Shuttle FDO MFD 0.1.6

by indy91

March 6, 2019

1 Introduction

The Shuttle FDO MFD contains tools to calculate rendezvous plans and individual maneuvers for Space Shuttle operations. It is based on the Orbital Maneuver Processor (OMP), which was the program used for this task by the actual Shuttle Flight Dynamics Officers (FDO). The MFD is mainly intended for use with the Space Shuttle Ultra addon for the Orbiter Space Flight Simulator 2016.

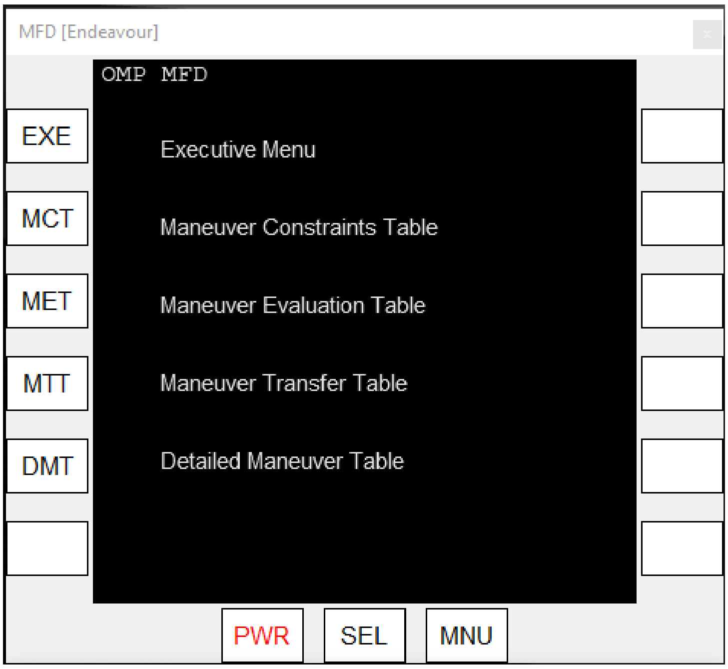


Figure 1: Main Menu

2 OMP User's Guide

2.1 Maneuvers and Constraints

The OMP is capable of computing many different types of maneuvers, for example it can target a desired orbit height for a Hohmann transfer, or downtrack distance from another spacecraft after a period of time. For all maneuver types, the user must specify a *primary constraint*, for example TIG of the burn in MET, or number of revs since a previous burn. Most maneuver types also require one or more *secondary constraints*; these are normally of a lighting or geometric nature. For the height adjust (HA) burn example mentioned above, a valid secondary constraint would be APO=1 in order to force TIG to occur at the next apoapsis. In other words, the OMP would begin searching for the next apoapsis, starting at the threshold time specified as the primary constraint. Another secondary constraint could be HD=160, which tells the OMP what height to target for the burn (160 nm in this example). Some secondary constraints define desired chaser-target relative position at a future time (downrange distance, or DR, for example).

The following passage is a complete list of all maneuvers supported by the OMP in the Shuttle FDO MFD.

2.1.1 Single Vehicle Maneuvers

The following list shows the maneuvers, which are supported in OMP for use with only a single vehicle. In other words, they are target independent.

APSO (Apsidal Shift)
This is a maneuver targeted to shift the chaser's line of apsides with a purely radial maneuver done halfway between the current and desired line of apsides. This maneuver is normally used with the A or P secondary constraints (not supported yet!).

CIRC (Circularization)
This maneuver is targeted to circularize the chaser's orbit at the maneuver time.

DVPY (Delta Velocity with Pitch and Yaw)
This maneuver is a PEG 7 maneuver, similar to the EXDV maneuver, defined by a delta velocity magnitude and a LVLH pitch and yaw thrust direction. These parameters are indicated by the DV, YAW and PIT secondary constraints.

DVYP (Delta Velocity with Yaw and Pitch)
Same as above.

EXDV (External Delta Velocity)

This is a PEG 7 targeted maneuver defined by LVLH velocity components as specified with DVLV secondary constraints in X, Y and Z order.

HA (Height Adjust)
This is a horizontally executed maneuver targeted to achieve a desired orbital altitude 180° from the maneuver point. Thus, this maneuver is targeted as a Hohmann transfer. The desired orbital altitude is indicated by the HD "‘height desired"’ secondary constraint.

HASH (Height Adjust and Apsidal Shift)
This is a maneuver targeted to achieve a desired orbital altitude 180° from the maneuver point and to simultaneously move the line of apsides to the maneuver point. The desired altitude is indicated by the HD secondary constraint.

2.1.2 Dual Vehicle Maneuvers

The follow list shows the maneuvers which are supported in OMP using two vehicles, a chaser and a target.

NC (n^{th} Closing Maneuver)
This is a horizontally executed maneuver targeted to obtain the desired offset position from the target (phase angle) at a future time. This maneuver controls the X axis curvilinear distance. The offset position is indicated using the DR secondary constraint.

NCC (n^{th} Corrective Combination)
This is a Lambert targeted maneuver correcting the chaser's trajectory to achieve the desired offset position relative to the target. The desired curvilinear LVLH offset position is indicated by CXYZ secondary constraints in X, Y, Z order. Alternative, DR, WEDG and DH constraints can be used. The maneuver controls all curvilinear axes. It is a combination of three maneuvers: NC, NH and NPC. Typically, Y-offset is set to zero, creating a common node at the subsequent maneuver.

NH (n^{th} Height Adjust)
This is a horizontally executed maneuver targeted to a differential height from the target at some future time. It controls the Z curvilinear distance. The differential height is indicated using the DG secondary constraint.

