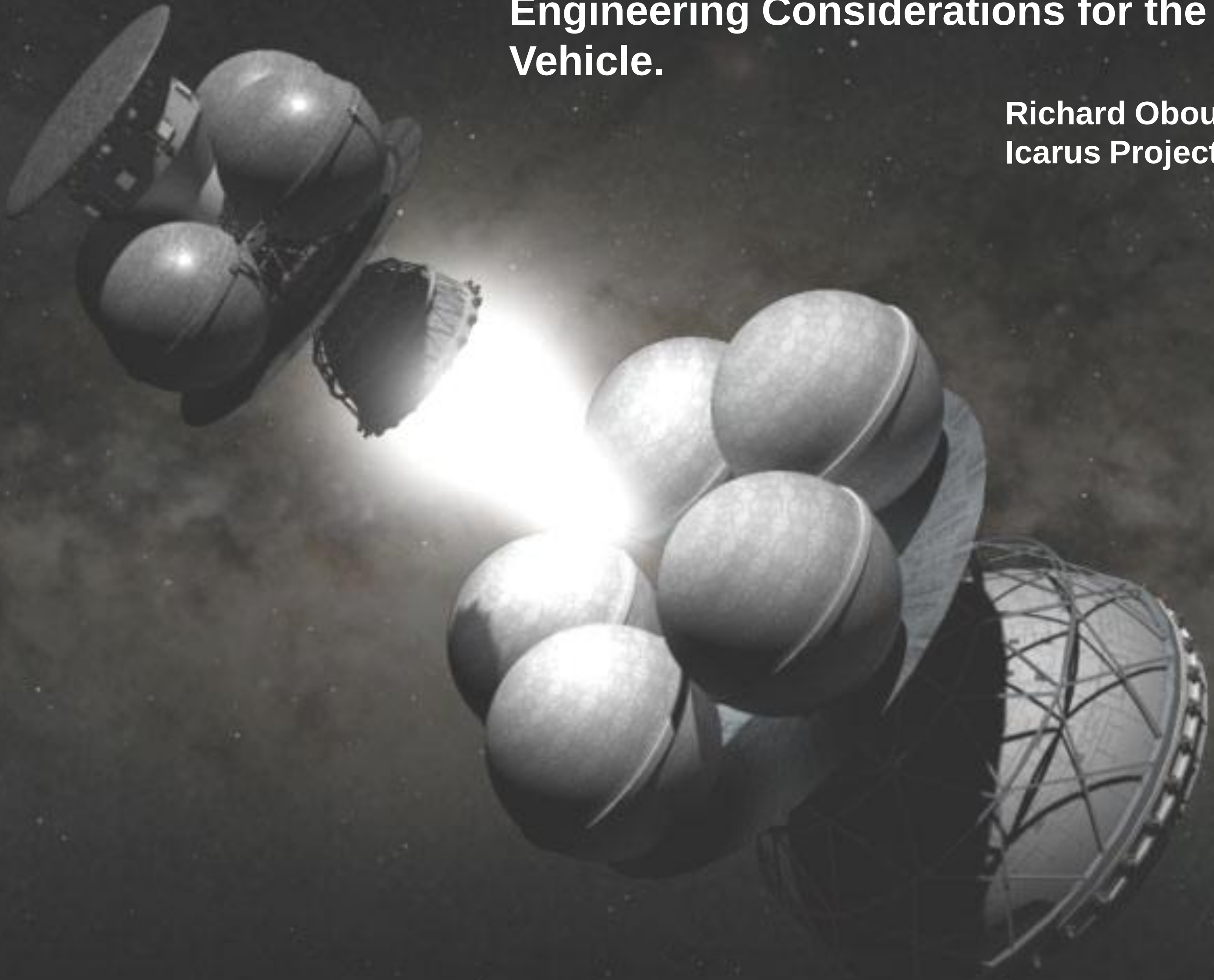
Icarus Project Leader



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.

