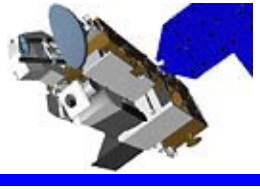


EARTH OBSERVING SYSTEM
MICROWAVE LIMB SOUNDER

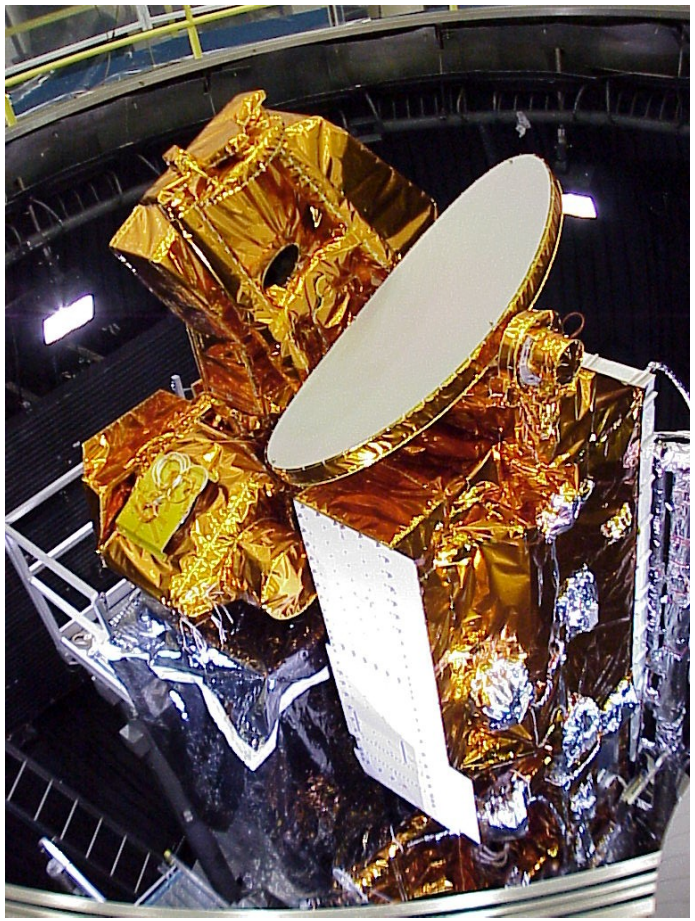
MLS Instrument Operations Status Update

Dominick Miller

Jet Propulsion Laboratory
California Institute of Technology

Pasadena, California
October 02, 2007

Overview



- MLS Ops Significant Events
- Instrument performance
- Mechanisms
- Trends since launch
- Anomalies in the past year
- Longevity Concerns
- Lessons learned
- Changes since last year
- MLS concerns, issues
- Plans
- Summary

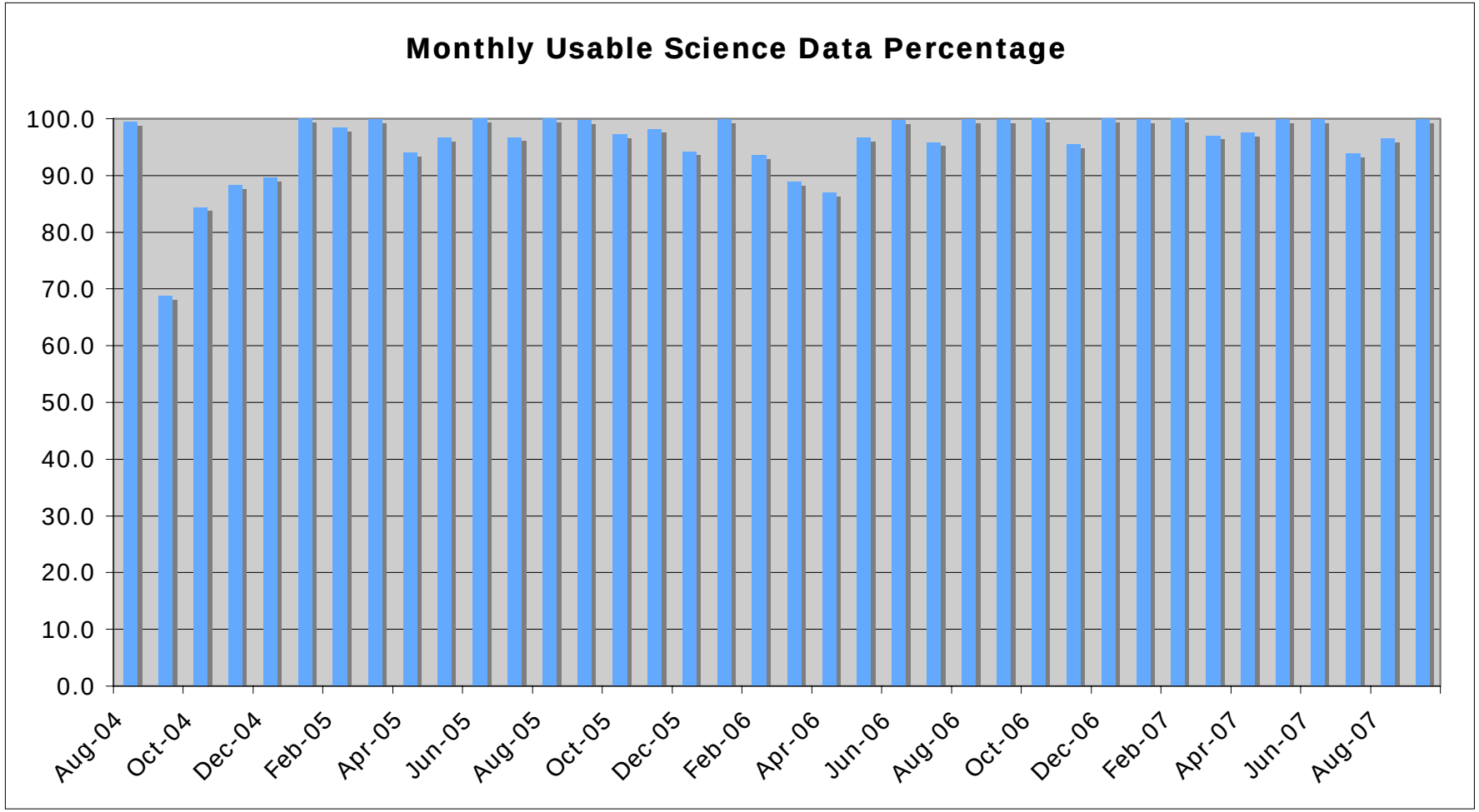
MLS Operations Significant Events

- **Instrument “first light” - Jul. 24, 2004**
- **Full-up science observations start - Aug. 13, 2005**
- **TSSM life test completion - Oct. 24, 2005**
- **Suspected HBT degradation leads to primary HCL band turn off - Feb. 16, 2006**
- **AAA life test completion - Mar. 06, 2006**
- **MLS performs its first MCL activity - Mar. 17, 2006**
- **MLS Fault Management Cascade after double mechanism fault - Mar. 29, 2006**
- **FM Cascade Recovery - Apr. 04, 2006**
- **Anomalous behavior leads to ClO band shutdown - Apr. 08, 2006**
- **ClO band on to observe southern polar winter - May 18, 2006**
- **SIF4 Fault Management Shutdown - Jul. 14, 2007**
- **SIF4 Recovery/ 2nd ASE/GME mechanism double fault - Aug. 07, 2007**
- **ASE/GME Recovery - Aug. 08, 2007**

Instrument Science Performance Overview

- **On-orbit performance and sensitivity are as seen in pre-launch testing**
  - **Performance parameters are routinely trended**
  - **Small reductions in signal gains have been noted in the 25 channel spectrometers**
  - **Gain adjustments implemented in April 2006 for most bands to boost the signals to approximately launch levels**
  - **Adequate signal/gain adjustment remaining for a 5 year mission**
    - **Based on extrapolation of current trends**
  - **Next gain adjustment expected in 3 – 6 mo.**

EOS MLS Instrument Performance
Percentage Data Usable by Month



Level 2 Data Processing Status, V2.2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Aug-04								221					226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244
Sep-04	245	246	247	248	249	250	251			254			257			260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	
Oct-04	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289				293	294	295	296	297	298	299	300	301	302	303	304	305
Nov-04	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	
Dec-04	335	336	337	338	339	340		342			345	346	347	348	349	350	351	352	353			356	357	358	359	360	361	362	363	364	365
Jan-05	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Feb-05	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59			
Mar-05	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Apr-05	91	92	93	94			97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	
May-05	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137		139	140	141	142	143	144	145	146	147	148	149	150	151
Jun-05	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	
Jul-05	182	183	184	185	186	187	188	189	190	191	192	193		195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212
Aug-05	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243
Sep-05	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	
Oct-05	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292		294	295	296	297	298	299	300	301	302	303	304
Nov-05	305		307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	
Dec-05	335	336	337	338	339	340	341	342	343		345	346	347	348	349	350	351		353	354	355	356	357	358	359	360	361	362	363	364	365
Jan-06	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Feb-06	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52		54	55	56	57	58	59			
Mar-06	60	61	62	63	64	65	66		68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87			
Apr-06					95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	
May-06	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151
Jun-06	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	
Jul-06	182	183	184	185	186	187	188	189	190		192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212
Aug-06	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243
Sep-06	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	
Oct-06	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304
Nov-06	305	306		308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333		
Dec-06	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365
Jan-07	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Feb-07	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59			
Mar-07		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Apr-07	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115		117	118	119	120	
May-07	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151
Jun-07	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	
Jul-07	182	183	184	185	186	187	188	189	190	191	192	193		195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212
Aug-07	213	214	215	216	217	218			221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243
Sep-07	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	
Oct-07	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304

