Icarus Interstellar

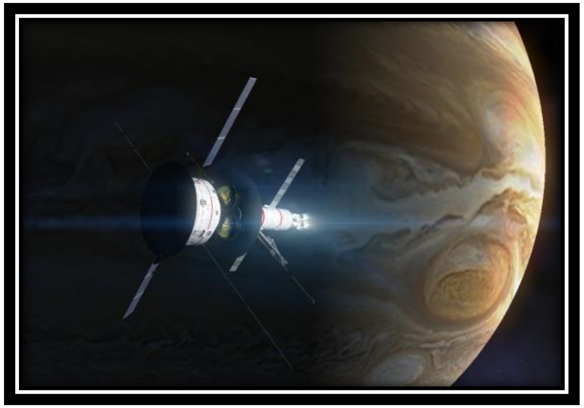
International Interstellar Spacecraft Design Team

Project Icarus: A 21st Century Interstellar Starship Study

Richard K. Obousy, Ph.D
President Icarus Interstellar Inc.
Senior Designer and Primary Propulsion Lead

Overview

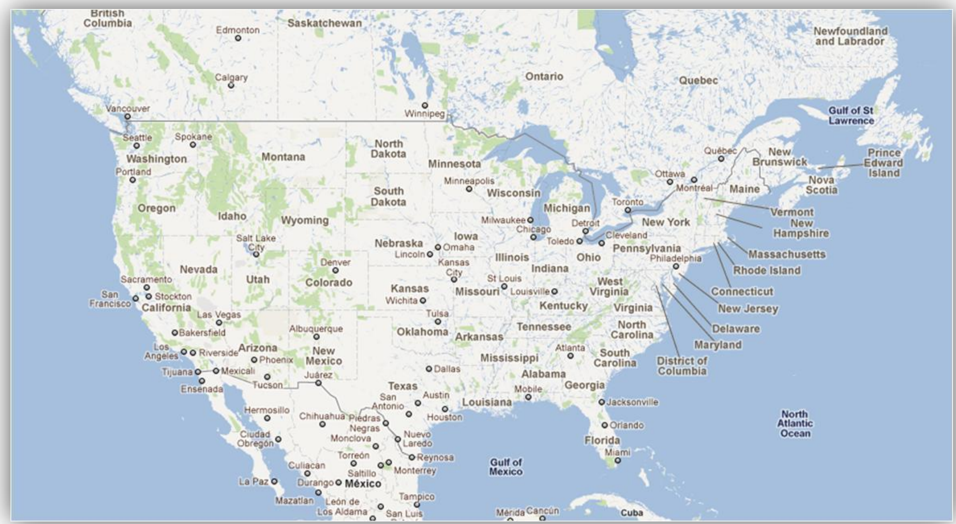
- Part 1: The Physics of Interstellar Travel
- Part 2: Project Icarus and Icarus Interstellar Inc.
- Part 3: Starships: General Classes and Specific Designs

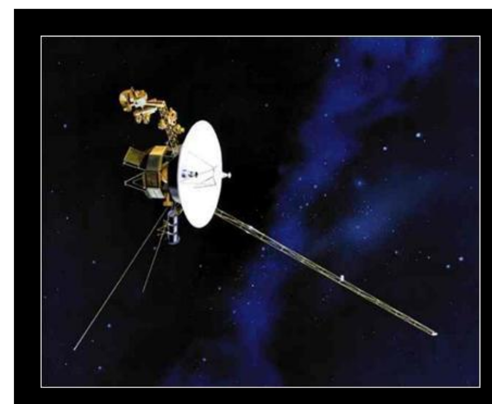


Interstellar Precursor Probe, "Icarus Pathfinder", designed by Project Icarus. Courtesy Adrian Mann

Part 1. The Physics of Interstellar Travel

- Currently four US spacecraft are travelling in interstellar space. These are the *Voyager* and *Pioneer* probes, travelling at speeds of 2.2 and 3.5 AU/year respectively.
- Voyager 1 is travelling at 17 km/s (38,000 mph) and is 116 AU from Earth.
- One of our closest neighbors, α-Centauri, is 272,000 AU from Earth.





