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MULTIPLE ENCOUNTER MISSIONS WITH THE TROJAN AND MAIN BELT ASTEROIDS

David F. Bender and Paul A. Penzo

Jet Propulsion Laboratory,
California Institute of Technology

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The clustering of 180 Trojan asteroids along the orbit of Jupiter about equally divided between the L4 and L5 libration point regions allows opportunities for double flybys of two asteroids in either group on a single trajectory from Earth. Also each passage through the main asteroid belt can generally include an additional flyby. Thus trajectories with four asteroid flybys in five years are obtained. A computer program that indicates possible pairs of Trojans for such a trajectory has been successful in locating about eight trajectories per year from 1998 through 2008 which require only a small impulse to approach the second Trojan after a launch with a C3 of about 80 km^2/s^2 to reach the first. The technique used for determining candidate pairs of Trojans is described and tables of examples of these trajectories are presented. In addition the technique of using a Jupiter flyby to obtain a trajectory for rendezvous with a Trojan asteroid is described and examples of such trajectories are presented. In all cases the use of a two year delta-V Earth gravity cam significantly improve the performance and include another asteroid flyby. The spacecraft mass attainable using the MEDLITE launch system is determined for the examples of all four types of trajectories..

INTRODUCTION

The Trojan asteroids reside in the L4 and L5 regions of the Sun-Jupiter system (locations centered 60 from degrees of Jupiter, leading and lagging it). They are important clusters of main-belt sized objects, and their number, as detected from Earth, has increased significantly in recent years. Though they are farther from the Sun than the main belt asteroids, and so more difficult to reach, this is compensated for by their clustering property, which provides a possibility of multiple encounters.

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+ Member of the Technical Staff, Missions and System Architecture Section, Jet Propulsion Laboratory, California Institute of Technology

++ Member of the Technical Staff, Navigation and Flight Mechanics Section, Jet Propulsion Laboratory, California Institute of Technology

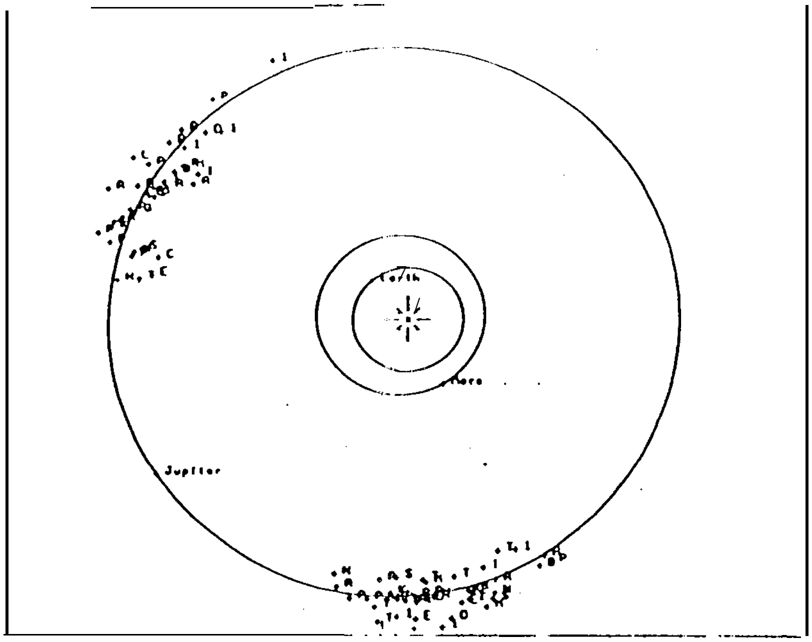

Figure 1 **Jupiter and 80 Trojan Asteroids on Feb. 1, 1994**
Ecliptic Plane Projection

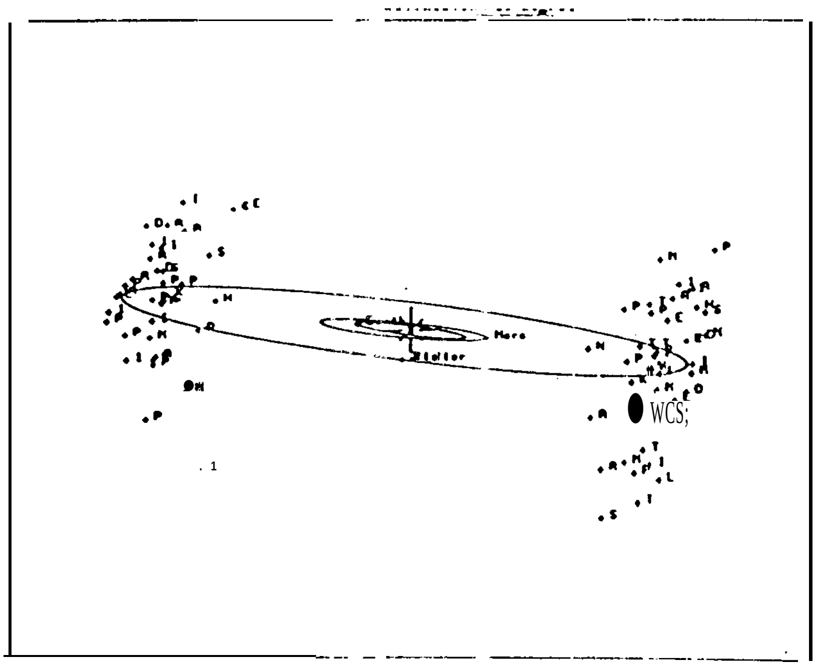

Figure 2 **Jupiter and $0 Trojan Asteroids on Feb. 1, 1994**
Inclined View 15 degrees

The clustering property is illustrated in Figure 1, which is an ecliptic plane projection of the positions of eighty Trojans on a particular date, Feb. 1,. 1994 (Ref. 1). The position of each Trojan is indicated by a "+" and the first letter of its name. As of June 1995 there are 115 numbered Trojans and 70 unnumbered ones (of less certain orbital elements). Figure 2 includes the same set of eighty Trojans as seen from a view point fifteen degrees above the ecliptic and with Jupiter in the foreground which shows that the inclinations extend to above 30 degrees. In fact the distribution in inclinations is remarkably flat out to 25 degrees and there are as many Trojans with inclination above 14.5 degrees as there are below it.

