Sep1sim with RWA and Jets

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Sep1sim.mdl is a Simulink program that simulates the motion of a LEO satellite deployed from a slowly rotating upper stage. The upperstage with the attached satellite is accelerated by a 100 lbf booster for 400 seconds prior to staging. The satellite then separates from the upper stage shortly after the orbit change with a short push by loaded springs between the upper stage and the satellite. The satellite then deploys its two solar arrays and uses its jet ACS to stabilize the vehicle and control its attitude to the LVLH orientation. It eventually switches to the RWA ACS for the attitude control for the rest of the simulation.

The topics covered in the following are:

1. Sep1sim Simulink Program
2. Sep1sim Simulation Result
3. Sep1sim Model Data

The model configuration of Sep1sim is:

```
b1(B)+-b2(A)
     |
     +-b3(A)
     |
     +-w[1:4]
     |
     +-xf[1:9]
     |
     +-cn[1,2]
```

where b1 = upperstage+satellite initially => satellite only after staging (B= 3dof rotational motion)
b2,b3 = array1 & array2 (A= 1 relative rotational dof)
w = wheels
xf(1:6) = ACS jet (0/1) signals
xf(7:8) = pushoff spring (0/1) signals
xf(9) = 100 lbf booster (0/1) signal
cn= constraint switches (0/1 signals)

1. Sep1sim Simulink Program

The Sep1sim Simulink Program is Sep1sim.mdl as shown in the figure 1. Its six processors are:

1)	xsim1_150715.dll	simulation engine
2)	ACS Subsystem	ACS subsystem
3)	acs_rwa.m	RWA ACS
4)	acs_jet.m	Jet ACS
5)	hinge_lock.m	controls locking of solar arrays 1:2
6)	booster.m	controls the firing of booster

The signal flow of these processors and their functionality are summarized in the next table.

processor	input	output	function
xsim1	- model file=cmg4sim.txt - wtq 1:3 = RWA torque - xf 1:6 = jet on/off - xf 7:8 = sat pushoff swc - xf9 = booster on/off - use1dt= fuel burn rate - stg1= staging on/off	- plot file=z.1 - ang 2:3 angles - rpy = attd error - use1= frac fuel use - use1dt= fuel burn rate - xf9 = booster status	- reads model file to setup the eom config., and integrates the eom - sends plot data to z.1 file - actuates rwa 1:3 and jets 1:6 - staging - unlock/lock sat arrays 1:2 * per input signals
acs_subsystem	- see acs_rwa.m - see acs_jet.m - see hinge-locks.m	- see acs_rwa.m - see acs_jet.m - see hinge-locks.m	- executes : acs_rwa.m, acs_jet.m hinge_locks.m
acs_rws	- ena= enable switch - w1= b1 ang rate - rpy= attd error	- wtq 1:4 = RWA torque	- issues RWA torque to null LVLH attitude errors
acs_jet	- ena= enable switch - 1 Hz pulse train - clock for t - w1= b1 ang rate - rpy= attd error	- xf 1:6= jet on/off signals	- issues jet on/off signals to null LVLH attitude errors
hinge_locks	- ang 2:3= array angles 2:3	- cn 1:2= lock constraint signals to array 1 and 2	- locks array joints after t=1050 sec if ang 2:3=0
booster	- on-time=[500:900] sec - use1= fraction fuel used - use1dt= fuel burn rate - xf9= current jet 9 status	-xf= booster on/off signal -use1dt=current fuel burn rate	- monitors the system angular momentum based on input

Table 1 Signal Flow and Functionality of Sep1sim.mdl Processors

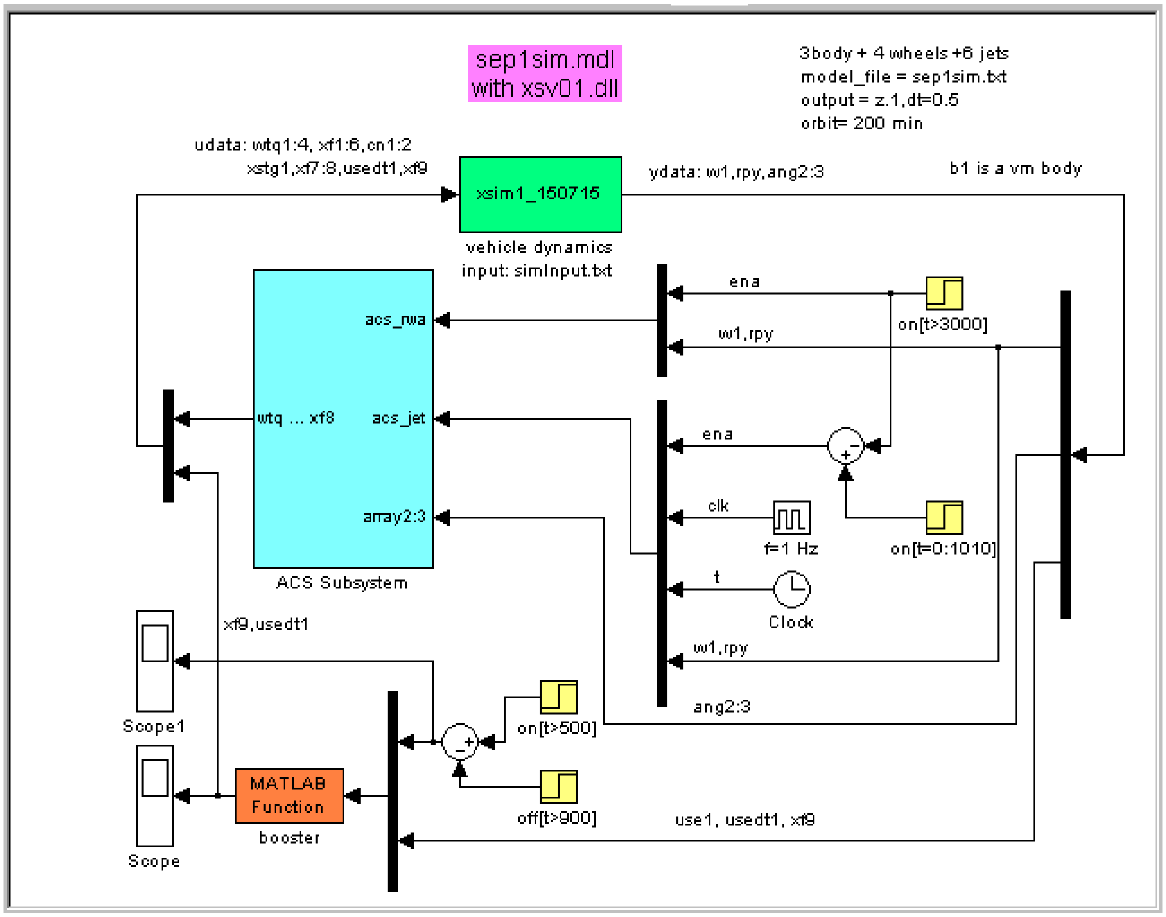


Figure 1 Sep1sim Simulink Program: Sep1sim.mdl

The next chart shows the expanded ACS Subsystem.