The Limitations of Chemical Rockets

- This challenge becomes more apparent if we consider one of the simplest equations that governs spaceflight; the Tsiolkovsky rocket equation.

$$R = exp(\Delta v / I_{sp} g_0)$$

- Plugging in the numbers relating to a chemical propellant fueled flyby of α-Centauri with a Δv of 10%c reveals that we would need more fuel than there exists mass in the known universe!

Propulsion Physics

- Classically, **chemical** reactions encompass changes that strictly involve the motion of electrons in the forming and breaking of chemical bonds.
- Only 13.6 eV of energy is required to ionize a Hydrogen atom.
- Contrast this with 200 MeV released from the fission of U-235, or the 17.6 MeV released during a DT fusion event.

Reaction	Specific Energy (J/Kg)	Specific Impulse (s)
Chemical	1.5 E7	~100
Fission	7.1 E13	~1000
Fusion	7.5 E14	10,000 - 1,000,000
Antimatter	9.0 E16	> 1,000,000

Energy Densities of Rocket Fuels

Part 2. Project Icarus and Icarus Interstellar

- Project Icarus is a five year theoretical design study for an interstellar mission using current and near term technology.

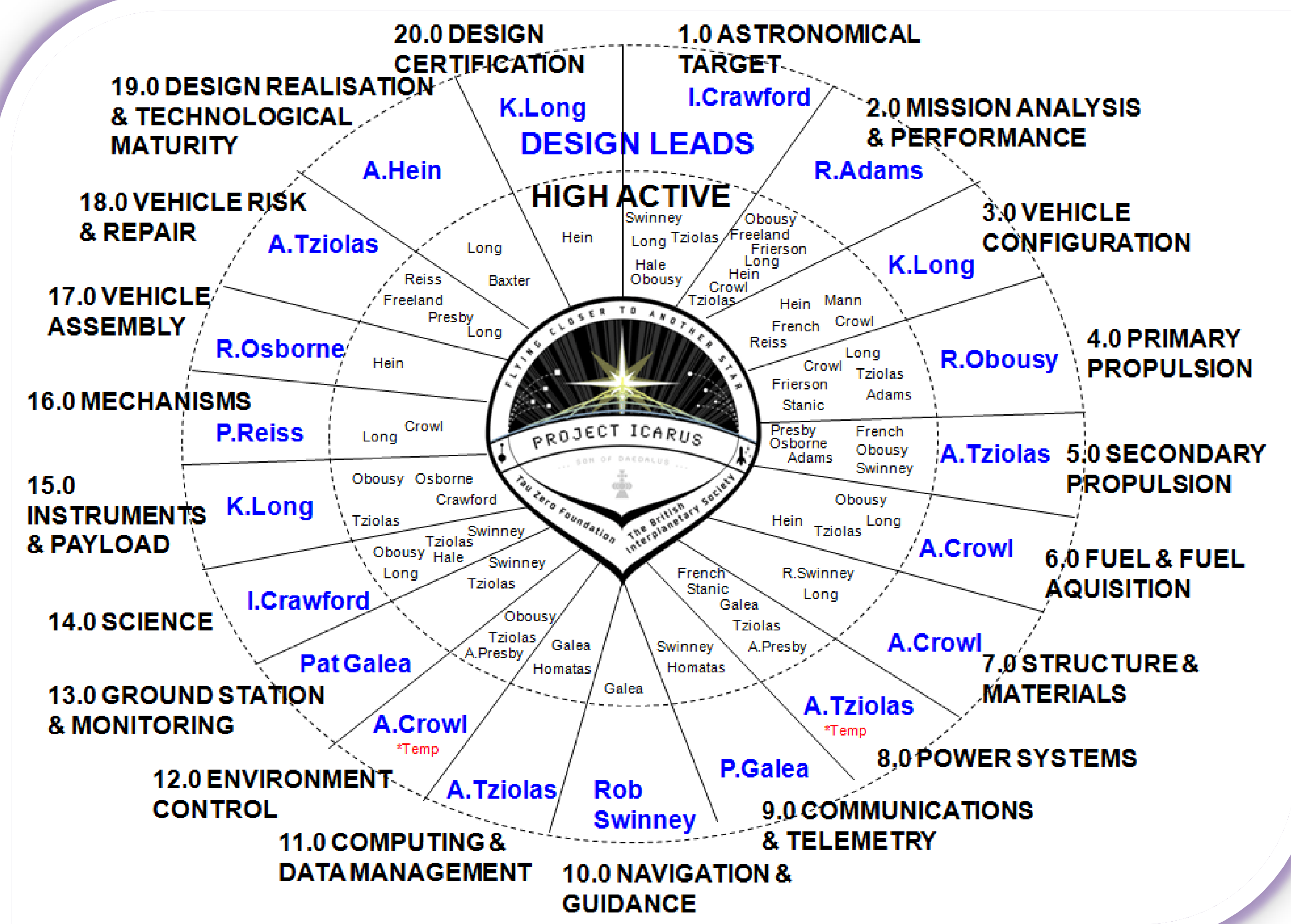
- Project Icarus was inspired by Project Daedalus which was a British Interplanetary Society Project that was conducted over 1973 - 1978.

