Mission Design Considerations for Mars Cargo of the Human spaceflight Architecture Team's Evolvable Mars Campaign

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Recent NASA interest in human missions to Mars has led to an Evolvable Mars Campaign by the agency's Human Architecture Team. Delivering the crew return propulsion stages and Mars surface landers, SEP based systems are employed because of their high specific impulse characteristics enabling missions requiring less propellant although with longer transfer times. The Earth departure trajectories start from an SLS launch vehicle delivery orbit and are spiral shaped because of the low SEP thrust. Previous studies have led to interest in assessing the divide in trip time between the Earth departure and interplanetary legs of the mission for a representative SEP cargo vehicle.

Nomenclature

ARV	Asteroid Redirect Vehicle
BOL	Beginning Of Life *(electric power level)*
COMPASS	Collaborative Modeling for Parametric Assessment of Space Systems *(GRC study team)*
EEO	Elliptical Earth Orbit
ELV	Expendable Launch vehicle
$E-M$	Earth-to-Mars
EMC	Evolvable Mars Campaign
GRC	Glenn Research Center
HAT	Human Architecture Team
LGA	Lunar Gravity Assist
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
SEP	Solar Electric Propulsion
SLS	Space Launch System
STMD	Space Technology Mission Directorate

I. Introduction

The NASA Human spaceflight Architecture Team (HAT) has kicked off an Evolvable Mars Campaign (EMC). This campaign involves two main mission components: human transport and pre-deployed asset, or cargo, delivery. While the human transport missions have a strong focus on duration, the cargo delivery missions allow for longer trip times in order to reduce required propellant. Recent developments in Solar Electric Propulsion (SEP) have enabled efficient propellant use during orbital transfers and are considered a viable option for the EMC's asset delivery missions. The focus of this study is on such SEP asset delivery missions. Examples of assets to be pre-deployed in support of human missions are: landers and crew return stages.

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To date, several HAT studies have been performed and documented by a number of NASA teams including those at MSFC and GRC. The GRC studies have focused on cargo delivery using SEP. These missions typically consist of an Earth departure to escape segment and an in-space segment. The results have led to further interest in studying the divide in mission duration between these two segments. To that end, parameters such as mission segment duration, SEP power level, payload mass and Mars arrival conditions may be varied to examine the trade space for mission planning purposes. Trades of all these parameters will be the topic of a planned NASA publication. From this study, mission planning trends are shown as a result of time variation only.

II. Overview of HAT Cargo Mission

A. Mission Background and Spacecraft Description

In 2014, the NASA Human spaceflight Architecture Team started a study known as the Evolvable Mars Campaign to define how near term investments could build upon one another to enable human missions to Mars. Two alternate architectures, both involving the use of Solar Electric Propulsion, have been investigated in detail. The first, and the one focused on here, involves the use of a combination of SEP and chemical propulsion elements. This combination of propulsion technologies takes advantage of the strengths of each propulsion system: the high efficiency SEP system to deliver cargo, and the faster trip times afforded by chemical propulsion for crew transport. Referred to in past studies as a split architecture, the SEP system delivers the cargo using a vehicle separate from the crewed chemical transportation system. The SEP cargo vehicle delivers payloads, to be used on the surface of Mars, as well as the crew return propulsion stages. The second architecture, not discussed here, is referred to as a SEP/Chemical hybrid architecture and consists of a single crewed spacecraft which contains both SEP and chemical propulsion systems.

For the EMC architecture studied in this paper, the low-thrust SEP spacecraft is used to pre-position elements such as habitats, orbital maneuvering systems, consumables, and landers for use in the Martian system. As shown in Figure 1, the representative SEP stage was based on an evolved configuration of the Asteroid Redirect Vehicle (ARV): the approximately 150 kW class SEP Stage assumed the same spacecraft bus and the same high power hall thruster and solar array technologies as the current approximately 50 kW ARV. The dry mass assumptions for the SEP stage were based on scaling relationships with preliminary ARV designs. This scaling varied the total dry mass as a function of total power to the EP thruster system and total Xe propellant mass. This scaling relationship is shown in section B. Table 1 shows the main design parameters and constraints of the SEP vehicle used in this study. With an assumed augmented propellant capability, increased based on study results from the five metric tons in the current ARV, this SEP stage is launched on a single SLS vehicle to an elliptical starting orbit.

Item	Description
Engine technology	Magnetically Shielded Hall
Engine Isp	3,000 sec
Power to EP system	150 kW (degradation: $1/r^2$ for r > 1 AU *where r= spacecraft radius to Earth*)
Thruster effeciency[a]	60%
Thruster duty cycle	90%
Propellant	Xe (amount derived from analysis)
Solar array technology	ROSA (shown)
Number of wings	2
Wing diameter	18.7 m
Power per wing	75 kW

[a] Reference value from ARV; HAT study value based on specific thruster model (see section B)

Table 1: *150 kW SEP Stage Design Parameters and Constraints*

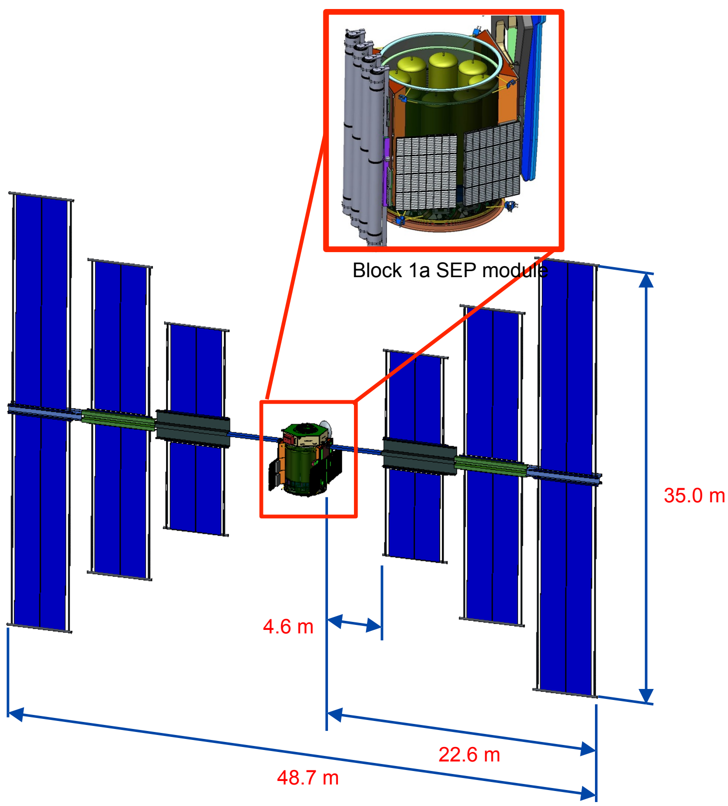

Figure 1: *Representative HAT Spacecraft Design*

B. Mission Description

In this study, the HAT cargo mission starts with an assumed SLS, or other ELV, launch delivery into Elliptical Earth Orbit (EEO). This orbit is always assumed to have a perigee altitude of 200 km while the apogee altitude may vary based on launch vehicle capability. From the EEO, the SEP powered spacecraft performs a low thrust spiral transfer to a near Earth escape condition defined as having a characteristic energy (or C_3) equal to -2.0 km^2/sec^2. From this condition there is an assumed Lunar Gravity Assist (LGA) that provides a free transfer to an Earth escape condition defined as having a characteristic energy (or C_3) equal to +2.0 km^2/sec^2. Finally, from the Earth escape condition, the SEP system performs an interplanetary transfer to the desired Mars arrival condition defined as having an incoming excess velocity (or V_{inf}) equal to 5.2 km/sec. This Mars arrival condition has been derived as a requirement for a subsequent aero-capture maneuver, not modeled in this study, that allows for the planetary capture into Mars' sphere of influence. Table 2 shows an overview of the Ground Rules and Assumptions (GRA) for the cargo mission.

Item	**Description**
Spacecraft power (kW)	BOL: 150
	Earth spiral degradation: *10% linearly as a function of perigee alt (Hp); from Hp= 1,200 to 24,000 km*
	Earth-Mars degradation: $1/r^2$ *where r= spacecraft radius to Earth*
	SEP system is off in shadow (for Earth spiral)
Spacecraft propulsion	Thrust and Mass flow per GRC developed "STMD rev 2.2" curves for High Isp[1];[2] Duty cycle = 90% (used for Earth departure spiral only)
	Averaged values (used for Earth-Mars transfer only): Isp= 3215.5360, Overall efficiency (thruster eff*duty cycle): 0.522139
Spacecraft Dry Mass (kg)	Scaling eq format: fixed component + power plant sizing + tank sizing
	Scaling eq[a]: 2274.61 [kg] + 30.1925 [kg/kW] * power [kW] + 0.0552 [n/d] * prop mass [kg]
Payload System	50,000 kg
Mission	
Starting date	Derived through optimization
Starting orbit at Earth	200 x *Ha* km, *where Ha= apogee altitude derived through optimization*
Earth escape condition	C_3 = +2.0 km^2/sec^2
Mars arrival condition	V_{inf} = 5.2 km/sec

[a] Mass scaling equation derived from spacecraft designs in previous NASA GRC COMPASS studies

Table 2: *Ground Rules and Assumptions for the Cargo Mission*

III. Analysis Strategy and Tools

As outlined above, there are three main components in the mission profile: Earth departure, LGA and interplanetary transfer. Each of these components is discussed below along with the corresponding analytical tools used. The overall goal of this study is to assess a fairly wide range of possible missions to enable proper mission planning. As such, appropriate analytical tools are used and assumptions made. It is considered that an overall medium level of analytical fidelity is appropriate for this study because only approximate and relative performance metrics are of interest. Once a down selection of feasible missions has been made, further refinement in the fidelity of mission models can be made to ascertain mission performance measures with greater accuracy, as needed.

A. Earth Departure Spiral

The Earth departure segment of the mission starts from an assumed SLS, or other ELV, delivery orbit around the Earth. This orbit always has a perigee altitude of 200 km and an inclination of 28.5 degrees. Because of the low thrust nature of the SEP system of the spacecraft, the orbit transfer to near Earth escape condition of C_3 = -2.0 km^2/sec^2 takes on the shape of a spiral. This occurs because the SEP provided acceleration is on the order of magnitude of the Earth's gravitational acceleration which causes the spacecraft to continue to orbit the Earth during the relatively long duration transfer, hence the spiral shape.

Spiral shaped orbits present unique challenges for proper analytical modeling because of their long duration; typically on the order of days, months or even years. This segment of the mission is modeled to a high level of analytical accuracy using version 4 of the Optimal Trajectories by Implicit Simulation (OTIS)[3] program. This version of OTIS employs a closed loop guidance algorithm that provides near optimal steering to achieve the desired orbital targets at the end of the orbital transfer. The OTIS simulation model accounts for, among others, gravitational effects due to the Earth and it's moon, the Sun and Jupiter. Shadowing effects on the vehicle are accounted for by turning off the thrusters while in shadow. A simplified solar array degradation model, to account for Van Allen belt radiation, is implemented by degrading the electric power to the thrusters as a linear function of the perigee altitude. This model reduces the power by a total of 10% starting at a perigee altitude of 1,200 km at BOL power and ending at a perigee altitude of 24,000 km at 90% of BOL power. This segment of the mission is modeled with the highest level of fidelity of all segments in this study and, consequently, is also the most expensive in terms of computer CPU time. Figure 2 shows a representative Earth departure spiral trajectory created with OTIS.

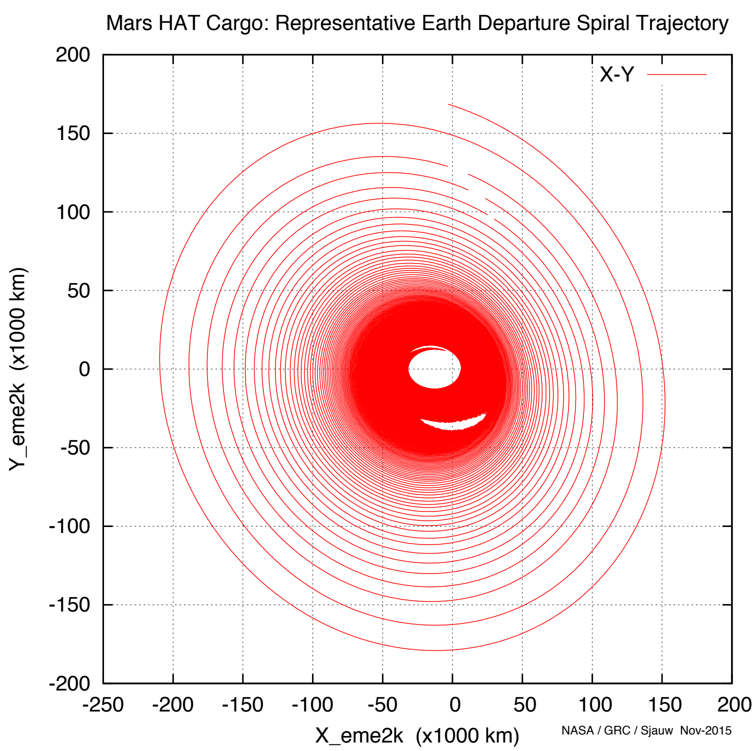

Figure 2: *Representative Earth Departure Spiral (to C_3 = -2.0 km^2/sec^2) - Cutouts indicate s/c in shadow*

To alleviate the CPU time cost, a database of Earth departure spirals has been created which is then interrogated for Earth spiral trajectories of interest. Several parameters are varied to generate the database and, as a result, it is actually a data surface for interpolation purposes. The assumption is that the Earth spiral performance is repetitive in nature from year to year; the year 2033 was chosen. To capture variations within the year, the stating date was varied on a quarterly basis; specifically, a date around the midpoint of each quarter was chosen as the reference date. Starting mass is derived from using a recent SLS ASB performance table[4] which provides SLS delivery performance as a function of apogee altitude of an Earth orbit with a 200 km perigee altitude and an inclination of 28.5 deg. To somewhat decouple the database from the SLS performance table, "bands" were placed around the reference performance for each selected starting orbit. This allows a reference orbit to have a range of possible launch vehicle performance values. The "bands" were chosen so that there was no overlapping performance between selected starting orbits in order to preserve the original orbit performance variation; i.e. a specific initial EEO can never have a higher delivered mass than a lower EEO from the reference SLS performance table. Earth spiral trajectories with a planar transfer were then generated per table 3. After the initial data surface was generated, it was resorted based on the final mass and quarter of the year. The intended use of the data surface is based on a specified final (near Earth escape) mass and reference quarter of the year. Multidimensional interpolation is performed to provide Earth spiral performance numbers based on final mass, desired BOL power level and quarter of the year. Table 4 lists the performance parameters that are available from the data surface. It should be noted that, even though a particular quarter of the year is determined for interpolation purposes, it serves merely as a guide to down select a subset from the data surface. Actual interpolation of the dates in the database are not of interest; however, the useful and desired output time parameter is the trip time of the Earth departure spiral trajectory. This duration is combined with the date near Earth escape (described below) to derive the starting date in the EEO. At no point is the data surface extrapolated since those results could be unpredictable. If the requested final mass is below the delivered SLS capability, this delivered capability is used and an excess capability from the Earth spiral is reported. If, however, the requested final mass exceeds that of the Earth spiral capability then no feasible Earth spiral is available and that condition is reported; no "end-to-end" scenario is possible in this case. The Earth spiral represents the first leg of the overall mission.

Input Parameter	**Value**
Date	Year: 2033 *(reference year, performance assumed repeating each year of interest)*
	Quarterly variation: q1, q2, q3, q4
BOL Power Level (kW)	Discrete reference values: 150, 250, 300
Initial Mass (kg)	Approx. range: 56k to 113k

Table 3: *Input Parameters to generate the Earth Spiral Data Surface*

Output Parameter	**Value**
Date (yyyy/mm/dd)	Initial, Final
Mass (kg)	Initial, Final, Propellant used
Other	Trip time (days), Delta V (km/sec)

Table 4: *Output Parameters from the Earth Spiral Data Surface and, also, from the Comprehensive Search Program*

B. Near Earth Escape and LGA

Following the near Earth escape condition at the end of the Earth spiral, defined as having a C_3 = -2.0 km^2/sec^2, there is an assumed Lunar Gravity Assist (LGA) to provide the transfer to an Earth escape condition defined as having a $C_3 = +2.0\ km^2/sec^2$. The LGA itself is not modeled in this study; the assumption is that the LGA is achieved via proper mission planning without propulsive contribution from the spacecraft.[5] This is a reasonable assumption for the purpose of this study and allows for modeling the two adjacent mission segments with separate tools while connecting them in a comprehensive optimization framework to provide end-to-end results that are reconciled; i.e. vehicle "closure" based on consistent mass and tank sizing is thus achieved. Once a down selection of feasible missions has been made, subsequent higher fidelity mission analysis is expected to actually model the LGA. To account for the LGA in the mission timeline, a shift of 60 days is implemented between the end of the Earth spiral and the start of the Earth-to-Mars transfer segment. Per current HAT analysis agreement, a time span of 60 days is sufficient to allow for proper alignment for achieving an LGA; it also allows for additional time margin for potentially unforeseen scenarios such as missed thrust.

C. Earth to Mars Transfer

The Earth-to-Mars (E-M) transfer starts at an Earth escape condition defined as having a $C_3 = +2.0$ km^2/sec^2 and ends at Mars with an incoming $V_{inf} = 5.2$ km/sec. The Mars arrival condition is driven by aero-capture requirements at Mars. This mission segment is modeled using the Chebytop III[6] program. Chebytop is chosen because of its flexibility and speed in providing optimized interplanetary trajectories. Chebytop has a medium level of simulation fidelity, as defined by specified vehicle and mission detail, and is suitable for the study at hand. Prior experience has shown that Chebytop solutions provide excellent seed values for higher level fidelity trajectory programs. Where higher level fidelity trajectory programs allow for more vehicle detail and mission constraints to be specified, they typically get "trapped" in local solution spaces; unlike Chebytop, they are simply not the tools for examining a wide range of the solution space. Their purpose is to provide added modeling detail to a specific mission of interest. Also, when examining a wide solution space of interest, the focus is on solutions that are feasible and, performance-wise, a comparative approach is needed; i.e. some vehicle and mission modeling details are sacrificed in favor of comparing multiple solutions from a somewhat simpler, common basis. Finally, Chebytop has two modes of solution: variable thrust mode and constrained thrust (i.e. fixed Isp) mode. For this study, the constrained thrust mode was used. Figure 3 shows a representative Earth-Mars transfer trajectory created with Chebytop III.

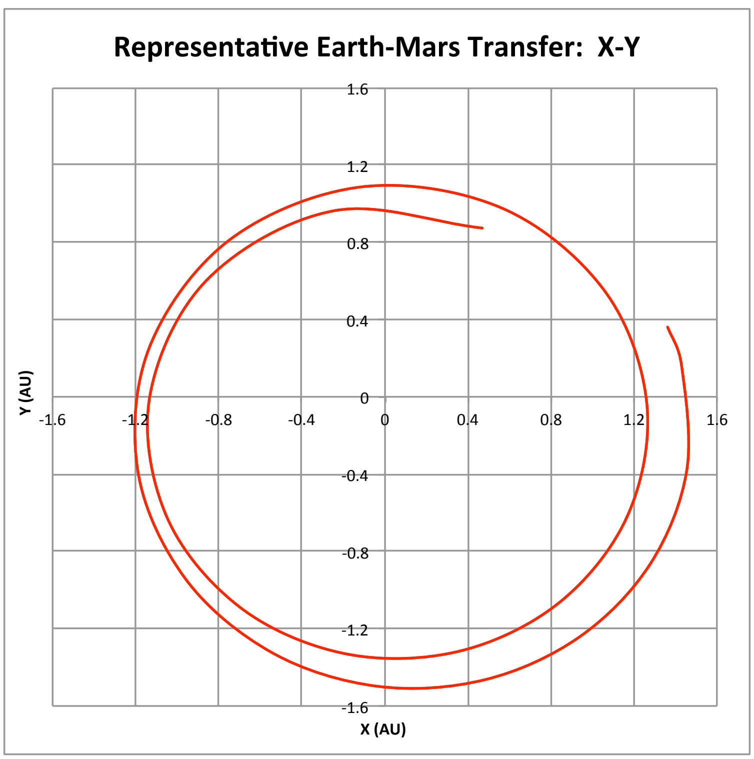

Figure 3: *Representative Earth-Mars Transfer (to* V_{inf} *= 5.2 km/sec - 2036_11_24 case for E-M trip= 975 days)*

Because of Chebytop's ability to derive good near optimal solutions in rapid fashion, it lends itself for incorporation into a comprehensive search and optimization framework. For the purposes of this study such a framework was specifically created. This newly developed software is described in the next section.