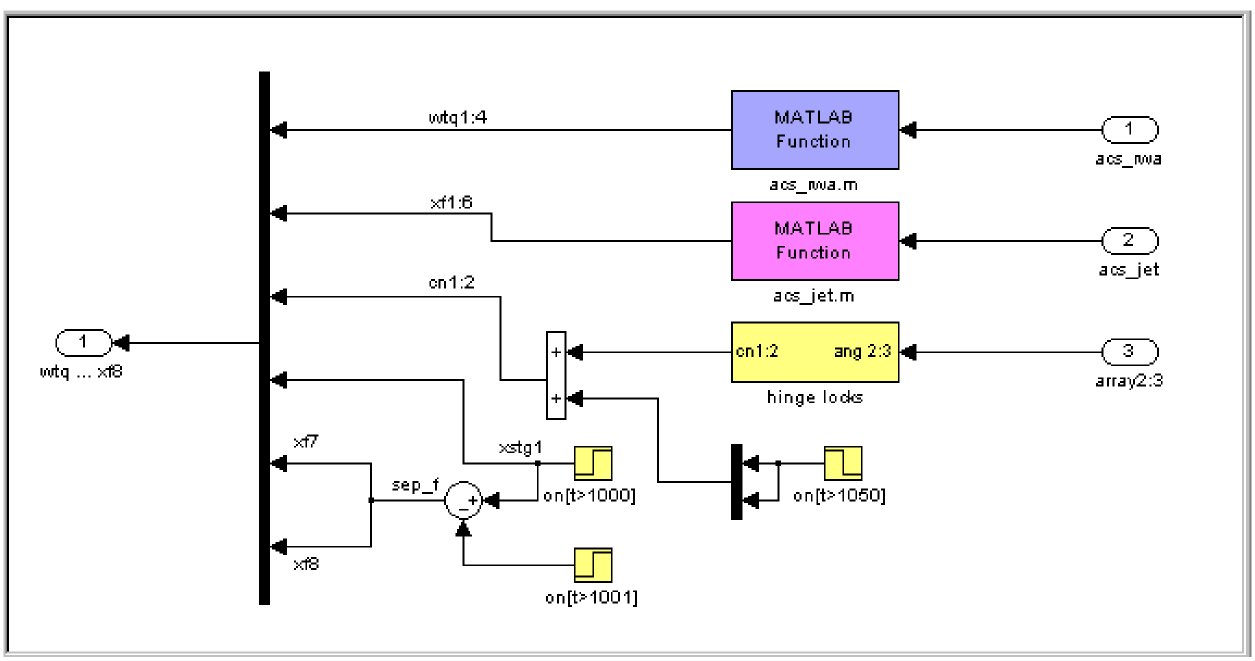
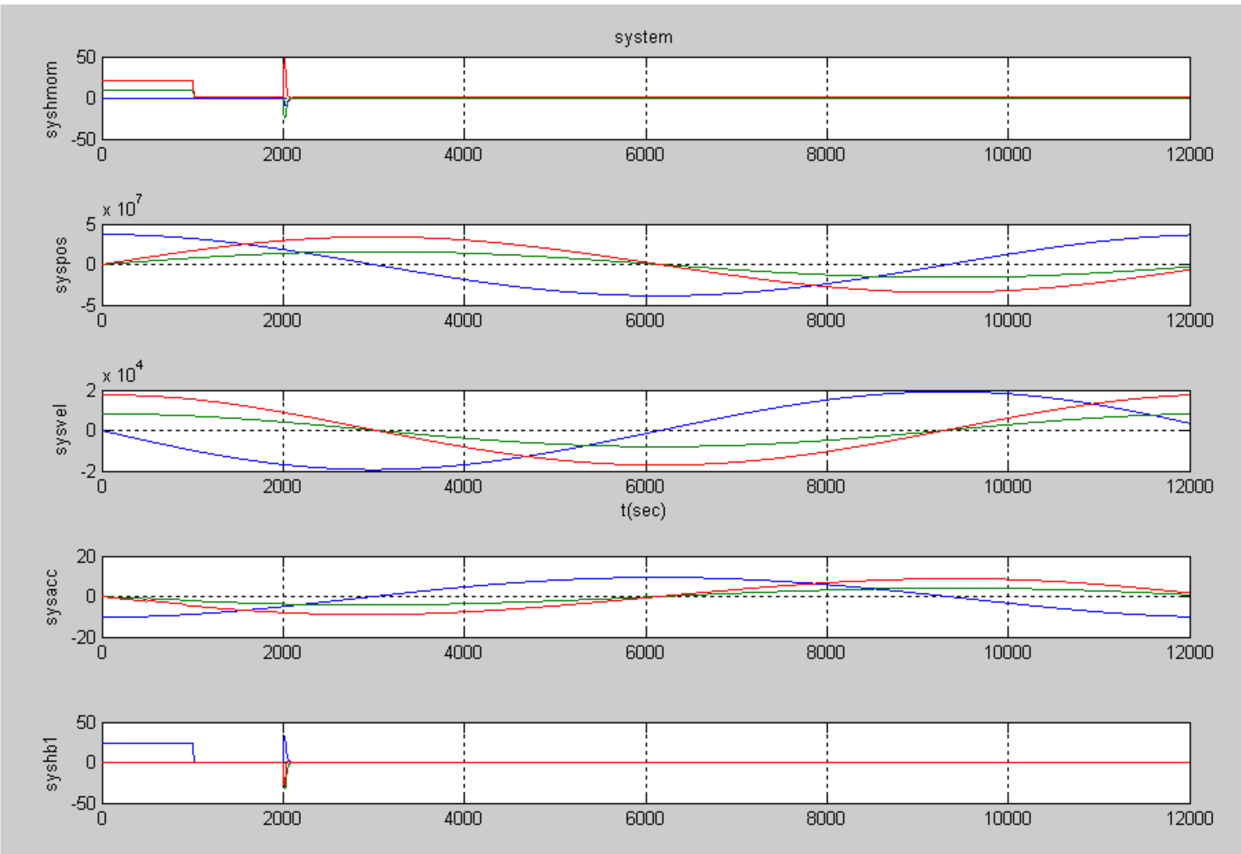


Figure 2 The ACS Subsystem

2. Sep1sim Simulation Result

Simulation scenario summary:
Orbit: near circular, 65 deg inclined, 200 minute period.
Total time simulated is 12,000 sec (200 min) = 1 orbit.
B1(upper stage+satellite) rotates at .5 d/s at t=0
Booster fires over t=[500:900] sec.: b1 mass property changes due to fuel depletion: see xf 9, use1
Satellite separates (xstg=1) at t=1000 sec: b1 becomes satellite only
A 1sec 5 lbf pulse pushes the satellite in the body x-axis direction: see xf 7:8
ACS by 6 jets for t =[1010:3000] sec: see xf 1:6
ACS by 4 RWA's for t > 3000 sec: see wtq 1:4

Observations from the following charts: The system angular momentum, syshmom, is constant for b1 (upperstage+satellite) until satellite ejection at t=1000 sec (no cg offset for booster firing). B1 becomes satellite after t=1000. Syshmom is reduced to near zero by the jet ACS over t=[1010:3000] and remained so t > 3000 sec even after transition to RWA ACS. The jet control showed an unexpected singularity at t=2000 and recovered shortly. The syspos shows one orbit of system *cm* motion.

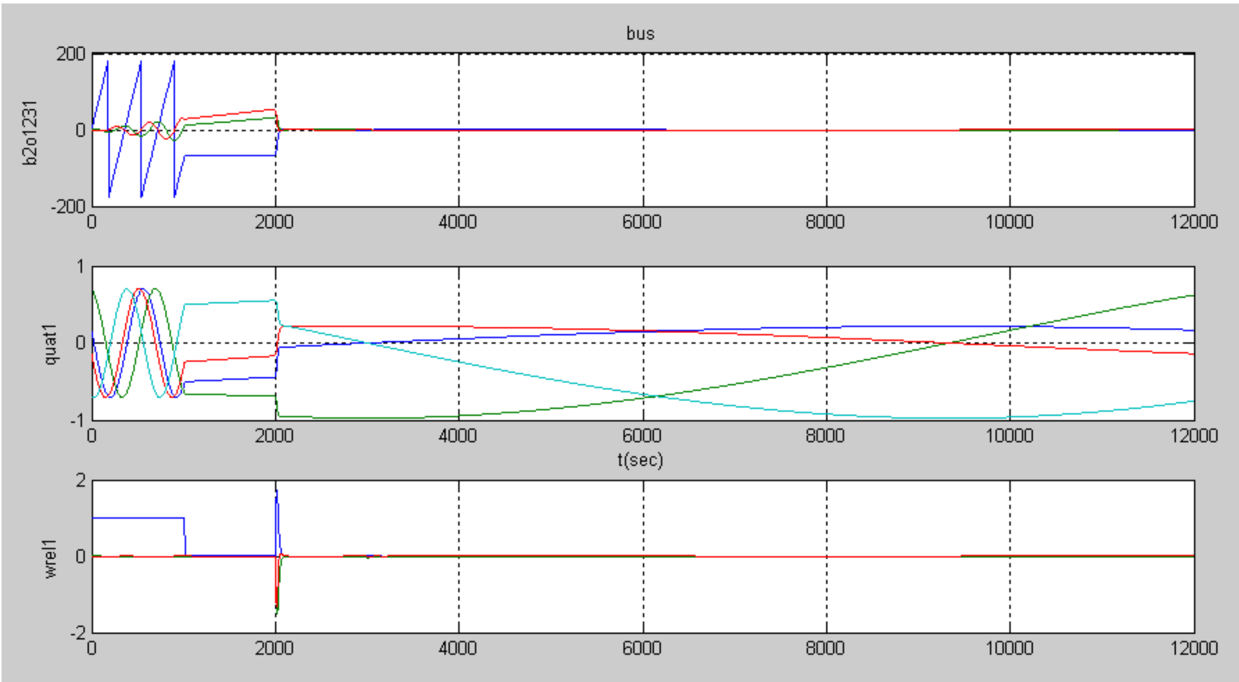


System Data

syshmom = system angular momentum in inertial coordinates
syshb1 = syshmom in b1 coordinates
syspos = system cm inertial position

sysvel   = system cm inertial velocity
b2o1231= bus attitude roll, pitch (green), yaw