MLS Mechanisms

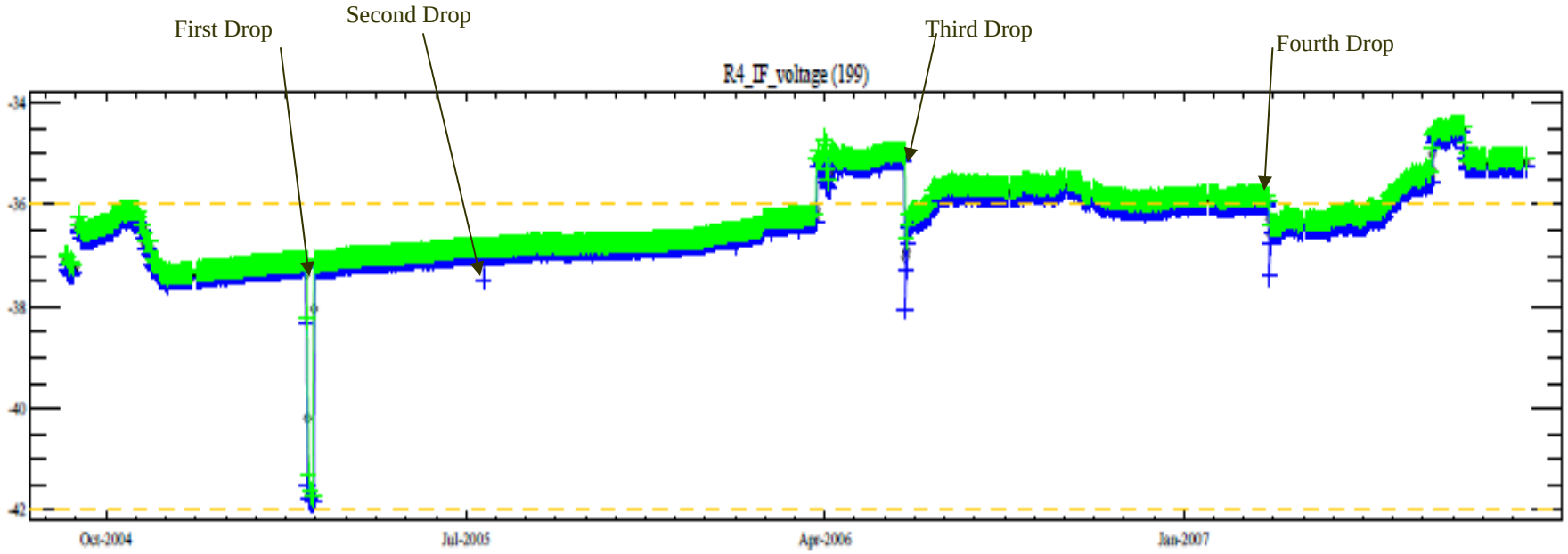
- **All MLS EM mechanisms exhibited acceptably low amounts of wear after one life test**
- **Flight mechanism performance and trends have been stable and show no adverse signs to indicate trouble**
- **The MLS mechanisms are known to be sensitive to power supply glitches**
- **Several on-orbit mechanism anomalies have led to a pre-authorized mechanism recovery plan for a faster return to science in the event of an understood mechanism anomaly**

Instrument Performance Trends

- **All engineering telemetry and Level 0 science data are reviewed and trended by the IOT daily (5/7)**
  - **Over 500 engineering telemetry points**
  - **Over 540 filterbank channels**
  - **Over 500 digital auto-correlator channels (trended daily as 16 high level parameters)**
- **Most trends are nominal**
  - **Selected trends included in backup slides**
- **Three Non-nominal Trends**

MLS Non-nominal Trends
R4 Receiver LO IF Power Monitor

- **The 640 GHz receiver (R4) LO IF power has temporarily dropped on four occasions but has recovered each time**
- **These drops have no corresponding impact on the science data**

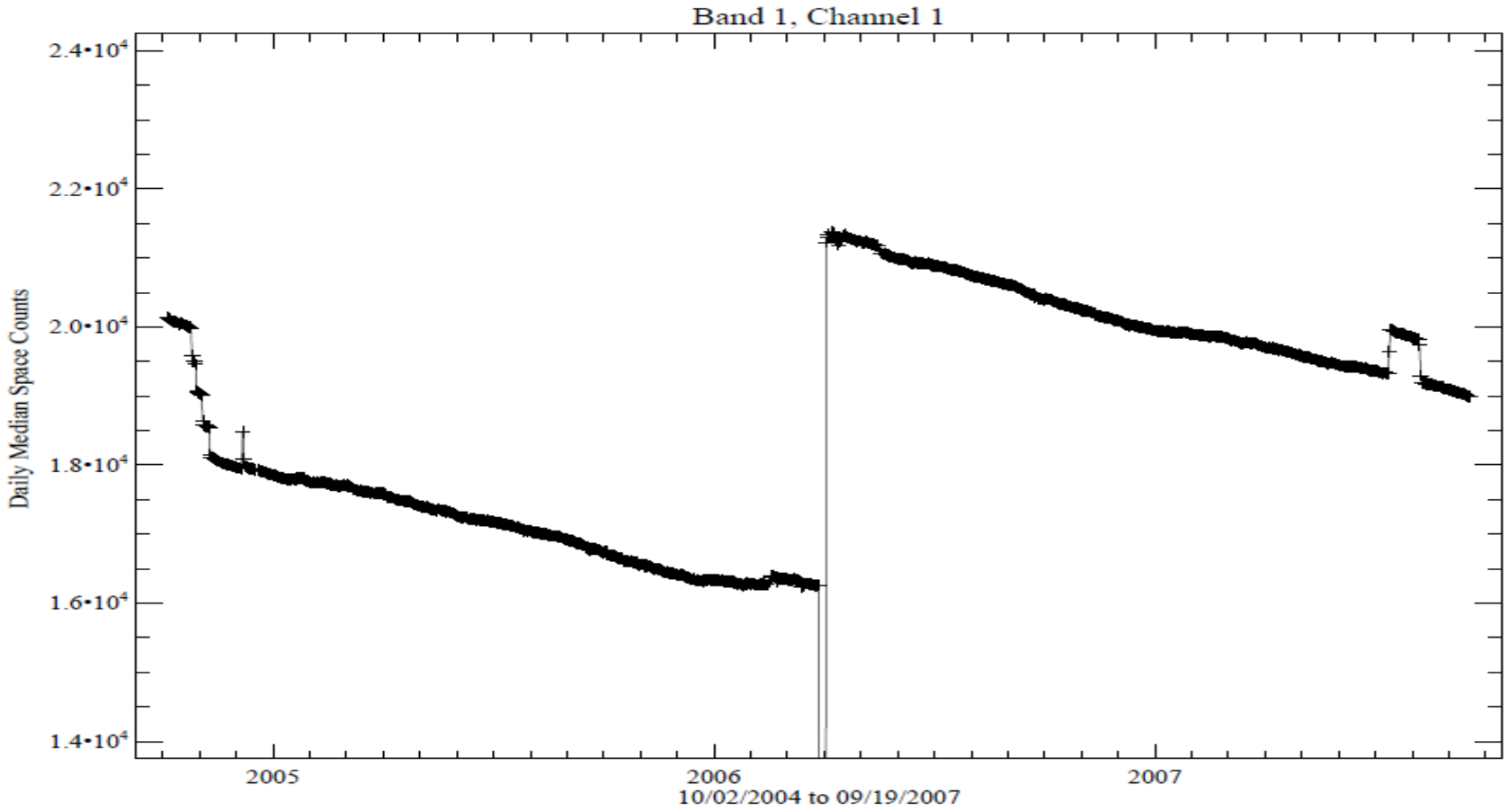


Non-nominal Trends
Bands 10, 29 & 13

- **The 640 GHz IF signal feeding Bands 10 & 29 (ClO & HOCl) shows increased thermal sensitivity and anomalous behavior**
- **Instrument operations have been modified to minimize thermal cycling on the Bands 10 & 29 electronics. Assuming current trends continue, it is projected that Bands 10 & 29 will viable throughout the 5 year mission**