D. Putting the pieces together

In order to arrive at end-to-end mission solutions for each data point in a wide solution space, a new software program was developed to manage the comprehensive search and optimization. Several layers of searching are performed over a wide range of dates. The top level trade is between the time span of the two main mission segments: Earth departure spiral (to near escape) and E-M transfer. The software allows for additional parameters that may be traded such as power level and final payload mass; these parameter trades vastly expand the solution set and are the subject of another planned NASA publication. For the purposes of this study, the BOL power level and required payload are each fixed to a single value in order to keep the number of results manageable.

The new software may be viewed as an executive program that manages the generation of valid solutions for dates of interest. The program may be run in two modes: end-to-end solution generation and interplanetary-only solution generation. For this study, both modes were used. Table 5 shows the input parameters for the comprehensive search process while Table 4 shows the output parameters.

Input Parameter	**Description**
y0, y1	start, end year (yyyy) at Earth escape *(i.e. starting year of E-M segment for the outermost search loop)*
em_trip0, em_trip1, em_trip_dt	start, end, step trip time (days) for the E-M segment *(i.e. duration of the E-M segment; used in an inner search loop in conjunction with each year in the outermost loop)*
refpwr	BOL power level (kW)
payload	payload mass (kg) at the end of the mission (i.e. at Mars)
sc_dry_in	spacecraft dry mass (kg): non-negative = fixed mass; negative = use mass scaling equation
cheby_only	false= end-to-end mission (i.e. include Esprl); true= E-M only
Other	
Filenames	input, output file names
Iteration, tolerance	iteration count, tolerance settings for search, optimization procedures

Table 5: *Input Parameters for the Comprehensive Search Program*

The program is built with a multi-layer search in mind. Figure 4 shows a top level diagram of the search process. The outermost layer sweeps through the years of interest; these apply at Earth escape. For each selected year, the next layer sets the E-M trip time of interest and, for each specified length, produces valid near optimal performance solutions based on an Earth escape date search for that year. A valid solution is one where the required power level to accomplish the mission does not exceed the available power level of the spacecraft. Using the the Earth escape date previously found, the next layer performs an iterative search for near optimal solutions that satisfy the payload target. For end-to-end mode, the Earth spiral data base is interrogated to select a matching Earth spiral. It should be noted that the Earth escape date is adjusted backwards by 60 days to account for the LGA and margin; this derived date is considered the "end" date of the Earth departure spiral to near escape. Therefore, once an Earth spiral is selected, the starting date of the mission, in Earth orbit, is known by adjusting backwards in time using the spiral duration. For cases where a spacecraft mass scaling equation is used (i.e. for this study), the propellant from the Earth spiral and that from the E-M transfer are used to compute the spacecraft dry mass such that the spacecraft tanks can contain the required amount of propellant. This newly computed mass, along with the payload mass, is used in another iterative loop to "close" the spacecraft mass. Closure of the spacecraft mass means that the optimized final mission mass delivered to Mars arrival condition accounts for the sum of the payload mass and the spacecraft dry mass. The whole process repeats for each specified E-M trip time. As the E-M trip time is varied, the Earth spiral time adjusts accordingly to match up the segments of the mission thereby providing the mechanism to trade the time divide between the mission segments. E-M trip time subsequently increases according to a user specified step size in the E-M trip time loop. Once the maximum E-M trip time is reached, the process then repeats for the next year in the outermost search loop; this whole process continues until the last specified year is reached.

For E-M transfer only (i.e. no end-to-end mission requested), the above process is the same except that the Earth spiral segment is not generated. The intent of this mode of analysis is to allow for additional mission planning where the spacecraft is delivered to the Earth escape condition via an assumed non-spiral out method; e.g. a chemical stage providing a high thrust impulse to place the spacecraft at the desired pre-LGA, or even at the desired Earth escape, condition. For those types of missions, the E-M transfer segment can be used to complete such alternate scenarios.

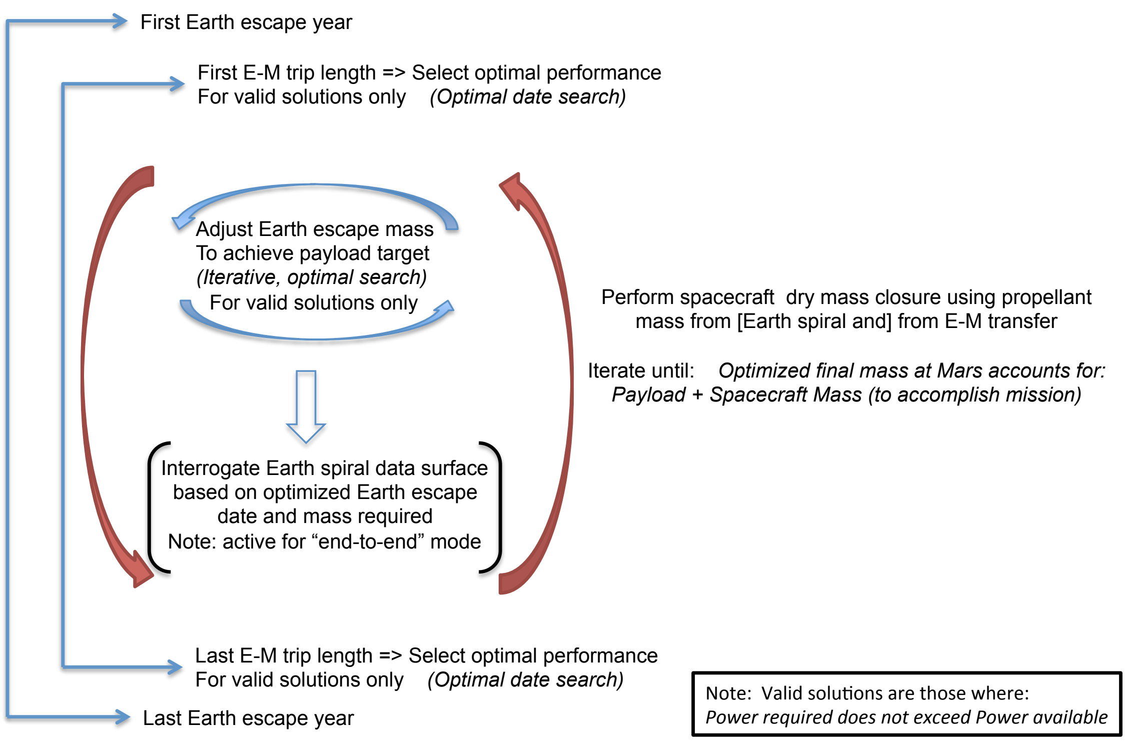

Figure 4: *Solution process for Comprehensive Search*

IV. Results

This study was first conducted for the end-to-end option of the HAT Cargo mission. The analysis was then repeated for the E-M segment only. Table 6 shows the analysis ranges in this study.

Parameter	Values
Year at Earth escape	2028 - 2048; 1 year increment
E-M trip time	600 - 1200 days; 37.5 day increment
BOL power level	150 kW
Payload (kg)	50,000 kg
Spacecraft dry mass (kg)	computed via Table 2 mass scaling equation

Table 6: *Analysis Ranges*

A. EEO to Mars Arrival

Figure 6 shows the total trip time for departure from EEO to Mars arrival; this plot shows the complete time span for Earth departures from 2026 to 2046; for purposes of this study, these are referred to as "launch date". It should be noted that the corresponding Earth escape dates range from 2028 to 2048 indicating Earth spiral out durations of up to 2+ years in some cases. For legibility purposes the time span is divided into two and plotted in the next two figures. Figure 7 shows the total trip time and the total mission deltaV for a launch date range from 2026 to 2037 while Figure 8 shows the same for a launch date range from 2037 to 2046. While Earth escape dates are sequential, launch dates are not because of the varying Earth spiral durations. Because of this non-sequential nature of the launch dates, for the boundary date of 2037, both figures 6 and 7 should be consulted. Figure 5 shows sample summary output for two of the data points in the plots: the output parameters indicated in Table 4 are shown along with mission totals. Appendix A shows the complete set of results; i.e. a summary for each data point. The intent is to use the plots to determine missions of interest based on launch date, mission duration and deltaV cost. Then specific missions of interest can be examined using the summary results. As mission planning efforts mature, the selected missions can subsequently be analyzed in greater detail.

Finally, figures 9 and 10 show the data for the Earth spiral portion of the end-to-end scenarios. While these results are not independent from corresponding end-to-end scenarios, examining them separately can help in launch vehicle planning and delivery options to Earth escape.

```
Esprl:  pwr: 150.0    m0:    68335.1      Start  2034_04_27      End  2036_01_24    mf:    60833.2     trip:  636.1     mp:     7501.9  dv:    3.6668
E-M:    pwr: 135.0    m0:    60833.2      Earth  2036_03_24      Mars 2039_07_07    mf:    57403.1     trip: 1200.0     mp:     3430.0  dv:    1.8301
                      E_Vinf:    1.4142   M_Vinf:    5.2000      s/c:     7403.1    p/l:   50000.0    Ttrip: 1836.1     Tmp:   10932.0 Tdv:    5.4969

Esprl:  pwr: 150.0    m0:    71257.3      Start  2034_11_08      End  2036_11_03    mf:    62597.3     trip:  726.1     mp:     8660.1  dv:    4.0511
E-M:    pwr: 135.0    m0:    62597.3      Earth  2037_01_02      Mars 2039_06_21    mf:    57555.6     trip:  900.0     mp:     5041.6  dv:    2.6479
                      E_Vinf:    1.4142   M_Vinf:    5.2000      s/c:     7555.6    p/l:   50000.0    Ttrip: 1626.1     Tmp:   13701.7 Tdv:    6.6990
```

