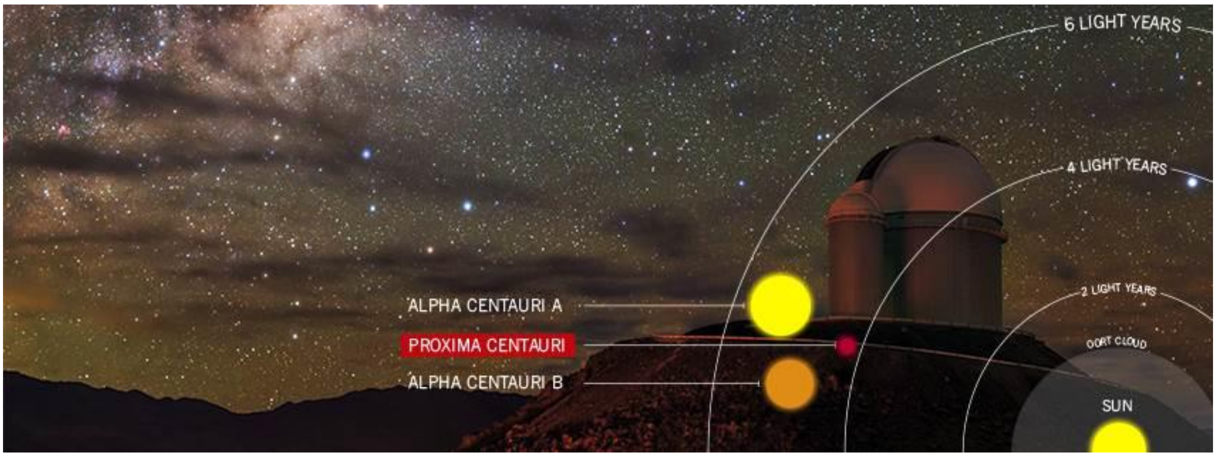
The Pale Red Dot– A Renewed Dream?

(Joachim J. Kehr, DLR, German Space Operations Center – GSOC, ret)

The newly discovered planet Proxima b – also dubbed "Pale Red Dot", based on the historical Voyager-1 photo of the Earth which became famous showing our planet as a "pale blue dot" in the Universe – kindled the dream of travelling to an exoplanet during a human lifetime. The extraordinary significance of this exoplanet is that the new planet orbits the dwarf planet Proxima Centauri - which is our closest neighbor, "only" 4.24 lightyears away. All of the so far discovered 3000 other so called extrasolar planets orbiting their home star in the "habitable" region, are too far away to even to think about to reach them. The observed spectral shifts of the newly detected rocky planet suggest that the planet must be orbiting in the "habitable" zone on an eccentric orbit around Proxima Centauri. [1] [1a]



This gives rise to the hope to explore such an exoplanet in the near (or not so near) future employing interstellar spaceflights.

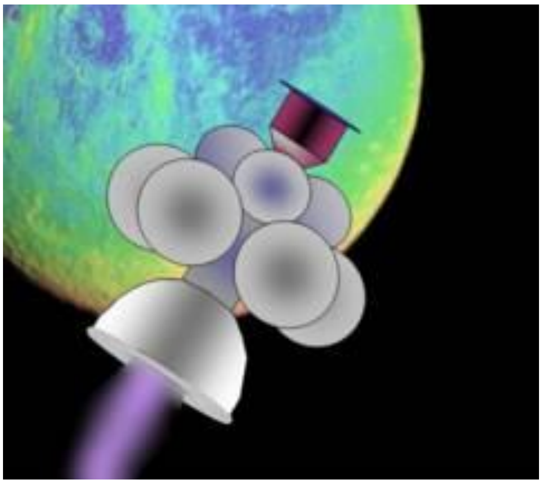
The basic idea of robotic interstellar spaceflight explorations was originated by an interstellar feasibility study group assembled by the British Interplanetary Society (BIS) during the 1970s. The study was called project Daedalus and, 30 years later was revised and updated by a successor interstellar design study, called project Icarus.