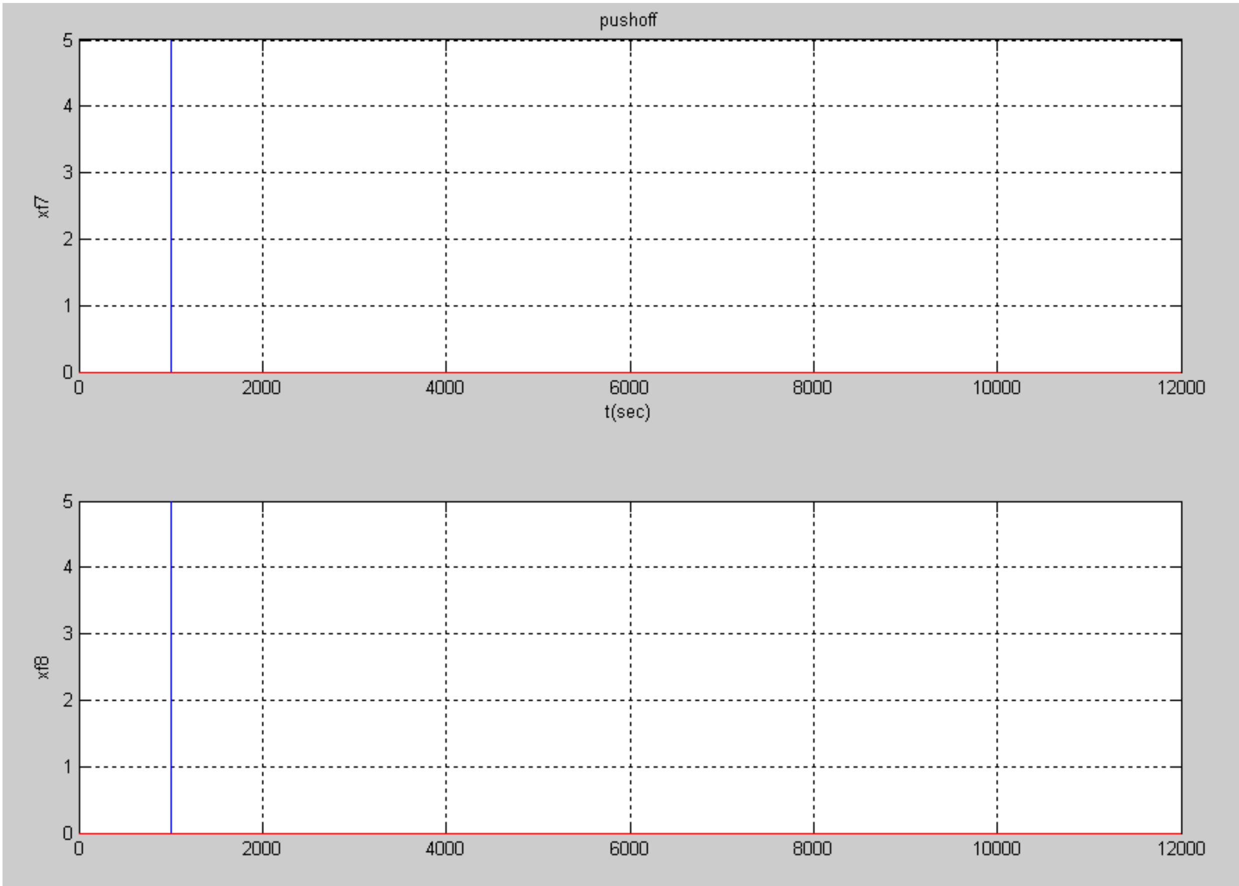
The three signals below show that the upperstage+satellite rotated at 1 d/s until separation at t=1000. Attitude is controlled to LVLH attitude at around t=2000 per jet ACS (see b2o1231). The LVLH attitude error stayed near zero thereafter.



B1 Attitude and Angular Rate

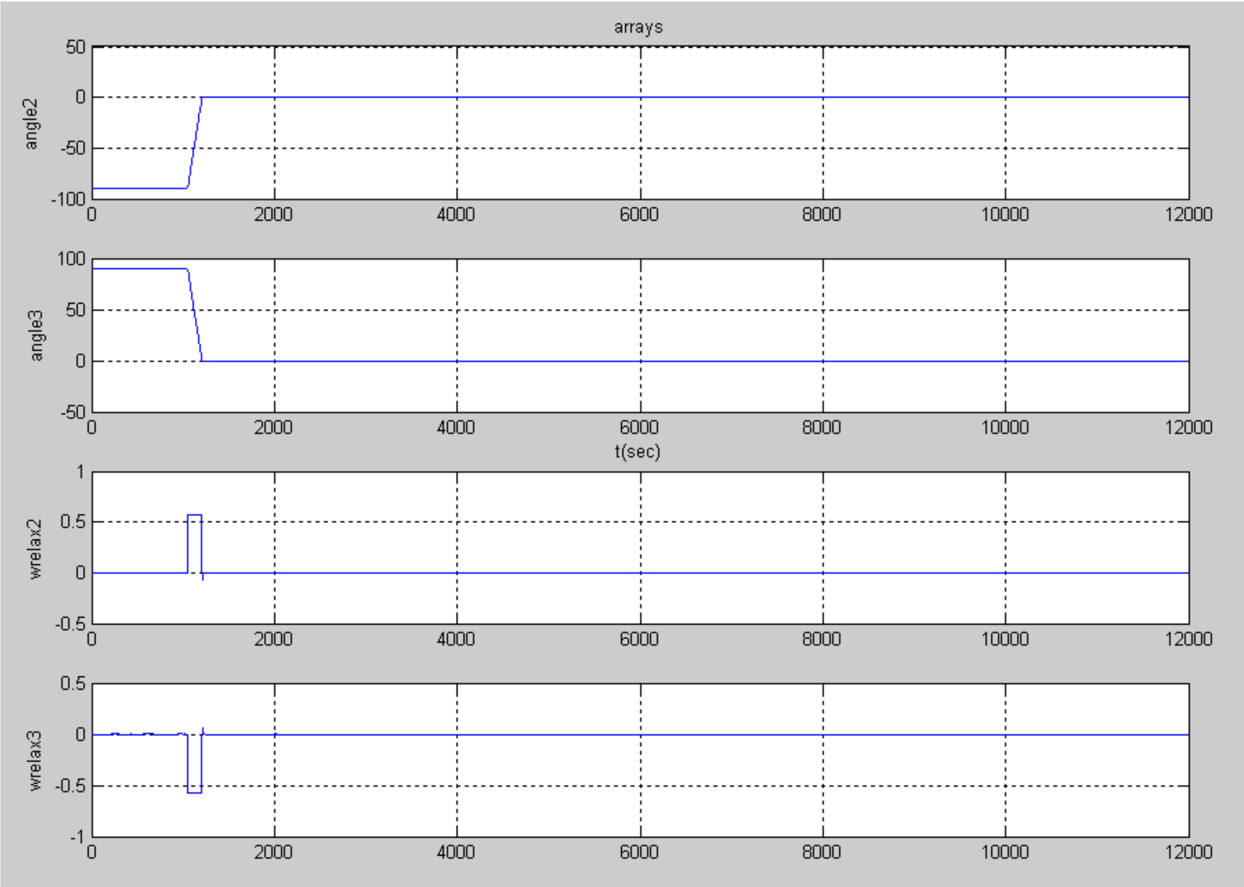
b2o1231= bus attitude roll, pitch (green), yaw
quat1= b1 inertial attitude quaternion
wrel1= angular rate vector

The xf7:8 signal (plot data) shows that the satellite was pushed off with two 5lbf forces at t=1000 sec.



