InterplanetaryMFD

(IMFD)

Version 5.3

for Orbiter

Space Flight Simulator 2006

May 14, 2009

Copying / Warranty

This software is created for Martin Schweiger's Orbiter space flight simulator 2006 Edition.

The Internet

Latest version of IMFD and tutorials are located in *http://koti.mbnet.fi/jarmonik/Orbiter.html*

Notes

Scenarios those are saved with an older version of IMFD won't work correctly if all. Remove the MFD sections from the scenarios.

Requirements

Orbiter 2006-P1

Installation

Unpack the package in to the Orbiter installation folder. Maintain directory structure. Config folder will contain IMFD5.cfg for configuration options.

General information

Setting values from keyboard

You can setup values in many formats from the keyboard by pressing [Set] button. The exponent format can be used like "12.4e3" or "11.45e-2". The exponent can also be replaced by a letter like "12.4k" or "33.2M" or "22.2G",where k is equal to "e3" and so on. "d"=day will multiply the input value by 86400. "h" is equal to an hour and "a" is one astronomical unit.

Time in GET and UT

It is possible to enter dates in UT format like "UT 14-nov-1969" or with the 24h clock "UT 14-nov-1969 17:45:21.1" Used names for the months are *Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov and Dec* (not case sensitive).

IMFD 5.0 is supporting GET (*Ground Elapsed Time*). This feature can be activated from the configuration page. Also the date of launch must be specified. You can enter data in GET format by pressing [Set] button and entering the time "GET 120:34:56.7". When flying with AMSO IMFD will receive GET time via inter-process-com link.

Sharing Flight Plans

a Single flight plan can be "shared" between multible MFDs by seting the IMFD into the remote access mode by pressing [PG] button in main menu. Popup window will ask about an ID code of the MFD being accessed. The ID codes are shown in a top right corner of the MFD. The flight plan will stay resident evenif the MFD containing the flight plan is closed so the other MFDs can still access into the plan. If you want to disconnect the MFD from others just setup an invalid ID. For an example the ID of the MFD itself. When using multible instances of IMFD they must not access in each other. For an example when using two instances only one of them can use remote access.

3D Rotation

Some of the programs are supporting display 3D rotation via mouse. Hold down shift and Z- or L-keys to rotate the display. Only the Left and Right MFD displays can be rotated. 3D Rotation is not supported by all programs.

Configuration Page

Figure 1: General Configuration Page

Configuration setting displayed in configuration page will apply in all IMFD instances.

Nodal Regression enables regression computations for source and target orbits.

Mission timer setting enables GET feature. Dates can be displayed in MJD or GET formats.

Timer Start MJD specifies the start date of the GET timer. If the date is not valid GET feature will be automatically disabled.

LambertAP Mode specifies primary operation mode of the guidance system. See more details below.

Landing Target option is used to defined an additional target like a ground base. This option is currently only used by Map Program.

Time Of Landing specifies time of landing. This option is used predict an alignment of ground base and it's only used by Map Program.

AutoBurn Maxrate specifies maximum angular velocity used in autoburn.

Entry Intrf.Alt specifies default setting for atmospheric entry interface altitude.

Propagate TEj enables numerical ignition state vector propagation.

P30 Comp Mode is used only by NASSP 7 beta. This setting must be "1" when used with NASSP 7 beta (March 22. 2009) or newer. And "2" when used with older beta versions. It will control direction of P30 compensation. Consider switching this option if TLI burn attitude is incorrect.

Burn Guidance Modes

Burn guidance mode is selected from the program options section. Available modes are "Realtime", "Off-Axis" and "ProGrade".

Realtime

mode is designed for short duration course correction maneuvers. The maneuver can be considered to be short when the travelled central angle during the burn is very small. Realtime mode is highly improper in long duration low orbit maneuvers like TLI burn. In this mode flight software is computing the target velocity vector in realtime and the vector will changes it's magnitude and direction while the vessel moves forward. This mode is recommended for any type of mid-course corrections.