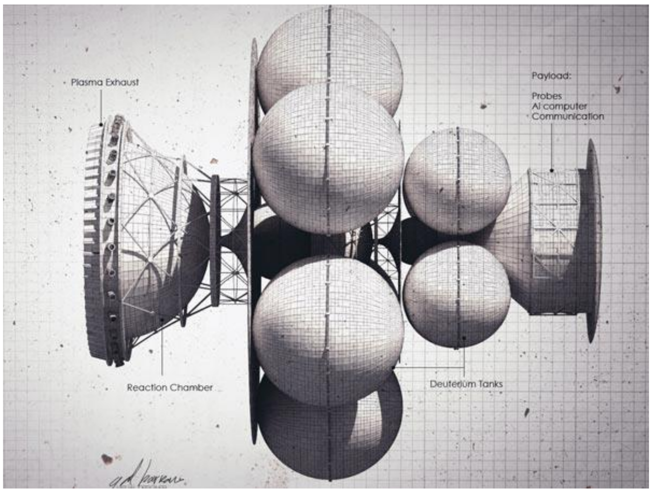
The author of this article tries to provide concise summary descriptions of the two projects and then wants to shed some light on political and operational difficulties which might to be expected in such an enterprise, drawing on his own experience with long term projects, in particular on his more than 20 years' experience with the international space station (ISS).

Project Deadalus [2]

In 1971 Friedwardt Winterberg explored the concept of using Marx generators to power electron particle beams. This idea was picked up by members of the British Interplanetary Society (BIS) who were embarking on an engineering design study to demonstrate that interstellar travel was, at least, possible with current, or near future, technology. Then in January 1973 members of the BIS met to discuss the challenges of interstellar propulsion and the idea of project Daedalus was born. Led by Alan Bond, Tony Martin and Bob Parkinson, members came together to create what has become one of the most comprehensive interstellar engineering studies ever undertaken.
Project Daedalus had three stated guidelines:
1. The spacecraft must use current or near future technology.
2. The spacecraft must reach its destination within a human lifetime.
3. The spacecraft must be designed to allow for a variety of target stars.

The members of the Daedalus study group were all volunteers but with a solid knowledge of engineering and science. The final design was published in 1978 and presented a two-stage spacecraft nearly 200m in length powered by electron driven D/He3 fusion reactions as proposed by Winterberg, eventually accelerating up to 12% of light speed to arrive at its target destination, Barnards star 5.9 light years away in under 50 years. The Daedalus first stage had a structural mass of 1,690 tons with 46,000 tons of propellant in six tanks and it would burn for 2.05 years before jettisoning it. The second stage had a structural mass of 980 tons with 4,000 tons of propellant in four smaller tanks and would burn for 1.76 years, the tanks all being jettisoned prior to reaching the destination. Both stages would achieve an exhaust velocity of around 10,000 km/s from the detonation of the D/He3 pellets at a frequency of 250 Hz. The second stage carried a 450 ton scientific payload with 18 probes to be used to study the target solar system planets. One of the interesting problems that Daedalus had to deal with was the transmission of a radio signal over vast distances back to earth. The team proposed the unique solution of using the parabolic reaction chamber to achieve a high antenna gain. It is too early in the design process (pre-concept stage) to identify how project Icarus may do things differently, giving the changes in technology over the past decades. However, at this stage we can speculate that likely design modifications will be in the areas of electronics, computing science probes, pellet ignition driver, the propellant and its acquisition.





Project Icarus [2]

“Icarus, son of Daedalus - flying closer to another star aims to `touch' the star and escape from the bounds of mother Earth.” …

This is the vision of this theoretical design study to re-examine the engineering solutions and fundamental assumptions behind project Daedalus. Like Daedalus, the intention for Icarus is to rely on fusion based engines - and to quote Alan Bond from the recent BIS symposium: “Now we are addressing the universe on its own terms", in reference of using fusion power to visit the stars – which are themselves fusion powered.

In the introduction to the Daedalus study report Alan Bond stated that “it is hoped that these `cunningly wrought' designs of Daedalus will be tested by modern day equivalents of Icarus, who will hopefully survive to suggest better methods and techniques which will work where those of Daedalus may fail, and that the results of this study will bring the day when mankind will reach out to the stars a step nearer". So in essence, the naming of the successor project as Icarus was suggested by the original study group already.

Project Icarus is a Tau Zero Foundation initiative in collaboration with the British Interplanetary Society (BIS) and so represents a true collaboration of international volunteers all sharing in the vision of a human presence in space in the coming centuries. This gives the project a strong support base and a large intellectual resource.

