SV1sim with RWA and Jets

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SV1sim.mdl is a Simulink program that simulates the motion of a LEO satellite that has four reaction wheels and six active jets for ACS. The satellite flies in a near circular 65 degree inclined orbit and with some user set arbitrary initial angular rate. The gravity model for the simulation is that of a spherical earth. After the start of the simulation the ACS would control the satellite attitude to track the LVLH attitude using alternately the RWA's and the jets. Two cases are simulated. The first case is one where RWA ACS is exercised first and transitions to Jet ACS. The second case is one with Jet ACS enabled first and transitions to a RWA ACS. The simulation runs for half orbit period of 6000 seconds.

Topics covered in the following sections are:

1. SV1sim Simulink Program
2. SV1sim Simulation 1 Result
3. SV1sim Simulation 2 Result
4. SV1sim Model Data

The model configuration of Sv1sim is:

```
b1(B)+ -w[1:4]
      |
      +-xf[1:6]
```

where b1= bus (B= 3 relative rotational dof)
w = wheels
xf = jet forces

1. SV1sim Simulink Program

The SV1sim Simulink Program is SV1sim.mdl as shown in figure 1. Its four processors are:

1) xsim1_150715.dll — simulation engine
2) acs_rwa.m — RWA ACS
3) acs_jet.m — Jet ACS
4) sysh.m — system angular momentum calculator

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

processor	input	output	function
xsim1	- model file=cmg4sim.txt - wtq 1:4 = RWA torque - xf 1:6 = jet on/off signals	- plot file=z.1 - cmg 1:4 angles - cmg 1:4 rates - w1= b1 ang rate - rpy=attd errors	- 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 per input signals
acs_rwa	- ena= enable switch - w1= b1 ang rate - rpy= attd error	- wtq 1:4 = RWA torque	- computes RWA torque using a PD error signal based on input
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 1Hz pulse width jet on/off signals to reduce the PD error signal based on input
sysh	- q1 = b1 attd quaternion - w1= b1 ang rate - r1 = b1 cm position - r1dt = b1 cm velocity - wspd 1:4=whl speed	-sysh= system angular momentum	- monitors the system angular momentum based on input

Table 1. Functionality of SV1sim Processors and their input/output signals

Simulation 1 Setup

The ACS for this simulation is an RWA ACS for t < 3000 and it is a Jet ACS for t > 3000. See the ena signals input to ACS_RWA.m and ACS_Jet.m.

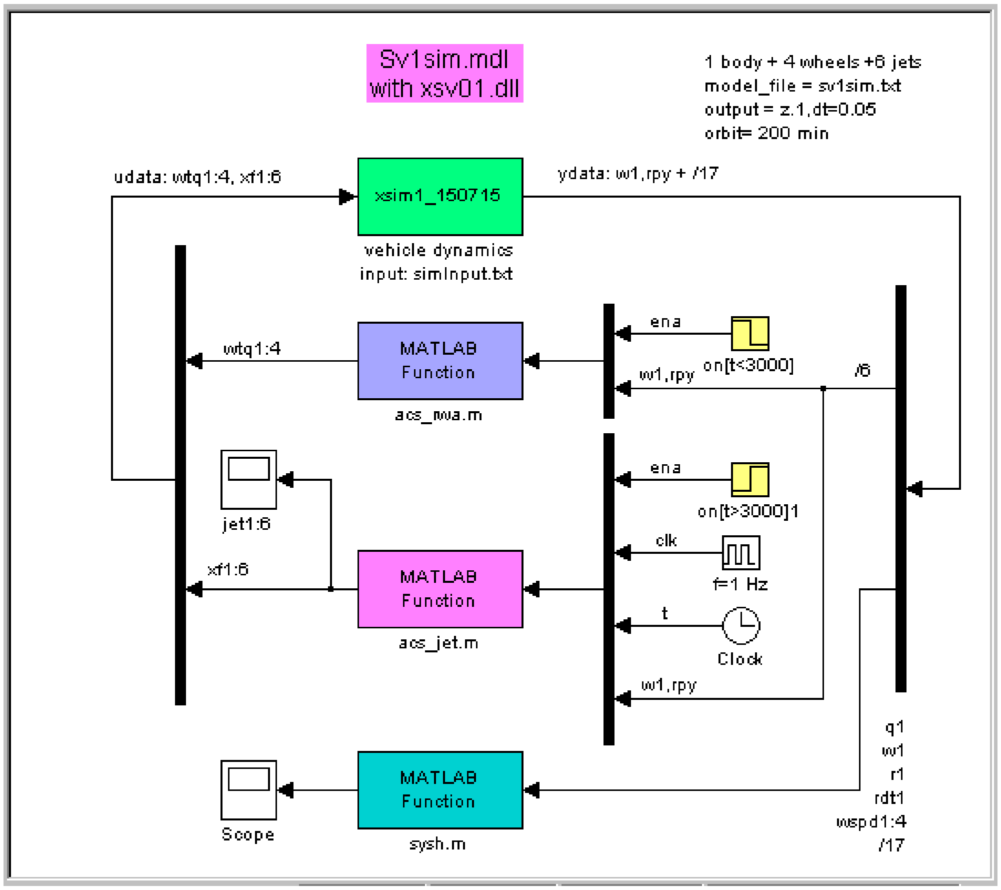


Figure 1 Simulink Program of SV1sat with RWA and Jet ACS

Simulation 2 Setup

The ACS for this simulation is a Jet ACS for t < 3000 and it is a RWA ACS for t > 3000. See the ena signals input to ACS_RWA.m and ACS_Jet.m.