Figure 5: *Sample Summary Output from Results Data Set of End-to-End Missions*

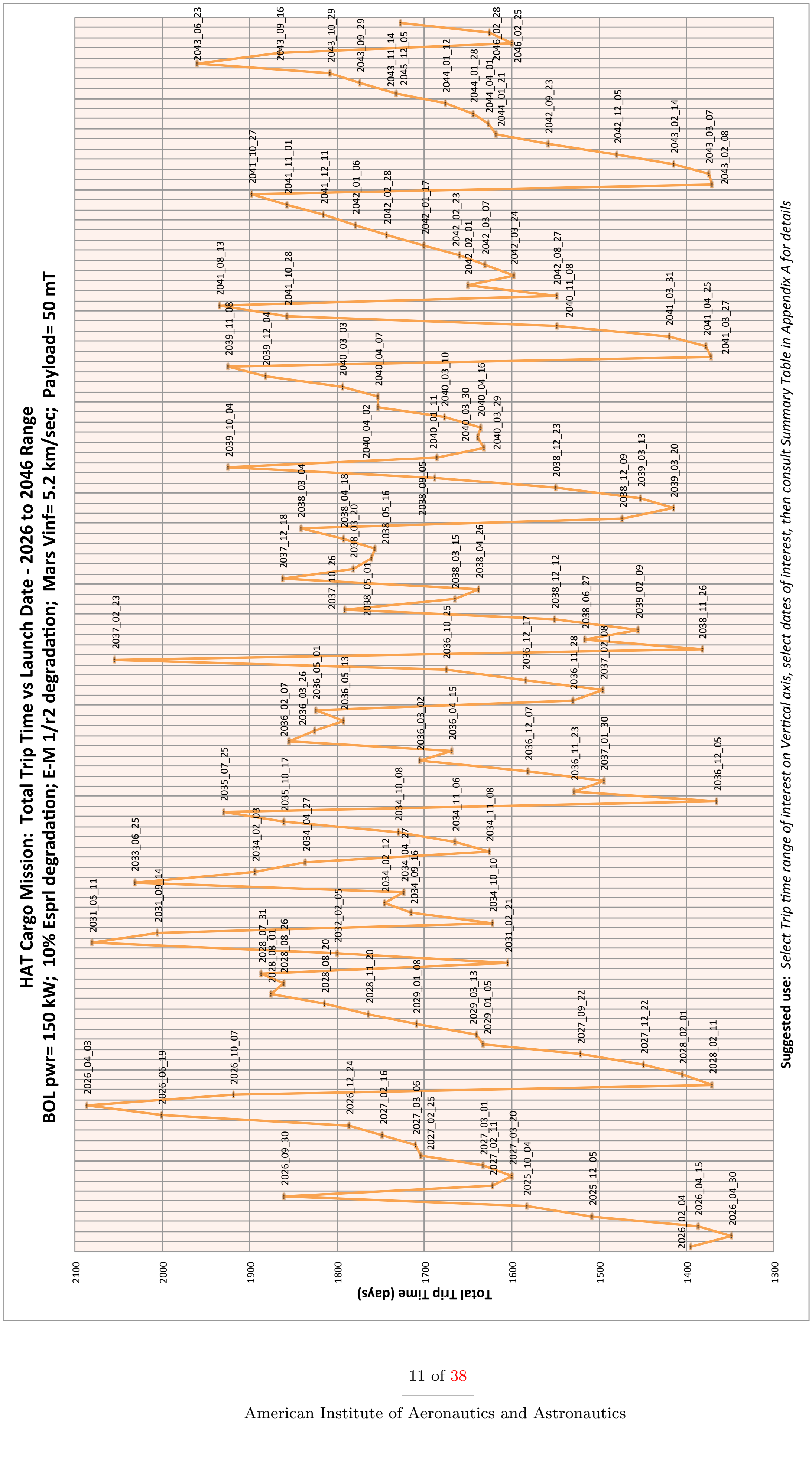

Figure 6: *EEO to Mars - Complete Launch Time Span: 2026 to 2046*

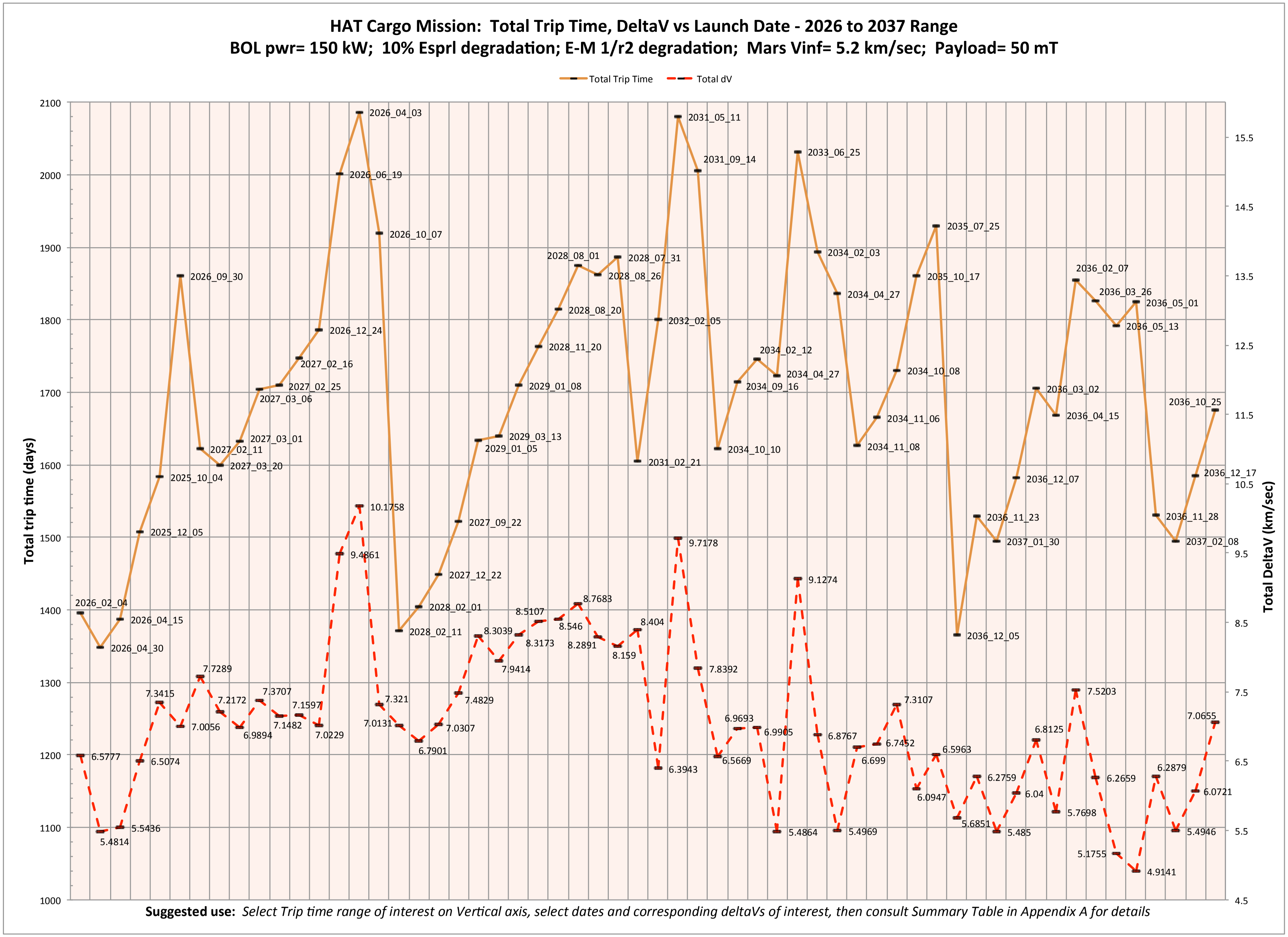

Figure 7: *EEO to Mars - Launch Time Span: 2026 to 2037*

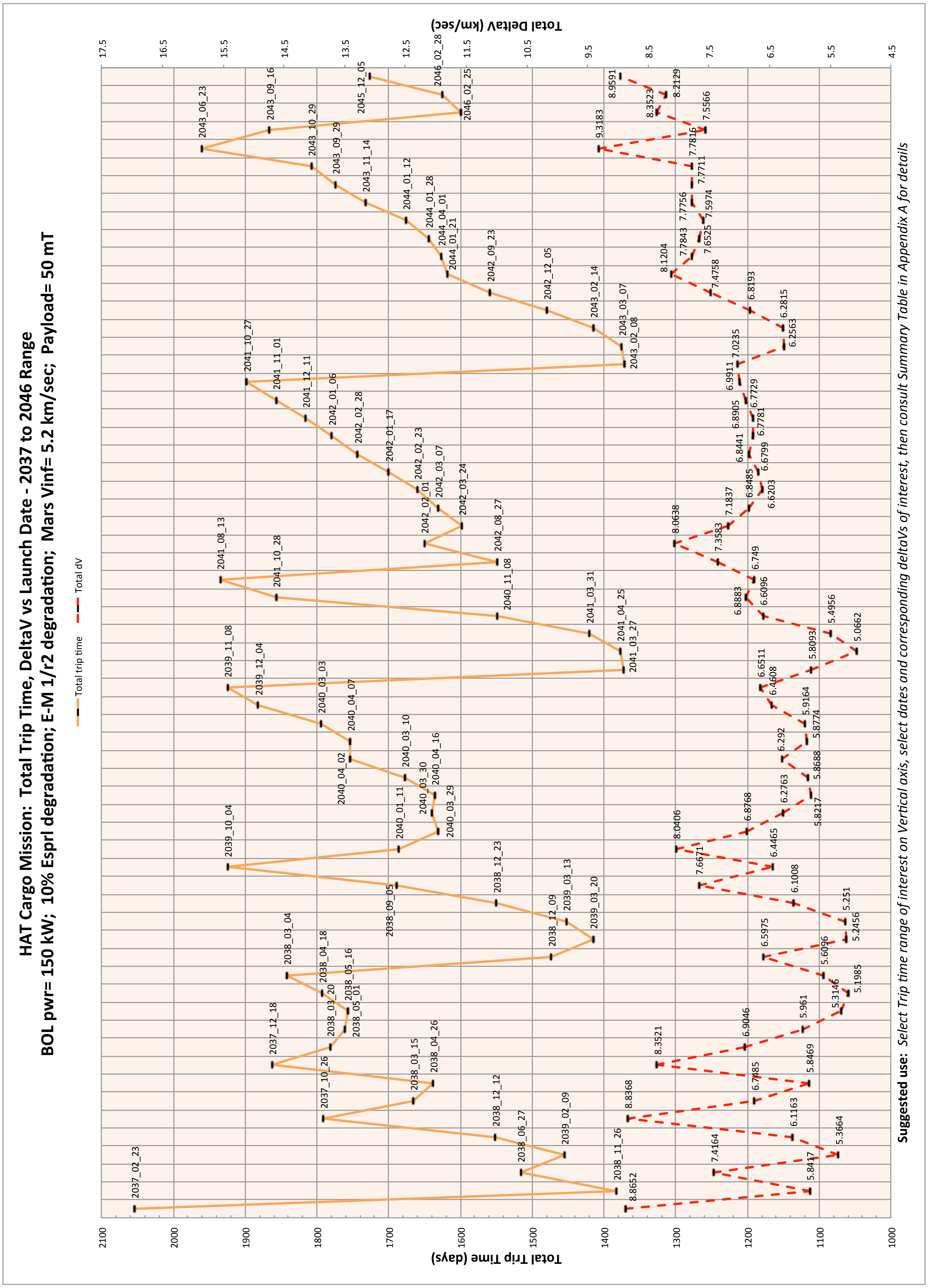

Figure 8: *EEO to Mars - Launch Time Span: 2037 to 2046*

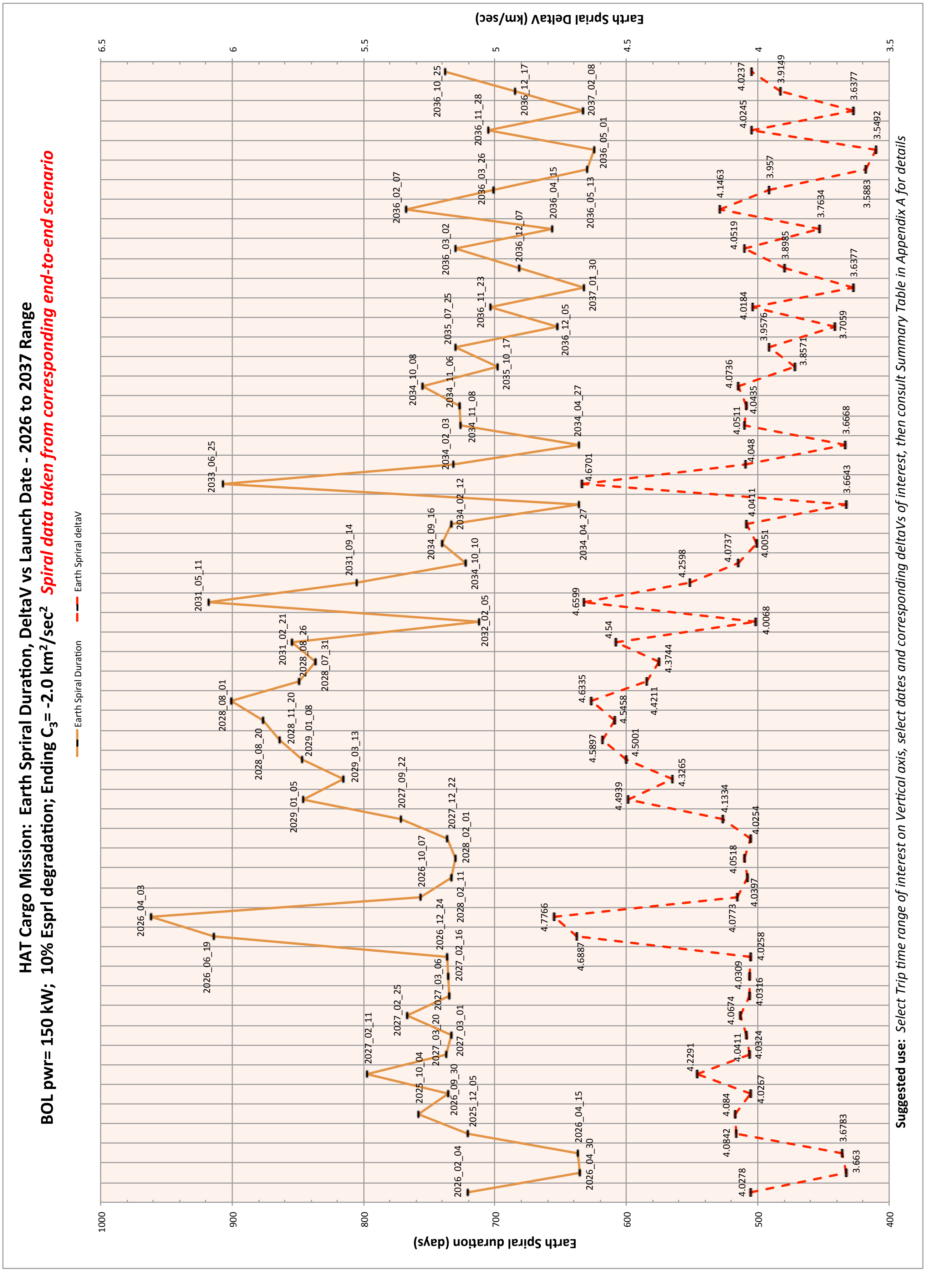

Figure 9: *Earth Spiral - Launch Time Span: 2026 to 2037*

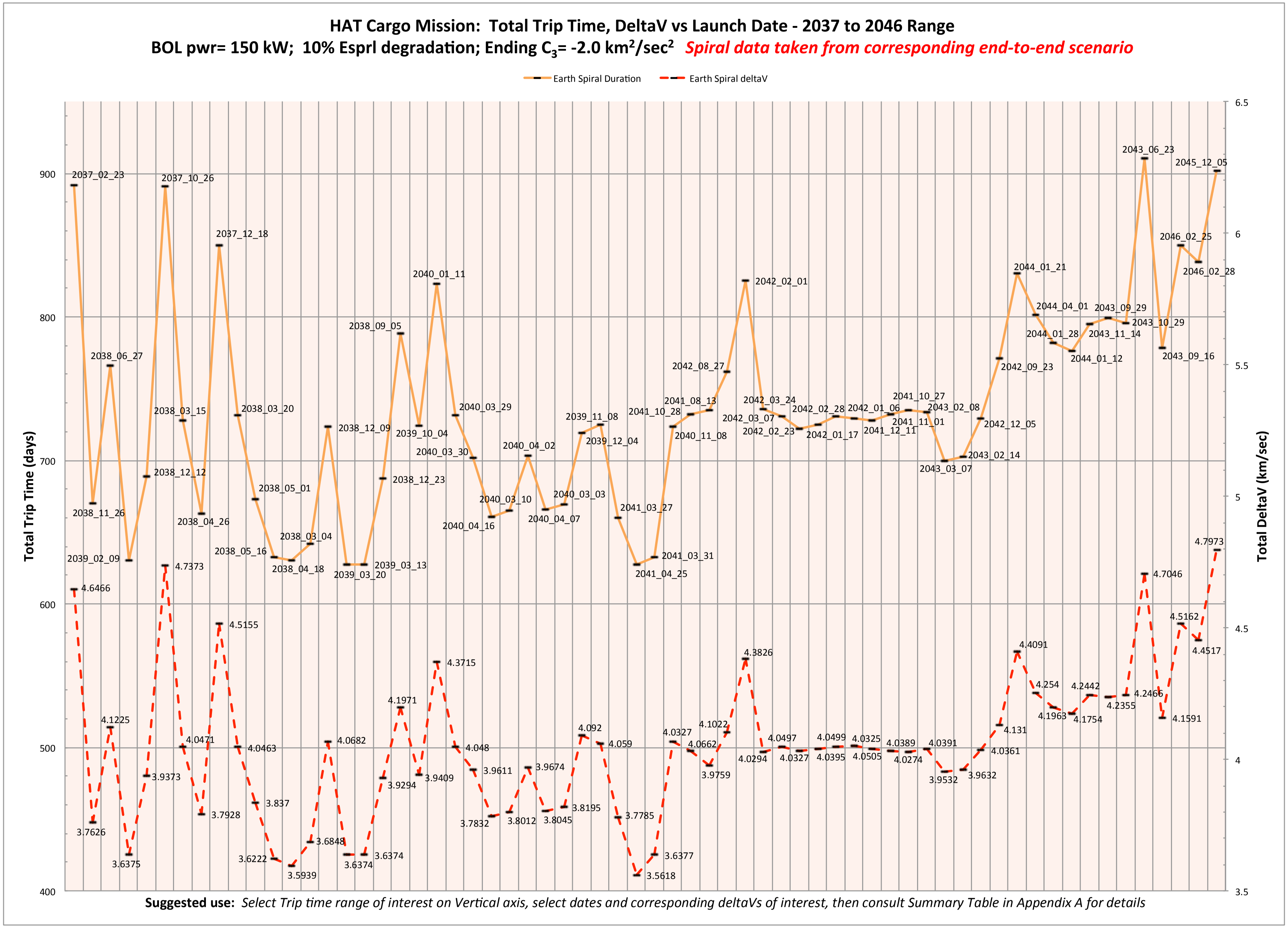

Figure 10: *Earth Spiral - Launch Time Span: 2037 to 2046*

B. Earth Escape to Mars Arrival (*interplanetary only*)

The analysis was repeated for only the Earth escape to Mars segment by skipping the Earth departure spiral trajectory. This interplanetary-only mission segment may be used by itself or in combination with other mission segments to arrive at end-to-end performance estimates. Figure 11 shows a snippet of the performance summary table. Figures 12, 13 and 14 show the total trip time versus launch date for the total time span and, again, split into two segments. The last two figures also show the total deltaV.

```
E-M:    pwr: 135.0    m0:    63812.0      Earth  2029_06_17       Mars 2031_09_20    mf:    57170.1     trip:  825.0     mp:     6641.8  dv:    3.4658
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:      7170.1   p/l:   50000.0    Ttrip:  825.0    Tmp:     6641.8 Tdv:    3.4658

E-M:    pwr: 135.0    m0:    63169.6      Earth  2029_05_25       Mars 2031_10_04    mf:    57136.5     trip:  862.5     mp:     6033.1  dv:    3.1653
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:      7136.5   p/l:   50000.0    Ttrip:  862.5    Tmp:     6033.1 Tdv:    3.1653

E-M:    pwr: 135.0    m0:    62681.5      Earth  2029_05_02       Mars 2031_10_19    mf:    57111.0     trip:  900.0     mp:     5570.5  dv:    2.9348
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:      7111.0   p/l:   50000.0    Ttrip:  900.0    Tmp:     5570.5 Tdv:    2.9348
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Figure 11: *Sample Summary Output from Results Data Set of E-M Missions*

Figure 12: *Earth Escape to Mars - Complete Launch Time Span: 2028 to 2048*

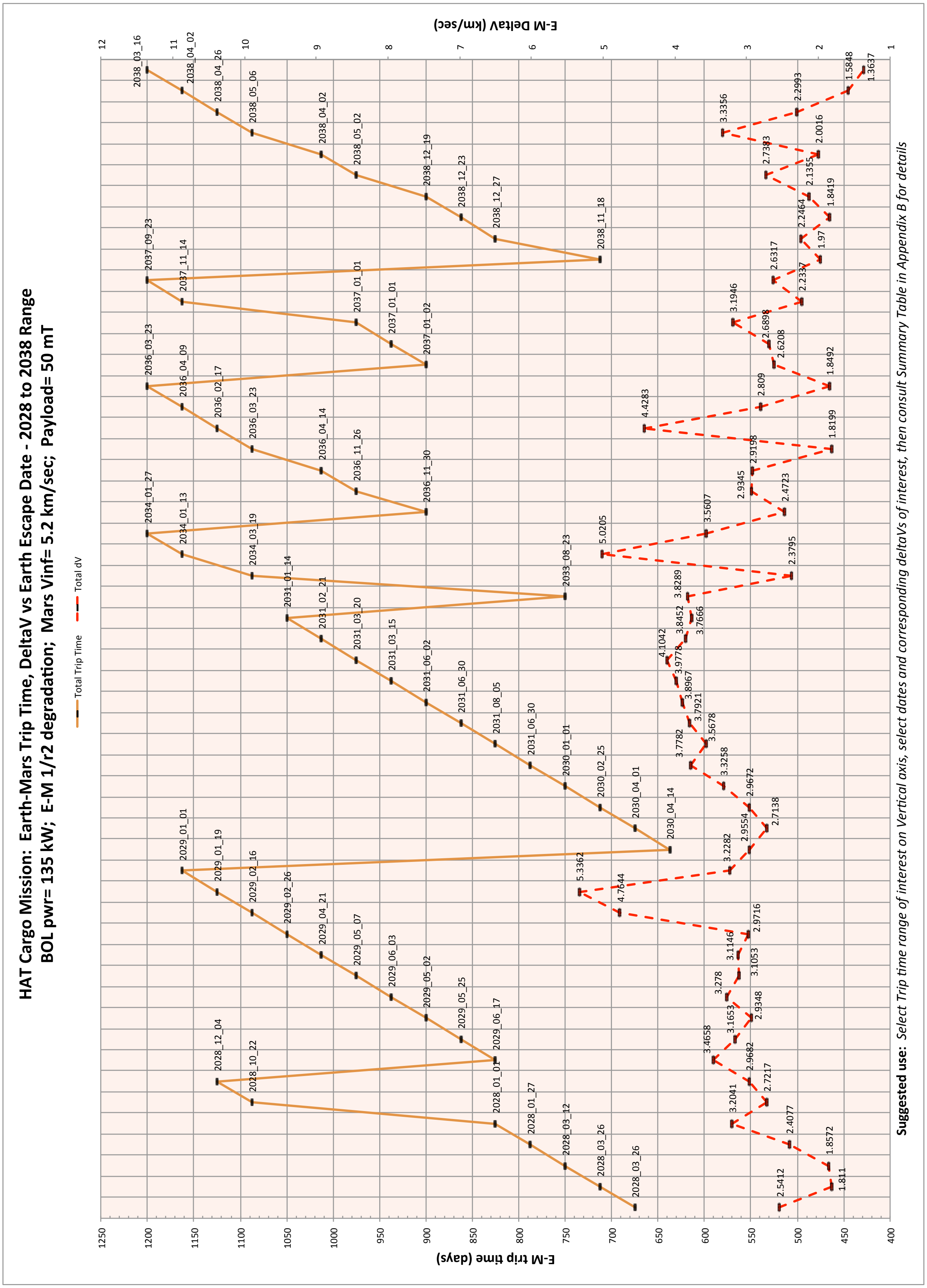

Figure 13: *Earth Escape to Mars - Launch Time Span: 2028 to 2038*

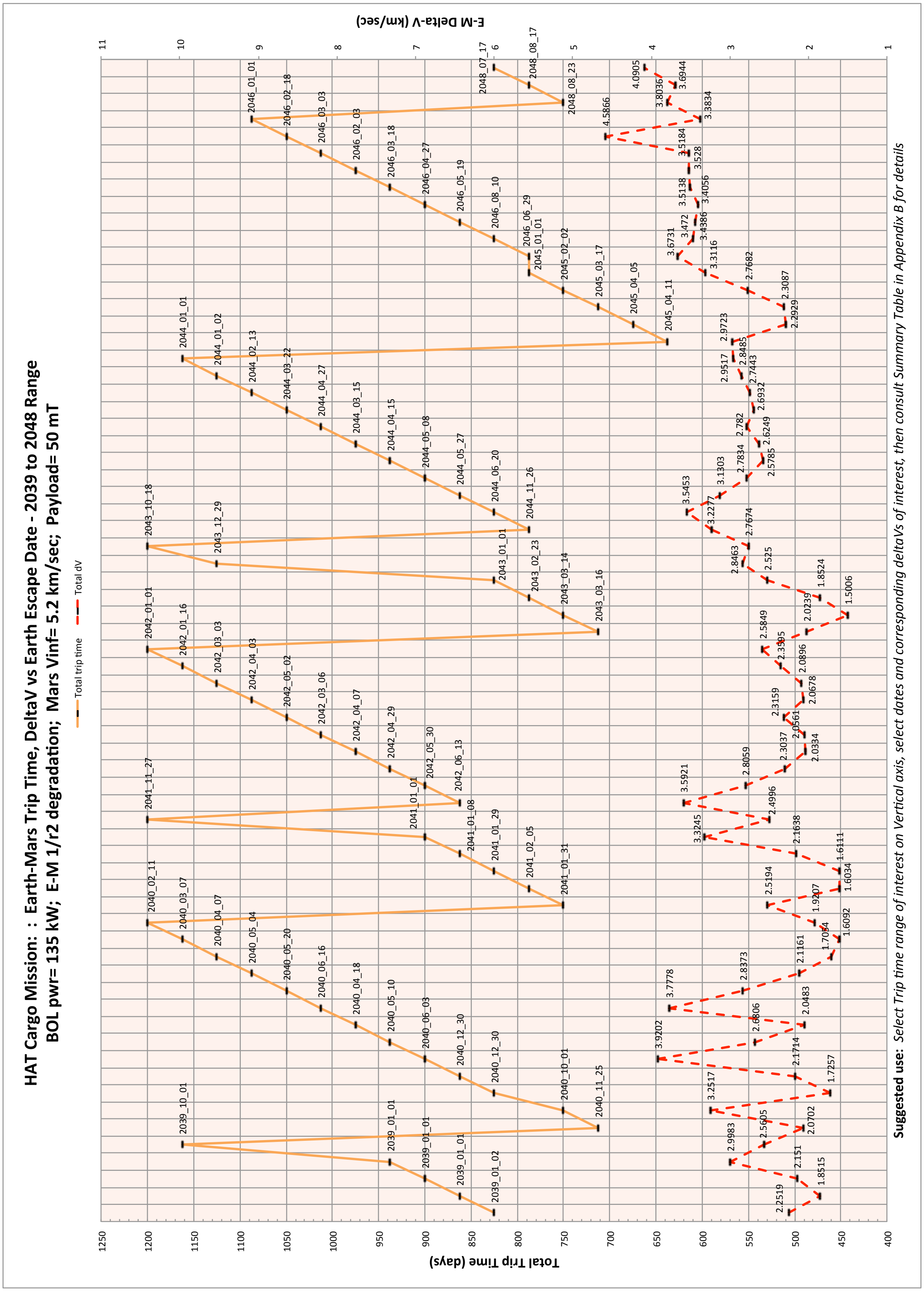

Figure 14: *Earth Escape to Mars - Launch Time Span: 2039 to 2048*

V. Summary and Conclusions

An integrated approach has been taken to assess feasible Earth to Mars missions in terms of their time and deltaV performance based on a specific set of ground rules and assumptions. Ground rules and assumptions, detailed in table 2, are those for NASA's HAT EMC Cargo missions. The intent of this study was to assess, for a wide range of years, the time divide between the major mission segments of Earth departure to escape and interplanetary transfer. To accomplish this goal, two existing trajectory simulation programs were used to model these mission segments. The OTIS program was used to generate high accuracy Earth departure spirals; the results were captured into an Earth departure spiral data surface. The Chebytop program was used to generate the Earth to Mars transfer segments. A new software program was created to manage the overall search, optimization and vehicle closure processes. This program uses the Earth spiral data surface, along with Chebytop, to perform a sweep through all the mission years of interest while optimizing departure dates and performing vehicle mass closure for all feasible missions. As described above, a multilayer search and optimization approach was taken.

The results of this study show the feasible missions for a specified SEP power level and required final payload mass at Mars. The intent is to use the graphs of total trip time and deltaV along with desired launch dates to down select missions of interest. The summary tables provide mission performance details that may be used for planning purposes. Feasible missions of interest can subsequently be analyzed in greater detail. Based on prior mission analysis experience, the overall level of fidelity in this study is deemed appropriate for the breadth of mission dates covered.

Additional parameter sweeps are planned for: power level, payload mass and Mars arrival condition. This will vastly expand the results database and will be the subject of a planned NASA Technical Data Book. To keep the present study manageable, these parameters were kept fixed. The study's goal, of showing the impact of varying mission segment times, has been demonstrated in the enclosed results.

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Appendix A

Summary data table for End-to-End missions: EEO to Mars

HAT Cargo Mission: Total Trip Time vs Launch Date - 2026 to 2046 Range
BOL pwr= 150 kW; 10% Earth spiral degradation; E-M $1/r^2$ degradation
Mars V_{inf} = 5.2 km/sec; Payload= 50,000 kg