- Our team is international and works chiefly via electronic collaboration.

Terms of Reference for Project Icarus

- 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.
- The spacecraft must use **current or near future technology** and be designed to be launched as soon as is credibly determined.
- The spacecraft must reach its stellar destination within as fast a time as possible, **not exceeding a century** and ideally much sooner.
- The spacecraft must be designed to allow for a **variety of target stars**.
- The spacecraft propulsion must be **mainly fusion based**.
- The spacecraft mission must be designed so as to **allow some deceleration** for increased encounter time at the destination.

Project Icarus Research Modules



Project Daedalus, 1973-1978

- BIS Initiative
- 11 Designers (Alan Bond R.E)
- 10,000 volunteer hours
- Pulsed Fusion Engine
- Deuterium Helium-3 Fuel
- Target: Barnard's Star
- Over 20 research papers comprising final study report
- Showed interstellar travel *is possible* with credible extrapolations of 1970s technology

Project Icarus

Project Icarus has a fourfold purpose:

1. To motivate a new generation of scientists in designing space missions that can explore beyond our solar system.

2. To generate greater interest in the real term prospects for interstellar precursor missions that are based on credible science.

3. To design a credible interstellar probe that is a concept design for a potential mission in the coming century.

4. To provide an assessment of the maturity of fusion based space propulsion for future precursor missions.

Origins of the Project

- Discussion between K. Long and M. Millis in 2008
- Original Daedalus group approached at IAC Glasgow
- Meetings with Bob Parkinson and Alan Bond led to go ahead for Project Icarus
- Obousy joins team late 2008 as Co-Founder and Tziolas early 2009. Further Recruitment drive.
- Project officially launched on September of 2009 at the BIS HQ in London

Recent Publications

- K. F. Long. "Project Icarus: Astronomical Considerations Relating to the Choice of Target Star", **JBIS**, Vol64. No.4/5. (2011).
- I. Crawford. "Project Icarus: Astronomical Considerations Relating to the Choice of Target Star ", Accepted for **JBIS** Publication (2011).
- K.F.Long, M.Fogg, R.Obousy, A.Tziolas, A.Mann, R.Osborne, A.Presby. Project Icarus: Son of Daedalus - Flying Closer to Another Star. **JBIS**, 62 No. 11/12, pp403-416 Nov/Dec 2009.
- S. Baxter, "Project Icarus: The Challenges of Mission Longevity", Accepted for publication in **JBIS** (2011).
- S. Baxter, "Project Icarus: Three Roads to the Stars", Accepted for publication in **JBIS** (2011).
- K.F.Long, "Project Icarus: The first unmanned interstellar mission, robotic expansion & technological growth", **JBIS** (under review).
- I. Crawford, "Project Icarus: A review of local interstellar medium properties of relevance for space missions to the nearest stars", **Acta Astronautica**, Accepted Oct 16th 2010.
- K.F.Long, R.K.Obousy, A.Hein, "Project Icarus: Optimisation of nuclear fusion propulsion for interstellar missions", **Acta Astronautica**, 68, pp. 1820-1829, (2011).

Icarus Interstellar Inc.

- Icarus Interstellar is a nonprofit corporation.
- Founded in March 2011
- Mission Statement:

The mission of Icarus Interstellar is to realize interstellar flight before the year 2100.

We will accomplish this objective by researching and developing the science and the technologies that will make interstellar flight a reality, igniting the public's interest, and engaging with all those prepared to invest in interstellar exploration.