Off-Axis

mode is specially designed for Apollo TLI burn. This mode applies some thrust for all 3 axies and can be used evenif the orbits are not perfectly aligned. This mode will compute a numerical solution to place the vessel in target trajectory. This mode requires that the time to ejection (TEj) is higher than 3 seconds. Below the 3 seconds the program is no longer generating new information for the burn execution programs (Autoburn / Thrust Monitor Program) while they are preparing to execute the burn. This mode is recommened for long duration low orbit maneuvers like TLI, TEI, Orbit Insertions/Ejections.

LambertAP Mode

This option specifies the primary opeartion mode of the guidance system of the IMFD. There are two options available "IMFD" and "ApolloP30". This setting will effect in reference frame of the Burn Vector view, powered flight attitude control, behaviour of the Autoburn and trajectory prediction of the map program.

IMFD Powered flight steering is using constant pitch and yaw angles respect to velocity vector of the vessel. Delta velocity is displayed relative to velocity vector in thrust monitor.

ApolloP30 This is AGC P30 compatibility mode using constant attitude in global frame during burn. Delta velocity is displayed in compensated local vertical system as P30 input requires. Autoburn is trying to operate as P30/40 does.

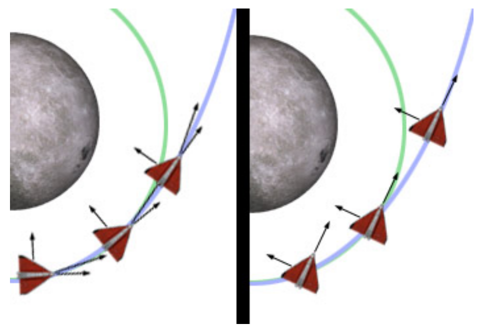

Figure 2: Fixed attitude and velocity relative attitude

Target Intercept - Program

From technical point of view this program will calculate a solution for the Lambert's problem sometimes known as Gauss problem.

This is the primary navigation program of the IMFD. The program will create a trajectory that will intercept the target you have defined by pressing [TGT] button. You must define the MJD of the intercept or alternatively the time to intercept (TIn). Time to ejection (TEj), in other words "Time to Burn". When the program is running in ProGrade guidance mode this parameter is not available to adjust. However, this parameter must be adjusted into the estimated time of ejection before enabling the prograde mode from the program options section. This is only nessecery when you wish to wait more than one orbit period before ejection.

dV Summary

Includes the most important dV values for the transfer plan or course correction. Outward and Invard velocities oV and iV excludes the effect of the gravity. Therefore the actual dV that is required is a little different than the oV or iV.

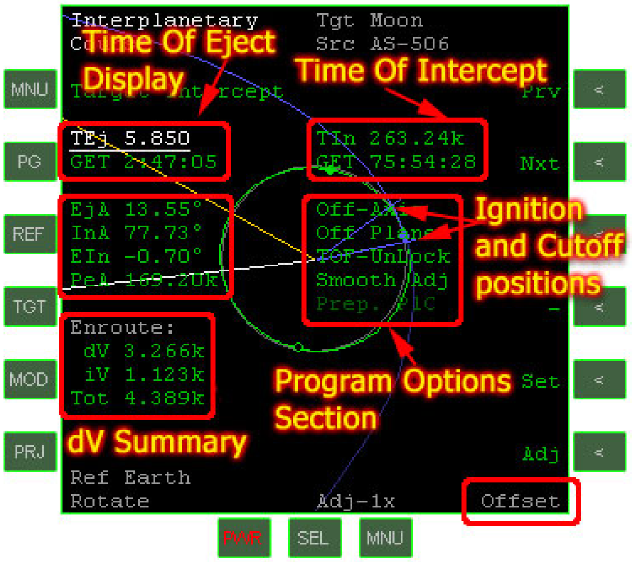

Figure 3: Target Intercept Program

dV	Magnitude of the required burn m/s
oV	Outward velocity (Magnitude of escape vector)
iV	Inward velocity (Magnitude of inbound/approach vector)
PlC	Magnitude of the plane change m/s
Tot	Total dV m/s

Table 1: dV Summary

TOF-UnLocked/TOF-Locked item allows to lock the Time Of Flight. You can adjust both item TEj and TIn but the difference remains constant.