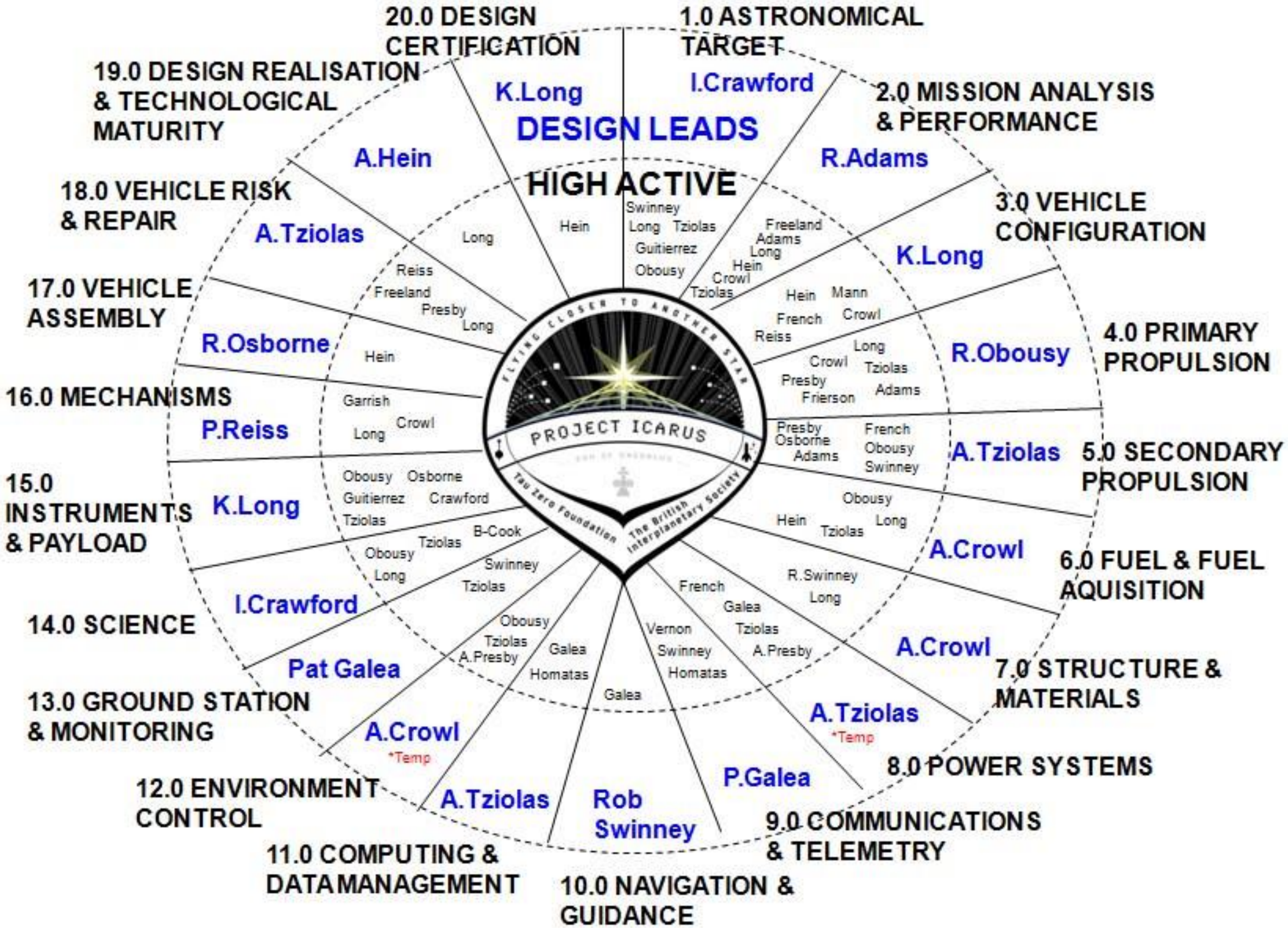
4. The spacecraft must be designed to allow for a variety of target stars.

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.

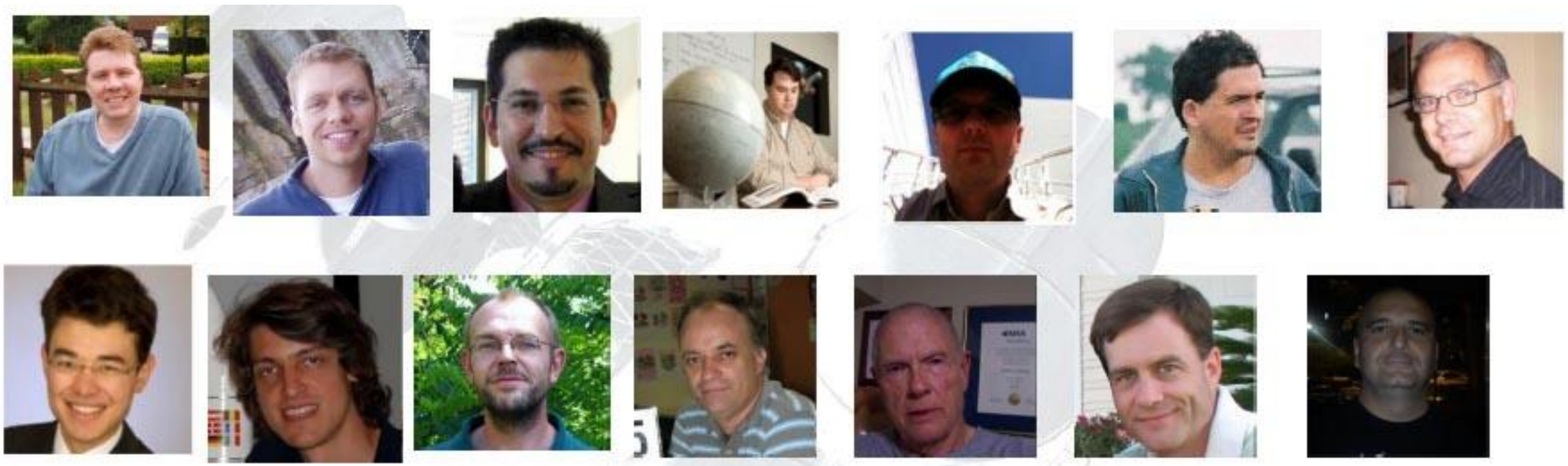
Introduction to Project Icarus

Modules



Introduction to Project Icarus

Design Team



Consultants

Students

Introduction to Project Icarus

Publications

Project Icarus: son of Daedalus - flying closer to another star. Presented BIS symposium September 2009. K.F.Long, M.Fogg, R.Obousy, A.Tziolas, A.Mann, R.Osborne, A.Presby. Published in **JBIS**

Project Icarus: Solar sail technology for the Icarus interstellar mission. P.Galea. Presented New York solar sailing meeting July 2010.

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: Optimisation of nuclear fusion propulsion for interstellar missions. K.F.Long, R.K.Obousy, A.Hein. Presented Prague 61st IAC October 2010.