Team Members

Designers:

1. R. Obousy, Ph.D (USA)
2. A. Tziolas, Ph.D (USA)
3. R. Adams, Ph.D (USA)
4. I. Crawford, Ph.D (UK)
5. A. Hale, Ph.D (USA)
6. J. Benford, Ph.D (USA)
7. S. Baxter, Ph.D (UK)
8. K. Long, (UK)
9. P. Galea, (UK)
10. R. Osborne, (UK)
11. R. Swinney, (UK)
12. P. Reiss, (Germany)
13. A. Hein, (Germany)
14. A. Mann, (Netherlands)
15. A. Crowl, (Australia)
16. J. French, (USA)
17. R. Freeland, (USA)
18. D. Homatas, (Greece)
19. M. Stanic, (Serbia)
20. B. Cress, (USA)
21. Kostas Konstantinidis, (Greece)

Consultants:

Dr. V. Cerf

- V.P of Google
- Served at DARPA
- Member of Stanford University Faculty
- Holds 18 honorary degrees

Dr. R. McNutt

- Project Scientist for MESSENGER
- Principle investigator for New Horizons Mission to Pluto
- Co-investigator for Solar Probe Plus

Prof. G. Matloff

- Tenured Professor of Physics at New York City College.
- Author of numerous books including 'The Starflight Handbook'
- Expert on solar sails

Mr. P. Gilster

- Author of 'Centauri Dreams'
- Co-Founder of TZF
- Lead Journalist for TZF

Dr. T. Pacher

- Worked on ESA Infrared Space Observatory
- Founder of Peregrinus Interstellar
- Founder of Faces from Earth.

Dr. E. Davis

- Senior Research Scientist IASA.
- Co published 'Frontiers of Propulsion Science'
- PhD in astrophysics

Student Designers:

1. B. Vernon, (USA)
2. T. Frierson, (USA)
3. D. Shankar, (India)

Icarus Interstellar Organization

Board of Directors

President: Obousy
VP American Operations: Tziolas
VP European Operations: Long

Secretary: Galea
Treasurer: Tziolas
Director: Crowl

Research

- Project Icarus
- Project Persephone
- Project Forward

Public Outreach

- Discovery Space News
- Blog
- Facebook groups page
- E-Newsletter
- Conferences
- Website

Business Development

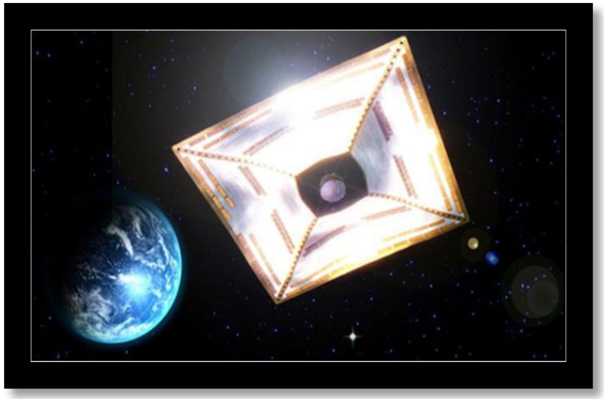
- Engaging with PR company
- Various ideas
- Membership Program
- Fund development

Experimental R&D

- Project Helios
- Project Bifrost

Solar Sails

- Harness solar photon pressure
- Typically large, low density structures
- Can be utilized for missions outside the solar system if a solar 'flyby' maneuver is executed.
- Could exit the solar system at 10's AU/Year

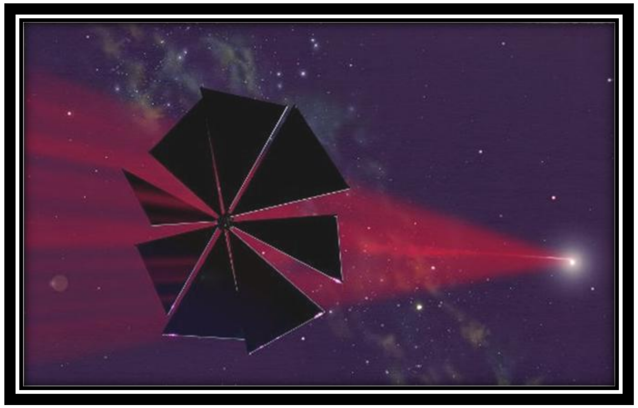


Japanese Ikaros probe. Image courtesy JAXA.