NHRD (Height Adjust with Radial Component)
This maneuver is similar to the NH maneuver except it contains a radial component to null the radial velocity at the time of the maneuver. The differential height is indicated using the DH secondary constraint.

NPC (n^{th} Plane Change)

This is an out-of-plane maneuver placing the chaser in the target's phantom plane. The phantom plane is the target's actual plane offset by the amount of differential nodal regression calculated to occur between the NPC maneuver and the desired in-plane time (function of height difference). The in-plane time is indicated by the WEDG=0 secondary constraint, placed on a future maneuver. In addition, the maneuver should be placed at a common node between the chaser and phantom target planes which is indicated by the CN=1 secondary constraint. If this is not done, the chaser and target will remain in separate planes. The NPC maneuver controls the Y axis curvilinear distance.

If the WEDG secondary constraint is not used, the maneuver will place the chaser in the target's actual plane at the time of the maneuver.

NS (Node Shift)
This maneuver is targeted to place a common node approximately 90 degrees from the maneuver point.

NSR (n^{th} Slow Rate Maneuver)
This maneuver is targeted to put the chaser in an orbit coelliptic to the target. Coelliptic is defined as a condition where there are coincident lines of apsides. This maneuver is often executed alone, allowing the next maneuver to set up lighting for intercept.

SOI (Stable Orbit Initiation)
This is a Lambert targeted maneuver correcting the chaser's trajectory to achieve the desired offset position relative to the target at the subsequent SOR maneuver. The offset position is indicated with the CXYZ secondary constraints. The SOI maneuver must be followed by a SOR maneuver.

SOR (Stable Orbit Rendezvous)
This is the second maneuver of the Lambert pair SOI/SOR. This maneuver is Lambert targeted to re-intercept the SOR offset position after 270° of orbital travel, essentially stabilizing the chaser in the same orbit as the target, assuming offsets are small.

SOR can also be a stand-alone maneuver. The maneuver computed will be the same as an NCC maneuver in a NCC/NSR combination when the primary constraint for the NSR is WT=270 (M=0.75) and the secondary constraint offsets are the same as the SOR maneuver.

2.1.3 Threshold (Primary) Constraints

The following descriptions reference the threshold constraints (referred to as "'primary constraints"') supported by OMP. These constraints are used to define the Time of Ignition (TIG) of the maneuver if no secondary constraint is specified. If a geometric or lighting secondary constraint exists for the maneuver, the threshold constraint defines the threshold, or the time at which the OMP starts to search for the geometric or lighting constraint's value.

APS (Delta Apsides)
This specifies the number of chaser half orbits from the previous maneuver. For example, APS=2.0 would yield the same result as M=1.0.

CAN (Central Travel Angle)
This specifies that the maneuver will occur when the chaser has flown through the central travel angle specified in degrees.

DT (Delta Time)
This specifies the delta time from the previous maneuver's impulsive ignition time to the current maneuver's impulsive ignition time. The OMP expects this delta time in a DDD:HH:MM:SS.SSS format.

M (Delta Orbits)
This specifies the number of chaser orbits from the previous maneuver. The value may be a decimal fraction.

N (Delta Apsides)
This specifies the number of chaser half orbits from the previous maneuver.

REV (Delta Revolutions)
This specifies the number of chaser orbits from the previous maneuver in orbits. This value may be a decimal fraction.

T (Time)
The maneuver's impulsive ignition time will occur at the specified time. The OMP expects MET in DDD:HH:MM:SS.SSS format.

WT (Central Travel Angle)
This specifies that the maneuver will occur when the chaser has flown through the central travel angle specified in degrees.

2.1.4 Geometric (Secondary) Constraints

The following documentation reference geometric (secondary) constraints supported by OMP. These constraints are used to alter the maneuver's TIG to meet the geometric constraint in relation to the Earth, inertial space, the chaser or target orbit, or the target.

APO ($\mathbf{n^{th}}$ Apogee)

The maneuver is executed at the n^{th} apogee of the chaser's orbit after the threshold constraint, where N is the constraint's value.

APS (n^{th} Apsidal Crossing)
The maneuver is executed at the n^{th} chaser apsidal crossing after the threshold constraint. To insure convergence, minimum delta-height between the chaser's apogee and perigee must be >10 nm.

CN (Common Node)
The maneuver is executed at a common nodal crossing of the target and chaser orbit planes. When used in conjunction with the WEDG secondary constraint, the chaser maneuver will be executed at a phantom common nodal crossing such that the two vehicles will be coplanar at the WEDG specified time.

PER (n^{th} Perigee)
The maneuver is executed at the n^{th} perigee of the chaser's orbit after the threshold constraint, where n is the constraint's value.

2.1.5 Lighting (Secondary) Constraints

The following descriptions reference lighting (secondary) constraints supported by OMP. These constraints allow maneuver times to be based on lighting events. All constraint values are input in minutes from the event, where positive values are after the event.

LITI (Time from Sunrise)
The maneuver is executed at a time relative to orbital sunrise. This is similar to the NITO lighting constraint.

LITM (Time from Noon)
The maneuver is executed at a time relative to orbital noon.

LITO (Time from Sunset)
The maneuver is executed at a time relative to orbital sunset. This is similar to the NITI lighting constraint.

NITI (Time from Sunset)
The maneuver is executed at a time relative to orbital sunset. This is similar to the LITO lighting constraint.

NITM (Time from Midnight)
The maneuver is executed at a time relative to orbital midnight.

NITO (Time from Sunrise)

The maneuver is executed at a time relative to orbital sunrise. This is similar to the LITI lighting constraint.