Project Icarus: Mechanisms for enhancing the stability of gravitationally lensed interstellar communications. P.Galea, R.Swinney. Presented Prague 61st IAC September 2010.

Project Icarus: son of Daedalus - flying closer to another star - a technical update and programme review. Presented Prague 61st IAC September 2010. R.Swinney, K.Long, P.Galea. Presented Prague 61st IAC.

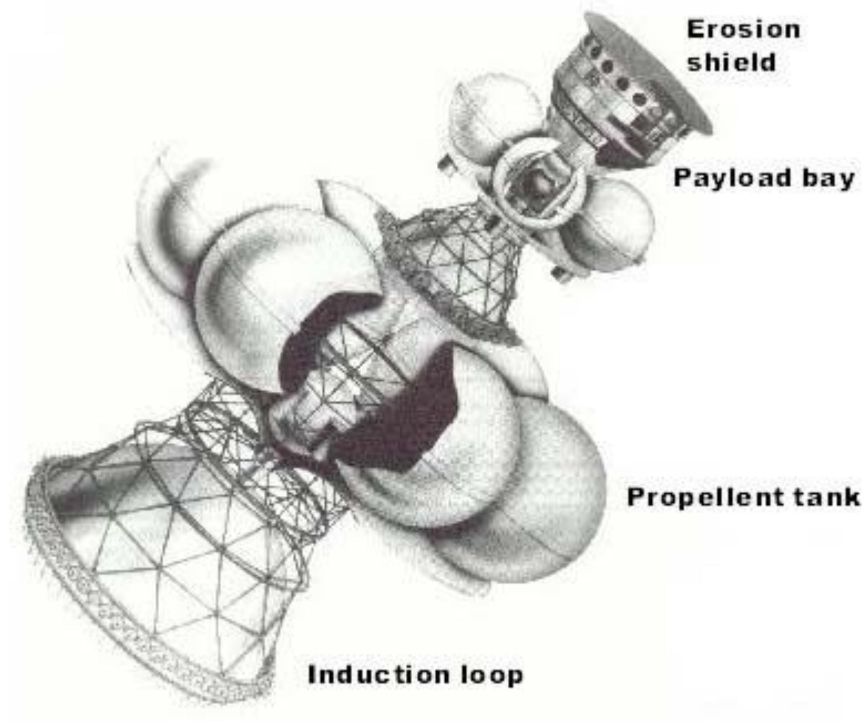
Project Icarus: Architecture development for atmospheric Helium 3 mining of the outer solar system gas planets for space exploration and power generation. A.Hein, A.Crowl, A.Tziolas. Presented Prague 61st IAC September 2010.

Project Icarus: Stakeholder analysis and prediction of technological maturity of key technologies for the development of the icarus interstellar probe. A.Hein, A.Tziolas, R.Osborne. Presented Prague 61st IAC September 2010.

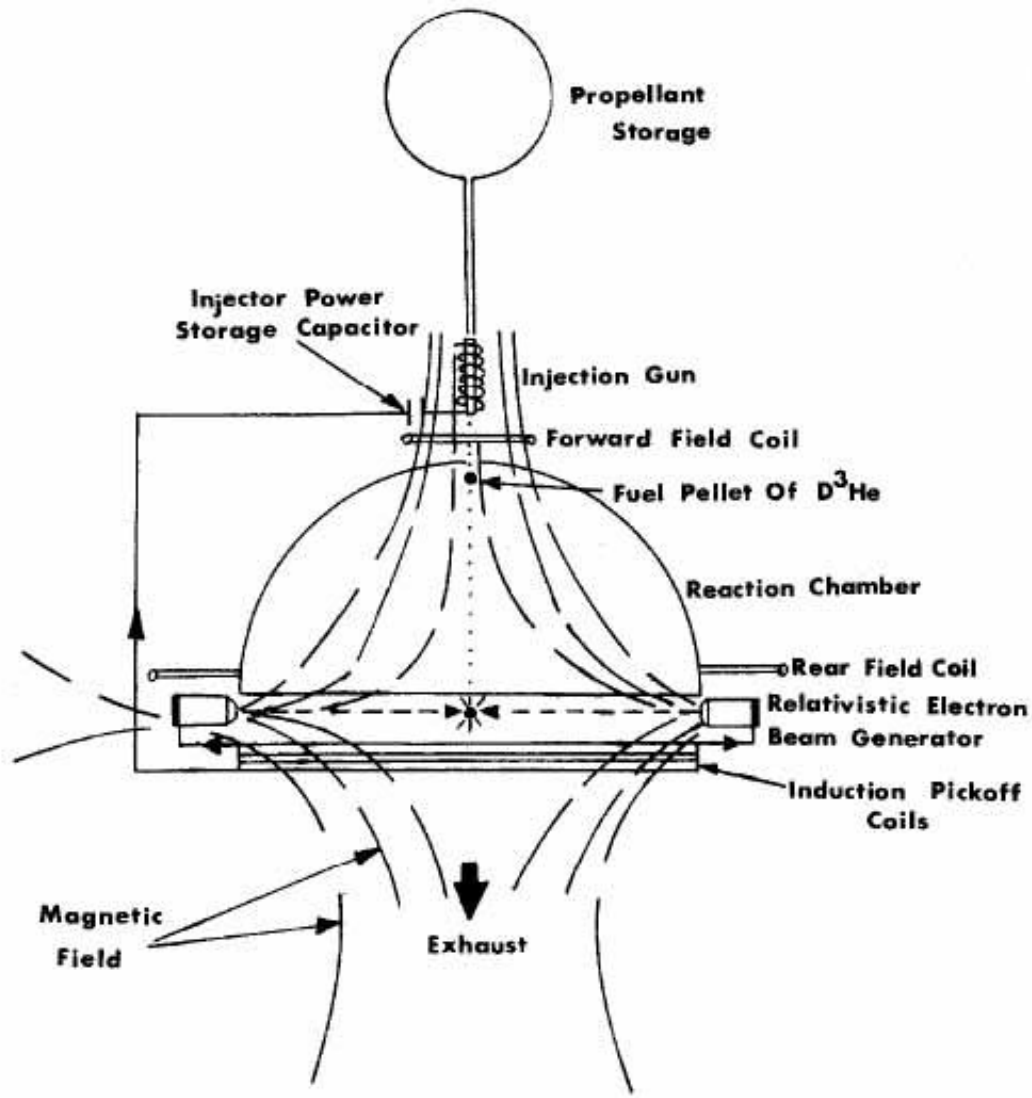
Project Icarus: Exploring the interstellar roadmap using the icarus pathfinder probe and icarus starfinder probe - a level on (concept builder) trade study report. K.F.Long, A.Hein, P.Galea, R.Swinney, A.Mann, M.Millis. INTERNAL PAPER.

