

3I/ATLAS – *the Interstellar Controversy*

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Adam Hibberd is our i4is lead astrodynamist and the creator of the software tool 'Optimum Interplanetary Trajectory Software' (OITS); serendipitously invented in the same year that the first interstellar interloper to our solar system 1I/'Oumuamua was discovered. He joined the i4is community and has been involved in Project Lyra since just after the first paper, authoring and collaborating on several peer-reviewed scientific papers on the subject. Here he discusses his journey throughout the co-authoring of the paper 'Intercepting 3I/ATLAS at Its Closest Approach to Jupiter with the Juno Spacecraft' with Abraham (Avi) Loeb (Harvard) and Adam Crowl (i4is).

When you have a surprise, uninvited visitor gatecrash your party, you are liable to treat them cautiously at first and then after a visual appraisal reveals they are worthy of acceptance, maybe curiosity will strike and you may start asking questions to find out more about them. You may by the end of this social interaction, and before the visitor has left, have discovered enough about the individual to form a fairly accurate notion of who they are and what they are like.

Well, the latest, and third, gatecrasher to our abode is a celestial body, an interstellar object (ISO) to be exact, from somewhere else in our Galaxy, the Milky Way. Furthermore, unlike all other objects we have observed orbiting the Sun (apart from the preceding 2 ISOs of course), it does NOT actually belong here and originated from some other System a long time ago, 7 billion years is one estimate, considerably older than our Solar System.

It was discovered on 1st July 2025 and later named 3I/ATLAS, since contrary to my expectations, it was not discovered by the recently operational Vera C Rubin Telescope, but instead ATLAS - the Asteroid Terrestrial-impact Last Alert System, though useful precovery images were subsequently found in the Rubin data archive a full month before 3I/ATLAS was discovered, and also even prior to this, images further back were taken by the TESS space telescope. Now when I received the news of the arrival of this ISO, I was distinctly unenthusiastic because I was still in the process of conducting research into so-called 'Dark Comets' and what they could be, and this thing was an unwelcome distraction. However, an acquaintance of mine who works with ISEC (the International Space Elevator Consortium) expressed surprise that I had not paid more attention to this object, especially in the context of investigating missions to it, and was unimpressed with the work I had instead been prioritizing.

Furthermore, news about the object was beginning to flood in from a myriad of sources and various connections of mine, in particular Marshall Eubanks (Space Initiatives) and Avi Loeb. For instance, it was quite clear early on, according to Avi, that he thought this was a very strange phenomenon, since despite its brightness, there was no spectroscopic signature for the presence of volatiles (such as water or ammonia, carbon dioxide and the like), which would point to it being a comet. This lack of evidence would indicate the calculated size for 3I/ATLAS, ~10 km, was not a result of a cometary coma, but that it genuinely WAS indeed that big - an asteroid in other words - 2 orders of magnitude larger than the previous 2 observed ISOs. Such a gargantuan object should only happen very rarely compared to 1I/'Oumuamua type objects, so how come we had observed one so soon after 1I/'Oumuamua, there should be millions of 'Oumuamuas before even one 3I/ATLAS?

It so happens that I was, at the time, in regular touch with Adam Crowl on Facebook, where the huge distance between he in Brisbane and me in Coventry was - so-it-appeared - magically nullified as we were able to discuss instantaneously the strangeness of 3I/ATLAS as though we were in the same room.

It was as a result of one such conversation that I decided to do some work on the astrodynamics of 3I/ATLAS, the most obvious approach being to consider the feasibility of missions from Earth to 3I/ATLAS. Having largely performed this analysis, I concluded that missions to 3I/ATLAS were simply out-of-the-question, either direct routes, or indirect. It was only later that it suddenly occurred to me - why not address the reverse route? - ie what would it take for 3I/ATLAS to intercept the Earth? That's a simple reversal of calculations that OITS was designed to accommodate very easily, and the results were extremely illuminating [1].

The relative ease of an intercept of Earth, for example, seemed initially inconsequential, but with further deliberation, the value of this research eventually dawned on me - what if 3I/ATLAS WAS alien tech, in precisely the way Avi had argued? - then these results showed how little effort would be needed for a probe - or weapon - sent from 3I/ATLAS to intercept Earth.

In a moment of gay abandon, I decided to share this plot with Avi Loeb and to my surprise - though in retrospect why should I have been? - he was extremely accepting of the premise that this object was alien technology and suggested collaborating on a paper on the subject. In view of my previous conversation with Adam C, I mooted that he be a co-author and so a very contentious research paper was born.

