Title			Document No.	Rev
Kepler Solar Pressure Torque Tables			SER.ACS.016	Orig
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Introduction

A high fidelity finite element model of the Kepler spacecraft was used to create solar pressure torque look-up tables to support momentum management calculations for on-orbit operations. Only the look-up tables are discussed in this report; details on the model can be found in Kepler.DFM.ACS.092.

Solar pressure torque model results

Figure 1 below shows the spacecraft configuration and the spacecraft body frame coordinate system. The X-axis is aligned with the photometer boresight, the Y-axis is aligned with the solar array "normal" vector, and the Z-axis completes the right-handed orthogonal triad.

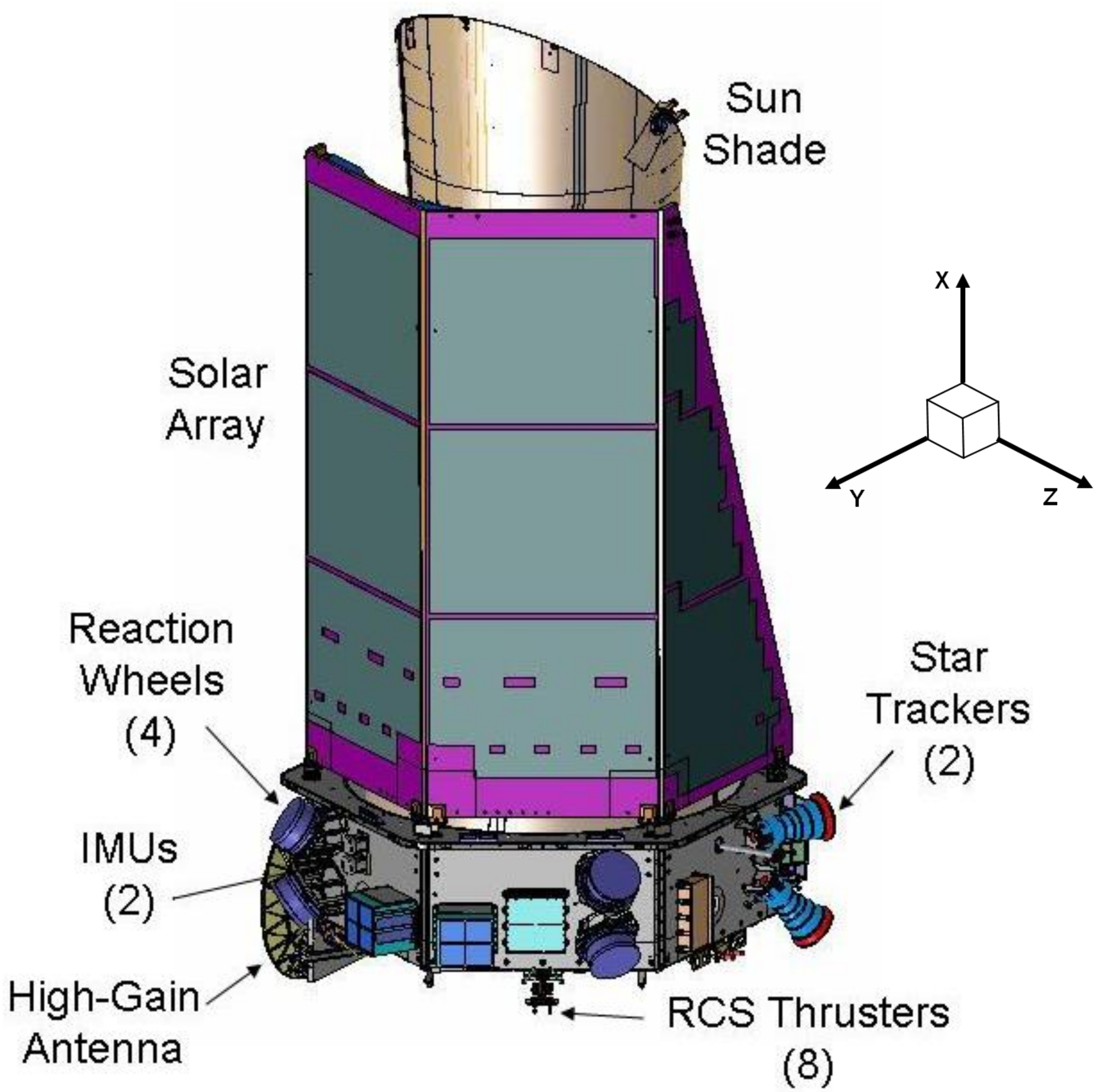

Figure 1
Kepler Spacecraft Attitude Components

The look-up tables are arranged with respect to the elevation and azimuth angles of the body frame Sun vector. Figure 2 below depicts the convention used for elevation and azimuth: azimuth represents a rotation of the vector about the Z-axis, and elevation is out of