The purpose of Project Icarus is as follows:
1. To design a credible interstellar probe that is a concept design for a potential mission in the coming centuries.
2. To allow a direct technology comparison with Daedalus and provide an assessment of the maturity of fusion based space propulsion for future precursor missions.
3. To generate greater interest in the real term prospects for interstellar precursor missions that are based on credible science.
4. To motivate a new generation of scientists to be interested in designing space missions that go beyond our solar system.

The Terms of Reference (ToR) for project Icarus essentially represent the initial design requirements and are as follows:
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., like Daedalus).
6. The spacecraft mission must be designed so as to allow some deceleration for increased encounter -time at the destination.

Icarus Study Modules

1.0 Astronomical Target	11.0 Computing & Data Management
2.0 Mission Analysis & Performance	12.0 Environment Control
3.0 Vehicle Configuration	13.0 Ground Station & Monitoring
4.0 Primary Propulsion	14.0 Science
5.0 Secondary Propulsion	15.0 Instruments & Payload
6.0 Fuel & Fuel Acquisition	16.0 Mechanisms
7.0 Structure & Materials	17.0 Vehicle Assembly
8.0 Power Systems	18.0 Vehicle Risk & Repair
9.0 Communications & Telemetry	19.0 Design Realization & Technological Maturity
10.0 Navigation & Guidance Control	20.0 Design Certification

Icarus Potential Science Drivers

Option	Characteristics
Gravitation	What is the nature of the Pioneer anomaly? What sources of gravitational waves can be detected?
Heliosphere	What is the extent of the solar wind and its interaction with the solar heliosphere?
Planetary formation	What are the conditions for planet formation? What is the extent of the habitable zone? How do other solar systems differ from ours?
Stellar physics	What is the accuracy of long distance measurements to the stars What is the origin of low-frequency heliospheric radio emissions
Colonisation	Is human colonization of the galaxy feasible? Can a technological species outlive its parent star? Life Is their life on planets around other stars? How long can life survive in deep space?
Interstellar space	What is the mass function of objects in the Kuiper belt or Oort cloud? What are the properties of the interstellar medium? What is the abundance of interstellar nuclides? What are the properties of the interstellar medium? What is the cosmic ray background in interstellar space? What is the dust population resulting from collisions of Edgeworth-Kuiper belt bodies?
Solar system	Is our solar system typical in structure and metal content to others in the galaxy?
Galactic	What is the age of the galaxy? What is the nature of dark matter?
Spacecraft	What is the long time survivability of a spacecraft structure and electronics on long duration deep space missions?

As a thought-experiment the author calculated a Lorentz Factor of 1.005 for the assumed travelling speed of 1/10 of the speed of light (disregarding the gravitational time dilation effects). Since this is a small yet measurable time dilation effect, one other interesting aspect of this project could be to investigate the equivalence of biological aging and relativistic clock time-keeping (twin experiment?). Although not very significant, a 50 years trip (outbound) would amount to a time dilation (i.e., a slow-down of the onboard clock) of approximately a quarter of a year, i.e., if astronauts would be on board they only would have biological aged by 50 years less than 3 months, because “all processes — chemical, biological, measuring apparatus functioning, human perception involving the eye and brain, the communication of force—everything, is constrained by the speed of light. There is clock functioning at every level, dependent on light speed and the inherent delay at even the atomic level. Biological aging, therefore, is in no way different from clock time-keeping.”[3] [4]

Practicability Considerations

From a technical point of view the feasibility studies are well worth their effort and it deserves highest respect to “push the envelope” to further limits.