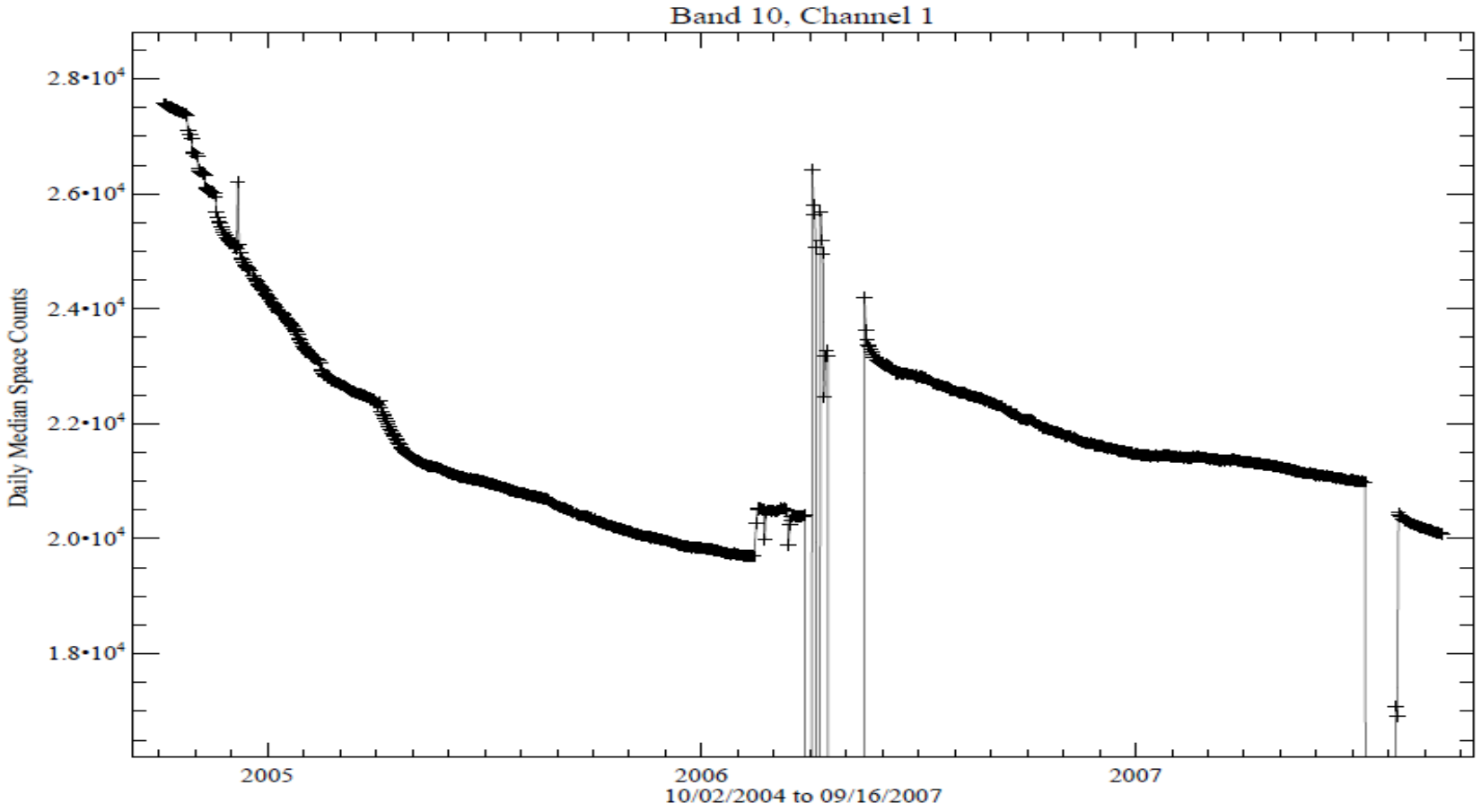
- **The 640 GHz IF Band 13 (HCl) electronics show a rapidly decreasing output signal level (2006)**
- **Band 14 overlaps the Band 13 HCl measurement (with slightly degraded measurement performance), and is being used to retrieve HCl science data**

MLS Band 1 Nominal Trend
(for comparison)



