3rd Annual Microgravity Environment Interpretation Tutorial

Microgravity Advanced Research and Support Center

QUASI-STEADY ACCELERATION ONBOARD INTERNATIONAL SPACE STATION

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GRAVITY GRADIENT (1)

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Considering a platform on a circular orbit. In the center of mass we have:

$$g_o \frac{R_o^2}{R^2} = \omega^2 R$$

Where g_o is the value of acceleration at see level, R_o is the Earth radius, ω is the orbital angular velocity and R is the orbit radius.

The gravity gradient can be computed by considering a point located at a distance ℓ separately for the three cases along x, along y and along z axes

1) ℓ along z

It is the simplest case and we have to substitute (R$\pm$ ℓ) to R and carry out a linearization process

$$\mu g = g_o \frac{R_o^2}{(R \pm \ell)^2} - \omega^2 (R \pm \ell) = g_o \frac{R_o^2}{R^2}\left(1 \pm \frac{\ell}{R}\right)^{-2} - g_o \frac{R_o^2}{R^3}(R \pm \ell) =$$

$$= g_o \frac{R_o^2}{R^2}\left[\left(1 \pm \frac{\ell}{R}\right)^{-2} - \left(1 \pm \frac{\ell}{R}\right)\right] \quad \pm 3 g_o \frac{R_o^2}{R^2}\frac{\ell}{R}$$

GRAVITY GRADIENT (2)

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2) ℓ along x

In this case you have to substitute $(R^2 + \ell^2)^{1/2}$ to R since R, ℓ and r form a rectangular triangle, where r is the hypotenuse:

$$\mu g = g_o \frac{R_o^2}{R^2+\ell^2} - \omega^2\left(R^2+\ell^2\right)^{\frac{1}{2}} = g_o \frac{R_o^2}{R^2}\left(1+\frac{\ell^2}{R^2}\right)^{-1} +$$

$$-g_o \frac{R_o^2}{R^2}\left(1+\frac{\ell^2}{R^2}\right)^{\frac{1}{2}} \quad \frac{3}{2} g_o \frac{R_o^2}{R^2}\frac{\ell^2}{R^2} \quad 0$$

2) ℓ along y

In this case the centrifugal force is the same. You have to project g along y taking into account that R, ℓ and r form a rectangular triangle, where r is the hypotenuse: :

$$\mu g = g_o \frac{R_o^2}{\left(R^2+\ell^2\right)^{\frac{3}{2}}}\left(R\mathbf{k}+\ell\mathbf{j}\right)\ \mathbf{j} = g_o \frac{R_o^2}{\left(R^2+\ell^2\right)^{\frac{3}{2}}}\ell \quad g_o \frac{R_o^2}{R^2}\left(1-\frac{3}{2}\frac{\ell^2}{R^2}\right)\frac{\ell}{R}$$

$$g_o \frac{R_o^2}{R^2}\frac{\ell}{R}$$

DAC5 ASSEMBLY COMPLETE MICROGRAVITY ISO-G CONTOURS

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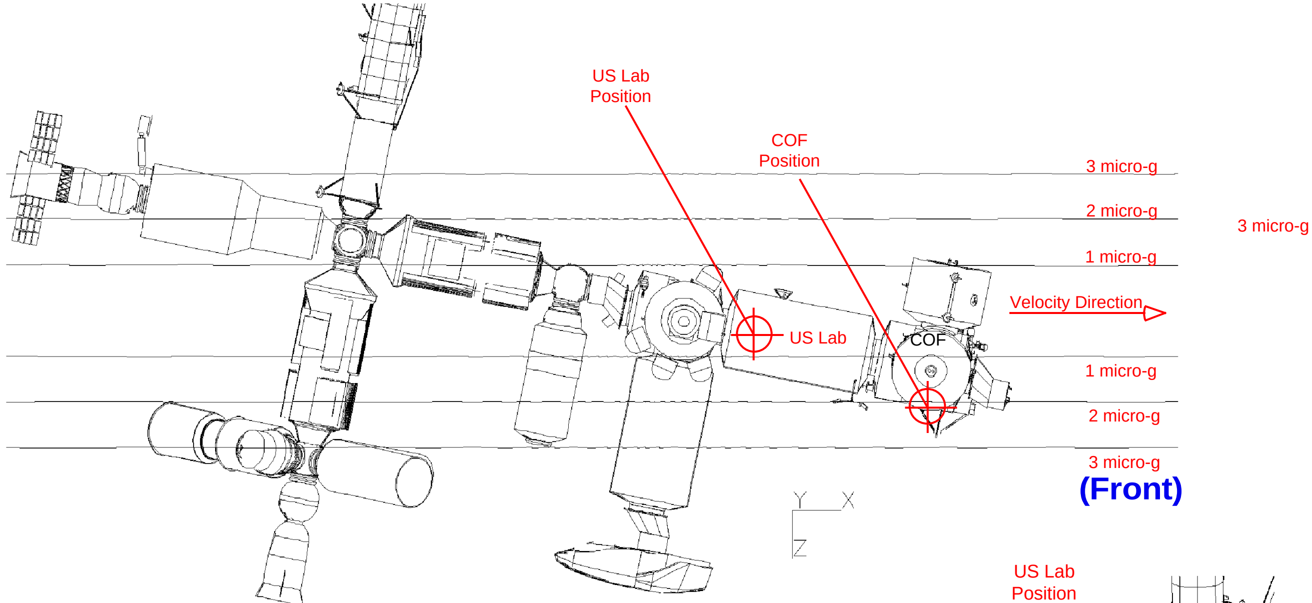
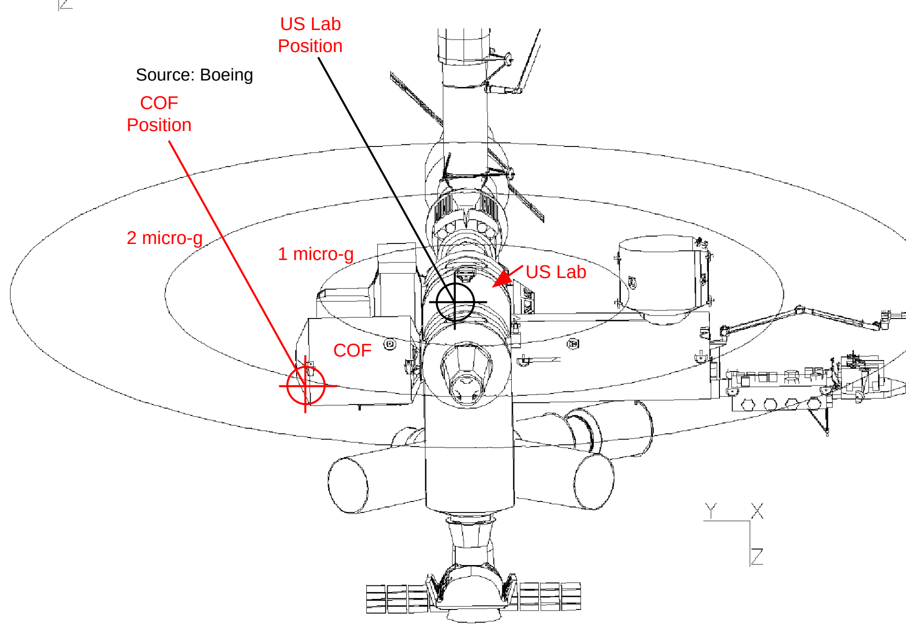
(Side)



