On Ultimately the Most Highly Inclined, the Most Concise Solar Polar Trajectory with Practically the Shortest Period

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Introduction

In 2009, the author presented the idea about how the concise, short period solar polar trajectory is built. It utilizes the Eccentricity-to-Inclination (E-2-I) conversion technique , which requests the repetition of multiple Earth (or Venus) gravity assists following the Jovian gravity assist.

By that time, Ulysses mission had been referred to as to accomplishing highly inclined solar polar flights. It successfully performed the mission.

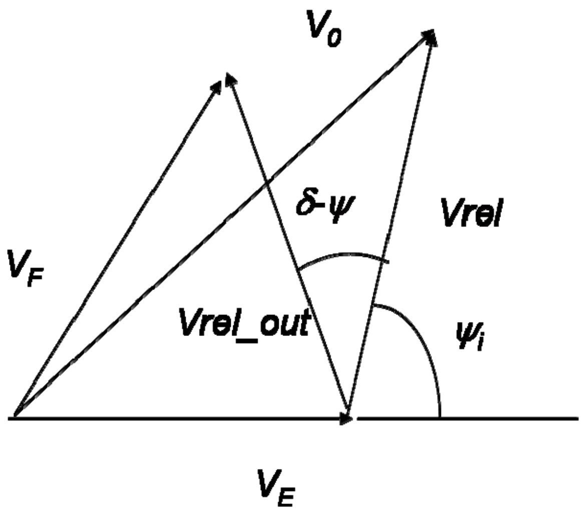
However, the major drawbacks revealed were in the fact that the spacecraft could not make frequent observations during the mission.
It failed to diminish the period.

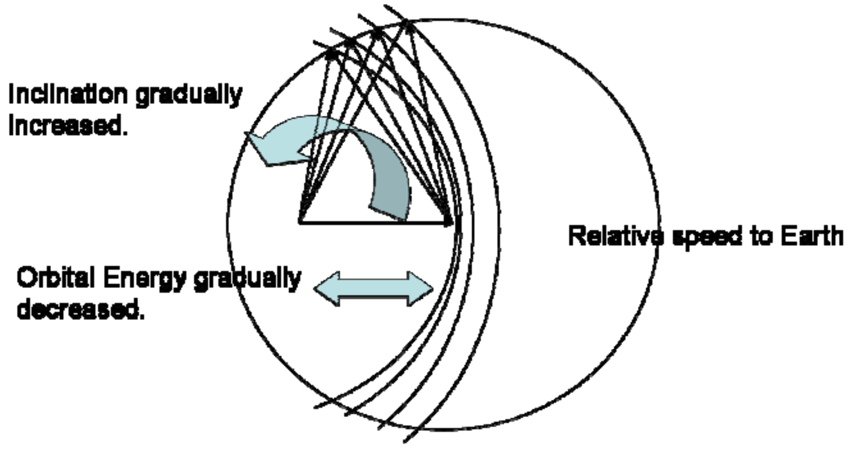
The Jovian swing-by enabled the inclination to be erect quite efficiently, but it results in very longer revolution periods that were hardly acceptable.

This paper presents how short-period, but erect trajectory is synthesized.

Preliminary and Fundamentals

Figure shows the technique of E-2-I conversion taking the advantage of Earth (or Venus) gravity assist. In this application, the perihelion distance should be preserved and the eccentricity be amended at the same time, which corresponds to the reduction of semi-major axis length. This in turn means the shorter revolution period. The strategies show a variety of trajectories.





Previous Results (2009)

5.5 AU is the best choice. Sensitive.

	Strategy-1	Strategy -2+, -2+U	Strategy V2+	Strategy V2+U
Sequences Evolution	• 65deg, 5.5 (1.5) AU in 2 years, • 67 deg, 3.2 (1.4) AU in 5 years, E1 • 70deg, 1.6 (1.2) AU in 8 years, E2 • 73deg, 1.2 (1.1) AU in 10 years, E3 • 78deg, 1 (1.0) AU in 13 years. E4, E5, …	• 30 deg, 5.5 (1.5) AU in 2 years, • 35 deg, 2.2 (1.4) AU in 5 years, • 39 deg, 1.0 (1.0) AU in 7 years, • 41 deg, 0.52 (0.7) AU in 8 years, • 41 deg, 0.26 (0.4) AU in 10 years.	• 42 deg, 5.5 (1.2) AU in 2 years, • 44 deg, 2.3 (1.1) AU in 5 years, • 45 deg, 1.6 (1.0) AU in 8 years, • 47 deg, 1.2 (0.9) AU in 9 years, • 49 deg, 1.0 (0.85) AU in 11 years. • 50 deg, 0.9 (0.8) AU in 13 years	• 39 deg, 5.5 (1.2) AU in 2 years, • 41 deg, 2.3 (1.1) AU in 5 years, • 42 deg, 1.6 (1.0) AU in 8 years, • 44 deg, 1.2 (0.9) AU in 9 years, • 46 deg, 1.0 (0.85) AU in 11 years. • 47 deg, 0.9 (0.8) AU in 13 years.
Observation Times	With NO scheduled Delta-V, Science Observation possible all the time.	With NO scheduled Delta-V but 27m/s. Science Observation possible all the time.	With NO scheduled Delta-V, Science Observation possible all the time.	With NO scheduled Delta-V, Science Observation possible all the time.

