Characterization and Simulation of ST-7 Experiments

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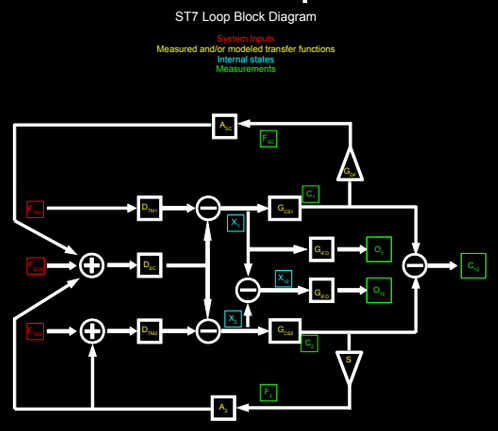
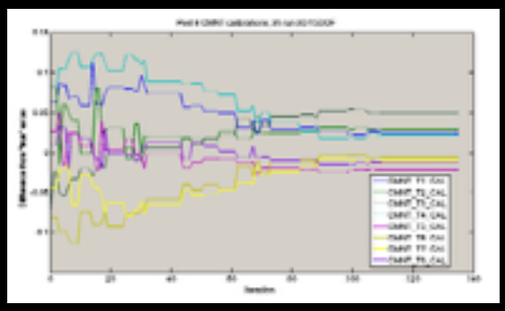
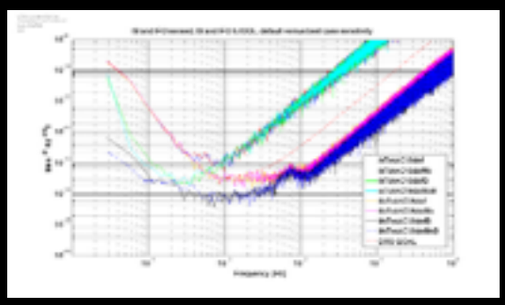


LISA SYMPOSIUM X
Tuesday, May 20th, 2014
Gainesville, FL





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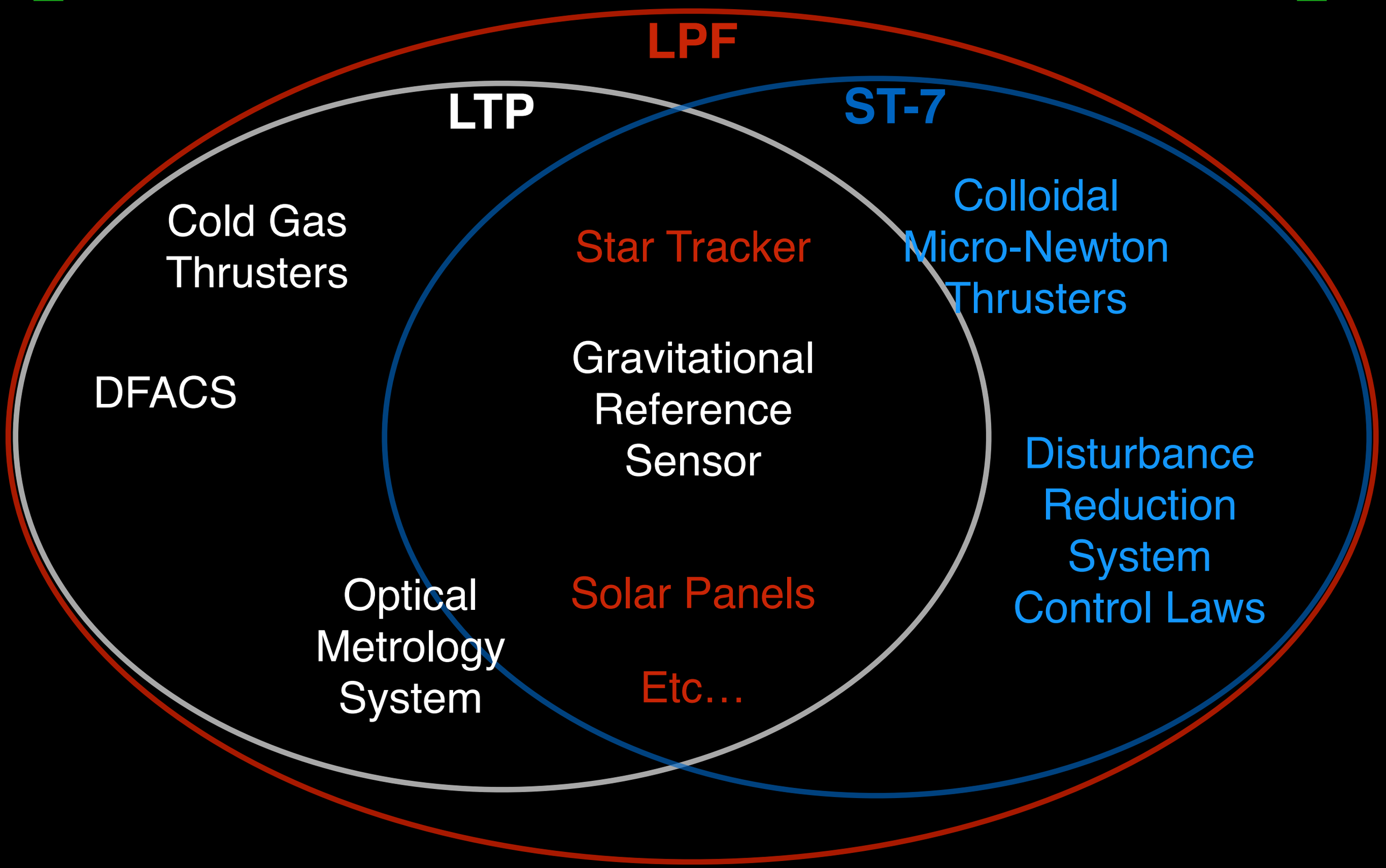
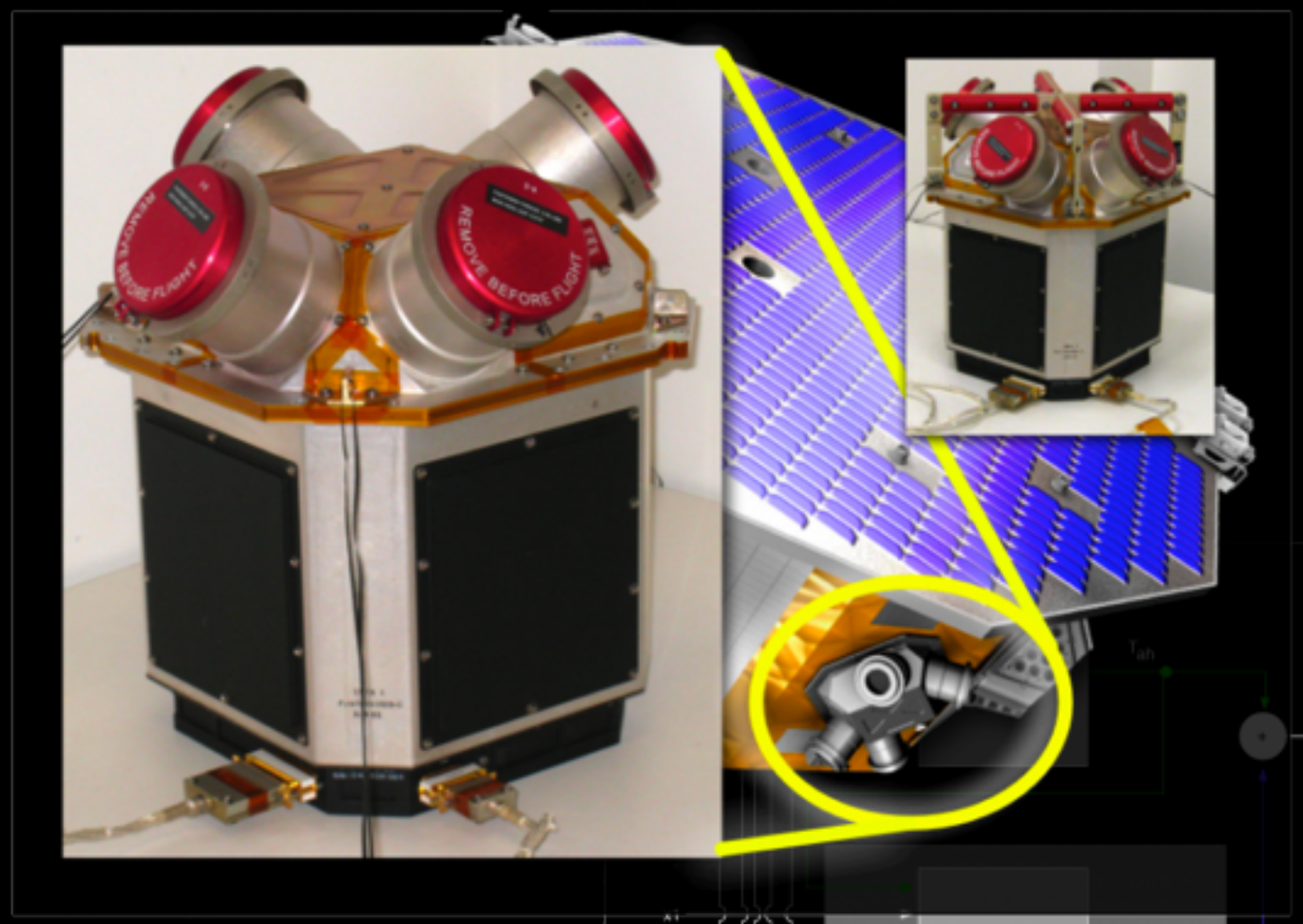
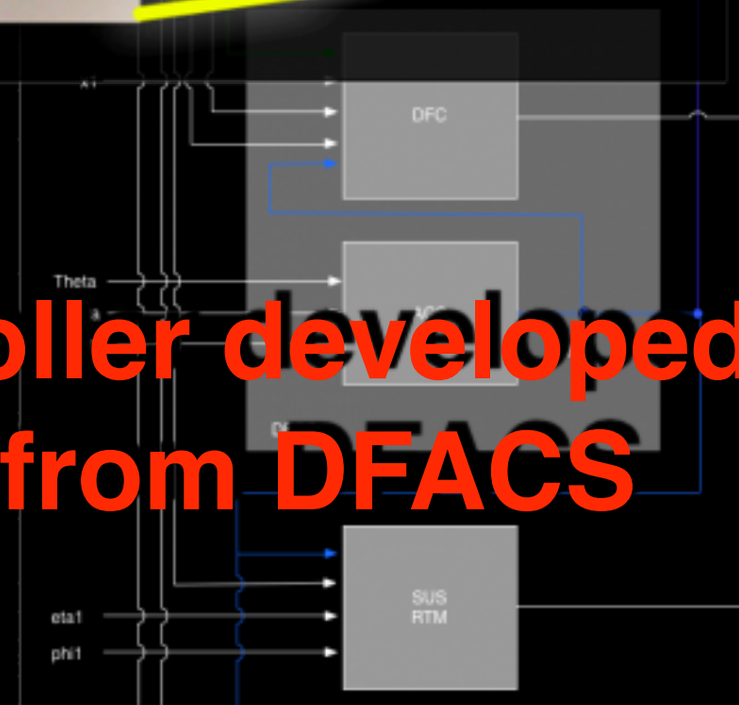
Space Technology 7 vs. LTP