(Front)



Source: Boeing

ISS Artistic View (Top)

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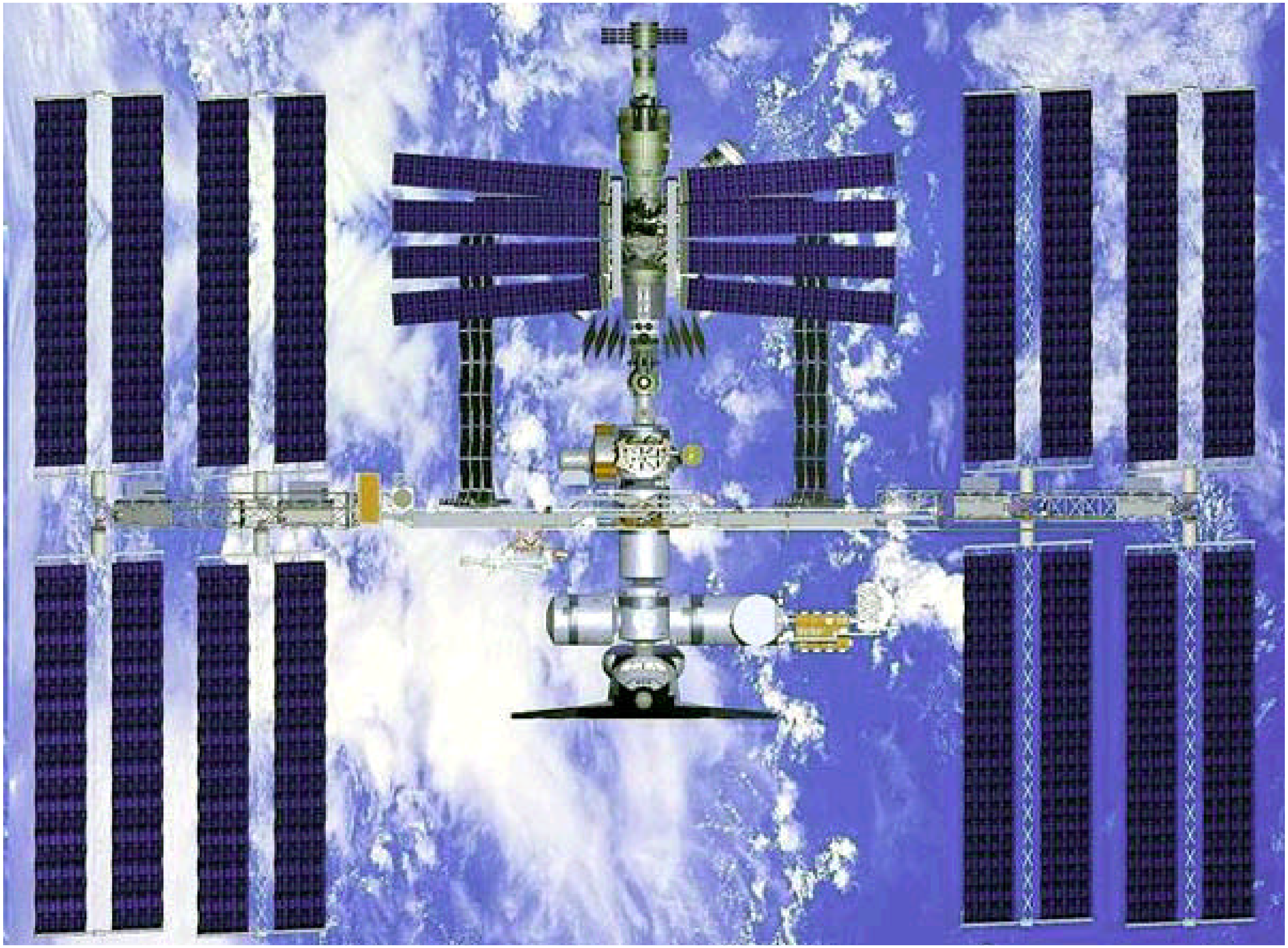