```
Esprl:  pwr: 150.0    m0:   70935.7      Start  2026_02_04      End  2028_01_26     mf:    62375.8     trip:  720.5    mp:     8559.8  dv:    4.0278
E-M:    pwr: 135.0    m0:   62375.8      Earth  2028_03_26      Mars 2030_01_30     mf:    57530.6     trip:  675.0    mp:     4845.3  dv:    2.5499
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7530.6     p/l:   50000.0     Ttrip: 1395.5   Tmp:   13405.1  Tdv:   6.5777

Esprl:  pwr: 150.0    m0:   68307.2      Start  2026_04_30      End  2028_01_25     mf:    60809.0     trip:  635.8    mp:     7498.2  dv:    3.6630
E-M:    pwr: 135.0    m0:   60809.0      Earth  2028_03_25      Mars 2030_03_07     mf:    57401.6     trip:  712.5    mp:     3407.4  dv:    1.8184
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7401.7     p/l:   50000.0     Ttrip: 1348.3   Tmp:   10905.6  Tdv:   5.4814

Esprl:  pwr: 150.0    m0:   68418.9      Start  2026_04_15      End  2028_01_12     mf:    60905.7     trip:  637.0    mp:     7513.1  dv:    3.6783
E-M:    pwr: 135.0    m0:   60905.7      Earth  2028_03_12      Mars 2030_04_01     mf:    57407.4     trip:  750.0    mp:     3498.3  dv:    1.8653
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7407.4     p/l:   50000.0     Ttrip: 1387.0   Tmp:   11011.4  Tdv:   5.5436

Esprl:  pwr: 150.0    m0:   70699.3      Start  2025_12_05      End  2027_11_26     mf:    62104.3     trip:  720.6    mp:     8595.0  dv:    4.0840
E-M:    pwr: 135.0    m0:   62104.3      Earth  2028_01_25      Mars 2030_03_22     mf:    57510.3     trip:  787.5    mp:     4594.0  dv:    2.4234
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7510.3     p/l:   50000.0     Ttrip: 1508.1   Tmp:   13189.0  Tdv:   6.5074

Esprl:  pwr: 150.0    m0:   72942.7      Start  2025_10_04      End  2027_11_02     mf:    63905.3     trip:  758.4    mp:     9037.4  dv:    4.0842
E-M:    pwr: 135.0    m0:   63905.3      Earth  2028_01_01      Mars 2030_04_05     mf:    57633.7     trip:  825.0    mp:     6271.7  dv:    3.2573
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7633.7     p/l:   50000.0     Ttrip: 1583.4   Tmp:   15309.0  Tdv:   7.3415

Esprl:  pwr: 150.0    m0:   72080.9      Start  2026_09_30      End  2028_10_05     mf:    63303.9     trip:  735.9    mp:     8776.9  dv:    4.0267
E-M:    pwr: 135.0    m0:   63303.9      Earth  2028_12_04      Mars 2032_01_03     mf:    57597.6     trip: 1125.0    mp:     5706.3  dv:    2.9788
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7597.6     p/l:   50000.0     Ttrip: 1860.9   Tmp:   14483.2  Tdv:   7.0056

Esprl:  pwr: 150.0    m0:   73890.8      Start  2027_02_11      End  2029_04_18     mf:    64439.3     trip:  797.2    mp:     9451.4  dv:    4.2291
E-M:    pwr: 135.0    m0:   64439.3      Earth  2029_06_17      Mars 2031_09_20     mf:    57670.2     trip:  825.0    mp:     6769.1  dv:    3.4997
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7670.2     p/l:   50000.0     Ttrip: 1622.2   Tmp:   16220.6  Tdv:   7.7289

Esprl:  pwr: 150.0    m0:   72504.8      Start  2027_03_20      End  2029_03_26     mf:    63745.6     trip:  737.1    mp:     8759.2  dv:    4.0324
E-M:    pwr: 135.0    m0:   63745.6      Earth  2029_05_25      Mars 2031_10_04     mf:    57621.9     trip:  862.5    mp:     6123.7  dv:    3.1848
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7621.9     p/l:   50000.0     Ttrip: 1599.6   Tmp:   14882.9  Tdv:   7.2172

Esprl:  pwr: 150.0    m0:   71944.3      Start  2027_03_01      End  2029_03_03     mf:    63236.4     trip:  732.9    mp:     8707.9  dv:    4.0411
E-M:    pwr: 135.0    m0:   63236.4      Earth  2029_05_02      Mars 2031_10_19     mf:    57592.1     trip:  900.0    mp:     5644.3  dv:    2.9482
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7592.1     p/l:   50000.0     Ttrip: 1632.9   Tmp:   14352.2  Tdv:   6.9894

Esprl:  pwr: 150.0    m0:   73095.0      Start  2027_02_25      End  2029_04_02     mf:    64004.1     trip:  767.3    mp:     9091.0  dv:    4.0674
E-M:    pwr: 135.0    m0:   64004.1      Earth  2029_06_01      Mars 2031_12_25     mf:    57638.5     trip:  937.5    mp:     6365.6  dv:    3.3033
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7638.5     p/l:   50000.0     Ttrip: 1704.8   Tmp:   15456.6  Tdv:   7.3707

Esprl:  pwr: 150.0    m0:   72334.2      Start  2027_03_06      End  2029_03_10     mf:    63598.9     trip:  735.1    mp:     8735.4  dv:    4.0316
E-M:    pwr: 135.0    m0:   63598.9      Earth  2029_05_09      Mars 2032_01_09     mf:    57613.7     trip:  975.0    mp:     5985.2  dv:    3.1166
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7613.7     p/l:   50000.0     Ttrip: 1710.1   Tmp:   14720.5  Tdv:   7.1482

Esprl:  pwr: 150.0    m0:   72362.4      Start  2027_02_16      End  2029_02_21     mf:    63625.1     trip:  735.3    mp:     8737.3  dv:    4.0309
E-M:    pwr: 135.0    m0:   63625.1      Earth  2029_04_22      Mars 2032_01_29     mf:    57615.2     trip: 1012.5    mp:     6009.9  dv:    3.1288
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7615.2     p/l:   50000.0     Ttrip: 1747.8   Tmp:   14747.3  Tdv:   7.1597

Esprl:  pwr: 150.0    m0:   72126.9      Start  2026_12_24      End  2028_12_30     mf:    63343.0     trip:  736.4    mp:     8783.9  dv:    4.0258
E-M:    pwr: 135.0    m0:   63343.0      Earth  2029_02_28      Mars 2032_01_14     mf:    57600.0     trip: 1050.0    mp:     5743.0  dv:    2.9970
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7600.0     p/l:   50000.0     Ttrip: 1786.4   Tmp:   14526.9  Tdv:   7.0229

Esprl:  pwr: 150.0    m0:   78266.0      Start  2026_06_19      End  2028_12_18     mf:    67439.9     trip:  913.8    mp:    10826.2  dv:    4.6887
E-M:    pwr: 135.0    m0:   67439.9      Earth  2029_02_16      Mars 2032_02_08     mf:    57922.1     trip: 1087.5    mp:     9517.7  dv:    4.7974
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7922.1     p/l:   50000.0     Ttrip: 2001.3   Tmp:   20343.9  Tdv:   9.4861

Esprl:  pwr: 150.0    m0:   80178.3      Start  2026_04_03      End  2028_11_20     mf:    68833.3     trip:  961.7    mp:    11345.1  dv:    4.7766
E-M:    pwr: 135.0    m0:   68833.3      Earth  2029_01_19      Mars 2032_02_18     mf:    58001.4     trip: 1125.0    mp:    10831.9  dv:    5.3992
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     8001.4     p/l:   50000.0     Ttrip: 2086.7   Tmp:   22176.9  Tdv:  10.1758
```

```
Esprl:  pwr: 150.0    m0:   72892.6       Start  2026_10_07       End  2028_11_02    mf:    63876.8    trip:  756.5    mp:    9015.9  dv:    4.0773
E-M:    pwr: 135.0    m0:   63876.8       Earth  2029_01_01       Mars 2032_03_08    mf:    57632.6    trip: 1162.5    mp:    6244.1  dv:    3.2438
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7632.6    p/l:   50000.0    Ttrip: 1919.0   Tmp:  15260.0  Tdv:   7.3210

Esprl:  pwr: 150.0    m0:   72002.7       Start  2028_02_11       End  2030_02_13    mf:    63290.7    trip:  733.2    mp:    8712.0  dv:    4.0397
E-M:    pwr: 135.0    m0:   63290.7       Earth  2030_04_14       Mars 2032_01_11    mf:    57595.6    trip:  637.5    mp:    5695.1  dv:    2.9734
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7595.6    p/l:   50000.0    Ttrip: 1370.7   Tmp:  14407.1  Tdv:   7.0131

Esprl:  pwr: 150.0    m0:   71454.2       Start  2028_02_01       End  2030_01_31    mf:    62783.8    trip:  729.9    mp:    8670.4  dv:    4.0518
E-M:    pwr: 135.0    m0:   62783.8       Earth  2030_04_01       Mars 2032_02_05    mf:    57561.9    trip:  675.0    mp:    5222.0  dv:    2.7383
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7561.9    p/l:   50000.0    Ttrip: 1404.9   Tmp:  13892.4  Tdv:   6.7901

Esprl:  pwr: 150.0    m0:   72147.6       Start  2027_12_22       End  2029_12_28    mf:    63360.6    trip:  736.7    mp:    8787.0  dv:    4.0254
E-M:    pwr: 135.0    m0:   63360.6       Earth  2030_02_26       Mars 2032_02_08    mf:    57600.8    trip:  712.5    mp:    5759.8  dv:    3.0053
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7600.8    p/l:   50000.0    Ttrip: 1449.2   Tmp:  14546.8  Tdv:   7.0307

Esprl:  pwr: 150.0    m0:   73296.0       Start  2027_09_22       End  2029_11_02    mf:    64106.8    trip:  771.6    mp:    9189.2  dv:    4.1334
E-M:    pwr: 135.0    m0:   64106.8       Earth  2030_01_01       Mars 2032_01_21    mf:    57646.6    trip:  750.0    mp:    6460.2  dv:    3.3495
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7646.6    p/l:   50000.0    Ttrip: 1521.6   Tmp:  15649.4  Tdv:   7.4829

Esprl:  pwr: 150.0    m0:   75192.9       Start  2029_01_05       End  2031_05_01    mf:    65151.6    trip:  846.0    mp:   10041.3  dv:    4.4939
E-M:    pwr: 135.0    m0:   65151.6       Earth  2031_06_30       Mars 2033_08_25    mf:    57736.7    trip:  787.5    mp:    7414.9  dv:    3.8100
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7736.7    p/l:   50000.0    Ttrip: 1633.5   Tmp:  17456.2  Tdv:   8.3039

Esprl:  pwr: 150.0    m0:   74369.4       Start  2029_03_13       End  2031_06_06    mf:    64701.1    trip:  815.1    mp:    9668.3  dv:    4.3265
E-M:    pwr: 135.0    m0:   64701.1       Earth  2031_08_05       Mars 2033_11_07    mf:    57693.4    trip:  825.0    mp:    7007.8  dv:    3.6149
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7693.4    p/l:   50000.0    Ttrip: 1640.1   Tmp:  16676.0  Tdv:   7.9414

Esprl:  pwr: 150.0    m0:   75223.6       Start  2029_01_08       End  2031_05_05    mf:    65168.3    trip:  847.2    mp:   10055.2  dv:    4.5001
E-M:    pwr: 135.0    m0:   65168.3       Earth  2031_07_04       Mars 2033_11_12    mf:    57738.4    trip:  862.5    mp:    7430.0  dv:    3.8172
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7738.4    p/l:   50000.0    Ttrip: 1709.7   Tmp:  17485.2  Tdv:   8.3173

Esprl:  pwr: 150.0    m0:   75664.2       Start  2028_11_20       End  2031_04_03    mf:    65409.4    trip:  863.7    mp:   10254.8  dv:    4.5897
E-M:    pwr: 135.0    m0:   65409.4       Earth  2031_06_02       Mars 2033_11_18    mf:    57761.3    trip:  900.0    mp:    7648.0  dv:    3.9211
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7761.3    p/l:   50000.0    Ttrip: 1763.7   Tmp:  17902.8  Tdv:   8.5107

Esprl:  pwr: 150.0    m0:   75991.8       Start  2028_08_20       End  2031_01_14    mf:    65590.4    trip:  876.8    mp:   10401.4  dv:    4.5458
E-M:    pwr: 135.0    m0:   65590.4       Earth  2031_03_15       Mars 2033_10_07    mf:    57776.2    trip:  937.5    mp:    7814.3  dv:    4.0001
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7776.2    p/l:   50000.0    Ttrip: 1814.3   Tmp:  18215.6  Tdv:   8.5460

Esprl:  pwr: 150.0    m0:   76586.8       Start  2028_08_01       End  2031_01_18    mf:    65905.2    trip:  900.7    mp:   10681.6  dv:    4.6335
E-M:    pwr: 135.0    m0:   65905.2       Earth  2031_03_19       Mars 2033_11_18    mf:    57805.9    trip:  975.0    mp:    8099.3  dv:    4.1349
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7805.9    p/l:   50000.0    Ttrip: 1875.7   Tmp:  18780.8  Tdv:   8.7683

Esprl:  pwr: 150.0    m0:   75361.8       Start  2028_08_26       End  2030_12_23    mf:    65284.8    trip:  849.1    mp:   10077.0  dv:    4.4211
E-M:    pwr: 135.0    m0:   65284.8       Earth  2031_02_21       Mars 2033_11_29    mf:    57748.6    trip: 1012.5    mp:    7536.2  dv:    3.8679
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7748.6    p/l:   50000.0    Ttrip: 1861.6   Tmp:  17613.2  Tdv:   8.2891

Esprl:  pwr: 150.0    m0:   75026.4       Start  2028_07_31       End  2030_11_15    mf:    65093.6    trip:  836.5    mp:    9932.8  dv:    4.3744
E-M:    pwr: 135.0    m0:   65093.6       Earth  2031_01_14       Mars 2033_11_29    mf:    57731.9    trip: 1050.0    mp:    7361.7  dv:    3.7846
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7731.9    p/l:   50000.0    Ttrip: 1886.5   Tmp:  17294.5  Tdv:   8.1590

Esprl:  pwr: 150.0    m0:   75420.0       Start  2031_02_21       End  2033_06_24    mf:    65275.8    trip:  854.5    mp:   10144.2  dv:    4.5400
E-M:    pwr: 135.0    m0:   65275.8       Earth  2033_08_23       Mars 2035_09_12    mf:    57748.0    trip:  750.0    mp:    7527.9  dv:    3.8639
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7748.0    p/l:   50000.0    Ttrip: 1604.5   Tmp:  17672.1  Tdv:   8.4040

Esprl:  pwr: 150.0    m0:   70482.2       Start  2032_02_05       End  2034_01_18    mf:    62019.0    trip:  712.4    mp:    8463.1  dv:    4.0068
E-M:    pwr: 135.0    m0:   62019.0       Earth  2034_03_19       Mars 2037_03_10    mf:    57496.7    trip: 1087.5    mp:    4522.3  dv:    2.3875
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7496.7    p/l:   50000.0    Ttrip: 1799.9   Tmp:  12985.4  Tdv:   6.3943
```

```
Esprl:  pwr: 150.0    m0:   78915.3      Start  2031_05_11      End  2033_11_14    mf:    68039.9    trip:  917.9    mp:   10875.3  dv:    4.6599
E-M:    pwr: 135.0    m0:   68039.9      Earth  2034_01_13      Mars 2037_03_20    mf:    57956.8    trip: 1162.5    mp:   10083.1  dv:    5.0579
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7956.8    p/l:   50000.0   Ttrip: 2080.4    Tmp:   20958.5 Tdv:    9.7178

Esprl:  pwr: 150.0    m0:   74203.3      Start  2031_09_14      End  2033_11_28    mf:    64624.2    trip:  805.6    mp:    9579.1  dv:    4.2598
E-M:    pwr: 135.0    m0:   64624.2      Earth  2034_01_27      Mars 2037_05_11    mf:    57689.7    trip: 1200.0    mp:    6934.5  dv:    3.5794
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7689.7    p/l:   50000.0   Ttrip: 2005.6    Tmp:   16513.6 Tdv:    7.8392

Esprl:  pwr: 150.0    m0:   70874.6      Start  2034_10_10      End  2036_10_01    mf:    62259.1    trip:  722.3    mp:    8615.4  dv:    4.0737
E-M:    pwr: 135.0    m0:   62259.1      Earth  2036_11_30      Mars 2039_05_19    mf:    57526.3    trip:  900.0    mp:    4732.9  dv:    2.4932
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7526.3    p/l:   50000.0   Ttrip: 1622.3    Tmp:   13348.3 Tdv:    6.5669

Esprl:  pwr: 150.0    m0:   72089.7      Start  2034_09_16      End  2036_09_25    mf:    63275.3    trip:  739.9    mp:    8814.4  dv:    4.0051
E-M:    pwr: 135.0    m0:   63275.3      Earth  2036_11_24      Mars 2039_07_27    mf:    57598.4    trip:  975.0    mp:    5676.9  dv:    2.9642
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7598.4    p/l:   50000.0   Ttrip: 1714.9    Tmp:   14491.3 Tdv:    6.9693

Esprl:  pwr: 150.0    m0:   71946.5      Start  2034_02_12      End  2036_02_15    mf:    63238.5    trip:  732.9    mp:    8708.0  dv:    4.0411
E-M:    pwr: 135.0    m0:   63238.5      Earth  2036_04_15      Mars 2039_01_22    mf:    57591.8    trip: 1012.5    mp:    5646.7  dv:    2.9494
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7591.8    p/l:   50000.0   Ttrip: 1745.4    Tmp:   14354.7 Tdv:    6.9905

Esprl:  pwr: 150.0    m0:   68316.3      Start  2034_04_27      End  2036_01_23    mf:    60816.9    trip:  635.9    mp:    7499.4  dv:    3.6643
E-M:    pwr: 135.0    m0:   60816.9      Earth  2036_03_23      Mars 2039_03_15    mf:    57402.2    trip: 1087.5    mp:    3414.7  dv:    1.8222
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7402.2    p/l:   50000.0   Ttrip: 1723.4    Tmp:   10914.1 Tdv:    5.4864

Esprl:  pwr: 150.0    m0:   77403.5      Start  2033_06_25      End  2035_12_19    mf:    66657.4    trip:  907.2    mp:   10746.1  dv:    4.6701
E-M:    pwr: 135.0    m0:   66657.4      Earth  2036_02_17      Mars 2039_03_18    mf:    57871.0    trip: 1125.0    mp:    8786.4  dv:    4.4573
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7871.0    p/l:   50000.0   Ttrip: 2032.2    Tmp:   19532.5 Tdv:    9.1274

Esprl:  pwr: 150.0    m0:   71666.8      Start  2034_02_03      End  2036_02_04    mf:    62978.5    trip:  731.3    mp:    8688.3  dv:    4.0480
E-M:    pwr: 135.0    m0:   62978.5      Earth  2036_04_04      Mars 2039_06_10    mf:    57575.0    trip: 1162.5    mp:    5403.5  dv:    2.8287
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7575.0    p/l:   50000.0   Ttrip: 1893.8    Tmp:   14091.8 Tdv:    6.8767

Esprl:  pwr: 150.0    m0:   68335.1      Start  2034_04_27      End  2036_01_24    mf:    60833.2    trip:  636.1    mp:    7501.9  dv:    3.6668
E-M:    pwr: 135.0    m0:   60833.2      Earth  2036_03_24      Mars 2039_07_07    mf:    57403.1    trip: 1200.0    mp:    3430.0  dv:    1.8301
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7403.1    p/l:   50000.0   Ttrip: 1836.1    Tmp:   10932.0 Tdv:    5.4969

Esprl:  pwr: 150.0    m0:   71257.3      Start  2034_11_08      End  2036_11_03    mf:    62597.3    trip:  726.1    mp:    8660.1  dv:    4.0511
E-M:    pwr: 135.0    m0:   62597.3      Earth  2037_01_02      Mars 2039_06_21    mf:    57555.6    trip:  900.0    mp:    5041.6  dv:    2.6479
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7555.6    p/l:   50000.0   Ttrip: 1626.1    Tmp:   13701.7 Tdv:    6.6990