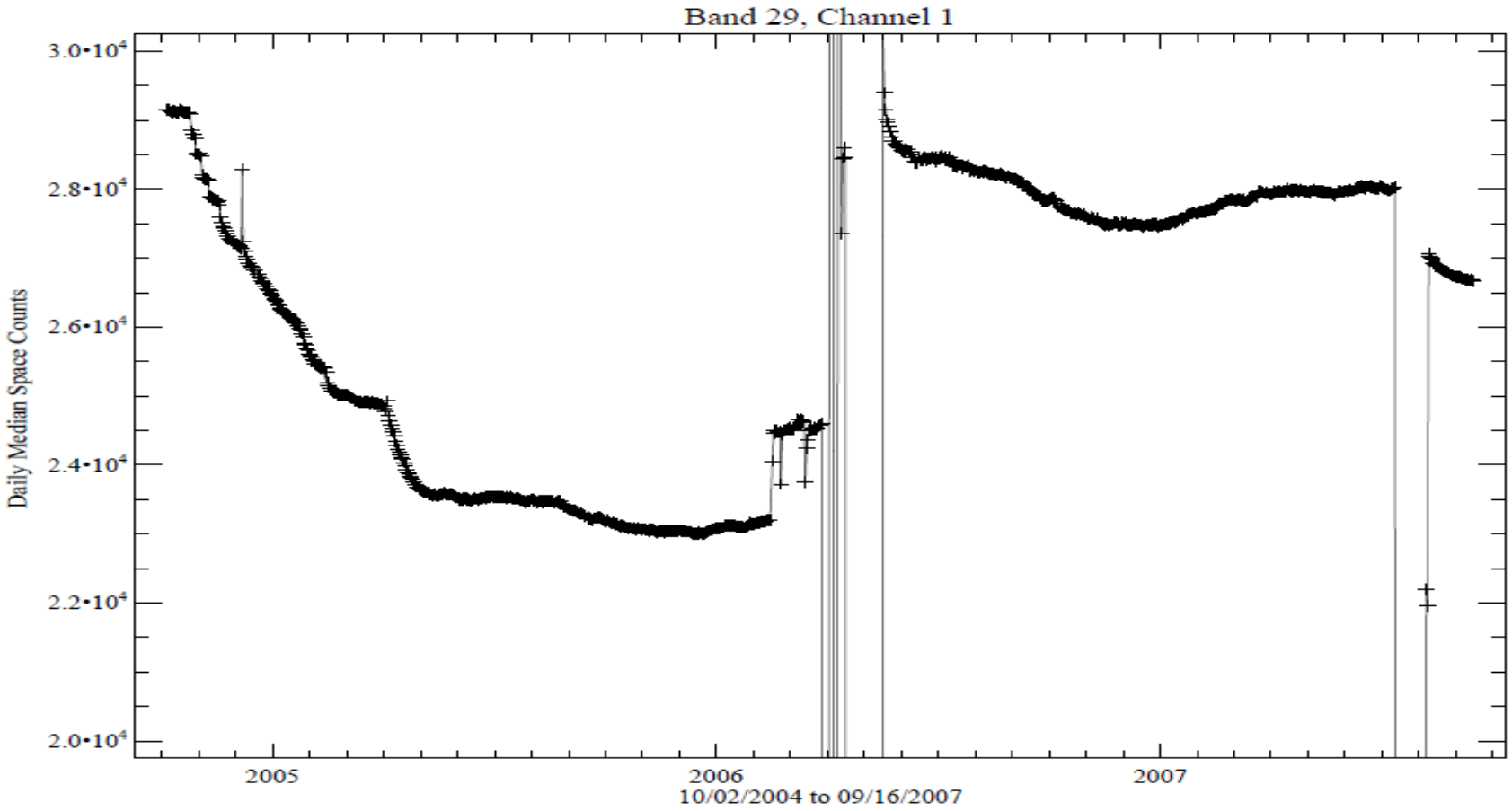
MLS Non-nominal Trends

Band 10 (ClO) Trend



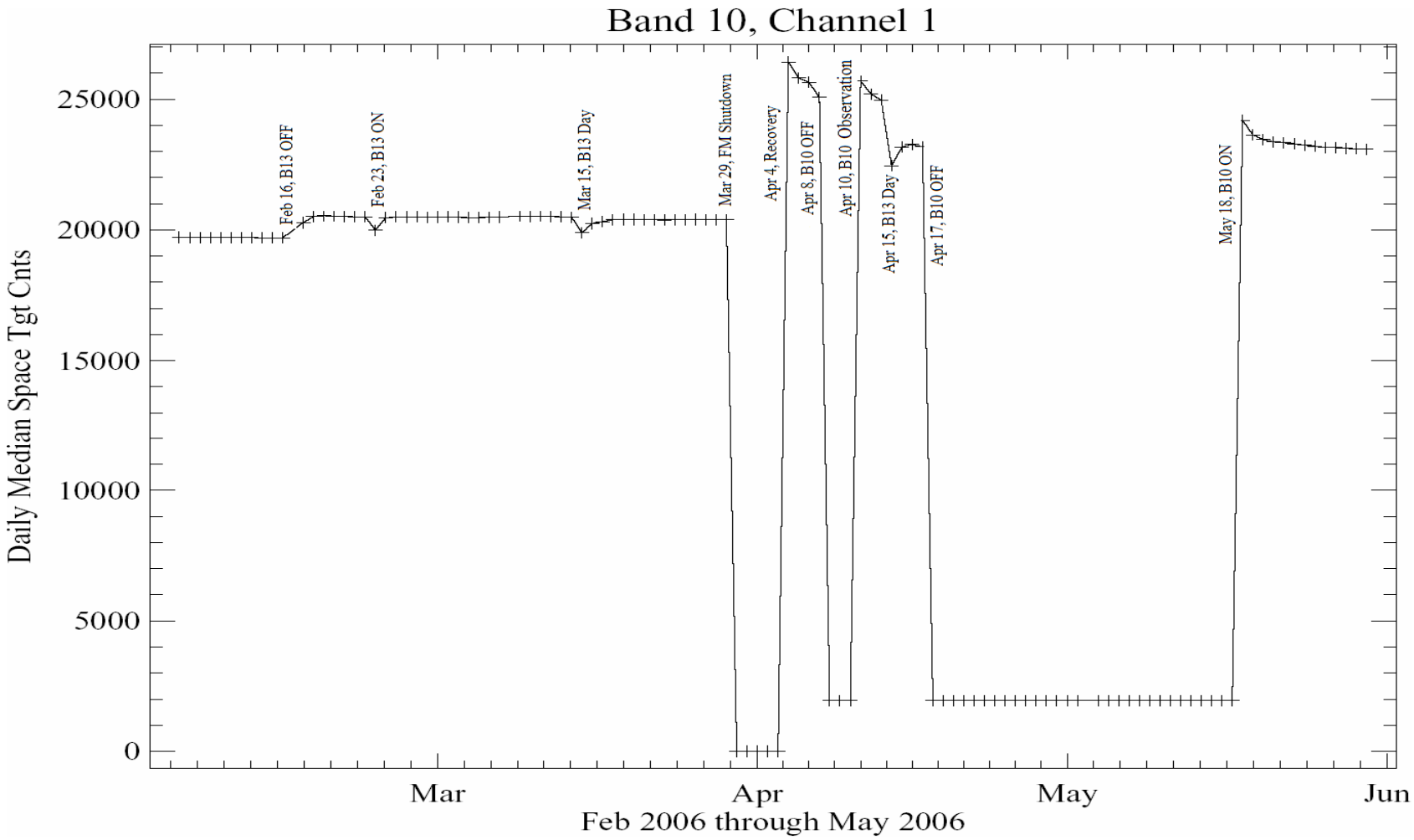
MLS Non-nominal Trends

Band 29 (HOCl) Trend



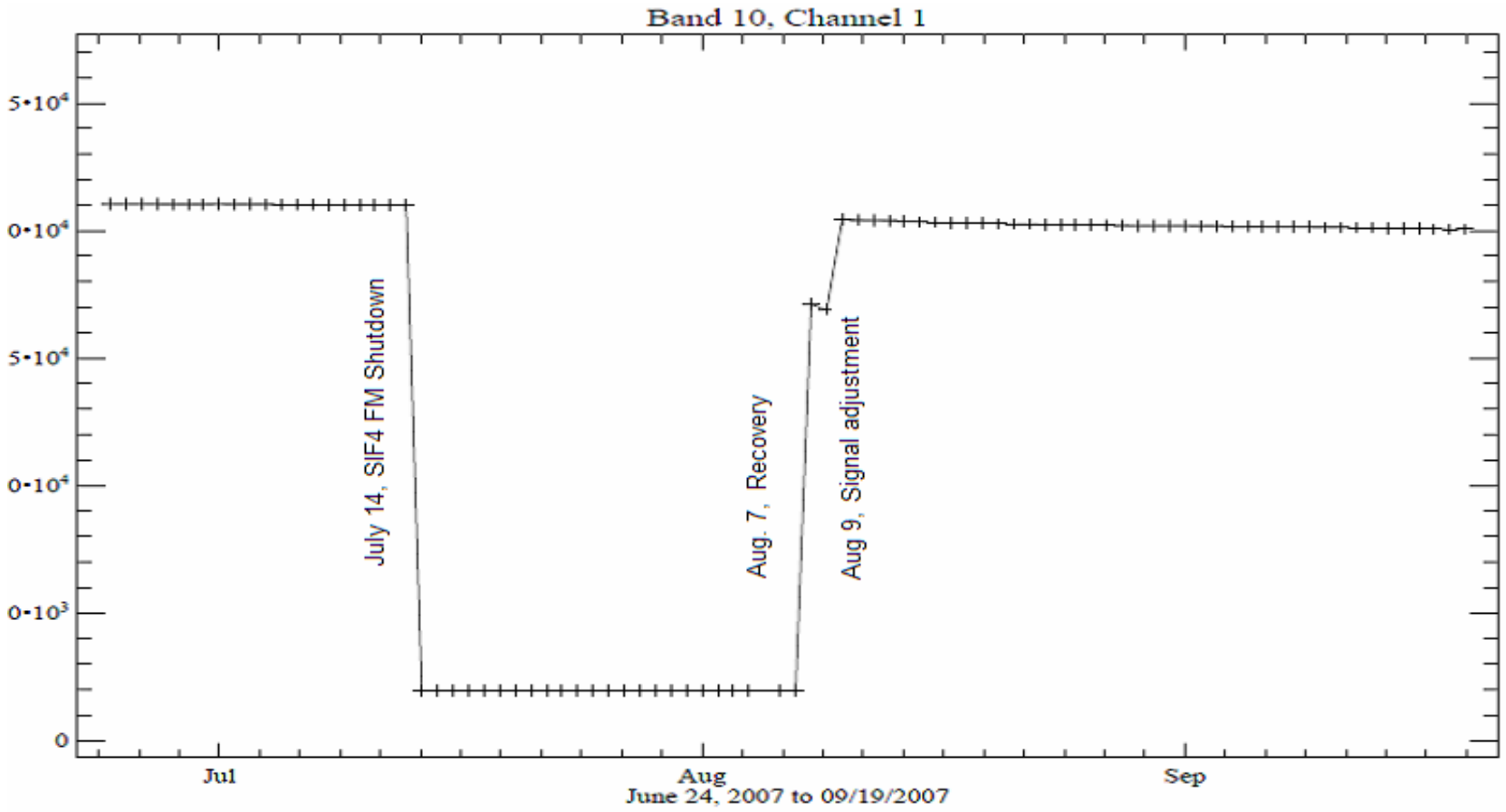
MLS Band 10 (ClO) Trend

Focus: Feb. to May, 2006



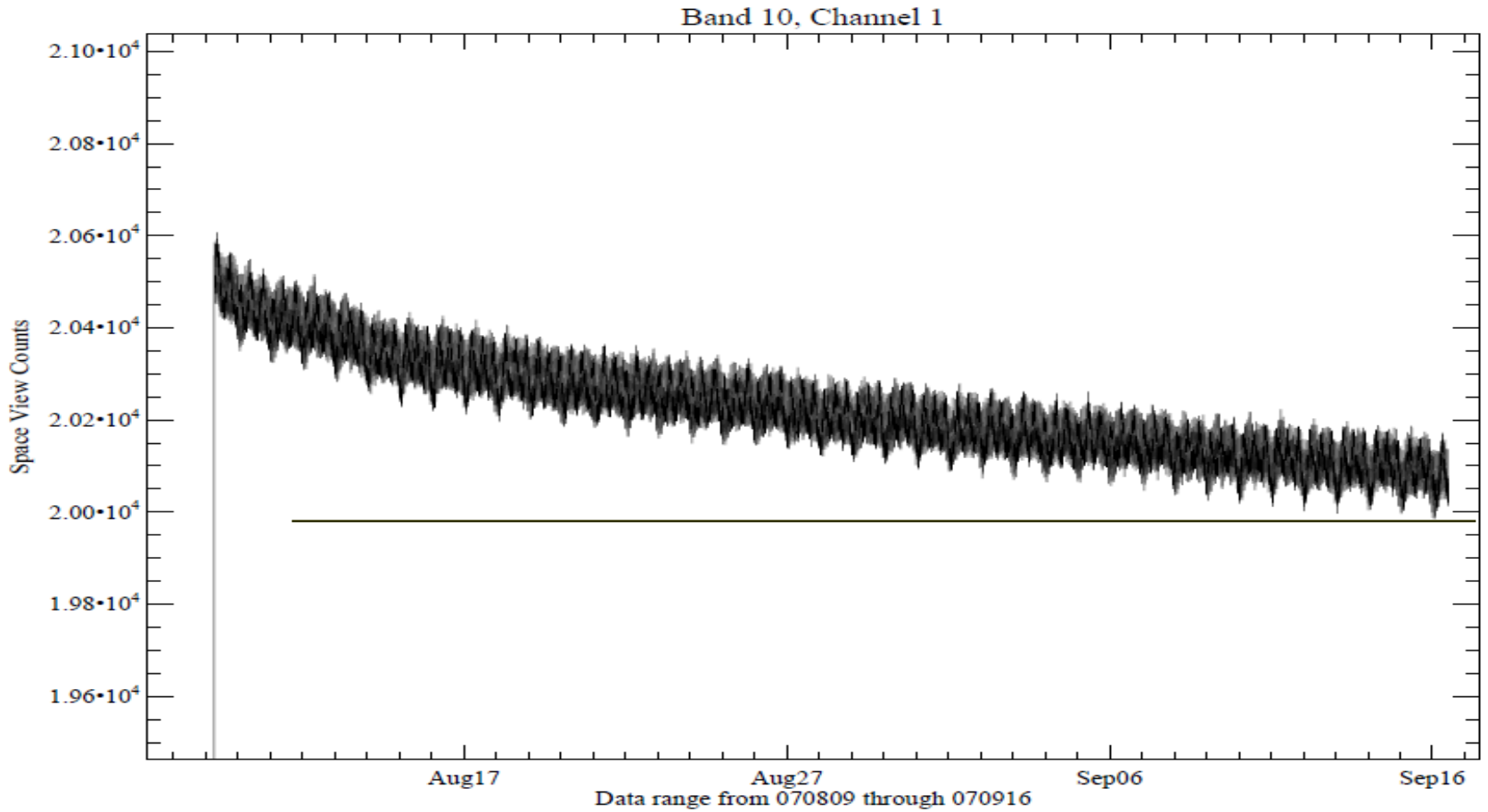
MLS Band 10 (ClO) Trend

Focus: June 24 to Sept. 19, 2007



Band 10 (ClO) Trend

From scan restart on 8/08/2007 to present



Anomalies in the past year

- **SIF4 Shutdown, July 2007**
  - **Shut down by MLS FSW during a back orbit**
  - **Examination of all data reveal no indications of anything abnormal before the shutdown**
  - **Suspected cause of shutdown is an SEU**
  - **Recovery was successful and hardware appears nominal 1+ months after the recovery**

- **Double mechanism fault, August 2007**
  - **Occurred during the final step of the SIF4 Recovery activity**
  - **Repeated the same movements seen in March 2006**
  - **Has no identifiable cause that we know of**
  - **Recovery successful, no issues**