The major purpose of this study is to explore the possibilities of multiple Trojan asteroid encounters, expecting that they will be numerous because of the clustering property. This is indeed the case, and because the spacecraft will pass through the main asteroid belt twice in one revolution opportunities to include two main belt objects will produce a four asteroid flyby trajectory that has a flight time of about five years. In the final section the technique of obtaining a rendezvous trajectory for a Trojan asteroid with the aid of a Jupiter gravity assist flyby is described. In presenting the data a MEDLITE launch vehicle is used to determine the mass of the spacecraft that can be devoted to science, control, and communication both for the direct trajectories as described, but also for the cases when the launch is replaced with at two-year delta-V Earth gravity assist.

AUTOMATED SEARCH FOR PAIRS OF TROJAN TARGETS

The trajectory that can encounter two Trojan asteroids with the least launch energy would have to be launched with perihelion at launch and would have to lie in the ecliptic plane. It would encounter each Trojans at its node. Such a trajectory is shown in Figure 3 where L represents the launch (at one AU); A and B the locations of the two encounters, (types 1 and 2 respectively); and Q the aphelion of the trajectory (at Q AU). Note that the angular speed of the spacecraft near its aphelion is much slower than that of the Trojans and hence that the encounter at A will be with a Trojan that may lead the second Trojan by some tens of degrees in their orbits around the Sun. For Q=5.2 AU the angular rate of the spacecraft at aphelion is .047 deg/day and the speed is 7.42 km/s while for Jupiter or an average Trojan these rates are .083 deg/day and 13.1 km/s. Thus one will expect flyby speeds of not less than 6 km/s as for the case of low energy trajectories to Jupiter.

In the computer a specific value of Q is adopted and it is assumed that the Spacecraft may encounter the asteroid at either A or B and that either one can be either the ascending node or the descending node. Thus for each node of each asteroid (of a group) during the specified time interval there will be four lines in the file produced. The L4 and L5 groups arc processed separately. Each line contains the trajectory type, the time of flight, the asteroid encountered, and the date and longitude of launch at one AU.

This file is now processed by a second program which computes the longitude of the , . Earth at the time given, and only those cases for which the Earth is within a specified angle of that required is the case kept. This angular separation has been set at 30.0 deg. (No investigation has yet been made to determine if this is the best choice.) This new file of selected possibilities is now sorted on launch date and printed for visual selection of possible pairs of targets. For both groups of Trojans files were made for each of the following values of Q: 5.0,5.2,5.3, and 5.4 AU.

As is indicated by Figure 2 the distribution of inclinations of the Trojans extends to quite high values. It is nearly flat out to 25 degrees and there are as many cases with inclination above 14.5 deg as there are below Still there are some with low inclination and it is not necessary to limit flybys of them to the nodes in this study. Consequently arrivals near the node in both directions were provided for in the program. A number of arrivals at plus and minus 3N deg were added up to N= 10 or to a latitude of one degree above or below the ecliptic. Note that it requires a little over a month for a Trojan to travel 3 degrees.

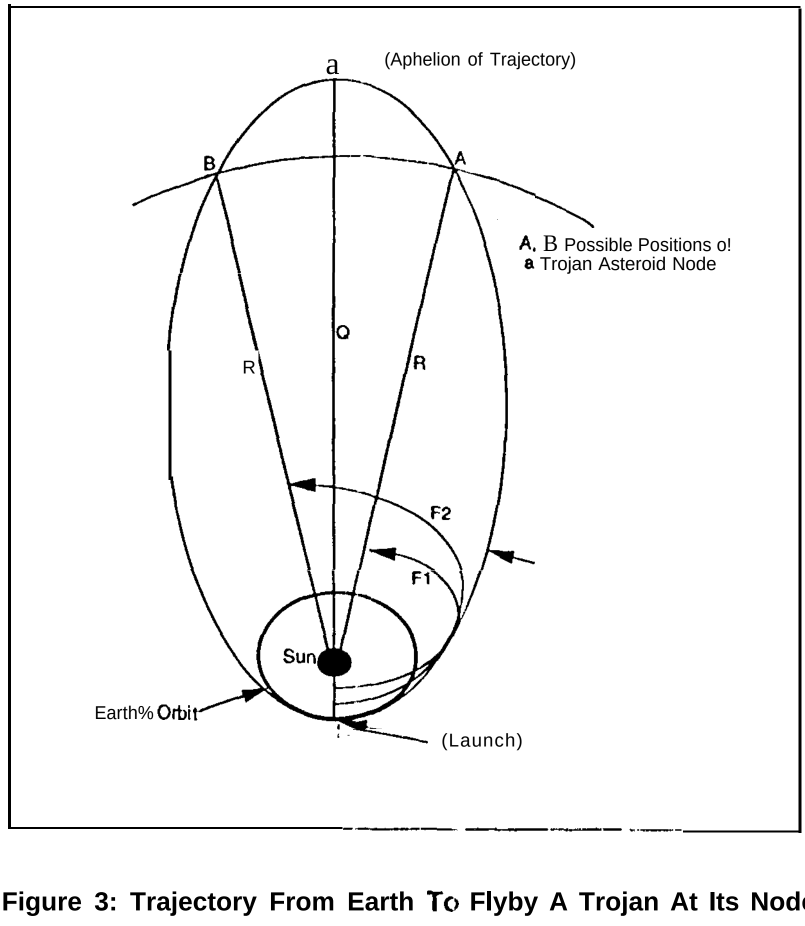

Figure 3: Trajectory From Earth To Flyby A Trojan At Its Node.

The data in the final tables was, as expected. arranged in sets covering from 80 to 140 days corresponding to low energy launch opportunities to the various members of the group(L4 or 1.5 region Trojans) under consideration. The tables used were only those with the lower values of the aphelion distance so as to minimize the launch energy that would be required. For the 5.2 AU case there would be from 2 to 5 different asteroids requiring a type' 1 transfer and at least as many requiring the type 2 transfer. It was a simple matter to test each pair and to discover which ones required the least delta-V to encounter the second one after passing the first. For most pairs the impulse was high but for about 10 percent of the pairs the it was under 200 m/s. The final choices shown in the tables were from a spotty distribution (in time). Numbered Trojans were preferred over unnumbered ones, and the larger ones over the smaller ones.