Pure Ballistic Fl[illegible]ble

5.3 AU lengthens flight time. Needs Optimization.

* 40m/s for raising altitude.

	Dates	Semi-Major Axis (AI)	Perihelion Distance (AU)	Period (Year)	Inclination (deg)	Delta-V at SW (m/s)	Swingby Alt. (km)	V-inf (km/s)
Launch	2015.11.19	5.27	0.99	N/A	2.3	0		10.30
1 (J)	2017.6.5	3.26	0.99	N/A	64.5	0	(933624)	(11.495)
2	2020.10.16	2.07	0.99	3	67.4	0	573	37.44
3	2023.10.16	1.58	0.99	2	70.0	0	1587	37.44
4	2025.10.16	1.31	0.99	1.5	72.6	0	2533	37.44
5	2028.10.16	1.16	0.99	1.25	74.6	0	5431	37.44
6	2033.10.16	1.00	0.98	1.0	77.6	0	1628	37.44
7	2034.10.16	0.86	0.72	0.8	81.5	(0)	(61)	37.44
8	2038.10.16	0.76	0.53	0.67	85.9	(0*)	(-56)	37.44
9	2040.10.16	0.71	0.42	0.60	89.0	0	2093	37.44

The 7th and 8th swing-bys are not well optimized, and the swing-by distance is not assured. It is true that some small delta-V may be required.

Flight with Chemical Propulsion

	Dates	Semi-Major Axis (AI)	Perihelion Distance (AU)	Period (Year)	Inclination (deg)	Delta-V at SW (m/s)	Swingby Alt. (km)	V-inf (km/s)
Launch	2015.11.19	5.27	0.99	N/A	2.3	0		10.30
1 (J)	2017.6.5	3.26	0.99	N/A	64.5	0	(933624)	(11.495)
2	2020.10.16	2.07	0.99	3	67.4	0	573	37.44
3	2023.10.16	1.58	0.99	2	70.0	0	1587	37.44
4	2025.10.16	1.21	0.99	1.33	73.0	374	234	37.05
5	2029.10.16	1.0	0.98	1.0	76.4	96	231	36.95
6	2030.10.16	0.86	0.72	0.8	80.3	0	204	36.95
7	2034.10.16	0.76	0.53	0.67	84.2	77	243	36.87
8	2036.10.16	0.71	0.42	0.6	87.3	0	3223	36.87
9	2039.10.16	0.67	0.35	0.56	90.1	0	4266	36.87
10	2044.10.16	0.63	0.26	0.5	94.8	0	504	36.87
11	2045.10.16	0.59	0.18	0.45	100.4	108	231	36.76
12	2050.10.16	0.56	0.13	0.42	107.1	134	237	36.62

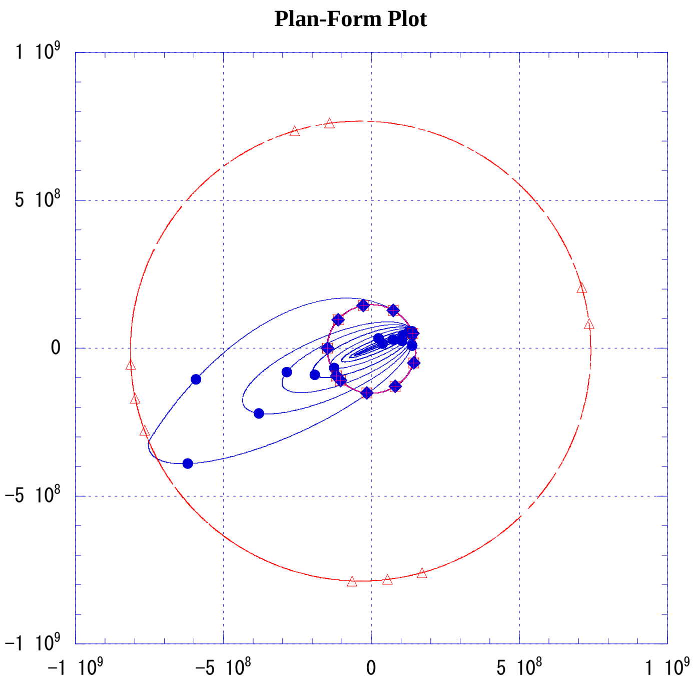
This shows an alternative trajectory that is not ballistic but with chemical delta-Vs. 800 m/s.