2.1.6 Other Secondary Constraints

The following descriptions reference remaining secondary constraints supported by OMP. These constraints are used to modify maneuver solutions or to provide the OMP with desired relative state information.

CXYZ (Curvilinear Offsets)
This specifies the chaser relative X, Y and Z position in the target centered local vertical curvilinear coordinate system. The distances are input in nm. Positive distances are when the chaser is leading, below and to the right of the target. OMP expects these to be input in an X, Y, Z ordered triplet (e.g. CXYZ= -8.0, CXYZ=0.0, CXYZ=0.2 for Ti position when targeting an NCC maneuver).

DH (Delta Altitude)
This specifies a desired differential height at the chaser maneuver time with the target propagated along its actual orbit to a condition of phase match. The distance is input in nautical miles. Positive distances are when the chaser is below the target.

DR (Down Range Offset)
This specifies the downrange position that is desired at the maneuver's TIG in nautical miles. Positive distances are when the chaser is leading the target.

DV (First Guess Delta Velocity)
This supplies an initial guess of a minimum DV magnitude for the chaser maneuver's NC and NH, in fps. This secondary constraint gives orbital wrap around capability for phasing. DV is used for NC maneuvers to insure convergence since OMP uses 0 fps for the default initial guess.

When used in conjunction with either the DVPY or DVYP maneuvers, this secondary constraint defines the total DV magnitude of the maneuver.

DVLV (Local Vertical Delta Velocity)
This specifies the external delta velocity component in the LVLH X, Y and Z direction for the EXDV maneuver, in fps. OMP expects these to be input in an X, Y, Z ordered triplet (e.g. DVLV=3.0, DVLV=0.0, DVLV=0.0 for a posigrade 3 fps maneuver).

HD (Height Desired)
This specifies the desired chaser altitude to be achieved after 180 degrees of orbital travel from a HA or HASH maneuver, in nautical miles. Positive altitudes are when the chaser

is above the surface of the Earth.

NULL (Null Y-dot)
This specifies that the out-of-plane relative velocity between the chaser and target be nulled at the time of the chaser's maneuver. This secondary constraint has no particular numeric value.

PIT (Pitch)
This specifies the pitch value for the DVPY or DVYP maneuvers in degrees.

WEDG (Wedge Angle) This specifies wedge angle for the NPC maneuver to target at some future maneuver. This secondary constraint should be placed on the maneuver for which the desired wedge angle is to be achieved. For example, in order to target an NPC maneuver to put the chaser in the target's plane at Ti, a secondary constraint of WEDG=0.0 should be placed on the SOI maneuver in the plan.

YAW (Yaw)
This specifies the yaw value for the DVPY or DVYP maneuvers, in degrees.

2.2 OMP Displays

There are several displays that OMP uses for data input, execution, and viewing. There is a section for each of the displays. A copy of the display along with a parameter definition will be given in each of these sections. The format for the parameter definitions will give the parameter on the left side of the page and the description on the right. After each description, the units of the parameter will be given in parenthesis, if applicable.

2.2.1 Maneuver Constraints Table (MCT)

The MCT is used to input maneuver constraints for the OMP to process when generating a rendezvous plan. Three columns are provided to allow the user to specify maneuver type, primary constraint, and secondary constraints for each maneuver.

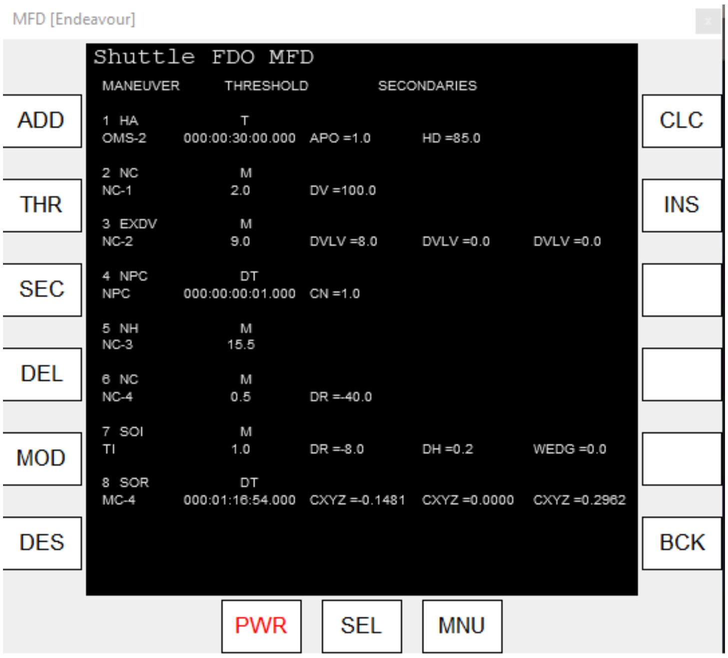


Figure 2: Maneuver Constraints Table

Parameter	Description	Units
MANEUVER	Maneuver ID	4 characters max.
THRESHOLD	Threshold constraint and associated value	4 characters max.
SECONDARIES	Secondary constraint and associated values	4 characters max.

Buttons:

ADD: Add a maneuver to the MCT. The input format is: "Maneuver-Type Maneuver-Name".
THR: Add/modify threshold (primary) constraints. Input format: "Maneuver-ID Threshold-Type Threshold-Value".
SEC: Add secondary constraint. Input format: "Maneuver-ID Constraint-Type Constraint-Value".
DEL: Delete maneuver from table. Input format: "Maneuver-ID".
MOD: Modify maneuver in the table. Input format: "Maneuver-ID Maneuver-Type Maneuver-Name".
DES: Delete secondary constraint from table. Input format: "Maneuver-ID Secondary-ID".
INS: Insert maneuver into table. Input format: "Maneuver-ID Maneuver-Type Maneuver-Name".
MOS: Modify secondary constraint in the table. Format: "Maneuver-ID Secondary-ID Constraint-Type Constraint-Value.