ADDING MAIN BELT TARGETS

Once a trajectory for a double flyby of two Trojan asteroids has been obtained the outbound leg can be searched for close flybys of asteroids. The asteroids considered are the currently listed 6465 numbered asteroids as well about 5000 somewhat less reliable cases of unnumbered objects of at least two oppositions. The closest asteroid to the trajectory was generally within 4 gigameters (=.027 AU), which is small enough so that the required extra delta-V is of the order of 100 m/s. For the target one chooses a numbered asteroid over an unnumbered one and one as large as can be found, and a new trajectory is determined that includes flybys of three asteroids. To find a fourth target on the return toward the Earth's orbit, the trajectory is propagated as a conic beyond the second Trojan and searched for close approaches as before. Finally a third trajectory is determined that includes four asteroid flybys. The total flight time from Earth is about five years and the post launch deRa-V is of the order of 200 m/s above that for just the Trojan pair. . The trajectory continues to near the Earth's orbit and returns eventually to Jupiter's orbit, but further use of it is not contemplated here.

The trajectories considered included launches from 1998 through 2008 and all that are shown contain four flybys. They are grouped in two separate tables: Table 1 for L4 Trojans and Table 2 for L5 Trojans. Each trajectory is described in two lines and five columns for the launch and the four flybys. The Trojan asteroids are thus in the third and fourth columns. Estimated spacecraft masses are obtained for each trajectory as described below and these are given in the first data column of Tables 3 and 4 for L4 and L5 Trojans respectively.

Table 1
L4 TROJAN ASTEROID MISSION OPPORTUNITIES

Traj.	Launch and PLDV	**Target 1**	**Target 2**	**Target 3**	**Target 4**
	Date C3 *DLA PLDV*	*Name No. Radius* *Time Flyby Speed*	*Name No. Radius* *Time Flyby Speed*	Name No. *Radius* *Time Flyby Speed*	*Name No. Radius* *Time Flyby Speed*
4A	*08106/98 78.8* km^2/s^2 *11.9* deg *588* m/s	Fabiola 1576 15.8 km 219 days 12.6 kin/s	Stentor 2146 24.7 km 914 days 8.5 km/s	Palamedes 2456 51.5 km 1122 days 6.8 km/s	Geisei *2571 4.3 km* *1762* days 11.4 km/s
4B	*10/3 1/00 80.9* km^2/s^2 *10.3* deg 413 m/s	Korolev 1855 5.4 km 150 days 16.5 kin/S	*4523* P-L(13920) *15.6 km* *797* days *6.9* km/s	Kalchas 4138 29.8 km 1399 days 6.3 km/s	Bavaria 301 27.8 km 1995 days 14.8 km/s
4C	11/06/01 85.9 km^2/s^2 *26.2* deg *290* m/s	Ostara *343 10.3* km 212 days 10.4 km/s	Kalchas 4138 29.8 km 814 days 6.6 km/s	Philoctetes 1869 17.1 km ! 304 days 5.7 km/s	Phaeton 3200 3.5 km 22! 8 days 44.0 km/s
4D	*03/21/06 78.7* km^2/s^2 *-27.2* deg 457m/s	Buxtehude 4344 8.6 km 285 days *10.3* km/s	Thessandrus 490234.2 km 996 days 5.9 km/s	*1973* SO1(10101)20.6 km 1151 days **6.0** km/s	Gyldenis 80632.6 km 1668 days 11.3 km/s
4E	*03/05/05 89.8* km^2/s^2 *-3.4* deg *431* m/s	Ruzena 1856 5.2 km 142 days 14.5 km/s	Hektor 624 112.5 km 894 days 6.9 km/s	Kalchas 4138 29.0 km 1373 days 7.4 km/s	Graff 3202 23.6 km 1642 days 9.1 km/s
4F	*04/! 8/06 81.0* km^2/s^2 -23.4 deg 275 m/s	Ushakov 301 O 9.9 km 229 days !2.2 km/s	*4523* P-L(13920) *15.6 km* *769* days *6.4* km/s	Eurymedon *501220.6 km* 1396 days *7.9* km/s	Alois 3045 14.3 km 1817 days 14.7 km/s
4G	*04127107 80.6* km^2/s^2 -21.6 deg 251 m/x	Voznesenski 37233.3 km 155 days 13.3 km/s	Thersites *1868 37.5 km* *623* days *8.7* km/s	Philoctetes 186917.1 km 1323 days 7.3 km/s	Behounek 3278 17.8k 1784 days 12.4 km/s
4H	05/11/08 78.6 km^2/s^2 17.4 deg 227 m/s	Vitja 1030 32.7 km 346 days 11.1 km/s	Odysseus 1143 67.5 km 761 days 7.2 kill/s	Yarnatotaker 525827.1 km 1202 days 8.3 km/s	Lutetia21 49.7 km 1758 days 15.2 km/s

