CubeSat Dynamics Simulation

Documentation

Prerequisites to use the model

- MATLAB and Simulink installed with versions R2023b or later
- Aerospace Toolkit and Aerospace Blockset installed.
- Geodetic Toolbox and Mapping Toolbox installed.

How to use the model

- Unzip the cubesat_dynamics_sim file.
- Open the folder, and open the parent_model.slx file.

How to use the model

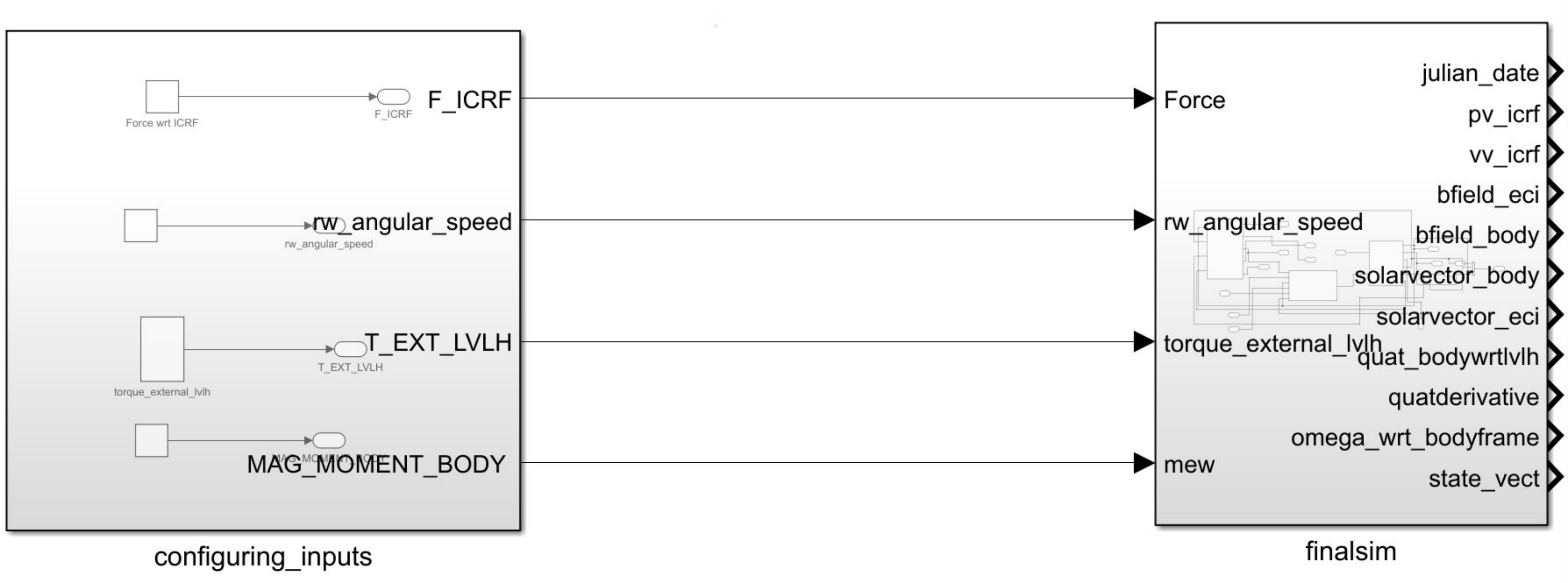
- Once the project opens, first set the parameters of the satellite and mission using the 'setparams.m' matlab script in the project- follow the instructions given in the comments of the script.
- Make sure to run this file irrespective of whether you have made any changes.

```
sat.sim_time=20;%time the simulation should run in seconds
sat.starttime=[2020, 1, 17, 10, 20, 36];%start time of simulation in UTC
sat.mass=4;%mass of satellite in kg
sat.orb.sma=6971000;%semi major axis of orbit in m
sat.orb.ecc=0.01;%eccentricity of orbit
sat.orb.inc=50;%inclination of orbit in degrees
sat.orb.raan=95;%RAAN of orbit in degrees
sat.orb.peri=93;%argument of periapse of orbit in degrees
sat.orb.theta=203;%true anomaly of satellite at start time
sat.dragco=2.179;%drag coefficient of satellite
sat.dragarea=1;%effective area for drag of satellite (square meters)
sat.inertiamatrix=[10, -5, 0; -5, 15, 0; 0, 0, 5];%MOI Matrix wrt Body Frame about COM
sat.initialorientation=quaternion([1, 0, 0, 0]);%quaternion of initial orientation of satell
```

How to use the model

- The simulation will run from the parent_model.slx file. This has two blocks: ‘configuring_inputs’ and ‘finalsim’
- The ‘finalsim’ block is actually running the simulation and takes four inputs. This block does not need to be tuned, edited, etc. by the user of the model who does not want to get into the nitty gritties.
- The four inputs, are given to this block by the ‘configuring_inputs’ block. These are the inputs that need to be tuned by the user based on the type of simulation that he/she wants to run, and the user can do so by opening this block. For now random test signals have been given.