5 Lbs Pushoff Force and Upperstage/Satellite Separation Signal

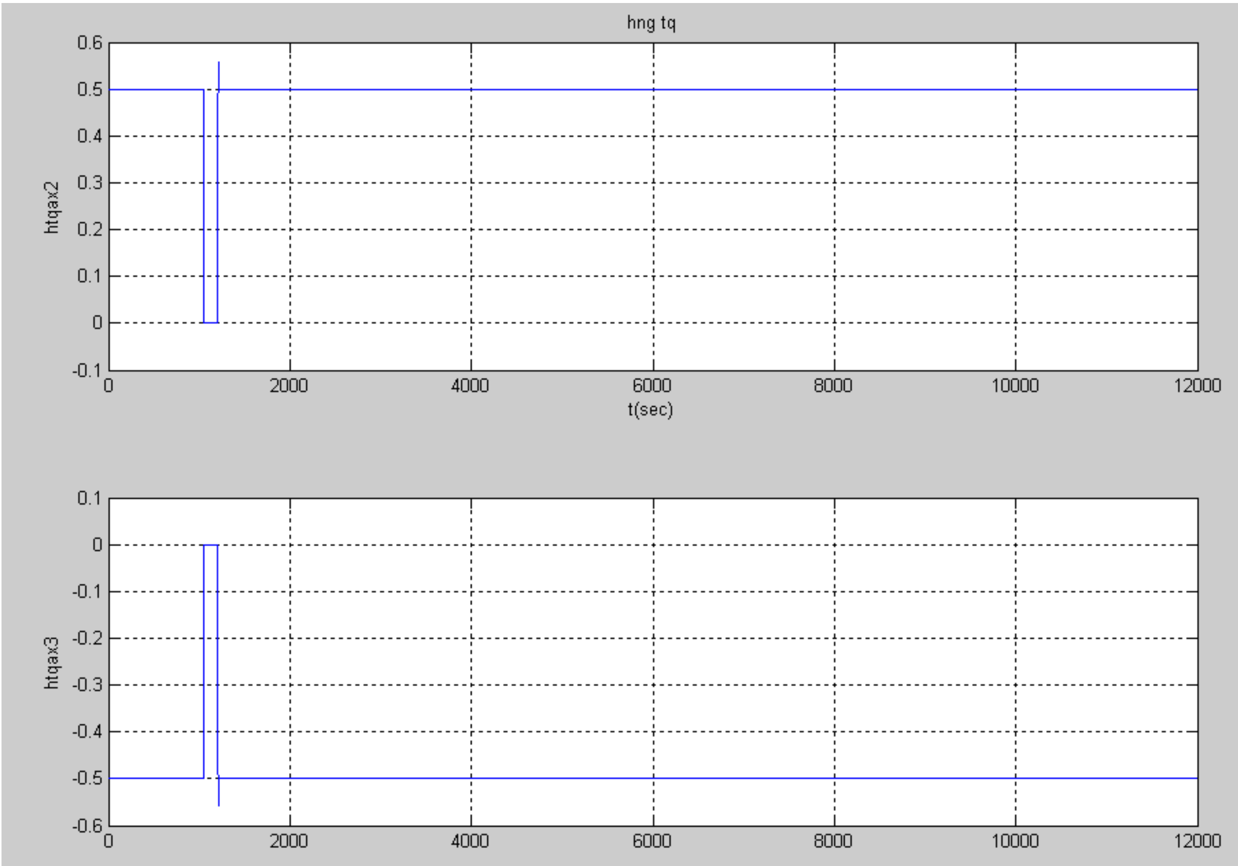
Angle2 and angle3 are at -90 and +90 degree stowed position till t=1000 when the satellite separation occurred. From then on the .5 lbf preload and a heavy rate damping at joint 2 and joint 3 causes the two arrays to deploy towards 0 degree. Once the deployment is complete, the 'lock' constraint at these array joint are enabled by the cn 1 and 2 to keep angle 2 and 3 at zero.



Array Angles and Rates

angle2=array1 panel angle (deg)
angle3=array2 panel angle (deg)
wrel2 = array1 panel rate (d/s)
wrel3 = array2 panel rate (d/s)

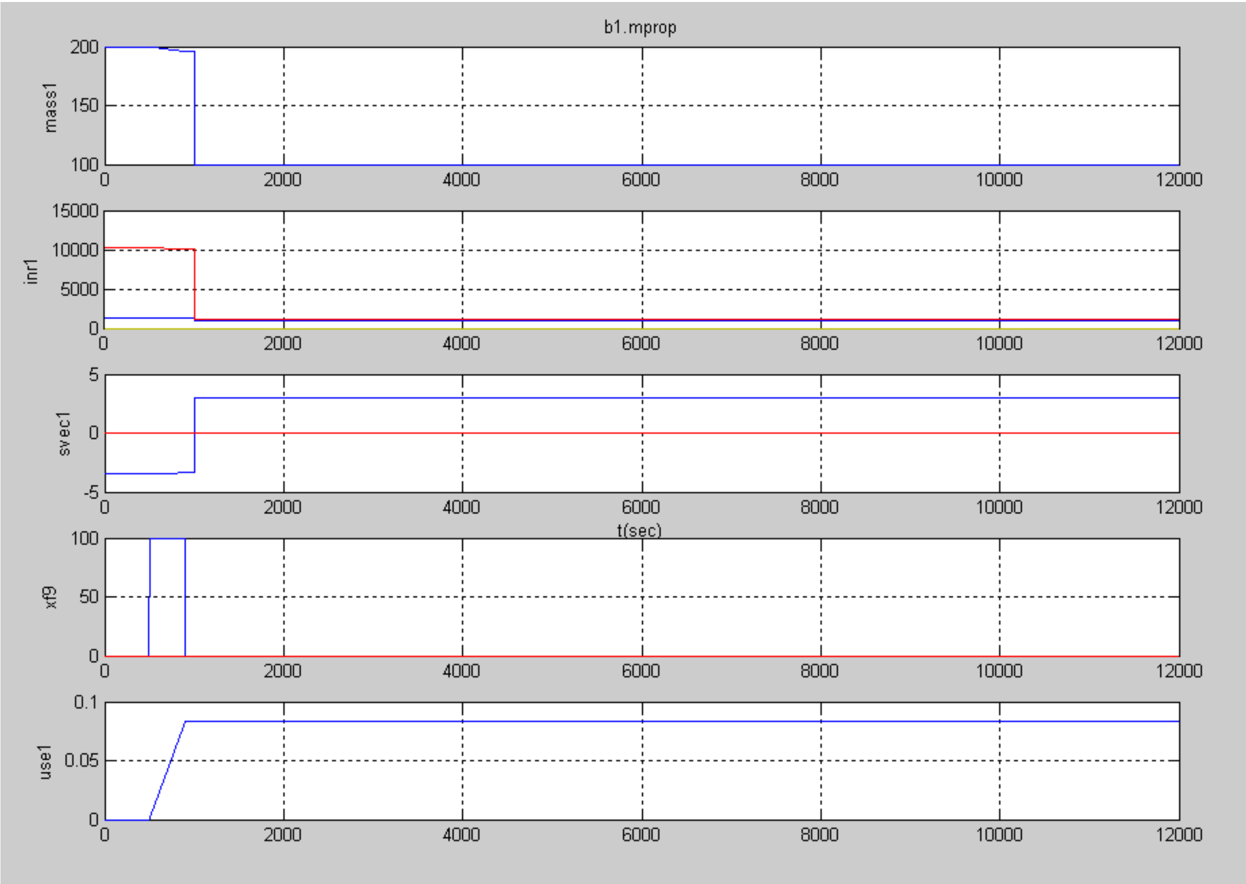
The array 1 and 2 hinge torque are initially at 0.5 ft-lbf to counter the preload to keep the array at the stowed position until t=1000 sec. During the deployment phase no active servo torque is applied. A constraint torque of 0.5 ft-lbf to keep the array angles at zero after the zero angle has been achieved.



Array hinge torque 2:3

htqax2=array1 hinge torque
htqax3=array2 hinge torque

The 100 lbf booster pushed the upperstage+satellite over t=[500:900] sec. Mass1, inr1 and svec1 are the mass property changes that occurred during that time.