Smooth Adj. / Src. Period / Tgt. Period item allows to select the adjusting method. In a smooth adjust the adjustment rate is selected with [Adj]-button and the rate is displayed in a bottom of the screen. Other modes will adjust the time (TEj, TIn) in full orbit periods of the source or target orbit.

Transfer type (**Plane control method**) is selected from the program options. There are four different kind of methods available "Off-Plane","Two-Plane","Source Plane" and "Target Plane". *See Appendix A.*

Longitude of plane change (2nd Maneuver) will be selected automatically. However, it can be adjusted manually by using (LPC) parameter but only in Source and Target plane methods. All methods except the Off-plane method will require a plane change burn

EjA	Angle between tangent vectors in ejection
InA	Angle between tangent vectors in intercept
RIn	Magnitude of the plane change in degrees
EIn	Plane alignment error
PeA	Periapsis altitude

Table 2: General information

(2nd maneuver) between the ejection and intercept positions. In a special cases when such a maneuver doesn't exist, meaning that there are no node between the eject and intercept positions, these methods can not create a trajectory. In such a case the Off-Plane method can be used.

Magnitude of the 2nd maneuver (in degrees) is minimized in Source and Target plane methods. However, the true magnitude of the maneuver is also depended about the distance from the reference body.

Off-Plane

method will create a trajectory that will intercept the target directly. This is the most easiest way to reach the destination but it's also very often the most inefficient way. In this method there is no plane change or any other maneuver during the flight. In some special cases this may be the only working method. In this method the EIn is presenting how much the target is out of source plane at time of interception.

Source Plane

method will create a trajectory that will follow the source plane for some time. Typically 90 degrees before the target intercepttion the off-plane section will begin requiring a plane change burn (2nd Maneuver). When the time of this maneuver is close the IMFD can be prepared for the 2nd maneuver using automatics by pressing "**Prep. PlC**" item.

Two-Plane

method creates a trajectory that will follow both Source and Target planes. This may not be a very useful method and it is just a special case of the Source-/Target Plane methods.

Target Plane

method will create a trajectory that will beging with an off-plane transfer section typically the first 90 degrees and then goes into the target plane. This would be good choise for the Earth to Mars transfer.

Offseting the Target

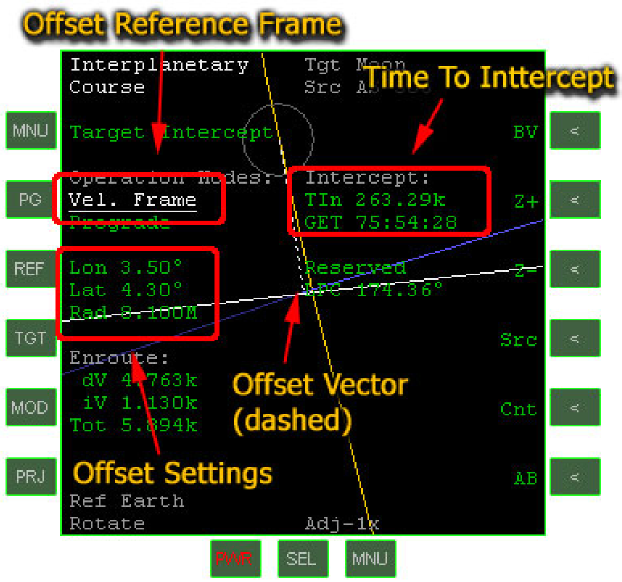

Figure 4: Offseting display

Target offseting allows to displace the target point from the center of the target planet. Target offseting is activated when the offset reference frame is selected. Lon, Lat, Rad items are defining the offset vector in **spherical coordinates**. When the offseting is activated "Offset" flag will appear in main program screen. Offset point can be displayed by pressing [**Cnt**]-button. This will switch the view between reference planet and offset point. The Offset vector is white and dashed. **Prograde/Retrograde** selector has nothing to do with offseting don't touch it. It is sometimes required in moon hopping in outer planets.