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



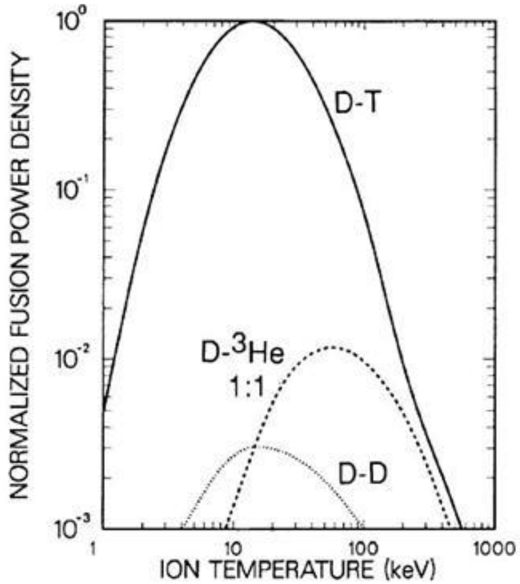
Choice of Fuel

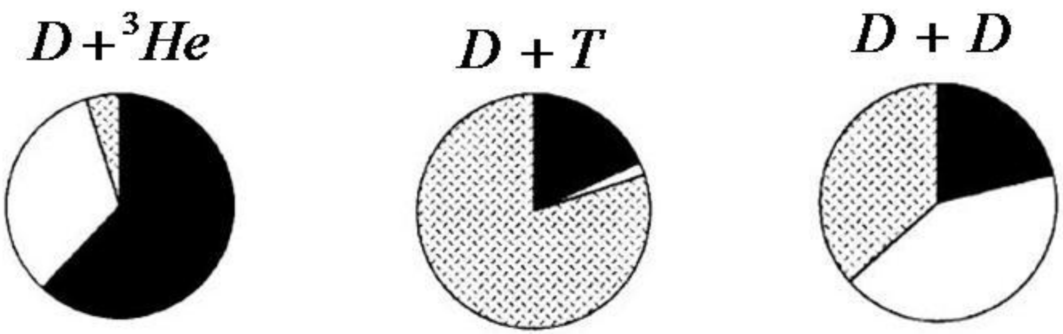
$$^{2}\mathrm{D} + ^{3}\mathrm{T} \rightarrow\ ^{4}\mathrm{He}(3.5) + ^{1}\mathrm{n}(14.1) \qquad \alpha = 0.0038$$

$$^{2}\mathrm{D} + ^{2}\mathrm{D} \rightarrow\ ^{3}\mathrm{T}(1.01) + ^{1}\mathrm{p}(3.03) \qquad \alpha = 0.0011$$

$$^{2}\mathrm{D} + ^{2}\mathrm{D} \rightarrow\ ^{3}\mathrm{He}(0.82) + ^{1}\mathrm{n}(2.45) \qquad \alpha = 0.0009$$

$$^{2}\mathrm{D} + ^{3}\mathrm{He} \rightarrow\ ^{4}\mathrm{He}(3.6) + ^{1}\mathrm{p}(14.7) \qquad \alpha = 0.0039$$