Table 2
L5 TROJAN ASTEROID MISSION OPPORTUNITIES

Traj.	Launch and PLDV	Target 1	Target 2	Target 3	Target 4
	Date C3 *DLA PLDV*	*Name No. Radius* *Time Flyby Speed*	*Name No. Radius* *Time Flyby Speed*	*Name No. Radius* *Time Flyby Speed*	*Name No. Radius* *Time Flyby Speed*
5A	03126/98 83.9 km²/s² -17.0 deg 219 m/s	Parvati 2847 5.4 km 126 days 15.1 km/s	Pandarus 2674 51.0 km 787 days 6.3 km/s	1988 RN11(1 1727) 10.8 km 1535 days 5.9 km/s	Fanatica 15896.8 km 2134 days 16.8 km/s
5B	03(27/98. 76.8 km²/s² -24.0 deg 172 m/s	Laputa 1819 22.3 km 197 days 15.7 km/s	Glaukos 1870 13.6 km 897 days 5.9 km/s	1988 RH11(11725) 5.9 km 1246 days 7.6 km/s	Yaronika 34705.2 km 1780 days 11.6 km/s
5C	0313 1/98 78.7 km²/s² -10.3 deg 215 m/s	1976 QP(10457) 1.7 km 150 days 17.2 km/s	Pherecles 2357 51.5 km 885 days 5.7 km/s	1988 RH11(11725) 5.9 km 1331 days 7.8 km/s	Graz 2806 10.1 km 1894 days 15.0 km/s
5D	05/12/99 85.6 km²/s² -0.7 deg 259 m/s	Sarahill 3065 11.8 km 247 days 13.3 km/s	Sarpedon 2223 52.5 km 823 days 6.4 km/s	Dares 4827 25.9 km 1401 days 7.5 km/s	Mavis 1607 7.4 km 1878 days 19.5 km/s
5E	08/1 9/02 82.7 km²/s² 28.4 km/s 286 m/s	Hermod 2630 11.8 km 256 days 11.3 km/s	Memnon 2895 37.5 km 836 days 7.7 km/s	Polites 4867 35.8 km 1226 days 7.5 km/s	ASP, 2848 12.6 km 1669 days 11.8 km/s
5F	09104103 79.5 km²/s² 26.9 deg 258 m/s	Barucci 3485 6.6 km 250 days 12.6 km/s	Antenor 2207 46,3 km 825 days 6.2 km/s	Misenos 4828 28.4 km ! ! 96 days 6.9 km/s	1986 QO 4697 3.1 km ! 825 days ! !.3 km/s
5G	!1/22/06 76.2 km²/s² 8.6 deg 241 m/s	Chang 205 !12.6 km 275 days 12.0 km/s	3108 T-3(14466) 13.6 km 775 days 7.0 km/s	1990 VU1 5648 39.2 km 1237 days 7.0 km/s	Werra 1302 20.6 km 1631 days 9.8 km/s
5H	12/25/07 75.8 km2/s2 8.2 deg 768 m/s	Merapi 536 79.0 km 381 days 11.9 km/s	1988 SG3(1 1755) 9.0 km 728 days 8.0 km/s	Asteropaios 480525.9 km 1014 days 680 km/s	Dido 209 74.5 km 1786 days 12.9 km/s

Table 3
ESTIMATED SPACECRAFT MASS USING MEDLITE
L4 REGION TRAJECTORIES(Direct and DVEGA with Asteroid Flyby)

Traj. Trojan Targets	Direct Case from Table 4	With Preceding Two Year DVEGA DVEGA Launch and PLDV		Target O	Spacecraft
	Mass Type	*Date C3* *Time*	*DLA PLDV*	*Name No. Rad.* *Time Flyby Speed*	*Flight Time* *Mass*
4A Stentor - Palamedes	73.1 kg	Not Considered			
40 4523 P-L - Kalchas	74.7 kg	2+ -761 days	10/01/9 29.7 km^2/s^2 31.9 deg 1,241 m/s	Meinel 4065 2.5 km -319 days 6.8 km/s	*7.54 years* *143.2* kg
4C Kalchas - Philoctetes	71.1 kg	2+ -758 days	i O/i O/99 29.3 km^2/s^2 31.6 deg 1,230 m/s	1968 FJ 41363.3 km -496 days 8.1 km/s	8.15 years 145.7 kg
4D Thessandrus -1973 S01	78.3 kg	2+ -774 days	02/05/04 27.7 km^2/s^2 -20.7 deg 1,122 m/s	Kulik 2794 4.0 'km -324 days 5.4 km/s	6.68 years 162.0 kg
4E Hektor - Kalchas	64.4 kg	2+ -771 days	01/12/03 28.7 km^2/s^2 -26,5 deg 1,039 m/s	Ots 3738 4.7 km -589 days 9.0 km/s	6.61 years 163.6 kg
4F 4523 P-L - Eurymedon	82.7 kg	2- -68 ! days	06{-1/04 27.4 km^2/s^2 =1.5 deg 999 m/s	Wolff 5674 3.8 km -405 days 4.9 km/s	6.87 yrars 171.7 kg
4G Thersites - Philoctetes	84. I kg	2- -687 dats	06109105 27.2 km^2/s^2 -1.6 deg 872 m/s	Yi Xinh 1972 3.6 km -428 days 8.0 km/s	6.77 years 182.4 kg
4H Odysseus - Yamatotaker	88.5 kg	2- -693 days	06/1 8/08 30.1 km^2/s^2 5.7 deg 949 m/s	Wurm 1785 4.9 km -387 days 5.0 km/s	6.72 years 162.6 kg

Table 4

ESTIMATED SPACECRAFT MASS USING MEDLITE
L5 REGION TRAJECTORIES(Direct and DVEGA with Asteroid Flyby)

Traj.	Trojan Targets	Direct Case from Table 5	With Preceding Two Year DVEGA: DVEGA Launch and PLDV		Target O	Spacecraft
		Mass Type	*Date C3* *Time*	*DLA PLD V*	*Name No. Rad.* *Time Flyby Speed*	*Flight Time* *Mass*
5A	Pandarus . 1099 RN 11	80.8 kg	Not Considered			
5B	Glaukos - 1988RH11	93.9 kg	Not Considered			
SC	Phereclos -1988 RH 1 !	90.2 kg	Not Considered			
SD	Sarpedon - Dares	76.7 kg	2+ -767 days	04/05/97 28.8 -17.0 deg 970 m/s	1986FX4 61803.3 km. -270 dats 10.5 km/s	7.24 years 175.9 kg
5E	Memnon - Polites	76.9 kg	2+ -770 days	07/1 0100 28.8 km²/s² 7.0 deg 793 m/s	Chiara 4398 4.5 km -366 dats 5.8 km/s	6.67 years 182.0 kg
5F	Antenor - Misenos	*85.9 kg*	2- -682 days	! 0/22/0 ! 27.4 km²/s² 17.1 deg 1,074 m/s	Saheki 4606 4.9 km -282 days 6.3 km/s	6.94 years 189.1 kg
5G	3108 T-3 - 1990 VU!	*91.7* kg	2- -690 days	01/01/05 25.2 km²/s² -3,7 deg 1,174 m/s	Chang 205: 12.6 km -275 dats 6.0 km/s	6.36 years 194.0 kg
5H	1988SG3 - Asteropaios	70.2 kg	2+ -772 days	11/13/05 27.0 km²/s² 1 1/13/05 1,471 m/s	Voznesnksi 37233.3 km -250 days 8.2 km/s	7.00 years 167.4 kg