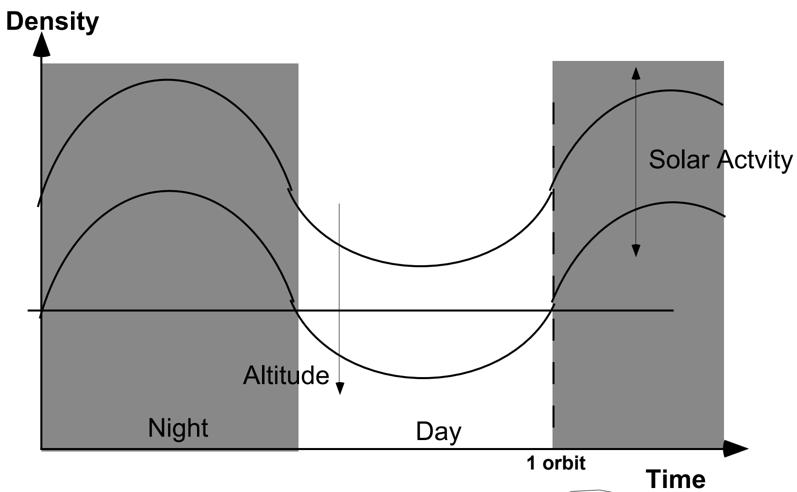
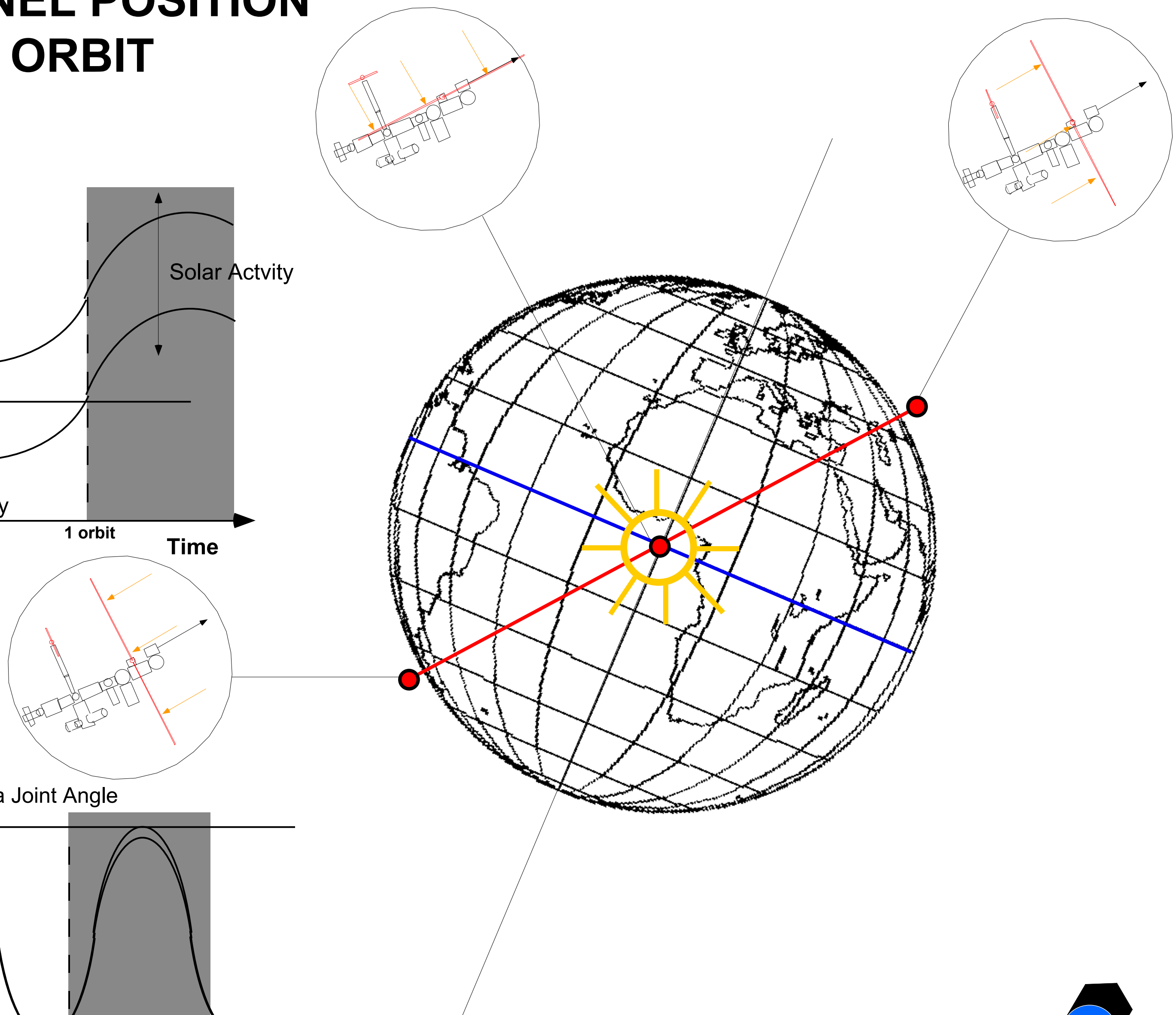
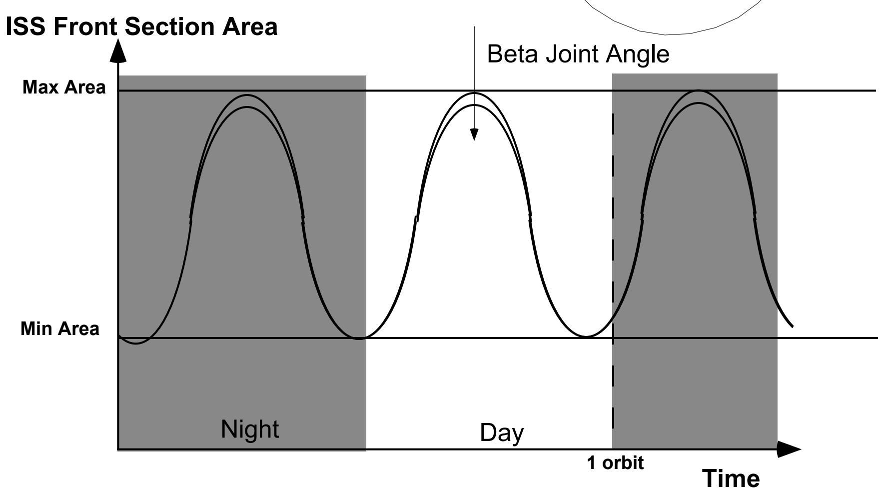