Longevity Concerns
Spectrometer Module

- **Certain parts within the spectrometer module have been degrading slowly since launch due to a known issue**
  - **The performance of these parts is the cause for the small decreasing slope seen in the filterbank trends**
  - **Existing test data on these parts is insufficient to project remaining life**
  - **While we are aware of this performance degradation, none of these parts have failed since launch**

Longevity Concerns

THz Module Laser Local Oscillator

- **The Laser Local Oscillator (LLO) output power level has been decreasing since launch**
- **This is an expected performance trend**
- **Once the LLO output drops below a certain threshold, the R5 signal chain will no longer function correctly**
- **Affected Bands are 15 – 19, affected science product is OH**
- **THz Module success criteria was 1 year, we are now at 3+ years**
- **From current trends in THz mixer bias, the LLO power is projected to produce valid science data for an additional ~2+ years**

Lessons learned

- **MLS Fault Management (FM)**
  - **MLS FSW has been found to be intolerant of certain double fault conditions**
    - **FSW shuts down anomalous subsystems along with numerous nominal subsystems (FM cascade) when a double fault occurs**
  - **Simultaneous double faults were not tested during I & T**
  - **Updates were made to procedures last year to avert an FM cascade in the event of a simultaneous double fault during ground commanding**
    - **An FM cascade was averted during a double fault event in August of 2007**
- **What has been learned**
  - **Changes made to FM procedures have been successful at averting an FM cascade since implementation in April 2006**
- **Changes**
  - **Operational changes are planned as an attempt to avert the double fault scenario in the future**
  - **These changes will give us more insight as to the cause of the anomalous behavior should it happen again**

Updates since last year

Product and Procedural Updates

- MLS Red Limit Responses have been re-evaluated to reflect the current operations philosophy
  - Early “broad response” approach was appropriate during the early mission timeframe when we were in a defensive posture
  - Updated responses minimize thermal disturbances while safing the offending subsystem(s)
  - 9 new/updated procedures have been developed as Red Limit Responses
  - Most procedures have been tested and are ready for CM submission
  - Updated Red Limit Responses to be reviewed with GSFC
- Mechanism safing procedure updated to account for numerous contingency modes and include FM commands
- Subsystem power control procedure updated to include FM commands and to load current instrument configuration before turning off subsystems
- Microprocessor load procedure updated to catch anomalous load types

Updates since last year

MLS Operations Personnel

- No Changes

Documentation Updates

- MLS Op Agreement updated by FOT
- MLS Crisis Response Plan updated by MLS Project Manager
- MLS Operations User's Guide updates in process to reflect operational changes since launch
  - Operational constraints
  - Recovery steps
  - IST system changes

Contact Information

	Office	Cell Phone	EMAIL Address
Dominick Miller (Operations Lead)	(818) 393-3564	(818) 653-7852	dominick.miller@jpl.nasa.gov
Mario Loo (Instrument FSW & Operations Team)	(818) 354-5607	(818) 687-8107	mario.s.loo@jpl.nasa.gov
Gerson Melgar (Operations Team)	(818) 354-6350	(818) 653-3078	gerson.melgar@jpl.nasa.gov
Robert Jarnot (Instrument Scientist)	(818) 354-5204	(818) 653-9266	robert.f.jarnot@jpl.nasa.gov
Herb Pickett (THz Principal Investigator)	(818) 354-6861	(818) 640-6068	herbert.m.pickett@jpl.nasa.gov
Vince Perun (Ground Software)	(818) 354-2271	N/A	vincent.s.perun@jpl.nasa.gov
Dave Cuddy (Project Manager)	(818) 354-2099	(818) 648-9762	david.cuddy@jpl.nasa.gov
Nathaniel Livesey (Principal Investigator)	(818) 354-4214	(818) 219-6394	nathaniel.j.livesey@jpl.nasa.gov

MLS Concerns & Issues

- **Instrument Support Terminal Status**
  - **Loss of remote access to MLS instrument data has been identified as critical for the planned Online IST Phase II security updates**
  - **IST Online connectivity is still having problems with the new DMZ**
    - **Remote Desktop disconnects and Workspace data resets are still occurring ~1-2 times per week**
    - **Remote Desktop Workspace sessions are not updating as they should**
      - **Workspace windows have no data or clock updates from the Remote Desktop disconnect to Remote Desktop reconnect**
    - **Denver Raytheon has been working these issues**
- **Auto-Ops Status**
  - **Changes? Data loss issues?**
- **MLS would like to see the following capabilities re-instated:**
  - **Dual head monitor capability**
  - **AOS/LOS clock display**

Instrument Plans

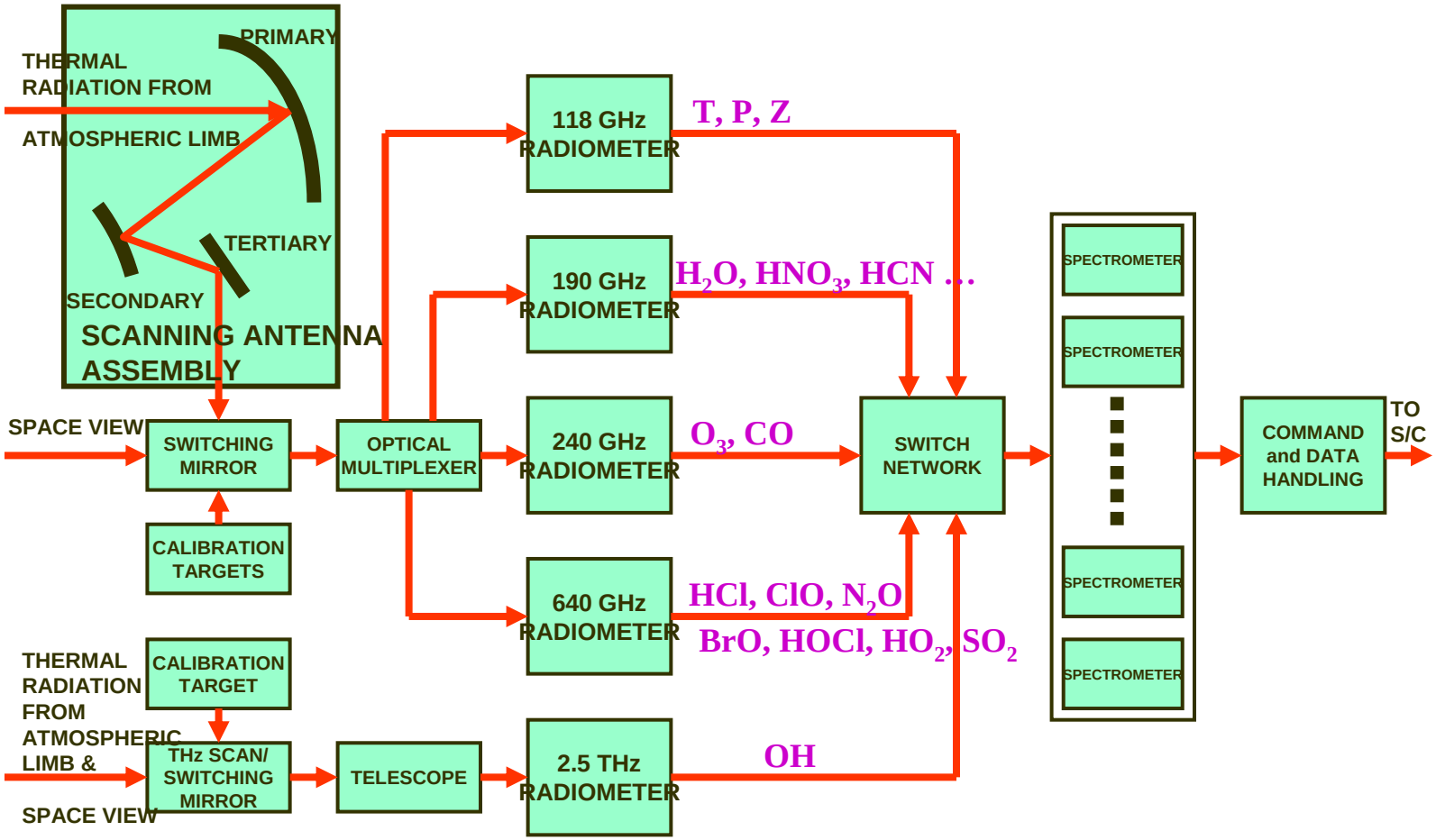
- **Support Aura inclination maneuvers, AVE campaigns and other spacecraft activities**
- **Continue with routine MLS activities**
- **Perform MLS special calibration activities**
  - **Moon Scans**
  - **Baseline updates**
  - **Other tests as needed**
- **Bands 10 & 29**
  - **Minimize thermally cycling of Bands 10 & 29 whenever practical**
- **Band 13**
  - **Leave Band 13 off to minimize thermal cycling**

Status Summary

- MLS instrument performance continues to be very good
  - All science products are still being retrieved with only a slight degradation in the quality of the HCL measurement
- There are a few longevity concerns but presently, all is well
- MLS calibration tests confirm the current health of the instrument
- MLS data processing systems are operating smoothly
- All Level 1 and Level 2 files routinely archived & available from GSFC DAAC