the XY-plane. The solar array normal is represented by an azimuth angle of 90° and an elevation angle of 0°. Solar pressure torque tables are populated in the region around the solar array normal because this is where the spacecraft is operated to remain power positive and to avoid Sun keep-out regions.

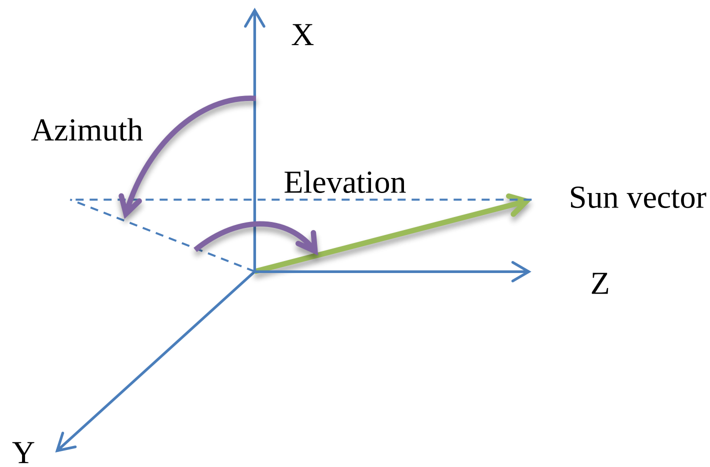

Figure 2. Azimuth and elevation convention

Specifically, elevation and azimuth angles can be computed from the sun vector:

Elevation = asin(sun_vect(3))
Azimuth = atan(sun_vect(2)/sun_vect(1))

Solar pressure torque values are computed for elevation angles from -45° to 45° at 1° increments, and for azimuth angles from 40° to 140° in 1° increments.

Figures 3, 4, and 5 show the X-axis, Y-axis, and Z-axis solar radiation pressure torques, respectively. For regions near the XY-plane, the X-axis and Y-axis components of the SRP torques are very small. Two-wheel operation in this region is ideal because a momentum biased system can still provide very stable pointing. Exact trim points (balance of torques) are available if the time to find them can be taken.