Source: Boeing

ISS SOLAR PANEL POSITION DURING ORBIT







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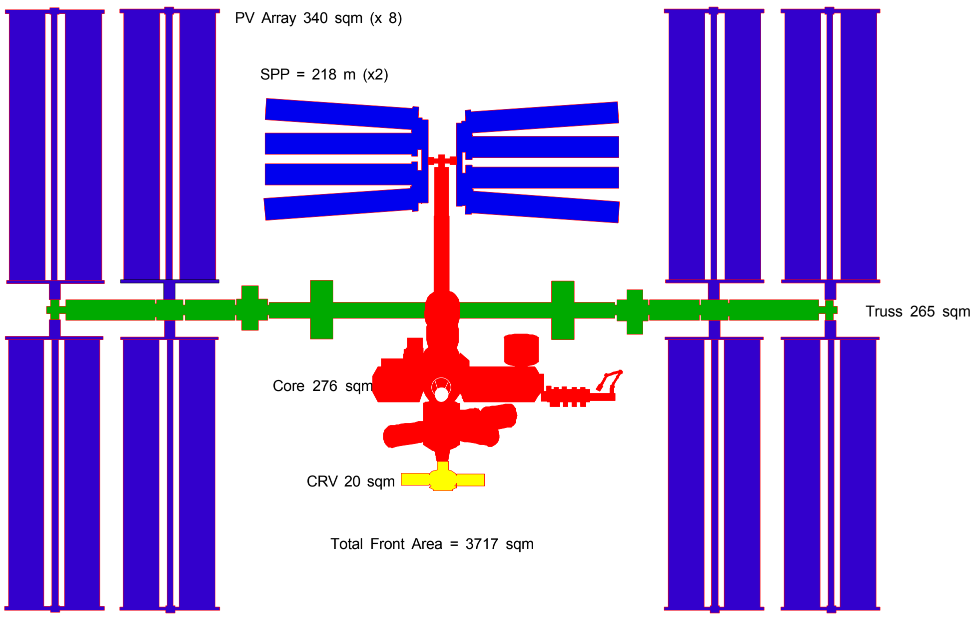
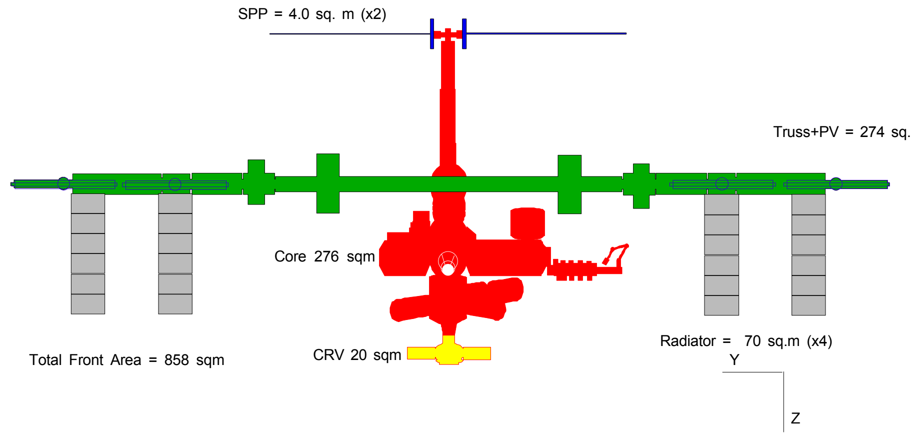
ISS RESIDUAL-g EVALUATION: aerodynamic drag contribution





maximum Drag:

Total Front Area = 3717 sqm
Altitude = 352.000 m
Velocity = 7694 m/s
Air Density = 7 x 10^{-12} Kg/m^3
Cd = 2.5

Drag X = 1.92 N
ISS Mass = 419.000 Kg

Acceleration X = 4.68 x 10^{-7} g_0

minumum Drag:

Total Front Area = 858 sqm
Altitude = 352.000 m
Velocity = 7694 m/s
Air Density = 7 x 10^{-12} Kg/m^3
Cd = 2.5

Drag X = .44 N
ISS Mass = 419.000 Kg

Acceleration X = 1.1 x 10^{-7} g_0

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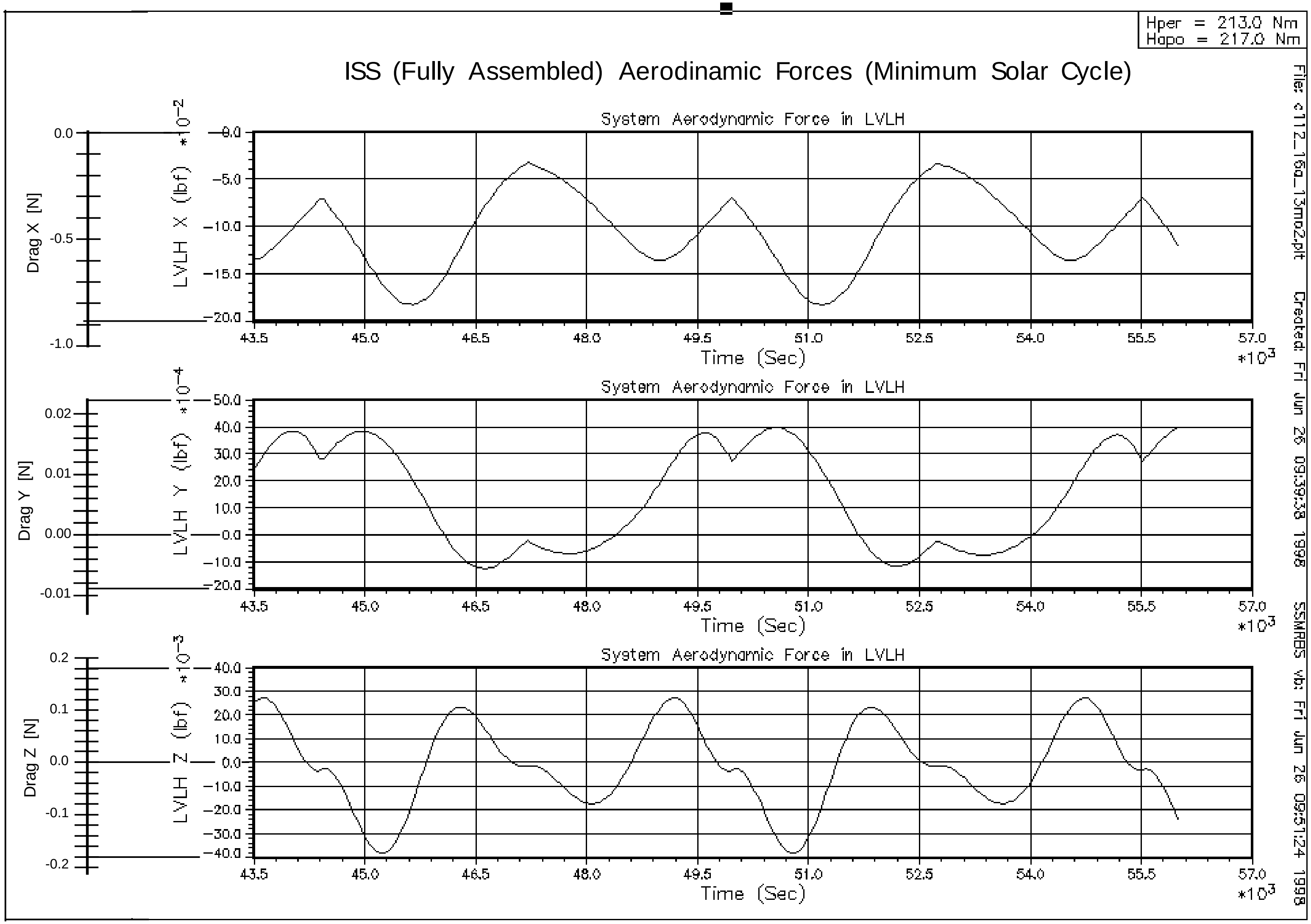

