‘Oumuamua: A Second Chance?

A Personal Memoir

Adam Hibberd

In this piece our finest astrodynamicist recollects how he came to be involved with i4is and how this developed into the highly productive relationship he now has with colleagues in both the technical and production teams.

A Fateful Day

Although I didn't realise it at the time, Thursday October 19th 2017 was a fateful day in my life. Previously that year I had been working on a personal project – a software application I called Optimum Interplanetary Trajectory Software (OITS), deriving all the necessary theory and equations whilst on holiday in Staffordshire, near Cheadle. My interest in the subject originated through my involvement in the '90s as a software engineer in the space industry. Subsequent to leaving this position, I was diagnosed with a mental health condition , and from 2001 onwards attempted to organise some kind of a living for myself as a pianist and composer. Indeed I had through the services of the Coventry Pod established myself on the arts scene in Coventry, and I'd like to think that my efforts were not entirely unrelated to the city eventually receiving the accolade of 'UK City of Culture' in December 2018. I had

before this fateful Thursday occasionally posted the animations and plots generated by my software on Facebook, although to be honest a lot of my artist friends were rather dubious and unimpressed by the whole venture, despite my enthusiasm at what my software was capable of achieving - at this time it was reproducing to great fidelity and with comparative ease historical missions to the planets like Cassini (Saturn), New Horizons (Pluto), Voyager (J-S-U-N) missions etc, etc.
However I am being rather egocentric when I mark this Thursday out as being a personally fateful one, because in fact it changed the lives of many members of a particular community of human beings – scientists and, to be more specific, astronomers and astrophysicists. It was on this fateful Thursday that astronomers, or an astronomer, made a momentous discovery. The astronomer in question was Robert Weryk, working for the PanSTARRS observatory on the Hawaiian island of Haleakala.
On Thursday October 19th 2017 the first interstellar object was discovered passing through our Solar System, which was later designated 1I/'Oumuamua.

Interstellar Objects

So what is an interstellar object (ISO)?
We live on the planet Earth, just one of many celestial bodies belonging to our own solar system. Now what is it about a particular object, say the planet Jupiter, which defines it as belonging to our solar system and not to a different system elsewhere in the Milky Way galaxy, like Proxima Centauri for example?
You might respond that it is simply Jupiter's proximity to our star, the sun. You would have a point but this isn't the whole story. Look at it this way: not only is Jupiter close to the sun but we know it's going to stay that way indefinitely (or at least as far into the future as we are able to accurately predict) - it will always remain bound to it.
In the language of science, more specifically orbital mechanics, Jupiter is in a bound elliptical orbit (almost circular) around the sun because its orbital eccentricity, e, is below a value of 1.
Interstellar objects stubbornly refuse to obey this condition, their orbital eccentricities, e, are greater than 1. This means that these objects are in hyperbolic orbits, so will escape the sun and never