B1 Mass Property

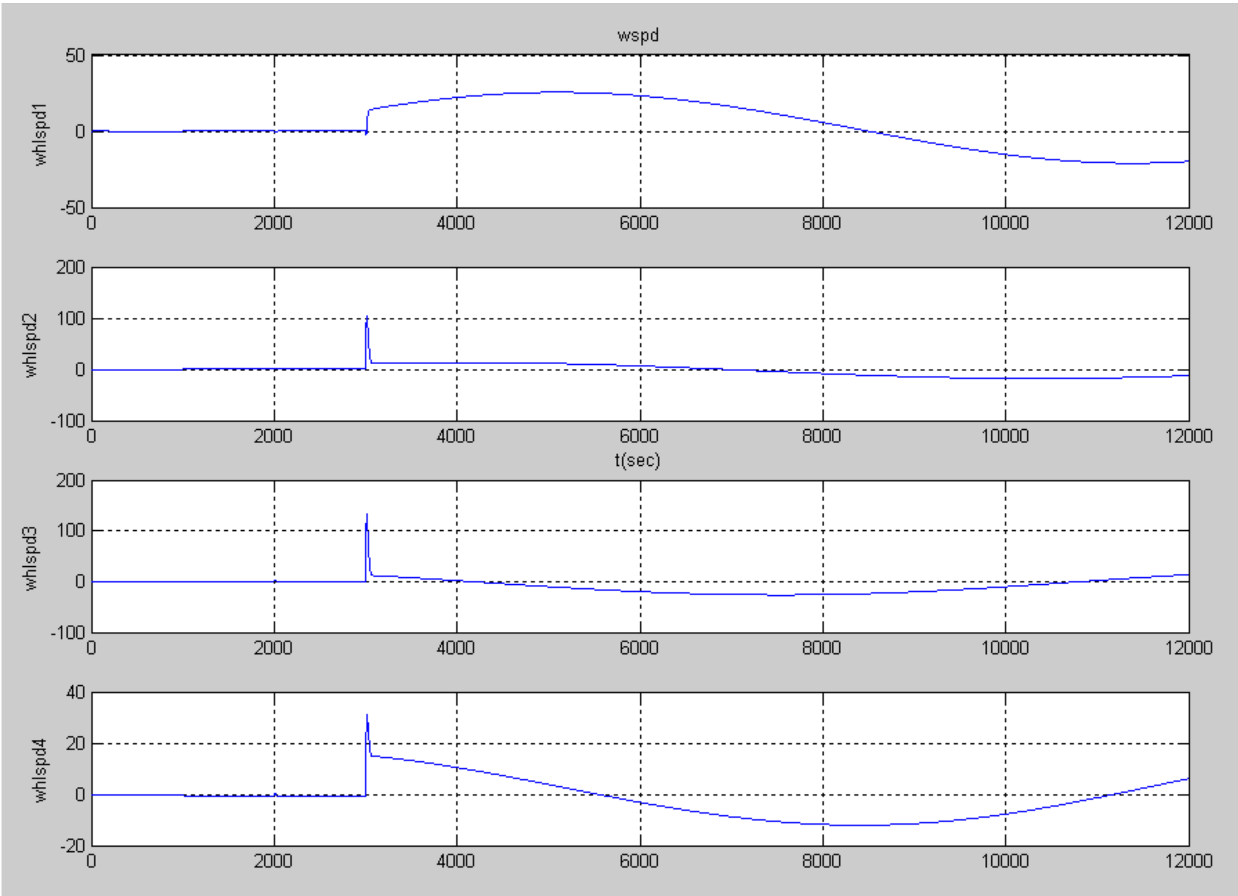
for t < 1000

mass1	= mass of upperstage+satellite
inr1	= moment of inertial of upperstage+satellite
svec1	= svec of upperstage+satellite
xf9(plot)	= 100 lbf booster force
use1	= fraction of fuel spent

for t > 1000

mass1	= mass of satellite
inr1	= moment of inertia of satellite
svec1	= svec of satellite
xf9	= na
use1	= na

Wheel speeds are near zero before the RWA ACS was actuated at t=3000 sec to keep vehicle orientation near LVLH attitude. The wheel activation occurs way past the satellite separation and array deployment times.



Wheel Speed

whlspd1= wheel1 speed (rpm)
whlspd2= wheel2 speed (rpm)
whlspd3= wheel3 speed (rpm)
whlspd4= wheel4 speed (rpm)

3. Sep1sim Model Data

The model file for this program defines the construction and the computation of the equations of motion underlying Sep1sim.mdl. It includes the mass property of the vehicle, the connectivity and dof's of bodies in the vehicle model. It defines the orbit this vehicle flies in. It sets the initial attitude and rate condition of the simulation. It defines the input/output signals of XSIM1.dll as well as the plot data sent to z.1 during run time.

The model data in Sep1sim.txt are divided into the following groups of information.

A. Configuration of the model
B. Mass property of the model
C. Variable mass model specification
D. Joint torque/force specifications
E. Ephemeris of the orbit
F. Reaction wheel elements
G. Force elements
H. Constraint Signals
I. Simulation engine input
J. Simulation engine output
K. Simulation plot data

The memo will show what the above data are for Sep1sim and how they can be modified through the Buildx.exe program.

A. Model Configuration

The Sep1sim has the model configuration

```
b1(B)+-b2(A)
      |
      +-b3(A)
      |
      +-w[1:4]
      |
      +-xf[1:9]
      |
      +-cn[1,2]
```

Here	b1	= upperstage+satellite initially => satellite only after staging (B= 3dof rotational motion)
	b2,b3	= array1 & array2 (A= 1 relative rotational dof)
	w	= wheels
	xf(1:6)	= ACS jet (0/1) signals
	xf(7:8)	= pushoff spring (0/1) signals
	xf(9)	= 100 lbf booster (0/1) signal
	cn= constraint switches (0/1 signals)	

This configuration is defined by the parent indices of the model objects.

B. Mass Property

The mass column of next figure shows the mass of b1:b3 taken from the ‘body’ submenus of Buildx.exe. The axis of motion, ‘ax’, for the array panels are along the ‘z’. The ‘pa’ of b2 and b3 are set to 1 because b1 is their parent body. The motion type ‘tp’ of b2 and b3 is set to ‘A’ meaning that they each have a 1 dof of rotation and torque at the xsim input is expected to move them. The bus has ‘tp’ set to B meaning it has a 3 dof rotation w.r.t. the inertial reference frame.

	idx	name	pa	u	fl	vm	tp	ax	-- angle -	-- del_x -	----mass----
=>	1	b1	0	FPS	0	*	B	x	.000	.000	.200000E+03
	2	arrayS	1	FPS	0	-	A	z	-90.000	.000	.100000E+01
	3	arrayN	1	FPS	0	-	A	z	90.000	.000	.100000E+01

Figure 3. Body Data from Body Menu

The next table displays the moment of inertia of b1:b3 in the order of ixx,iyy,izz,ixy,ixz and iyz.

	idx	name	- ixx - / ---- ixy ---	- iyy - / ---- ixz ---	- izz - / ---- iyz ---
=>	1	b1	.130000E+04	.102500E+05	.102500E+05
			.000000E+00	.000000E+00	.000000E+00
	2	arrayS	.100000E+01	.100000E+01	.100000E+01
			.000000E+00	.000000E+00	.000000E+00
	3	arrayN	.100000E+01	.100000E+01	.100000E+01
			.000000E+00	.000000E+00	.000000E+00

Figure 4. MOI Data from Moment of Inertia Menu

The next two are the svec and dvec definitions for b1:b3. The svec’s are the positions of the body cm wrt to the inboard hinge in the local body coordinates.

	idx	name	u	------------	----svec----	------------
=>	1	b1	FPS	-.350000E+01	.000000E+00	.000000E+00
	2	arrayS	FPS	.000000E+00	.300000E+01	.000000E+00
	3	arrayN	FPS	.000000E+00	-.300000E+01	.000000E+00

Figure 5. Svec Data from Svec Menu

The dvec’s are the joint position wrt to the inboard joint of the parent body in the parent body coordinates.

idx	name	u	------------	----dvec----	------------
1	b1	FPS	.000000E+00	.000000E+00	.000000E+00
2	arrayS	FPS	.000000E+00	.300000E+01	.000000E+00
3	arrayN	FPS	.000000E+00	-.300000E+01	.000000E+00

Figure 6. Dvec Data from Dvec Menu

The values of the body mass property can be changed using the instructions below.

Edit Mass Property

1. Start Buildx.exe and see Main Menu as in Figure 5.

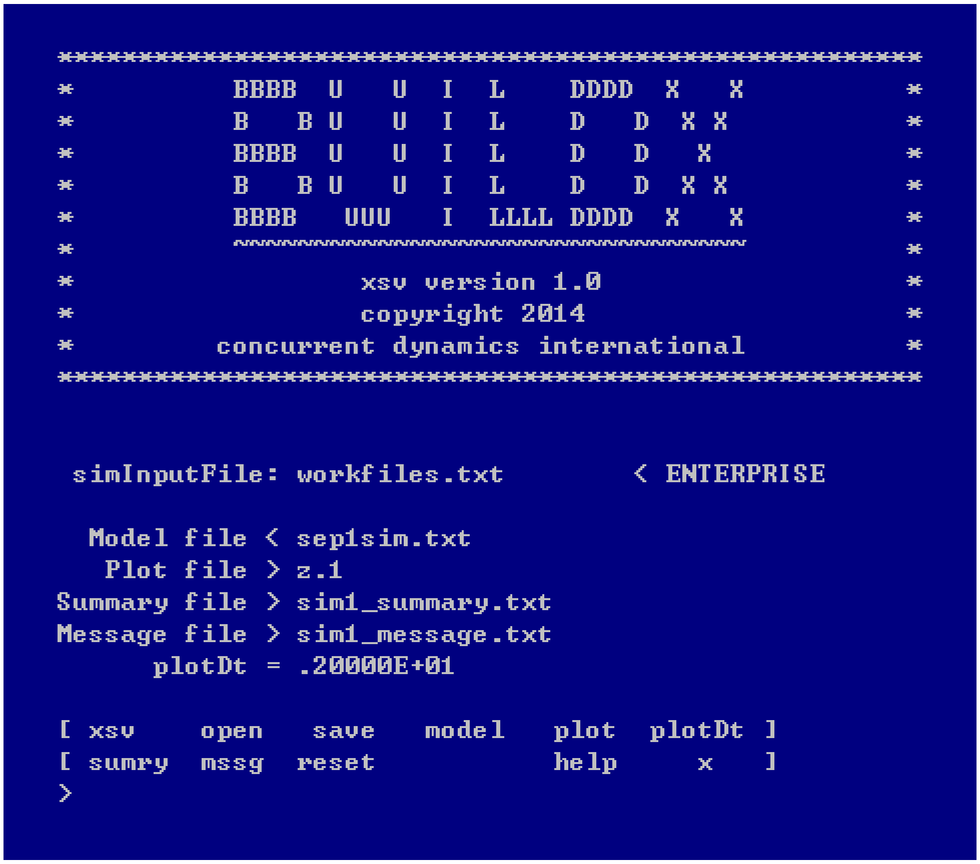


Figure 7. Main Menu

Note that the model file is Sep1sim.txt and the plot data are sent to the plot file, z.1.