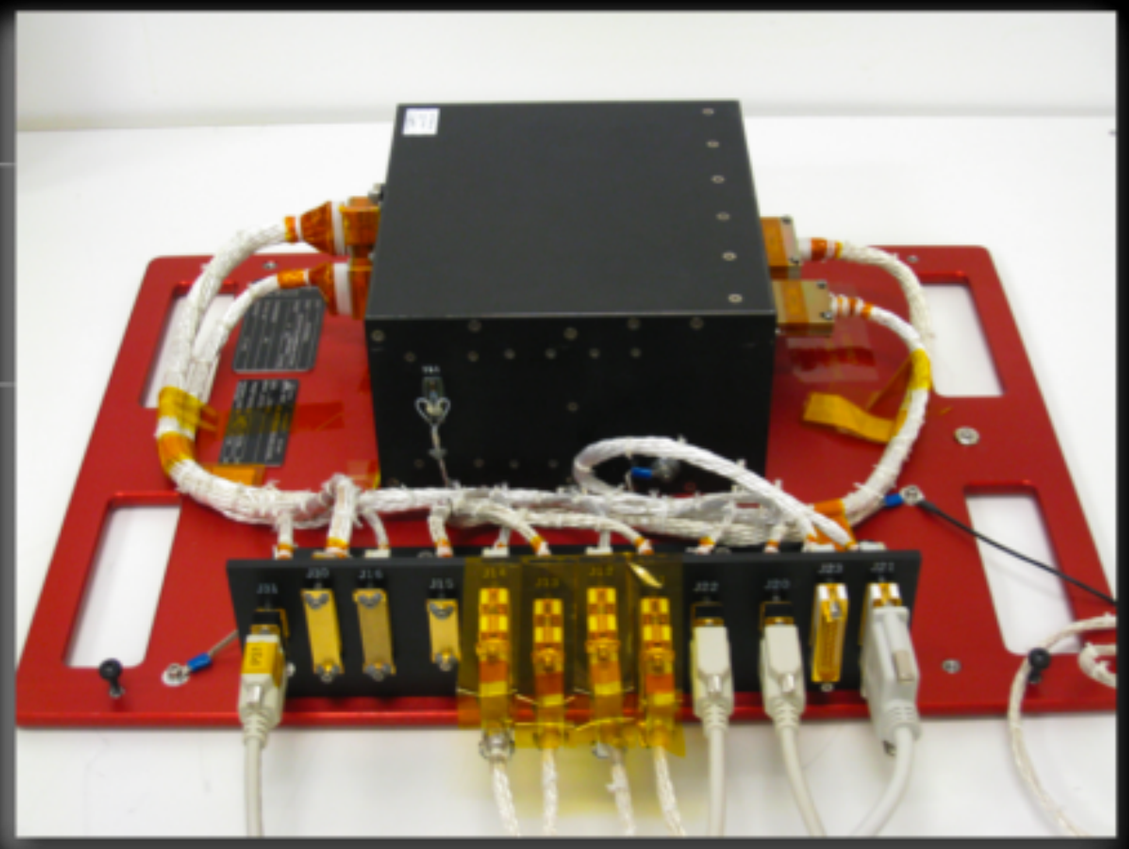
Space Technology 7 vs. LTP



CMNTs



DRS controller developed separately from DFACS

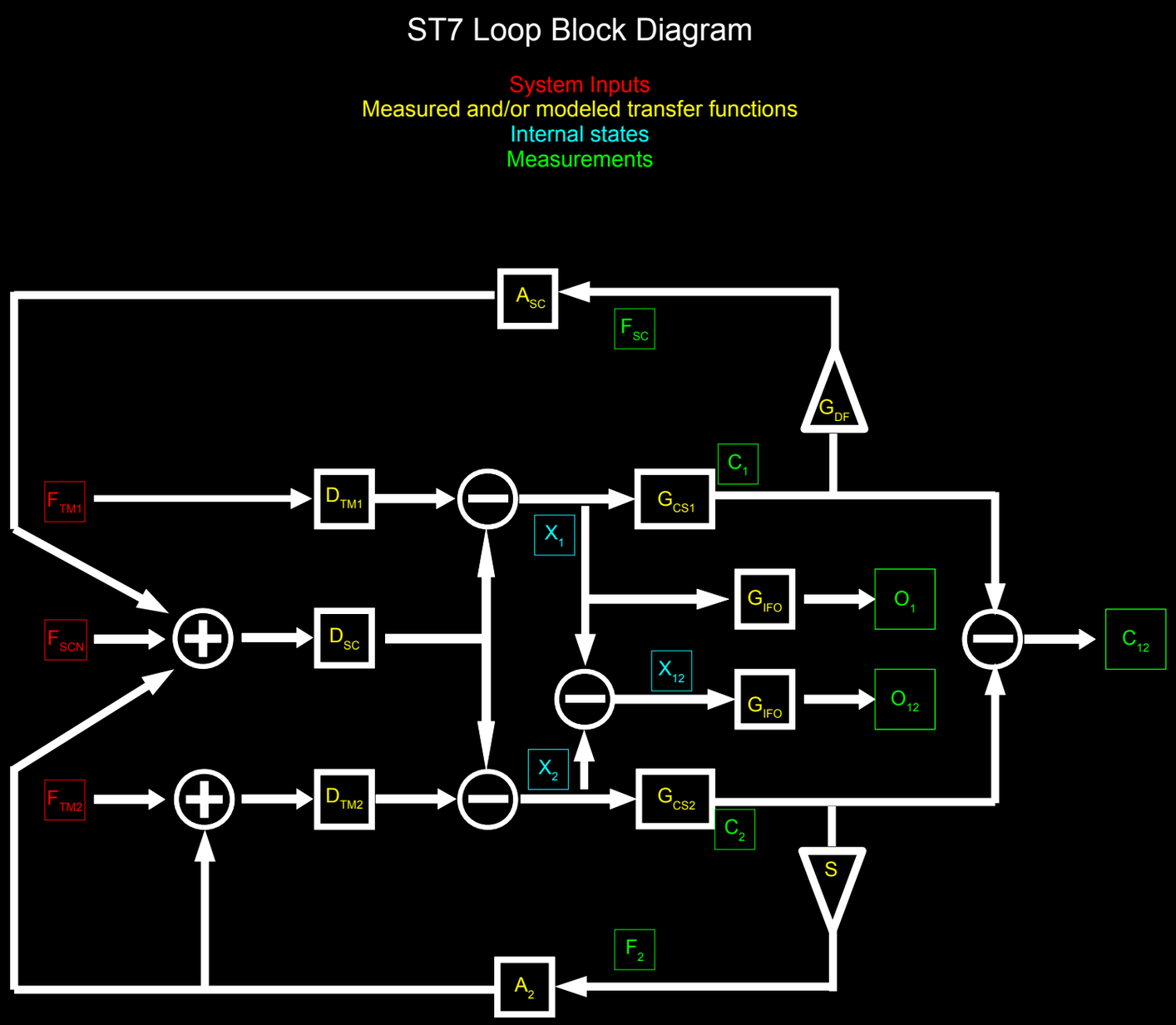


**Photos "courtesy" of eLISA website*

ST7 science mode differences

OMS is not used in-loop

Spacecraft follows TM1 (RTM), TM2 (NTM) follows spacecraft



ST-7 experimental runs

60 days of dedicated DRS operations, mainly thruster characterization…

How will ST7 perform?

How will we tell?

Should we prepare?
(yes)

90	18				
91	1	Determine Operating Point (7 days)	Aprioi setting	3 days	DRS Operations (60 days)
92	2				
93	3				
94	4		Attitude Bias Point (ABP)	1 day	
95	5		ABP verification	1 day	
96	6		Thrust Bias Point (TBP)	1 day	
97	7		TBP verification	1 day	
98	8	Thruster Optimisation (2 days)	Control Loop Measurement	1 day	
99	9		Control Loop Verification	1 day	
100	10	s/c Position Control (16 days)			
101	11		Drag-Free Mode Initial	3 days	
102	12				
103	13		Drag Free Mode Update	3 days	
104	14				
105	15				
106	16				
107	17		Dual Drag-Free Mode	10 days	
108	18				
109	19				
110	20				
111	21				