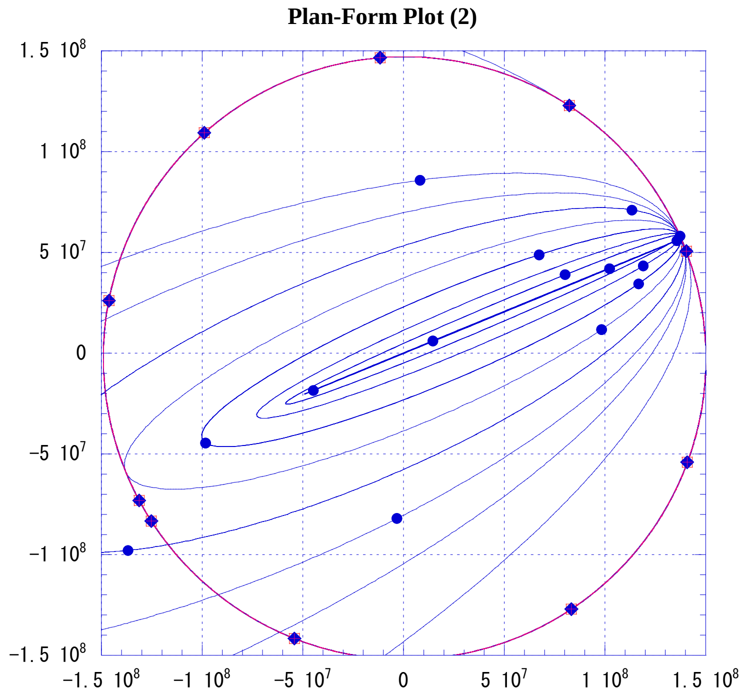
Flight with Electric Propulsion

	Dates	Semi-Major Axis (AI)	Perihelion Distance (AU)	Period (Year)	Inclination (deg)	Delta-V at SW (m/s)	Swingby Alt. (km)	V-inf (km/s)
Launch	2015.11.19	5.27	0.99	N/A	2.3	0		10.30
1 (J)	2017.6.5	3.26	0.99	N/A	64.5	0	(933624)	(11.495)
2	2020.10.16	2.07	0.99	3	67.4	0	573	37.44
3	2023.10.16	1.58	0.99	2	70.0	0	1587	37.44
4	2025.10.16	1.21	0.99	1.33	73.0	0	2533	37.44
5	2028.10.16	1.0	0.98	1.0	73.8	1497	225	35.88
6	2029.10.16	0.82	0.65	0.75	75.4	1233	223	34.59
7	2032.10.16	0.76	0.53	0.67	77.8	0	4544	34.59
8	2034.10.16	0.71	0.42	0.60	80.5	0	3334	34.59
9	2037.10.16	0.63	0.26	0.50	79.8	1946	211	32.55
10	2038.10.16	0.58	0.17	0.44	83.9	1801	224	32.36
11	2042.10.16	0.54	0.088	0.40	79.2	2188	218	30.05
12	2044.10.16	0.53	0.058	0.33	81.5	0	5075	30.05