When a two year DVEGA (Delta-V Earth Gravity Assist) trajectory is used to replace the launch an asteroid flyby can be obtained near the impulse point at about 2.2 AU from the Sun. The delta-V can be at the asteroid if it is at the right place at the right time or it can be before or after the flyby if need be. The DVEGA trajectories with an asteroid flyby for all case of Tables 1 and 2 with launches in 1999 or later are shown Tables 3 and 4. The last column of each table contains the flight time in years and the mass of the MEDLITE spacecraft that could be flown on the trajectory. All the times given in days in the Tables 1, 2, 3, and 4 are in days from the launch dates shown in Tables 1 and 2. Figure 5 is an ecliptic plane projection of trajectory 5E with the DVEGA.

SPACECRAFT MASS ESTIMATION

The estimation of the mass of the spacecraft that can be placed on each of the trajectories shown is based on using a MEDLITE launch vehicle and an advanced chemical propulsion system for all impulses after the launch. The capability of the launch system is shown in Figure 4: New Millennium Launch Vehicle Capability(Ref. 3). The launch vehicle used here is the Delta-Lite (Star 37) + SSRMs for trajectories out to 5.2 AU.. .When the C3 is above 40 km^2/s^2 the mass launched is taken to 215 kg and the additional impulse to provide the required amount of launch energy has to be supplied by the chemical propulsion system. This requires an additional impulse of about 1.6 km/s. For the trajectories shown in this paper the post launch delta-V varies from 900 m/s to more than 3000 m/s. In the absence of referable propulsion system properties the following characteristics are assumed: The ISP of the fuel is 311 sec., the mass of the engine and supports is 20 kg., and the fuel is carried in tanks whose mass is 15°/0 of that of the fuel. The post launch delta-V was increased by 100 m/s to allow for navigation. . For all DVEGA cases the navigation delta-V was increased to 150 m/s. The masses shown do not include the emgine and propulsion system, they are just the spacecraft with control, science, and communication.

TROJAN RENDEZVOUS TRAJECTORIES

It is possible to provide a trajectory to rendezvous with a Trojan asteroid by means of a Jupiter gravity assist, but the flight time will be quite long, a minimum of about ten years. The Jupiter flyby places the spacecraft in an orbit like that of the target and in the target's orbital plane. The spacecraft then has simply to gain on the target if it is an L4 object or to let the target gain on the spacecraft if it is an L5 object. This can take nearly a whole revolution of the spacecraft. The departing speed form Jupiter will have to be reduced significantly below the 6 km/s approach speed (the lowest possible on trajectories from the Earth) unless the target is significantly inclined, so inclined orbits will be favored as well as those which happen to be as close to Jupiter in longitude as possible In fact the only target Trojan for which no delta-V along the trajectory was found except the rendezvous impulse was Cebriones, 2363, which has an inclination of 32.2 degrees. A determination of the dates at which Jupiter passes the nodes of a target Trojan allows a choice of launch year and flight time for the Earth to Jupiter leg.. The second leg of the trajectory will have a perihelion near 4 AU if the target asteroid is leading(an L4 Trojan) of an aphelion near 6 AU if the target is trailing(an L5 Trojan). Such a trajectory to any one inclined Trojan asteroid will occur every six years since either the ascending or the descending node may be employed. Low energy Earth to Jupiter flight times can differ by more than a year for any launch year so that a particular date at Jupiter may be available after a two or a three year flight. That is to say any arrival date at Jupiter will generally be available. The nodes of the orbits of the Trojans lie in the range of 35 to 100 degrees either ahead of or behind Jupiter(Ref 1). The distribution of the ascending nodes around the ecliptic is roughly uniform but with a few more in the fourth quadrant than in the other three. Since every Trojan asteroid is reachable on one of these trajectories one expects to find a uniform distribution of launch years for Trojans as rendezvous targets. For Trojans of low inclination such as Phereclos, 2357, the Jupiter gravity assist is not restricted to the node, but a significant reduction in the Jupiter relative velocity is needed.

A set of seven Trojan rendezvous trajectories obtained by means of a Jupiter flyby is shown in Table 5. There are three to two different L4 objects and four to four different L5 objects. The remarkable case of Cebriones for which the only post launch delta-V is that of the rendezvous at 527 m/s is included. Figures 7 and 8 are ecliptic plane projections of trajectories 4Q and 5T which refer to Hektor and Cebriones respectively.

These rendezvous trajectories may also be preceded by a two year DVEGA. Such trajectories were first suggested by Chen Wan Yen(Ref 2), except that she considered only L5 targets. The trajectories obtained by using two year DVEGAs are shown in Table 6. It is possible to add two asteroid flybys on these trajectories as was done for the outbound and EGA sections for the Trojan flybys. It is even conceivable that a flyby could be found on the Jupiter to target leg for L4 Trojans.

CONCLUSIONS

A special technique has been developed which enables one to locate pairs of Trojan asteroids in either the L4 or the L5 region which can be approached on a single trajectory. By means of adding a two year Delta-V Earth Gravity Assist and finding asteroids to flyby on the delta-V leg, the outbound leg, and the inbound leg trajectories have been generated which include 5 asteroid flybys in seven years. The launch energies are modest (C3 less than 30 km^2/s^2) and the post launch delta-V is near 1. km/s and thus the spacecraft mass available excluding the fuel and engine is above 140 kg for the MEDLITE launch system. In addition it is shown that a rendezvous trajectory can be found to every Trojan asteroid using a Jupiter gravity assist which places the spacecraft in the orbit plane of the target. The rendezvous takes place nearly a whole orbit later with low delta-V. These trajectories can also be improved by means of a two year Earth Gravity Assist. Several examples of all these types of trajectories are presented.