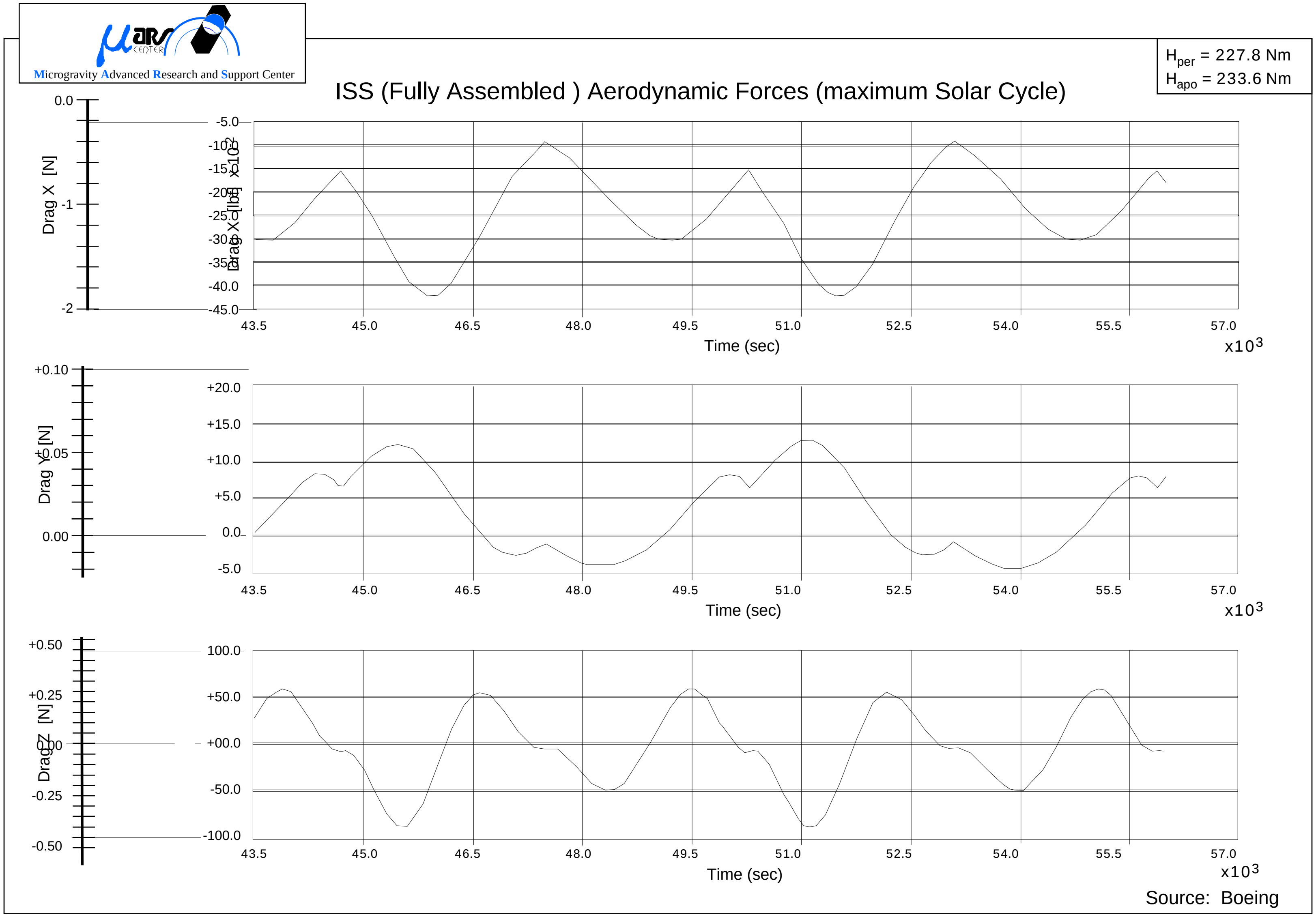
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ISS (Fully Assembled) Aerodynamic Forces (maximum Solar Cycle)
H_{per} = 227.8 Nm
H_{apo} = 233.6 Nm
Drag X [N]
Drag X [lbf] x10-3
Time (sec)
Drag Y [N]
Drag Z [N]
x10^3
Source: Boeing