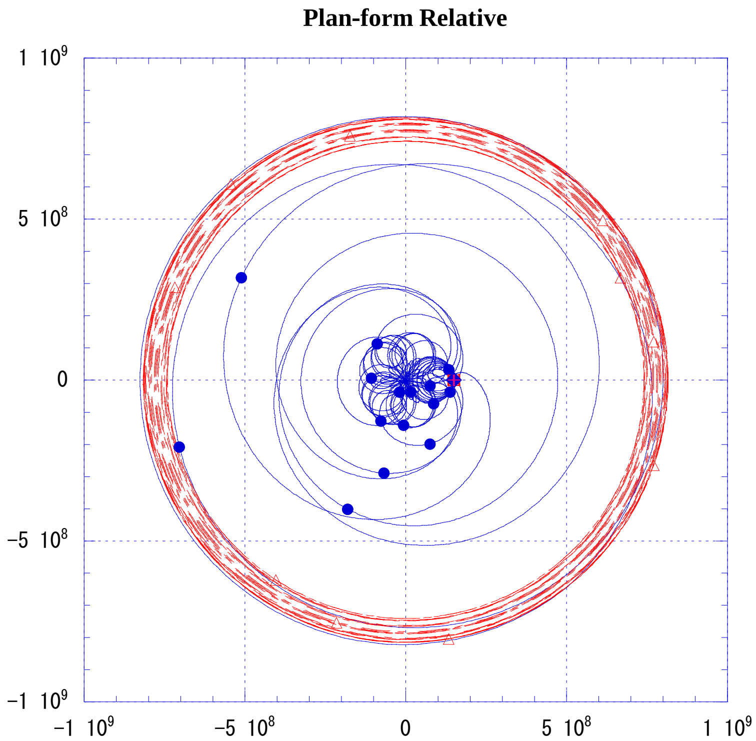
This sequence costs almost 7.7 km/s by the end of the long mission.

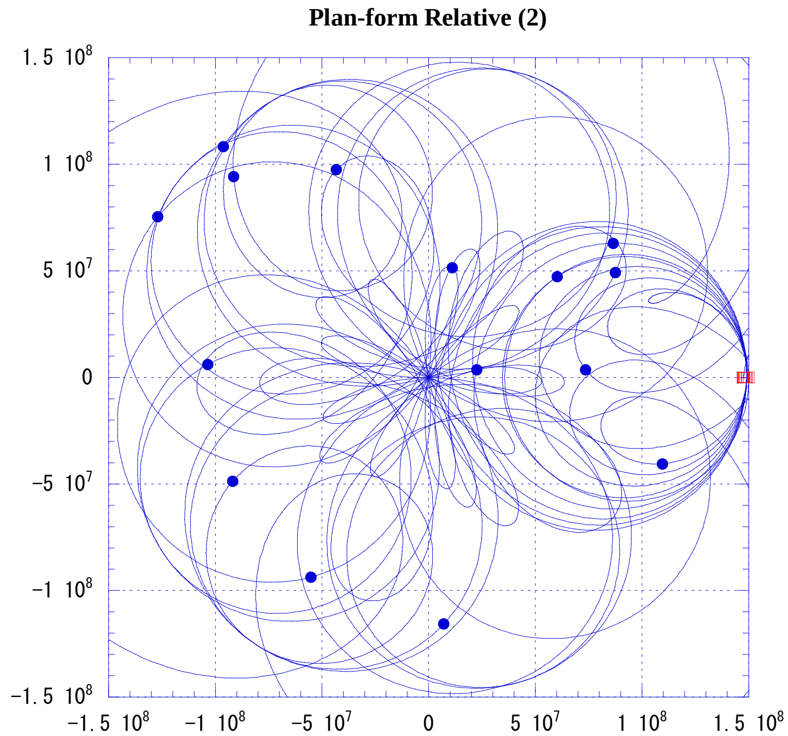
Trajectory Plot in Plan-form (Inertial)