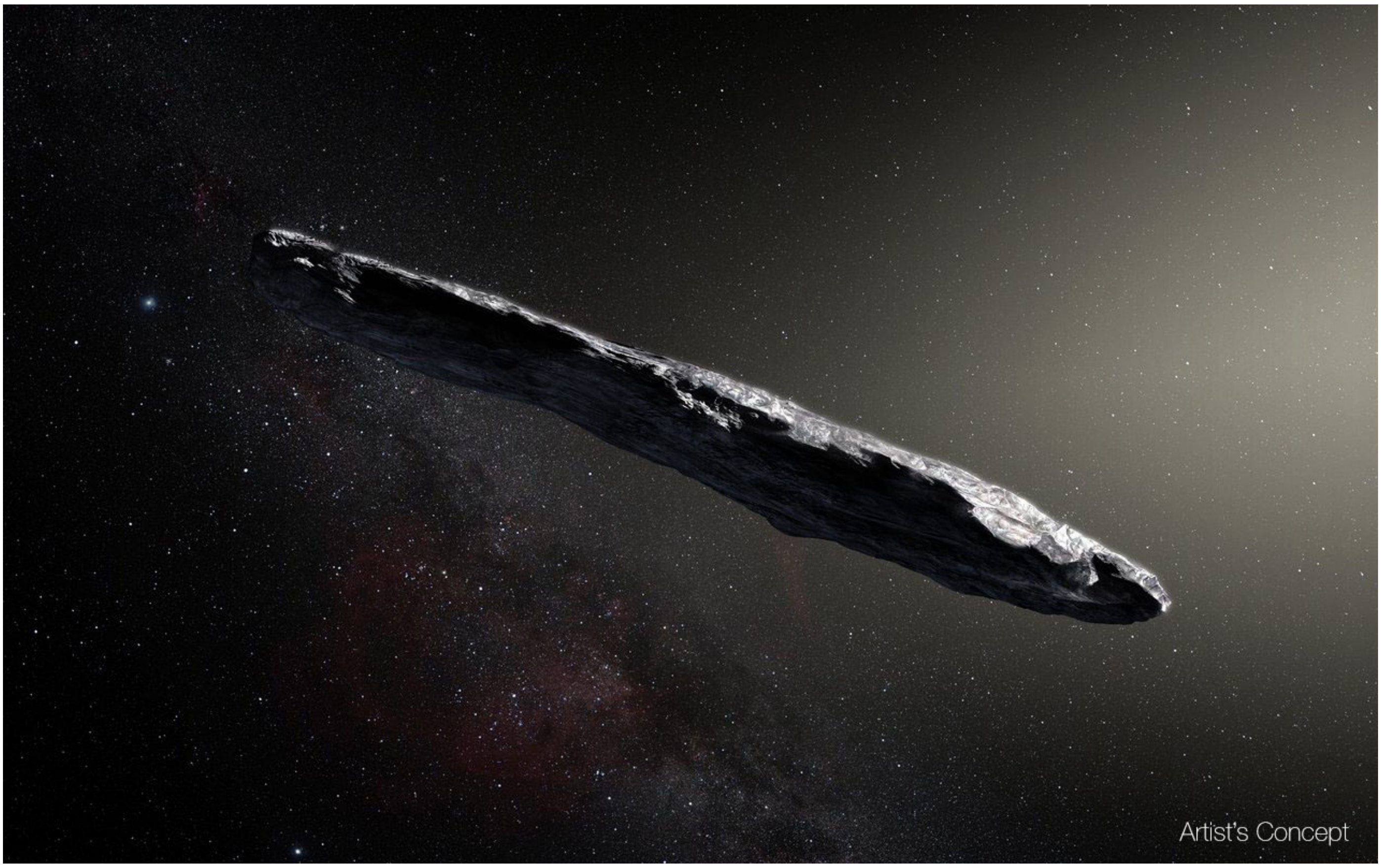

Figure 1 Image Credit: European Southern Observatory / M Kornmesser

return. It turns out by conservation of energy, they must have arrived from a great distance - originating from somewhere else in the Milky Way galaxy - and will also escape to a great distance. So 'Oumuamua has the honour of being the first interstellar object discovered in our solar system, travelling through it with such a speed, that even the gravitational pull of the sun will not prevent it from continuing its journey, out of our celestial locale and on to somewhere else in our galaxy.

An Opportunity

The news was reported widely in newspapers and initially I made no connection to my own work, which at that time involved using OITS to replicate old NASA/ESA robotic missions to the planets. It suddenly dawned on me a week or two later, possibly stimulated by the reference to 'Rendezvous with Rama' (the Arthur C Clarke sci-fi novel) in the papers, that I could study the feasibility of spacecraft missions to 'Oumuamua.
The first 'eureka moment' came when I was able to acquire a binary SPICE kernel file for 'Oumuamua through the NASA Horizons service [1]. To clarify here, essentially for my software to operate it needs precise positions and velocities of the planets and other celestial bodies – in fact whichever bodies are the subject of investigation by the user. In simple language, we need to know where a planet is, in order to work out how a spacecraft might get there.
No problem, NASA can do this you might think. You'd be right – there is some free software called SPICE [2] which, in combination with NASA data files for each object (called kernels) you can link in with OITS, and which OITS can then use to solve trajectories to it. Lo-and-behold it so happened I could generate just such a file for 'Oumuamua. So this was the first step. However further issues remained before I could research missions using OITS.

Optimum Trajectories

With Optimum Interplanetary Trajectory Software (OITS), the user selects a sequence of celestial bodies to be visited by a spacecraft launched from Earth. Depending upon your knowledge of the field, you may be surprised that the direct route isn't always the most efficient or effective to get to a target body in our solar system. Sometimes visiting objects in-between launch from Earth and arrival at the target can be beneficial, despite invariably taking a longer time.
The reasoning behind this becomes clear when one analyses what is actually meant by 'beneficial' in this context – how is it quantified? Generally in the domain of space, scientists and engineers want to limit the mass budget of a mission to as low as possible. The reasoning for this is many-fold but two of the most compelling reasons are (a) the cost of launching spacecraft grows dramatically with the mass of the spacecraft payload, and (b) the lower fuel mass means that more mass is available to dedicate to useful stuff - like instrumentation for example - which will be needed to satisfy the mission requirements.
It so happens that a spacecraft manoeuvre known as gravitational assist (GA), where the spacecraft slingshots close by a planet, is a useful mechanism by which its speed relative to the sun can be augmented without the necessity for thrust being applied by its on-board engines, and so requiring no precious fuel. Hence to reach a particular destination (and so the reason why a user might specify a planet or certain sequence of planets to visit on the way), it would seem exploiting a GA, or even multiple GAs, might be extremely advantageous for mission planners in that less fuel would be consumed.
Now back to the story.

[1] ***Horizons System***, The JPL Horizons on-line solar system data and ephemeris computation service provides access to key solar system data and flexible production of highly accurate ephemerides for solar system objects (1,233,593 asteroids, 3,826 comets, 211 planetary satellites {includes satellites of Earth and dwarf planet Pluto}, 8 planets, the Sun, L1, L2, select spacecraft, and system barycenters). Horizons is provided by the Solar System Dynamics Group of the Jet Propulsion Laboratory. https://ssd.jpl.nasa.gov/horizons/
[2] ***The SPICE Toolkit.*** NASA's Navigation and Ancillary Information Facility (NAIF) was established at the Jet Propulsion Laboratory to lead the design and implementation of the "SPICE" ancillary information system. SPICE is used throughout the life cycle of NASA planetary science missions to help scientists and engineers design missions, plan scientific observations, analyze science data and conduct various engineering functions associated with flight projects. https://naif.jpl.nasa.gov/naif/about.html