How to use the model



Inputs to configure_inputs	Outputs from finalsim
F_ICRF- net external force(with respect to the ICRF/ECI frame)	juliandate - the live juliandate as the sim runs.
RW_ANGULAR_SPEED- angular speed of reaction wheel in rad/s	pv_icrf - position vector of the satellite wrt ICRF frame
T_EXT_LVLH - external disturbance torque to satellite with respect to LVLH frame	vv_icrf - velocity vector of the satellite wrt ICRF frame
MAG_MOMENT_BODY - magnetic moment vector of the magnetorquers with respect to body frame.	bfield_eci - the earth's magnetic field as a function of live satellite position in eci frame
	bfield_body - the earth's magnetic field as a function of live satellite position in body frame
	sv_eci - same as b_eci but for solar vector
	sv_body - same as b_body but for solar vector
Note- ICRF and ECI are two names for one and the same frame	quat_bodywrtlvlh - quaternion of the body frame of the satellite wrt the LVLH frame(orientation of the satellite) quatderivative- derivative of preceding quaternion omega_wrt_bodyframe- angular velocity vector wrt the body frame state _vector - (pv_icrf, vv_icrf, quat_bodywrtlvlh, quatderivative)

How to use the model

- Take desired results/signals from output ports.
- Run the simulation ‘parent_model.slx’
- Ignore warnings if any.

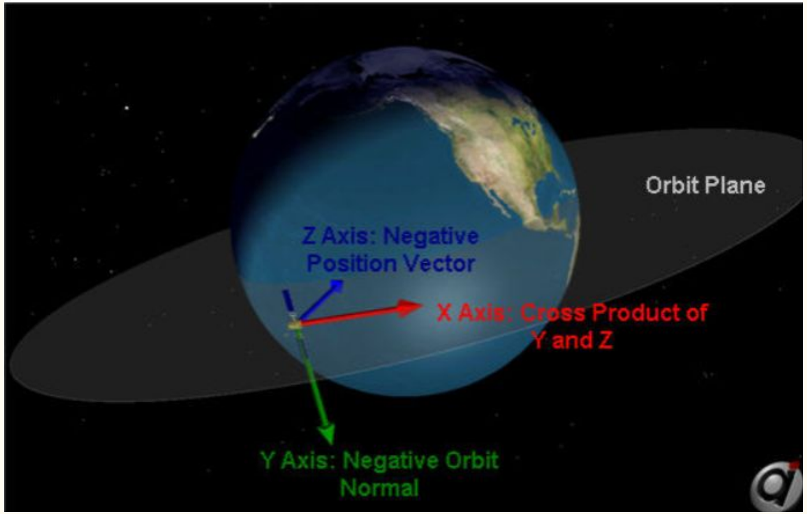
LVLH Frame

Z-Axis: Oriented in the direction of -**r** (points to center of Earth) - Local Vertical

Y-Axis: Negative to the orbit normal, or in the direction of -**h**

X-Axis: Perpendicular to Y and Z, forming a right-handed coordinate system - Local Horizontal

Origin: Center of the Spacecraft

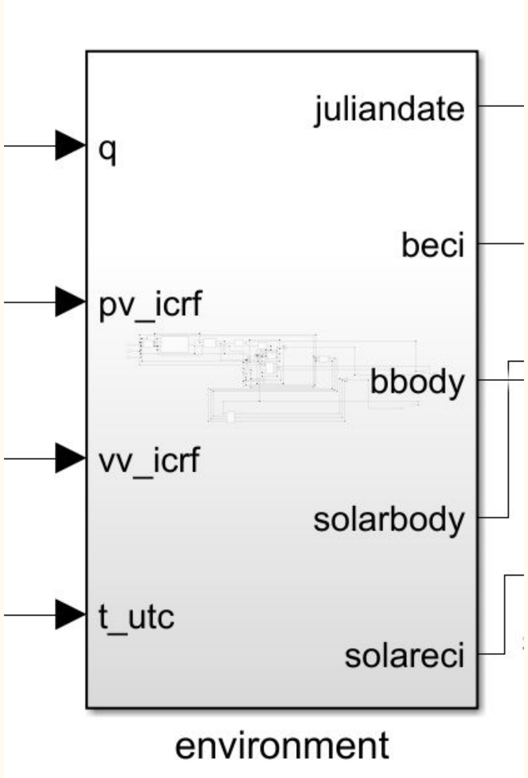


- Useful to represent attitude because a certain orientation will have the same quaternion wrt this frame irrespective of where the satellite is in orbit