2. Choose ‘xsv’ command at the Main Menu prompt to open Model_Menu page as shown in Figure 8.

3. Select ‘body’ command from Model Menu page (Fig. 3) to open Body_Menu. See Figure 1
   -use ‘mass’ command to edit mass of the bodies: follow the prompts

4. Select ‘inr’ command from Body_Menu to open MOI_Menu. See figure 4.
   -use ‘inr’ command to edit moment of inertia of bodies: follow the prompts

5. Select ‘svec’ command from Body_Menu to open SVEC_Menu. See figure 5.
   -use ‘svec’ command to edit svec of bodies: follow the prompts

6. Select ‘dvec’ command from Body_Menu to open DVEC_Menu. See figure 6.
   -use ‘dvec’ command to edit dvec of bodies: follow the prompts

Select the ‘x’ command to exit the current menu. Select the ‘save’ command from the Model Menus page to save the current model data. Always follow the prompted instructions.

```
                       ~ Model Menus ~
System Graph:

b1(B)+-b2(A)
     |
     +-b3(A)
     |
     +-w[1,2,3,4]

total bodies:        7     ; reg. bodies& wheels:   3,  4
ext. forces,torque:  9,  0 ; pos.& dir markers:     0,  0
system units:      FPS     ; constraints:           2
sflag,gflag:         1, 10 ; input (param,size):   17, 17
dscrt,odes:          0,  0 ; output(parmm,size):    7, 11
accels,gyros:        0,  0 ; plot  (parmm,size):   29, 60
vmass,pmass:         1,  0 ; swiches,states:        0, 22
```

Figure 8. Model Menus

C. Joint Variable Mass Specification

The ‘Variable Mass’ Menu is a way to model bodies with changing mass properties in mass, moi and cm position as a function of fuel depletions due to jet firing. The index under the ‘vm’ is the variable mass body, value 50 slugs under ‘fuel’ is the total fuel mass that changes according to the burn rate ‘use1dt’ that’s input to the xsim1.dll. The value under ‘ff’ is the fraction of the fuel that has been consumed.

The following definitions apply for terms in this menu:

b1.mass0	satellite mass only
b1.mass	effective booster+fuel+satellite mass given ff
b1.svec	effective booster+fuel+satellite *cm* position in b1 frame given ff
b1.inr	effective booster+fuel+satellite *inertia* in b1 coordinates given ff
b1.w	booster+fuel+satellite angular rate in b1 coordinates
b1.hvec	booster+fuel+satellite angular momentum in b1 coordinates
vm.dvec	variable mass nominal position in b1 frame
vm.svec	variable mass interpolated (i.e. per ff) cm position relative to vm.dvec
vm.inr	variable mass interpolated (i.e. per ff) inertia about vm.svec
fuel	variable fuel mass
ff	fraction of fuel consumed
act.mass	act.mass= tot.mass-fuel*ff
total.mass	booster+fuel
n	number of interpolation points in calculating effective mass, inertia and svec of a vmass

```
                     ~ Variable Mass Menu ~
  vm.bodies      :  1
  vm.total_mass :   100.000
  vm.actual_mass:   100.000
  stages         :  1

  b1.mass0=   100.000
  b1.mass>=   200.000
  b1.svec>=    -3.500        .000        .000
  b1.inr> =  1300.000  10250.000  10250.000
                 .000        .000        .000

  b1.w    =     1.000        .000        .000
  b1.hvec =    23.038        .000        .000

  vm   name      tp  loc  n    tot.mass       fuel     ff>     act.mass
=> 1 Mship        1   22  2     100.000     50.000   .0000     100.000
```

Figure 9 Variable Mass Menu Excerpt for Sep1sim

Edit VMASS Parameters

Select the ‘vmass’ command from Model Menus page to open the Variable Mass Menu. See Figure 9.

change tot.mass of a vmass:

- use ‘mass<j>’ command to change the tot.mass of the j-th variable mass: follow prompt instructions change fuel mass:

- use ‘fuel<j>’ command to change the fuel portion of the j-th variable mass: follow prompt instructions

change fraction of fuel consumed:

- use ‘ff>’ command to change the fuel consumend fraction of the j-th vmass: follow prompt instructions

change number interpolation points used for calculating vm.mass, vm.svec and vm.inr:

- use ‘n’ command: supply a value between 1 to 5

change post staging mass property command:

- use ‘stage<j>’ command to change post-staging of vmass(*j*): follow prompt instructions

change nominal position of vmass(*j*) in local frame command:

- use ‘dvec<j>’: follow prompt instructions

change svec-interpolation data command:

- use ‘svec<j>’ cmd: follow prompt instructions

change inr-interpolation data command:

- use ‘inr<j>’ cmd: follow prompt instructions

Select the ‘x’ command to exit the menu. Select the ‘save’ command from the Model Menus page to save the current model data. Always follow the prompted instructions.

D. Joint Actuation Specification

The ‘jnt’ Menu is a way to model the force/torque signals to all single axis joints without having to program that signals outside the xsim1.dll engine. Figure 10 shows the ‘jnt’ Menu except display for Sep1sim shows the ‘jnt’ specifications for all 3 bodies. The values under the ‘tp’ column indicate the type of the joints, values under the ‘ax’ column are the free axis of the joints, the value of [0 0 0] under the ‘mode’ column means that the corresponding joint is not actuated by the ‘jnt’ module in xsim1.dll. The mode value of [1 0 0] means that the joint in controlled by angle, and [2 0 0] means that the joint is controlled by rate. The values under ‘kp’ and ‘kv’ are the position gains and rate gains for the joint controller. The values under ‘pLoad’ are the constant force/torque or preload applied to the indicated joints.

	idx	name	tp	ax	mode	----kp----	----kv----	---pLoad--
=>	1	b1	B	x	0 0 0	.0000	.0000	.0000
	2	arrayS	A	z	1 0 0	.0000	50.0000	.5000
	3	arrayN	A	z	1 0 0	.0000	50.0000	-.5000

Figure 10 The JNT Menu Excerpt for Sep1sim

The heavy damping coefficients for b2 and b3 are chosen against the +/-0.5 ft-lb preload is meant to deploy the two arrays at a slow ~.01 r/s rate.

On typing ‘show’ command, one can see the command angles/positions, and the Coulomb friction specified for the joints. The command is angle/position for a joint when its mode-value for is [1 - -]. The same command becomes the angular_rate/displacement_rate command when the mode-value for the joint is [2 - -].

	idx	name	--ang(d)--	----pos---	--j_coul--
=>	1	b1	.0000	.0000	.00000
	2	arrayS	.0000	.0000	.00000
	3	arrayN	.0000	.0000	.00000

Figure 11 The JNT angle/displacement commands and Coulomb friction settings for Sep1sim

Edit JNT Parameters

Select the ‘jnt’ command from Model Menus page to open the Joint Force Menu. See Figure 9.

change mode-value of a joint:

- use ‘mode<j>’ command to change the mode of j-th joint: follow prompt instructions

change joint position gain:

- use ‘kp<j>’ command to change the position gain of j-th joint: follow prompt instructions

change joint rate gain:

- use ‘kv<j>’ command to change the rate gain of j-th joint: follow prompt instructions

change angular position command:

- use ‘ang<j>’ command to change ang-command of j-th joint: follow prompt instructions change displacement command:

- use ‘pos<j>’ command to change pos-command of j-th joint: follow prompt instructions

change preload command:

- use ‘pl<j>’ command to change preload of j-th joint: follow prompt instructions

change Coulomb friction command:

- use ‘coul<j>’ cmd to change Coulomb friction of j-th joint: follow prompt instructions

Select the ‘x’ command to exit the menu. Select the ‘save’ command from the Model Menus page to save the current model data. Always follow the prompted instructions.

E. Ephemeris

The orbit is specified by the ‘grav’ menu in Buildx.exe. The Sep1sim has the following orbit information.

```
                     ~ gravity Menu ~

> units      (U)=  FPS
> syspos        =    37130491.887          27.245          58.427
> sysvel        =           -.034        8232.778       17655.249

> refpos        =    37130491.887          28.697          61.541
> refvel        =           -.034        8232.778       17655.249

  gravity:
> gx gy gz      =  -10.2101349554    -.0000074919    -.0000160664
  mu            =  .140764418E+17

  ephemeris:
> semimajor (U)=    37167659.547
> ecc           =      .001000
> incl     (deg)=   65.000000
> rasc     (deg)=      .000000
> argp     (deg)=      .000000
> t_anom   (deg)=      .000099
  e_anom   (deg)=      .000099
  m_anom   (deg)=      .000099
  m_motion(d/s)=    .03000000

> LST_ang (deg)=  268.291360    ; sun_beta(deg)=    .000
> LST(h:m:s)    = 17:53: 9.9

> period   (min)=        200.000; revs/day=   7.200
> period   (sec)=       12000.000
  range      (U)=    37130491.887
  equ. radius   =    20925646.325; J2=  .108263E-02
  prg.altitude  =    16204845.562; apg.altitude=    16279180.881
  we   (d/s,r/s)=       .00417807        .00007292

> sysacc flag   =  1
> gravity flag = 10
```

Figure 12. Gravity Menu

This orbit specification shows that the Sep1sim is in a 65 deg inclined near circular orbit with a period of 200 minutes. The gravity flag of 10 means that the spherical earth gravity is chosen for the simulation.