General Classes of Vehicles

Beamed Energy

- Harness manmade photon pressure, typically laser or microwave.
- Thrust is generated by transmitting a collimated electromagnetic beam from a transmitter to the spacecraft.
- No power is lost as a function of distance.



Courtesy of James Benford, Microwave Sciences.

General Classes of Vehicles

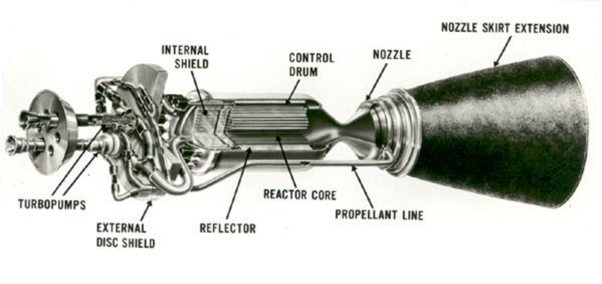
Nuclear Rockets

- Wide range of fission/fusion propulsion ideas exist in the literature.

- Two general classes; *pulsed* propulsion and *continuous*.

- Solid Core fission rockets flight certified and relatively technologically mature.

- US NERVA program lead to flight certified fission rockets.

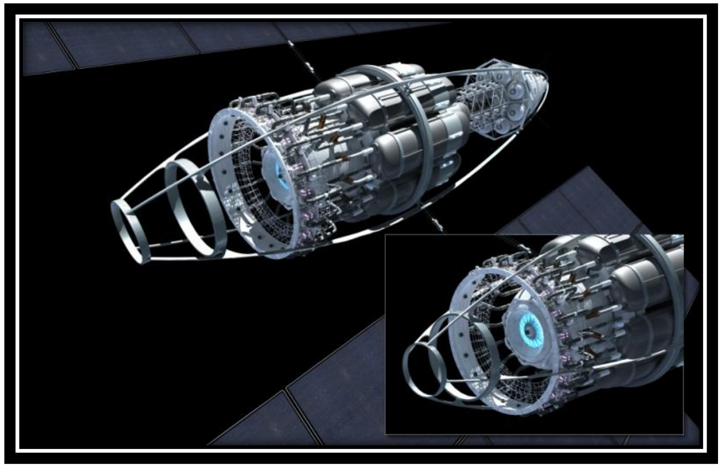


Solid Core Rocket Engine. Public domain image.

General Classes of Vehicles

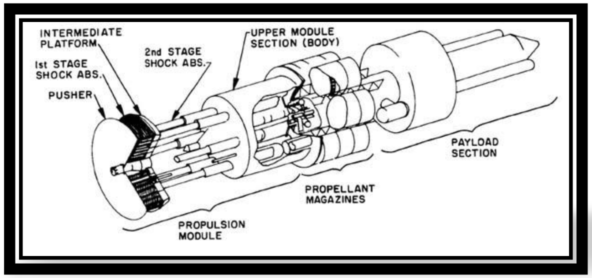
Antimatter Rockets

- Theoretical models for positron/electron and proton/antiproton propulsion engines exist in the literature.
- No known reaction yields more energy than matter antimatter annihilation.
- Main issues; creation and storage of antiparticles.



Antimatter concept craft created for Obousy courtesy of Adrian Mann.

Orion



- Initiated in 1958 by Ted Taylor at General Atomics. Inspired by Stanislaw Ulam.
- Pulse units detonated and transfer thrust to the vehicle via the pusher plate.
- Original design utilized fission pulse units
- *Ablation Space Ship* is modified for interstellar.

