Launch to Intercept Orbiting Target

Parameters: HAB fuel load @ MES = 25000 kg
intercept target's orbital altitude = 315 km
HAB intended orbital altitude = 350 km (so we end up above the target)

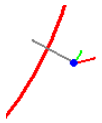
Abreviations: MES = main engine start
MECO = main engine cut-off
SRBI = solid rocket booster ignition
MET = mission elapsed time
Qmax = point of maximum dynamic atmospheric pressure
indicated by top readout in second display box on orbit software

Plan: The spacecraft is vulnerable to re-entry in the case of engine failure until orbital Vtan is reached. Launch to orbit profile is designed to minimize the time taken to reach ref Vo orbital speed. Initial vertical launch takes the spacecraft out of the thick part of the atmosphere as rapidly as possible to minimize fuel use and time to reach orbital speed. Roll to ccw prog orientation is initiated at a point such that when ccw prog orientation is reached, the spacecraft has the necessary vertical velocity to coast up to the desired orbital altitude while the engines are used only to accelerate the spacecraft to the necessary Vtan as rapidly as possible. If the procedure is followed, the spacecraft should reach the desired maximum orbital altitude (Vcen = 0) at the same time as Vtan reached the required value to maintain a circular orbit at that altitude. This minimizes the time taken to circularize the orbit after final MECO. With the correct angular separation from the target at liftoff, the spacecraft should reach the top of its orbit and complete circularization just as the target pulls along side.

Procedure

Start ORBIT5tm.exe
Press "x"
Press "r" to load "OCESS".

MET	Conditions	Actions
-0:30:00		Pilot: cen=HAB; (press "tab" to get to "center" then press "L") targ=earth; (press "tab" to get to "target" then press "3") ref=earth; (press "tab" to get to "target" then press "3") NAVmode=deprt ref ("F5") press "t" and <space> to lock view center targ = ISS (press "tab" to get to "target" then press "s")
-0:10:00		Use "{" or "}" to offload or load fuel to get a fuel load of 26000 kg Press the same key ("{" or "}") to stop the process.
-0:01:50	θHRT = 20°	press "Z" & select "launch1" (to redraw track, press "z")
-0:00:30		Pilot: throttle to 70% (press "PgDn" until at 70%)
-0:00:20		confirm engine acceleration >10.00 m/s^2
-0:00:02	θHRT = 12.92°	press "w" for SRB ignition
0:00:00	θHRT = 12.76°	confirm acceleration > 53.9 m/s^2 (accel increases at constant engine setting as fuel mass drops)
0:00:02		Pilot: sets NAVmode = MAN (press F1) targ = Earth (tab to "target" and press "3")
0:00:17	Qmax Vcen > 480 m/s	Pilot increases throttle to 90% ("PgDn" until at 90%) confirm accel > 56.9 m/s^2
0:00:31	alt = 13.00 km Vcen > 740 m/s	Pilot initiates 2°/s ccw roll (press "Home" 4 times)

0:1:17	oriented ccw prog Vcen > 1640 m/s Vtan > 1520 m/s alt > 70.00 km apoapsis > 215 km	When the green arrow is parallel to the earth's surface and perpendicular to the grey vector (θ Pch = 90°), stop the roll maneuver by going to ccw prog Press F2 
0:01:32	alt = 100.00 km Vcen > 1550 m/s Vtan > 2550 m/s	Confirm atmospheric drag < 0.001 m/s^2
0:02:01	alt = 140.00 km Vcen > 1300 m/s Vtan > 4000 m/s apoapsis > 280 km	Confirm SRB shutdown confirm accel > 13.1 m/s^2
0:06:06	apoapsis = 348 km alt > 320 km Vcen = 280 m/s Vtan > 7200 m/s	MECO (critical that this happens at apoapsis = 348 km) Vcen will reach zero at the top of the orbit (apoapsis). Since it is important that Vtan equal ref Vo at the top of the orbit, the engines must be fired to accelerate the spacecraft so Vtan = ref Vo starting just before the top of the orbit, when Vcen is approx. 40 m/s
0:09:10	Vcen = 40 m/s Vtan > 7150 m/s alt = 348 km	Main engines to 100% thrust Monitor Vtan
0:09:51	Vtan = ref Vo Vcen = 0 m/s alt = 350 km	MECO Evaluate Vcen and Vtan
0:10:15		If Vcen and Vtan have large variances from target values: 1) correct Vtan using main engines at small throttle settings 2) set NAV mode to deprt ref and adjust Vcen to zero 3) set NAV mode to ccw prog and reset Vtan to ref Vo If Vcen and Vtan variances are small: 1) use RCS thrusters to correct each velocity
0:11:15		Confirm orbit cicularization at near 350 km (± 20 km)
0:12:00		Confirm distance, direction, and relative speed for target 1) Set targ = desired target 2) Note direction vector to target 3) Note Vcen, Vtan, velocity vector to target 4) Note distance to target
0:12:30		Plan approach to dock with target.

Extension Activity: can orbit be attained after loss of an engine?

Repeat the process and simulate a loss of engine by reducing engine percent to 67% between T=0:02:00 and T=0:06:00.

1) Can you attain orbit with a loss of an engine at any point between 2 and 6 minutes after launch?

a) can stable orbit be attained with 1 engine malfunction or two engine malfunctions?

b) which is more of a problem, an early or late malfunction?

c) what are the options if attaining orbit is not possible?

i) hold a nose up attitude to maintain climb rate - what will this do to total fuel used?

ii) dump fuel - what effect might this have on the mission?

- what might you have to do before departing from orbit?

2) If orbit cannot be achieved, an abort must be made.

What should you do before attempting a landing?