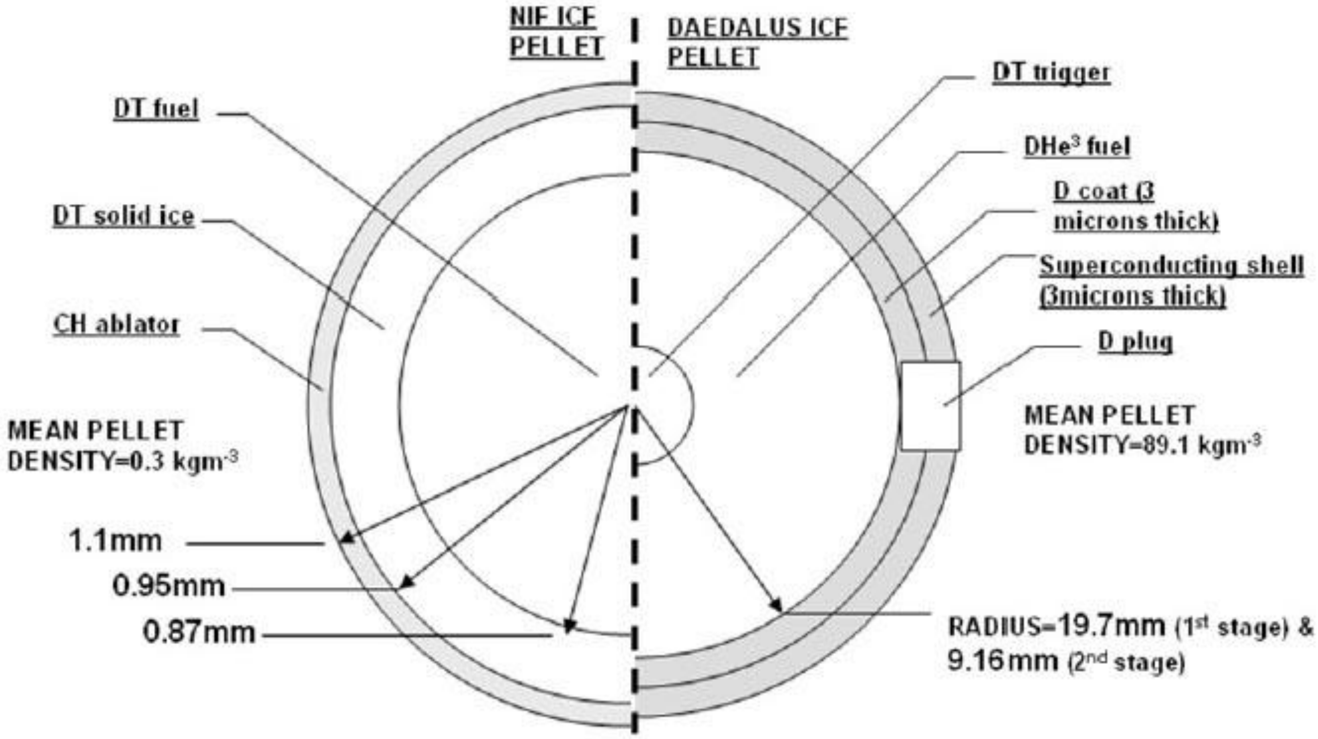


Large fraction of charged particles

Lowest burn temperature

Fuel is most plentiful on Earth

Pellet Design

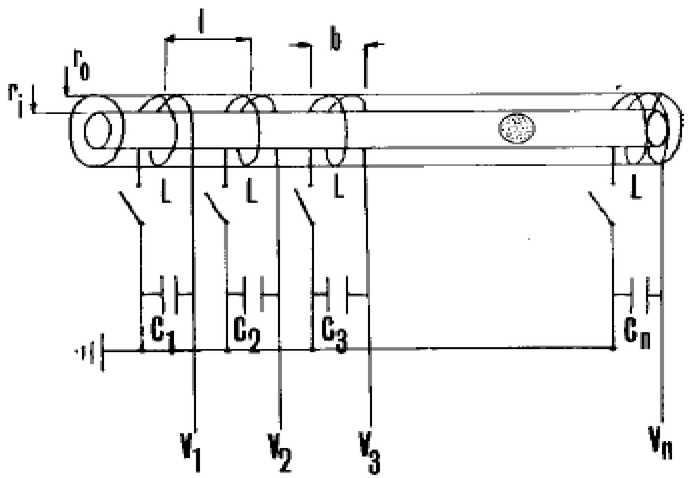


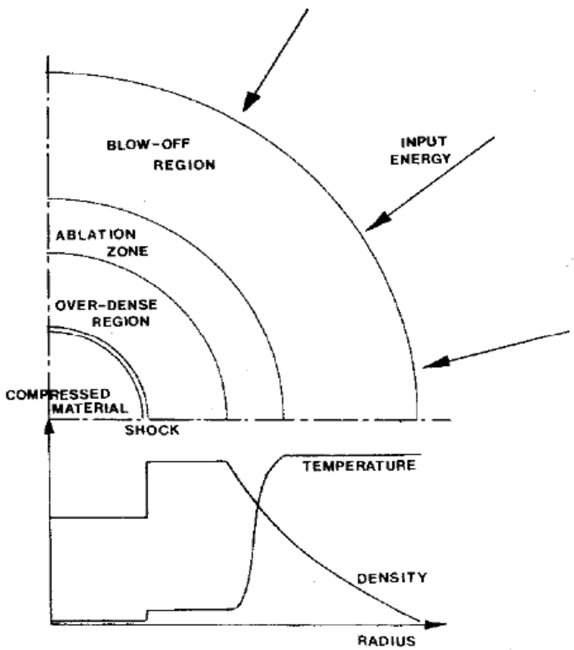
- Stored at Crygenic Temperatures at 3K and 0.813 atm

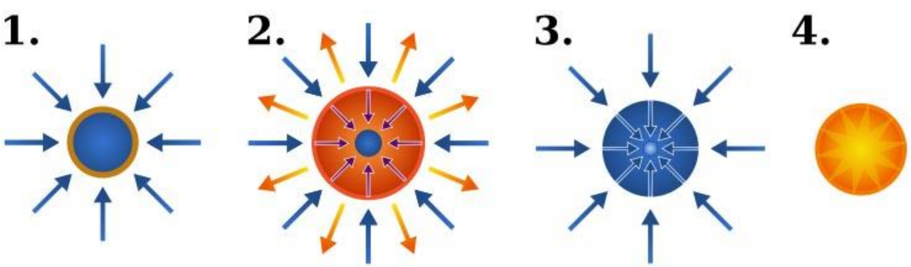
Pellet Ignition

- Magnetic gun
- Field Stength 15T
- 1^{st} stage acceleration 3.83×10^7 m/s^2
- 2^{nd} stage acceleration 8.21×10^7 m/s^2
- Fired at 250 Hz

