SDP Modal Identification

- Using the methods of Lai and Bhavnani (1975) an analytic estimate of the system modes for a spacecraft consisting of a base-body and four radial (symmetrically deployed) booms.
- McGee, Shankar, and Kemp, "Analysis of Spinning Spacecraft with Wire Booms Part 2: Out of Plane Dynamics and Maneuvers", AIAA 2009

SDP Modal Identification

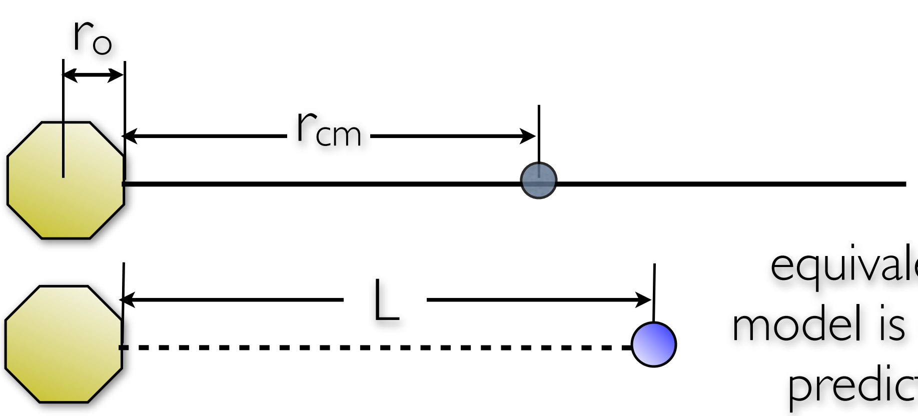
Pure Uncoupled "Crab" Mode

$$\omega_4 = \omega_s \sqrt{\frac{r_o}{L}}$$

r_o is the radius to boom attach point

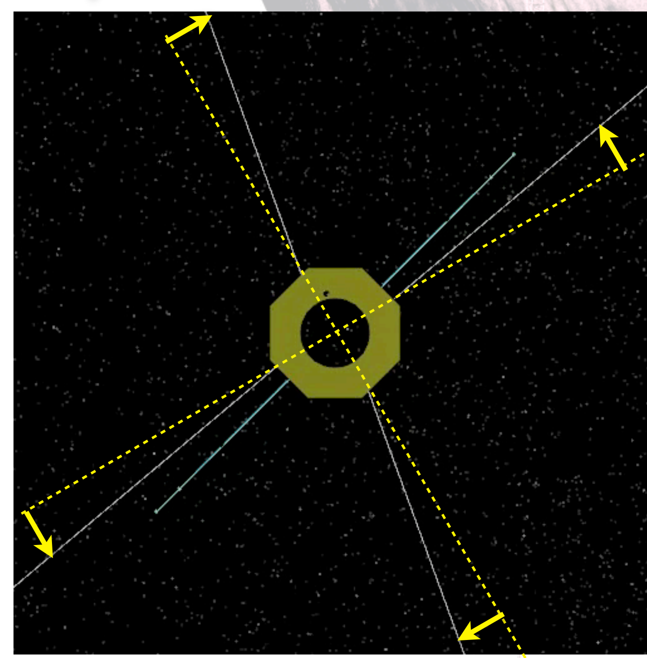
L is the "effective" length of the boom

$$L = \sqrt{\frac{I_{cm} + m r_{cm}^2}{m}} = 42.875 \text{ kg-m}^2$$



equivalent point mass model is used for analytic prediction (not sim)

Spin Plane Motion



SDP Modal Identification

Uncoupled “Flex” Mode with Translation

$$\omega_{5,6} \simeq \omega_s \sqrt{\frac{r_o}{L}} \left(1 + \frac{m}{M} \cdot \frac{L + r_o}{r_o}\right)$$