CLC: Calculate rendezvous plan.
BCK: Go back to previous menu.

2.2.2 OMP Executive Menu

The Executive Menu is the place where several options can be selected before a rendezvous plan is created or run. Additionally the rendezvous plans can be saved or loaded in this menu.

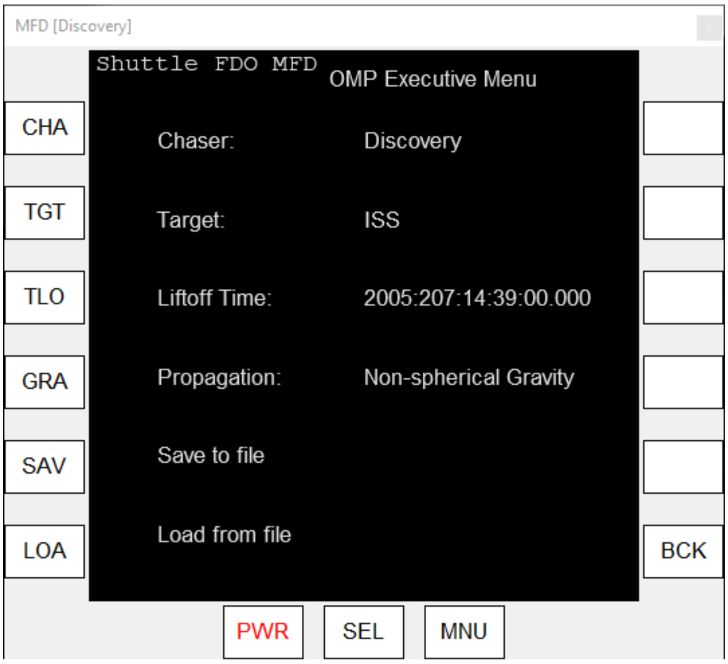


Figure 3: OMP Executive Menu

Buttons

CHA: Select the chaser vehicle.
TGT: Select the target vehicle.
TLO: Set the time of liftoff. Format: "YYYY:DDD:HH:MM:SS".
GRA: Cycle between the two gravity options of the MFD (Taking non-spherical gravity into account or not).
SAV: Save a constraints table to file.
LOA: Load a constraints table from file.
BCK: Go back to previous menu.

2.2.3 Maneuver Evaluation Table (MET)

After a plan is run, the output may be viewed on the Maneuver Evaluation Table (MET). The table contains numbers associated with each maneuver of the mission plan.

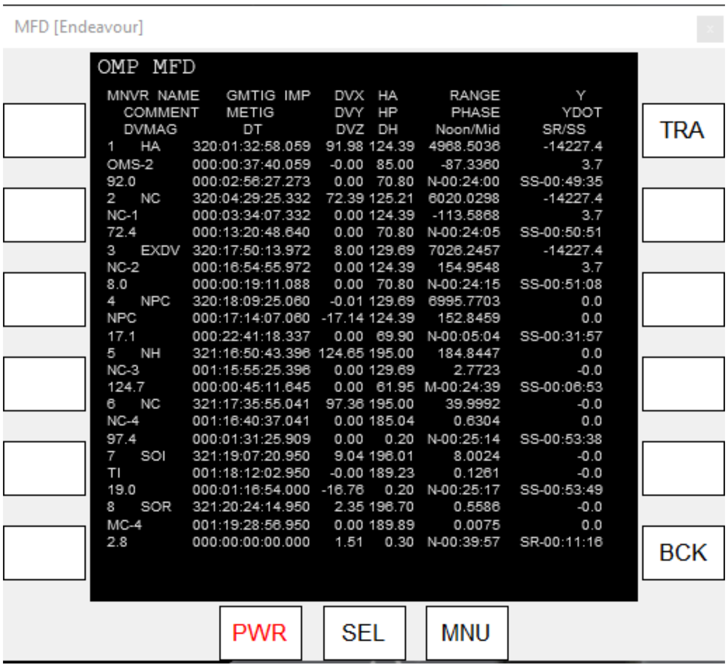


Figure 4: Maneuver Evaluation Table

Parameter	Description	Units
MNVR NAME	Maneuver type	
COMMENT	Maneuver comment/name	
DVMAG	Total DV of maneuver	fps
GMTIG	Impulsive GMT of ignition	DDD:HH:MM:SS.SSS
METIG	Impulsive MET of ignition	DDD:HH:MM:SS.SSS
DT	Time until next maneuver	DDD:HH:MM:SS.SSS
DVX,Y,Z	Cartesian components of DV in Orbiter-centered LVLH coordinates	fps
HA, HP	Chaser apsis altitude above a spherical Earth at the maneuver's burnout	NM
DH	Chaser altitude minus target altitude at phase match with the chaser at the maneuver's TIG	NM
RANGE	Distance between the chaser and target at the maneuver's TIG	NM
PHASE	Phase angle between the chaser and target at the maneuver's TIG. + if chaser is trailing the target	deg
NOON/MID	Time from TIG until next orbital noon or midnight	HH:MM:SS
Y	Distance of the chaser from the target's orbital plane at the maneuver's TIG	feet
YDOT	Chaser's out-of-plane velocity at the maneuver's burnout	fps
SR/SS	Time from TIG until next orbital sunrise or sunset	HH:MM:SS

Buttons
TRA: Transfer maneuver plan to Maneuver Transfer Table.
BCK: Go back to previous menu.