112	22				
113	23				
114	24				
115	25				
116	26	Thruster Characterisation (22 days)			
117	27				
118	28		Accuracy	8 days	
119	29				
120	30				
121	31				
122	32				
123	33				
124	34				
125	35				
126	36		Controllability	8 days	
127	37				
128	38				
129	39				
130	40				
131	41				
132	42				
133	43		Throttleability	6 days	
134	44				
135	45				
136	46				
137	47				
138	48	Thrust Noise Measurement (9 days)			
139	49				
140	50		Thrust Dependent Noise	6 days	
141	51				
142	52				
143	53				
144	54				
145	55		Open Loop Thrust Noise	3 days	
146	56				
147	57	Additional Thruster Characterisation (4 days)	Voltage Control Noise	1 day	
148	58		Current Control Noise	1 day	
149	59		Mechanical Noise	2 days	
150	60				

ST7DA Toolbox

- Mature, extensive Matlab infrastructure for characterization
  - Time and frequency domain analysis
  - State Space Modeling and simulation
- Modularity allows substitution for components and controls

LTPDA Toolbox + ST7

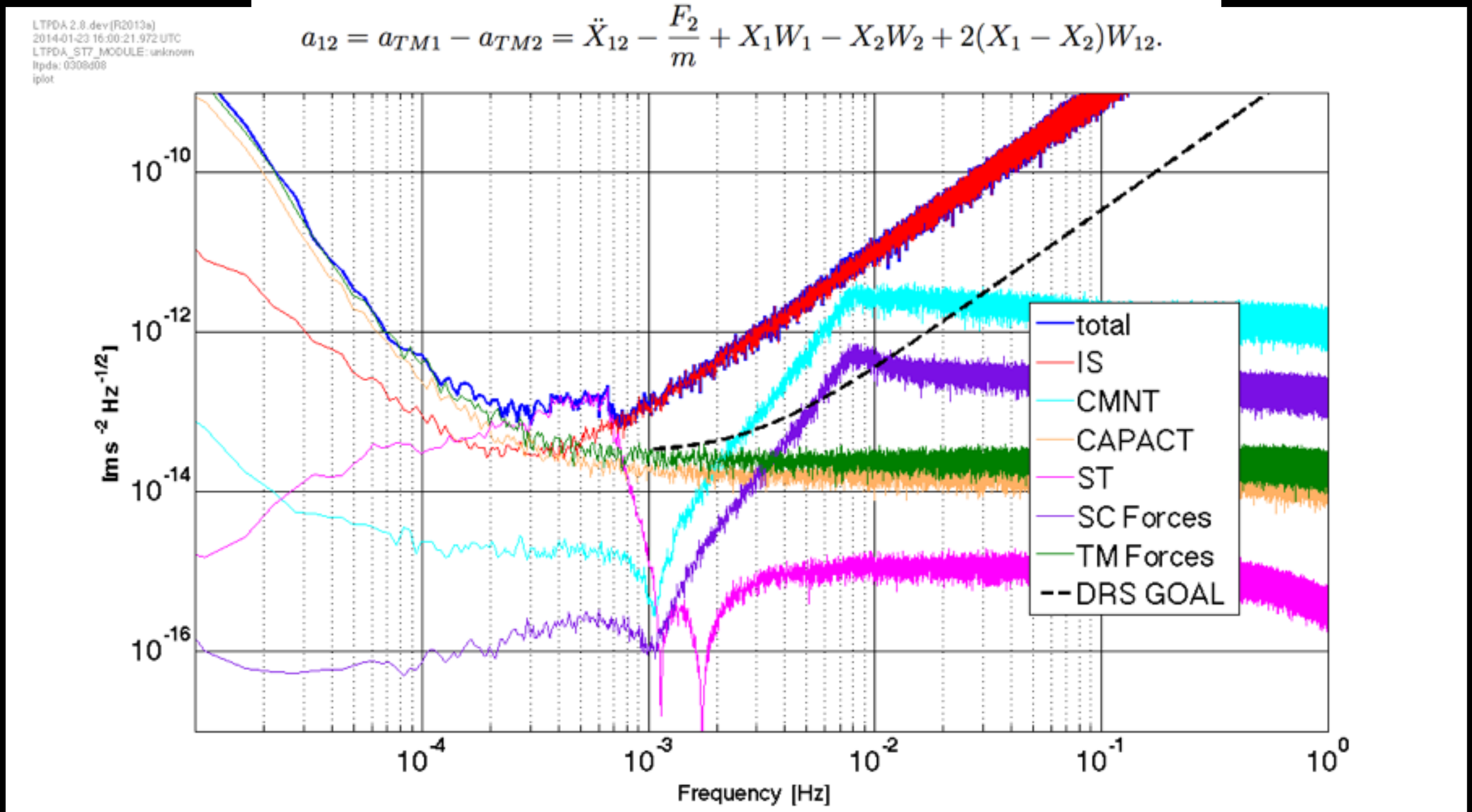
Nah, lets just use LTPDA and substitute in CMNTs & DRS for FEEPS & DFACS