Pellet Injector Schematic

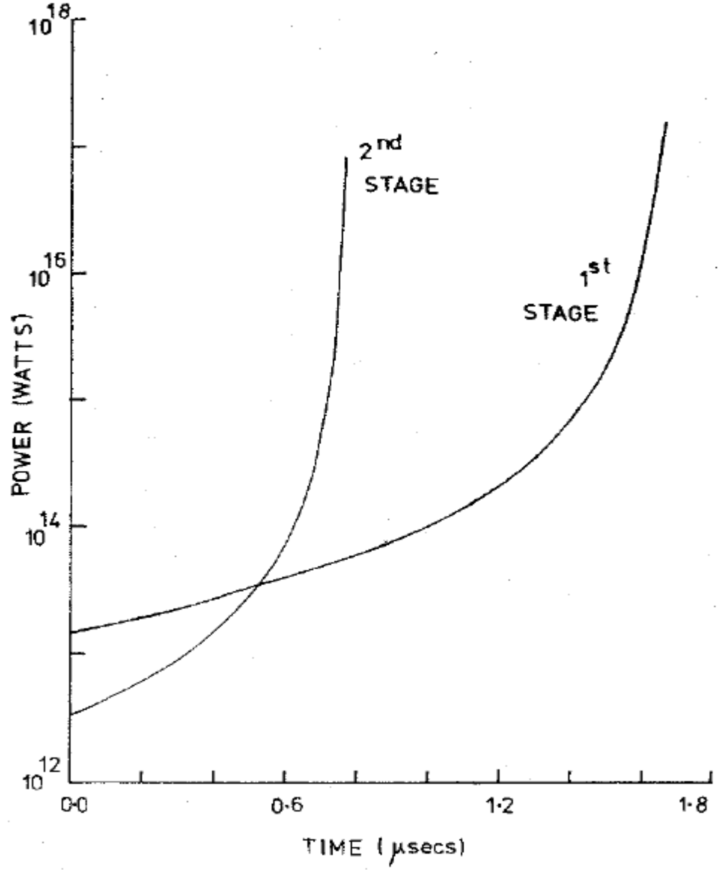






Pellet Performance

	Stage 1	Stage 2
Mass	2.84g	0.288g
Radius	1.97 cm	0.916 cm
Exhaust Velocity	1.1 E7	0.96 E7
Driver Energy	2.7 GW	0.4 GW
Burn up Fraction	0.175	0.133
Power Output	136 PW	64.3 PW



Power Profile

Radiation Output

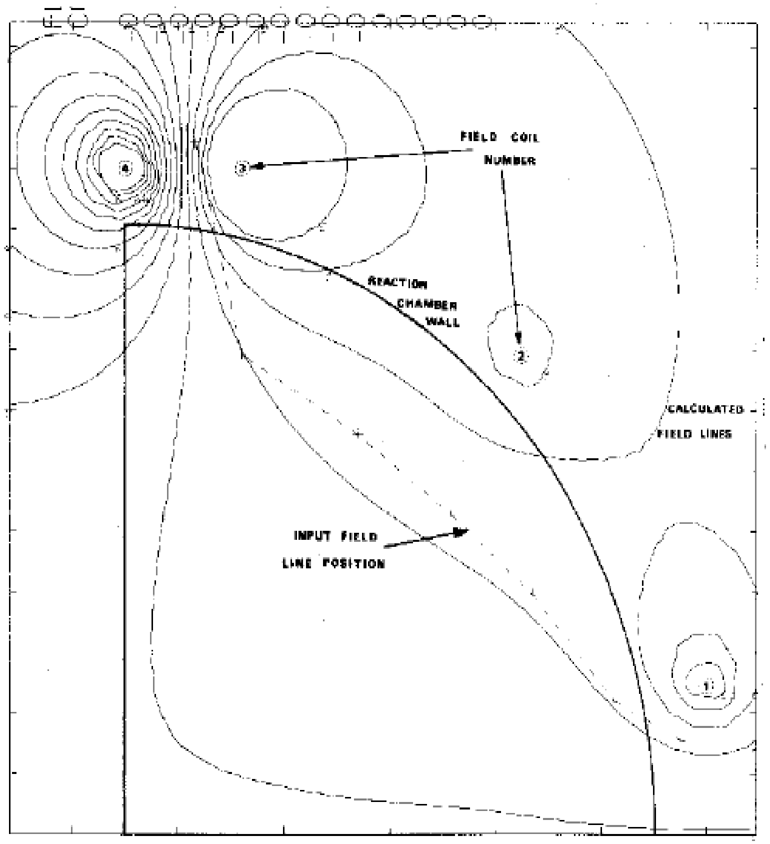
Stage 1: 1.5×10^{24} n/s
Stage 2: 1.1×10^{23} n/s