2.2.4 Maneuver Transfer Table (MTT)

A rendezvous plan may be transferred to the Detailed Maneuver Table after it has been generated. The OMP computes an impulsive TIG and LVLH DV components, but the DMT needs more information about the burn. It requires the chaser vehicle's thruster selection and thrust vector roll angle (TVR) in order to compute burn attitude, plus guidance mode. The Maneuver Transfer Table (MTT) is used to define this information before a plan is transferred to the DMT - it essentially allows the burn to be converted from impulsive to finite.

At the bottom of the MTT are ten slots where different configurations may be defined. A standard configuration is provided when the display is first called, one for each potential maneuver in the plan. The user may choose from any of the ten slots to define the configuration for a burn. Manual editing of the options is not supported in the MFD at this time.

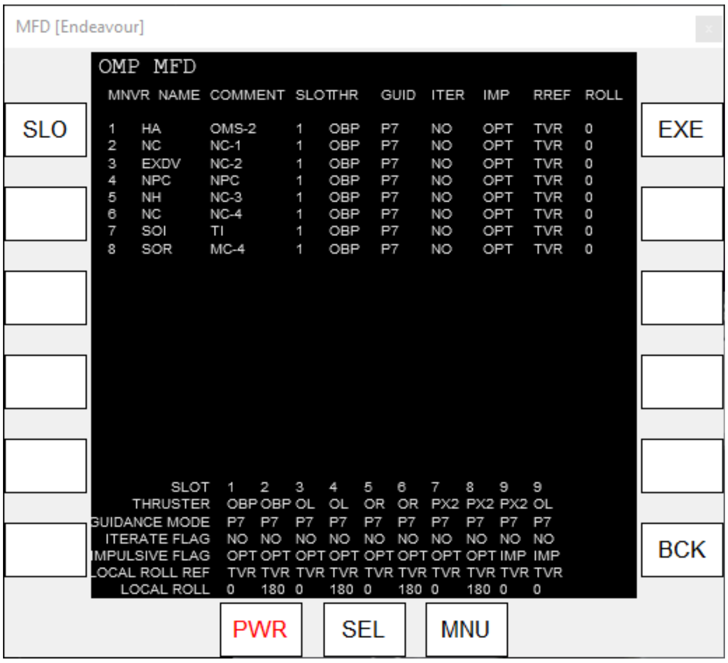


Figure 5: Maneuver Transfer Table

Parameter	Description	Units
MNVR	Maneuver number	1-9
NAME	Maneuver type	4 characters
COMMENT	Comment associated with maneuver	10 characters max.
SLOT	Slot number to reference characteristics from table below	
THRUSTERS	Thruster selection for the maneuver	PX2, OL, OR, OBP
GUID	Guidance mode for the maneuver	PEG7
ITER	Iteration flag	YES, NO
IMP	Impulsive/Optimize flag	IMP, OPT
RREF	Local roll reference for the maneuver	TVR
ROLL	Local roll angle for the maneuver	deg

Buttons

SLO: Choose which of the slots with maneuver options is applied to the maneuver. Input format: ”Maneuver-ID Slot-ID”

EXE: Calculate maneuver parameters based on the thruster and attitude selection and transfer them to the Detailed Maneuver Table.
BCK: Go back to previous menu.

The currently available thruster options are two +X thrusters (PX2), both OMS engines (OBP), left OMS engine (OL) and right OMS engine (OR).

The impulsive flag may be set to either IMPulsive (IMP) or OPTimize (OPT) to control TIG selection during the transfer to the DMT. If OPT is chosen, the maneuver's burn arc is taken into account by "splitting the TIG". That is, the transferred TIG is set equal to the OMP TIG minus one-half of the length of the burn. The OMP's impulsive delta velocities, converted to the inertial frame, are then applied to the burn. When IMP is chosen, the transferred TIG is the same as the OMP-computed TIG. In normal practice, the impulsive flag is set to OPT for any non-Lambert burns in order to center the burn arc about the impulsive TIG. This is extremely important for big burns (>50 fps) that have a significant burn arc. On day of rendezvous, NCC, Ti, and all mid-course burns are transferred as IMP so that the same TIG is used consistently between ground and onboard, to assure that the timeline in the Rendezvous Checklist is adhered to.

3 Detailed Maneuver Table

Any maneuver residing in the Maneuver Transfer Table may be placed in a DMT for display purposes. As such, DMTs function as the primary means of gaining insight into a maneuver's specifications. The central portion of the DMT is associated with Pre-Advisory Data (PAD) parameters. This segment is used to generate a PAD Flight note. The other parts of the DMT, which contain additional data about each maneuver, are currently not supported in the MFD.

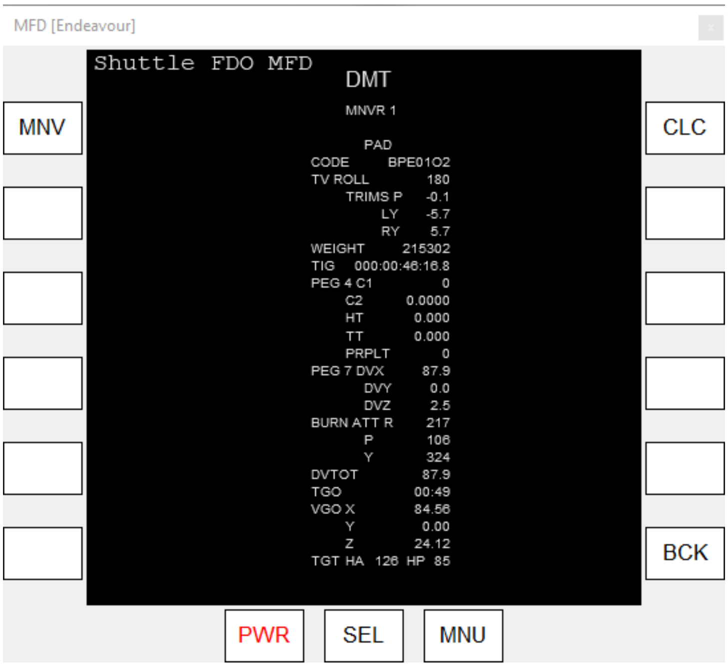


Figure 6: Detailed Maneuver Table

Buttons
MNV: Choose which of the maneuvers in the list transferred from the MTT should be displayed.
CLC: Calculate maneuver parameters for the chose burn.
BCK: Go back to previous menu.