- Mature, extensive Matlab infrastructure for characterization
  - Time and frequency domain analysis
  - State Space Modeling and simulation
- Modularity allows substitution for components and controls

SSM noise models and budgets

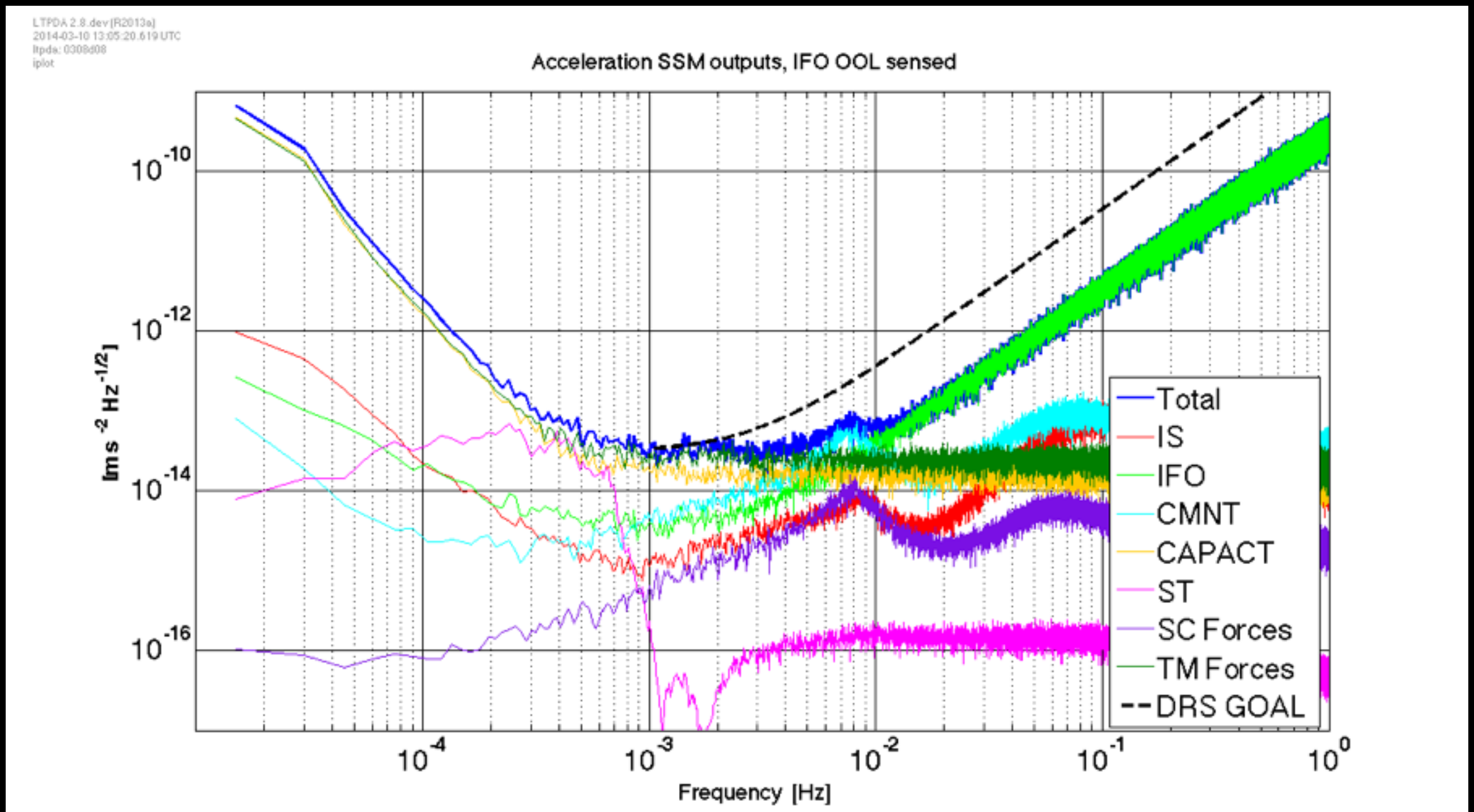
Inertial (capacitive) sensor noise dominant

$$a_{12} = a_{TM1} - a_{TM2} = \ddot{X}_{12} - \frac{F_2}{m} + X_1 W_1 - X_2 W_2 + 2(X_1 - X_2) W_{12}.$$