Lon	Longitude in a reference frame
Lat	Latitude in a reference frame
Rad	Offset vector length

Table 3: Spherical Offset

See Appendix C for more information about Apollo offsets

Planet Approach - Program

You can easily change the orbit altitude with the planet approach program, provided you are in an approach stage. *(Close to the sphere of influence and on hyperbolic orbit)* Also the equatorial inclination can be adjusted. This is good when planning to approach a high inclination orbit. However, you can not choose the inclination lower than your current inclination to the equator. To reach lower inclinations, normal plane change maneuver must be used and executed in the ascending or descending node of the equator. "Min EqI" and "Max EqI" is displaying the limits where the inclination can be adjusted. Inclinations higher than -90 and lower than 90 degrees are presenting a pro-grade orbits and inclinations higher than 90 and lower than -90 degrees are presenting a retro-grade orbits. When the inclination is negative you will approach the planet from the south pole, and otherwise from the north pole.

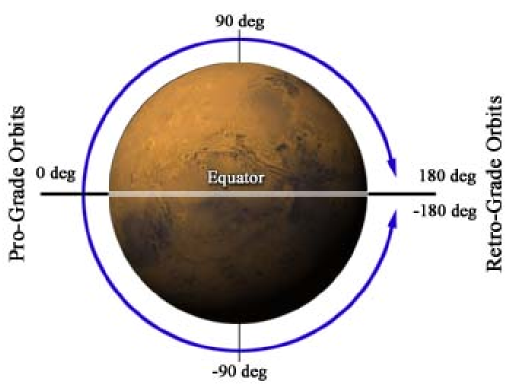

Figure 5: Equatorial Inclination

The burn created by this program should be executed as far from the planet as possible. Sometimes it is possible to execute the burn as far as three times the sphere of influence. This will minimize the fuel usage. Smaller correction burn can be executed later if required.

Latest addition to this program is a manual PeT override. Automatic (Optimized) PeT can be enabled by setting PeT to zero.

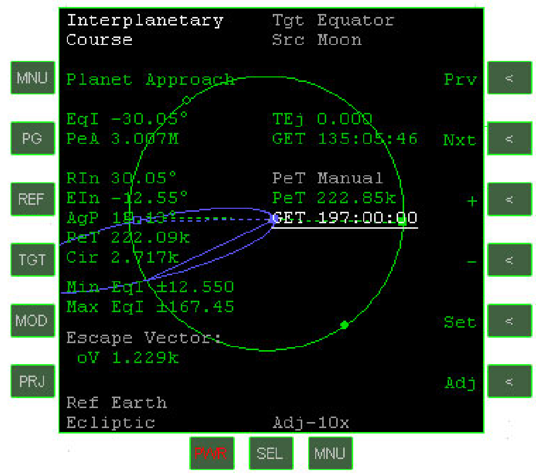

Figure 6: Planet approach program

PeA	Altitude of the periapsis
EqI	Equatorial inclination of the orbit
TEj	Time to ejection
PeT	Time To Periapis (manual override)
RIn	Inclination relative to target plane
EIn	How much src position is out of tgt plane
AgP	Argument of Periapis
Cir	Orbit circularization