4 Walkthrough

The following text is a walkthrough of a full rendezvous with the FDO MFD. It is intended to be used with the "STS-126 - FDO MFD Test" scenario which can be found in the SSU/Testing Scenarios folder. The scenario is starting at L-10 minutes, but any planning with the MFD can not be done before orbital insertion, best after OMS-1 and/or the MPS dump, so that no trajectory changes are done during the planning phase. The mission should be flown with non-spherical gravity disabled.

4.1 Pre OMS-2 Planning

The first step is to load the STS-126 config file for the MFD. Open the OMP Executive Page by pressing EXE in the main menu of the MFD. Then load the file by pressing LOA and typing "STS-126". This should load several parameters to the page.

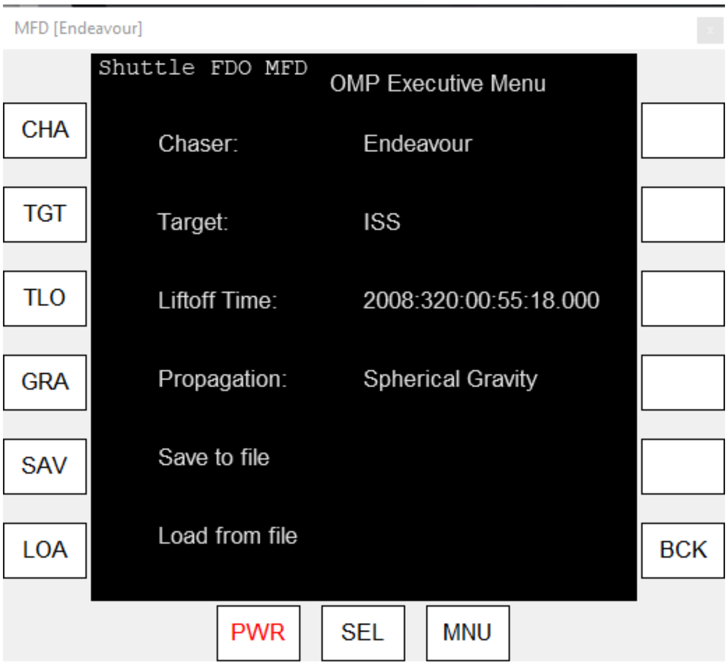
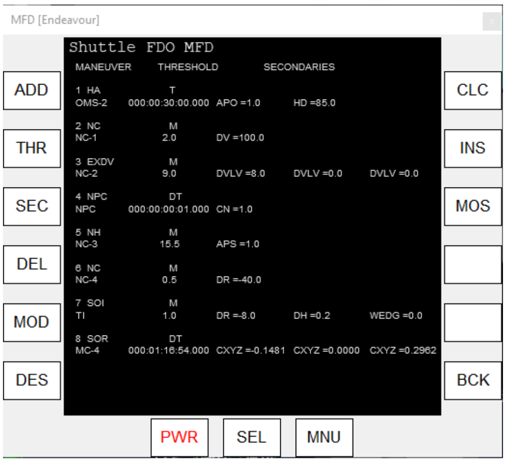


Figure 7: STS-126 Executive Page

Next go back (press BCK) to the main menu and open the Maneuver Constraints Table (press MCT). You should now see the initial, TIG-less plan for the rendezvous. TIG-less means that it is kept as generic as possible, so that it will work for any insertion conditions, and no time of ignition of a maneuver has been fixed in time yet. Run this initial plan by pressing CLC. It is useful to have two instances of the MFD open at all times, the External MFD is quite useful for this. At this stage it is best to have the maneuver constraints table and the maneuver evaluation table (in the main menu press MET) open. When the initial plan was run the MET should be populated with numbers for each maneuver:



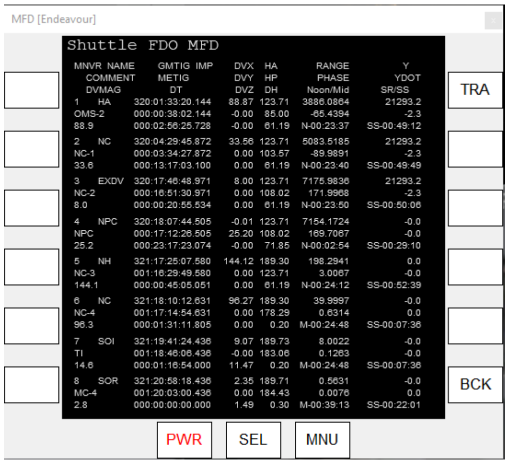


Figure 8: First iteration

4.1.1 Iteration to Correct TI Lighting and Radial DV

After the TIG-free plan has been run and verified to be a good "ballpark" estimate of the actual rendezvous, the next step is to "freeze" TIGs and perform fine-tuning of the profile. This includes: fixing TI lighting and eliminating radial DV. The first step is to re-save the TIG-free plan to another name in order to begin working with a new plan name. This can be done on the OMP Executive page by pressing SAV and giving the modified plan a new name. This might be something like "STS-126A". Next, use the TIG-free MET to determine TI lighting under the "SR/SS" column. The desired TIG is generally near orbit noon and conforms to a mission-specific offset from sunset. For an ISS rendezvous the desired TI TIG will generally be SS -36 min.