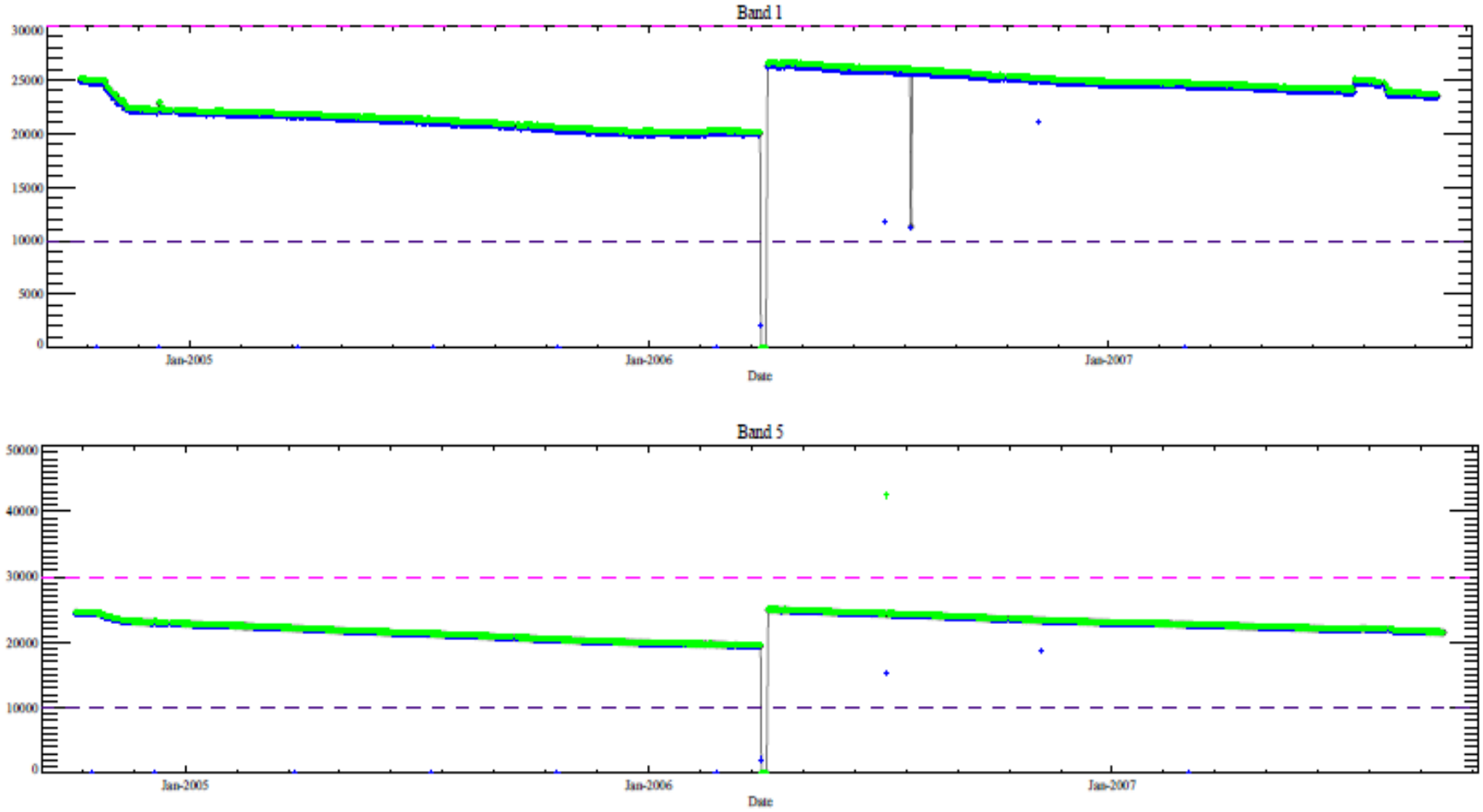
Backup Slides

Instrument Overview
Signal Flow Block Diagram



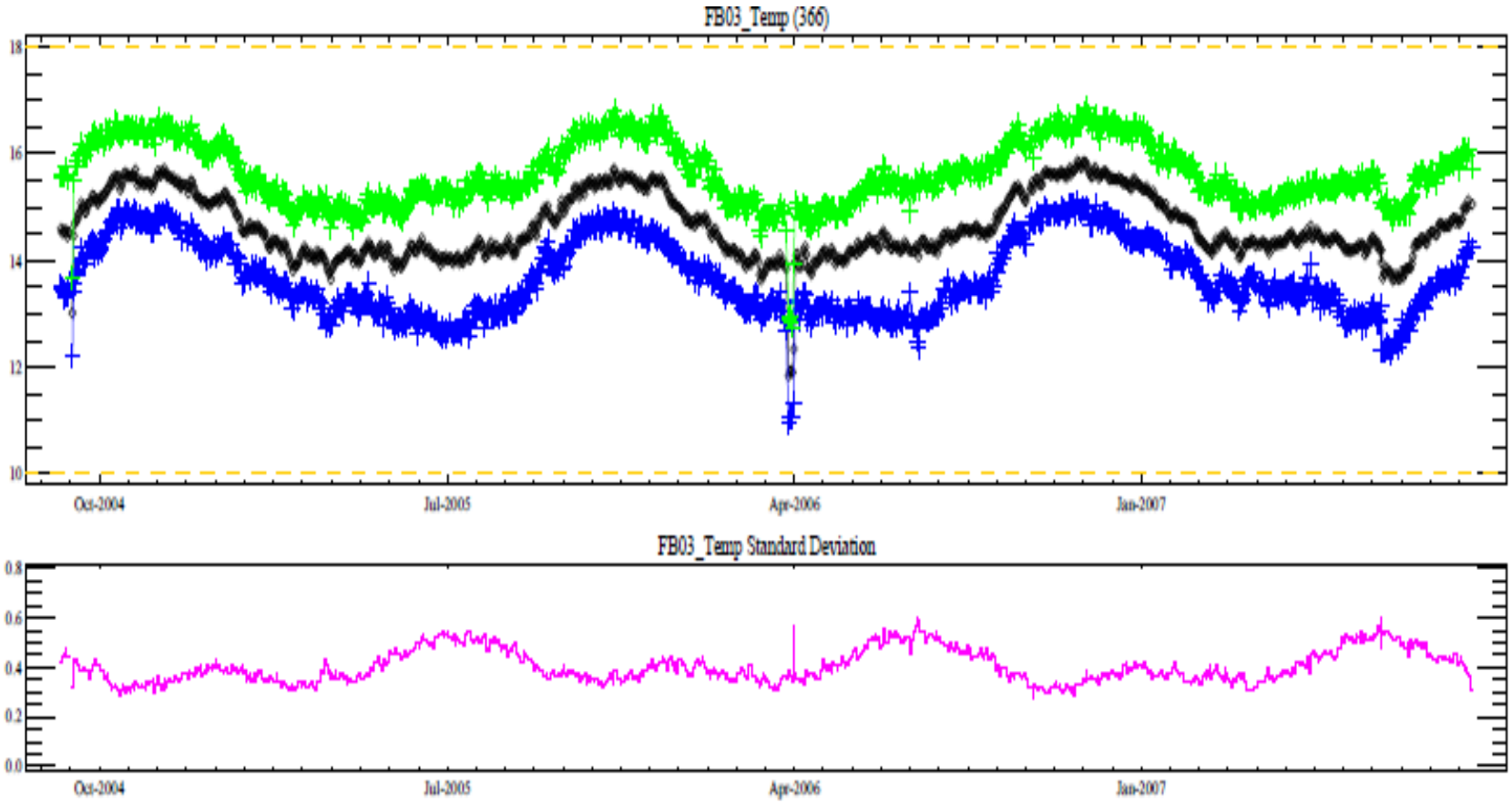
MLS Nominal Trends

Typical Signal Trends



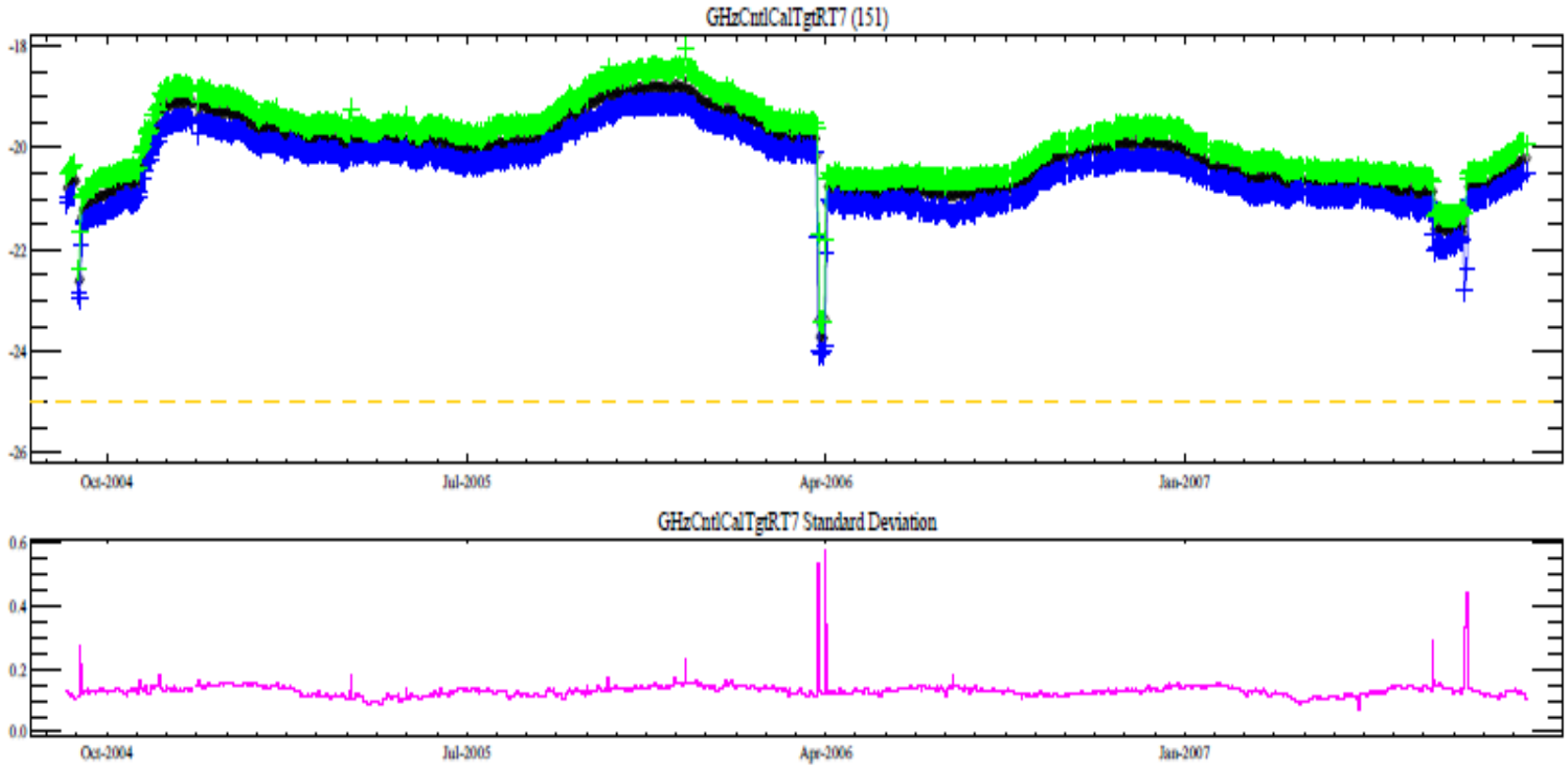
MLS Nominal Trends

Spectrometer Module Temperature



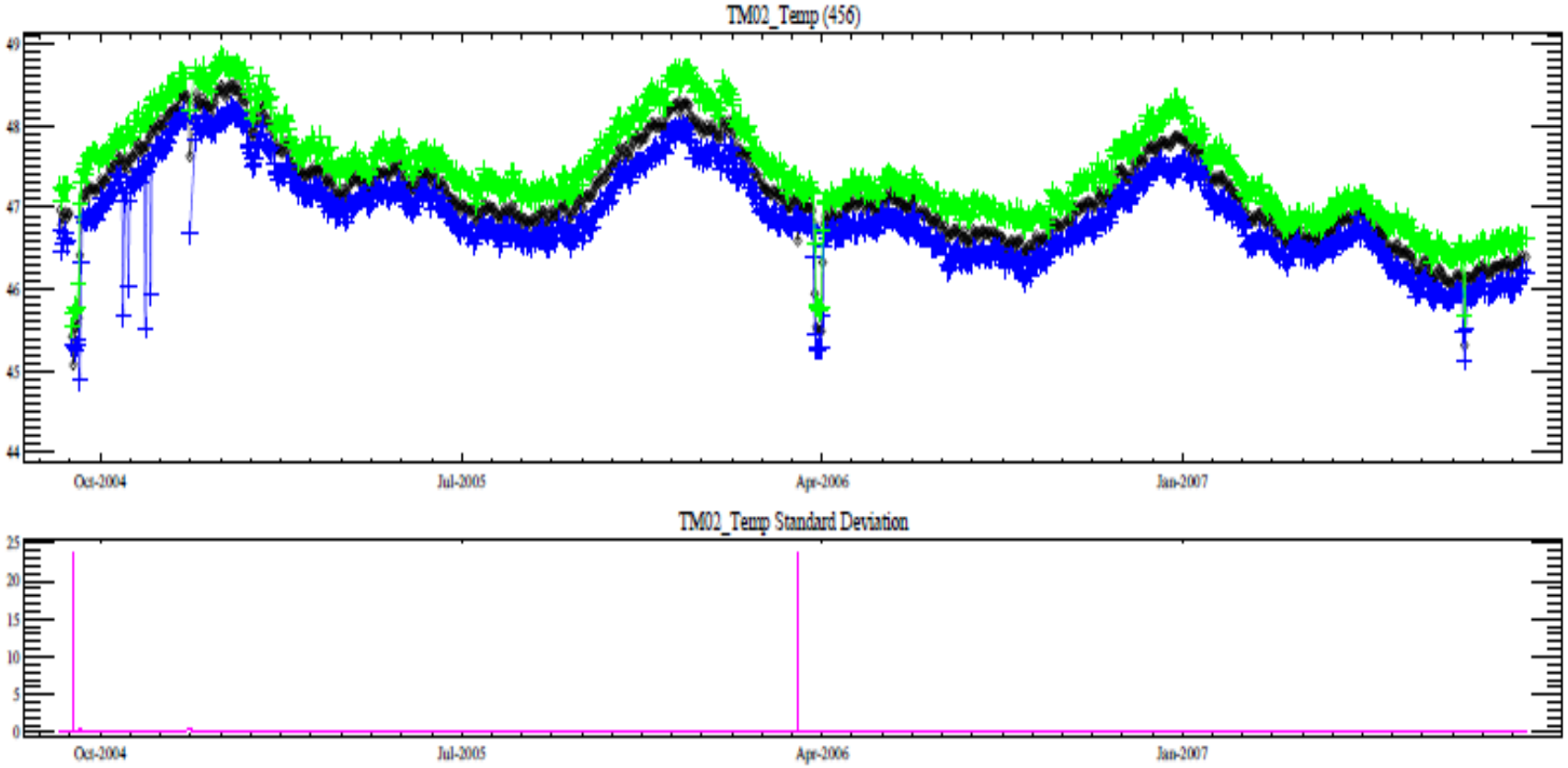