r_o is the radius to boom attach point

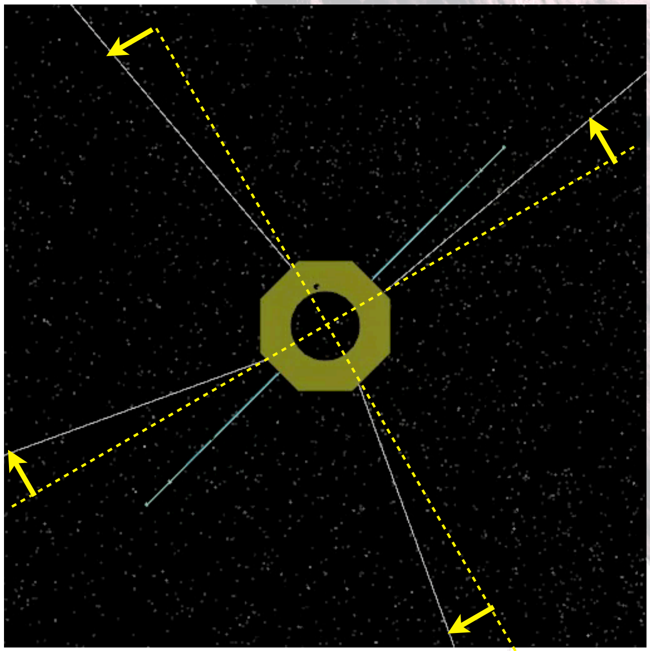
L is the “effective” length of the boom

m is the mass of the boom

M is the mass of the base body

ω_s is the spin rate

Spin Plane Motion



SDP Modal Identification

Coupled "Twist" Mode

$$\omega_7 = \omega_s \sqrt{\frac{r_o}{L} \cdot \frac{I_s + 4m\left(r_o + L\right)^2}{I_s}}$$

r_o is the radius to boom attach point

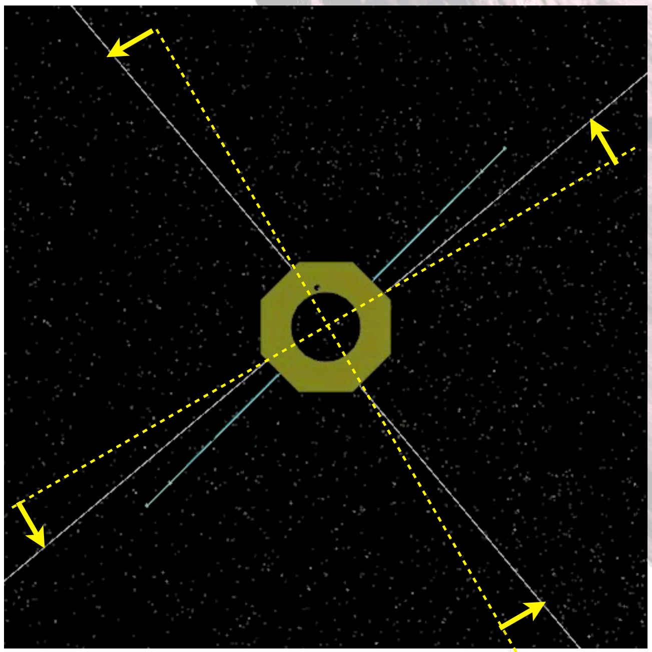
L is the "effective" length of the boom

I_s is the spin-axis inertia of the base

m is the mass of the boom

ω_s is the spin rate

Spin Plane Motion



SDP Modal Identification

Coupled "Twist" Mode

$$\omega_{11,12} = \omega_s \sqrt{\frac{L + r_o}{L} \cdot \frac{I_t + 2m\left(r_o + L\right)^2}{I_t}}$$