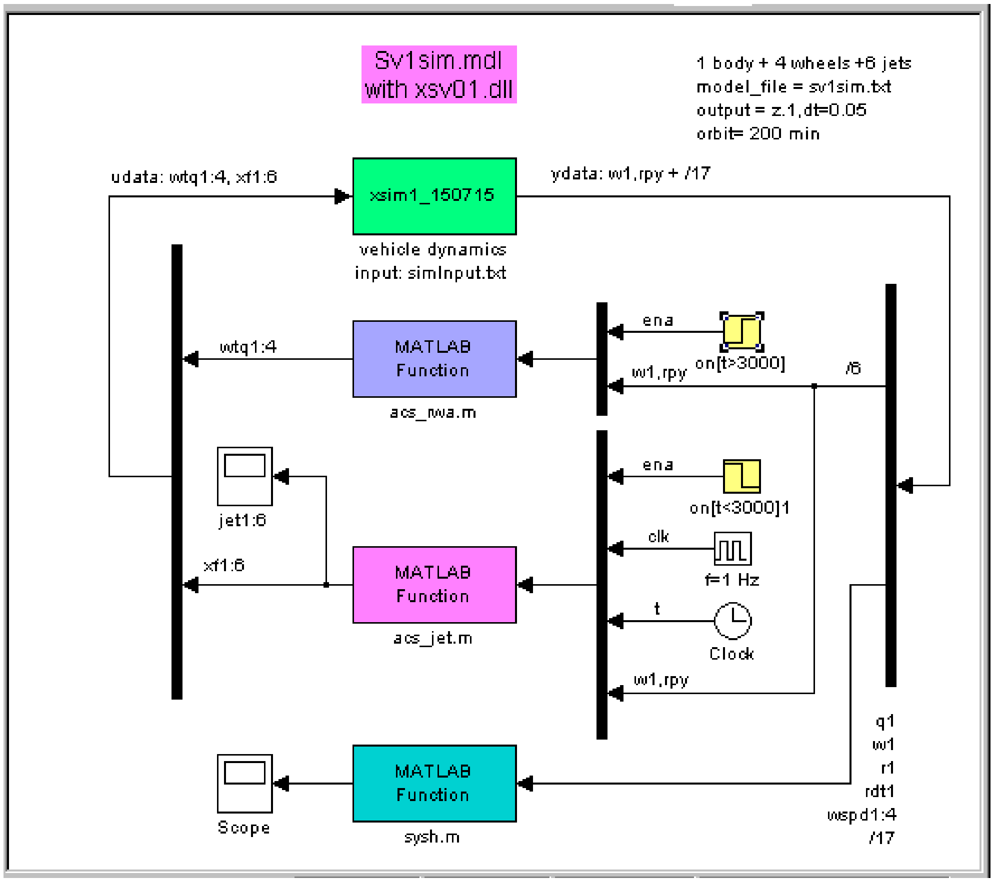
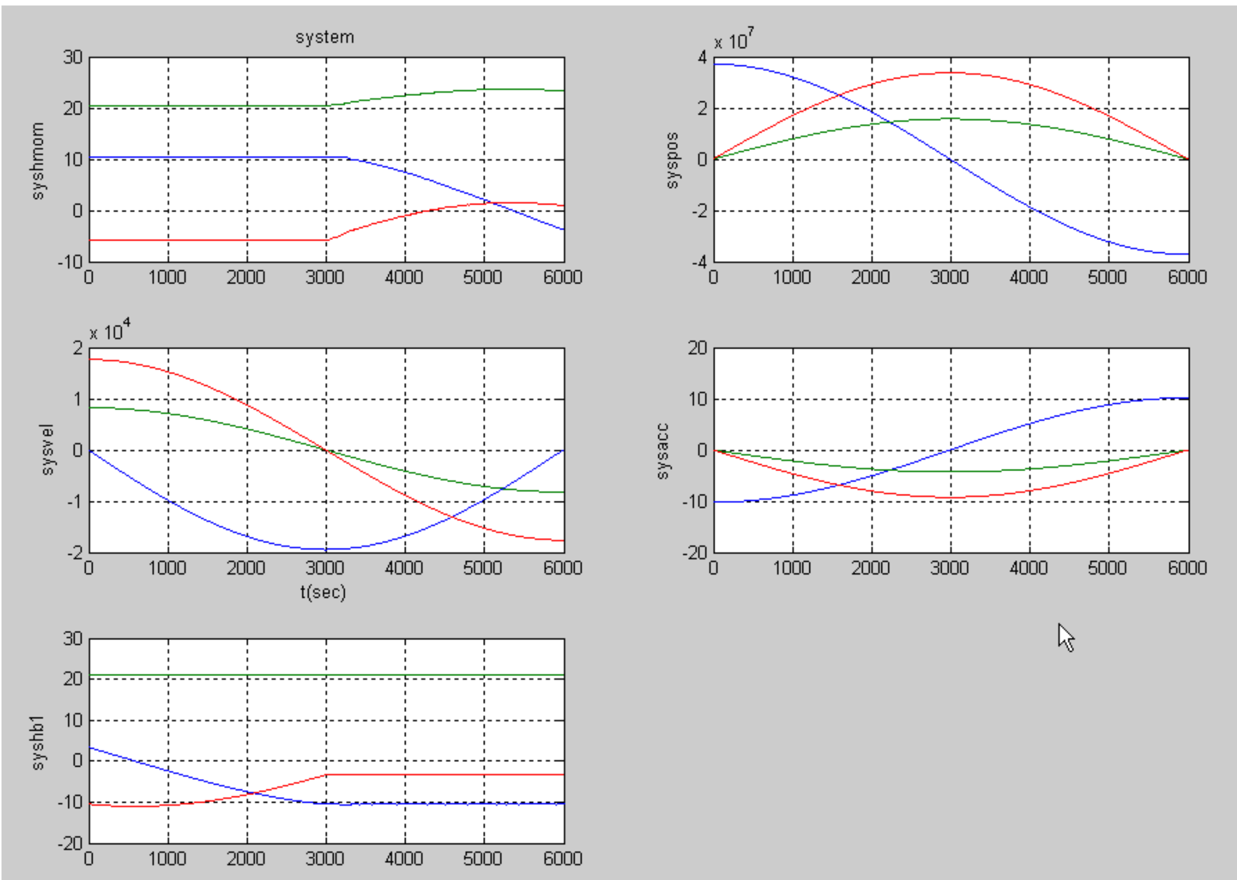


Figure 2 Simulink Program of SV1sat with RWA and Jet ACS

2. Sv1sim Simulation 1 Result

Simulation Scenario Summary:
Orbit: near circular, 65 deg inclined, 200 minutes period.
Total time simulated is 6,000 sec or half orbit period.
ACS by RWA's for t < 3000 seconds.
ACS by Jets for t > 3000 seconds.