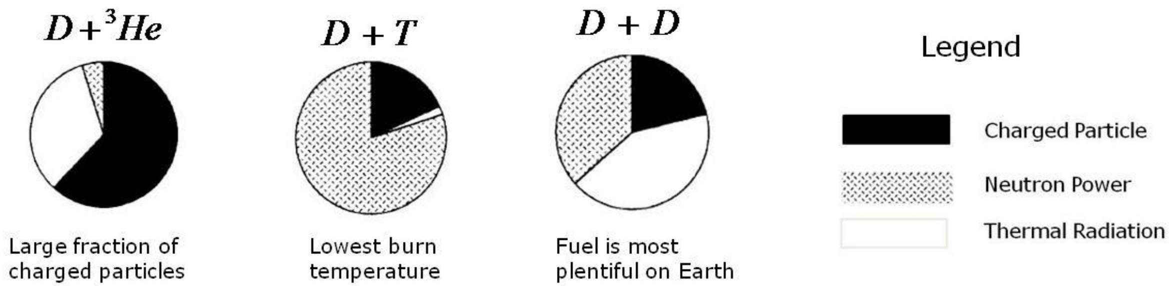
Ablation Space Ship Specs

- Total mass of 400,000 tonnes.
- 300,000 pulse units comprising 60% of the total mass.
- 1 g acceleration for 10 days
- 10,000 km/s (3.3%c)
- α Centauri in 130 years.

Daedalus

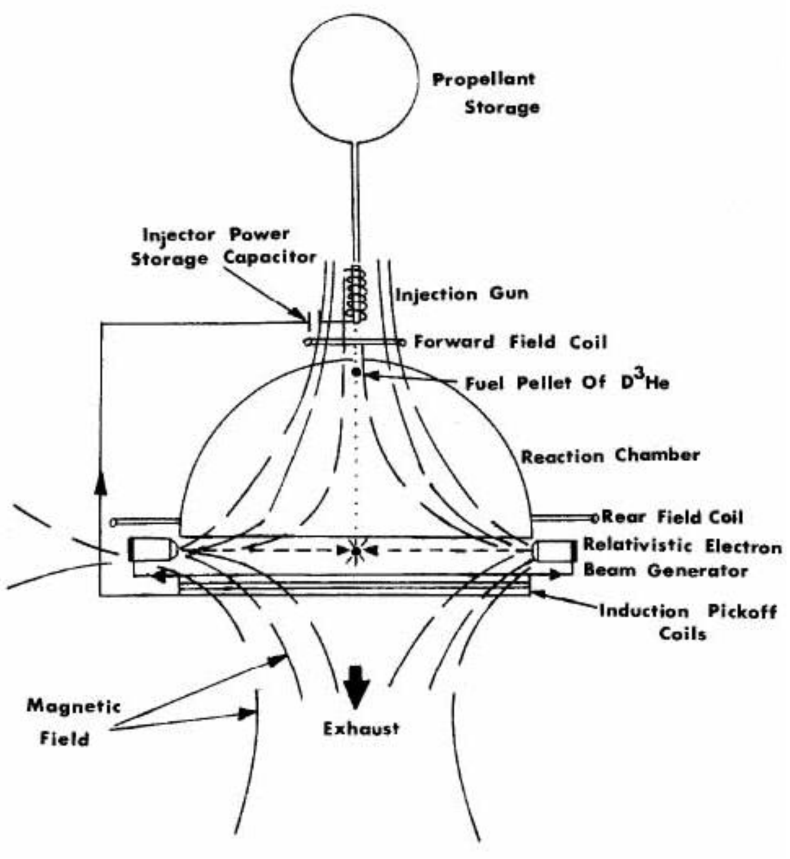
- Detailed 5 year starship study initiated in 1973 by British Interplanetary Society.
- Internal/external hybrid fusion pulsed propulsion engine.
- Target: Barnards star.
- Estimated top speed, 12%c
- Est. 10,000 man hours put into project.
- Deuterium Helium-3 fuel