Someone had to write the skeleton, and since I clearly had more time and also the necessary Latex skills (Latex is a kind of language used by scientists for neat and tidy science paper generation), I came up with the initial draft which then the other two contributed to.

I shan't go into a detailed description of how the paper was received by the science community as most readers will be aware of this. It was hardly unpredictable that it would be entirely misrepresented and for that matter completely misunderstood by certain social media commentators. Arguments surfaced such as it 'claimed 3I MUST be alien technology because....' This latter was largely typical of the level of debate concerning the research and a wholly misleading summary of the paper, since we had 'claimed' nothing of the sort. We HAD 'claimed' that the object was most likely a comet, and we had only 'hypothesised' otherwise, a stark and clear fact which was almost entirely overlooked by most of the negative social media commentary.

I've reached an age when I get a wee bit tired of the prejudice and extremist nonsense pedalled by so many critics of papers such as ours. The reason for this is that many, many advances in science research have been at the periphery of what has at the time been considered acceptable, mainstream and orthodox scientific dogma, and although the paper was probably incorrect in its hypothesis (that remains to be seen), nevertheless surely we should have learned by this time of the dangers of prematurely casting out what might be considered on the fringe of science? - we should not throw out the baby with the bath water.

Email conversations between Avi, Adam C and I then tended towards the subject of missions, and the Juno probe soon became dominant in our thinking. Adam C did some calculations which showed that at perijove (closest it gets to Jupiter), Juno was teetering on the brink of Jupiter escape, with a velocity kick of only a few hundreds of metres per second necessary to send the probe on a course out of the Jovian system. The relevance of this fact was that 'The Object' (as Adam C had christened it) would come close to Jupiter on March 16th 2026 - in fact within 0.36 au of the planet, becoming a possible target for the Juno spacecraft as the mission could be repurposed to probe this ISO.

[1] OITS was first introduced to Principium readers in *How to reach Interstellar Visitors - Optimum Interplanetary Trajectory Software*, Principium Issue 27, November 2019, <https://i4is.org/principium-27/>.

When I used OITS to investigate Juno missions to 3I/ATLAS, two windows of opportunity presented themselves: in mid-August and in mid-September of 2025. These windows were so soon, this immediately sent alarm bells ringing and we contacted NASA immediately, setting in motion the publication of the preprint on arXiv, whilst I continued on with research to answer the question: 'how close could Juno actually get?'

It hardly surprised me that in the meantime a certain unmentioned scientist who had been so cynical about the first paper, then attacked the second paper, taking my quite legitimate, though admittedly politically naïve, answer to a question of his on social media and then parading it in front of his many followers and prefacing it with a sarcastic 'FWIW' (For What It's Worth). I have been reassured by one of my colleagues that this particular individual tended to be much more 'nuanced' in a personal conversation he had engaged him in at a science conference and only seemed to reserve this hostile manipulation to his activity on social media. I confess to be distinctly unimpressed by this attempt at an excuse.

Nevertheless I continued on with my relentless battle against my mental health condition and eventually the required results necessary to complete the paper were forthcoming, showing that Juno could get significantly closer to 3I/ATLAS with only 5.4% propellant remaining in the tank.

It still remains to be seen whether NASA believe they can restart the Juno engine, and even if it can, how much propellant might be left in the tanks. However one should be mindful that this probe was slated for termination by the end of September anyhow, with a kamikaze plunge into Jupiter's atmosphere, so instead maybe a risky manoeuvre, and an extension of its mission would be worth the risk?

So all-in-all an exciting few weeks for me personally as well as the scientific community as a whole. Weeks where I learned the humility of being a scientist - let the facts speak for themselves - and never, EVER allow yourself to introduce your own deeply prejudiced perspective into someone else's motives. My motive as a scientist is always, ALWAYS to find the truth and until that truth is found, hypothesis (based on evidence) but possibly not wild speculation (based on no evidence) should be encouraged and NOT scorned.

The Juno paper

The Juno mission to 3I/ATLAS was a shot in the dark before the publication of my paper with Avi Loeb and Adam Crowl, titled 'Intercepting 3I/ATLAS at Its Closest Approach to Jupiter with the Juno Spacecraft', now published by Aerospace journal [here](#).