Esprl:  pwr: 150.0    m0:   71387.2      Start  2034_11_06      End  2036_11_02    mf:    62712.0    trip:  727.3    mp:    8675.2  dv:    4.0435
E-M:    pwr: 135.0    m0:   62712.0      Earth  2037_01_01      Mars 2039_07_27    mf:    57562.6    trip:  937.5    mp:    5149.3  dv:    2.7018
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7562.6    p/l:   50000.0   Ttrip: 1664.8    Tmp:   13824.5 Tdv:    6.7452

Esprl:  pwr: 150.0    m0:   72866.2      Start  2034_10_08      End  2036_11_02    mf:    63861.7    trip:  755.5    mp:    9004.5  dv:    4.0736
E-M:    pwr: 135.0    m0:   63861.7      Earth  2037_01_01      Mars 2039_09_03    mf:    57631.2    trip:  975.0    mp:    6230.5  dv:    3.2371
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7631.2    p/l:   50000.0   Ttrip: 1730.5    Tmp:   15235.0 Tdv:    7.3107

Esprl:  pwr: 150.0    m0:   70017.8      Start  2035_10_17      End  2037_09_15    mf:    61696.9    trip:  698.4    mp:    8320.9  dv:    3.8571
E-M:    pwr: 135.0    m0:   61696.9      Earth  2037_11_14      Mars 2041_01_19    mf:    57470.6    trip: 1162.5    mp:    4226.2  dv:    2.2376
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7470.6    p/l:   50000.0   Ttrip: 1860.9    Tmp:   12547.1 Tdv:    6.0947

Esprl:  pwr: 150.0    m0:   71276.5      Start  2035_07_25      End  2037_07_25    mf:    62577.4    trip:  730.3    mp:    8699.1  dv:    3.9576
E-M:    pwr: 135.0    m0:   62577.4      Earth  2037_09_23      Mars 2041_01_05    mf:    57554.0    trip: 1200.0    mp:    5023.4  dv:    2.6387
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7554.0    p/l:   50000.0   Ttrip: 1930.3    Tmp:   13722.5 Tdv:    6.5963

Esprl:  pwr: 150.0    m0:   68925.6      Start  2036_12_05      End  2038_09_19    mf:    61142.2    trip:  652.8    mp:    7783.4  dv:    3.7059
E-M:    pwr: 135.0    m0:   61142.2      Earth  2038_11_18      Mars 2040_10_30    mf:    57422.7    trip:  712.5    mp:    3719.6  dv:    1.9792
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7422.7    p/l:   50000.0   Ttrip: 1365.3    Tmp:   11503.0 Tdv:    5.6851
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Esprl:  pwr: 150.0    m0:   70123.9       Start  2036_11_23       End  2038_10_28    mf:    61737.6    trip:  703.8    mp:    8386.3  dv:   4.0184
E-M:    pwr: 135.0    m0:   61737.6       Earth  2038_12_27       Mars 2041_03_31    mf:    57472.4    trip:  825.0    mp:    4265.2  dv:   2.2574
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7472.4    p/l:   50000.0    Ttrip: 1528.8   Tmp:   12651.5 Tdv:   6.2759

Esprl:  pwr: 150.0    m0:   68367.7       Start  2037_01_30       End  2038_10_24    mf:    60868.9    trip:  632.7    mp:    7498.8  dv:   3.6377
E-M:    pwr: 135.0    m0:   60868.9       Earth  2038_12_23       Mars 2041_05_03    mf:    57405.5    trip:  862.5    mp:    3463.4  dv:   1.8473
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7405.5    p/l:   50000.0    Ttrip: 1495.2   Tmp:   10962.2 Tdv:   5.4850

Esprl:  pwr: 150.0    m0:   69591.9       Start  2036_12_07       End  2038_10_20    mf:    61482.8    trip:  681.6    mp:    8109.1  dv:   3.8985
E-M:    pwr: 135.0    m0:   61482.8       Earth  2038_12_19       Mars 2041_06_06    mf:    57446.1    trip:  900.0    mp:    4036.7  dv:   2.1415
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7446.1    p/l:   50000.0    Ttrip: 1581.6   Tmp:   12145.8 Tdv:   6.0400

Esprl:  pwr: 150.0    m0:   71509.1       Start  2036_03_02       End  2038_03_03    mf:    62831.9    trip:  730.4    mp:    8677.2  dv:   4.0519
E-M:    pwr: 135.0    m0:   62831.9       Earth  2038_05_02       Mars 2041_01_01    mf:    57565.1    trip:  975.0    mp:    5266.8  dv:   2.7607
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7565.1    p/l:   50000.0    Ttrip: 1705.4   Tmp:   13944.0 Tdv:   6.8125

Esprl:  pwr: 150.0    m0:   68953.7       Start  2036_04_15       End  2038_02_01    mf:    61197.7    trip:  656.3    mp:    7756.0  dv:   3.7634
E-M:    pwr: 135.0    m0:   61197.7       Earth  2038_04_02       Mars 2041_01_08    mf:    57425.1    trip: 1012.5    mp:    3772.6  dv:   2.0064
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7425.1    p/l:   50000.0    Ttrip: 1668.8   Tmp:   11528.6 Tdv:   5.7698

Esprl:  pwr: 150.0    m0:   73278.0       Start  2036_02_07       End  2038_03_16    mf:    64154.7    trip:  768.1    mp:    9123.3  dv:   4.1463
E-M:    pwr: 135.0    m0:   64154.7       Earth  2038_05_15       Mars 2041_05_06    mf:    57644.8    trip: 1087.5    mp:    6509.9  dv:   3.3740
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7644.8    p/l:   50000.0    Ttrip: 1855.6   Tmp:   15633.2 Tdv:   7.5203

Esprl:  pwr: 150.0    m0:   70164.7       Start  2036_03_26       End  2038_02_25    mf:    61846.8    trip:  700.9    mp:    8317.9  dv:   3.9570
E-M:    pwr: 135.0    m0:   61846.8       Earth  2038_04_26       Mars 2041_05_25    mf:    57480.2    trip: 1125.0    mp:    4366.6  dv:   2.3089
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7480.2    p/l:   50000.0    Ttrip: 1825.9   Tmp:   12684.5 Tdv:   6.2659

Esprl:  pwr: 150.0    m0:   67760.3       Start  2036_05_13       End  2038_02_02    mf:    60335.2    trip:  629.7    mp:    7425.1  dv:   3.5883
E-M:    pwr: 135.0    m0:   60335.2       Earth  2038_04_03       Mars 2041_06_08    mf:    57373.5    trip: 1162.5    mp:    2961.6  dv:   1.5872
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7373.5    p/l:   50000.0    Ttrip: 1792.2   Tmp:   10386.7 Tdv:   5.1755

Esprl:  pwr: 150.0    m0:   67247.0       Start  2036_05_01       End  2038_01_15    mf:    59883.8    trip:  624.5    mp:    7363.1  dv:   3.5492
E-M:    pwr: 135.0    m0:   59883.8       Earth  2038_03_16       Mars 2041_06_28    mf:    57347.2    trip: 1200.0    mp:    2536.7  dv:   1.3649
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7347.2    p/l:   50000.0    Ttrip: 1824.5   Tmp:    9899.8 Tdv:   4.9141

Esprl:  pwr: 150.0    m0:   70151.1       Start  2036_11_28       End  2038_11_03    mf:    61750.6    trip:  705.0    mp:    8400.5  dv:   4.0245
E-M:    pwr: 135.0    m0:   61750.6       Earth  2039_01_02       Mars 2041_04_06    mf:    57473.7    trip:  825.0    mp:    4276.9  dv:   2.2633
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7473.7    p/l:   50000.0    Ttrip: 1530.0   Tmp:   12677.3 Tdv:   6.2879

Esprl:  pwr: 150.0    m0:   68390.0       Start  2037_02_08       End  2038_11_02    mf:    60888.7    trip:  632.9    mp:    7501.3  dv:   3.6377
E-M:    pwr: 135.0    m0:   60888.7       Earth  2039_01_01       Mars 2041_05_12    mf:    57406.7    trip:  862.5    mp:    3482.0  dv:   1.8569
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7406.7    p/l:   50000.0    Ttrip: 1495.4   Tmp:   10983.3 Tdv:   5.4946

Esprl:  pwr: 150.0    m0:   69664.4       Start  2036_12_17       End  2038_11_02    mf:    61517.5    trip:  684.6    mp:    8146.9  dv:   3.9149
E-M:    pwr: 135.0    m0:   61517.5       Earth  2039_01_01       Mars 2041_06_19    mf:    57449.7    trip:  900.0    mp:    4067.8  dv:   2.1573
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7449.7    p/l:   50000.0    Ttrip: 1584.6   Tmp:   12214.7 Tdv:   6.0721

Esprl:  pwr: 150.0    m0:   72239.7       Start  2036_10_25       End  2038_11_02    mf:    63438.7    trip:  737.9    mp:    8800.9  dv:   4.0237
E-M:    pwr: 135.0    m0:   63438.7       Earth  2039_01_01       Mars 2041_07_26    mf:    57605.2    trip:  937.5    mp:    5833.6  dv:   3.0418
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7605.2    p/l:   50000.0    Ttrip: 1675.4   Tmp:   14634.5 Tdv:   7.0655

Esprl:  pwr: 150.0    m0:   76663.6       Start  2037_02_23       End  2039_08_03    mf:    66094.3    trip:  891.8    mp:   10569.3  dv:   4.6466
E-M:    pwr: 135.0    m0:   66094.3       Earth  2039_10_02       Mars 2042_12_07    mf:    57818.1    trip: 1162.5    mp:    8276.2  dv:   4.2186
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7818.1    p/l:   50000.0    Ttrip: 2054.3   Tmp:   18845.5 Tdv:   8.8652

Esprl:  pwr: 150.0    m0:   69335.3       Start  2038_11_26       End  2040_09_26    mf:    61350.3    trip:  669.9    mp:    7985.0  dv:   3.7626
E-M:    pwr: 135.0    m0:   61350.3       Earth  2040_11_25       Mars 2042_11_07    mf:    57435.8    trip:  712.5    mp:    3914.5  dv:   2.0791
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7435.8    p/l:   50000.0    Ttrip: 1382.4   Tmp:   11899.5 Tdv:   5.8417
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Esprl:  pwr: 150.0    m0:   73108.5     Start  2038_06_27     End  2040_08_02    mf:    63987.6    trip:  766.3    mp:     9120.9  dv:    4.1225
E-M:    pwr: 135.0    m0:   63987.6     Earth  2040_10_01     Mars 2042_10_21    mf:    57641.0    trip:  750.0    mp:     6346.6  dv:    3.2939
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7641.0    p/l:   50000.0    Ttrip: 1516.3   Tmp:   15467.5 Tdv:    7.4164

Esprl:  pwr: 150.0    m0:   68093.8     Start  2039_02_09     End  2040_10_31    mf:    60625.6    trip:  630.1    mp:     7468.2  dv:    3.6375
E-M:    pwr: 135.0    m0:   60625.6     Earth  2040_12_30     Mars 2043_04_04    mf:    57391.2    trip:  825.0    mp:     3234.4  dv:    1.7289
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7391.2    p/l:   50000.0    Ttrip: 1455.1   Tmp:   10702.6 Tdv:    5.3664

Esprl:  pwr: 150.0    m0:   69763.9     Start  2038_12_12     End  2040_10_31    mf:    61565.2    trip:  688.8    mp:     8198.8  dv:    3.9373
E-M:    pwr: 135.0    m0:   61565.2     Earth  2040_12_30     Mars 2043_05_11    mf:    57454.6    trip:  862.5    mp:     4110.6  dv:    2.1790
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7454.6    p/l:   50000.0    Ttrip: 1551.3   Tmp:   12309.3 Tdv:    6.1163

Esprl:  pwr: 150.0    m0:   76390.6     Start  2037_10_26     End  2040_04_04    mf:    65806.7    trip:  891.0    mp:    10583.9  dv:    4.7373
E-M:    pwr: 135.0    m0:   65806.7     Earth  2040_06_03     Mars 2042_11_20    mf:    57784.4    trip:  900.0    mp:     8022.4  dv:    4.0995
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7784.4    p/l:   50000.0    Ttrip: 1791.0   Tmp:   18606.3 Tdv:    8.8368

Esprl:  pwr: 150.0    m0:   71353.9     Start  2038_03_15     End  2040_03_12    mf:    62704.9    trip:  728.1    mp:     8649.0  dv:    4.0471
E-M:    pwr: 135.0    m0:   62704.9     Earth  2040_05_11     Mars 2042_12_04    mf:    57556.8    trip:  937.5    mp:     5148.1  dv:    2.7014
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7556.8    p/l:   50000.0    Ttrip: 1665.6   Tmp:   13797.1 Tdv:    6.7485

Esprl:  pwr: 150.0    m0:   69138.0     Start  2038_04_26     End  2040_02_18    mf:    61296.5    trip:  663.1    mp:     7841.5  dv:    3.7928
E-M:    pwr: 135.0    m0:   61296.5     Earth  2040_04_18     Mars 2042_12_19    mf:    57431.0    trip:  975.0    mp:     3865.5  dv:    2.0540
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7431.0    p/l:   50000.0    Ttrip: 1638.1   Tmp:   11706.9 Tdv:    5.8469

Esprl:  pwr: 150.0    m0:   75299.6     Start  2037_12_18     End  2040_04_16    mf:    65209.9    trip:  850.0    mp:    10089.6  dv:    4.5155
E-M:    pwr: 135.0    m0:   65209.9     Earth  2040_06_15     Mars 2043_03_24    mf:    57739.8    trip: 1012.5    mp:     7470.1  dv:    3.8365
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7739.8    p/l:   50000.0    Ttrip: 1862.5   Tmp:   17559.7 Tdv:    8.3521

Esprl:  pwr: 150.0    m0:   71735.1     Start  2038_03_20     End  2040_03_20    mf:    63042.0    trip:  731.7    mp:     8693.1  dv:    4.0463
E-M:    pwr: 135.0    m0:   63042.0     Earth  2040_05_19     Mars 2043_04_04    mf:    57579.1    trip: 1050.0    mp:     5462.9  dv:    2.8583
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7579.1    p/l:   50000.0    Ttrip: 1781.7   Tmp:   14156.0 Tdv:    6.9046

Esprl:  pwr: 150.0    m0:   69414.2     Start  2038_05_01     End  2040_03_05    mf:    61444.5    trip:  673.2    mp:     7969.6  dv:    3.8370
E-M:    pwr: 135.0    m0:   61444.5     Earth  2040_05_04     Mars 2043_04_26    mf:    57442.1    trip: 1087.5    mp:     4002.4  dv:    2.1240
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7442.1    p/l:   50000.0    Ttrip: 1760.7   Tmp:   11972.0 Tdv:    5.9610

Esprl:  pwr: 150.0    m0:   68008.4     Start  2038_05_16     End  2040_02_08    mf:    60550.1    trip:  632.4    mp:     7458.3  dv:    3.6222
E-M:    pwr: 135.0    m0:   60550.1     Earth  2040_04_08     Mars 2043_05_08    mf:    57386.1    trip: 1125.0    mp:     3164.0  dv:    1.6924
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7386.1    p/l:   50000.0    Ttrip: 1757.4   Tmp:   10622.3 Tdv:    5.3146

Esprl:  pwr: 150.0    m0:   67801.2     Start  2038_04_18     End  2040_01_09    mf:    60370.6    trip:  630.1    mp:     7430.6  dv:    3.5939
E-M:    pwr: 135.0    m0:   60370.6     Earth  2040_03_09     Mars 2043_05_15    mf:    57375.6    trip: 1162.5    mp:     2995.0  dv:    1.6045
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7375.6    p/l:   50000.0    Ttrip: 1792.6   Tmp:   10425.6 Tdv:    5.1985

Esprl:  pwr: 150.0    m0:   68643.7     Start  2038_03_04     End  2039_12_06    mf:    61028.7    trip:  642.0    mp:     7615.1  dv:    3.6848
E-M:    pwr: 135.0    m0:   61028.7     Earth  2040_02_04     Mars 2043_05_19    mf:    57414.9    trip: 1200.0    mp:     3613.8  dv:    1.9248
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7414.9    p/l:   50000.0    Ttrip: 1842.0   Tmp:   11228.8 Tdv:    5.6096

Esprl:  pwr: 150.0    m0:   70967.3     Start  2038_12_09     End  2040_12_02    mf:    62341.0    trip:  723.3    mp:     8626.2  dv:    4.0682
E-M:    pwr: 135.0    m0:   62341.0     Earth  2041_01_31     Mars 2043_02_20    mf:    57536.1    trip:  750.0    mp:     4804.9  dv:    2.5292
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7536.1    p/l:   50000.0    Ttrip: 1473.3   Tmp:   13431.2 Tdv:    6.5975

Esprl:  pwr: 150.0    m0:   67816.6     Start  2039_03_20     End  2040_12_07    mf:    60379.3    trip:  627.5    mp:     7437.3  dv:    3.6374
E-M:    pwr: 135.0    m0:   60379.3     Earth  2041_02_05     Mars 2043_04_03    mf:    57377.1    trip:  787.5    mp:     3002.2  dv:    1.6082
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7377.1    p/l:   50000.0    Ttrip: 1415.0   Tmp:   10439.5 Tdv:    5.2456