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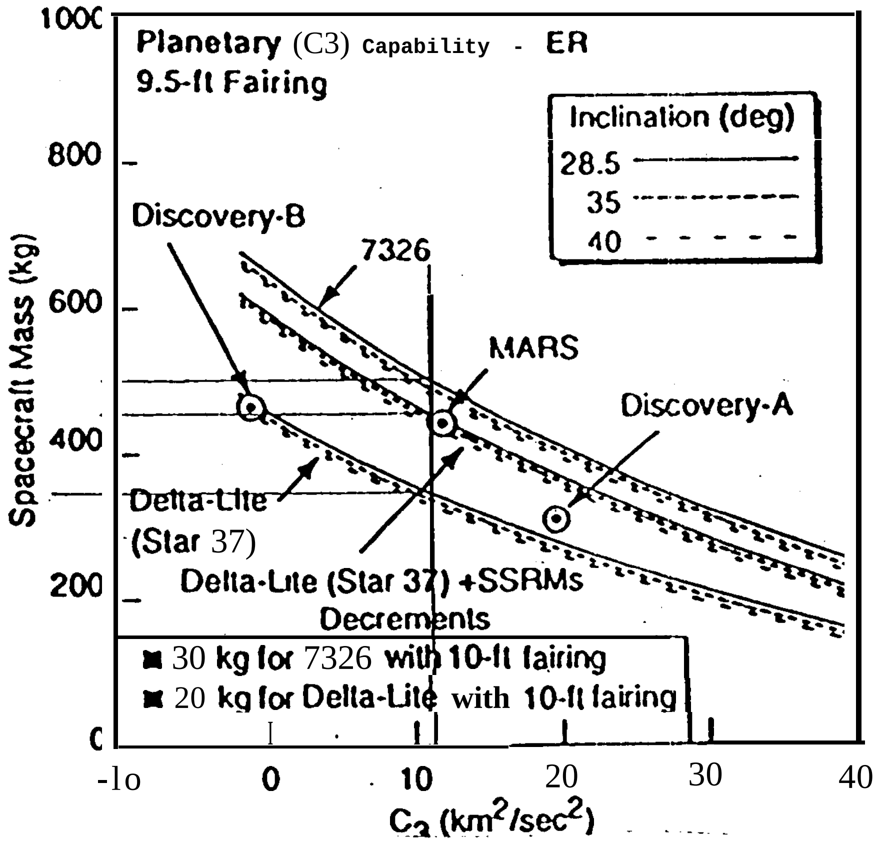

Figure 4 New Millennium Launch Vehicle {capability

Table 5
JUPITER GRAVITY ASSIST TO TROJAN RENDEZVOUS

Quantity							
Trajectory	4Q	4R	4s	5Q	5R	5s	5T
Target'	Hektor	1988 AK	1988 AK	Aneas	Sarpedon	Phereclos	Cebriones
Number	624	4489	4489	1172	2223	2357	2363
Inclination	18.2 deg	22.1 deg	22. I deg	16.7 ddeg	16.0 deg	2.7 deg	32.2 deg
Radius	112.5 km	43.0 km	43.0 km	75.5 km	52.5 km	51.5 km	45.8 km
Launch Date	09/13/01	07/04/99	12/14/04	11/22/03	1 1/14/03	10/21/02	11/15/03
C3	83.3 km^2/s^2	82.3 km^2/s^2	75,9 km^2/s^2	78.3 km^2/s^2	78.1 km^2/s^2	79,7 km^2/s^2	69.5 km^2/s^2
DLA	31.2 deg	-0.4 deg	0.1 deg	*6.3* deg	19.5 deg	14.6 deg	31. ! deg
PLDV	*2.457* m/s	1.375 m/s	1.219 m/s	1.416 m/s	1.614 m/s	1.639 m/s	527 m/s
Midcourse DV	272 m/s	o	97 m/s	132 m/s	318 m/s	268 m/s	o
Jupiter Flyby							
Time	857 days	760 days	1040 days	1231 days	963 days	1199 days	761 days
Distance	*24.6* RJ	22.7 RJ	42.0 RJ	30.4 RJ	39.0 RJ	6.0 RJ	19.7 RJ
Vel in	*5.9* km/s	6.4 km/s	5.6 km/x	5.7 km/s	5.6 km/s	5.5 km/s	7.2 km/s
Vel out	*5.2 km/s*	5.1 km/s	4.6 km/s	4.2 km/s	3.0 km/s	0.8 km/s	7.2 km/s
DV	*296* m/s	*558* m/s	463 m/s	646 m.s	762 m/s	601 m/s	o
Midcourse DV	649 m/s	*286* m/s	o	o	o	272 m/s	0
Rendezvous							
Time	*3743 days*	4330 days	4018 days	4988 days	4783 days	5854 days	4429 days
	10.2 years	11.9 years	11.0 years	13.6 years	13.1 years	16.0 years	12. I years
DV	1,240 m/s	531 m/s	*658* m/s	639 m/s	533 m/s	497 m/s	527 m/s

Table 6
ESTIMATED SPACECRAFT MASS USING MEDLITE RENDEZVOUS TRAJECTORIES

Trajectory	Target	Direct Case from Table 6	With Preceding Two Year DVEGA						
		Mass	DVEGA	Launch Date	C3	DLA	PLDV	Mass	Flight Time
4Q	Hektor	14.6 kg	2+	10/20/99	28.8 km^2/s^2	15.1 deg	2,854 m/s	63.4 kg	12.3 years
4R	1988 AK	42.0 kg	Not Considered						
4s	1988 AK	53.9 kg	2-	0 1/24/03	25.5 km^2/s^2	-12.7 deg	1,703 m/s	131.9 kg	12.9 years
5Q	Aeneas	45.0 kg	2-	01 /02/02	25.5 km^2/s^2	-4.3 deg	1,928 m/s	117.7 kg	15,5 years
5R	Sarpedon	39.4 kg	2+	10/06/0 1	28.1 km^2/s^2	22.8 deg	1,913 km/s	109.1 kg	15.2 years
5s	Phereclos	37.1 kg	2-	12/29[0 I	28.2 km^2/s^2	-2.7 deg	2,099 m/s	98.4 kg	17.4 years
5T	Cebriones	89.6 kg	2+	10/03/01	28.2 km^2/s^2	23.0 deg	1,177 m/s	155.9 kg	14.2 years