I first needed access to the exact Juno orbit around Jupiter, but where could I get this data exactly? Fortunately from experience I knew precisely where to go, and it was to NASA, to be precise the NAIF, JPL database of SPICE binary kernel files which are available for many missions online ([go here](#)).

Having retrieved this data, I could then set to work on the research using OITS. But why use OITS?

The answer is for many reasons. One of which, of course, is that the process of learning tools such as GMAT (created by NASA) is a steep learning curve, and the GUI (Graphical User Interface) is certainly NOT intuitive. On the other hand, I know exactly how OITS works inside out (since I am the creator) and I find the GUI far more user-friendly, consequently I know precisely what to expect. What's more my software is just as accurate as the equivalent features in GMAT, and on top of this, also has the facility to allow the user to select 'Intermediate Points', my personal invention, expanding the utility of the software to solve a much wider range of missions (such as those with Solar Oberth Manoeuvres).

In order to exploit OITS in the context of Juno, I needed to shift the central gravitating body from the Sun (for interplanetary missions) to the planet Jupiter, which, naturally, is the body that the Juno probe is currently orbiting. However, since I had incorporated 'Object-Oriented Programming' techniques into the software when it was developed, this central body alteration was a very straightforward task indeed. By so-doing I could also model the possibility of Juno receiving a gravitational assist (GA) from a moon of Jupiter.

As it turned out, GAs from Jupiter's moons would not be at all helpful in getting the probe to 3I/ATLAS, simply because the probe is in a high inclination orbit wrt Jupiter's equator. Thus the Probe intersects this equator at two points only and also at quite a high angle, meaning that there would be low likelihood of any encounter with a moon, and it being not in the least bit beneficial if one could be realised anyway.

Adam Crowl and I were aware of this high inclination orbit of Juno from early on and it actually stimulated the subsequent research, as the inclination turned out to have a huge advantage as far as reaching 3I/ATLAS was concerned - it's all to do with the exact nature of 3I/ATLAS's closest approach to Jupiter.

To explain how, imagine an athletic competition, where a hammer thrower is preparing to do his stuff. Such a discipline requires the athlete to spin on the spot and then release the hammer at the right point in time to hurl it as far away as possible. Let's call the plane of the hammer's rotation before release, the 'rotation plane', then clearly the 'axis of rotation' will be the thrower. Some consideration will show that if the axis of rotation of this plane is perpendicular to the direction of throw, then that would be the optimal alignment to release the hammer in the right direction. However let's say this rotation axis were aligned with the direction of throw. That would be no good at all, since as well as being jolly uncomfortable for the thrower (his body would have to somehow hover horizontally in space), in addition, the hammer would be released in entirely the wrong direction anyway (in fact at 90 degrees from the required direction).

It so happened that Juno's orbital plane had an inclination almost perfectly aligned so that, given sufficient kick (ΔV), it could be hurled close to the target 3I/ATLAS (albeit the Ascending Node turns out to present difficulties).

There were other problems, however. Having solved this challenge using OITS, the natural question was, what practical use would it be? You see OITS assumes intercept can be achieved and since the sort of ΔV s necessary for Juno intercept of 3I/ATLAS were about equivalent to that available to a fully-fuelled Juno, it would seem unlikely that such an intercept could actually be realised, given the probe was coming to the end of its mission.

That is not to say that this work was entirely redundant since it emphasized the level of urgency if a mission were really going to happen, and furthermore that any extra research into this would need to be expedited, since for any mission at all to 3I/ATLAS to be viable, would require a Juno 'launch' (ie initial application of ΔV) as soon as possible. But how on Earth could the problem of getting as close as possible to 3I/ATLAS, as a dependency on remaining propellant, be solved?

At this point I had a 'Eureka' moment. I remembered some old work I had conducted for an article I wrote for, as it happens, Principium, go [here](#) to have a look. This was all to do with how much ΔV would be needed for the potentially hazardous object (PHO) known as Apophis, to send it on a collision course with Earth on 2029 April 13th, as opposed to missing it, as indeed will happen (it will miss by $\sim 31,000$ km).

The more insightful amongst you will realise the relevance of this latter research to the problem of getting Juno to approach 3I/ATLAS as closely as possible. All we have to do is surround 3I/ATLAS in an R million km radius, and find the minimum ΔV needed for Juno to enter inside this radius. Thus the two problems are fundamentally equivalent.