Overview of model blocks

Environment Block

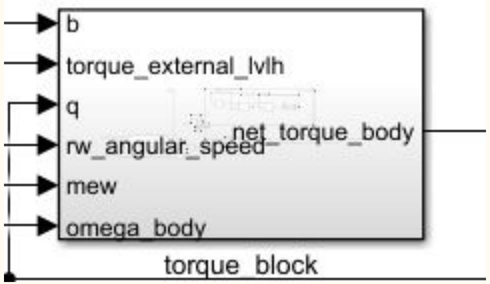
- Takes inputs from dynamics blocks and gives output informations regarding the environment of the satellite.
- Most of the blocks are frame conversions.
- References for magnetic model and sun vector calculations:
- https://in.mathworks.com/help/aeroblks/worldmagneticmodel.html
- https://in.mathworks.com/matlabcentral/fileexchange/78766-approxecisunposition



Overview of model blocks

Torque Block

- Takes external torque with respect to LVLH frame, reaction wheel angular speed and magnetic moment as well as field with respect to body frame, as well as quaternion from dynamics block, and runs scripts and blocks to output net torque with respect to body frame.
- Many blocks are frame conversions

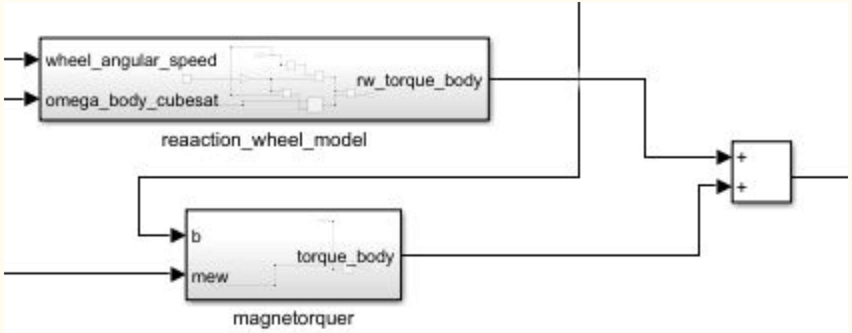


Overview of model blocks

Torque Block- Actuator Modelling is within the block

- Magnetorquer- T= mew cross B
- Reaction Wheel torque model reference: Analytical Mechanics of Aerospace Systems
- Formula used:

$$-\hat{\boldsymbol{g}}_s J_s \dot{\Omega} - \boldsymbol{\omega} \times J_s \Omega \hat{\boldsymbol{g}}_s$$

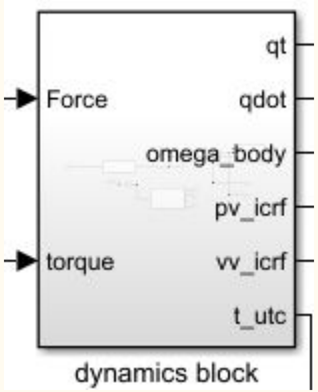


- gscap- uv in direction of rw axis in body frame
- Js- MOI of RW wrt axis(scalar)
- CapOmega- angular speed of RW in body frame
- SmallOmega- angular speed of satellite projected on body frame

Overview of model blocks

Dynamics Block

- Takes net force(other than gravity) wrt ICRF as input and outputs the orbital propagation(pv, vv and time)
- Takes net torque with respect to body frame from torque block, and propagates the quaternion. Formulae used:
- 1. $[I]\dot{\boldsymbol{\omega}} = -\boldsymbol{\omega} \times [I]\boldsymbol{\omega} + \boldsymbol{L}$ L: net torque body frame, [I]: inertia matrix wrt body frame
- 2. Quaternion propagation formula using omega_wrt_body



Body frame

- Perpendicular to faces of the cube
- Z is that which points towards earth when satellite is in nadir pointing mode
- Reaction wheel axis points along Y-axis.

Pendencies

- More detailed documentation of each part of the model
- Accounting for albedo and shadow in solar vector
- Linearised reduced order control model