Table 4: Items in Planet Approach

Thrust Monitor Program

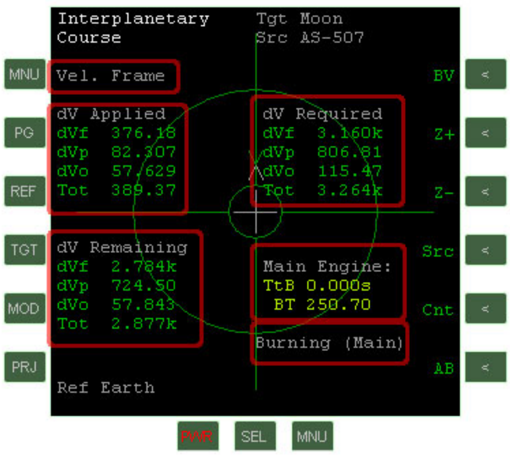

Figure 7: BurnVector View

BurnVector View

is displaying more detailed information about the burn. The contents of this display depends about the guidance mode (realtime, off-axis or prograde). When using realtime mode only applied and remaining delta velocity is displayed. Remaining delta velocity is computed by flight software in realtime. In other modes the delta velocity is numerically computed predefined for the burn. You can select the reference frame used in burnvector view from the configuration page.

dV Applied - section displays the delta velocity that is senced by onboard equipment. It is integrated from the thrust generated by thrusters over time. dV Applied can be reset by switching the Autoburn [AB] on and off.

dV Requird - section is displaying required total delta velocity. This section is displayed only if excat values are known, not in a realtime mode. $\overrightarrow{\mathbf{\Delta_{vRq}}} = \overrightarrow{\mathbf{T_{hrust}}} * ISP * ln(M_{ign}/M_{cut})$ that is equal to numerically integrated accelerations over time.

P30 Local Vertical

Defines a reference system where z-axis (dVi) is pointing in the planet center. x-axis (dVf) is pointing in forward direction of flight and is perpendicular to z (dVi). y-axis (dVp) completes the right-handed triad. (i.e. Is pointing in direction of orbit anti-normal)

Local Velocity Frame

Defines a reference system where x-axis (dVf) is pointing in prograde direction. z-axis (dVi) is pointing towards the planet and is perpendicular to x (dVf). y-axis (dVp) completes the left-handed triad. (i.e. Is pointing in direction of orbit normal plus)

Delta Velocity Program

This program can be used to increase or decrease the velocity of the vessel. When using this program the time to ejection TEj must be higher than 3 seconds. Below the 3 seconds the program is preparing to execute the burn and targeting parameters are no longer updated. Delta Velocity program is using Off-Axis guidance by default and it can't be changed.

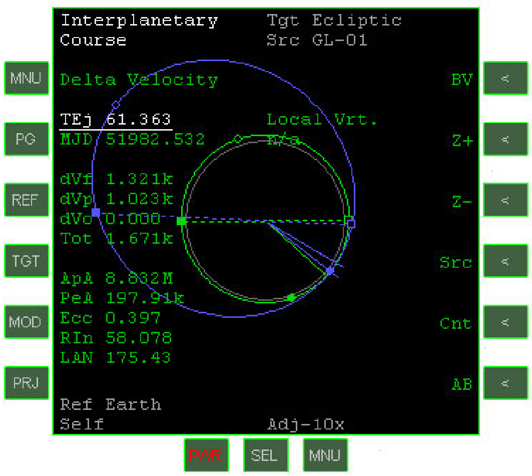

Figure 8: Delta Velocity Program

When planning burns those are longer than 1800 seconds resulting trajectory is not displayed in Delta Velocity porgram anymore. But you can use Map program to display the trajectory within a limitations of the map program.

dVf =Forward (prograde) velocity

dVp =Plane change velocity

dVi =Inbound velocity (towards planet)

Reference frame setting is in a top right corner. See more details about reference frames from the Thrust Monitor section.