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

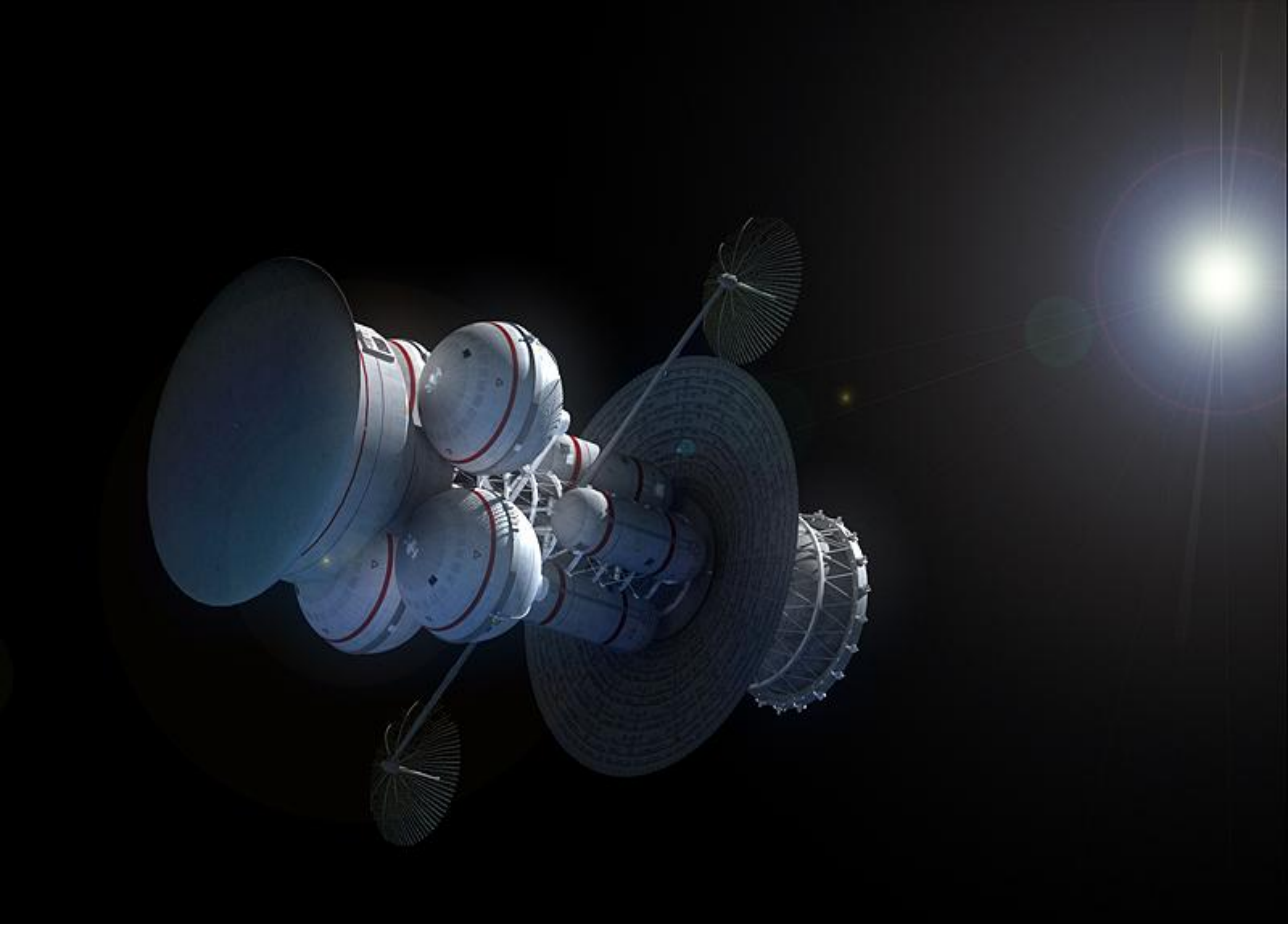
Coil 1: 25.9 Tonnes
Coil 2: 3.2 Tonnes
Coil 3: 42.6 Tonnes
Coil 4: 53.0 Tonnes