A Slingshot by the Sun

What it came down to was that the interplanetary trajectory to 'Oumuamua would inevitably necessitate what is known as a Solar Oberth Manoeuvre (SOM). A SOM is where the spacecraft reaches a low perihelion (a closest approach to the sun) and delivers a burn/thrust of its rockets, a velocity increment ΔV (deltaV), to generate a considerable velocity at infinity, V_∞, relative to the sun. (This V_∞, also known as the heliocentric hyperbolic excess speed, is the speed the spacecraft will achieve at a great distance, when the sun's influence is no longer slowing it down significantly.) The spacecraft needs such a high V_∞ because 'Oumuamua was discovered after its own perihelion and was itself receding from the sun at a huge speed (V_∞ for 'Oumuamua is around 26.3 km/s). It does not take a great mathematical brain to fathom that the spacecraft must exceed 26.3 km/s to enable it to catch up with 'Oumuamua.
Sci-fi fans reading this will be quite familiar with this solar slingshot because at the advice of Mr Spock and under the captaincy of James T Kirk, the starship Enterprise conducted just such a manoeuvre both in the original series of Star Trek [1] as well as in the 1986 film production directed by Leonard Nimoy, Star Trek IV: The Voyage Home. In these sci-fi adventures, the purpose of the solar slingshot was not to chase an interstellar object but to travel in time. However, back to the real world.
The second eureka moment arrived when I came up with the notion of what I called an 'Intermediate Point' (IP) to enhance the flexibility of OITS and solve all sorts of mission scenarios, including those involving a SOM. This neat little trick opened the path to studying trajectories to 'Oumuamua.
I was initially uncertain as to how to introduce this functionality into my software, at this stage all the objects along the interplanetary trajectory to be optimised were classed as celestial bodies, each with their own NASA SPICE kernel. However it turned out – and this is the great asset of Object-Oriented Programming – that the change was quite minor, though the flexibility and power of the software was enhanced enormously by this modification. It fairly quickly became a matter of how to try out the modified software on a mission to 'Oumuamua.

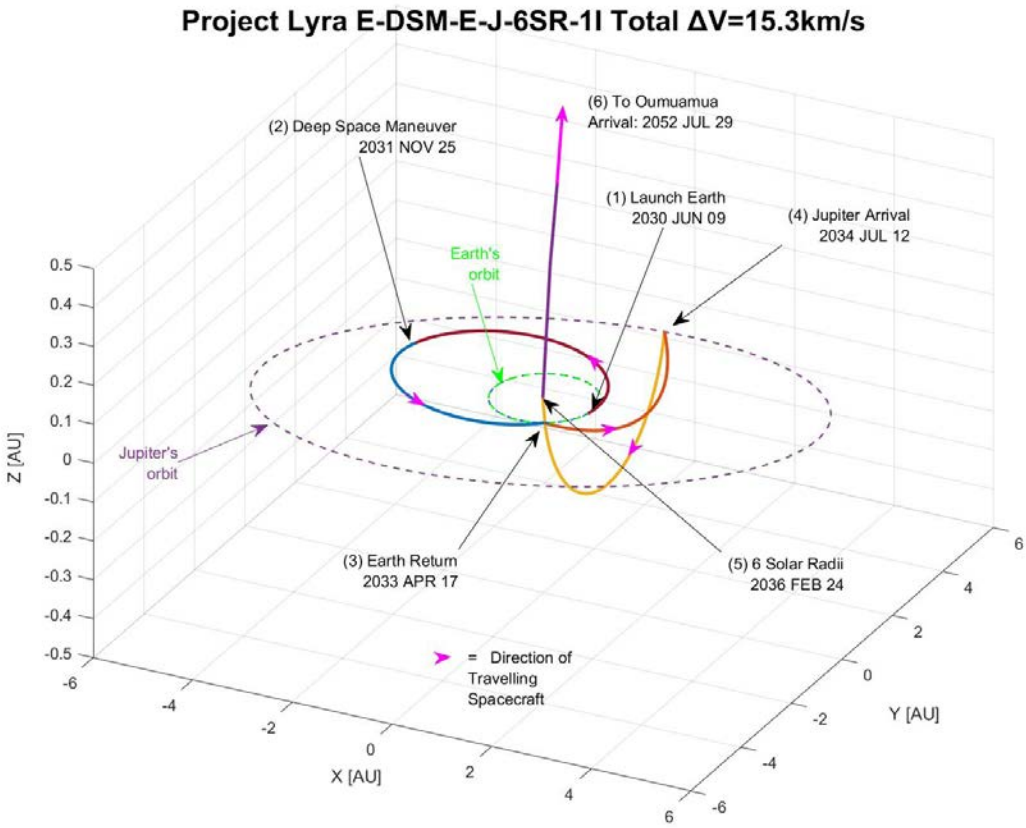

Figure 2 Project Lyra with a spacecraft using a SOM at 6 solar radii (see Bibliography #1)

[1] Star Trek, Season 1, Episode 19, *Tomorrow Is Yesterday*, 1967 https://en.wikipedia.org/wiki/Tomorrow_Is_Yesterday

Perihelion for the Solar Slingshot

The question was what the perihelion of the SOM should be. This wasn't straightforward. You see one would expect the closer one gets to the sun, the greater the slingshot (Oberth) effect, and so the more 'bang-for-your-buck'; or more specifically, the greater the V_∞ generated by any ΔV burn at perihelion. (The actual situation turns out far more complicated than this as will be elucidated further down.) However conversely the closer one gets to the sun, the more massive any heat shield would need to be and so the less usable and useful mass for the spacecraft, in the form of instrumentation for example, available to study 'Oumuamua upon arrival. I settled on the same value used by the KISS (Keck Institute for Space Studies) theoretical study into missions to the interstellar medium (ISM), of 3 Solar Radii from the centre of the sun. This KISS study was relevant because to reach 'Oumuamua would inevitably mean travelling into the ISM – attaining large distances as quickly as possible.