The orbit parameters in the gravity menu can be changed using the following instructions.

Edit Ephemeris

Select ‘grav’ command from the Models Menu page to open the Gravity Menu. See Figure 12.

change ephemeris data:

- use ‘semi’ command to change the semi-major axis
- use ‘ecc’ command to change the eccentricity
- and so forth to modify ephemeris data
- note: other variables, i.e. syspos, sysvel, refpos, refvel, are automatically changed with changed ephemeris data

change orbit period:

- use ‘perm’ command to change orbit period in minutes
- use ‘pers’ command to change orbit period in seconds
- note: all other affected ephemeris data are automatically changed

change syspos, sysvel, refpos, refvel:

- use ‘spos’ command to change syspos
- use ‘svel’ command to change sysvel
- use ‘rpos’ command to change refpos
- use ‘rvel’ command to change refvel
- note: all other affected ephemeris data are automatically changed

change gravity model:

- use ‘gflag’ command to select gravity model
    - gflag= 10 means spherical earth gravity (seg)
      11 means seg with gravity gradient (gg)
      12 means seg with gg and gg torque
      20 means oblate earth gravity with J2 effect (gJ2)
      21 means gJ2 with gg
      22 maans gJ2 with gg and gg torque
      30 means oblate earth gravity with J2, J3 and J4 effects
      31 means gJ234 with gg
      32 means gJ234 with gg and gg torque

Select the ‘x’ command to exit the menu. Select the ‘save’ command from this page to save the current model data. Always follow the prompted instructions.

F. Reaction Wheels

The Sep1sim here has 4 wheels for ACS. The wheels attributes are displayed below.

	idx	name	pa	t	----------	---axis---	----------	--winr-	-w(rpm)-
=>	1	whl1	1	A	.5773503	-.5773503	.5773503	.1000	.0
	2	whl2	1	A	.5773503	.5773503	.5773503	.1000	.0
	3	whl3	1	A	-.5773503	.5773503	.5773503	.1000	.0
	4	whl4	1	A	-.5773503	-.5773503	.5773503	.1000	.0

Figure 13 Wheel Data Exerpt from Wheel Menu

This table shows that wheels 1-4 are attached to b1 (pa=1). Their types are all ‘A’ meaning that they require actuation torque from Simulink workspace to the simulation engine xsim1.dll. The axis column shows the spinning axes of the wheels in the attached body coordinates. ‘winr’ is the wheel spinning axis moment of inertia. The ‘rpm’ column are the initial spinning speed of the wheels.

The values of the wheel parameters in the Wheel Menu can be changed using the following instructions.

Edit Reaction Wheel Parameters
Select the ‘whl’ command from Model Menus page to open the Wheel Menu. See Figure 12.

change wheel axis on the attached body:
- use ‘axis’ command to change the wheel axis: follow prompt instructions

change wheel inertia about wheel axis:
- use ‘winr’ command to change the wheel axis inertia: follow prompt instructions

change wheel spin rate:
- use ‘rpm’ command to change the wheel spin rate in rpm: follow prompt instructions

Select the ‘x’ command to exit the menu. Select the ‘save’ command from the Model Menus page to save the current model data. Always follow the prompted instructions.

G. Jet Forces

The Sep1sim here has 6 ACS jets (#1:6), 2 pushoff spring forces(#7:8), and one 100 lbf thruster for the upper stage. Their attributes are displayed in next two tables. All Jets are attached to b1 (p=1). All jets are type 1 (t=1) meaning that the simulation engine xsim1.dll expects on/off (0/1) signals to be in the sim-input channel to turn on and off these jets. 'fmag' is the force magnitude when jets are fired. 'fx,fy,fz' are the force vectors of the jets in the attached body coordinates.

	idx	name	p	t	c	---fmag---	----fx----	----fy----	----fz----
=>	1	f1	1	1	1	1.000	1.000	.000	.000
	2	f2	1	1	1	1.000	1.000	.000	.000
	3	f3	1	1	1	1.000	1.000	.000	.000
	4	f4	1	1	1	1.000	1.000	.000	.000
	5	f5	1	1	1	1.000	.000	-1.000	.000
	6	f6	1	1	1	1.000	.000	-1.000	.000
	7	f7	1	1	1	5.000	5.000	.000	.000
	8	f8	1	1	1	5.000	5.000	.000	.000
	9	f9	1	1	1	100.000	100.000	.000	.000

Figure 14 Jet Force Data from Force Menu

The next table shows the position of the jet thrusters on their attached bodies that is b1 in this case.

	idx	name	p	t	c	---fmag---	---posx---	---posy---	---posz---
=>	1	f1	1	1	1	1.000	.000	-3.000	.000
	2	f2	1	1	1	1.000	.000	3.000	.000
	3	f3	1	1	1	1.000	.000	.000	3.000
	4	f4	1	1	1	1.000	.000	.000	-3.000
	5	f5	1	1	1	1.000	3.000	3.000	3.000
	6	f6	1	1	1	1.000	3.000	3.000	-3.000
	7	f7	1	1	1	5.000	-3.000	2.000	.000
	8	f8	1	1	1	5.000	-3.000	-2.000	.000
	9	f9	1	1	1	100.000	.000	.000	.000

Figure 15 Jet Impact Position Data from Force Menu

The next table show the torque produced when each jet is fired by itself.

	idx	name	---tqmag--	---tqx----	---tqy----	---tqz----
=>	1	f1	3.000	.000	.000	3.000
	2	f2	3.000	.000	.000	-3.000
	3	f3	3.000	.000	3.000	.000
	4	f4	3.000	.000	-3.000	.000
	5	f5	7.159	3.000	.000	-6.500
	6	f6	7.159	-3.000	.000	-6.500
	7	f7	10.000	.000	.000	-10.000
	8	f8	10.000	.000	.000	10.000
	9	f9	.000	.000	.000	.000

Figure 16 Torque by firing each jet by itself

The values of the force parameters can be changed using the following instructions.

Edit Force Parameters
Select the ‘force’ command from Model Menus page to open the Force Menu. See Figure 14.

change force vectors in the list:
- use ‘fvec’ command to change the force vector: follow prompt instructions

change force magnitudes in the list:
- use ‘fmag’ command to change the force vector: follow prompt instructions

change force positions in the list:
- use ‘fpos’ command to change the force position: follow prompt instructions

display force vectors:
- use ‘vec’ command to display force vectors

display force positions:
- use ‘pos’ command to display force positions

display torque vectors:
- use ‘rxf’ command to display force positions

add forces:
- use ‘add’ command: flow promt instructions

remove forces:
- use ‘rem’ command: flow promt instructions

Select the ‘x’ command to exit the menu. Select the ‘save’ command from this page or the Model Menus page to save the current model data. Always follow the prompted instructions.

H. Constraint Signals

The Sep1sim here has 2 constraint signals that control the deployment of the two Sep1sim arrays. Constraints 1 and 2 switches lock the innermost panels (b2, b3) when their inboard joint angles (ang2, ang3) reaches 0. The values under the 'ic' column in the cn Menu are the initial values of the cn switches (0-off, 1-on), indices under the 'b1 b2' columns indicate the joints for which the constraints apply.

```
   idx type    ic ln ov   b1 b2 f1 f2 d1 d2 d3 p1 p2
   --- ----    -- -- --   -- --+-- --+-- -- --+-- --
=>   1 LOCK     0  1  0    2  0¦ 0  0¦ 0  0  0¦ 0  0
     2 LOCK     0  1  0    3  0¦ 0  0¦ 0  0  0¦ 0  0
```

Figure 17 Constraint Signals Summary from CN Menu for Sep1sim

Edit CN Parameters
Select the 'cn' command from Model Menus page to open the Constraint Menu. See Figure 17.

change the parameters of a cn signal:
- use 'edit<j>' command to change the j-th cn signal: follow prompt instructions

add a lock constraint:
- use 'lock' command to create a lock constraint: follow prompt instructions

add a constraints:
- use 'add' command: flow promt instructions

remove constraints:
- use 'rem<j>' command to remove j-th cn signal

Select the 'x' command to exit the menu. Select the 'save' command from this page or the Model Menus page to save the current model data. Always follow the prompted instructions.