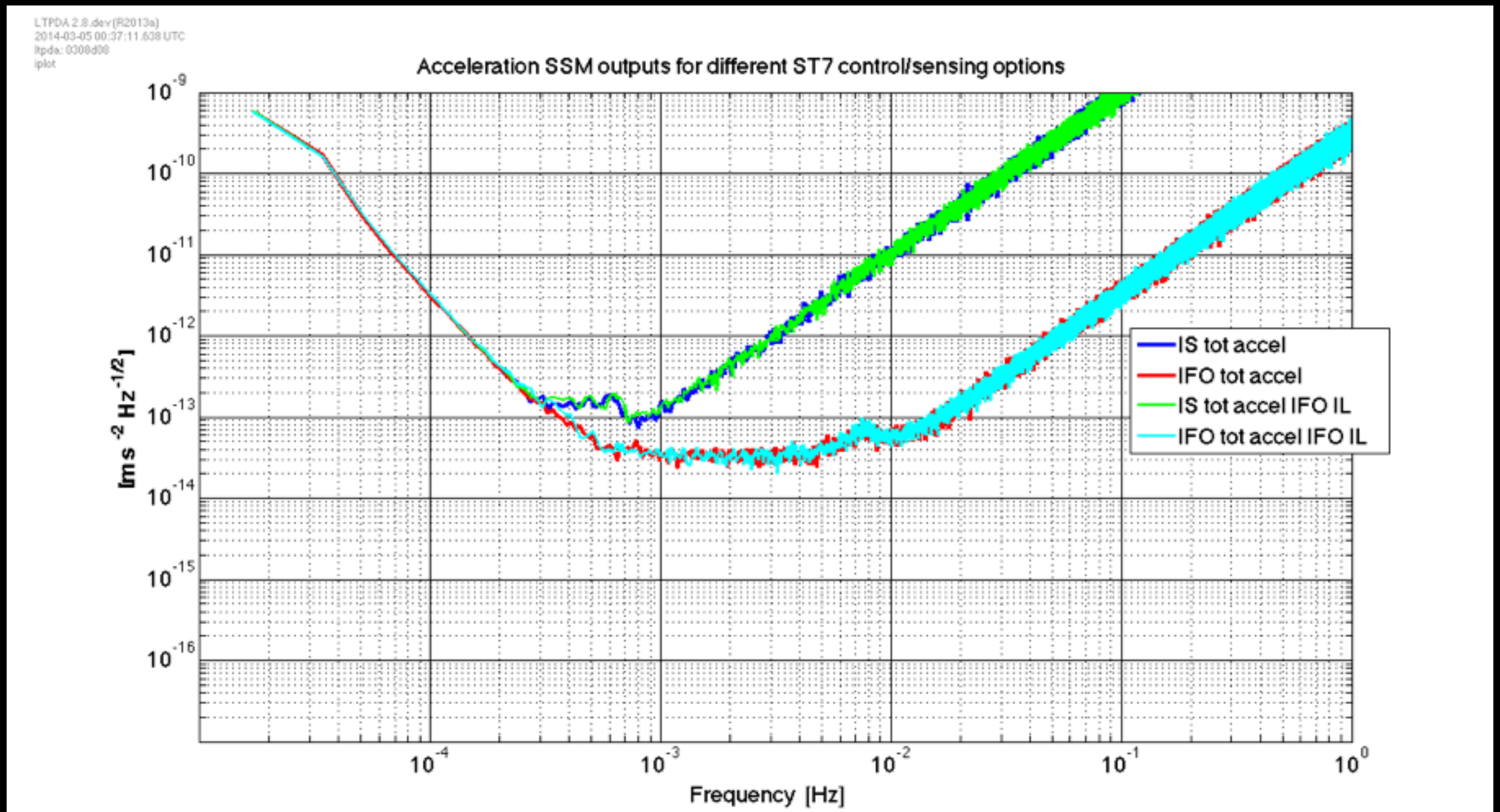
SSM noise models and budgets

Same simulation, different readout



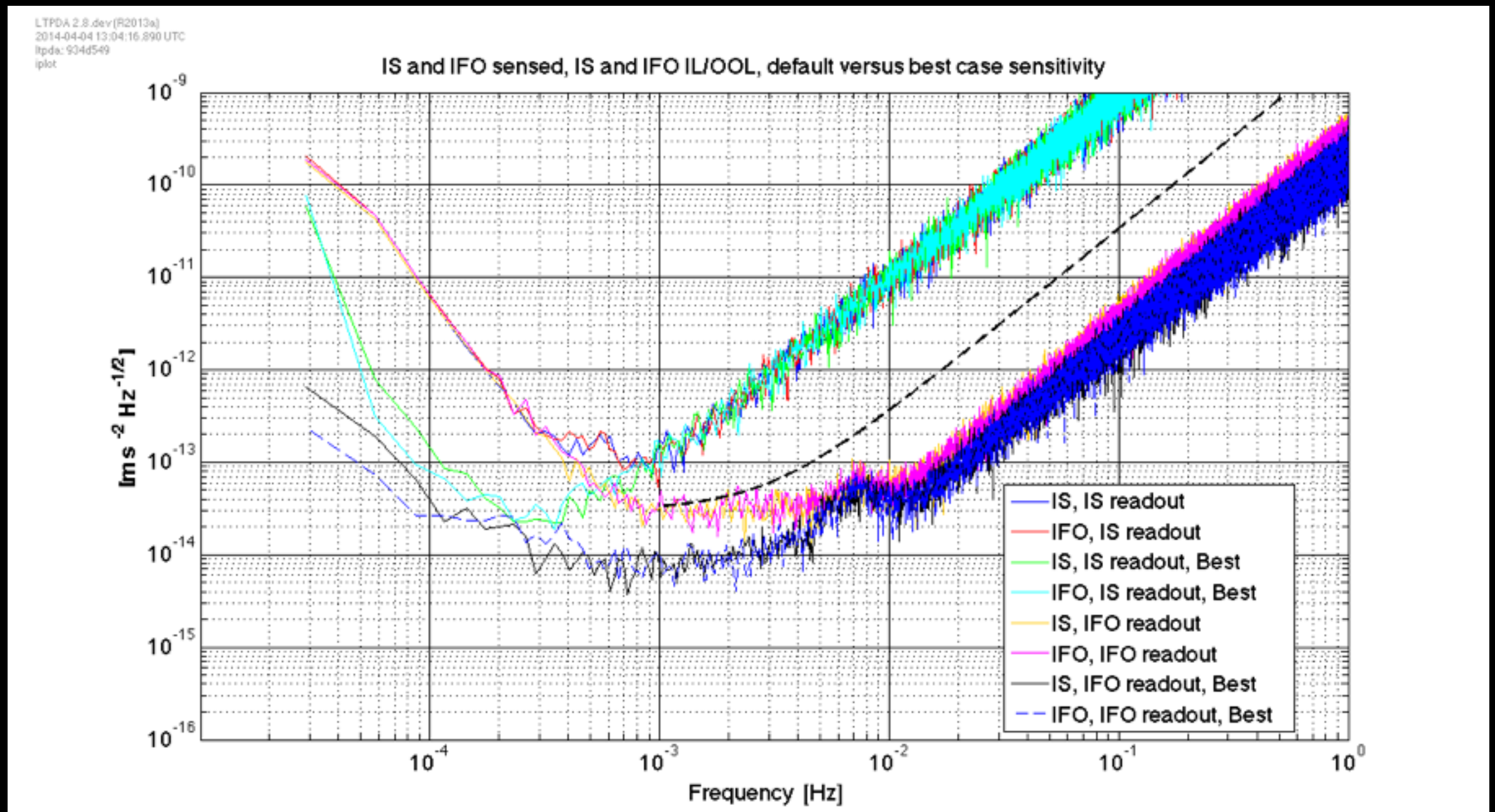
SSM noise models and budgets

In-loop indistinguishable from out of loop, **for SSM**

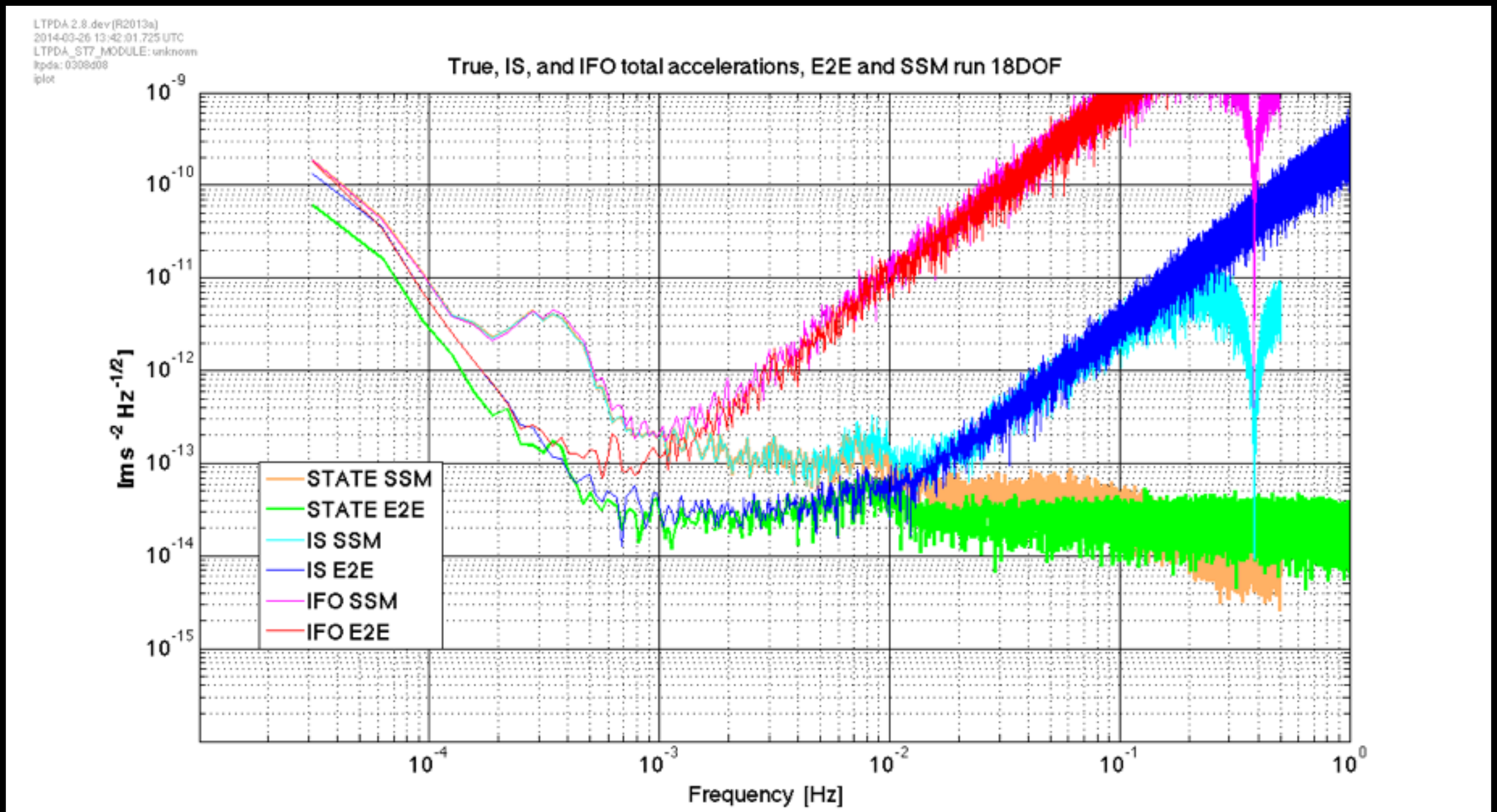


SSM noise models and budgets

Best estimate… is better!



