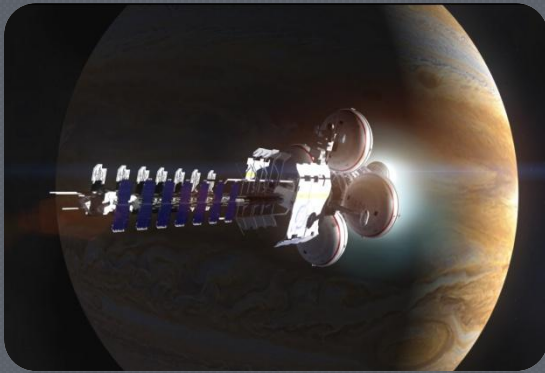




# Project Icarus

## Interstellar Travel and Possible Propulsion Spin-offs for Mars Exploration





# Overview of Project Icarus

- **Part 1 – Introduction to Project Icarus**
- **Part 2 – Beyond Chemical Rockets**



## Part 1: Overview of Project Icarus

- 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.
- The team consists of 19 team members, plus 6 consultants and 3 student designers. There are a total of 11 Ph.D's on the team, with the remainder having advanced science degrees.



## 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 feasible* with credible extrapolations of 1970s technology







# Origins of Project Icarus

- Discussion between K. F. Long and M. Millis in 2008.
- Original Daedalus group approached at 59<sup>th</sup> IAC in Glasgow.
- Meetings with Bob Parkinson and Alan Bond led to go ahead for Project.
- Obousy joins team late 2008 as Co-Founder. Further recruitment drive follows.
- Project officially launched in September of 2009 at the BIS HQ in London.
- Patton Boggs agrees to represent Project Icarus Pro Bono (*October 2010*).
- Project Icarus receives Articles of Incorporation (*March 2011*). 501c(3) status imminent.





# Project Icarus Terms of Reference

- 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.



# Project Icarus Terms of Reference

- The spacecraft must be designed to allow for a variety of target stars.
- The spacecraft propulsion must be mainly fusion based (i.e. Daedalus).
- The spacecraft mission must be designed so as to allow some deceleration for increased encounter time at the destination.



# Icarus Design Modules

- Astronomical Target
- Mission Analysis and Performance
- Vehicle Configuration
- Primary Propulsion
- Secondary Propulsion
- Fuel and Fuel Acquisition
- Structure and Materials
- Power Systems
- Communications and Telemetry
- Navigation and Guidance Control
- Computing and Data Management
- Environmental Control
- Ground Station and Monitoring
- Science
- Instruments and Payload
- Mechanisms
- Vehicle Assembly
- Vehicle Risk and Repair
- Design Realization and Maturity
- Design Certification





# Icarus Design Team

## 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)



## Student Designers:

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

## Friends of Icarus:

1. S. You, Ph.D (Cambodia)
2. J. Barrington-Cook (UK)



# Icarus 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

## **Dr. E. Davis**

- Senior Research Physicist at Institute for Advanced Study in Austin
- Expert in exotic propulsion

## **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



## Recent Publications and Conferences

- 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.
- 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 and R. Obousy, “*The Challenge of Interstellar Flight: Starships of the Future.*” **Spaceflight**, pp 140-144, 2011.
- S.Baxter, “*Project Icarus: The Challenge of Longevity.*” (Accepted to **JBIS**) 2011.
- 33 Popular Articles published on our public website.
- 11 conference presentations including: New York, Prague, Colorado Springs, London And Novi Sad (Serbia).



## Education Outreach

Project Icarus believes in inspiring the next generation of space scientists and we actively promote our enthusiasm for space research.

- We encourage student designers to join the team and set them challenging projects.
- We give talks at universities and astronomy clubs.
- We maintain an active blog and encourage participation from the public.
- We publish non-technical articles in magazines.
- Dr. Hale using astronomy, space as a tool for breaking down international and intercultural barriers.