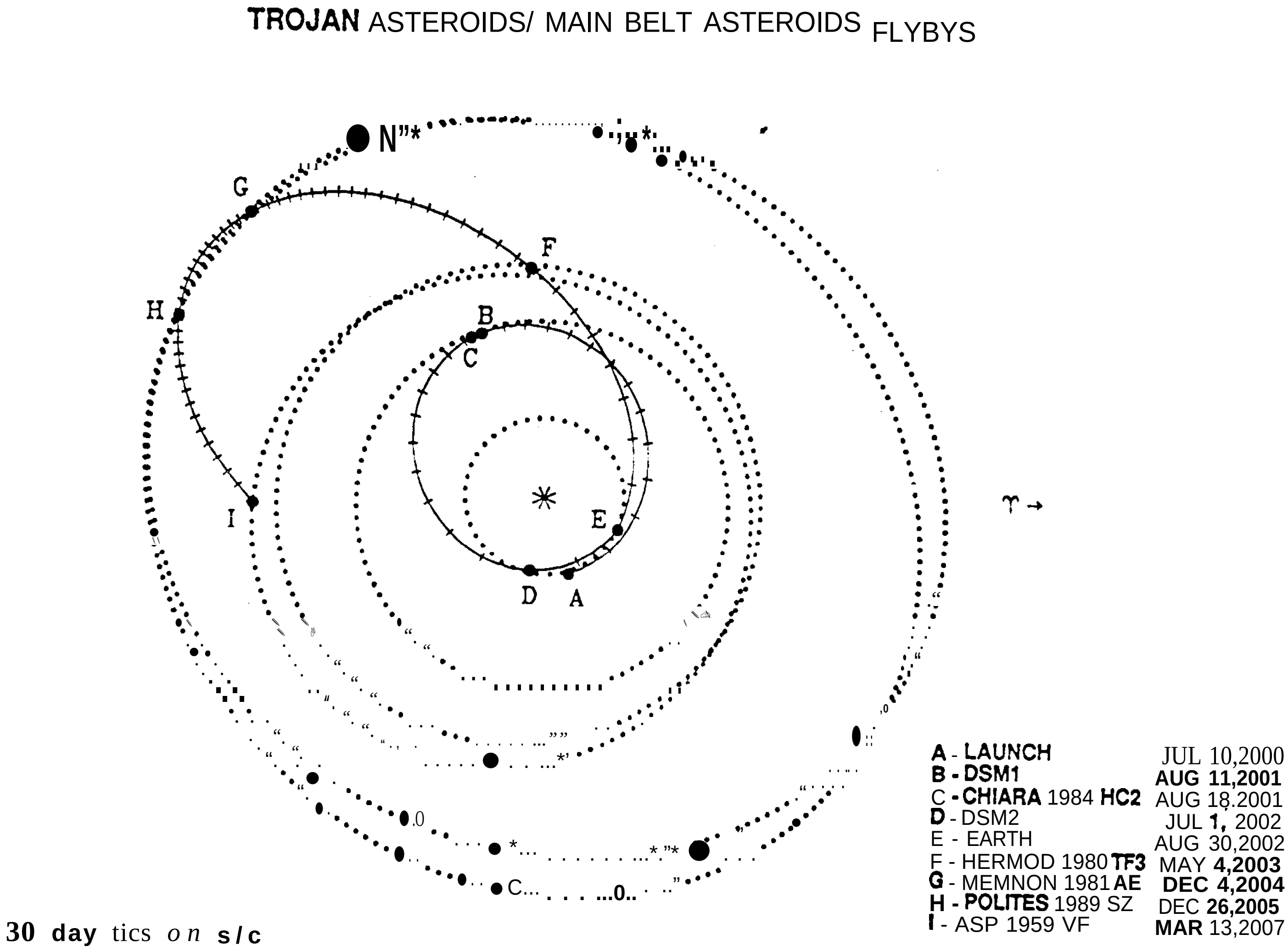

Figure 5 Trajectory **5E (with DVEGA) to Memnon and Polites**

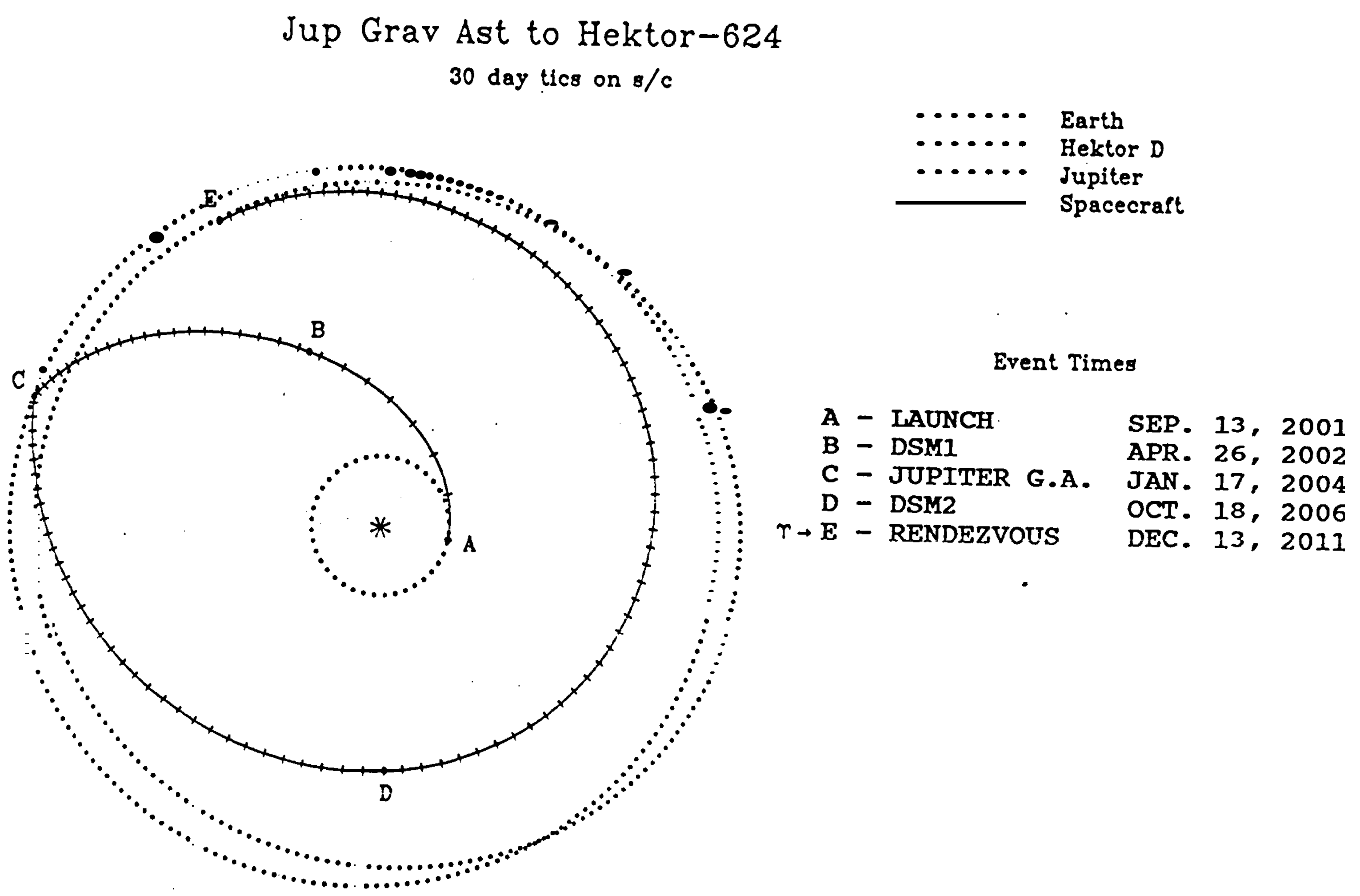