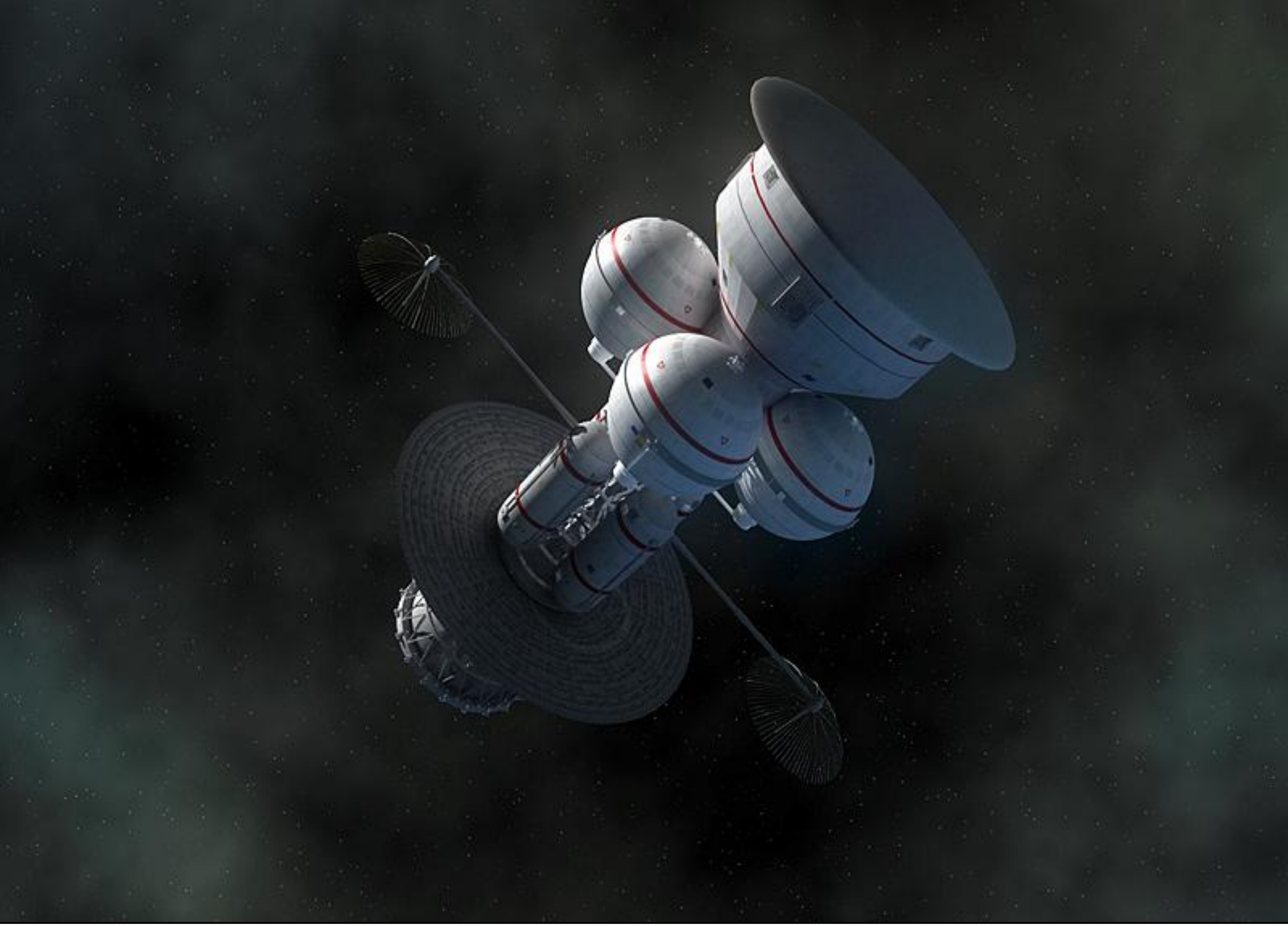
Stage 2 Coil Masses

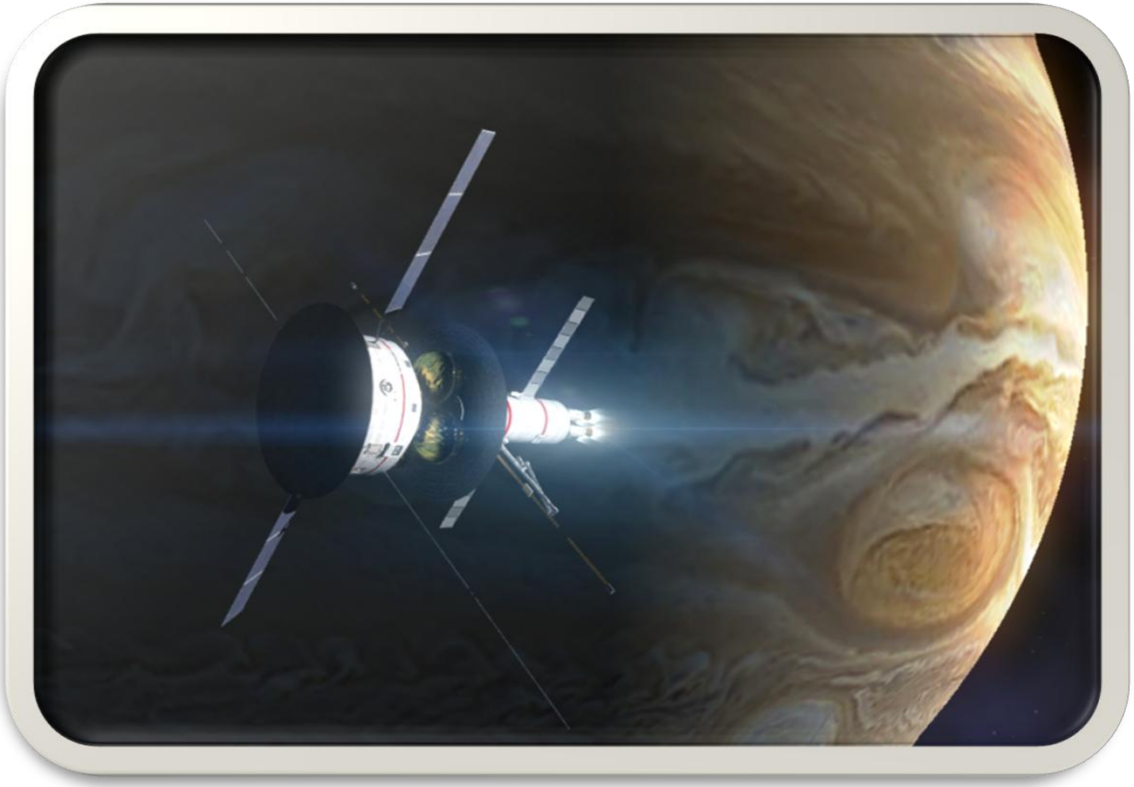
Coil 1: 8.9 Tonnes
Coil 2: 1.2 Tonnes
Coil 3: 14.9 Tonnes
Coil 4: 18.6 Tonnes

Daedalus Summary

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







From Imagination to reality

Ad Astra Incrementis