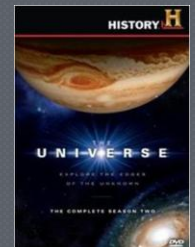




# Media Outreach

Project Icarus is getting high visibility and actively interacting with the media.

- Discovery News has published 10 articles on Project Icarus, with 16 more to come.
- We have featured on BBC News.
- Dr. Adams was interviewed on Dr. Michio Kaku's Radio show.
- Dr. Obousy was interviewed for by Seth Shostak of SETI Institute for his radio show.
- Dr. Obousy has been invited to appear (for a second time) on the History Channels 'The Universe'.





## Fund Raising Goals

We have accomplished so much in a 100% volunteer capacity. With support, we believe we can achieve so much more. With resources behind us we would:

- Interact more completely with the scientific community and attend more conferences, with an aim to organize our own interstellar conference.
- Pursue a more aggressive educational outreach program with much more talks at local schools, universities, and astronomy clubs.
- Work more closely with students and engage in greater international collaboration.
- Look to move designers from volunteer to part/full time researchers.
- Aim to create a dedicated interstellar propulsion research institute.



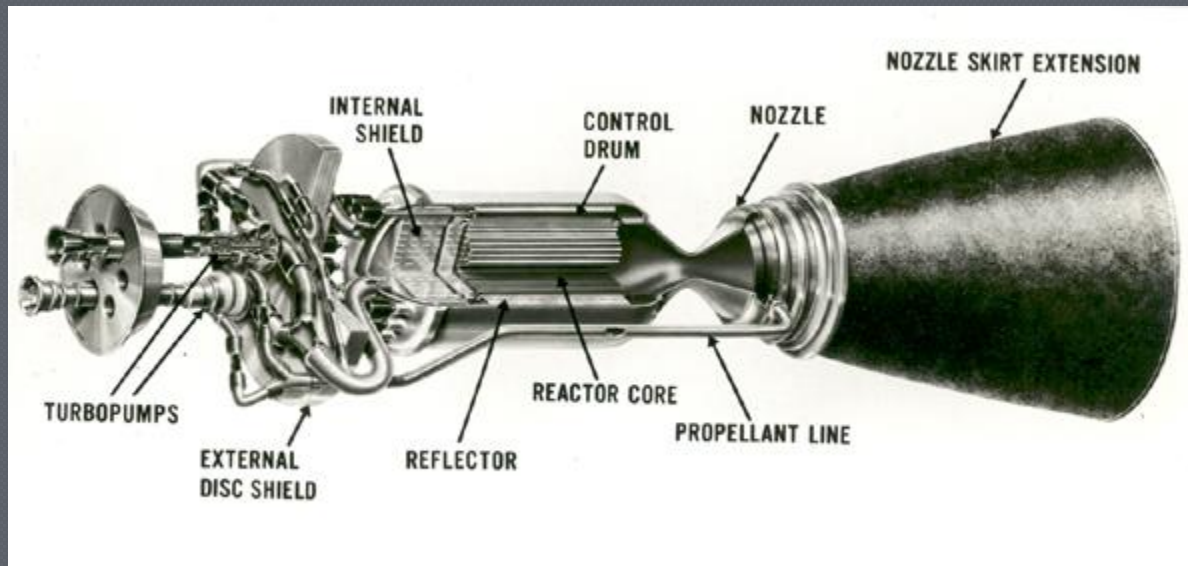
## Part 2: Beyond Chemical Rockets

- Chemical rockets are great for delivering high thrust and launching objects from Earth, into orbit.
- Regarding fuel, chemical rockets are actually very inefficient and even trips to some of our closest neighbors (Mars) is measured in months.