Image Courtesy Adrian Mann



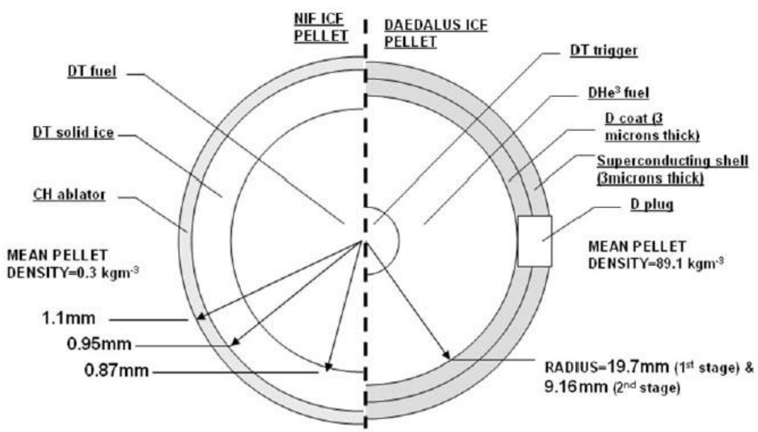
Daedalus Engine Components

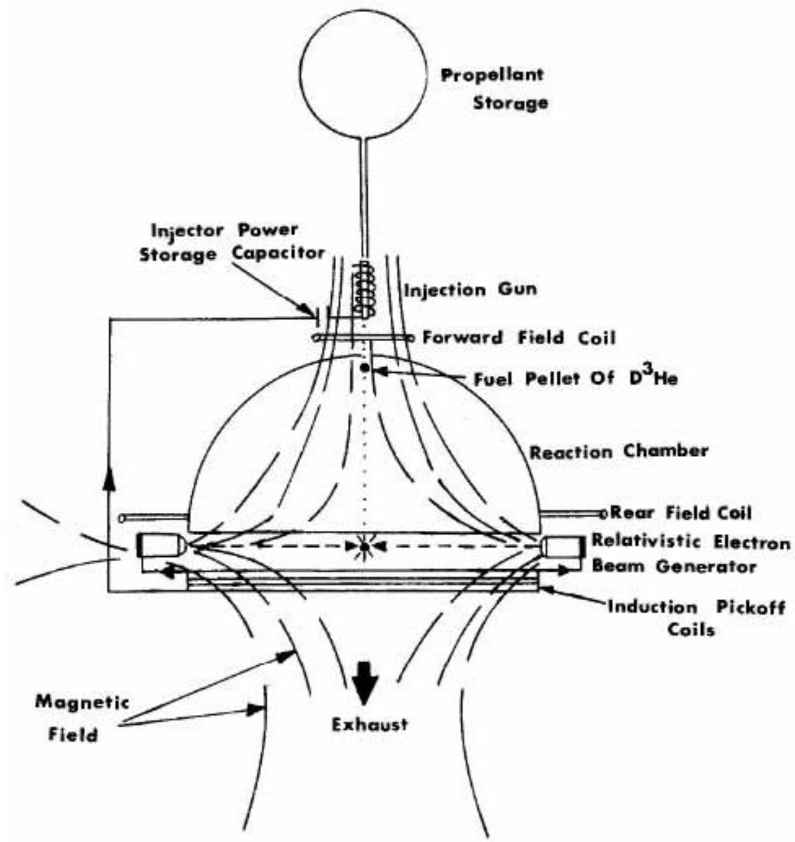
- Propellant Storage
- Pellet Injection Gun
- Electron Beams
- Reaction Chamber
- Magnetic Nozzle Coils



Propellant Storage

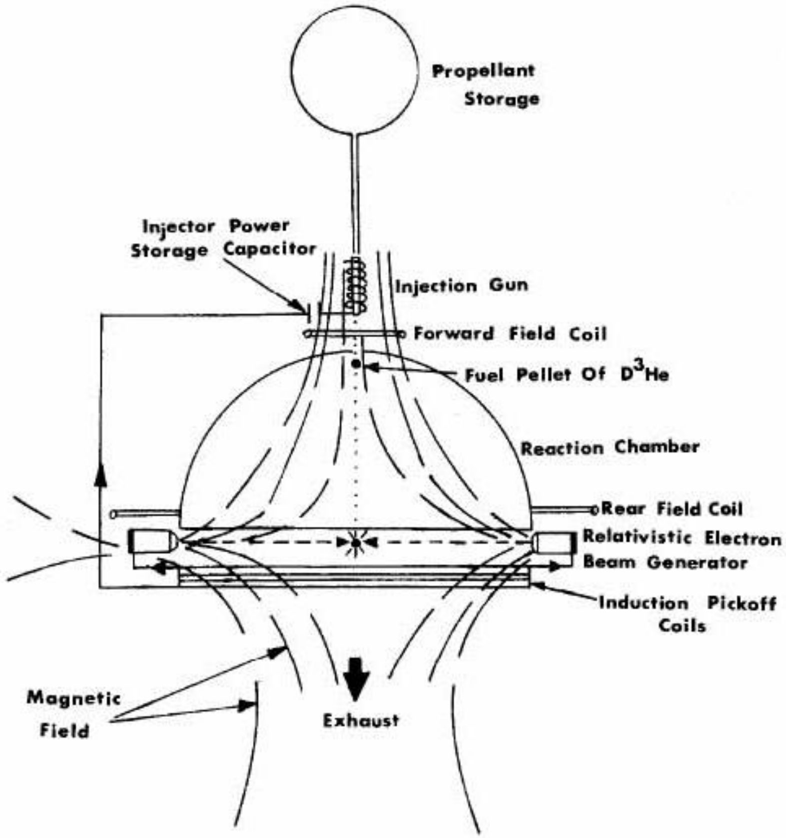
- Stage 1: 46,000 tonnes of fuel
- Stage 2: 4,000 tonnes of fuel
- Storage Tanks Cooled to 3K and held at 0.812 atm.