Appendix A - Transfer Orbits

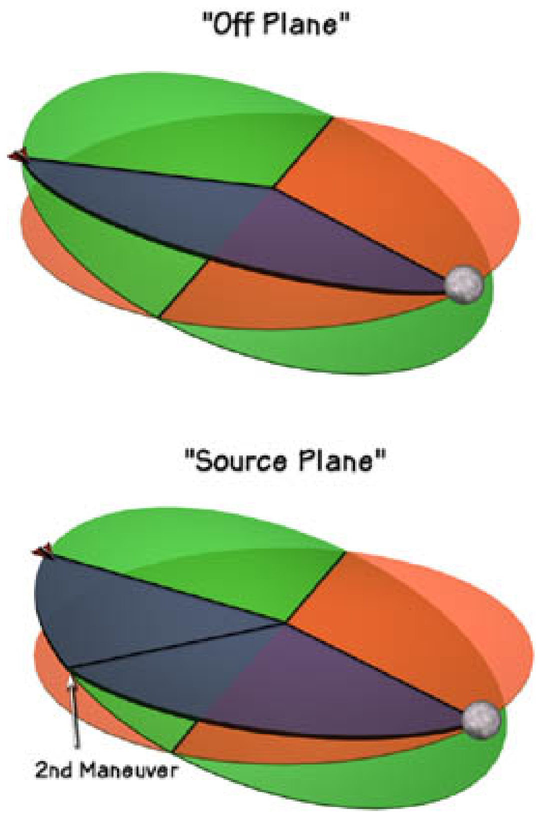

Figure 9: Transfer types used in IMFD

Figure 10: Transfer types used in IMFD

Appendix B - Items in displays

PeT Time to periapsis

PeD Periapsis distance from the center of the reference planet

PeV Relative velocity to the reference planet in a periapsis

PeA periapsis altitude from the surface of the reference planet

ReT Time to re-entry, time to landing

ReV Re-entry velocity

ReA Re-entry angle

Inc This is the inclination of current orbit relative to the ecliptic plane.

RIn This is the relative inclination to the target orbit. $\angle(\overrightarrow{\mathbf{n_s}}, \overrightarrow{\mathbf{n_t}})$

EqI Equatorial inclination of orbit. Inclination respect to equator

EIn Escape/Ejection Inclination. An angle between escape vector and the orbital plane of the ship, it is defined as: $\pi/2 - \angle(\overrightarrow{\mathbf{n_s}}, \overrightarrow{\mathbf{E}})$. In a transfer programs, It is also the angle between the orbital plane of the ship and the target position at the time of interception.

TEj Time to ejection. Time to launch window. (MJD) below this item is presenting the modified julian date of ejection.

TIn Time to intercept the target. (MJD) below this item is presenting the modified julian date of intercept.

TtB Time To Burn. Time to main engine start

EjA Ejection Angle. Angle between the velocity vectors of ship's orbit and transfer orbit at a time of ejection

InA Angle between the velocity vectors of ship's orbit and transfer orbit at a time of interception

Lon Longitude in degrees

Lat Latitude in degrees

Hed Heading of the Launch or Landing

AgP Argument of periapsis. Angle between periapsis and line of nodes

Ecc Orbit eccentricity

LAN Longitude of ascending node relative to ecliptic

Rad This item presents the radius of the orbit being targeted

BT Remaining burn time in seconds at full thrust

Tn Time to next node. When negative it is presenting the time after the node.

Cir dV for orbit circularization in periapsis

PlC dV for plane change burn and the attitude mode to be used with the maneuver.

Tot Total dV including the dVs above the Tot item

dV Delta velocity for the burn

oV Outward delta velocity

iV Inward delta velocity

KeyBoard commands

To be able to access the commands in a second column you must change the page with [PG] Shift-I command. Open InterplanetaryMFD with the Shift-I command.