Esprl:  pwr: 150.0    m0:   67829.0     Start  2039_03_13     End  2040_11_30    mf:    60390.3    trip:  627.7    mp:     7438.7  dv:    3.6374
E-M:    pwr: 135.0    m0:   60390.3     Earth  2041_01_29     Mars 2043_05_04    mf:    57377.8    trip:  825.0    mp:     3012.5  dv:    1.6136
                      E_Vinf:    1.4142 M_Vinf:    5.2000     s/c:     7377.8    p/l:   50000.0    Ttrip: 1452.7   Tmp:   10451.2 Tdv:    5.2510
```

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Esprl:  pwr: 150.0    m0:   69729.0      Start  2038_12_23      End  2040_11_09    mf:    61548.4    trip:  687.3    mp:     8180.5  dv:    3.9294
E-M:    pwr: 135.0    m0:   61548.4      Earth  2041_01_08      Mars 2043_05_20    mf:    57452.9    trip:  862.5    mp:     4095.6  dv:    2.1714
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7452.9    p/l:   50000.0    Ttrip: 1549.8    Tmp:   12276.1 Tdv:    6.1008

Esprl:  pwr: 150.0    m0:   73753.3      Start  2038_09_05      End  2040_11_02    mf:    64367.6    trip:  788.8    mp:     9385.7  dv:    4.1971
E-M:    pwr: 135.0    m0:   64367.6      Earth  2041_01_01      Mars 2043_06_20    mf:    57660.2    trip:  900.0    mp:     6707.3  dv:    3.4700
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7660.2    p/l:   50000.0    Ttrip: 1688.8    Tmp:   16093.0 Tdv:    7.6671

Esprl:  pwr: 150.0    m0:   70917.4      Start  2039_10_04      End  2041_09_28    mf:    62287.1    trip:  724.5    mp:     8630.4  dv:    3.9409
E-M:    pwr: 135.0    m0:   62287.1      Earth  2041_11_27      Mars 2045_03_11    mf:    57529.4    trip: 1200.0    mp:     4757.7  dv:    2.5056
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7529.4    p/l:   50000.0    Ttrip: 1924.5    Tmp:   13388.1 Tdv:    6.4465

Esprl:  pwr: 150.0    m0:   74590.8      Start  2040_01_11      End  2042_04_14    mf:    64822.2    trip:  823.4    mp:     9768.6  dv:    4.3715
E-M:    pwr: 135.0    m0:   64822.2      Earth  2042_06_13      Mars 2044_10_22    mf:    57702.0    trip:  862.5    mp:     7120.3  dv:    3.6692
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7702.0    p/l:   50000.0    Ttrip: 1685.9    Tmp:   16888.9 Tdv:    8.0406

Esprl:  pwr: 150.0    m0:   71666.7      Start  2040_03_29      End  2042_03_31    mf:    62978.4    trip:  731.3    mp:     8688.3  dv:    4.0480
E-M:    pwr: 135.0    m0:   62978.4      Earth  2042_05_30      Mars 2044_11_15    mf:    57574.8    trip:  900.0    mp:     5403.7  dv:    2.8288
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7574.8    p/l:   50000.0    Ttrip: 1631.3    Tmp:   14092.0 Tdv:    6.8768

Esprl:  pwr: 150.0    m0:   70190.2      Start  2040_03_30      End  2042_03_02    mf:    61860.5    trip:  701.8    mp:     8329.7  dv:    3.9611
E-M:    pwr: 135.0    m0:   61860.5      Earth  2042_05_01      Mars 2044_11_23    mf:    57481.4    trip:  937.5    mp:     4379.1  dv:    2.3152
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7481.4    p/l:   50000.0    Ttrip: 1639.3    Tmp:   12708.8 Tdv:    6.2763

Esprl:  pwr: 150.0    m0:   69077.8      Start  2040_04_16      End  2042_02_06    mf:    61264.2    trip:  660.9    mp:     7813.5  dv:    3.7832
E-M:    pwr: 135.0    m0:   61264.2      Earth  2042_04_07      Mars 2044_12_07    mf:    57429.1    trip:  975.0    mp:     3835.1  dv:    2.0385
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7429.1    p/l:   50000.0    Ttrip: 1635.9    Tmp:   11648.7 Tdv:    5.8217

Esprl:  pwr: 150.0    m0:   69190.4      Start  2040_03_10      End  2042_01_04    mf:    61324.6    trip:  665.0    mp:     7865.8  dv:    3.8012
E-M:    pwr: 135.0    m0:   61324.6      Earth  2042_03_05      Mars 2044_12_11    mf:    57432.7    trip: 1012.5    mp:     3891.8  dv:    2.0675
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7432.7    p/l:   50000.0    Ttrip: 1677.5    Tmp:   11757.6 Tdv:    5.8688

Esprl:  pwr: 150.0    m0:   70229.7      Start  2040_04_02      End  2042_03_06    mf:    61881.6    trip:  703.2    mp:     8348.0  dv:    3.9674
E-M:    pwr: 135.0    m0:   61881.6      Earth  2042_05_05      Mars 2045_03_20    mf:    57483.9    trip: 1050.0    mp:     4397.8  dv:    2.3246
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7483.9    p/l:   50000.0    Ttrip: 1753.2    Tmp:   12745.8 Tdv:    6.2920

Esprl:  pwr: 150.0    m0:   69211.1      Start  2040_04_07      End  2042_02_02    mf:    61335.7    trip:  665.8    mp:     7875.4  dv:    3.8045
E-M:    pwr: 135.0    m0:   61335.7      Earth  2042_04_03      Mars 2045_03_25    mf:    57433.4    trip: 1087.5    mp:     3902.3  dv:    2.0729
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7433.4    p/l:   50000.0    Ttrip: 1753.3    Tmp:   11777.7 Tdv:    5.8774

Esprl:  pwr: 150.0    m0:   69304.8      Start  2040_03_03      End  2042_01_01    mf:    61385.9    trip:  669.2    mp:     7918.9  dv:    3.8195
E-M:    pwr: 135.0    m0:   61385.9      Earth  2042_03_02      Mars 2045_03_31    mf:    57436.8    trip: 1125.0    mp:     3949.1  dv:    2.0968
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7436.8    p/l:   50000.0    Ttrip: 1794.2    Tmp:   11868.0 Tdv:    5.9164

Esprl:  pwr: 150.0    m0:   70563.6      Start  2039_12_04      End  2041_11_22    mf:    61984.4    trip:  719.3    mp:     8579.2  dv:    4.0920
E-M:    pwr: 135.0    m0:   61984.4      Earth  2042_01_21      Mars 2045_03_28    mf:    57498.7    trip: 1162.5    mp:     4485.7  dv:    2.3688
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7498.7    p/l:   50000.0    Ttrip: 1881.8    Tmp:   13064.8 Tdv:    6.4608

Esprl:  pwr: 150.0    m0:   71124.1      Start  2039_11_08      End  2041_11_02    mf:    62479.5    trip:  724.8    mp:     8644.5  dv:    4.0590
E-M:    pwr: 135.0    m0:   62479.5      Earth  2042_01_01      Mars 2045_04_15    mf:    57549.0    trip: 1200.0    mp:     4930.6  dv:    2.5922
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7549.0    p/l:   50000.0    Ttrip: 1924.8    Tmp:   13575.1 Tdv:    6.6511

Esprl:  pwr: 150.0    m0:   69048.1      Start  2041_03_27      End  2043_01_15    mf:    61248.3    trip:  659.8    mp:     7799.8  dv:    3.7785
E-M:    pwr: 135.0    m0:   61248.3      Earth  2043_03_16      Mars 2045_02_25    mf:    57428.1    trip:  712.5    mp:     3820.2  dv:    2.0309
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7428.1    p/l:   50000.0    Ttrip: 1372.3    Tmp:   11620.0 Tdv:    5.8093

Esprl:  pwr: 150.0    m0:   67565.8      Start  2041_04_25      End  2043_01_13    mf:    60166.7    trip:  627.5    mp:     7399.1  dv:    3.5618
E-M:    pwr: 135.0    m0:   60166.7      Earth  2043_03_14      Mars 2045_04_02    mf:    57363.7    trip:  750.0    mp:     2803.1  dv:    1.5044
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7363.7    p/l:   50000.0    Ttrip: 1377.5    Tmp:   10202.2 Tdv:    5.0662
```

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Esprl:  pwr: 150.0    m0:   68392.1      Start  2041_03_31      End  2042_12_24    mf:    60890.6    trip:  632.9    mp:     7501.5  dv:    3.6377
E-M:    pwr: 135.0    m0:   60890.6      Earth  2043_02_22      Mars 2045_04_19    mf:    57406.8    trip:  787.5    mp:     3483.8  dv:    1.8578
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7406.8    p/l:   50000.0    Ttrip: 1420.4    Tmp:   10985.3 Tdv:    5.4956

Esprl:  pwr: 150.0    m0:   71001.7      Start  2040_11_08      End  2042_11_02    mf:    62371.5    trip:  723.6    mp:     8630.3  dv:    4.0662
E-M:    pwr: 135.0    m0:   62371.5      Earth  2043_01_01      Mars 2045_04_05    mf:    57538.4    trip:  825.0    mp:     4833.1  dv:    2.5434
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7538.4    p/l:   50000.0    Ttrip: 1548.6    Tmp:   13463.4 Tdv:    6.6096

Esprl:  pwr: 150.0    m0:   71769.9      Start  2041_10_28      End  2043_10_30    mf:    63039.9    trip:  731.9    mp:     8730.0  dv:    4.0327
E-M:    pwr: 135.0    m0:   63039.9      Earth  2043_12_29      Mars 2047_01_27    mf:    57582.0    trip: 1125.0    mp:     5457.9  dv:    2.8556
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7582.0    p/l:   50000.0    Ttrip: 1856.9    Tmp:   14187.8 Tdv:    6.8883

Esprl:  pwr: 150.0    m0:   71620.3      Start  2041_08_13      End  2043_08_19    mf:    62864.9    trip:  735.0    mp:     8755.4  dv:    3.9759
E-M:    pwr: 135.0    m0:   62864.9      Earth  2043_10_18      Mars 2047_01_30    mf:    57572.6    trip: 1200.0    mp:     5292.3  dv:    2.7731
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7572.6    p/l:   50000.0    Ttrip: 1935.0    Tmp:   14047.7 Tdv:    6.7490

Esprl:  pwr: 150.0    m0:   72970.6      Start  2042_08_27      End  2044_09_27    mf:    63905.9    trip:  761.4    mp:     9064.7  dv:    4.1022
E-M:    pwr: 135.0    m0:   63905.9      Earth  2044_11_26      Mars 2047_01_22    mf:    57636.3    trip:  787.5    mp:     6269.6  dv:    3.2561
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7636.3    p/l:   50000.0    Ttrip: 1548.9    Tmp:   15334.3 Tdv:    7.3583

Esprl:  pwr: 150.0    m0:   74645.8      Start  2042_02_01      End  2044_05_07    mf:    64852.3    trip:  825.5    mp:     9793.5  dv:    4.3826
E-M:    pwr: 135.0    m0:   64852.3      Earth  2044_07_06      Mars 2046_10_09    mf:    57706.8    trip:  825.0    mp:     7145.5  dv:    3.6812
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7706.8    p/l:   50000.0    Ttrip: 1650.5    Tmp:   16939.0 Tdv:    8.0638

Esprl:  pwr: 150.0    m0:   72421.2      Start  2042_03_24      End  2044_03_28    mf:    63679.7    trip:  735.6    mp:     8741.5  dv:    4.0294
E-M:    pwr: 135.0    m0:   63679.7      Earth  2044_05_27      Mars 2046_10_06    mf:    57618.2    trip:  862.5    mp:     6061.5  dv:    3.1542
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7618.2    p/l:   50000.0    Ttrip: 1598.1    Tmp:   14803.0 Tdv:    7.1837

Esprl:  pwr: 150.0    m0:   71597.6      Start  2042_03_07      End  2044_03_07    mf:    62914.1    trip:  730.9    mp:     8683.4  dv:    4.0497
E-M:    pwr: 135.0    m0:   62914.1      Earth  2044_05_06      Mars 2046_10_23    mf:    57570.8    trip:  900.0    mp:     5343.3  dv:    2.7988
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7570.8    p/l:   50000.0    Ttrip: 1630.9    Tmp:   14026.7 Tdv:    6.8485

Esprl:  pwr: 150.0    m0:   71041.6      Start  2042_02_23      End  2044_02_15    mf:    62459.2    trip:  722.4    mp:     8582.4  dv:    4.0327
E-M:    pwr: 135.0    m0:   62459.2      Earth  2044_04_15      Mars 2046_11_08    mf:    57538.5    trip:  937.5    mp:     4920.7  dv:    2.5876
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7538.5    p/l:   50000.0    Ttrip: 1659.9    Tmp:   13503.1 Tdv:    6.6203

Esprl:  pwr: 150.0    m0:   71188.4      Start  2042_01_17      End  2044_01_12    mf:    62574.7    trip:  725.1    mp:     8613.7  dv:    4.0395
E-M:    pwr: 135.0    m0:   62574.7      Earth  2044_03_12      Mars 2046_11_12    mf:    57548.5    trip:  975.0    mp:     5026.2  dv:    2.6404
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7548.5    p/l:   50000.0    Ttrip: 1700.1    Tmp:   13639.9 Tdv:    6.6799

Esprl:  pwr: 150.0    m0:   71587.0      Start  2042_02_28      End  2044_02_29    mf:    62904.3    trip:  730.9    mp:     8682.7  dv:    4.0499
E-M:    pwr: 135.0    m0:   62904.3      Earth  2044_04_29      Mars 2047_02_05    mf:    57570.3    trip: 1012.5    mp:     5334.1  dv:    2.7942
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7570.3    p/l:   50000.0    Ttrip: 1743.4    Tmp:   14016.7 Tdv:    6.8441

Esprl:  pwr: 150.0    m0:   71425.8      Start  2042_01_06      End  2044_01_05    mf:    62761.5    trip:  729.3    mp:     8664.3  dv:    4.0505
E-M:    pwr: 135.0    m0:   62761.5      Earth  2044_03_05      Mars 2047_01_19    mf:    57560.8    trip: 1050.0    mp:     5200.6  dv:    2.7276
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7560.8    p/l:   50000.0    Ttrip: 1779.3    Tmp:   13865.0 Tdv:    6.7781

Esprl:  pwr: 150.0    m0:   71464.9      Start  2041_12_11      End  2043_12_09    mf:    62780.7    trip:  728.1    mp:     8684.3  dv:    4.0389
E-M:    pwr: 135.0    m0:   62780.7      Earth  2044_02_07      Mars 2047_01_29    mf:    57566.7    trip: 1087.5    mp:     5214.0  dv:    2.7341
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7566.7    p/l:   50000.0    Ttrip: 1815.6    Tmp:   13898.2 Tdv:    6.7729

Esprl:  pwr: 150.0    m0:   71775.9      Start  2041_11_01      End  2043_11_03    mf:    63045.0    trip:  732.0    mp:     8730.9  dv:    4.0325
E-M:    pwr: 135.0    m0:   63045.0      Earth  2044_01_02      Mars 2047_01_31    mf:    57582.3    trip: 1125.0    mp:     5462.7  dv:    2.8580
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7582.3    p/l:   50000.0    Ttrip: 1857.0    Tmp:   14193.5 Tdv:    6.8905

Esprl:  pwr: 150.0    m0:   72042.5      Start  2041_10_27      End  2043_11_02    mf:    63271.3    trip:  735.4    mp:     8771.1  dv:    4.0274
E-M:    pwr: 135.0    m0:   63271.3      Earth  2044_01_01      Mars 2047_03_08    mf:    57595.7    trip: 1162.5    mp:     5675.6  dv:    2.9637
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7595.7    p/l:   50000.0    Ttrip: 1897.9    Tmp:   14446.8 Tdv:    6.9911
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Esprl:  pwr: 150.0    m0:   72028.5      Start  2043_02_08      End  2045_02_10    mf:    63314.7    trip:  733.4    mp:     8713.8  dv:    4.0391
E-M:    pwr: 135.0    m0:   63314.7      Earth  2045_04_11      Mars 2047_01_08    mf:    57597.3    trip:  637.5    mp:     5717.4  dv:    2.9844
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7597.3    p/l:   50000.0    Ttrip: 1370.9    Tmp:   14431.2 Tdv:    7.0235

Esprl:  pwr: 150.0    m0:   70141.0      Start  2043_03_07      End  2045_02_04    mf:    61834.1    trip:  700.0    mp:     8306.9  dv:    3.9532
E-M:    pwr: 135.0    m0:   61834.1      Earth  2045_04_05      Mars 2047_02_09    mf:    57479.0    trip:  675.0    mp:     4355.1  dv:    2.3031
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7479.0    p/l:   50000.0    Ttrip: 1375.0    Tmp:   12662.0 Tdv:    6.2563

Esprl:  pwr: 150.0    m0:   70203.3      Start  2043_02_14      End  2045_01_17    mf:    61867.5    trip:  702.3    mp:     8335.8  dv:    3.9632
E-M:    pwr: 135.0    m0:   61867.5      Earth  2045_03_18      Mars 2047_02_28    mf:    57482.2    trip:  712.5    mp:     4385.3  dv:    2.3184
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7482.2    p/l:   50000.0    Ttrip: 1414.8    Tmp:   12721.1 Tdv:    6.2815

Esprl:  pwr: 150.0    m0:   71587.6      Start  2042_12_05      End  2044_12_03    mf:    62885.1    trip:  729.6    mp:     8702.4  dv:    4.0361
E-M:    pwr: 135.0    m0:   62885.1      Earth  2045_02_01      Mars 2047_02_21    mf:    57572.8    trip:  750.0    mp:     5312.3  dv:    2.7831
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7572.8    p/l:   50000.0    Ttrip: 1479.6    Tmp:   14014.8 Tdv:    6.8193

Esprl:  pwr: 150.0    m0:   73278.1      Start  2042_09_23      End  2044_11_02    mf:    64096.6    trip:  770.9    mp:     9181.5  dv:    4.1310
E-M:    pwr: 135.0    m0:   64096.6      Earth  2045_01_01      Mars 2047_02_27    mf:    57645.8    trip:  787.5    mp:     6450.8  dv:    3.3449
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7645.8    p/l:   50000.0    Ttrip: 1558.4    Tmp:   15632.3 Tdv:    7.4758

Esprl:  pwr: 150.0    m0:   74775.9      Start  2044_01_21      End  2046_04_30    mf:    64923.5    trip:  830.4    mp:     9852.4  dv:    4.4091
E-M:    pwr: 135.0    m0:   64923.5      Earth  2046_06_29      Mars 2048_08_24    mf:    57714.9    trip:  787.5    mp:     7208.6  dv:    3.7113
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7714.9    p/l:   50000.0    Ttrip: 1617.9    Tmp:   17061.0 Tdv:    8.1204

Esprl:  pwr: 150.0    m0:   74013.0      Start  2044_04_01      End  2046_06_12    mf:    64506.2    trip:  801.7    mp:     9506.8  dv:    4.2540
E-M:    pwr: 135.0    m0:   64506.2      Earth  2046_08_11      Mars 2048_11_13    mf:    57674.1    trip:  825.0    mp:     6832.1  dv:    3.5303
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7674.1    p/l:   50000.0    Ttrip: 1626.7    Tmp:   16338.9 Tdv:    7.7843

Esprl:  pwr: 150.0    m0:   73618.0      Start  2044_01_28      End  2046_03_20    mf:    64334.6    trip:  781.7    mp:     9283.5  dv:    4.1963
E-M:    pwr: 135.0    m0:   64334.6      Earth  2046_05_19      Mars 2048_09_27    mf:    57656.0    trip:  862.5    mp:     6678.6  dv:    3.4562
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7656.0    p/l:   50000.0    Ttrip: 1644.2    Tmp:   15962.0 Tdv:    7.6525

Esprl:  pwr: 150.0    m0:   73475.6      Start  2044_01_12      End  2046_02_26    mf:    64259.2    trip:  776.0    mp:     9216.4  dv:    4.1754
E-M:    pwr: 135.0    m0:   64259.2      Earth  2046_04_27      Mars 2048_10_13    mf:    57650.8    trip:  900.0    mp:     6608.4  dv:    3.4221
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7650.8    p/l:   50000.0    Ttrip: 1676.0    Tmp:   15824.8 Tdv:    7.5974

Esprl:  pwr: 150.0    m0:   73943.4      Start  2043_11_14      End  2046_01_17    mf:    64506.7    trip:  794.8    mp:     9436.7  dv:    4.2442
E-M:    pwr: 135.0    m0:   64506.7      Earth  2046_03_18      Mars 2048_10_10    mf:    57672.6    trip:  937.5    mp:     6834.2  dv:    3.5314
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7672.6    p/l:   50000.0    Ttrip: 1732.3    Tmp:   16270.9 Tdv:    7.7756

Esprl:  pwr: 150.0    m0:   74029.2      Start  2043_09_29      End  2045_12_06    mf:    64524.9    trip:  799.1    mp:     9504.3  dv:    4.2355
E-M:    pwr: 135.0    m0:   64524.9      Earth  2046_02_04      Mars 2048_10_06    mf:    57681.1    trip:  975.0    mp:     6843.8  dv:    3.5356
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7681.1    p/l:   50000.0    Ttrip: 1774.1    Tmp:   16348.1 Tdv:    7.7711

Esprl:  pwr: 150.0    m0:   73959.4      Start  2043_10_29      End  2046_01_02    mf:    64515.2    trip:  795.4    mp:     9444.2  dv:    4.2466
E-M:    pwr: 135.0    m0:   64515.2      Earth  2046_03_03      Mars 2048_12_09    mf:    57673.5    trip: 1012.5    mp:     6841.7  dv:    3.5350
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7673.5    p/l:   50000.0    Ttrip: 1807.9    Tmp:   16285.9 Tdv:    7.7816

Esprl:  pwr: 150.0    m0:   77810.2      Start  2043_06_23      End  2045_12_20    mf:    67019.6    trip:  910.9    mp:    10790.5  dv:    4.7046
E-M:    pwr: 135.0    m0:   67019.6      Earth  2046_02_18      Mars 2049_01_03    mf:    57897.6    trip: 1050.0    mp:     9122.0  dv:    4.6137
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7897.6    p/l:   50000.0    Ttrip: 1960.9    Tmp:   19912.6 Tdv:    9.3183

Esprl:  pwr: 150.0    m0:   73480.2      Start  2043_09_16      End  2045_11_02    mf:    64211.9    trip:  778.5    mp:     9268.4  dv:    4.1591
E-M:    pwr: 135.0    m0:   64211.9      Earth  2046_01_01      Mars 2048_12_23    mf:    57653.3    trip: 1087.5    mp:     6558.6  dv:    3.3975
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7653.3    p/l:   50000.0    Ttrip: 1866.0    Tmp:   15827.0 Tdv:    7.5566

Esprl:  pwr: 150.0    m0:   75302.8      Start  2046_02_25      End  2048_06_24    mf:    65211.7    trip:  850.1    mp:    10091.1  dv:    4.5162
E-M:    pwr: 135.0    m0:   65211.7      Earth  2048_08_23      Mars 2050_09_12    mf:    57742.2    trip:  750.0    mp:     7469.5  dv:    3.8361
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7742.2    p/l:   50000.0    Ttrip: 1600.1    Tmp:   17560.6 Tdv:    8.3523
```