Figure 6 Trajectory 4Q Jupiter Gravity Assist to Hektor Rendezvous

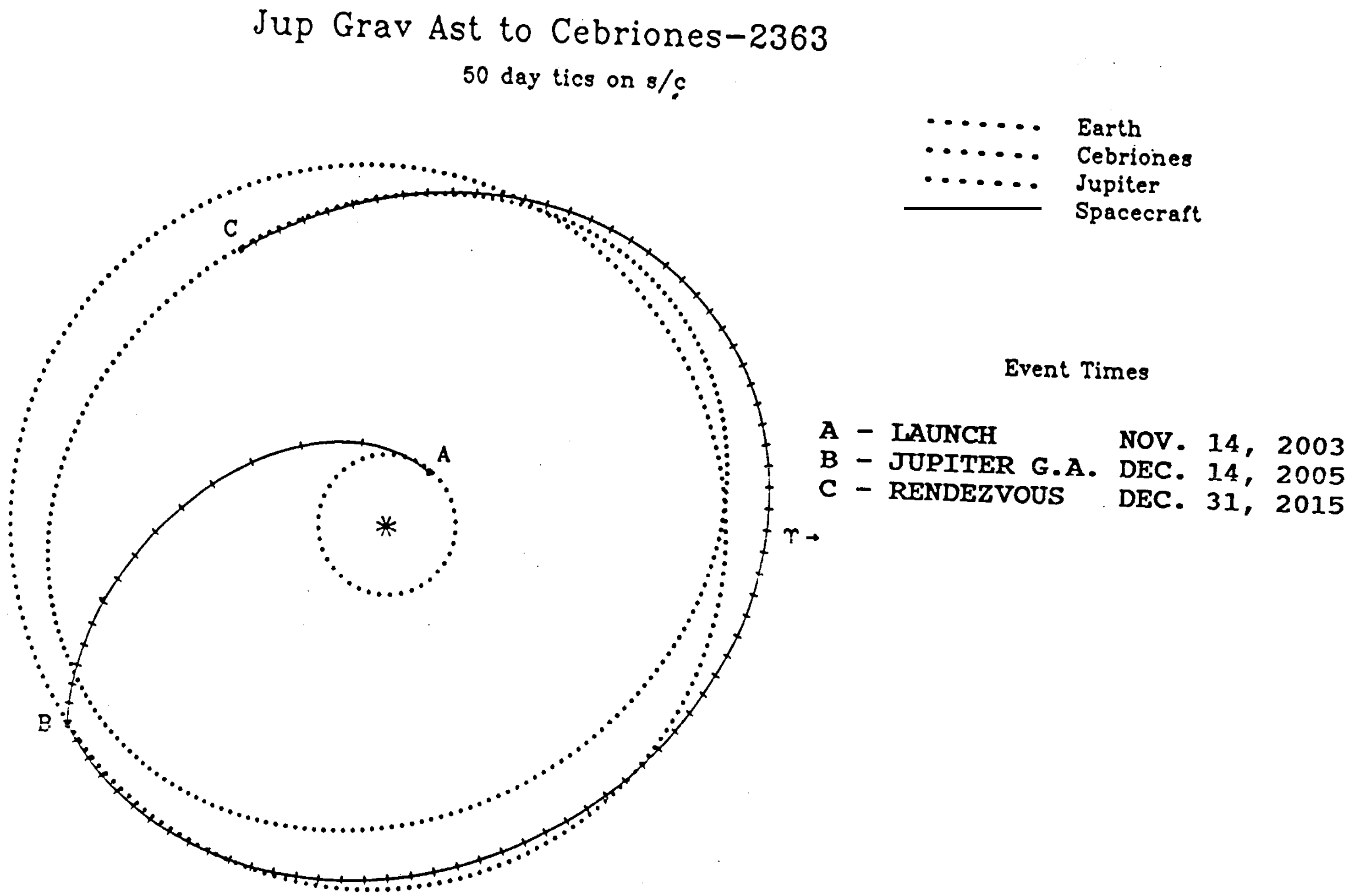

Figure 7 Trajectory 5T Jupiter Gravity Assist to Cebriones Rendezvous