I. Simulation Engine Input

The signals required by xsim1.dll (simulation engine) for the Sep1sim are in the next table.

```
Udata list:

 1) whltq,1            | 2) whltq,2            | 3) whltq,3
 4) whltq,4            | 5) xf,1               | 6) xf,2
 7) xf,3               | 8) xf,4               | 9) xf,5
10) xf,6               |11) cn,1               |12) cn,2
13) xstg,1             |14) xf,7               |15) xf,8
16) xf,9               |17) usedt,1
```

Figure 18 Udata List from the Input Data Menu

where, cn,1:2 = array deployment constraint signals (1/0)
usedt,1 = mass depletion rate for b1
whltq,1:4 = b1 wheel torque
xf ,1:6 = ACS jet firing (1/0) commands
xf, 7:8 = pushoff spring (1/0) commands
xf, 9 = 100 lbf thruster (1/0) command
xstg,1 = satellite ejection (1/0) signal to activate the vmass procedure

Note: no array torque input for Sep1sim, that's defined through menu.

The size of each of these signals are as follows.

```
> len
  #   uDef         Len  Loc    #   uDef         Len  Loc
  1. whltq,1        1    1|   2. whltq,2        1    2
  3. whltq,3        1    3|   4. whltq,4        1    4
  5. xf,1           1    5|   6. xf,2           1    6
  7. xf,3           1    7|   8. xf,4           1    8
  9. xf,5           1    9|  10. xf,6           1   10
 11. cn,1           1   11|  12. cn,2           1   12
 13. xstg,1         1   13|  14. xf,7           1   14
 15. xf,8           1   15|  16. xf,9           1   16
 17. usedt,1        1   17
```

Figure 19 Length of Udata Elements

The parameters in the xsim input list can be changed using the following instructions.

Edit XSIM Inut Data
Select the 'input' command from Model Menus page to open the (XSIM) Input Menu. See Figure 18.
append new data to the input list:
- use 'add' command to add data to the list
  > this opens a data selection menu
- use 'sel<k>' to add selected kth parameter to the list
- use 'x' to exit the selection

insert new data to the input list:

- use ‘add<j>’ command to insert data before the j-th data in the list
  > this opens a data selection menu
- use ‘sel<k>’ to add selected kth parameter to the list
- use ‘x’ to exit the selection

change data in the input list:

- use ‘chg<j>’ command to change the j-th data in the list
  > this opens a data selection menu
- use ‘sel<k>’ to add selected kth parameter to the list
- use ‘x’ to exit the selection

remove data from the list:

- use ‘rem’ command to remove one or more data in the list: follow prompt instructions

see data length or dimensions of data in the list as shown in Figure 19:

- use ‘len’ command to see size of data in the list

Select the ‘x’ command to exit the menu. Select the ‘save’ command from the Model Menus page to save the current model data. Always follow the prompted instructions.

J. Simulation Engine Output

These are the signals that xsim1.dll (simulation engine) output to the Simulink workspace for control signal computation purposes. Sep1sim's output data are in the next table.

```
Ydata list:

 1) w,1                 | 2) b2osml,1          | 3) angle,2
 4) angle,3             | 5) use,1             | 6) usedt,1
 7) xf,9
```

Figure 20 XSIM Output Data from Output Menu

where, angle, 2:3 = solar array drive joint angles (b2,b3)
b2osml,1 = small angle roll-pitch-yaw of b1 wrt orbit frame
use,1 = 1-fuel fraction fill for b1
usedt,1 = fuel depletion rate for b1
w,1 = total angular rate of b1 in b1 coordinates
xf,9 = booster firing on/off (1/0) switch

The size of each of these signals are shown under the 'len' column next.

```
> len
  #   yDef          Len  Loc    #   yDef          Len  Loc
  1. w,1             3    1|    2. b2osml,1        3    4
  3. angle,2         1    7|    4. angle,3         1    8
  5. use,1           1    9|    6. usedt,1         1   10
  7. xf,9            1   11
```

Figure 21 XSIM Output Data Size

The parameters in the Xsim output list can be changed using the following instructions.

Edit XSIM Output Data

Select the 'output' command from Model Menus page to open the (XSIM) Output Menu. See Figure 20.

append new data to the input list:
- use 'add' command to add data to the list: follow prompt instructions
  > this opens a data selection menu
- use 'sel<k>' to add selected kth parameter to the list
- use 'x' to exit the selection

insert new data to the input list:
- use 'add<j>' command to insert data before the j-th data in the list
  > this opens a data selection menu
- use 'sel<k>' to add selected kth parameter to the list
- use 'x' to exit the selection

change data in the input list:
- use 'chg<j>' command to change the j-th data in the list
  > this opens a data selection menu
- use 'sel<k>' to add selected kth parameter to the list
- use 'x' to exit the selection

remove data from the list:

- use ‘rem’ command to remove one or more data in the list: follow prompt instructions

see data length or dimensions of data in the list as shown in Figure 21:

- use ‘len’ command to see size of data in the list

Select the ‘x’ command to exit the menu. Select the ‘save’ command from the Model Menus page to save the current model data. Always follow the prompted instructions.

K. Simulation Plot Data

The time response of signals selected for performance evaluation are saved in the plot_file=z.1. These signals are listed in the next table.

```
Odata list:

 1) QUAT,1            | 2) WREL,1          | 3) whlspd,1
 4) whlspd,2          | 5) whlspd,3        | 6) whlspd,4
 7) whltq,1           | 8) whltq,2         | 9) whltq,3
10) whltq,4           |11) syshmom         |12) SYSPOS
13) SYSVEL            |14) SYSACC          |15) B2O123,1
16) syshb1            |17) angle,2         |18) angle,3
19) wrelax,2          |20) wrelax,3        |21) htqax,2
22) htqax,3           |23) mass,1          |24) inr,1
25) svec,1            |26) xf,7            |27) xf,8
28) xf,9              |29) use,1
```

Figure 22 XSIM Plot Data List from Plot Menu

where, quat,1= attitude quaternion of b1
wrel,1 = angular rate vector of b1 in b1 coordinates
whlspd,1:4= wheel spinning speed in d/s
whltq,1:4 = wheel torque
syshmom= Sep1sim angular momentum about system cm
syspos = composite tether cm position in inertial frame
sysvel = composite tether cm velocity in inertial frame
sysacc = system cm acceleration in inertial frame
b2osml,1 = small angle b1 attitude roll-pitch-yaw wrt orbit frame
syshb1 = syshmom in b1 coordinates
angle, 2:3= array angle 2:3
wrelax,2:3= array1 and 2 joint rates
htqax,2:3= array1 and 2 joint torque
mass,1 = mass of b1
inr,1 = moment of inertia of b1
svec,1 = svec of b1
xf,7:8 = 5 lb pushoff spring on/off signals
xf,9 = 100 lb thruster on/off signal
use,1 = 1-fraction fill of b1

The size of each of these signals are shown under the ‘len’ column next.

```
> len
  #   oDef         Len  Loc    #   oDef         Len  Loc
  1. QUAT,1         4    2|   2. WREL,1         3    6
  3. whlspd,1       1    9|   4. whlspd,2       1   10
  5. whlspd,3       1   11|   6. whlspd,4       1   12
  7. whltq,1        1   13|   8. whltq,2        1   14
  9. whltq,3        1   15|  10. whltq,4        1   16
 11. syshmom        3   17|  12. SYSPOS         3   20
 13. SYSVEL         3   23|  14. SYSACC         3   26
 15. B20123,1       3   29|  16. syshb1         3   32
 17. angle,2        1   35|  18. angle,3        1   36
 19. wrelax,2       1   37|  20. wrelax,3       1   38
 21. htqax,2        1   39|  22. htqax,3        1   40
 23. mass,1         1   41|  24. inr,1          6   42
 25. svec,1         3   48|  26. xf,7           3   51
 27. xf,8           3   54|  28. xf,9           3   57
 29. use,1          1   60
```

Figure 23 Data Size of Plot Data

The parameters in the Xsim plot data list can be changed using the following instructions.

Edit XSIM Plot Data

Select the ‘plot’ command from Model Menus page to open the (XSIM) Plot Menu. See figure 22.

append new data to the input list:
- use ‘add’ command to add data to the list
  > this opens a data selection menu
- use ‘sel<k>’ to add selected kth parameter to the list
- use ‘x’ to exit the selection

insert new data to the input list:
- use ‘add<j>’ command to insert data before the j-th data in the list
  > this opens a data selection menu
- use ‘sel<k>’ to add selected kth parameter to the list
- use ‘x’ to exit the selection

change data in the input list:
- use ‘chg<j>’ command to change the j-th data in the list
  > this opens a data selection menu
- use ‘sel<k>’ to add selected kth parameter to the list
- use ‘x’ to exit the selection

remove data from the list:
- use ‘rem’ command to remove one or more data in the list: follow prompt instructions

see size of data in the list as shown in figure 23:
- use ‘len’ command to see size of data in the list

Select the ‘x’ command to exit the menu. Select the ‘save’ command from the Model Menus page to save the current model data. Always follow the prompted instructions.