Thus, so equipped with the new software and with a plan of action in terms of how one might get to 'Oumuamua, I attempted to exploit OITS to solve missions to 'Oumuamua. The sequence I selected was E-J-3SR-1I, where E is the Earth launch, J is the encounter with Jupiter, 3SR indicates a SOM distance of 3 Solar Radii and 1I is 'Oumuamua. A Solar Radius, SR, has a magnitude of 696,340 km, and is defined as half the diameter of the sun, or in other words the distance from the centre to the surface. With my innovation of the 'Intermediate Point', mentioned in the preceding section, I could use it to model the SOM at 3SR. Thus 3SR means that the SOM will happen at 2,089,020 km or 0.014 AU , three times farther from the centre of the sun than its surface.

The encounter with Jupiter preceding the SOM is required for complicated reasons which are associated with orbital mechanics - suffice to note that Jupiter, due to its huge mass, would have to play a pivotal role in virtually whatever mission scenario destined for 'Oumuamua.

A Strategy for Success

Almost immediately OITS was generating optimal solutions. Those familiar with OITS will know that the MATLAB window to which the optimizer outputs its progress displays the most recent value of overall ΔV computed along the trajectory in units of m/s, thus one observes a gradually reducing sequence of numbers as the trajectories computed get closer and closer to the optimal one. For this trajectory scenario, the optimizer was converging on something around 18,300 m/s. This was a result!

Once the optimizer had completed its work, naturally I looked at the data corresponding to the optimal solution it had found and there was that launch date: 2021. There was a nagging doubt in my mind, how reliable were the results OITS had found?

This doubt was exacerbated when upon running OITS a second time, the optimal ΔV turned out to be much lower: around 14000m/s. I was initially rather stumped as to the explanation for this disagreement. However it soon occurred to me that the discrepancy was for the following reason. (Here it gets a bit technical, so feel free to skip the next paragraph if you prefer.)

The Intermediate Point, IP, for the SOM had to be, by definition, at the perihelion point of the spacecraft. Unfortunately for the latter result of 14000 m/s, the spacecraft trajectory was actually intersecting the sun because the perihelion was less ,than 1SR, both on the inbound (from Jupiter to the IP) and outbound (from the IP to 'Oumuamua) paths. There was an easy fix to this: my software already included the functionality allowing the user to specify minimum perihelia distances for the trajectory arcs in question. When I specified perihelia just lower than the distance the IP was placed from the sun (3SR), but way above the surface of the sun (ie > 1SR) the 14,000 m/s solution disappeared, and the 18,300 m/s mission became the winner for this scenario.

Discovering Something Only I Knew

Well I had clearly discovered something amazing, something no one else knew, but I didn't realise the full implications of these findings. To summarise - I had constructed some software, and it had, as a result of its computations, generated a number: 18.3 km/s, and a launch date: 2021. My naivety at this stage left me stumped on two counts: a) was this 18.3 km/s figure genuinely achievable by any existing or near-future propulsion system and b) was 2021 (at that time 4 years in the future) a realistic timeframe to build a spacecraft and prepare a mission. I concluded I needed assistance - and assistance was forthcoming.