Now using the Maneuver Evaluation Table and desired time of TI, you can compute how many minutes the lighting is off, and then move the TIG of the final NC burn as necessary to nail TI lighting. The best way to change TI TIG is to switch the TIG of the first burn on Day-of-Rendezvous (DOR) to a primary constraint of T (time). That time will be equal to its TIG-free MET output plus TI error computed above. In this example case the relevant numbers for the TI burn from the evaluation table were:

-METIG: 001:18:46:06.436
-SR/SS: SS-00:07:36

So the TIG is in error by 28:24 minutes for the desired lighting conditions. As described above it is best to change the first burn on DOR by those 28 minutes. This is an easier technique than fixing TI first and then working backwards to determine fixed TIGs for NC-3 and NC-4. In this case the first burn on the DOR is NC-3, a NH type burn and the 5th burn in the table with a TIG of currently 001:16:29:49.580. Now change its TIG to 28:24 minutes earlier by pressing THR and typing: 5 T 1:16:1:26. This will give the NC-3 maneuver a fixed TIG of the specified time. There also was a secondary constraint on the maneuver to place it at an apsis. That will now have to be removed to use the fixed TIG that was input. To delete the constraint press DES and type: "5 1" to delete the 1st secondary constraint of the 5th maneuver. Calculate the plan again by pressing CLC and check the TI lighting condition. In my case it is now "SS-00:36:06", which should be close enough to the desired lighting.

When the plan is re-generated, it likely that TI will have a non-zero radial component. In fact, in the example case, SOI DVZ is -73 fps! This is because TI is not located on the line of apsides. This is the "maneuver line" connecting apogee and perigee. (For the case of rendezvous with a target in a non-circular orbit we are actually referring to *relative* apses, where the chaser-target height differences are minimum and maximum. In this case, the chaser-target "line of *relative* apsides" maybe not necessarily coincide with the geocentric line of apsides.) In order for TIG to be purely horizontal/prop efficient, it must be performed very close to the line of apsides, and it must be located at the correct relative height, which is assured by a NH maneuver (NC-3 in this case). If either of these are not met, a radial component will be added to SOI in order to simultaneously satisfy downtrack, height, and time-of-flight constraints for SOR.

The preferred technique to place TI on the line of apsides (and thus eliminate DVZ) is to move the TIG of one of the prior large phasing burns. This rotates the line of apsides so that TI falls on the line. To do this, locate a prior NC or NH maneuver in the profile that starts from as nearly a circular orbit as possible. It must be a large burn (DV >about 20 fps) in order to have enough "muscle" to move the line of apsides. There may be one or two candidate burns that can be used. In this case we would normally use the NC-1 burn for this purpose, but with 30 fps we can figure out (by trial and error) that it doesn't have enough muscle to get the TI DVZ to 0. So instead we will fix the TIGs of NC-3 and NC-4. The NC-4 TIG will now assure the TI lighting and by modifying the NC-3 TIG, the orientation of the line of apsides is moved without significant DV penalty to the plan. In the OMP, this is done by changing the primary constraints to T and fixing the time based on previous MET output. Add a small bias to the NC-3 TIG in order to see if it improves TI DVZ. Continue tweaking until TI DVZ is less than 1 fps. This is very much a trial and error process. In the example case the NC-4 TIG to get the TI lighting right was 1:16:46:29, the NC-3 TIG to get the TI DVZ component to close to zero is 1:16:05:47. This concludes the pre OMS-2 planning, so it is best to save the current plan under a new name. This is also the best time to give NC-1 a fixed TIG. The first maneuver in the constraints table always needs a "T" as the primary threshold and soon OMS-2 will be deleted from the table. So press THR and type: "2 T XXX:XX:XX:XX.XXX" and use the exact time of NC-1 from the previous run, on the evaluation page.

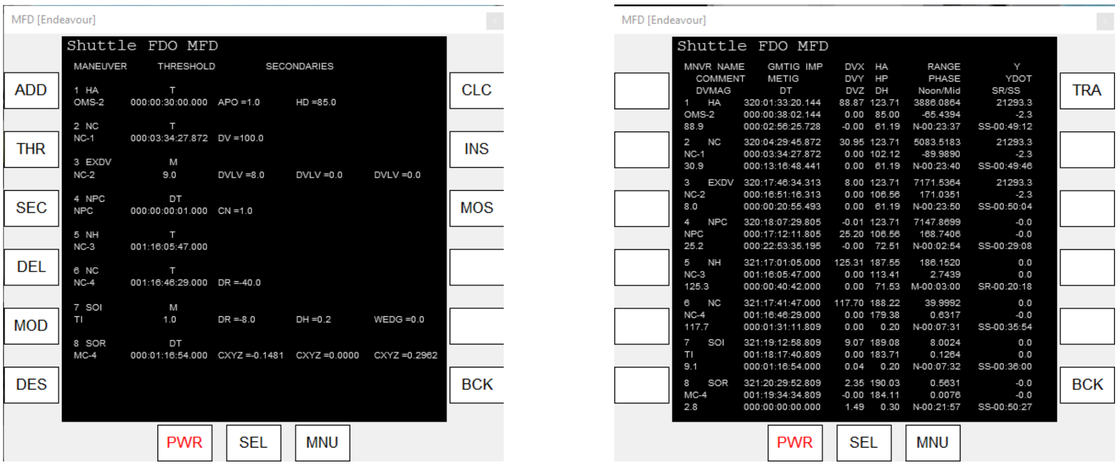


Figure 9: Final state before OMS-2

4.1.2 Executing OMS-2

OMS-2 targeting is not directly covered by the Orbital Maneuver Processor, but it needs to achieve the same perigee altitude that was used in planning the rendezvous profile. For STS-126 this was 85 NM. The FDO MFD currently doesn't export PEG-4 targets, so OMS-2 targeting can be done by trial and error for the PEG-4 targets, or by using a FDO MFD provided PEG-7 burn. As an example for executing a burn we will use PEG-7.