```
Esprl:  pwr: 150.0    m0:   74985.5       Start  2046_02_28       End  2048_06_15    mf:    65038.1    trip:  838.2    mp:    9947.4  dv:   4.4517
E-M:    pwr: 135.0    m0:   65038.1       Earth  2048_08_14       Mars 2050_10_10    mf:    57725.3    trip:  787.5    mp:    7312.8  dv:   3.7613
                      E_Vinf:   1.4142    M_Vinf:   5.2000        s/c:    7725.3    p/l:    50000.0   Ttrip: 1625.7    Tmp:   17260.2 Tdv:   8.2129

Esprl:  pwr: 150.0    m0:   76685.4       Start  2045_12_05       End  2048_05_25    mf:    65968.0    trip:  902.0    mp:   10717.4  dv:   4.7973
E-M:    pwr: 135.0    m0:   65968.0       Earth  2048_07_24       Mars 2050_10_27    mf:    57811.6    trip:  825.0    mp:    8156.4  dv:   4.1618
                      E_Vinf:   1.4142    M_Vinf:   5.2000        s/c:    7811.6    p/l:    50000.0   Ttrip: 1727.0    Tmp:   18873.8 Tdv:   8.9591
```

Appendix B

Summary data table for interplanetary-only missions: Earth Escape to Mars

HAT Cargo Mission: Total Trip Time vs Earth Escape Date *(C_3 = +2.0 km^2/sec^2)* - 2028 to 2048 Range
BOL pwr= 135 kW; E-M $1/r^2$ degradation
Mars V_{inf} = 5.2 km/sec; Payload= 50,000 kg

```
E-M:    pwr: 135.0    m0:   61857.2       Earth  2028_03_26       Mars 2030_01_30    mf:    57067.9    trip:  675.0    mp:     4789.3  dv:    2.5412
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7067.9   p/l:    50000.0   Ttrip:  675.0    Tmp:    4789.3 Tdv:    2.5412

E-M:    pwr: 135.0    m0:   60358.1       Earth  2028_03_26       Mars 2030_03_08    mf:    56989.4    trip:  712.5    mp:     3368.7  dv:    1.8110
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     6989.4   p/l:    50000.0   Ttrip:  712.5    Tmp:    3368.7 Tdv:    1.8110

E-M:    pwr: 135.0    m0:   60451.8       Earth  2028_03_12       Mars 2030_04_01    mf:    56994.3    trip:  750.0    mp:     3457.5  dv:    1.8572
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     6994.3   p/l:    50000.0   Ttrip:  750.0    Tmp:    3457.5 Tdv:    1.8572

E-M:    pwr: 135.0    m0:   61580.1       Earth  2028_01_27       Mars 2030_03_24    mf:    57053.4    trip:  787.5    mp:     4526.8  dv:    2.4077
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7053.4   p/l:    50000.0   Ttrip:  787.5    Tmp:    4526.8 Tdv:    2.4077

E-M:    pwr: 135.0    m0:   63252.1       Earth  2028_01_01       Mars 2030_04_05    mf:    57140.8    trip:  825.0    mp:     6111.3  dv:    3.2041
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7140.8   p/l:    50000.0   Ttrip:  825.0    Tmp:    6111.3 Tdv:    3.2041

E-M:    pwr: 135.0    m0:   62233.7       Earth  2028_10_22       Mars 2031_10_14    mf:    57087.6    trip: 1087.5    mp:     5146.2  dv:    2.7217
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7087.6   p/l:    50000.0   Ttrip: 1087.5    Tmp:    5146.2 Tdv:    2.7217

E-M:    pwr: 135.0    m0:   62752.0       Earth  2028_12_04       Mars 2032_01_03    mf:    57114.7    trip: 1125.0    mp:     5637.3  dv:    2.9682
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7114.7   p/l:    50000.0   Ttrip: 1125.0    Tmp:    5637.3 Tdv:    2.9682

E-M:    pwr: 135.0    m0:   63812.0       Earth  2029_06_17       Mars 2031_09_20    mf:    57170.1    trip:  825.0    mp:     6641.8  dv:    3.4658
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7170.1   p/l:    50000.0   Ttrip:  825.0    Tmp:    6641.8 Tdv:    3.4658

E-M:    pwr: 135.0    m0:   63169.6       Earth  2029_05_25       Mars 2031_10_04    mf:    57136.5    trip:  862.5    mp:     6033.1  dv:    3.1653
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7136.5   p/l:    50000.0   Ttrip:  862.5    Tmp:    6033.1 Tdv:    3.1653

E-M:    pwr: 135.0    m0:   62681.5       Earth  2029_05_02       Mars 2031_10_19    mf:    57111.0    trip:  900.0    mp:     5570.5  dv:    2.9348
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7111.0   p/l:    50000.0   Ttrip:  900.0    Tmp:    5570.5 Tdv:    2.9348

E-M:    pwr: 135.0    m0:   63409.6       Earth  2029_06_03       Mars 2031_12_27    mf:    57149.1    trip:  937.5    mp:     6260.6  dv:    3.2780
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7149.1   p/l:    50000.0   Ttrip:  937.5    Tmp:    6260.6 Tdv:    3.2780

E-M:    pwr: 135.0    m0:   63042.0       Earth  2029_05_07       Mars 2032_01_07    mf:    57129.8    trip:  975.0    mp:     5912.2  dv:    3.1053
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7129.8   p/l:    50000.0   Ttrip:  975.0    Tmp:    5912.2 Tdv:    3.1053

E-M:    pwr: 135.0    m0:   63061.9       Earth  2029_04_21       Mars 2032_01_28    mf:    57130.9    trip: 1012.5    mp:     5931.0  dv:    3.1146
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7130.9   p/l:    50000.0   Ttrip: 1012.5    Tmp:    5931.0 Tdv:    3.1146

E-M:    pwr: 135.0    m0:   62759.0       Earth  2029_02_26       Mars 2032_01_12    mf:    57115.0    trip: 1050.0    mp:     5644.0  dv:    2.9716
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7115.0   p/l:    50000.0   Ttrip: 1050.0    Tmp:    5644.0 Tdv:    2.9716

E-M:    pwr: 135.0    m0:   66668.4       Earth  2029_02_16       Mars 2032_02_08    mf:    57319.5    trip: 1087.5    mp:     9348.9  dv:    4.7644
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7319.5   p/l:    50000.0   Ttrip: 1087.5    Tmp:    9348.9 Tdv:    4.7644

E-M:    pwr: 135.0    m0:   67968.9       Earth  2029_01_19       Mars 2032_02_18    mf:    57387.6    trip: 1125.0    mp:    10581.3  dv:    5.3362
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7387.6   p/l:    50000.0   Ttrip: 1125.0    Tmp:   10581.3 Tdv:    5.3362

E-M:    pwr: 135.0    m0:   63303.3       Earth  2029_01_01       Mars 2032_03_08    mf:    57143.5    trip: 1162.5    mp:     6159.8  dv:    3.2282
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7143.5   p/l:    50000.0   Ttrip: 1162.5    Tmp:    6159.8 Tdv:    3.2282

E-M:    pwr: 135.0    m0:   62724.8       Earth  2030_04_14       Mars 2032_01_11    mf:    57113.2    trip:  637.5    mp:     5611.6  dv:    2.9554
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7113.2   p/l:    50000.0   Ttrip:  637.5    Tmp:    5611.6 Tdv:    2.9554

E-M:    pwr: 135.0    m0:   62217.1       Earth  2030_04_01       Mars 2032_02_05    mf:    57086.7    trip:  675.0    mp:     5130.5  dv:    2.7138
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7086.7   p/l:    50000.0   Ttrip:  675.0    Tmp:    5130.5 Tdv:    2.7138

E-M:    pwr: 135.0    m0:   62749.8       Earth  2030_02_25       Mars 2032_02_07    mf:    57114.5    trip:  712.5    mp:     5635.2  dv:    2.9672
                      E_Vinf:    1.4142   M_Vinf:    5.2000       s/c:     7114.6   p/l:    50000.0   Ttrip:  712.5    Tmp:    5635.2 Tdv:    2.9672
```

```
E-M:    pwr: 135.0    m0:   63511.7      Earth  2030_01_01      Mars 2032_01_21    mf:    57154.4    trip:  750.0    mp:    6357.3  dv:   3.3258
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7154.4   p/l:    50000.0   Ttrip:  750.0   Tmp:    6357.3 Tdv:   3.3258

E-M:    pwr: 135.0    m0:   64486.9      Earth  2031_06_30      Mars 2033_08_25    mf:    57205.4    trip:  787.5    mp:    7281.5  dv:   3.7782
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7205.4   p/l:    50000.0   Ttrip:  787.5   Tmp:    7281.5 Tdv:   3.7782

E-M:    pwr: 135.0    m0:   64031.5      Earth  2031_08_05      Mars 2033_11_07    mf:    57181.6    trip:  825.0    mp:    6849.9  dv:   3.5678
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7181.6   p/l:    50000.0   Ttrip:  825.0   Tmp:    6849.9 Tdv:   3.5678

E-M:    pwr: 135.0    m0:   64517.2      Earth  2031_06_30      Mars 2033_11_08    mf:    57207.0    trip:  862.5    mp:    7310.2  dv:   3.7921
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7207.0   p/l:    50000.0   Ttrip:  862.5   Tmp:    7310.2 Tdv:   3.7921

E-M:    pwr: 135.0    m0:   64745.0      Earth  2031_06_02      Mars 2033_11_18    mf:    57218.9    trip:  900.0    mp:    7526.1  dv:   3.8967
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7218.9   p/l:    50000.0   Ttrip:  900.0   Tmp:    7526.1 Tdv:   3.8967

E-M:    pwr: 135.0    m0:   64922.4      Earth  2031_03_15      Mars 2033_10_07    mf:    57228.2    trip:  937.5    mp:    7694.2  dv:   3.9778
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7228.2   p/l:    50000.0   Ttrip:  937.5   Tmp:    7694.2 Tdv:   3.9778

E-M:    pwr: 135.0    m0:   65199.6      Earth  2031_03_20      Mars 2033_11_19    mf:    57242.7    trip:  975.0    mp:    7956.9  dv:   4.1042
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7242.7   p/l:    50000.0   Ttrip:  975.0   Tmp:    7956.9 Tdv:   4.1042

E-M:    pwr: 135.0    m0:   64632.7      Earth  2031_02_21      Mars 2033_11_29    mf:    57213.0    trip: 1012.5    mp:    7419.7  dv:   3.8452
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7213.1   p/l:    50000.0   Ttrip: 1012.5   Tmp:    7419.7 Tdv:   3.8452

E-M:    pwr: 135.0    m0:   64461.8      Earth  2031_01_14      Mars 2033_11_29    mf:    57204.1    trip: 1050.0    mp:    7257.7  dv:   3.7666
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7204.1   p/l:    50000.0   Ttrip: 1050.0   Tmp:    7257.7 Tdv:   3.7666

E-M:    pwr: 135.0    m0:   64597.2      Earth  2033_08_23      Mars 2035_09_12    mf:    57211.2    trip:  750.0    mp:    7386.0  dv:   3.8289
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7211.2   p/l:    50000.0   Ttrip:  750.0   Tmp:    7386.0 Tdv:   3.8289

E-M:    pwr: 135.0    m0:   61522.0      Earth  2034_03_19      Mars 2037_03_10    mf:    57050.3    trip: 1087.5    mp:    4471.6  dv:   2.3795
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7050.3   p/l:    50000.0   Ttrip: 1087.5   Tmp:    4471.6 Tdv:   2.3795

E-M:    pwr: 135.0    m0:   67247.6      Earth  2034_01_13      Mars 2037_03_20    mf:    57349.8    trip: 1162.5    mp:    9897.7  dv:   5.0205
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7349.8   p/l:    50000.0   Ttrip: 1162.5   Tmp:    9897.7 Tdv:   5.0205

E-M:    pwr: 135.0    m0:   64016.3      Earth  2034_01_27      Mars 2037_05_11    mf:    57180.8    trip: 1200.0    mp:    6835.5  dv:   3.5607
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7180.8   p/l:    50000.0   Ttrip: 1200.0   Tmp:    6835.5 Tdv:   3.5607

E-M:    pwr: 135.0    m0:   61714.1      Earth  2036_11_30      Mars 2039_05_19    mf:    57060.4    trip:  900.0    mp:    4653.8  dv:   2.4723
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7060.4   p/l:    50000.0   Ttrip:  900.0   Tmp:    4653.8 Tdv:   2.4723

E-M:    pwr: 135.0    m0:   62680.8      Earth  2036_11_26      Mars 2039_07_29    mf:    57110.9    trip:  975.0    mp:    5569.8  dv:   2.9345
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7110.9   p/l:    50000.0   Ttrip:  975.0   Tmp:    5569.8 Tdv:   2.9345

E-M:    pwr: 135.0    m0:   62649.8      Earth  2036_04_14      Mars 2039_01_21    mf:    57109.3    trip: 1012.5    mp:    5540.4  dv:   2.9198
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7109.3   p/l:    50000.0   Ttrip: 1012.5   Tmp:    5540.4 Tdv:   2.9198

E-M:    pwr: 135.0    m0:   60376.2      Earth  2036_03_23      Mars 2039_03_15    mf:    56990.4    trip: 1087.5    mp:    3385.8  dv:   1.8199
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     6990.4   p/l:    50000.0   Ttrip: 1087.5   Tmp:    3385.8 Tdv:   1.8199

E-M:    pwr: 135.0    m0:   65916.3      Earth  2036_02_17      Mars 2039_03_18    mf:    57280.2    trip: 1125.0    mp:    8636.1  dv:   4.4283
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7280.2   p/l:    50000.0   Ttrip: 1125.0   Tmp:    8636.1 Tdv:   4.4283

E-M:    pwr: 135.0    m0:   62416.7      Earth  2036_04_09      Mars 2039_06_15    mf:    57097.1    trip: 1162.5    mp:    5319.5  dv:   2.8090
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     7097.1   p/l:    50000.0   Ttrip: 1162.5   Tmp:    5319.5 Tdv:   2.8090

E-M:    pwr: 135.0    m0:   60435.7      Earth  2036_03_23      Mars 2039_07_06    mf:    56993.5    trip: 1200.0    mp:    3442.2  dv:   1.8492
                      E_Vinf:    1.4142  M_Vinf:   5.2000       s/c:     6993.5   p/l:    50000.0   Ttrip: 1200.0   Tmp:    3442.2 Tdv:   1.8492
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E-M:    pwr: 135.0    m0:   62022.8      Earth  2037_01_02      Mars 2039_06_21   mf:   57076.5    trip:  900.0    mp:    4946.3  dv:   2.6208
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7076.5   p/l:  50000.0    Ttrip:  900.0   Tmp:   4946.3 Tdv:   2.6208

E-M:    pwr: 135.0    m0:   62167.0      Earth  2037_01_01      Mars 2039_07_27   mf:   57084.1    trip:  937.5    mp:    5082.9  dv:   2.6898
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7084.1   p/l:  50000.0    Ttrip:  937.5   Tmp:   5082.9 Tdv:   2.6898

E-M:    pwr: 135.0    m0:   63231.9      Earth  2037_01_01      Mars 2039_09_03   mf:   57139.8    trip:  975.0    mp:    6092.2  dv:   3.1946
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7139.8   p/l:  50000.0    Ttrip:  975.0   Tmp:   6092.2 Tdv:   3.1946

E-M:    pwr: 135.0    m0:   61221.2      Earth  2037_11_14      Mars 2041_01_19   mf:   57034.6    trip: 1162.5    mp:    4186.6  dv:   2.2337
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7034.6   p/l:  50000.0    Ttrip: 1162.5   Tmp:   4186.6 Tdv:   2.2337

E-M:    pwr: 135.0    m0:   62045.6      Earth  2037_09_23      Mars 2041_01_05   mf:   57077.7    trip: 1200.0    mp:    4967.9  dv:   2.6317
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7077.7   p/l:  50000.0    Ttrip: 1200.0   Tmp:   4967.9 Tdv:   2.6317

E-M:    pwr: 135.0    m0:   60681.3      Earth  2038_11_18      Mars 2040_10_30   mf:   57006.3    trip:  712.5    mp:    3675.0  dv:   1.9700
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7006.3   p/l:  50000.0    Ttrip:  712.5   Tmp:   3675.0 Tdv:   1.9700

E-M:    pwr: 135.0    m0:   61247.3      Earth  2038_12_27      Mars 2041_03_31   mf:   57035.9    trip:  825.0    mp:    4211.3  dv:   2.2464
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7035.9   p/l:  50000.0    Ttrip:  825.0   Tmp:   4211.3 Tdv:   2.2464

E-M:    pwr: 135.0    m0:   60420.9      Earth  2038_12_23      Mars 2041_05_03   mf:   56992.7    trip:  862.5    mp:    3428.2  dv:   1.8419
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     6992.7   p/l:  50000.0    Ttrip:  862.5   Tmp:   3428.2 Tdv:   1.8419

E-M:    pwr: 135.0    m0:   61019.5      Earth  2038_12_19      Mars 2041_06_06   mf:   57024.0    trip:  900.0    mp:    3995.5  dv:   2.1355
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7024.0   p/l:  50000.0    Ttrip:  900.0   Tmp:   3995.5 Tdv:   2.1355

E-M:    pwr: 135.0    m0:   62268.5      Earth  2038_05_02      Mars 2041_01_01   mf:   57089.4    trip:  975.0    mp:    5179.1  dv:   2.7383
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7089.4   p/l:  50000.0    Ttrip:  975.0   Tmp:   5179.1 Tdv:   2.7383

E-M:    pwr: 135.0    m0:   60745.7      Earth  2038_04_02      Mars 2041_01_08   mf:   57009.7    trip: 1012.5    mp:    3736.0  dv:   2.0016
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7009.7   p/l:  50000.0    Ttrip: 1012.5   Tmp:   3736.0 Tdv:   2.0016

E-M:    pwr: 135.0    m0:   63532.7      Earth  2038_05_06      Mars 2041_04_27   mf:   57155.5    trip: 1087.5    mp:    6377.2  dv:   3.3356
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7155.5   p/l:  50000.0    Ttrip: 1087.5   Tmp:   6377.2 Tdv:   3.3356

E-M:    pwr: 135.0    m0:   61356.4      Earth  2038_04_26      Mars 2041_05_25   mf:   57041.7    trip: 1125.0    mp:    4314.7  dv:   2.2993
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7041.7   p/l:  50000.0    Ttrip: 1125.0   Tmp:   4314.7 Tdv:   2.2993

E-M:    pwr: 135.0    m0:   59901.7      Earth  2038_04_02      Mars 2041_06_07   mf:   56965.6    trip: 1162.5    mp:    2936.1  dv:   1.5848
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     6965.6   p/l:  50000.0    Ttrip: 1162.5   Tmp:   2936.1 Tdv:   1.5848

E-M:    pwr: 135.0    m0:   59459.0      Earth  2038_03_16      Mars 2041_06_28   mf:   56942.4    trip: 1200.0    mp:    2516.6  dv:   1.3637
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     6942.4   p/l:  50000.0    Ttrip: 1200.0   Tmp:   2516.6 Tdv:   1.3637

E-M:    pwr: 135.0    m0:   61258.6      Earth  2039_01_02      Mars 2041_04_06   mf:   57036.5    trip:  825.0    mp:    4222.1  dv:   2.2519
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7036.5   p/l:  50000.0    Ttrip:  825.0   Tmp:   4222.1 Tdv:   2.2519

E-M:    pwr: 135.0    m0:   60440.3      Earth  2039_01_01      Mars 2041_05_12   mf:   56993.7    trip:  862.5    mp:    3446.6  dv:   1.8515
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     6993.7   p/l:  50000.0    Ttrip:  862.5   Tmp:   3446.6 Tdv:   1.8515

E-M:    pwr: 135.0    m0:   61051.4      Earth  2039_01_01      Mars 2041_06_19   mf:   57025.7    trip:  900.0    mp:    4025.7  dv:   2.1510
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7025.7   p/l:  50000.0    Ttrip:  900.0   Tmp:   4025.7 Tdv:   2.1510

E-M:    pwr: 135.0    m0:   62815.5      Earth  2039_01_01      Mars 2041_07_26   mf:   57118.0    trip:  937.5    mp:    5697.6  dv:   2.9983
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7118.0   p/l:  50000.0    Ttrip:  937.5   Tmp:   5697.6 Tdv:   2.9983