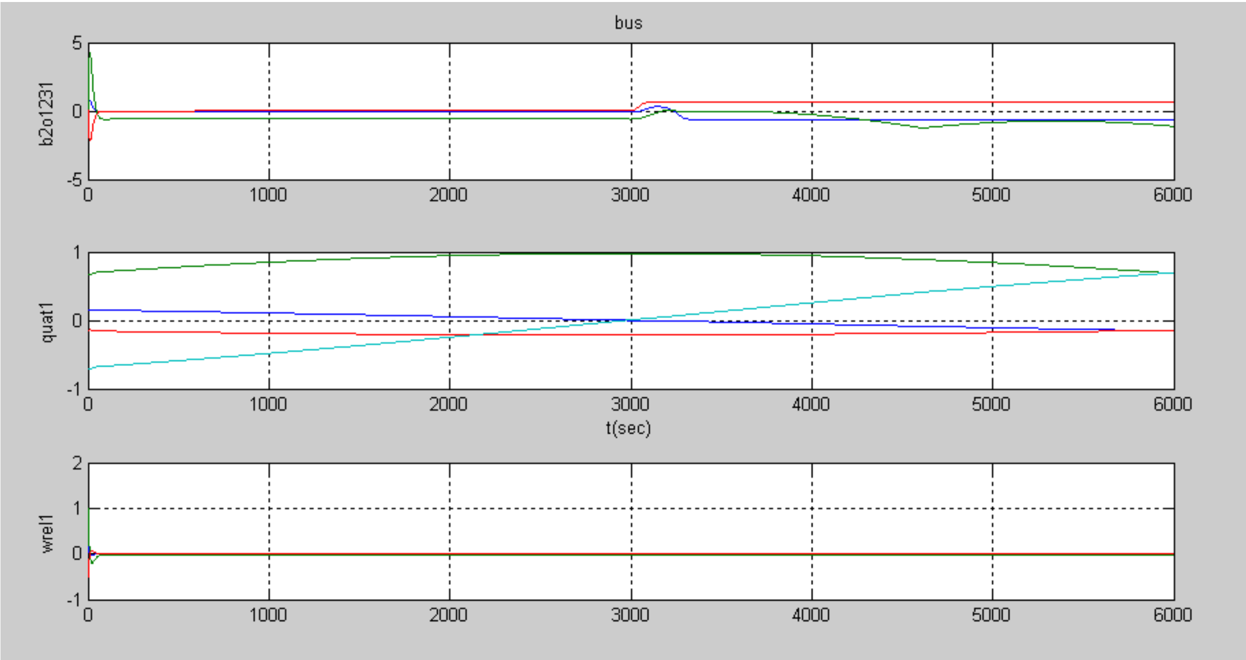
Observations of the case 1 result: the total system angular momentum (syshmom) is constant until t=3000. This is because the RWA ACS is in effect until it transitions to Jet ACS at t=3000 seconds.



System Data (simulation 1)

syshmom= system angular momentum in inertial coordinates
syspos= system cm inertial position
sysvel= system cm inertial velocity
sysacc= system cm acceleration
syshb1= system angular momentum in b1 coordinates

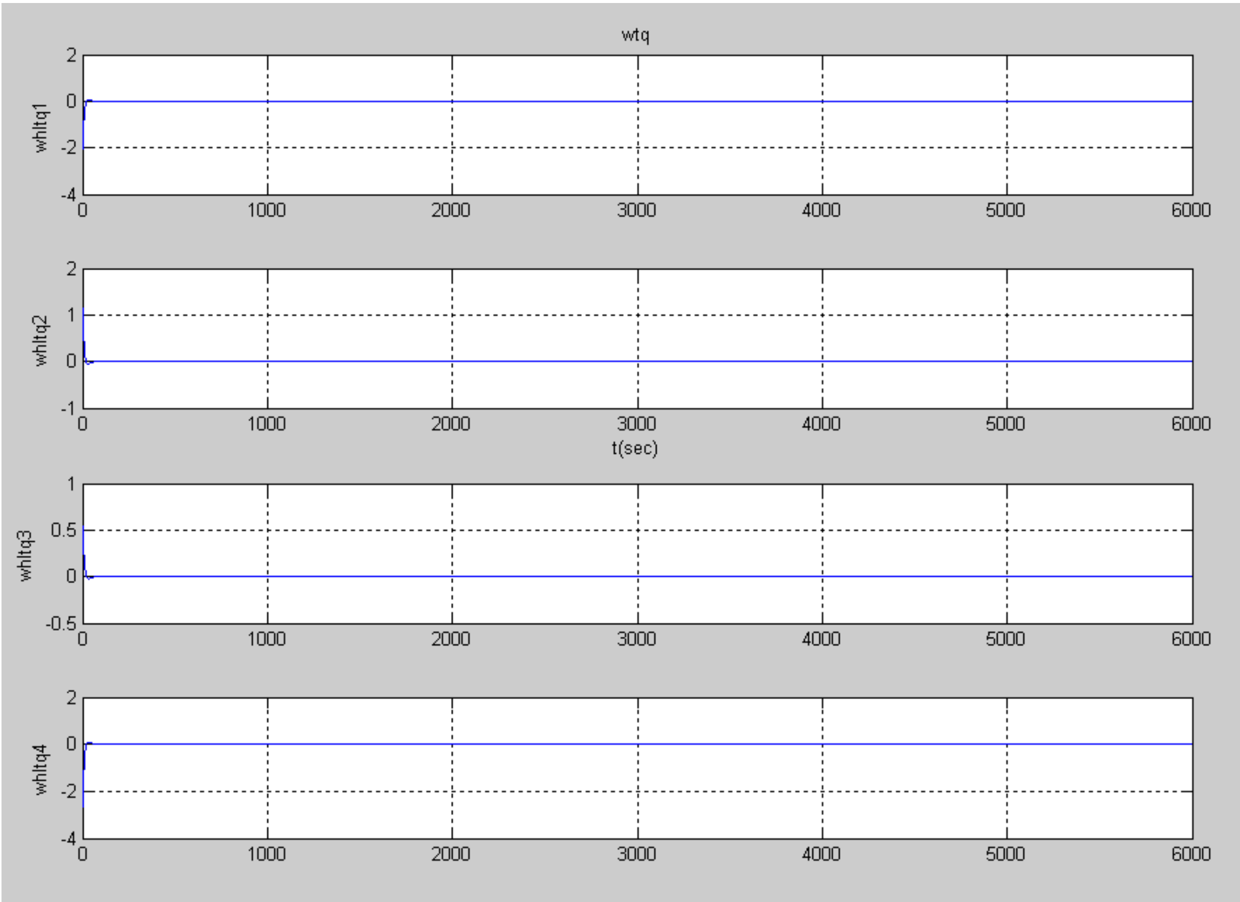
b1 attitude error is reduced from ~5 degrees quickly early on to < 1 deg by the RWA ACS for t < 3000 seconds and transitions to the Jet ACS at t=3000. The jets maintained the LVLH attitude error for t > 3000 to around 2 degrees. The Jet ACS performed poorer than the the RWA ACS.