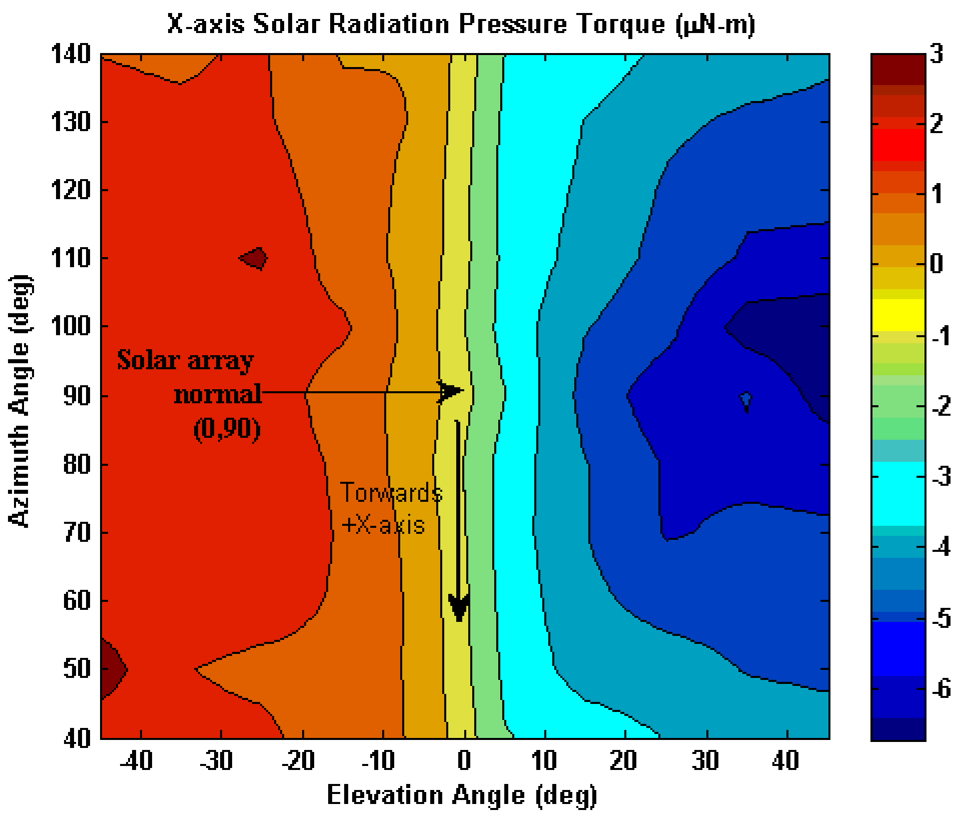

Figure 3. X-axis SRP torque contours demonstrate a strong function with respect to elevation angle (sun vector out of X/Y plane)