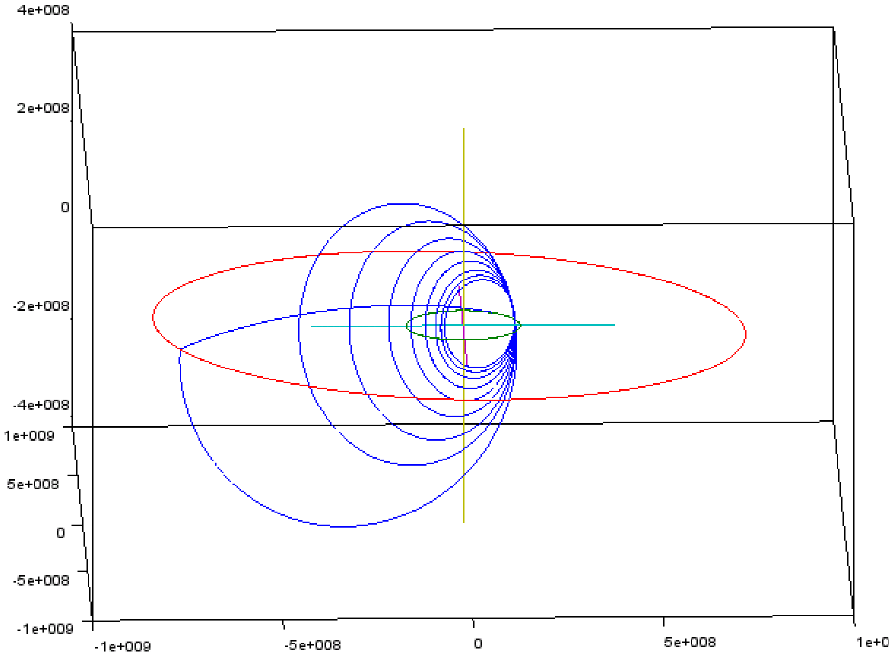


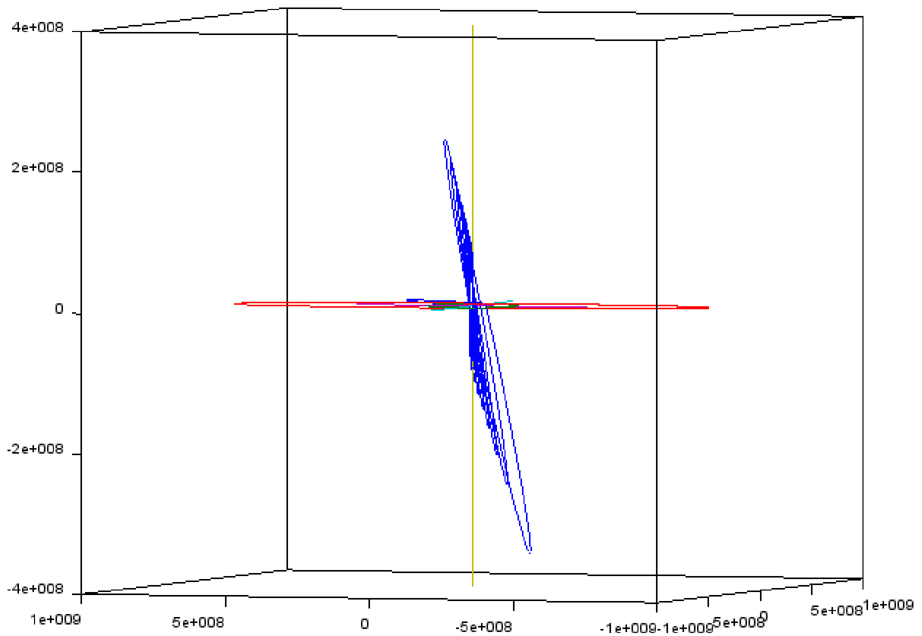
Trajectory Plot in Plan-form (S-E Line Fixed)





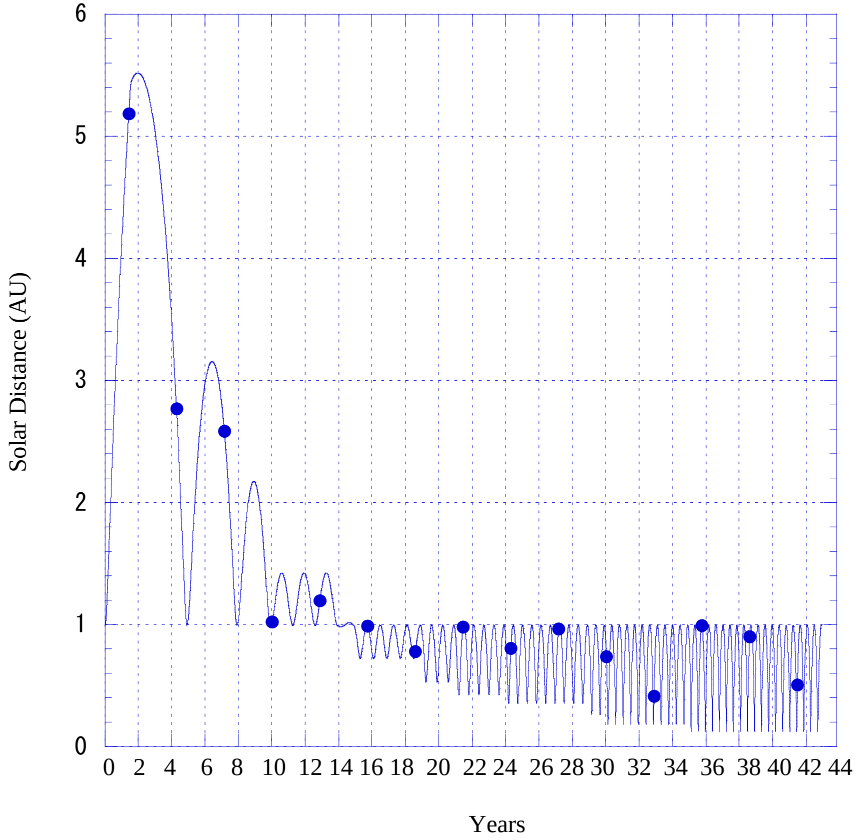
Trajectory Plot in 3D (Inertial)