Attitude and Attitude Rate (simulation 1)

b2o1231= body1 to orbit attitude error, roll, pitch and yaw (deg)
quat1= body1 attitude quaternion
wrel1 = body1 angular rate (deg/sec)

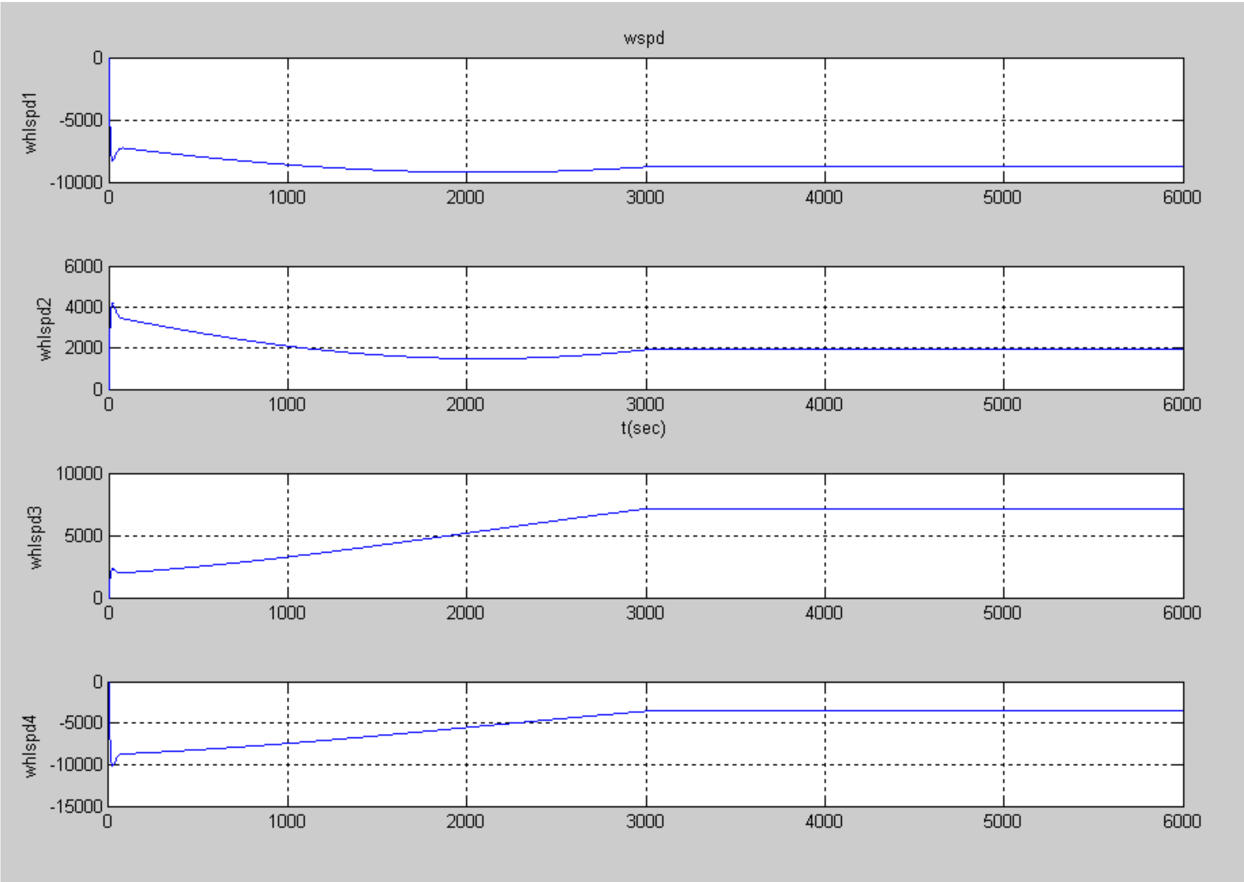
The wheel torque exerted for the ACS is quite small over t=[0:3000] and is 0 thereafter because the RWA's are disabled after t=3000 seconds.



Wheel Torque 1:4 (simulation 1)

whltq1= wheel1 torque (ft-lb)
whltq2= wheel2 torque (ft-lb)
whltq3= wheel3 torque (ft-lb)
whltq4= wheel4 torque (ft-lb)

Wheel speed variations over t=[0:3000] means that the wheel torque is non-zero over that time. They become constant after t=3000 because the RWA's are disabled after that time.