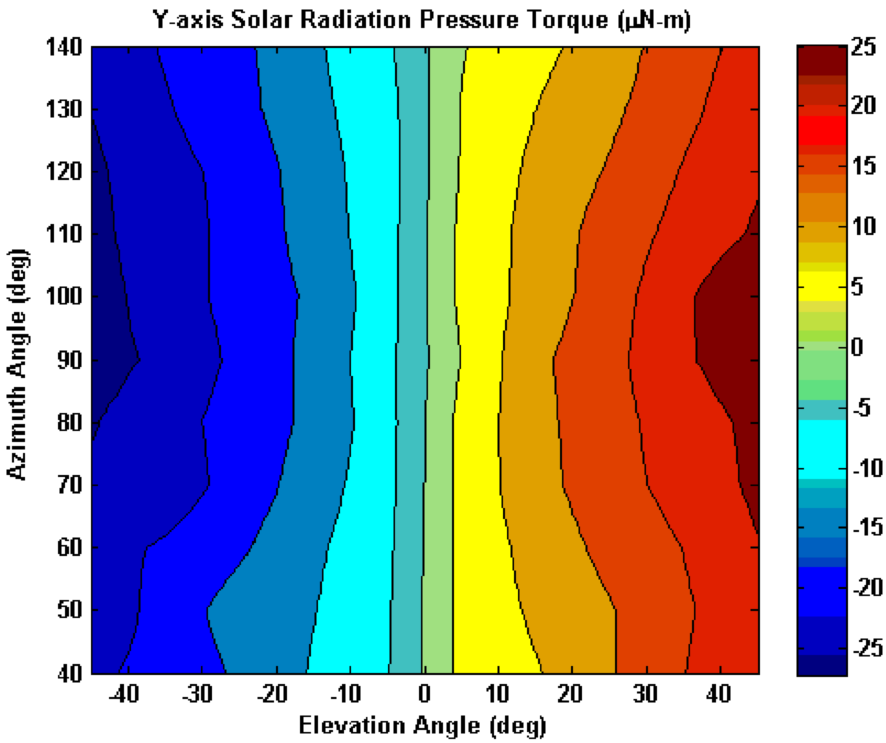

Figure 4. Y-axis SRP torque is a strong function of sun vector elevation angle

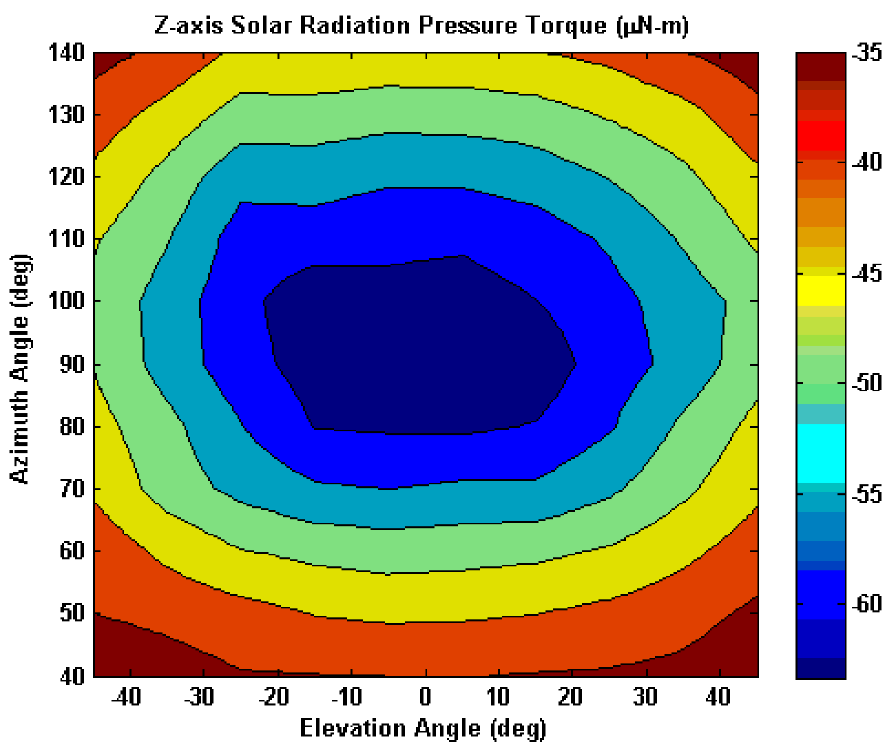

Figure 5. Z-axis SRP torque is maximimzed at the solar array normal

Figure 6 belows shows a plot generated for the third Kepler Year-in-Review report, comparing flight calculated values of SRP torques (from momentum accumulation) to preflight predictions. Preflight predictions for the X- (blue) and Y-axes (green) appear very close to the on orbit measurements, and the Z-axis (red) predictions are about 20% greater than the on orbit values.