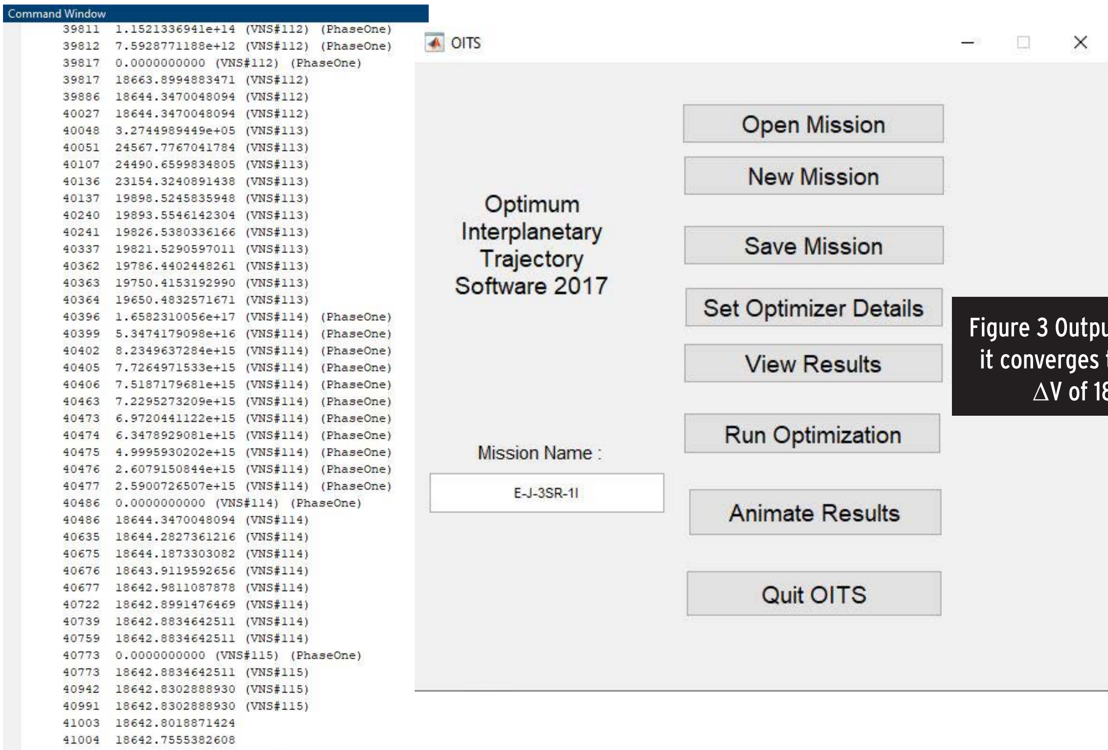

Figure 3 Output from OITS as it converges to a SOM with ΔV of 18.3 km/s

I should mention that while I was conducting my investigations, observations of 'Oumuamua were continuing, and its idiosyncratic nature was steadily unfolding before our eyes, with a steady flux of science papers on its unusual if not enigmatic properties. A long cigar-shaped object with aspect ratio 10:1 (from its light curve); no appearance of a coma or tail, for that matter no observable outgassing; unusually bright for its size; a reddish hue to its spectrum indicating space-weathering; a mysterious force as it sped away from the sun in inverse proportion to the solar distance or possibly the square of this distance. The latter finding led Avi Loeb [1] to suggest this could be an alien solar sail. The overall impact on scientists was one of bewilderment – what in the universe could this interloper to our celestial neighbourhood possibly be? Subsequently origin theories were plentiful and sometimes speculative but none of them seem satisfactory to everyone. Loeb has his own ideas as to the nature and origin of 'Oumuamua and is not averse to finding faults with those in conflict with his own [2].

Whatever the case, the relevance and importance of my findings in terms of resolving all this uncertainty and bewilderment was becoming increasingly persuasive. After all, what better way of discovering the true nature of this object, hitherto resolved as only a single pixel in telescope images – a speck of reflected sunlight - than by sending a mission and taking a close-up picture of it. In Loeb's own words: 'A picture paints a thousand words'.

[1] Professor Abraham Loeb, Harvard University, is a distinguished astrophysicist, former head of astronomy at Harvard and a prominent advocate of the probability of finding alien artefacts near or close to the Earth. He is the co-author of *Life in the Cosmos - From Biosignatures to Technosignatures*, reviewed in our previous issue, and author of *Extraterrestrial* reviewed in Principium 33. See also *News Feature: Loeb on an Artificial Origin for `Oumuamua* in Principium 35.

[2] Examples: *The mass budget necessary to explain 'Oumuamua as a nitrogen iceberg*, A Siraj & A Loeb, New Astronomy Volume 92, April 2022, 101730, www.sciencedirect.com/science/article/abs/pii/S1384107621001445. Open acccess at arxiv.org/pdf/2103.14032.pdf *Destruction of Molecular Hydrogen Ice and Implications for 1I/2017 U1 ('Oumuamua)*, Thiem Hoang & Abraham Loeb,
The Astrophysical Journal Letters, Volume 899, Number 2, iopscience.iop.org/article/10.3847/2041-8213/abab0c/meta Open accces at arxiv.org/abs/2006.08088

Project Lyra

I looked for help on the internet and found Project Lyra. The UK not-for-profit company known as the 'Initiative for Interstellar Studies' (i4is) had been founded several years previously with the noble ambition of research and education in the field of interstellar travel. Its Project Lyra initiative had been inaugurated quite expeditiously after the discovery of 'Oumuamua. Various scientists of world renown contributed to the content of the paper, which was eventually published as a preprint (without peer-review) only 10 days after 'Oumuamua's detection. To summarise, their work had slightly preceded mine and was independent of it, but its remit was to study the feasibility of spacecraft missions to 'Oumuamua, exactly the task I had undertaken with OITS.

It was a no-brainer, I contacted the Project Lyra team leader Andreas Hein providing him with some results of my research in an email. At this point a lesser scientist, indeed a lesser man, would have been wary of, ignored, or even discounted the information I had furnished him – I was after all only a BSc, and my previous experience of Optimum Trajectory Software had been 2 decades earlier when I worked as a software engineer for the Ariane 4 Project. However, instead Andreas was extremely accommodating and open-minded over my approach to him, suggesting he pass my findings on to the Project Lyra team. Thus history was made.

Welcomed into the Fold

At this stage the Project Lyra paper had already been published as a preprint, though had not yet been peer-reviewed. I was not privy to the conversations that were happening between Andreas and the other Project Lyra scientists, however I do know that Andreas eventually invited me to contribute to future versions of their paper. The obvious reasoning was that their research largely assumed direct trajectories from Earth to 'Oumuamua, and so there was a gap where indirect missions had not been studied in great detail. However I must credit Adam Crowl and Marshall Eubanks here and others, who had already done some useful work on missions with a SOM (also the aforementioned KISS workshop had studied SOMs for reaching the ISM). My software could readily fill this information gap, as I have already mentioned above. It seemed my studies would easily dovetail into those which Project Lyra had so far undertaken, bolstering, and contributing materially to the general conclusions and case for a mission to 'Oumuamua.