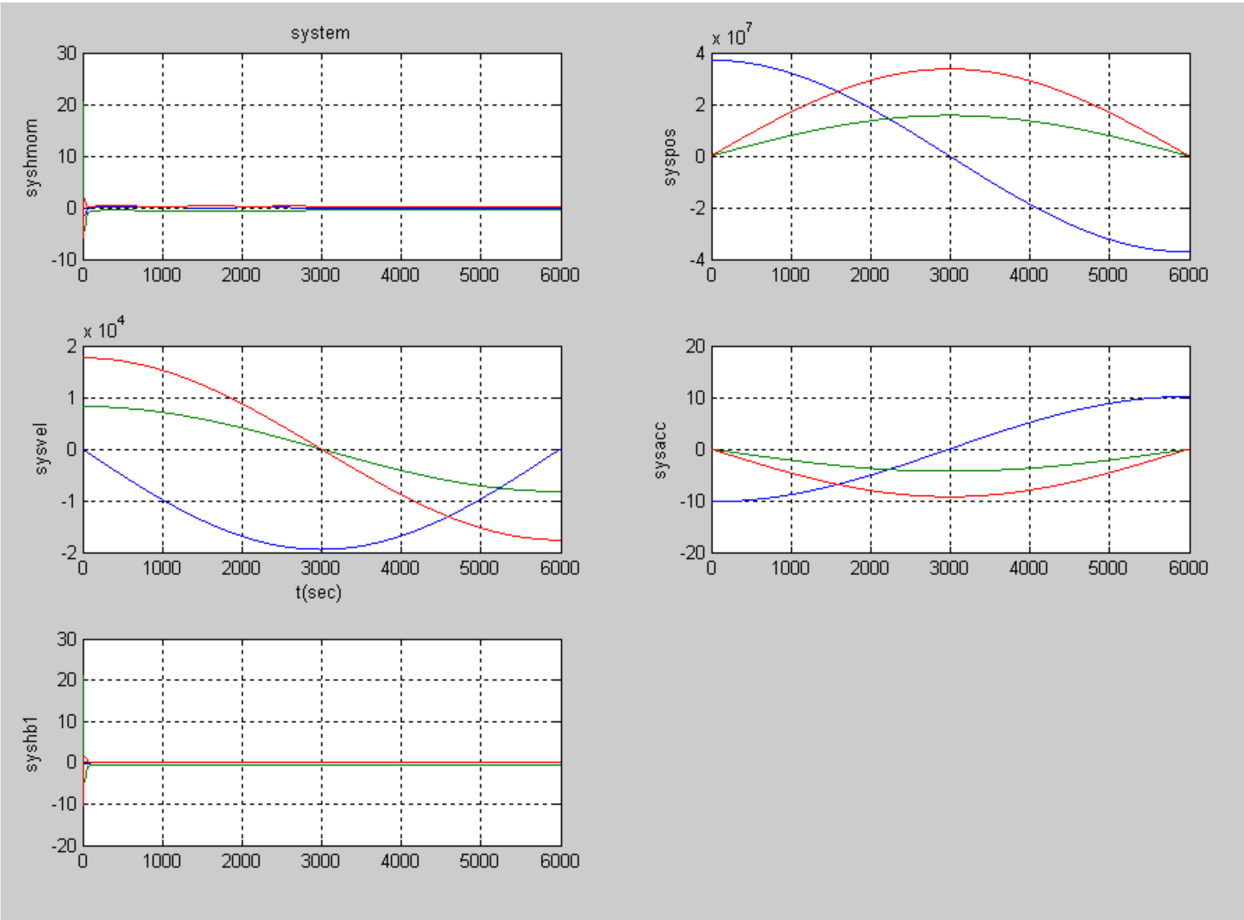
Wheel Speed 1:4 (simulation 1)

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

3. Sv1sim Simulation 2 Result

Simulation Scenario Summary:
Orbit: near circular, 65 deg inclined, 200 minutes period.
Total time simulated is 6,000 sec or half orbit period.
ACS by Jets for t < 3000 seconds.
ACS by RWA's for t >3000 seconds.

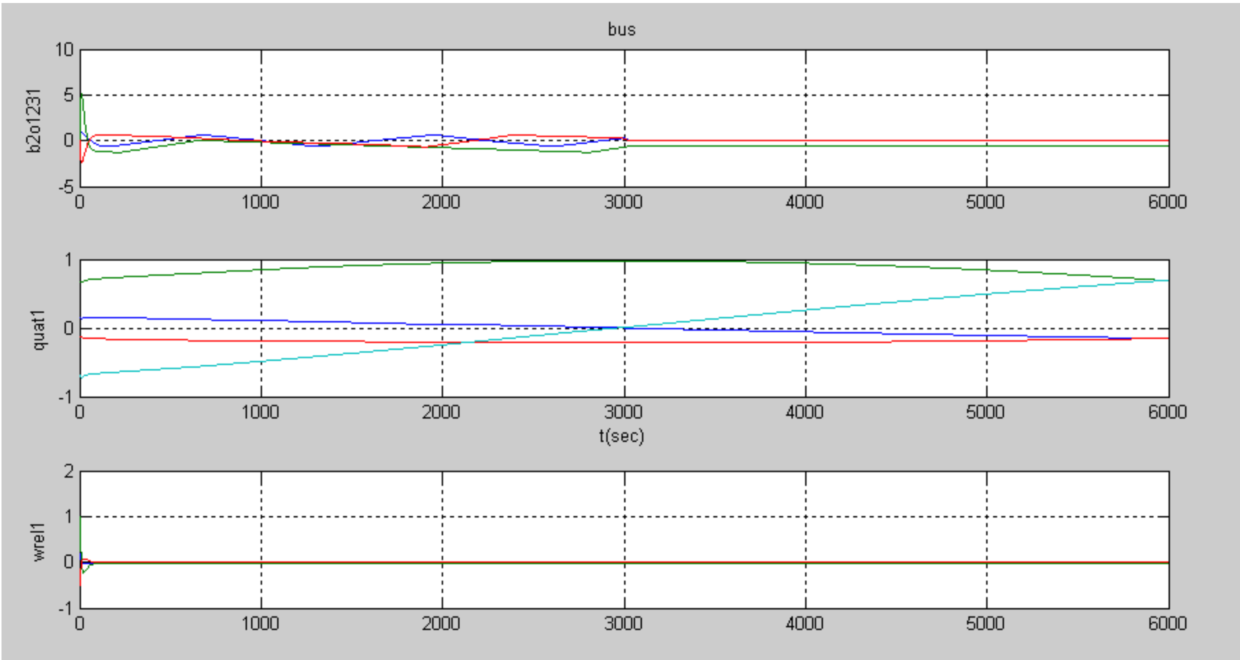
Observations of the case 2 result: the total system angular momentum (syshmom) is reduced from some 20 ft-lb-s to near zero early on due to Jet ACS. Syshmom stays at a low value and remain constant for t > 3000. This is because Jet ACS transitions to RWA ACS at t=3000.