# Near Term: Fission Rockets



Solid Core

$$I_{sp} \approx 500 - 1,100 \text{ s}$$

Liquid Core

$$I_{sp} \approx 1,300 - 1,600 \text{ s}$$

Gas Core

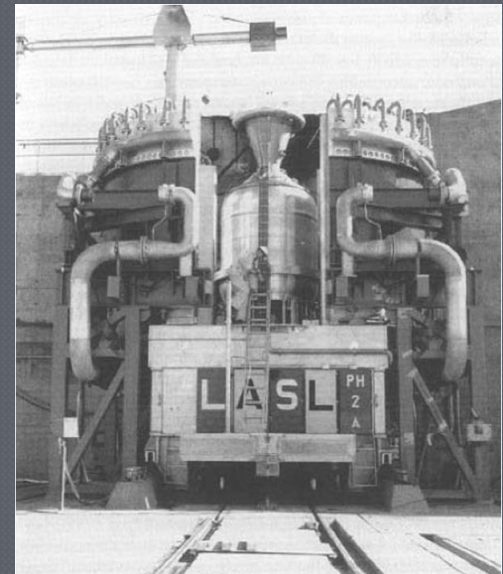
$$I_{sp} \approx 3,000 - 7,100 \text{ s}$$





# Fission Rockets – Nuclear Thermal

- Both East and West have invested time and money into Nuclear Thermal Rocket Technology.
- The most well known program in the West was NERVA.
  - Top Speed  $\sim 22$  km/s
  - 4.5 GW of power (12.1 mins)
  - 250,000 lbs of Thrust
  - Earth to Mars in  $\sim 3$  months
  - Cancelled in 1972 for political reasons

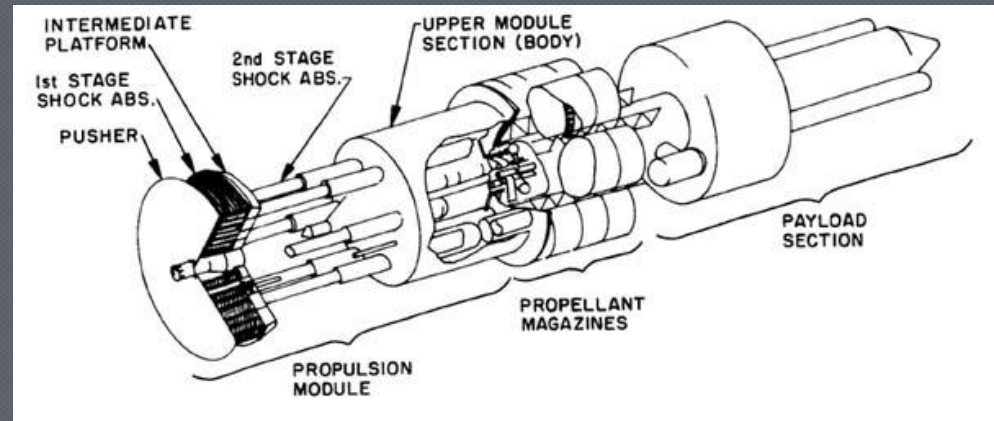




# Fission Pulse Rockets: Project Orion

## ■ Project Orion

- 1958-1965
- Nuclear Pulse Propulsion
- Interplanetary
- 3-5% c (fission)
- 8-10% c (fusion)
- Earth to Mars in ~ 45 Days!