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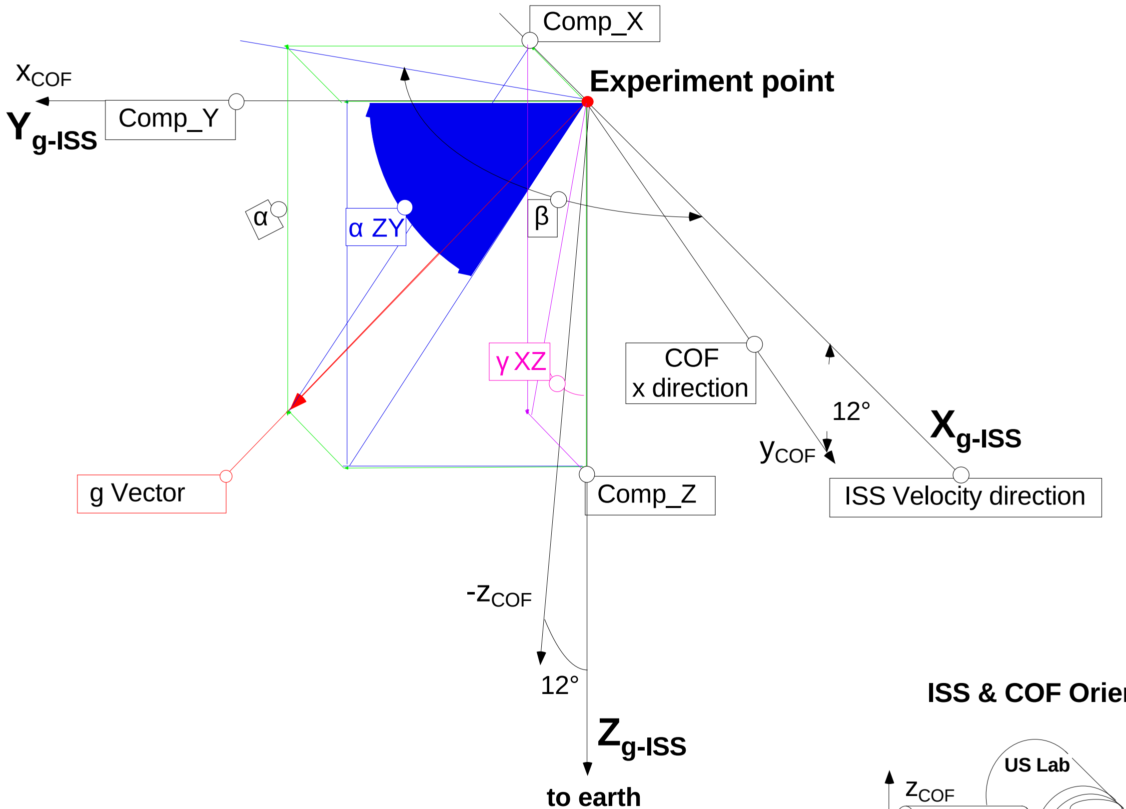
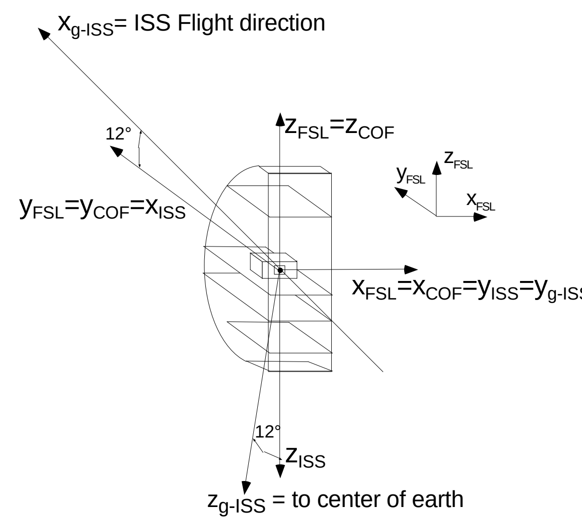
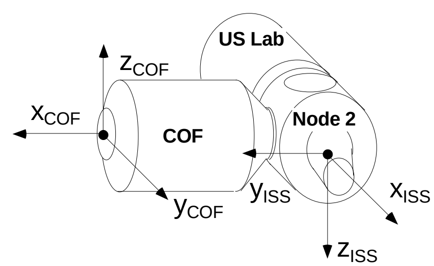
Coordinates systems, Vectors and Angles used in the description of the residual g

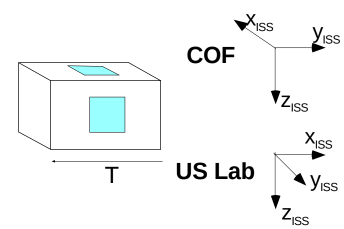




FSL Orientation

ISS & COF Orientation





Orientation respect to the cell

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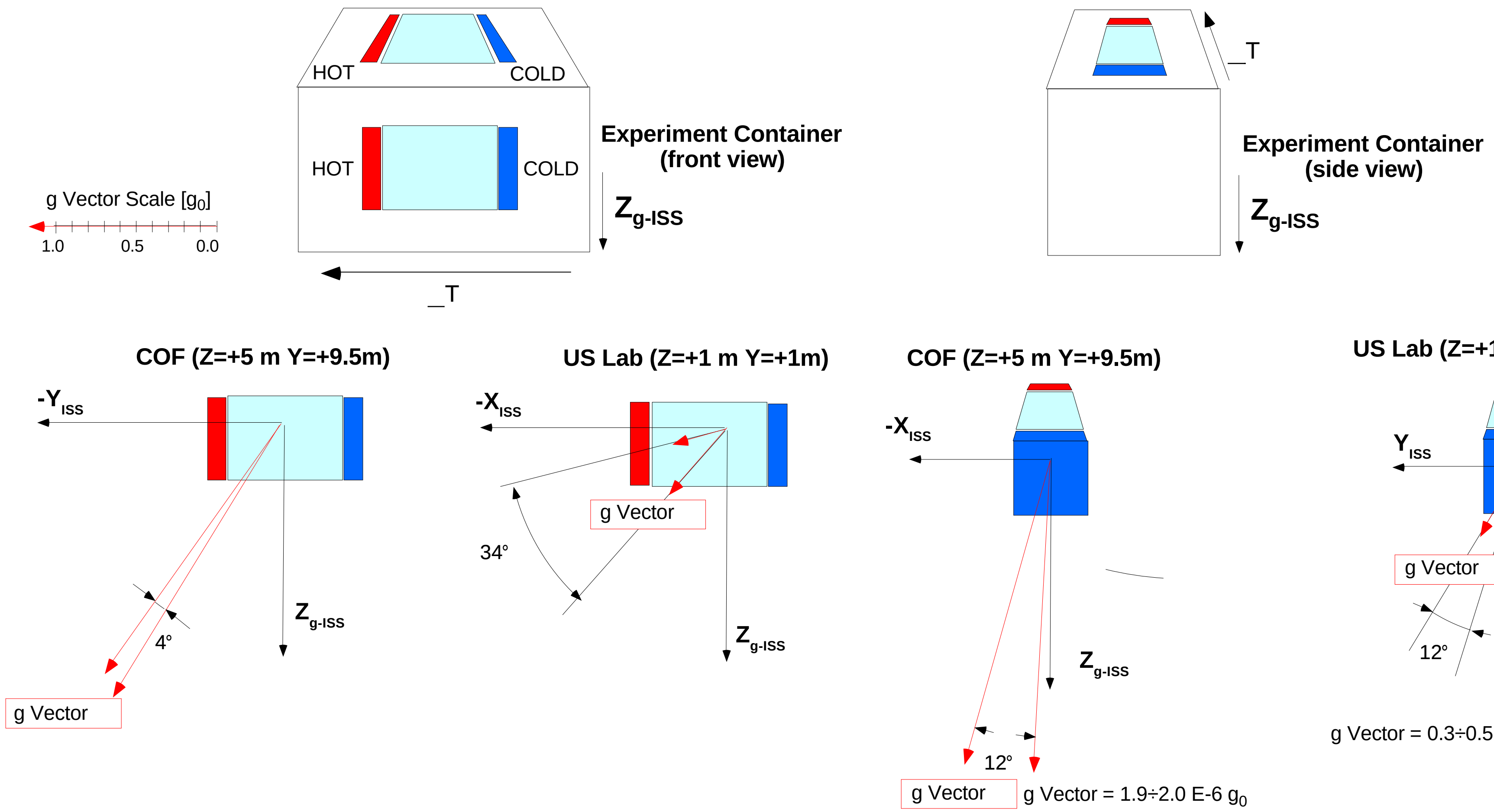
Variation range of residual-g directions and module during ISS Orbit (g-vectors are in scale)