System Data (simulation 2)

syshmom= system angular momentum in inertial coordinates
syspos= system cm inertial position
sysvel= system cm inertial velocity
sysacc= system cm acceleration
syshb1= system angular momentum in b1 coordinates

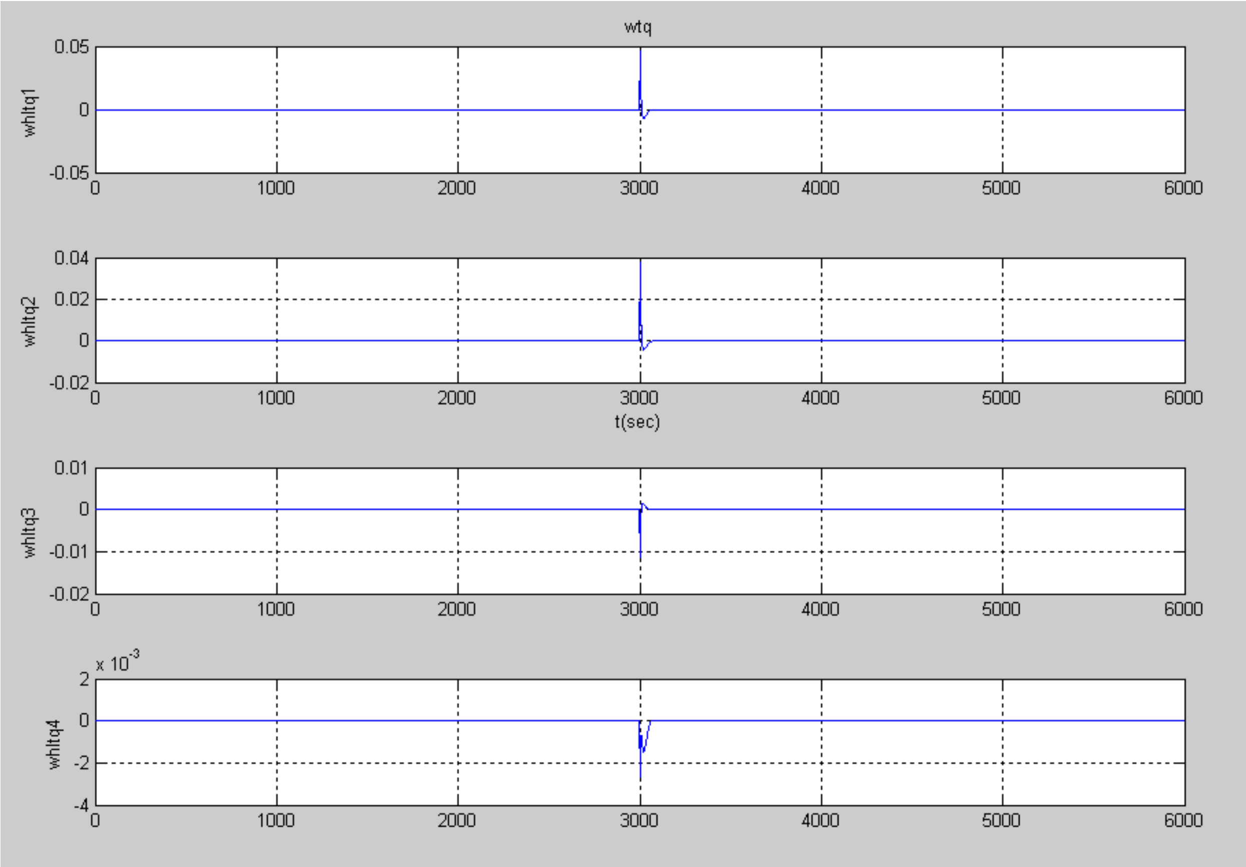
b1 attitude error is reduced from ~5 degrees quickly early on to < 1 deg by jets. The Jet ACS maintained the LVLH attitude error to ~2 degrees for t < 3000 and transitions to RWA ACS at t=3000. The attitude error is much smaller during the RWA ACS phase.



Attitude and Attitude Rate (simulation 2)

b2o1231= body1 to orbit attitude error, roll, pitch and yaw (deg)
quat1= body1 attitude quaternion
wrel1 = body1 angular rate (deg/sec)

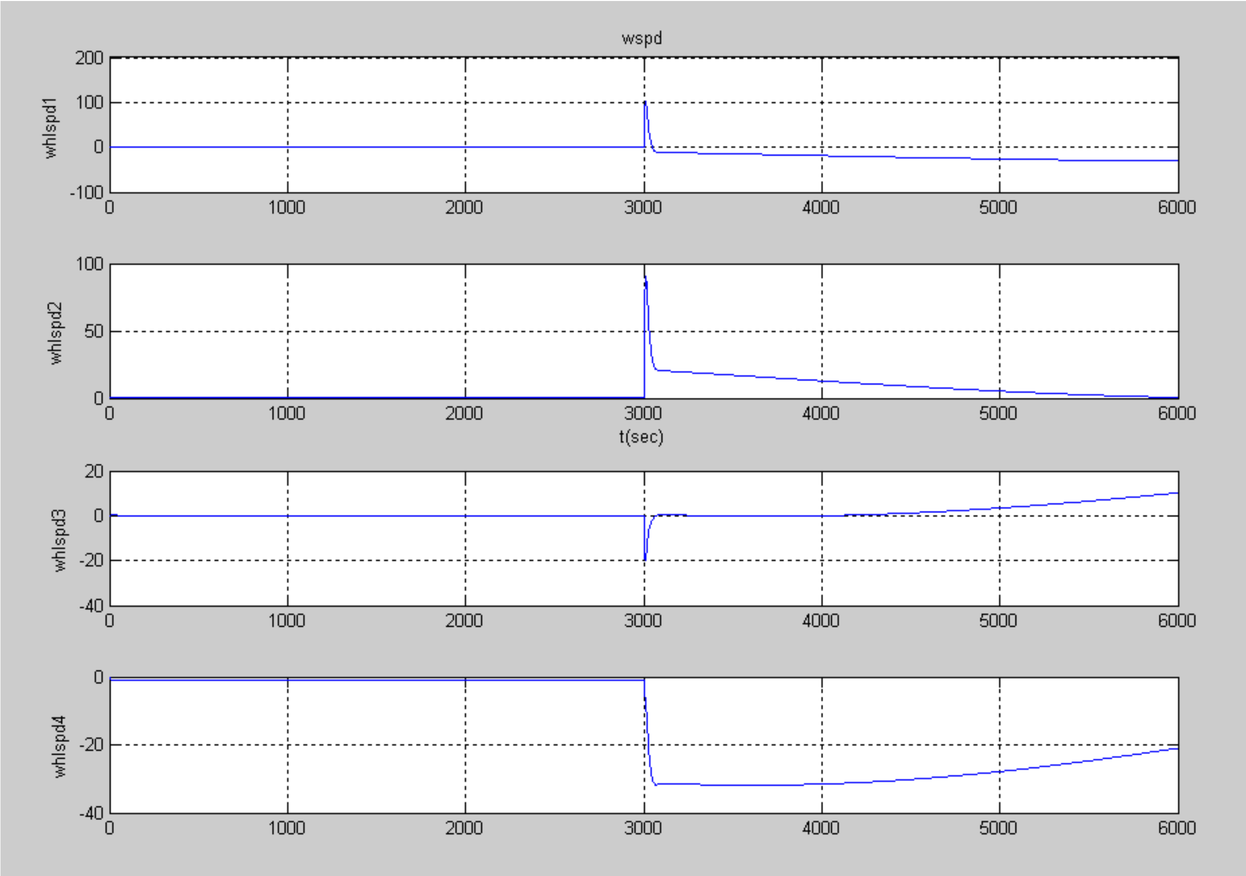
Wheels torque are zero over t=[0:3000] because Jet ACS is on and RWA ACS is disabled during that time. It then transitions to RWA ACS at t=3000. The spike at that time means that the wheels are torqued not only for control but also to absorb the angular momentum of the bus. The wheels are torqued at a very low level for t > 3000 and is reflected in the wheels speed response in the chart after the next chart.