End-to-end Simulink Model Validation



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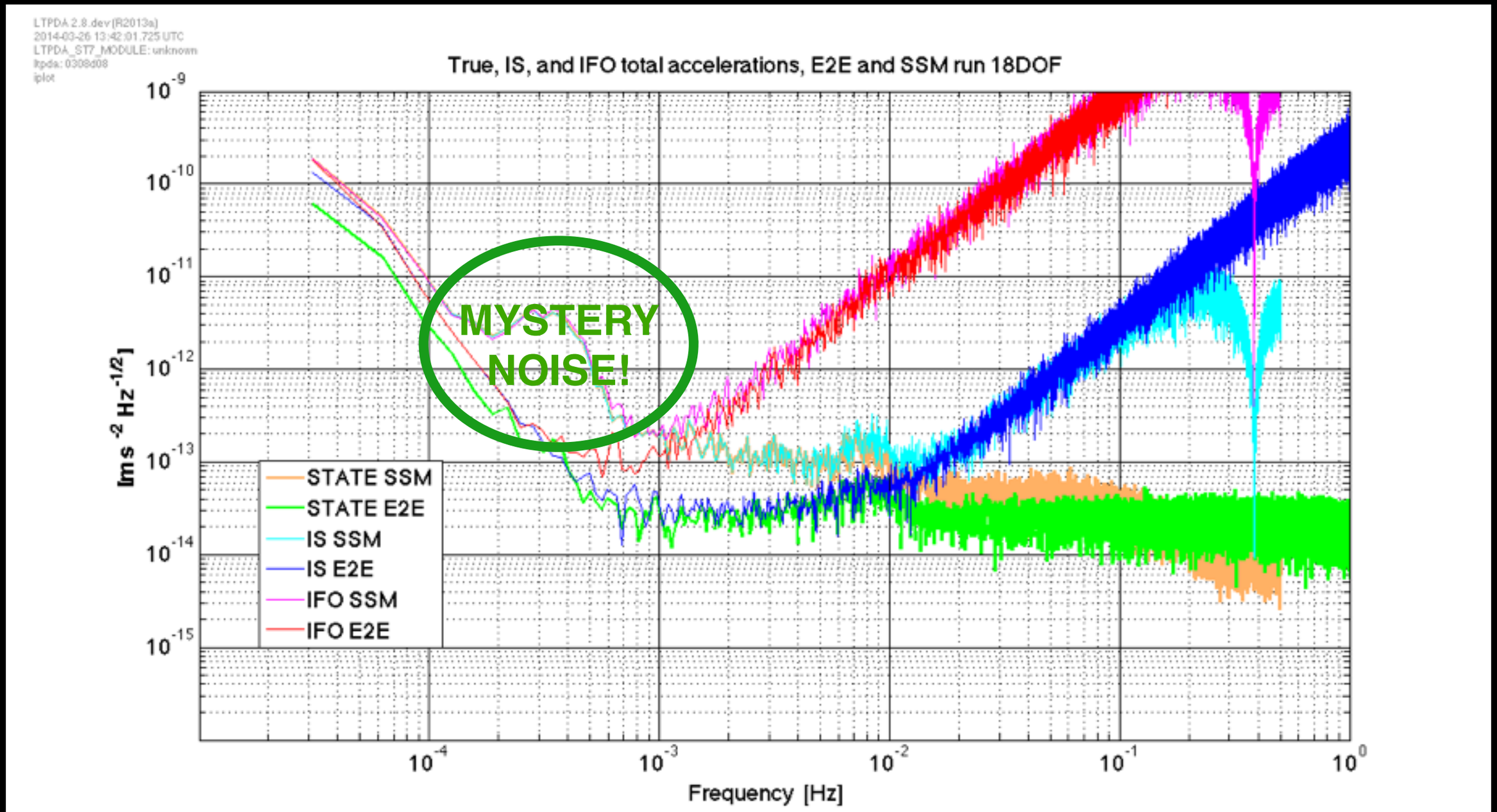
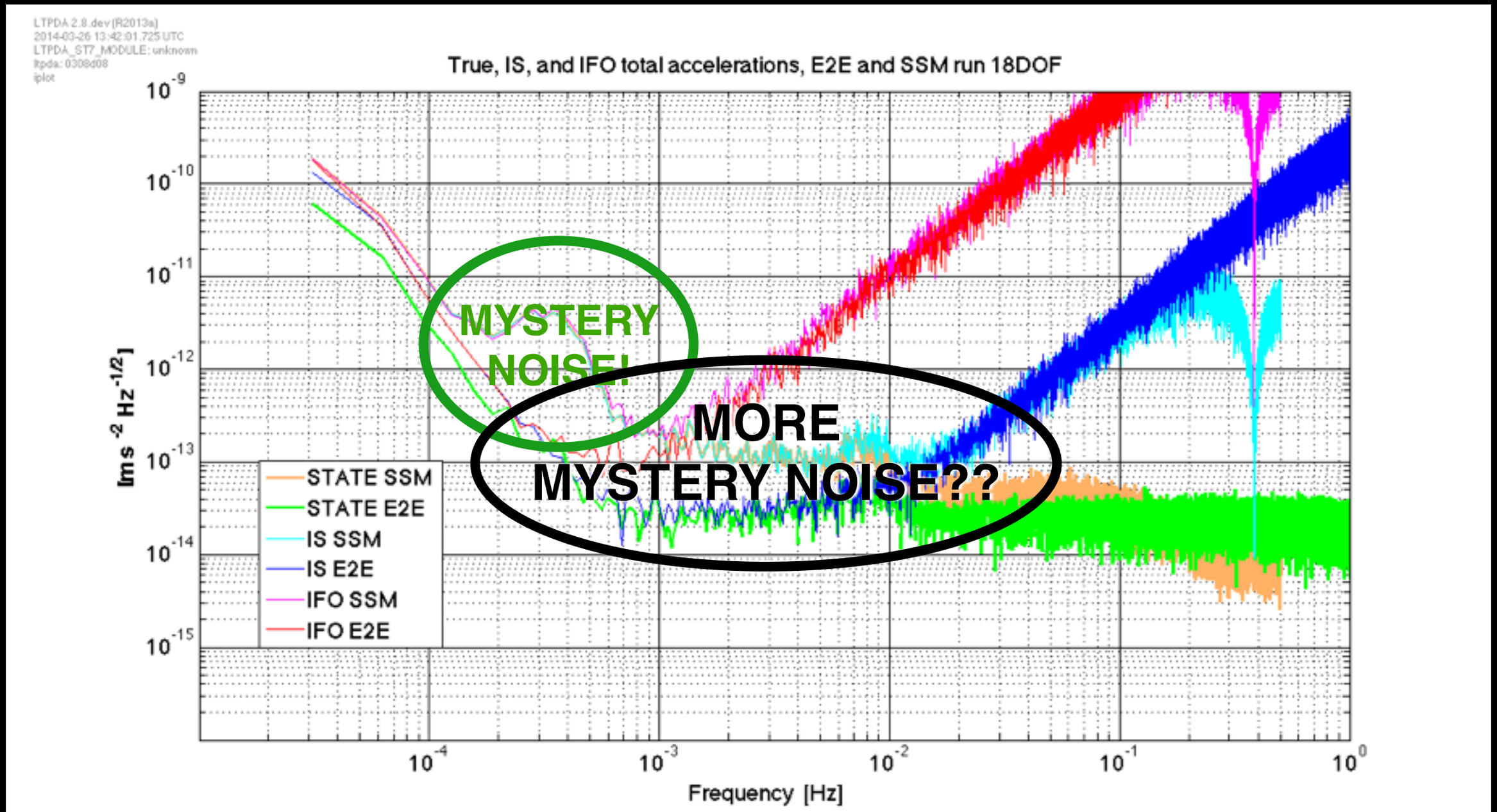
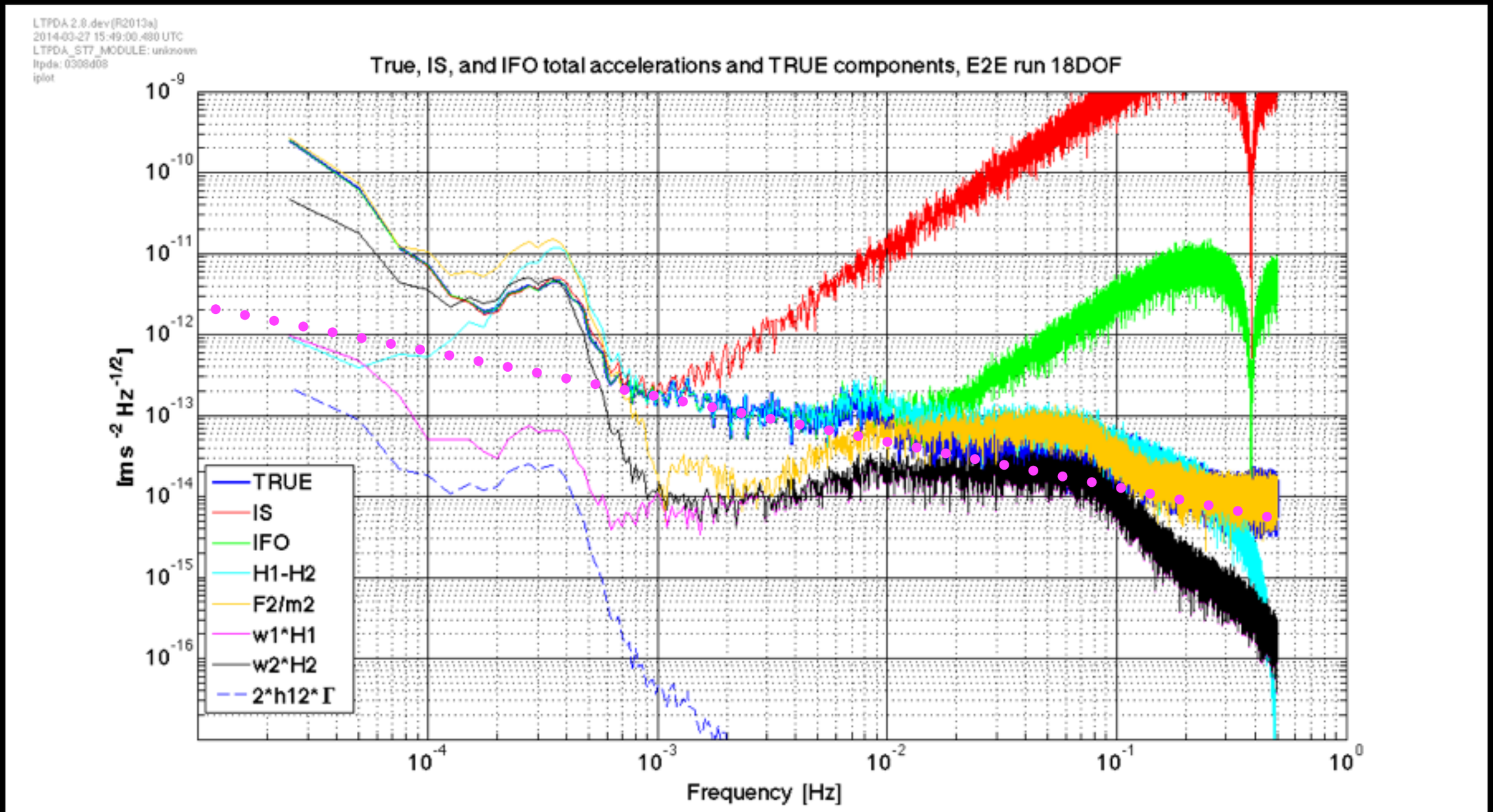