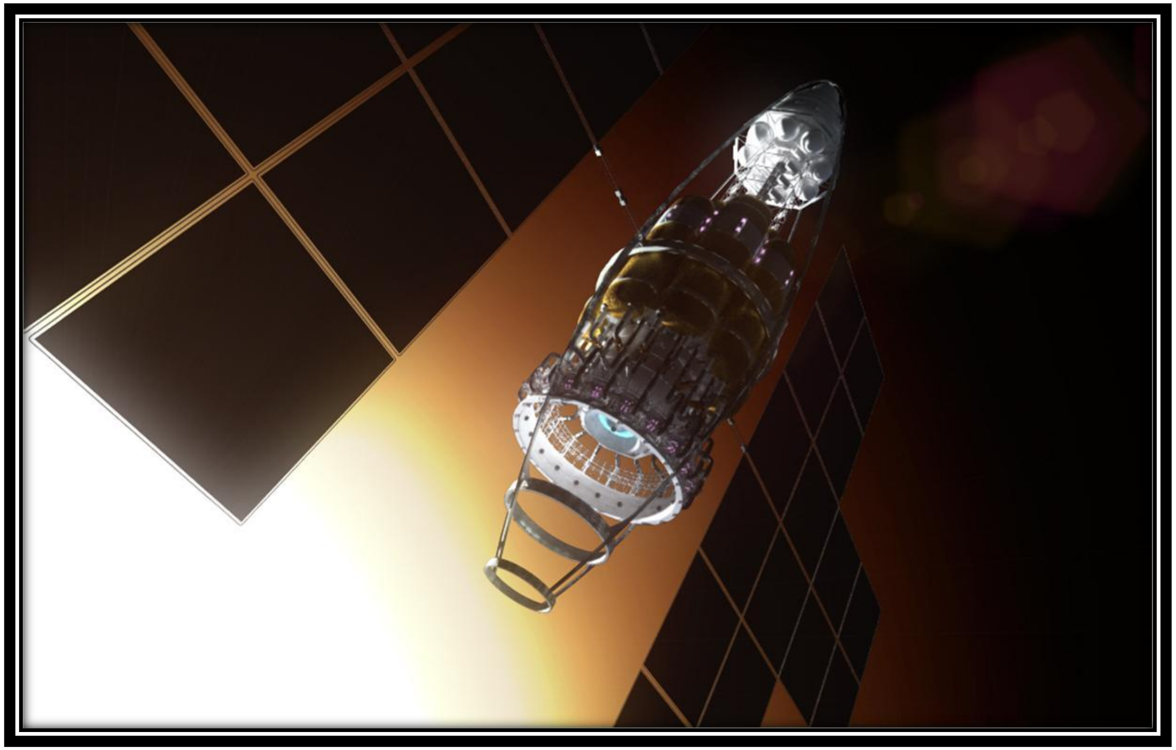


Pellet Injection Gun

- Injected pellets at 250 per second using a magnetic wave.
- Field strength of 15T
- Pellet acceleration 3.83 x 10^7 m/s^2 (1st stage) and 8.21 x 10^7 m/s^2 (2nd stage).
- Massive capacitors (~30 tonnes)
- Massive cooling system (~40 tonnes)



The End



"All of this seems an incredible undertaking, but if we are to tackle the problem on the astronomical scale, then we must attempt to visualize solutions to suit."

Dr. Anthony Martin,
Project Daedalus