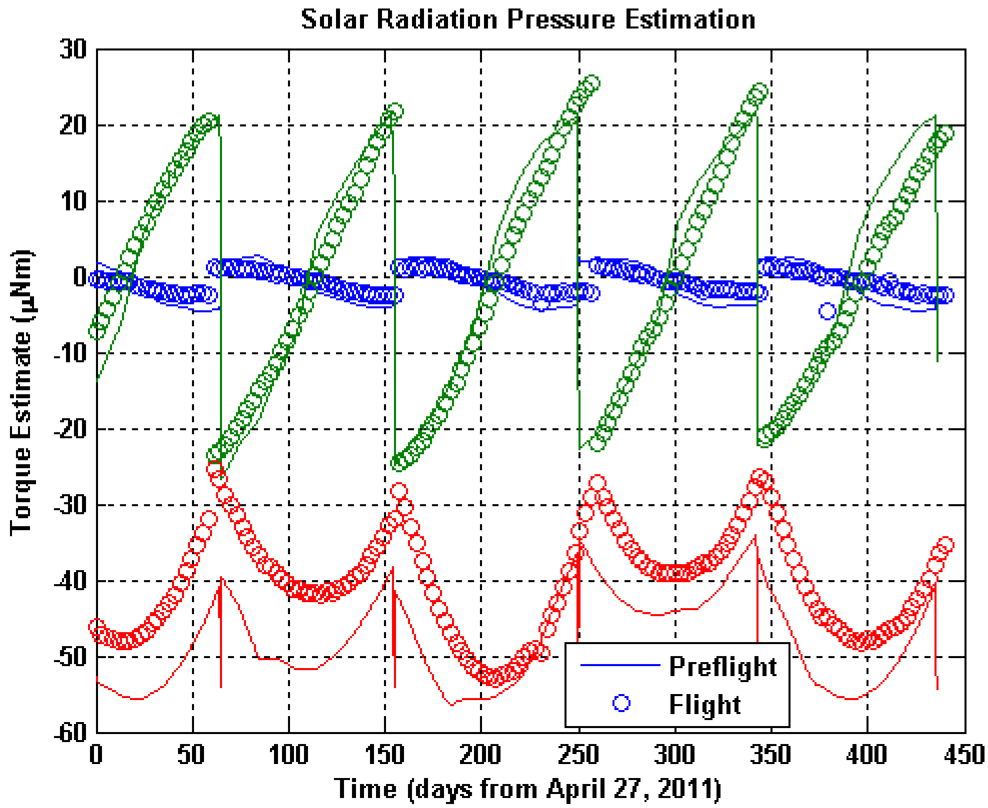

Figure 6. The comparison between flight values and preflight predictions of solar radiation pressure torque are very favorable.

This solar pressure model can be easily integrated into a Matlab simulation of the flight dynamics. Code is supplied in the appendix.

Summary

The solar pressure model for the Kepler spacecraft matches flight data very well. For future mission planning, the X- and Y-axes of the table look-up can be used directly and a simple scalar value (0.8) can be applied to the Z-axis torque to make it match flight data more accurately. A 2-dimensional table look-up can quickly be integrated into dynamic simulations.

Appendix – Matlab code

The Matlab code below can be used to integrate the solar pressure torque model in to a dynamic simulation. Data is attached in a .zip file at the bottom of the page (no icon).

Load data in a script or from workspace:

```
load Kepler_torques_t_no_cover
TorqSunX = Tx_t_interp';
TorqSunY = Ty_t_interp';
TorqSunZ = Tz_t_interp';
elvec = -45:45;
azvec = 40:140;
```

Look-up table subroutine

```
%   Solar radiation pressure torque calculation
%   Utilizes 2-D table lookups based on the output of SPAD model
%
%   sp_torque = srp_torque(sun_vect,AZ_vect,EL_vect,Tx,Ty,Tz);
%
%   Inputs
%        sun_vect - body frame spacecraft to sun vector             (3 x 1)
%        AZ_vect  - vector of azimumth angles for torque table      (n x 1)
%        EL_vect  - vector of elevation angles for torque tables    (m x 1)
%        Tx       - X-axis torque table values                      (n x m)
%        Ty       - Y-axis torque table values                      (n x m)
%        Tz       - Z-axis torque table values                      (n x m)
%    Output
%        sp_torque - body frame solar pressure torque               (3 x 1)


function sp_torque = srp_torque(sun_vect,AZ_vect,EL_vect,Tx,Ty,Tz);

el = asin(sun_vect(3))*180/pi;
az = atan2(sun_vect(2),sun_vect(1))*180/pi;

%  check to see if sun vector is within the range of the SPAD data
if el > min(EL_vect) & el < max(EL_vect) & az > min(AZ_vect) & az < max(AZ_vect)
   sp_torque(1,1) = interp2(EL_vect,AZ_vect,Tx,el,az);
   sp_torque(2,1) = interp2(EL_vect,AZ_vect,Ty,el,az);
   sp_torque(3,1) = interp2(EL_vect,AZ_vect,Tz,el,az);
else
   sp_torque = [0;0;0];
end
```

Kepler_torques_t_no_cover.zip