End-to-end Simulink Model Validation



End-to-end ‘new’ mystery noise

Motion appears in positions only, not forces, stiffnesses
Building noise budget of runs with single noise sources



Preliminary Thruster Characterization

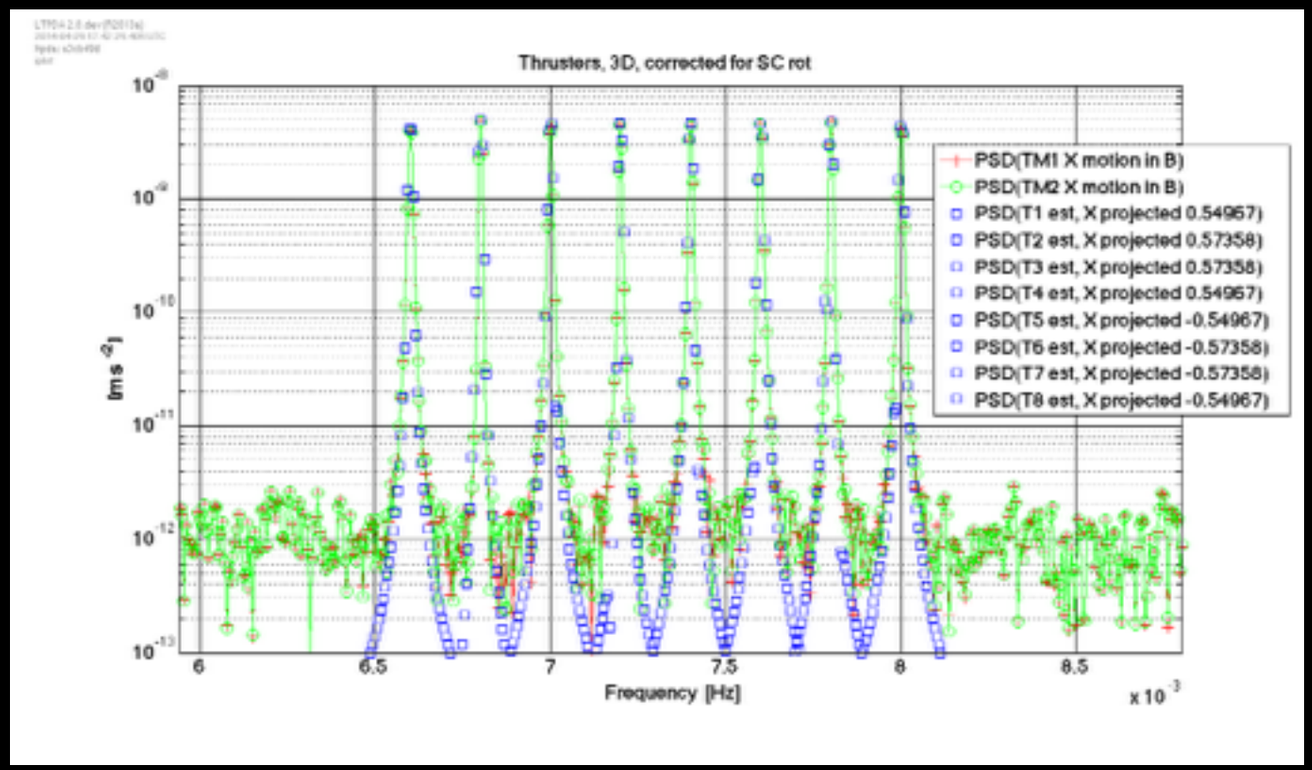
- Simulate w/ full noises, lines injected in CMNTs
- Modify CMNT model to allow difference between assumed and actual thruster configurations
- “Technical note on Thruster Characterization” by E. Plagnol
- Reconstruct injections and motion in SC B frame