When you are happy with the general rendezvous plan, press the TRA button the evaluation page. This transfers the maneuvers in the plan to the next page. Now go to the Maneuver Transfer Table. This table will now be populated by the maneuvers from the plan. We only care about the OMS-2 burn here, because we don't need to plan the later burns in all detail yet. On this page we need to select a burn profile for OMS-2. The maneuver will be with both OMS engines (OBP option), using PEG-7 guidance (P7), it should have an optimized time of ignition (OPT option) with a roll angle of 180 degrees. All this is covered by slot 2 of the default burn profiles. To use this profile for OMS-2 press SLO and type: 1 2. This will have changed the roll angle of the burn to 180 degress. Nothing else needs to be changed here, so press EXE to export the maneuver data to the next page.

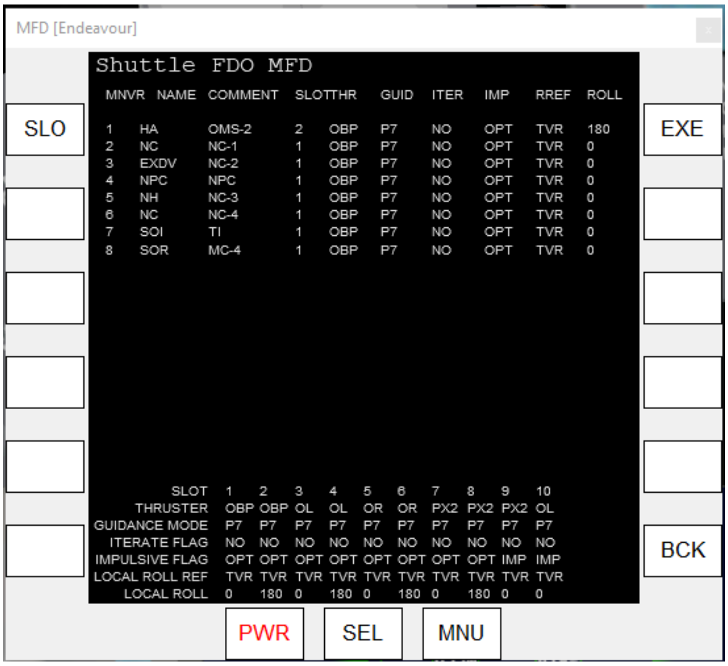


Figure 10: MTT for OMS-2

On the Detailed Maneuver Table you can find all the numbers that would be found on a Maneuver PAD. To get the PAD for OMS-2 press MNV and type 1 to choose the first maneuver in the table. Then press CLC to calculate the PAD. The TIG and PEG 7 DV from this page need to be input to the MNVR EXEC display of the Shuttle computer. Note that the TIG and DV are not identical to the ones on the maneuver evaluation table for the maneuver. On the MTT we calculated a finite burn from the impulsive burn in the OMP, so the TIG was moved to an earlier time to achieve the same trajectory as if the maneuver was impulsive. The DV was kept inertial and thus has now a small, positive DVZ component.The numbers that are used in the actual execution of a burn should always be taken from the DMT, and not the MET, because in case of longer burns they will give much more accurate results.

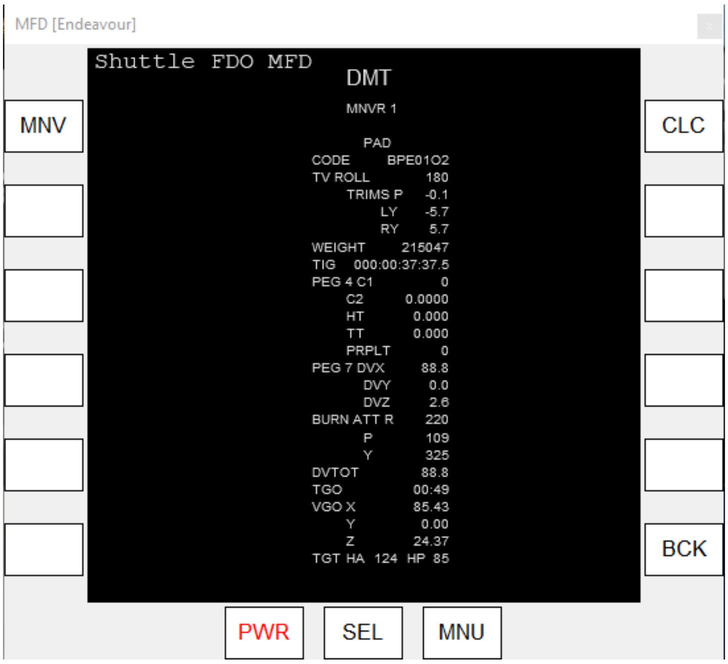


Figure 11: DMT for OMS-2

4.2 Pre NC-1 Planning

After OMS-2 has been executed the maneuver should be deleted from the constraints table. Press DEL and type 1 to delete the 1st maneuver in the list. Then re-save the plan under a new name.