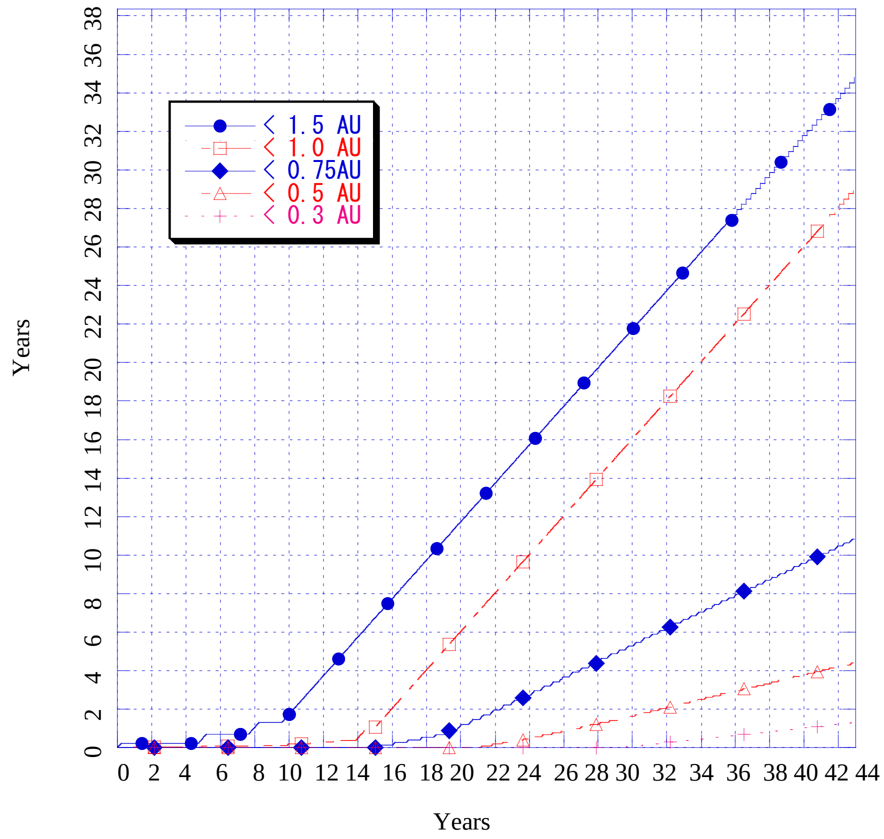


History of Distance from Sun (AU) and Stay Period (Years)

Solar Distance (AU)



Observation Days



What was presented :

This paper presents the extended orbital synthesis results from the author's work in 2009 to achieve ballistic and short period out-of ecliptic trajectories which possess ultimately the most highly and most concise solar polar properties.

Further sequences that make the perihelion distance even lower than one tenth AU with the shortest period and the highest inclination.

Those are realized through almost ballistic flight . The contents here deal also with the use of chemical and electric propulsion.

The strategy developed utilizes a Jovian gravity assist first, followed by very high speed synchronized multiple polar gravity assists by Earth. This utilizes very high speed gravity assist.

The paper presents those still effectively contribute to amending the trajectories periods, in other words, to diminishing the size of them, which leads to acquiring small sized out-of-ecliptic ballistic trajectories.

The process simply converts orbital energy or eccentricity to inclination. (E-2-I Conversion)

The biggest advantage of this strategy is to reduce propellant mass to be carried drastically, even close to zero, like ballistic flight.

Concluding Remarks

The flight sequence presented here shows the new strategies to have the most concise, the shortest period, the highest inclined orbit is synthesized .

The author previously presented the sequence using Venus. However, targeting precise swing-by with respect to the Venus is hardly practical from the navigation accuracy point of view. So, the paper here does not provide those sequence.

And the author also presented before about the use of the combination of both Venus and Earth instead of the use of Jupiter. This paper did not refer to them, as the highest inclination is the primary focus of the paper.