The Apophis software used three different software libraries:

1. NASA SPICE, to compute accurate initial ephemerides of all the relevant bodies.
2. REBOUND to integrate the trajectory forwards in time to see 'where things go'.
3. NOMAD which finds the minimum of a multivariate function subject to constraints.

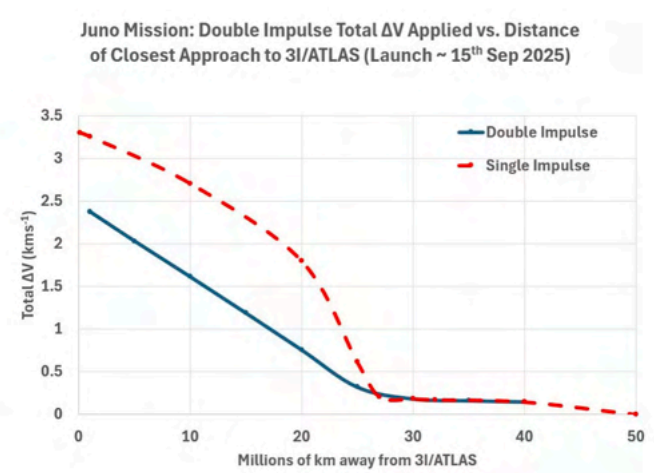
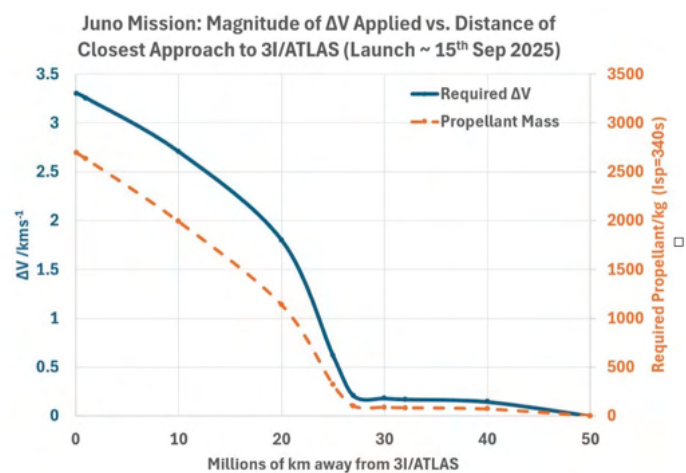
It was PRECISELY this combination of ingredients that I needed to solve the problem I was now presented with in the context of Juno, so I set to work modifying my previously constructed Apophis software accordingly.

The results were astonishingly rapidly derived (after all I reckon I am a talented astrodynamist), and it was extremely interesting to discover the answer to this question.

I provide three pertinent plots below.

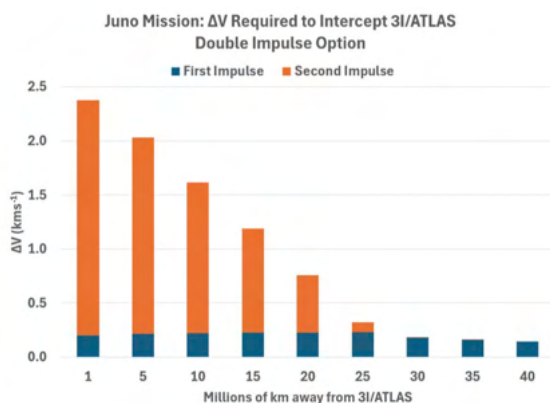
The first plot shows the ΔV (left vertical axis), and remaining propellant needed (right vertical axis), to approach within a certain distance of 3I/ATLAS (the previously mentioned radius, R). The launch is on September 15th, and subsequent analysis revealed that this required ΔV and propellant would increase steeply with delayed launch date (since the arrival of 3I/ATLAS would become more imminent). Thus the sooner the launch the better.

The second plot required further software adjustments so that I could expand the research to introduce TWO possible deliveries of the remaining ΔV , an initial fraction and then another portion at some 'intermediate point'. Thus we find that the double impulse scenario brings the required overall velocity increment down quite considerably compared to the single impulse scenario, allowing more to be accomplished from the mission on less propellant.



The third plot shows a comparison of the two impulse case with the single impulse, and we find that for values of $R > 27$ M km, there is no particular advantage of a second impulse.