Comb of 8 lines

8 μN offset, +/- 5 μN

6 to 8 mHz

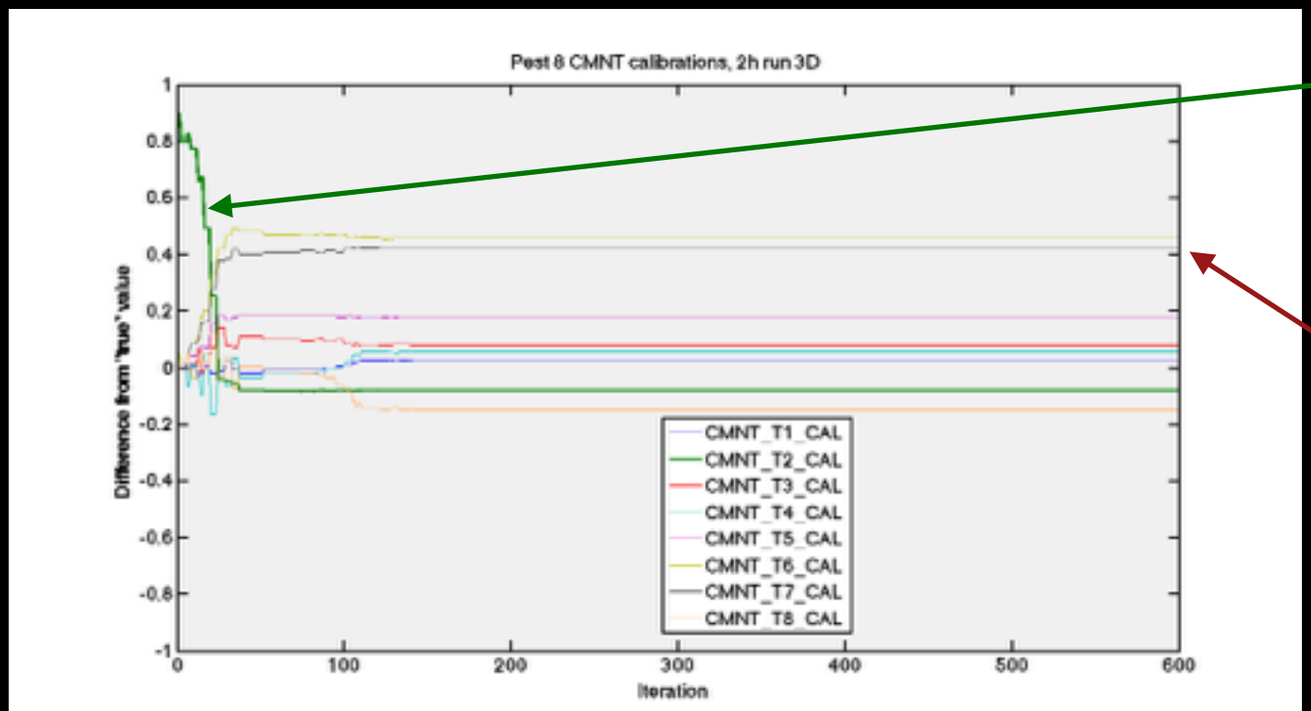
Reconstructed in COM frame



Preliminary Thruster Characterization

- Observables:
  (6 per TM + 3 SC) * 8 frequencies, TOTAL= 128
- Parameters:
  TM: (3 positions + 2 angles + 1 cal) * 8 CMNTs = 48
  Housings add 6 positions, angles w.r.t. B frame = 12
  TOTAL = 60
- In principle, enough information to fit parameters

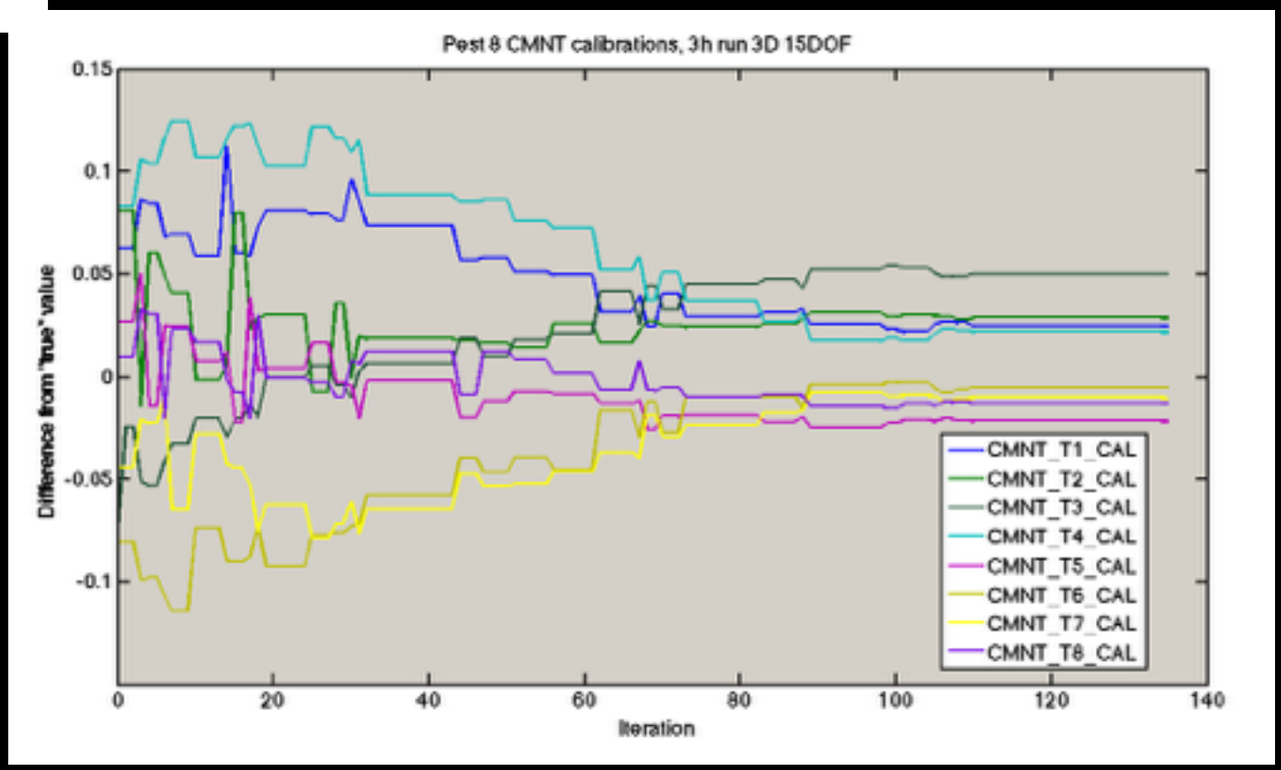
Fminsearch parameter fitting



Quick identification of "broken" thruster

Other thrusters wander far off nominal correct values

- Refine choices of output variables to examine
- Use PCA, MCMC, other advanced techniques beyond fminsearch
- Reconfigure to take Euler angles rather than direction cosines



Going forward

Access to LTP IFO data important to verify DRS goals

Reconcile and validate different simulations

Analyze ST-7 experiments before operations, prep to extract important physical parameters…

One year till launch. Much to do!

Extra

ST7 Loop Block Diagram

System Inputs
Measured and/or modeled transfer functions
Internal states
Measurements