Wheel Torque 1:4 (simulation 2)

whltq1= wheel1 torque (ft-lb)
whltq2= wheel2 torque (ft-lb)
whltq3= wheel3 torque (ft-lb)
whltq4= wheel4 torque (ft-lb)

Wheels speed are constant zero over t=[0:3000] because Jet ACS is on and RWA ACS is disabled during that time. It then transitions to RWA ACS at t=3000. The spike at that time means that the wheels are torqued not only for control but also to absorb the angular momentum of the bus. The non-constant nature of the wheels speed means that the wheels are being torqued for t > 3000.



Wheel Speed 1:4 (simulation 2)

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

4. SV1sim Model Data

The model data for this program define the construction and the computation of the equations of motion underlying SV1sim.mdl. It includes the mass property of the vehicle, the connectivity and dof's of bodies in the vehicle model. It defines the jet parameters. 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. These data are saved in SV1sim.txt file.

The model data in SV1sim.txt can be divided into the following groups.

A. Configuration of the model
B. Mass property of the model
C. Initial relative angular rates
D. Static Orientations
E. Ephemeris of the orbit
F. Reaction wheel elements
G. Force elements
H. Simulation engine input
I. Simulation engine output
J. Simulation plot data

The following sections will show how each data group is defined and how they can be modified.

A. Model Configuration

The model configuration of Sv1sim is:

```
b1(B)+ -w[1:4]
     |
     +-xf[1:6]
```

where b1= bus (B= 3 relative rotational dof)
w = wheels
xf = jet forces

This the parent-child relations define the connectivity of the bodies in the model. These relations are represented by the parent indices of the model objects.

B. Mass Property

The following are the mass properties of b1 taken from the ‘body’ submenus of Buildx.exe. The first table displays the mass of the bus. There is only one body for the Sv1sim example.

```
  idx name     pa  u   fl vm tp ax -- angle - -- del_x - ----mass----
=>  1 b1        0 FPS  0  -  B  x        .000        .000   .100000E+03
```

Figure 3. Body Data from Body Menu

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

```
   idx name    -     ixx    - -     iyy    - -     izz    -
               ---- ixy --- ---- ixz --- ---- iyz ---
=>   1 b1        .100000E+04  .120000E+04  .120000E+04
                 .000000E+00  .000000E+00  .000000E+00
```

Figure 4. MOI Data from Moment of Inertia Menu

The next two are the svec and dvec definitions. 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  .000000E+00  .000000E+00  .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
```

Figure 6. Dvec Data from Dvec Menu

Edit Mass Property

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

```
**********************************************************
*          BBBB  U   U  I  L     DDDD  X   X             *
*          B   B U   U  I  L     D   D  X X              *
*          BBBB  U   U  I  L     D   D   X               *
*          B   B U   U  I  L     D   D  X X              *
*          BBBB   UUU   I  LLLL DDDD  X   X              *
*          ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~             *
*                 xsv version 1.0                        *
*                 copyright 2014                         *
*         concurrent dynamics international              *
**********************************************************


 simInputFile: sim1files.txt        < ENTERPRISE

   Model file < sv1sim.txt
    Plot file > z.1
Summary file > sim1_summary.txt
Message file > sim1_message.txt
      plotDt = .20000E+01

[ xsv    open   save   model   plot  plotDt ]
[ sumry  mssg   reset          help     x   ]
> _
```

Figure 7. Main Menu

Note that the model file is sv1sim.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 7.

```
                       ~ Model Menus ~
System Graph:

b1(B)+-w[1,2,3,4]

total bodies:          5     ; reg. bodies& wheels:    1,  4
ext. forces,torque:  8,  0 ; pos.& dir markers:      1,  0
system units:        FPS     ; constraints:            0
sflag,gflag:           1, 10 ; input (param,size):    10, 10
dscrt,odes:            0,  0 ; output(parmm,size):    10, 23
accels,gyros:          0,  0 ; plot  (parmm,size):    16, 34
vmass,pmass:           0,  0 ; swiches,states:         0, 17
```

Figure 8. Model Menus

3. Select ‘body’ command from Model Menu page (fig. 8) to open Body_Menu. See Figure 3
   -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.

C. Initial Relative Rates

Go to the Relative Angular Rate Menu to set the initial angular rates of bodies relative to their parents. Figure 9 is displayed in that rate menu for SV1sim. Tp=B means the joint has 3 rotational dof relative to its parent. The initial angular rate of b1 for this case is set to an arbitrary [.2, 1, -.5] deg/sec.

```
  idx name      tp  ax ------------ --wrel(d/s)- ------------
=>  1 b1         B   x  .200000E+00  .100000E+01 -.500000E+00
```

Figure 9 Relative Angular Rate Menu for SV1sim

Edit Initial Relative Body Rates
Select the ‘wrel’ command from Body Menu page to open the Relative Angular Rate Menu. See figure 9.

change body bi’s rate relative to its parent in bi coordinates:

- use ‘wrel<i>’ command to change the inboard joint relative rate of bi: 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. Static Orientations

The initial orientation of b1 in the orbit frame is set in the Body1 Menu. Figure 10 displays the body to orbit frame dcm for b1 of SV1sim. The displayed identity means that the vehicle attitude is set to the LVLH attitude.