MLS Nominal Trends

GHz Module Temperature



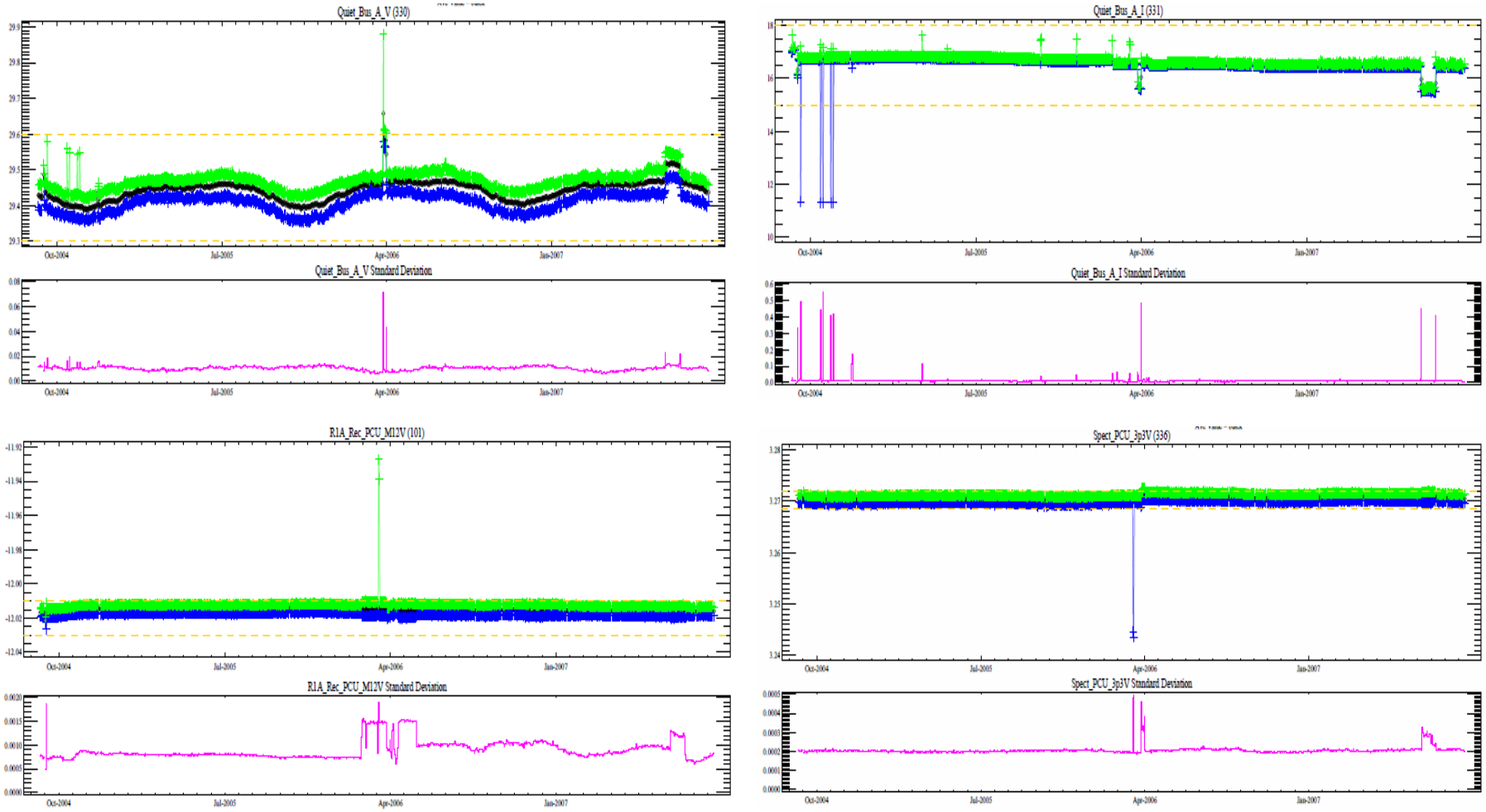
MLS Nominal Trends

THz Module Temperature



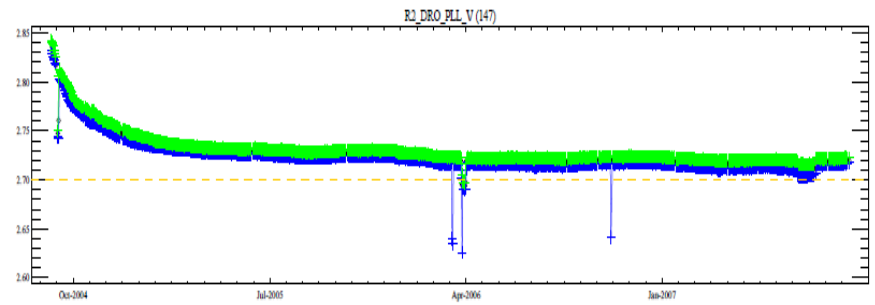
MLS Nominal Trends

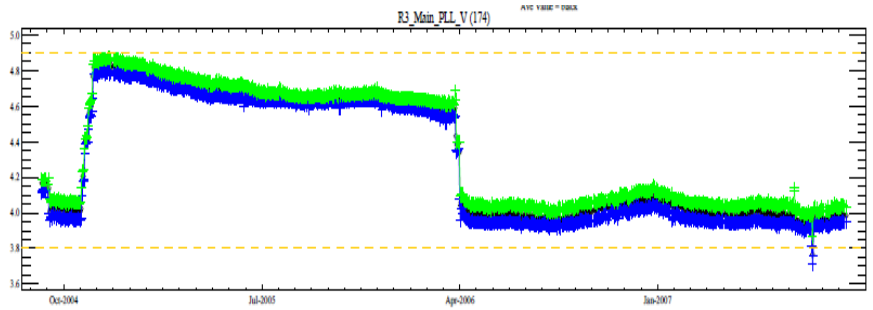
Bus V and I, Assembly Supply Voltages

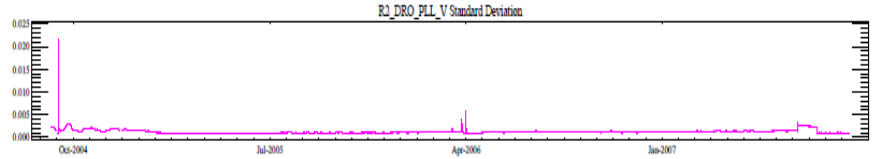