Plausible technical solutions are proposed for fusion propulsion, navigation and communications although many detailed technical questions have to be solved yet – but the Friedwardt Winterberg fusion propulsion concept together with Jupiter and/or Moon He3 harvesting might be the solution. However more experimental data on ICF pellet production is needed. The current status of the (ICF-research based) US National Ignition Facility (NIF) is according to Wikipedia: “Bringing the system to its full potential was a lengthy process that was carried out from 2009 to 2012. During this period a number of experiments were worked into the process under the National Ignition Campaign, with the goal of reaching ignition just after the laser reached full power, sometime in the second half of 2012. The campaign officially ended in September 2012, at about 1⁄10 of the conditions needed for ignition. Experiments since then have pushed this closer to 1⁄3, but considerable theoretical and practical work is required if the system is ever to reach ignition". Similar problems occurred with the French (ICF-) Laser MegaJoule (LMJ) facility (Wikipedia): "The first Laser Integration Line (LIL) was completed in 2002. The first laser beam shots were planned for the beginning of 2014, but commencement of operations was later postponed until December of that year. Full power capability is currently planned to be reached in 2025"

The planned structure assembly using pre-integrated modules in low earth orbit was successfully used for ISS construction and is state-of-the-art however a replacement for the shuttle (STS) transportation system is still missing. Communications and navigation problems probably can be solved – as indicated in the studies.

However drawing from ISS experience I see almost unsurmountable problems for financing such a project:
The most significant problem will be project **funding,** given the current, well known state of affairs worldwide (environment destruction, resources shortage, economic imbalances etc., migration problems) with respect to life threatening political crises and problems a project like that could only be carried out by all spacefaring nations joining together and relying on each other. That means appropriate shares and returns have to be negotiated and agreed upon assuming responsibilities and commitments over a time period of at least 50 years.
For the ISS this (much smaller scale agreement) took more than 10 years to be finalized and finally came about only because of coincidental political developments, i.e., the dissolving of the USSR. Nowadays China will be a partner not to be forgotten – on the other hand the "inventors" of the interstellar spaceflight project just left the European Union (BREXIT) heading into an uncertain European future. It will take an outstanding and charismatic personality to pull the willing "partners" together and shepherd them through the negotiations.

Assuming the "seeding" money comes together and the shares are distributed over a feasible design concept the usual time delays, cost increases and cost reduction exercises will start ending up with a minimum design solution which barely will be acceptable (e.g., the European Columbus lab was cut in half, several essential assets, the free-flying man-tended lab-module and an prestigious European space transportation system – HERMES, were cancelled).

Of course all this has to be held together by public motivation and public support drawing some national pride or other benefits from it (e.g., creating high tech jobs). Currently I see no motivators like we had in the early years of the Apollo program (national pride, technological superiority, jobs) or used for the ISS (space being a place where people come together in a world-class laboratory and work together despite all differences and problems on the Earth for the benefit of humankind).

A less overwhelming yet important issue is the standardization of system- and communication interfaces (saving lots of money if done correctly beforehand). The know-how transfer and securing the maintenance of the systems onboard and on ground during cruise phases lasting 20…50 years requires a tremendous and costly planning effort e.g., the Voyager project is relying on the good will of retired volunteers to maintain the flight sequences because nobody knows them anymore after almost 40 years flight time.

Public interest but also the enthusiasm of space managers are "volatile gifts" – as the examples of the Pioneers and Voyagers and even the ISS show. In order to get funds flowing for new projects the old

ones are getting less and less interesting, i.e., allocated operations resources are getting exhausted premature and experts tend to transition to new (more interesting) projects.
There are no “benchmarks” of what happens if the “prime mission” (flyby and exploration) starts only after 50 years! (Dr. Ed Stone, Voyager Project Manager since the beginning might have some notions).

Altogether interstellar spaceflight will be a very difficult and costly enterprise, meaning the “spaceflight culture” on Earth has to change i.e., if we want to explore or even “settle” interstellar space we have to act as a united world-community.
It should also be clear that whatever we want to achieve in interstellar space later is much easier to be achieved on our good old Earth because we are “in situ” already. So let us try harder to improve and secure our situation here!

References

[1] Der Spiegel, issue 33, 13th August 2016

[1a] Discovery of potentially Earth-like planet Proxima b raises hopes for life (24.Aug.2016) https://www.theguardian.com/science/2016/aug/24/earth-like-planet-found-orbiting-our-suns-nearest-star-raises-hopes-for-life-proxima-b

[2] PROJECT ICARUS: Son of Daedalus Flying Closer to another Star
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[3] Taylor, Edwin F.; Wheeler, John Archibald (1992).Spacetime Physics (2nd, illustrated ed.). W. H. Freeman. p. 50. ISBN 978-0-7167-2327-1.

[4] https://en.wikipedia.org/wiki/Twin_paradox#cite_note-30

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