As far as my reservations were concerned, Andreas got to work on calculating a mass budget assuming rocket propulsion (chemical) corresponding to the ΔVs my software had calculated. The results of his analysis were unequivocal. A mission would indeed be feasible with significant spacecraft masses to 'Oumuamua, launching in 2021, particularly if one assumed the NASA super heavy-lift launch vehicle known as the Space Launch System (of course we now know that its maiden flight has been delayed time and again and it still hasn't launched as of the time of writing, June 2022).

Figure 4 Logos for Initiative for Interstellar Studies and Project Lyra

Reflection on the Initial Findings

You would think that would be the end of the matter. However the whole analysis I had conducted and results obtained using OITS left various questions unanswered. For instance, why did the optimal launch year happen to be 2021? What was so special about this time specifically? I concluded that there must be some special alignment of the celestial bodies involved – Earth, Jupiter, 'Oumuamua - which makes this departure date for some reason particularly propitious. Investigation of long-term missions to 'Oumuamua using OITS, looking forward decades into the future, indicated a 12 year periodicity in the feasibility of trajectories with this E-J-3SR-1I scenario. This was especially interesting on two fronts – first that there were indeed viable missions to 'Oumuamua beyond 2021, and second that these missions seemed to follow an approximate Jupiter year (11.9 Earth years) cycle. The latter observation indicated that viability must be dependent almost entirely on Jupiter, which must occupy a particular point in its orbit around the sun (a sweet spot) to allow missions to 'Oumuamua.
At the time I was distinctly underwhelmed by this finding because the flight duration for the 2021+12 = 2033 launch was what I considered exorbitantly protracted – 19 years – and actually significantly longer for 2033 + 12 = 2045 (26 years) and even longer for 2045 + 12 = 2057 (37 years).
Consequently I was extremely surprised when Andreas expressed consternation and excitement at this finding, suggesting it be written up in a further Project Lyra paper. In retrospect I now see he was correct and I can appreciate his perspective on multiple counts. Firstly, his view must have been that travel to another system beyond our own solar system would take tens of thousands of years using spacecraft with chemical propulsion, and here we had with this interstellar object the possibility of conducting just such an examination in the space of as little as 20 odd years. Secondly the findings indicated that viable missions to 'Oumuamua allowed launch dates years if not decades into the future, so plenty of opportunity to organise and prepare a mission. Finally the Voyager missions are still operating 45 years since their launch in 1977 and have now travelled well beyond the heliopause, so comparatively speaking these protracted flight durations might not actually be all that protracted.

A Difficult Time

I had carried out all this work – development of OITS and Project Lyra research - in an ordinary semi-detached house in Coventry on a Dell laptop. My father was struggling with all kinds of health issues and I found a good deal of my time was spent caring for him. Unfortunately he was to pass away with only a vague idea of my achievements re Project Lyra, despite his endless efforts to try and understand. What was particularly sad was that he had been extremely intelligent in his prime. I was also experiencing severe mental health difficulties throughout this period, I look back in wonderment that I was able to achieve anything at all. I therefore can be forgiven, perhaps, for not involving myself proactively in the field of science in which I had found myself.
It was second hand then – via communications with Andreas and other volunteers for i4is – that I was to learn of the scepticism by Avi Loeb of the Project Lyra findings. It is possible therefore that his own hypothesis on the nature of 'Oumuamua as alien technology will neither be proven nor disproven or at least the resolution would have to be kicked into the long grass, when propulsion technology allowed. Waiting for another interstellar object and then sending a mission to that would be another option, but who knows when such an unusual object like 'Oumuamua and such a wonderful opportunity will arise in our system again?
Make no bones, 'Oumuamua was an invitation for humanity to take its first serious steps into interstellar space and embark on travel beyond our own solar system, on to the stars. Put starkly, will humanity die out on its home planet or will it extend its outreach and establish a long-term presence in the universe? Maybe the reality of the Covid pandemic is timely, perhaps this is an opportunity for humanity to regroup, rethink and decide what exactly it wishes to achieve by its precious existence in this universe.

Further Work

Spurred on by Loeb's scepticism of Project Lyra, I decided to investigate the effects of changing the perihelion distance of the SOM, in particular increasing it to a longer, safer distance away from the sun, to see how it would influence the viability of missions. Indeed my decision to investigate further turned out to be rather fruitful and I was pleasantly surprised at the results.

It seems that larger perihelion distances are actually not only viable but in certain respects beneficial in terms of reducing the overall ΔV budget associated with the mission - so in other words taking into account the burn at Jupiter perijove (closest approach to Jupiter) as well as that needed at the SOM. The baseline mission I discovered utilising OITS had a launch in 2030 and a SOM perihelion of 6SR but even larger perihelia were possible, markedly reducing the complexity of the mission by enabling heat shield technology to be deployed by Project Lyra identical to that used by the very real NASA mission designed to study the sun close up, the Park Solar Probe (PSP).