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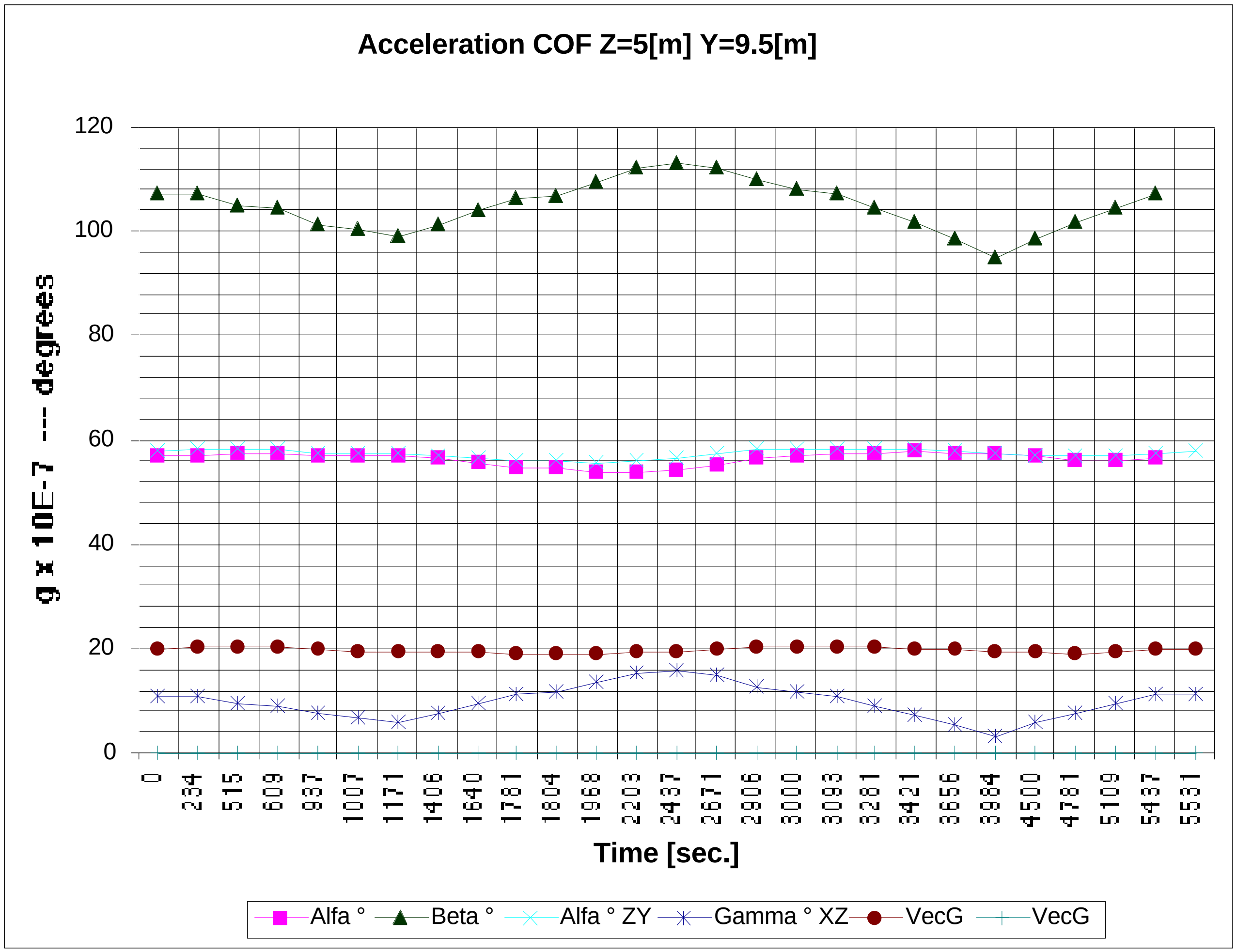

Time evolution of residual-g directions and module during ISS Orbit (inside COF)

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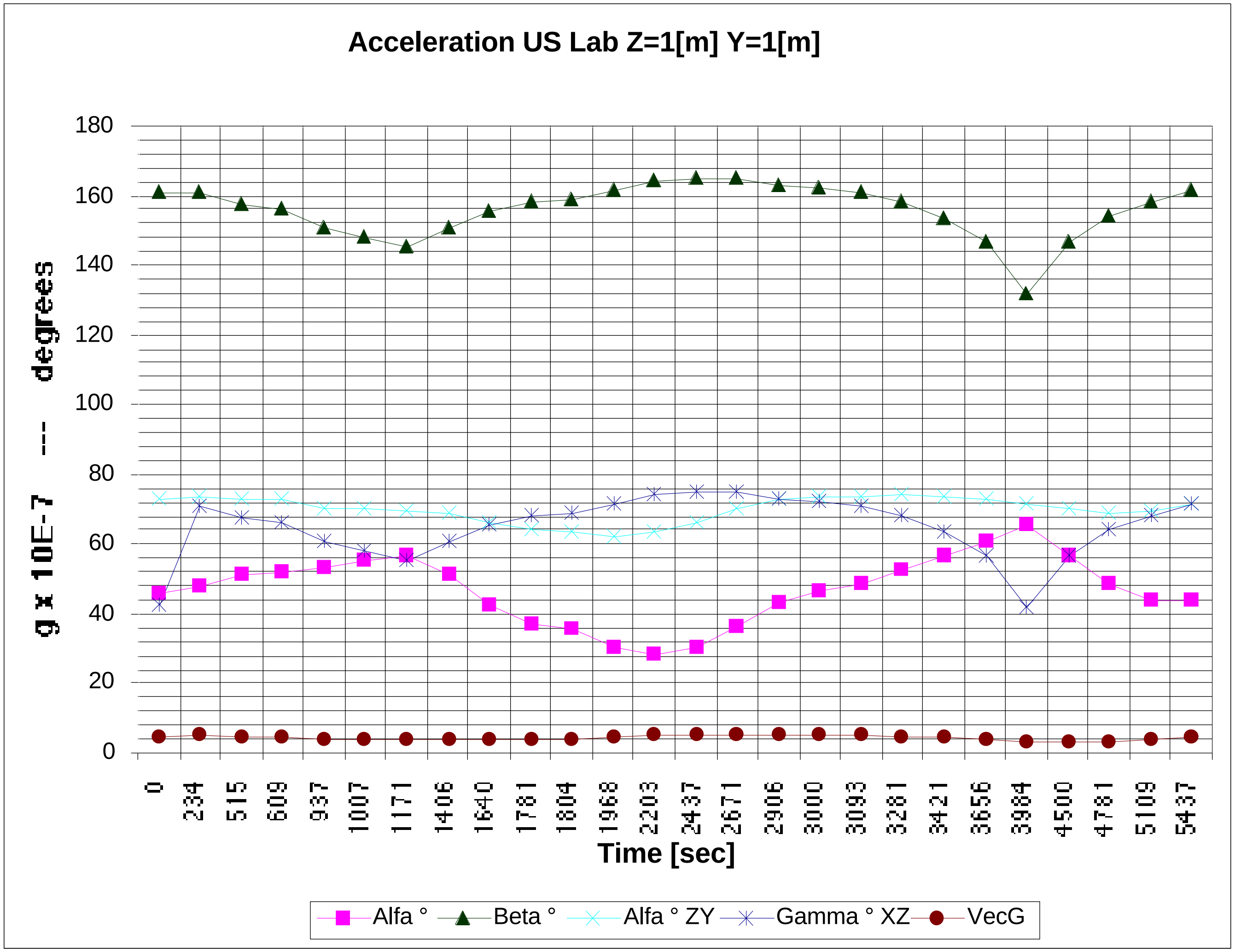