E-M:    pwr: 135.0    m0:   61897.4      Earth  2039_10_01      Mars 2042_12_06   mf:   57070.0    trip: 1162.5    mp:    4827.4  dv:   2.5605
                      E_Vinf:    1.4142  M_Vinf:    5.2000      s/c:     7070.0   p/l:  50000.0    Ttrip: 1162.5   Tmp:   4827.4 Tdv:   2.5605
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E-M:    pwr: 135.0    m0:   60885.8      Earth  2040_11_25       Mars 2042_11_07    mf:    57017.0    trip:  712.5     mp:     3868.8  dv:    2.0702
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7017.0   p/l:    50000.0   Ttrip:  712.5    Tmp:     3868.8 Tdv:    2.0702

E-M:    pwr: 135.0    m0:   63353.6      Earth  2040_10_01       Mars 2042_10_21    mf:    57146.1    trip:  750.0     mp:     6207.5  dv:    3.2517
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7146.1   p/l:    50000.0   Ttrip:  750.0    Tmp:     6207.5 Tdv:    3.2517

E-M:    pwr: 135.0    m0:   60185.5      Earth  2040_12_30       Mars 2043_04_04    mf:    56980.4    trip:  825.0     mp:     3205.1  dv:    1.7257
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     6980.4   p/l:    50000.0   Ttrip:  825.0    Tmp:     3205.1 Tdv:    1.7257

E-M:    pwr: 135.0    m0:   61093.2      Earth  2040_12_30       Mars 2043_05_11    mf:    57027.9    trip:  862.5     mp:     4065.4  dv:    2.1714
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7027.9   p/l:    50000.0   Ttrip:  862.5    Tmp:     4065.4 Tdv:    2.1714

E-M:    pwr: 135.0    m0:   64796.4      Earth  2040_06_03       Mars 2042_11_20    mf:    57221.6    trip:  900.0     mp:     7574.8  dv:    3.9202
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7221.6   p/l:    50000.0   Ttrip:  900.0    Tmp:     7574.8 Tdv:    3.9202

E-M:    pwr: 135.0    m0:   62147.7      Earth  2040_05_10       Mars 2042_12_03    mf:    57083.1    trip:  937.5     mp:     5064.6  dv:    2.6806
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7083.1   p/l:    50000.0   Ttrip:  937.5    Tmp:     5064.6 Tdv:    2.6806

E-M:    pwr: 135.0    m0:   60841.1      Earth  2040_04_18       Mars 2042_12_19    mf:    57014.7    trip:  975.0     mp:     3826.4  dv:    2.0483
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7014.7   p/l:    50000.0   Ttrip:  975.0    Tmp:     3826.4 Tdv:    2.0483

E-M:    pwr: 135.0    m0:   64486.2      Earth  2040_06_16       Mars 2043_03_25    mf:    57205.4    trip: 1012.5     mp:     7280.8  dv:    3.7778
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7205.4   p/l:    50000.0   Ttrip: 1012.5    Tmp:     7280.8 Tdv:    3.7778

E-M:    pwr: 135.0    m0:   62476.2      Earth  2040_05_20       Mars 2043_04_05    mf:    57100.2    trip: 1050.0     mp:     5375.9  dv:    2.8373
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7100.2   p/l:    50000.0   Ttrip: 1050.0    Tmp:     5375.9 Tdv:    2.8373

E-M:    pwr: 135.0    m0:   60979.7      Earth  2040_05_04       Mars 2043_04_26    mf:    57022.0    trip: 1087.5     mp:     3957.8  dv:    2.1161
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7022.0   p/l:    50000.0   Ttrip: 1087.5    Tmp:     3957.8 Tdv:    2.1161

E-M:    pwr: 135.0    m0:   60144.7      Earth  2040_04_07       Mars 2043_05_07    mf:    56978.3    trip: 1125.0     mp:     3166.4  dv:    1.7054
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     6978.3   p/l:    50000.0   Ttrip: 1125.0    Tmp:     3166.4 Tdv:    1.7054

E-M:    pwr: 135.0    m0:   59950.7      Earth  2040_03_07       Mars 2043_05_13    mf:    56968.1    trip: 1162.5     mp:     2982.6  dv:    1.6092
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     6968.1   p/l:    50000.0   Ttrip: 1162.5    Tmp:     2982.6 Tdv:    1.6092

E-M:    pwr: 135.0    m0:   60580.8      Earth  2040_02_11       Mars 2043_05_26    mf:    57001.1    trip: 1200.0     mp:     3579.8  dv:    1.9207
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7001.1   p/l:    50000.0   Ttrip: 1200.0    Tmp:     3579.8 Tdv:    1.9207

E-M:    pwr: 135.0    m0:   61811.8      Earth  2041_01_31       Mars 2043_02_20    mf:    57065.5    trip:  750.0     mp:     4746.3  dv:    2.5194
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7065.5   p/l:    50000.0   Ttrip:  750.0    Tmp:     4746.3 Tdv:    2.5194

E-M:    pwr: 135.0    m0:   59939.2      Earth  2041_02_05       Mars 2043_04_03    mf:    56967.5    trip:  787.5     mp:     2971.6  dv:    1.6034
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     6967.5   p/l:    50000.0   Ttrip:  787.5    Tmp:     2971.6 Tdv:    1.6034

E-M:    pwr: 135.0    m0:   59954.5      Earth  2041_01_29       Mars 2043_05_04    mf:    56968.3    trip:  825.0     mp:     2986.2  dv:    1.6111
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     6968.3   p/l:    50000.0   Ttrip:  825.0    Tmp:     2986.2 Tdv:    1.6111

E-M:    pwr: 135.0    m0:   61077.7      Earth  2041_01_08       Mars 2043_05_20    mf:    57027.1    trip:  862.5     mp:     4050.6  dv:    2.1638
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7027.1   p/l:    50000.0   Ttrip:  862.5    Tmp:     4050.6 Tdv:    2.1638

E-M:    pwr: 135.0    m0:   63509.0      Earth  2041_01_01       Mars 2043_06_20    mf:    57154.3    trip:  900.0     mp:     6354.7  dv:    3.3245
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7154.3   p/l:    50000.0   Ttrip:  900.0    Tmp:     6354.7 Tdv:    3.3245

E-M:    pwr: 135.0    m0:   61770.8      Earth  2041_11_27       Mars 2045_03_11    mf:    57063.3    trip: 1200.0     mp:     4707.4  dv:    2.4996
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7063.3   p/l:    50000.0   Ttrip: 1200.0    Tmp:     4707.4 Tdv:    2.4996

E-M:    pwr: 135.0    m0:   64083.8      Earth  2042_06_13       Mars 2044_10_22    mf:    57184.3    trip:  862.5     mp:     6899.5  dv:    3.5921
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7184.3   p/l:    50000.0   Ttrip:  862.5    Tmp:     6899.5 Tdv:    3.5921
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E-M:    pwr: 135.0    m0:   62410.3      Earth  2042_05_30       Mars 2044_11_15    mf:    57096.8    trip:  900.0    mp:     5313.5  dv:    2.8059
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7096.8   p/l:    50000.0   Ttrip:  900.0    Tmp:    5313.5 Tdv:    2.8059

E-M:    pwr: 135.0    m0:   61365.3      Earth  2042_04_29       Mars 2044_11_21    mf:    57042.1    trip:  937.5    mp:     4323.2  dv:    2.3037
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7042.1   p/l:    50000.0   Ttrip:  937.5    Tmp:    4323.2 Tdv:    2.3037

E-M:    pwr: 135.0    m0:   60810.6      Earth  2042_04_07       Mars 2044_12_07    mf:    57013.1    trip:  975.0    mp:     3797.5  dv:    2.0334
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7013.1   p/l:    50000.0   Ttrip:  975.0    Tmp:    3797.5 Tdv:    2.0334

E-M:    pwr: 135.0    m0:   60856.9      Earth  2042_03_06       Mars 2044_12_12    mf:    57015.5    trip: 1012.5    mp:     3841.4  dv:    2.0561
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7015.5   p/l:    50000.0   Ttrip: 1012.5    Tmp:    3841.4 Tdv:    2.0561

E-M:    pwr: 135.0    m0:   61390.5      Earth  2042_05_02       Mars 2045_03_17    mf:    57043.4    trip: 1050.0    mp:     4347.0  dv:    2.3159
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7043.4   p/l:    50000.0   Ttrip: 1050.0    Tmp:    4347.0 Tdv:    2.3159

E-M:    pwr: 135.0    m0:   60881.0      Earth  2042_04_03       Mars 2045_03_25    mf:    57016.8    trip: 1087.5    mp:     3864.2  dv:    2.0678
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7016.8   p/l:    50000.0   Ttrip: 1087.5    Tmp:    3864.2 Tdv:    2.0678

E-M:    pwr: 135.0    m0:   60925.4      Earth  2042_03_03       Mars 2045_04_01    mf:    57019.1    trip: 1125.0    mp:     3906.3  dv:    2.0896
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7019.1   p/l:    50000.0   Ttrip: 1125.0    Tmp:    3906.3 Tdv:    2.0896

E-M:    pwr: 135.0    m0:   61480.4      Earth  2042_01_16       Mars 2045_03_23    mf:    57048.1    trip: 1162.5    mp:     4432.3  dv:    2.3595
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7048.1   p/l:    50000.0   Ttrip: 1162.5    Tmp:    4432.3 Tdv:    2.3595

E-M:    pwr: 135.0    m0:   61948.2      Earth  2042_01_01       Mars 2045_04_15    mf:    57072.6    trip: 1200.0    mp:     4875.6  dv:    2.5849
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7072.6   p/l:    50000.0   Ttrip: 1200.0    Tmp:    4875.6 Tdv:    2.5849

E-M:    pwr: 135.0    m0:   60791.2      Earth  2043_03_16       Mars 2045_02_25    mf:    57012.1    trip:  712.5    mp:     3779.1  dv:    2.0239
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7012.1   p/l:    50000.0   Ttrip:  712.5    Tmp:    3779.1 Tdv:    2.0239

E-M:    pwr: 135.0    m0:   59732.6      Earth  2043_03_14       Mars 2045_04_02    mf:    56956.7    trip:  750.0    mp:     2775.9  dv:    1.5006
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     6956.7   p/l:    50000.0   Ttrip:  750.0    Tmp:    2775.9 Tdv:    1.5006

E-M:    pwr: 135.0    m0:   60442.2      Earth  2043_02_23       Mars 2045_04_20    mf:    56993.8    trip:  787.5    mp:     3448.3  dv:    1.8524
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     6993.8   p/l:    50000.0   Ttrip:  787.5    Tmp:    3448.3 Tdv:    1.8524

E-M:    pwr: 135.0    m0:   61823.5      Earth  2043_01_01       Mars 2045_04_05    mf:    57066.1    trip:  825.0    mp:     4757.4  dv:    2.5250
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7066.1   p/l:    50000.0   Ttrip:  825.0    Tmp:    4757.4 Tdv:    2.5250

E-M:    pwr: 135.0    m0:   62495.1      Earth  2043_12_29       Mars 2047_01_27    mf:    57101.2    trip: 1125.0    mp:     5393.8  dv:    2.8463
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7101.2   p/l:    50000.0   Ttrip: 1125.0    Tmp:    5393.8 Tdv:    2.8463

E-M:    pwr: 135.0    m0:   62329.5      Earth  2043_10_18       Mars 2047_01_30    mf:    57092.6    trip: 1200.0    mp:     5237.0  dv:    2.7674
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7092.6   p/l:    50000.0   Ttrip: 1200.0    Tmp:    5237.0 Tdv:    2.7674

E-M:    pwr: 135.0    m0:   63302.3      Earth  2044_11_26       Mars 2047_01_22    mf:    57143.5    trip:  787.5    mp:     6158.8  dv:    3.2277
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7143.5   p/l:    50000.0   Ttrip:  787.5    Tmp:    6158.8 Tdv:    3.2277

E-M:    pwr: 135.0    m0:   63983.0      Earth  2044_06_20       Mars 2046_09_23    mf:    57179.1    trip:  825.0    mp:     6803.9  dv:    3.5453
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7179.1   p/l:    50000.0   Ttrip:  825.0    Tmp:    6803.9 Tdv:    3.5453

E-M:    pwr: 135.0    m0:   63095.1      Earth  2044_05_27       Mars 2046_10_06    mf:    57132.6    trip:  862.5    mp:     5962.4  dv:    3.1303
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7132.6   p/l:    50000.0   Ttrip:  862.5    Tmp:    5962.4 Tdv:    3.1303

E-M:    pwr: 135.0    m0:   62363.1      Earth  2044_05_08       Mars 2046_10_25    mf:    57094.3    trip:  900.0    mp:     5268.8  dv:    2.7834
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7094.3   p/l:    50000.0   Ttrip:  900.0    Tmp:    5268.8 Tdv:    2.7834

E-M:    pwr: 135.0    m0:   61934.9      Earth  2044_04_15       Mars 2046_11_08    mf:    57071.9    trip:  937.5    mp:     4862.9  dv:    2.5785
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7071.9   p/l:    50000.0   Ttrip:  937.5    Tmp:    4862.9 Tdv:    2.5785
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E-M:    pwr: 135.0    m0:   62031.6      Earth  2044_03_15       Mars 2046_11_15    mf:    57077.0    trip:  975.0    mp:     4954.6  dv:    2.6249
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7077.0   p/l:    50000.0   Ttrip:  975.0   Tmp:     4954.6 Tdv:    2.6249

E-M:    pwr: 135.0    m0:   62360.0      Earth  2044_04_27       Mars 2047_02_03    mf:    57094.2    trip: 1012.5    mp:     5265.9  dv:    2.7820
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7094.2   p/l:    50000.0   Ttrip: 1012.5   Tmp:     5265.9 Tdv:    2.7820

E-M:    pwr: 135.0    m0:   62174.2      Earth  2044_03_22       Mars 2047_02_05    mf:    57084.4    trip: 1050.0    mp:     5089.7  dv:    2.6932
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7084.4   p/l:    50000.0   Ttrip: 1050.0   Tmp:     5089.7 Tdv:    2.6932

E-M:    pwr: 135.0    m0:   62281.0      Earth  2044_02_13       Mars 2047_02_04    mf:    57090.0    trip: 1087.5    mp:     5190.9  dv:    2.7443
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7090.0   p/l:    50000.0   Ttrip: 1087.5   Tmp:     5190.9 Tdv:    2.7443

E-M:    pwr: 135.0    m0:   62499.7      Earth  2044_01_02       Mars 2047_01_31    mf:    57101.5    trip: 1125.0    mp:     5398.3  dv:    2.8485
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7101.5   p/l:    50000.0   Ttrip: 1125.0   Tmp:     5398.3 Tdv:    2.8485

E-M:    pwr: 135.0    m0:   62717.1      Earth  2044_01_01       Mars 2047_03_08    mf:    57112.8    trip: 1162.5    mp:     5604.3  dv:    2.9517
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7112.8   p/l:    50000.0   Ttrip: 1162.5   Tmp:     5604.3 Tdv:    2.9517

E-M:    pwr: 135.0    m0:   62760.6      Earth  2045_04_11       Mars 2047_01_08    mf:    57115.1    trip:  637.5    mp:     5645.5  dv:    2.9723
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7115.1   p/l:    50000.0   Ttrip:  637.5   Tmp:     5645.5 Tdv:    2.9723

E-M:    pwr: 135.0    m0:   61343.2      Earth  2045_04_05       Mars 2047_02_09    mf:    57041.0    trip:  675.0    mp:     4302.2  dv:    2.2929
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7041.0   p/l:    50000.0   Ttrip:  675.0   Tmp:     4302.2 Tdv:    2.2929

E-M:    pwr: 135.0    m0:   61375.6      Earth  2045_03_17       Mars 2047_02_27    mf:    57042.7    trip:  712.5    mp:     4332.9  dv:    2.3087
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7042.7   p/l:    50000.0   Ttrip:  712.5   Tmp:     4332.9 Tdv:    2.3087

E-M:    pwr: 135.0    m0:   62331.1      Earth  2045_02_02       Mars 2047_02_22    mf:    57092.6    trip:  750.0    mp:     5238.5  dv:    2.7682
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7092.7   p/l:    50000.0   Ttrip:  750.0   Tmp:     5238.5 Tdv:    2.7682

E-M:    pwr: 135.0    m0:   63481.3      Earth  2045_01_01       Mars 2047_02_27    mf:    57152.8    trip:  787.5    mp:     6328.5  dv:    3.3116
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7152.8   p/l:    50000.0   Ttrip:  787.5   Tmp:     6328.5 Tdv:    3.3116

E-M:    pwr: 135.0    m0:   64259.1      Earth  2046_06_29       Mars 2048_08_24    mf:    57193.5    trip:  787.5    mp:     7065.6  dv:    3.6731
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7193.5   p/l:    50000.0   Ttrip:  787.5   Tmp:     7065.6 Tdv:    3.6731

E-M:    pwr: 135.0    m0:   63825.2      Earth  2046_08_10       Mars 2048_11_12    mf:    57170.8    trip:  825.0    mp:     6654.4  dv:    3.4720
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7170.8   p/l:    50000.0   Ttrip:  825.0   Tmp:     6654.4 Tdv:    3.4720

E-M:    pwr: 135.0    m0:   63753.3      Earth  2046_05_19       Mars 2048_09_27    mf:    57167.1    trip:  862.5    mp:     6586.3  dv:    3.4386
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7167.0   p/l:    50000.0   Ttrip:  862.5   Tmp:     6586.3 Tdv:    3.4386

E-M:    pwr: 135.0    m0:   63682.7      Earth  2046_04_27       Mars 2048_10_13    mf:    57163.4    trip:  900.0    mp:     6519.3  dv:    3.4056
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7163.4   p/l:    50000.0   Ttrip:  900.0   Tmp:     6519.3 Tdv:    3.4056

E-M:    pwr: 135.0    m0:   63915.1      Earth  2046_03_18       Mars 2048_10_10    mf:    57175.5    trip:  937.5    mp:     6739.6  dv:    3.5138
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7175.5   p/l:    50000.0   Ttrip:  937.5   Tmp:     6739.6 Tdv:    3.5138

E-M:    pwr: 135.0    m0:   63945.7      Earth  2046_02_03       Mars 2048_10_05    mf:    57177.1    trip:  975.0    mp:     6768.6  dv:    3.5280
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7177.1   p/l:    50000.0   Ttrip:  975.0   Tmp:     6768.6 Tdv:    3.5280

E-M:    pwr: 135.0    m0:   63925.1      Earth  2046_03_03       Mars 2048_12_09    mf:    57176.0    trip: 1012.5    mp:     6749.1  dv:    3.5184
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7176.0   p/l:    50000.0   Ttrip: 1012.5   Tmp:     6749.1 Tdv:    3.5184

E-M:    pwr: 135.0    m0:   66269.5      Earth  2046_02_18       Mars 2049_01_03    mf:    57298.7    trip: 1050.0    mp:     8970.8  dv:    4.5866
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7298.7   p/l:    50000.0   Ttrip: 1050.0   Tmp:     8970.8 Tdv:    4.5866

E-M:    pwr: 135.0    m0:   63635.1      Earth  2046_01_01       Mars 2048_12_23    mf:    57160.9    trip: 1087.5    mp:     6474.3  dv:    3.3834
                      E_Vinf:    1.4142  M_Vinf:    5.2000       s/c:     7160.9   p/l:    50000.0   Ttrip: 1087.5   Tmp:     6474.3 Tdv:    3.3834
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E-M:    pwr: 135.0    m0:   64542.3      Earth  2048_08_23       Mars 2050_09_12    mf:    57208.3    trip:  750.0    mp:    7334.0  dv:   3.8036
                      E_Vinf:   1.4142   M_Vinf:   5.2000        s/c:     7208.3   p/l:    50000.0   Ttrip:  750.0   Tmp:    7334.0 Tdv:   3.8036

E-M:    pwr: 135.0    m0:   64305.3      Earth  2048_08_17       Mars 2050_10_13    mf:    57195.9    trip:  787.5    mp:    7109.3  dv:   3.6944
                      E_Vinf:   1.4142   M_Vinf:   5.2000        s/c:     7195.9   p/l:    50000.0   Ttrip:  787.5   Tmp:    7109.3 Tdv:   3.6944

E-M:    pwr: 135.0    m0:   65169.4      Earth  2048_07_17       Mars 2050_10_20    mf:    57241.1    trip:  825.0    mp:    7928.3  dv:   4.0905
                      E_Vinf:   1.4142   M_Vinf:   5.2000        s/c:     7241.1   p/l:    50000.0   Ttrip:  825.0   Tmp:    7928.3 Tdv:   4.0905
```