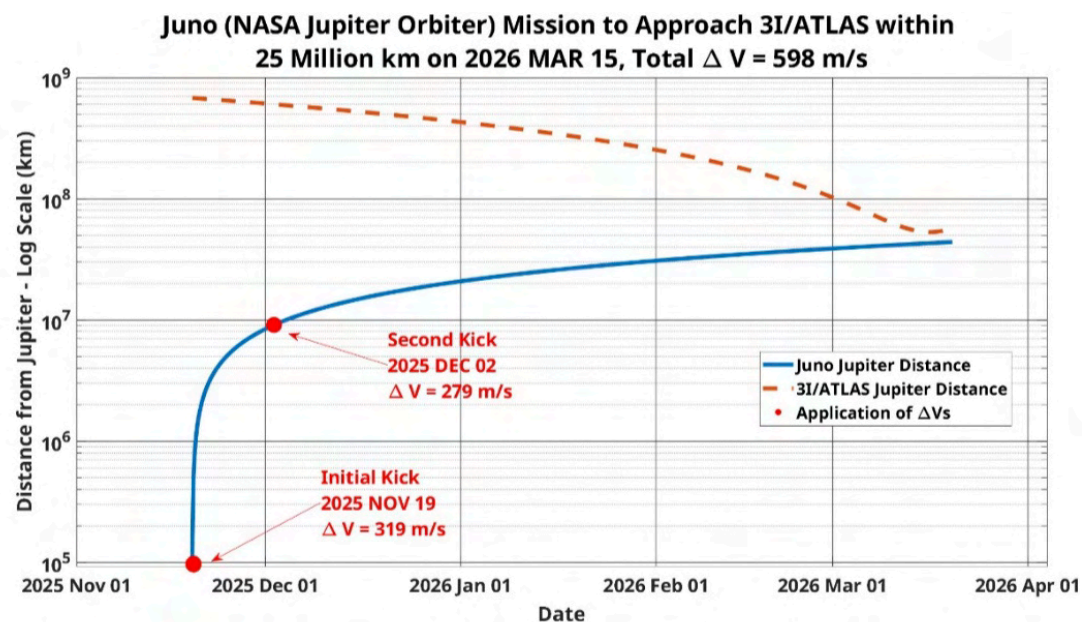
As far as scientific return is concerned, that is not my particular area of expertise, go to Marshall's paper [here](#) on the subject to expand on this.



Epilogue

As I write now, this Principium article is close to being published, so I think it would be useful to update the interested reader on my progress regarding the feasibility of a mission to 3I/ATLAS using Juno. So, to this end, the paper has now been published in the *Aerospace Journal*, do go [here](#) to read this fascinating analysis into the feasibility of Juno to intercept or get closer to 3I/ATLAS.

This also gives a prediction of how the overall ΔV to achieve this goal gradually increases with delayed launch time. Thus, the longer we delay, the more imminent the arrival of 3I/ATLAS gets, and so the greater the velocity needed by Juno to intercept it. In addition I was contacted by Tony Dunn, the celestial mechanics guru who tweets/posts extensively on twitter/X, and I decided to exploit more up-to-date Juno orbital data available from NASA SPICE (see above) to find a possible FUTURE mission to 3I/ATLAS. The result can be seen in the figure below, which shows the radial distance of Juno and 3I/ATLAS from Jupiter's centre over the course of the next few months.



What we find is another double impulse option is available to Juno with the initial kick on 2025 November 19th and a secondary kick on 2025 December 2nd. The magnitudes are 319 m/s and 279 m/s respectively, summing to a total of ~600 m/s. But is this doable? That would be a decision for NASA to make, but I have to honestly say I very much doubt it. The decision to choose the Juno trajectory as a possible mission to animate was a difficult one since as far as missions to 3I/ATLAS are concerned, opportunities are thin on the ground, if not positively non-existent. The direct approach is now defunct since the optimal transfer date has passed, and a Solar Oberth Manoeuvre (as investigated for Project Lyra), has now also expired as of September this year, [go here for an animation](#).

Thus ultimately the Juno option was posted and there was some criticism of this from certain commentators on Twitter/X, pointing out that the required ΔV was next-to-impossible, despite Tony emphasizing in his tweet/post that the animation was just fun orbital mechanics, not to be taken too seriously. Go [here](#) for the tweet.

As far as 3I/ATLAS being alien technology is concerned...is it? Well weirdness has multiplied with weirdness where this object is concerned, true, and it's kind of fun arguing the point, but not particularly productive nonetheless.