$$I_{sp} = \frac{C_0 V_e}{g}$$

$$I_{sp} \approx 2,000 - 6,000 \text{ s}$$

Fission

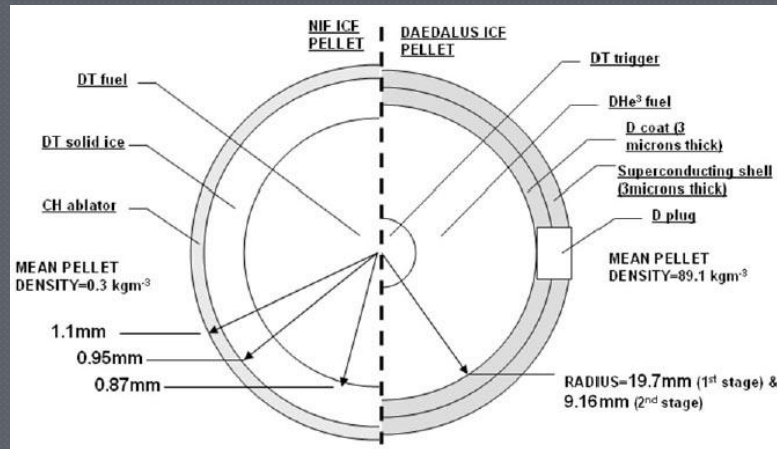
$C_0$  Collimation factor

$$I_{sp} \approx 10,000 - 20,000 \text{ s}$$

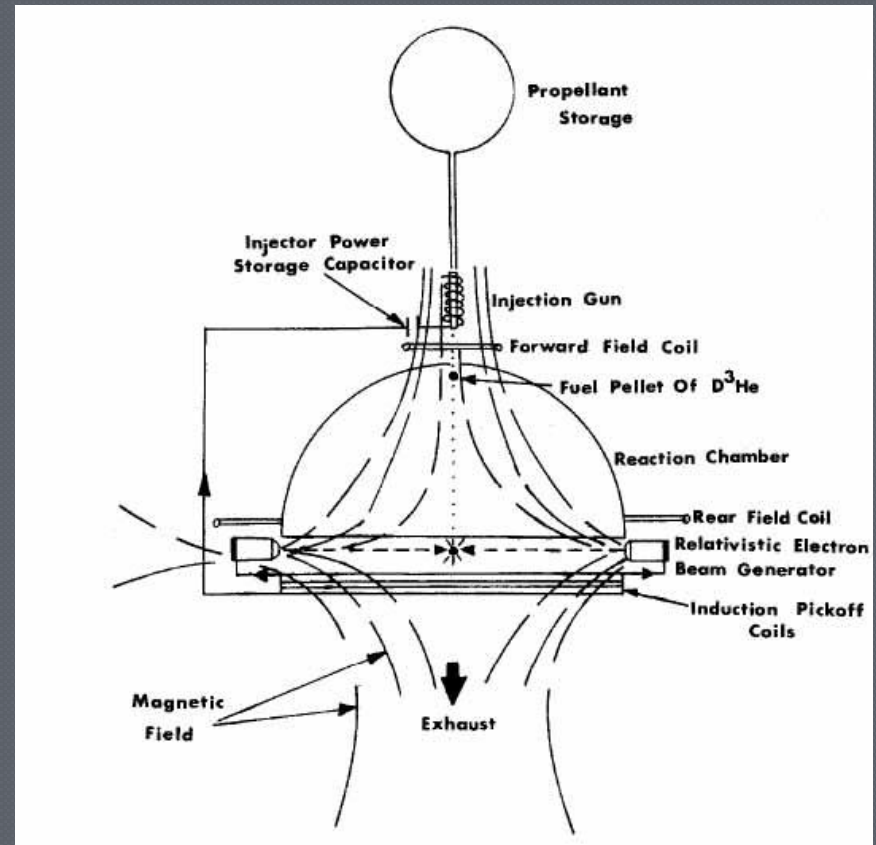
Fusion



# Fusion Pulse Rockets: Project Daedalus



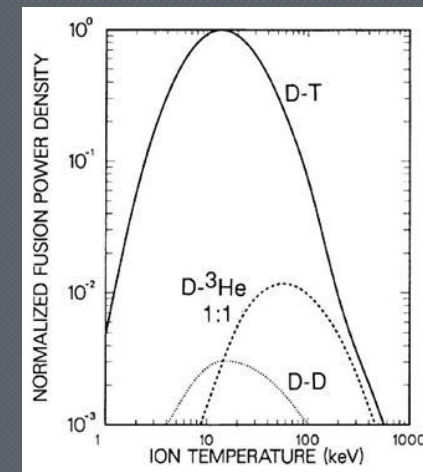
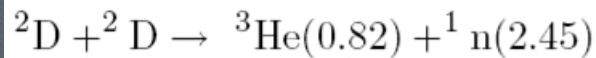
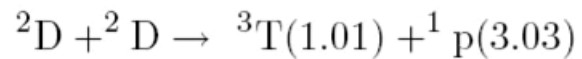
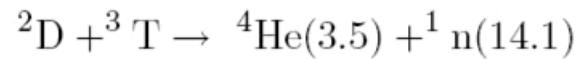
NIF Fuel Pellet (Left)  
Daedalus Fuel Pellet (Right)