Time evolution of residual-g directions and module during ISS Orbit (inside US Lab)

INTERNATIONAL SPACE STATION

DAC5 Quasi-Steady Microgravity Assessment

DAC5 ASSEMBLY COMPLETE PERFORMANCE

Location	Magnitude	Stability	Unit Vector Components			Angle
(ISPRs)	(µg)	(µg)	X	Y	Z	(deg)
USL-C1	**0.525**	0.126	0.641	-0.109	0.760	17.370
USL-C2	**0.468**	0.116	0.721	-0.133	0.680	20.710
USL-C3	**0.419**	0.100	0.819	-0.165	0.549	24.820
USL-C4	**0.380**	0.078	0.922	-0.204	0.330	28.370
USL-C5	**0.356**	0.064	0.972	-0.237	-0.002	25.280
USL-S1	1.062	0.145	0.385	-0.227	0.895	7.927
USL-S2	**0.989**	0.143	0.400	-0.248	0.883	8.421
USL-S3	**0.917**	0.141	0.417	-0.272	0.867	8.973
USL-S4	**0.846**	0.138	0.437	-0.300	0.848	9.859
USL-P1	1.019	0.145	0.396	0.166	0.903	8.310
USL-P2	**0.945**	0.143	0.413	0.180	0.893	8.866
USL-P4	**0.799**	0.138	0.458	0.215	0.862	10.230
JPM1-A1	1.250	0.150	0.348	0.333	0.877	7.015
JPM2-F1	1.480	0.154	0.325	0.282	0.903	6.095
JPM3-A2	1.296	0.151	0.334	0.433	0.838	6.819
JPM4-F2	1.519	0.154	0.316	0.370	0.874	5.979
JPM5-A3	1.355	0.151	0.318	0.520	0.793	6.570
JPM6-F3	1.569	0.155	0.305	0.450	0.839	5.824
JPM7-A4	1.425	0.152	0.301	0.594	0.746	6.288
JPM8-A5	1.505	0.153	0.284	0.657	0.699	5.992
JPM9-F5	1.700	0.156	0.280	0.584	0.762	5.441
JPM10-F6	1.778	0.157	0.266	0.638	0.723	5.234
APM-FWD1	1.605	0.155	0.305	-0.386	0.871	5.573
APM-FWD2	1.681	0.157	0.291	-0.465	0.836	5.370
APM-FWD3	1.768	0.159	0.277	-0.532	0.800	5.167
APM-FWD4	1.863	0.161	0.263	-0.590	0.763	4.968
APM-AFT1	1.397	0.152	0.318	-0.451	0.834	6.275
APM-AFT2	1.482	0.154	0.300	-0.534	0.791	5.989
APM-AFT3	1.578	0.157	0.282	-0.603	0.747	5.709
APM-AFT4	1.682	0.160	0.264	-0.659	0.704	5.450

Location	Magnitude	Stability	Unit Vector Components			Angle
(Others)	(µg)	(µg)	X	Y	Z	(deg)
USL-CG	0.793	0.137	0.466	-0.052	0.883	10.360
APM-CG	1.624	0.157	0.288	-0.533	0.795	5.547
APM-CLG1	1.010	0.151	0.350	-0.649	0.676	8.635
APM-CLG2	1.120	0.154	0.313	-0.726	0.612	7.944
RS-FGB	1.119	0.139	-0.003	-0.060	-0.998	7.802
RS-SM	2.179	0.129	-0.099	-0.038	-0.994	3.655
JEM-CG	1.811	0.157	0.244	0.745	0.621	5.143
JEF1-F1	2.954	0.165	0.223	0.627	0.746	3.325
JEF2-A1	2.613	0.160	0.218	0.706	0.674	3.646
JEF3-F2	3.039	0.167	0.216	0.658	0.722	3.265
JEF4-A2	2.710	0.162	0.209	0.734	0.646	3.558
JEF5-F3	3.129	0.169	0.209	0.685	0.698	3.208
JEF6-A3	2.811	0.164	0.201	0.760	0.619	3.477
JEF7-F4	3.223	0.171	0.203	0.710	0.674	3.155
JEF8-A4	2.915	0.167	0.194	0.782	0.593	3.401
JEF9-O1	3.303	0.174	0.188	0.771	0.608	3.135
JEF10-O2	3.091	0.174	0.174	0.838	0.517	3.334
JEF11-U1	2.456	0.169	0.184	0.861	0.474	4.064
JEF12-U2	2.553	0.171	0.170	0.890	0.423	3.955
S3LO	3.299	0.223	0.038	-0.994	-0.104	3.918
S3LI	2.945	0.212	0.042	-0.991	-0.124	4.180
S3UO	3.958	0.209	-0.056	-0.846	-0.530	3.142
S3UI	3.644	0.196	-0.062	-0.810	-0.584	3.222
P3LO	3.260	0.191	0.022	0.973	-0.231	3.355
P3UO	4.043	0.176	-0.068	0.780	-0.622	2.494

10 ISPRs Have Quasi-Steady Magnitude </= 1.0 µg