```
> dcm0          =    1.000000      .000000      .000000
                      .000000     1.000000      .000000
                      .000000      .000000     1.000000
```

Figure 10 Initial orbit frame attitude of b1

Edit Static Orientation of bodies relative to their respective parents

Select the ‘edit<j>’ command from Body Menu page to open the Body Menu of bj. For example, type ‘edit2’ form Body Menu to see figure 9a in b2 Body Menu. Type ‘edit3’ to see figure 9b in b3 Body Menu and so forth.

change body bi’s static orientation relative to its parent:

- use ‘dcm’ command to change the static orientation of bi relative to its parent: 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 Sv1sim as 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         27.245           58.427
  > 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
  > atd option   = LVLH attitude unchanged
```

Figure 11 Gravity Menu

This orbit specification shows that the Sv1sim is in a 65 deg inclined slightly non circular orbit with an orbit period of 200 minutes. The gravity flag of 10 means that the spherical earth gravity is chosen for the simulation.

Edit Ephemeris

Select ‘grav’ command from the Models Menu page to open the Gravity Menu. See Figure 11.

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 Sv1sim here has 4 wheels for each 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 12. Wheel Data 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.

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 Sv1sim here has 8 jets and 6 of them are active jets. Their attributes are displayed next. Jets 1-8 are all attached to b1 (p=1), and Jets 1-6 are active (fmag > 0). 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	.000	.000	.000	.000
	8	f8	1	1	1	.000	.000	.000	.000

Figure 13 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	-3.000	-3.000	.000
	2	f2	1	1	1	1.000	-3.000	3.000	.000
	3	f3	1	1	1	1.000	-3.000	.000	3.000
	4	f4	1	1	1	1.000	-3.000	.000	-3.000
	5	f5	1	1	1	1.000	.000	3.000	3.000
	6	f6	1	1	1	1.000	.000	3.000	-3.000
	7	f7	1	1	1	.000	.000	.000	.000
	8	f8	1	1	1	.000	.000	.000	.000

Figure 14a Jet Impact Position Data from Force Menu

	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	3.000	3.000	.000	.000
	6	f6	3.000	-3.000	.000	.000
	7	f7	.000	.000	.000	.000
	8	f8	.000	.000	.000	.000

Figure 14b Torque by each jet firing

Edit Force Parameters

Select the 'force' command from Model Menus page to open the Force Menu. See Figure 13.

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 (figure 13)

display force positions:
- use ‘pos’ command to display force positions (figure 14a)

display torque vectors:
- use ‘rxf’ command to display torque vectors (figure 14b)

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. Simulation Engine Input

The signals required by xsim1.dll (simulation engine) for the Sv1sim 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
```

Figure 15 Udata List from the Input Data Menu

where,   whltq,1:4=b1 wheel torque
xf,1:6= b1 jet on/off signals

The size of each of these signals are as follows.

```
[ newList  add  rem  chg  value  lenLoc  help  x ]
> 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

usize=  10
```

Figure 16 Length of Udata Elements

Edit XSIM Inut Data
Select the ‘input’ command from Model Menus page to open the (XSIM) Input Menu. See Figure 15.

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

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 the selected kth parmeter to list: follow prompt instructions
- use ‘x’ to exit selection menu

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 the selected kth parmeter to list: follow prompt instructions
- use ‘x’ to exit selection menu

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 16:

- 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.

I. Simulation Engine Output

These are the signals that xsim1.dll (simulation engine) output to the Simulink workspace for control signal computation purposes. The are defined for the Sv1sim in the next table.

```
Ydata list:

 1) wrel,1             | 2) b2osml,1          | 3) quat,1
 4) w,1                | 5) mkrpos,1 ,1       | 6) mkrvel,1 ,1
 7) whlspd,1           | 8) whlspd,2          | 9) whlspd,3
10) whlspd,4
```

Figure 17 XSIM Output Data from Output Menu

where, quati,1= attitude quaternion of b1
mkrposr,1,1= marker 1 displacement in b1 coordinates
mktvel,1,1= marker 1 displacement rate in b1 coordinates
w,1 = angular rate of b1 in b1 coordinates
b2osml,1= small angle roll-pitch-yaw of b1 wrt orbit frame
wspd,1:4= reaction wheels 1:4 speed in d/s

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

```
[ newList  add  chg  rem  value  lenLoc  help  x ]
> len
  #   yDef         Len  Loc   #   yDef         Len  Loc
  1. wrel,1         3    1|  2. b2osml,1        3    4
  3. quat,1         4    7|  4. w,1             3   11
  5. mkrpos,1 ,     3   14|  6. mkrvel,1 ,      3   17
  7. whlspd,1       1   20|  8. whlspd,2        1   21
  9. whlspd,3       1   22| 10. whlspd,4        1   23

ysize=  23
```

Figure 18 XSIM Output Data Size

Edit XSIM Output Data
Select the 'output' command from Model Menus page to open the (XSIM) Output Menu. See Figure 17.
append new data to the input list:
- use 'add<j>' command to append data to the list: follow prompt instructions
  > this opens a data selection menu
- use 'sel<k> to add the selected kth parmeter to list: follow prompt instructions
- use 'x' to exit selection menu

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 the selected kth parmeter to list: follow prompt instructions
- use 'x' to exit selection menu
instructions

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 the selected kth parmeter to list: follow prompt instructions
- use ‘x’ to exit selection menu

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 18:

- 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 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
```

Figure 19 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
syspos = composite tether cm position in inertial frame
sysvel = composite tether cm velocity in inertial frame
sysacc = system cm acceleration in inertial frame
syshmom= Sv1sim angular momentum about system cm
b2o123,1 = b1 attitude roll-pitch-yaw wrt orbit frame

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

```
[ newList add  chg  rem  value  lenLoc  simPlot help  x ]
> 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. b2o123,1        3   29|   16. syshb1          3   32

osize=  34
```

Figure 20 Data Size of Plot Data

Edit XSIM Plot Data
Select the 'plot' command from Model Menus page to open the (XSIM) Plot Menu. See Figure 19.
append new data to the input list:
- use 'add' command to append data to the list
  > this opens a data selection menu
- use 'sel<k> to add the selected kth parmeter to list: follow prompt instructions
- use 'x' to exit selection menu

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 the selected kth parmeter to list: follow prompt instructions
- use ‘x’ to exit selection menu

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 the selected kth parmeter to list: follow prompt instructions
- use ‘x’ to exit selection menu

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 20:

- 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.