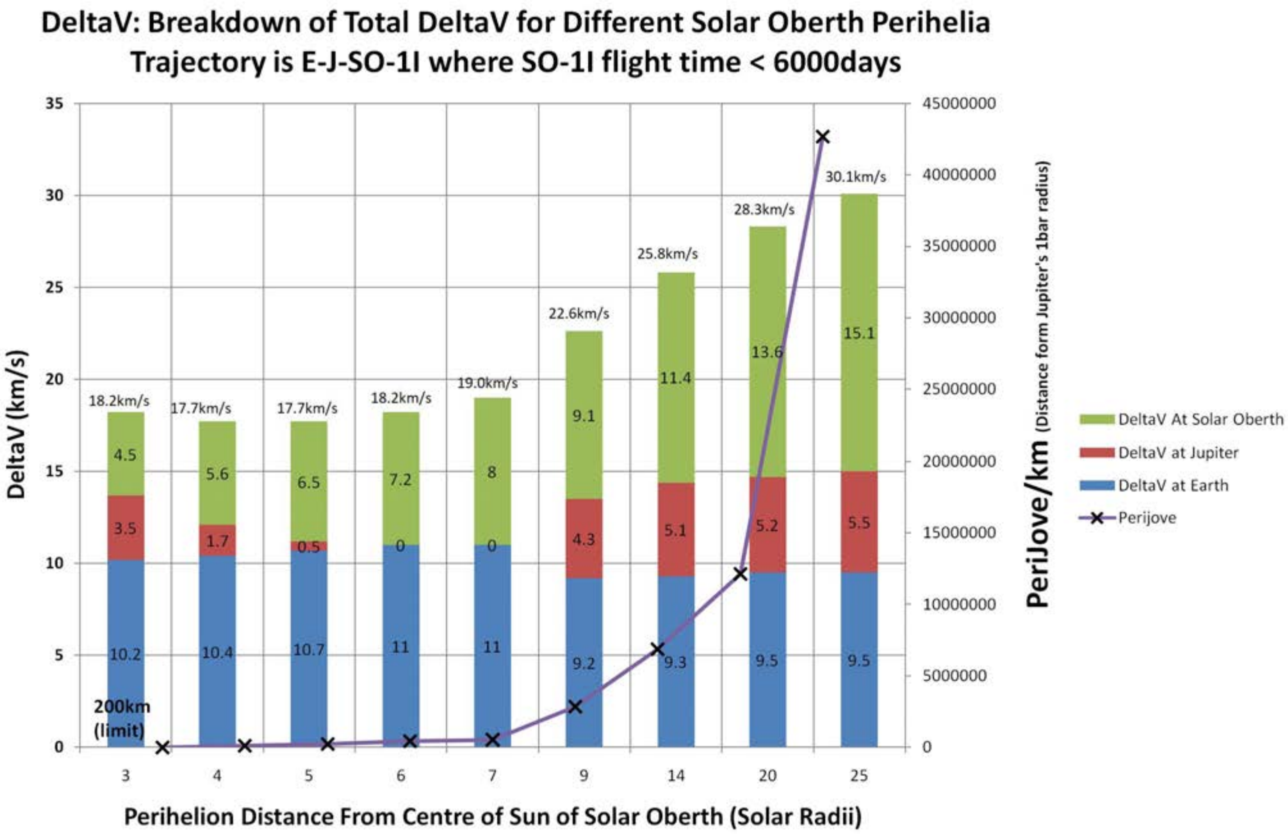

Figure 5 Bar Chart Indicating Optimal ΔV at around 5SR/6SR for Project Lyra (see Bibliography # 1)