MNU	Shift-F	Prv	BV	Shift-1
PG	Shift-I	Nxt	Z+	Shift-2
REF	Shift-R	(+)	Z-	Shift-3
TGT	Shift-T	(-)	Src	Shift-4
MOD	Shift-M	Set	Cnt	Shift-5
PRJ	Shift-P	Adj	AB	Shift-6

Key commands for programs other than Map

MNU	Shift-F	Cnt	Slf	Shift-1
PG	Shift-I	Z+	SOI	Shift-2
REF	Shift-R	Z-		Shift-3
TGT	Shift-T	Sel		Shift-4
MOD	Shift-M	Dsp	Plan	Shift-5
PRJ	Shift-P	Azo	Find	Shift-6

Key commands for Map program

Prv	Shift-1	Select previous variable
Nxt	Shift-2	Select next variable
+,-	Shift-3,4	Adjust variable
Set	Shift-5	Set variable manually
Adj	Shift-6	Change adjustment speed
Z+-	Shift-2,3	Change a zoom factor
Src	Shift-4	Setup source object
Cnt	Shift-5	Center the display in other position
AB	Shift-6	Enable/Disable autoburn
BV	Shift-1	Open/Close burn vector display

Key commands for programs other than Map

PG	Shift-I	Change a button list in right edge
MNU	Shift-F	Open program menu
TGT	Shift-T	Select target orbit
REF	Shift-R	Select the reference planet
MOD	Shift-M	Change a display mode Text/Graphics
PRJ	Shift-P	Change the projection plane

Buttons available in a left edge

Sel	Shift-4	Select the periapsis to use
Dsp	Shift-5	Display additional graphics in map
Azo	Shift-6	Enable or Disable autozoom feature
Slf	Shift-1	Display or Hide ship‘s trajectory
Soi	Shift-2	Display the Sphere of influence
Plan	Shift-5	Switch flight planning mode on and off
Find	Shift-6	Find targets from the reference

Appendix C - AMSO Apollo Offsets

These offsets are created for AMSO scenarios and there is no any quarantee of correctness of this data. Some of the parameters are from the original mission plan, some of them are presenting actual historic values, some of them has been found to be good with AMSO and finally some of them are guesstimated to archive good trajectory shape and MCC magnitude in a historic perspective.

Due to minor bugfix this data is not accurate with IMFD 5.1 and it will become obsollete after auto-offset.

	Apollo11	Apollo12	Apollo13	Apollo14	Apollo15	Apollo16	Apollo17
Lon	6.0	19.5	0.7	18.0	-12.0	3.0	17.0
Lat	6.5	14.0	4.00	10.0	-7.8	10.4	-16.2
Rad	7.92M	15.25M	8.9M	14.9M	9.29M	9.57M	10.34M
TLI	2:44:16	2:47:22	2:35:46	2:28:32	2:51:00	2:35:52	3:14:40
LOI	75:54:28	83:22:53	77:26	81:56:40	78:26	74:26	86:13
PC-Alt	120km	3430km	390km	3760km	146km	132km	94km
PC	LOI	84:07:53	77:36	82:42:40	LOI	LOI	LOI
Trajectory	Freereturn	Freereturn, Hybrid	Freereturn, Hybrid	Freereturn, Hybrid	Hybrid	Hybrid	Hybrid

Table 5: Apollo TLI Offsets

When executing TLI burn remember to change realtime guidance to Off-Axis guidance.

	Apollo11	Apollo12	Apollo13	Apollo14	Apollo15	Apollo16	Apollo17
Lon	-16.5	-2.0	-19.7	-9.2	-20.0	-15.3	-10.2
Lat	2.3	13.2	1.1	6.2	-8.4	6.3	-11.2
Rad	10.15M	10.86M	10.63M	11.95M	10.62M	10.78M	11.82M
dV	1.6	21.3	3-5	21.7	0.9	0.8	0.4
Time	26:44:58	30:52:00	30:40:49	30:36:07	28:40:22	30:39:00	35:29:59

Table 6: Apollo MCC

When executing MCCs remember to change Off-Axis guidance to realtime.