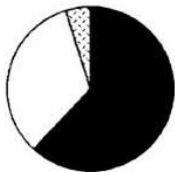
The Daedalus Engine



# Fusion Pulse Rockets: Project Daedalus

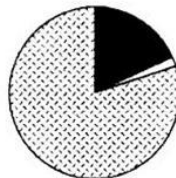


*D + <sup>3</sup>He*



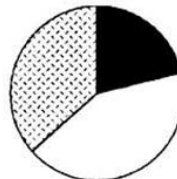
Large fraction of charged particles

*D + T*



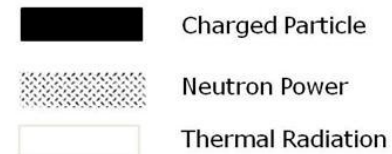
Lowest burn temperature

*D + D*



Fuel is most plentiful on Earth

Legend



Earth to Mars in ~ Days





# Antimatter Rockets

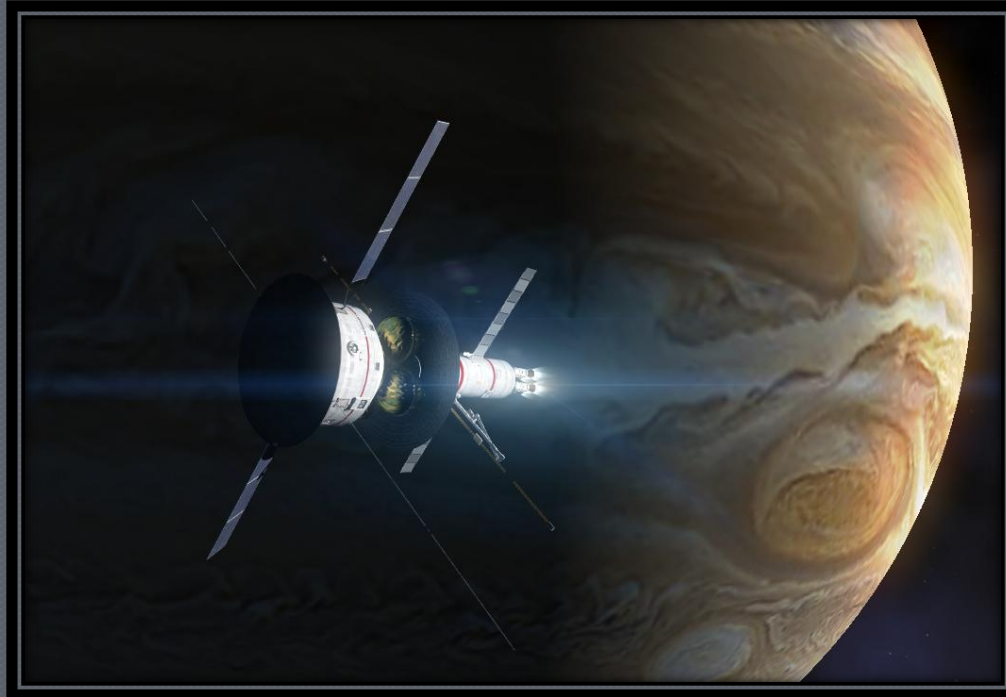


Icarus Interstellar Antimatter Concept Craft

- Existence of antimatter predicted by Dirac in 1928.
- There exists an antimatter counterpart to all matter.
- Extremely energetic.
- 1g of antihydrogen has an estimated value of \$62.5 T.



# The End



**From Imagination to Reality**

[www.IcarusInterstellar.org](http://www.IcarusInterstellar.org)