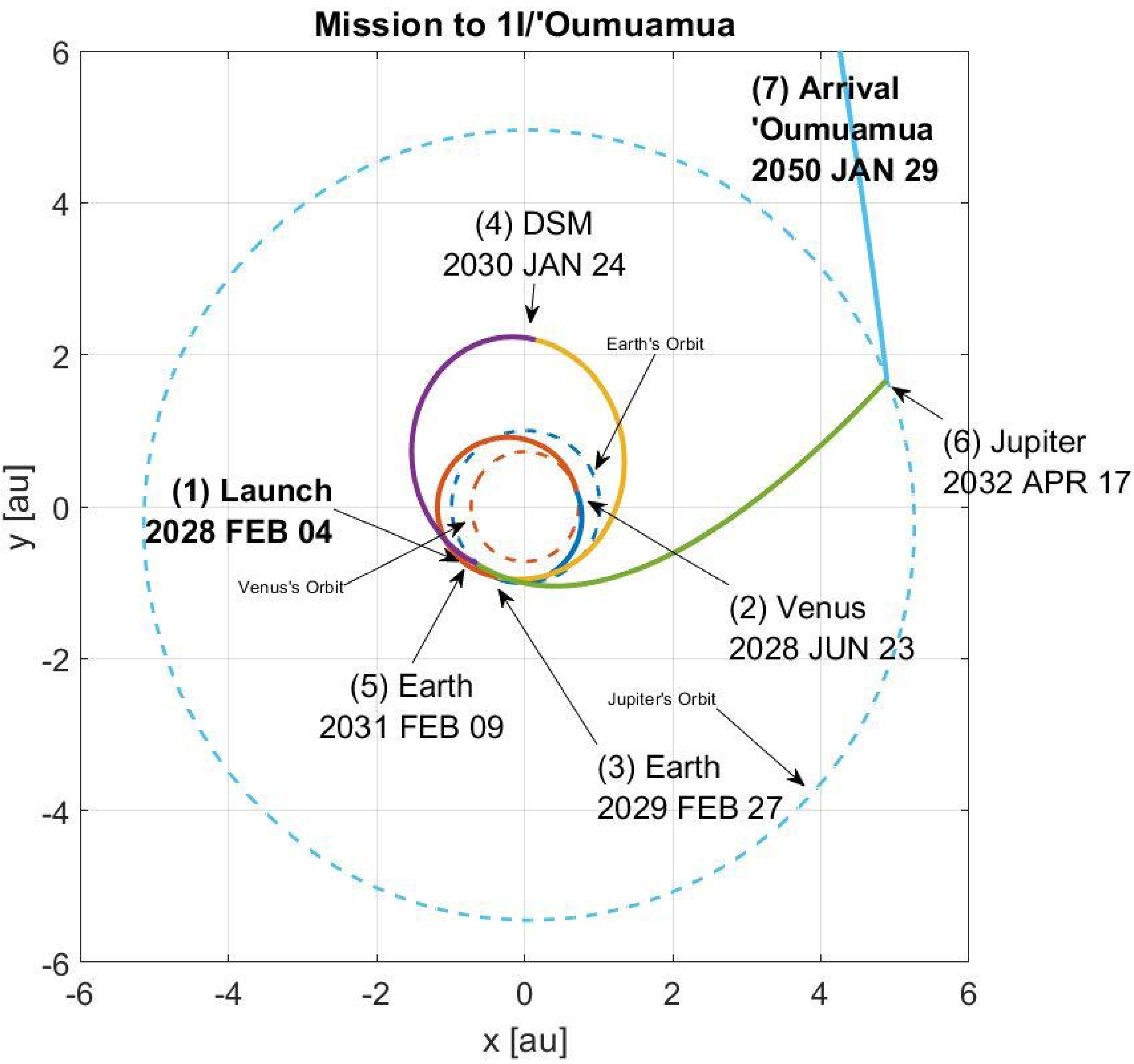

Figure 6 Project Lyra, using a JOM, an alternative to a SOM (see Bibliography #2)

An Encounter with Jupiter

At this juncture, let us embark upon a spot of time travel and leap forward to December 2021 and the publication of the ‘Interstellar Probe’ Concept Report by The Johns Hopkins University (JHU) Applied Physics Laboratory (APL). The Interstellar Probe project is all to do with sending a mission to the Very Local Interstellar Medium (VLISM). This VLISM is not entirely virgin territory for humanity as the Voyager 1 and Voyager 2 probes have both broken out of the heliopause – the boundary layer between the solar wind and interstellar wind - placed at approximately 122 AU from the sun. In its goal to reach and study the VLISM very quickly, APL had effectively dumped the theoretical benefits of a solar slingshot (SOM) for the far more practically achievable benefits of a Jupiter slingshot. As their baseline mission they selected a passive Jupiter gravitational assist (without a rocket burn at Jupiter). The second mission scenario they considered was a powered Jupiter gravitational assist, ie a Jupiter Oberth Manoeuvre (JOM), the SOM being the least preferred option.

However one might wish to argue the case one way or another for a SOM/JOM, the fact remained that I had not yet exhaustively considered the case for a Jupiter slingshot. The publication of the Interstellar Probe Concept Report inspired and stimulated me to reconsider a mission to ‘Oumuamua in the context of a JOM rather than a SOM.

My research was fruitful in that I was able to discover an efficacious route to Jupiter – the VEEGA sequence of gravitational assists – and then conducting a JOM at Jupiter. Although the route was not as effective as the SOM, it nevertheless circumvented the solar shield requirement, thus contributing to the overall mass of the payload eventually arriving at ‘Oumuamua.

Conclusion

After the paper on missions to ‘Oumuamua using the VEEGA sequence had been published as a preprint, with contributions from my colleagues and co-authors Andreas M Hein, Marshall T Eubanks and Robert G Kennedy III, the popularity of the paper was somewhat of a surprise, even outshining the initial Project Lyra paper, completed 4 years before. The paper was widely reported in the global media.

It seems that an appetite to resolve the ‘Oumuamua conundrum had not abated to any extent since that first paper and certain social media activists were even extolling the virtues of dedicating a NASA Space Launch System (SLS) as a priority over their moon Artemis plans, their logic being that a mission to the moon would happen eventually and there was no cause for hurry, whilst the realisation of a mission to ‘Oumuamua was pressing and required urgent attention due to the near-future launch opportunities.

In 2022, I have written two further papers about missions to ‘Oumuamua. The first elaborates a different trajectory, also without a SOM but with a JOM, which requires virtually no burn from the spacecraft at any of the planetary encounters on the way to Jupiter. For various reasons this makes for a very attractive proposition, although the launch date, in 2026, is a mere 4 years away at the time of writing. The second paper details the notion of ‘Intermediate Points’ as a means of modelling SOMs for example, so that missions to exit the heliosphere and chase ISOs can be investigated.

My contribution to all this has been one of a volunteer. Where before there was some degree of uncertainty and speculation, my work has brought order and engineering know-how to the task of resolving the problem of ‘Oumuamua. It would be such a shame if this work and this opportunity were to go to waste, but there lies the folly of humanity.

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