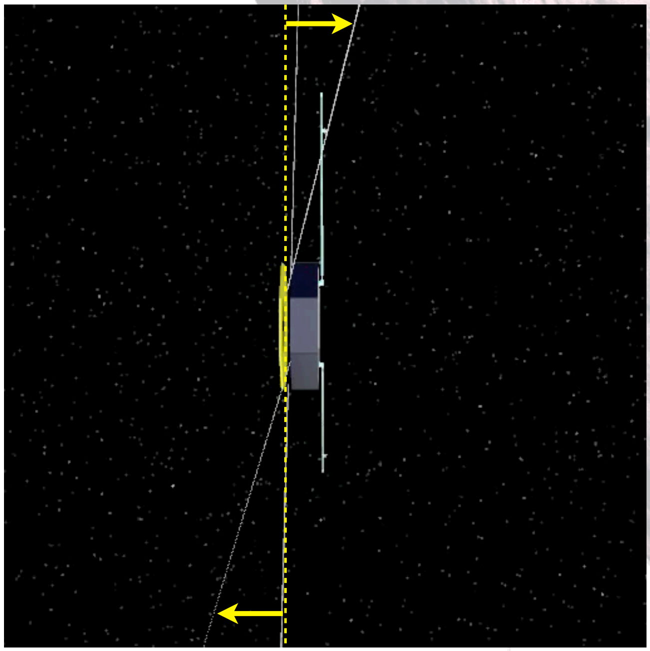
r_o is the radius to boom attach point

L is the "effective" length of the boom

I_t is the transverse inertia of the base

ω_s is the spin rate

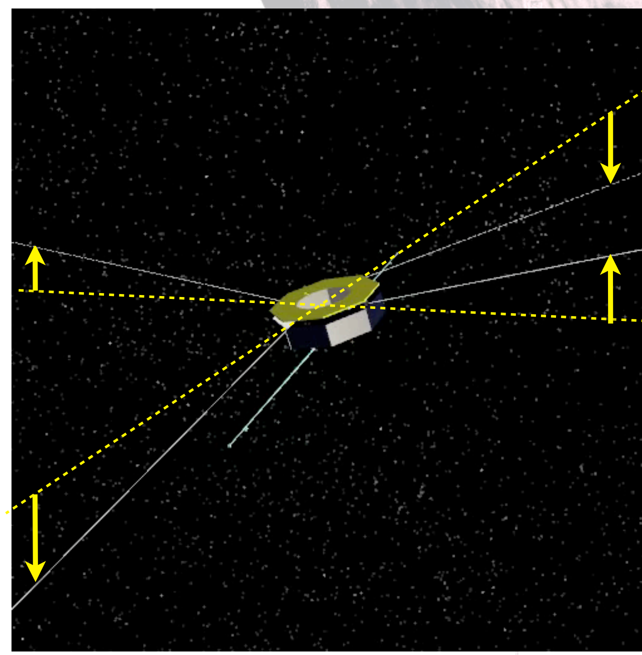
Out-of-Plane Motion



SDP Modal Identification

Coupled "Saddle" Mode

Out-of-Plane Motion



$$\omega_{13} = \omega_s \sqrt{\frac{L + r_o}{L}}$$

r_o is the radius to boom attach point

L is the "effective" length of the boom

ω_s is the spin rate

SDP Modal Identification

Coupled “Jellyfish” Mode

$$\omega_{14} = \omega_s \sqrt{\frac{L + r_o}{L} \frac{M + 4m}{M}}$$

r_o is the radius to boom attach point

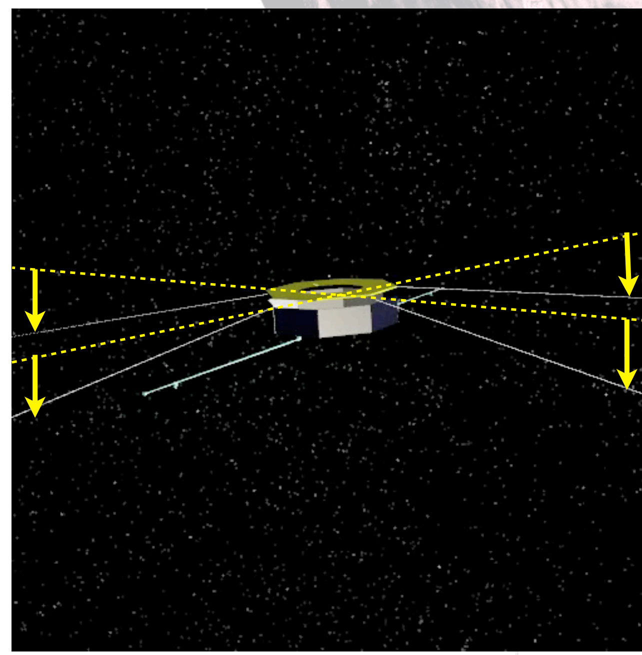
L is the “effective” length of the boom

m is the mass of the boom

M is the mass of the base body

ω_s is the spin rate

Out-of-Plane Motion



SDP Modal Identification

Frequency Summary for Fully Deployed Configuration

Mode Designations			Predicted ✳		Simulated ✳		Error
Name	Spin Plane	Id	Hz	sec	Hz	sec	%
Uncoupled (Crab)	In	ω_4	0.00983	101.73	0.00995	100.50	1.21
Uncoupled + Translation (Flex)	In	ω_5, ω_6	0.00996	100.40	0.01007	99.30	1.09
Coupled (Twist)	In	ω_7	0.01787	55.96	0.01813	55.16	1.43
Uncoupled (Saddle)	Out	ω_{13}	0.05096	19.62	0.05096	19.62	0.00
Jellyfish	Out	ω_{14}	0.05100	19.61	0.05103	19.60	0.06
Mutual Precession	Shape	-	0.05237	19.09	0.05103	19.60	2.63
Boom Nutation	Shape	-	0.05066	19.74	0.05103	19.60	0.73
Hub Nutation	Shape	-	0.02202	45.41	0.01990	50.25	10.65
✳ Base-body includes Mag Boom+ADP+Fuel (40% fill) rigid approximation							