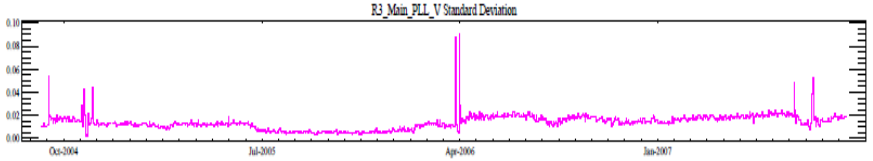
MLS Nominal Trends

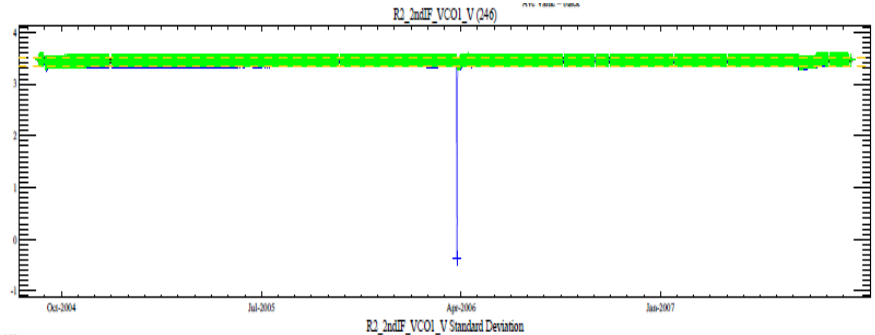
Control Voltages

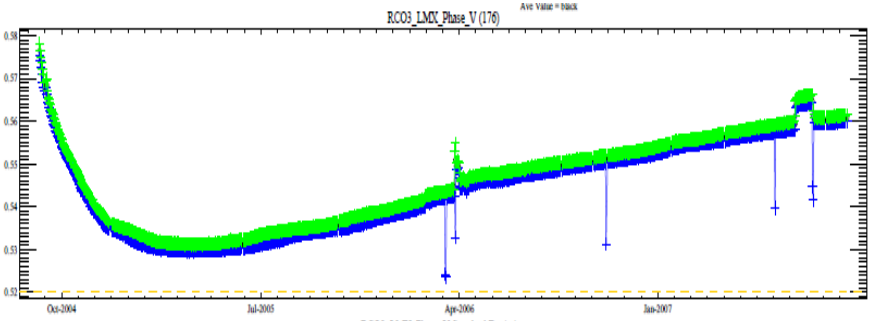


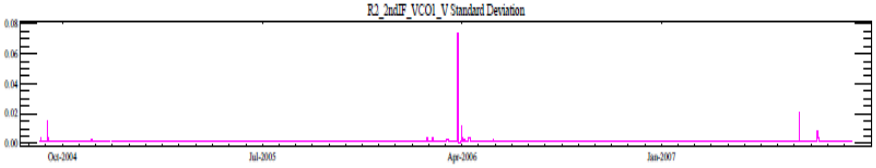


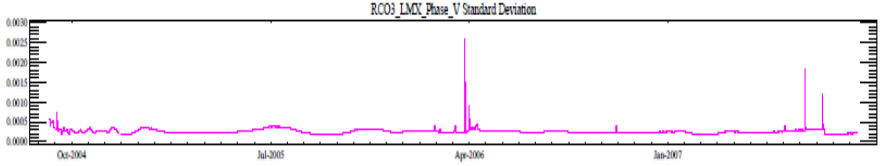






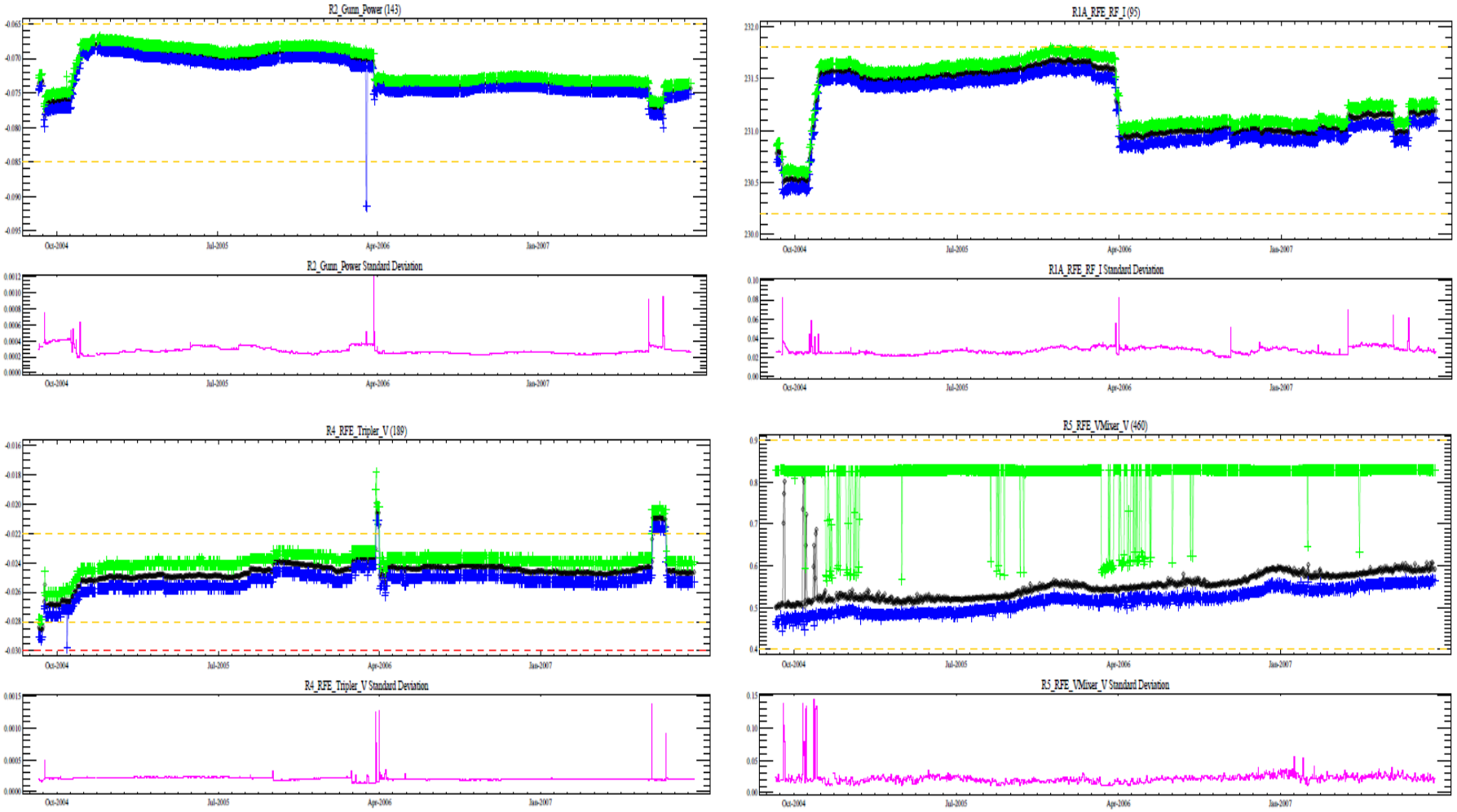






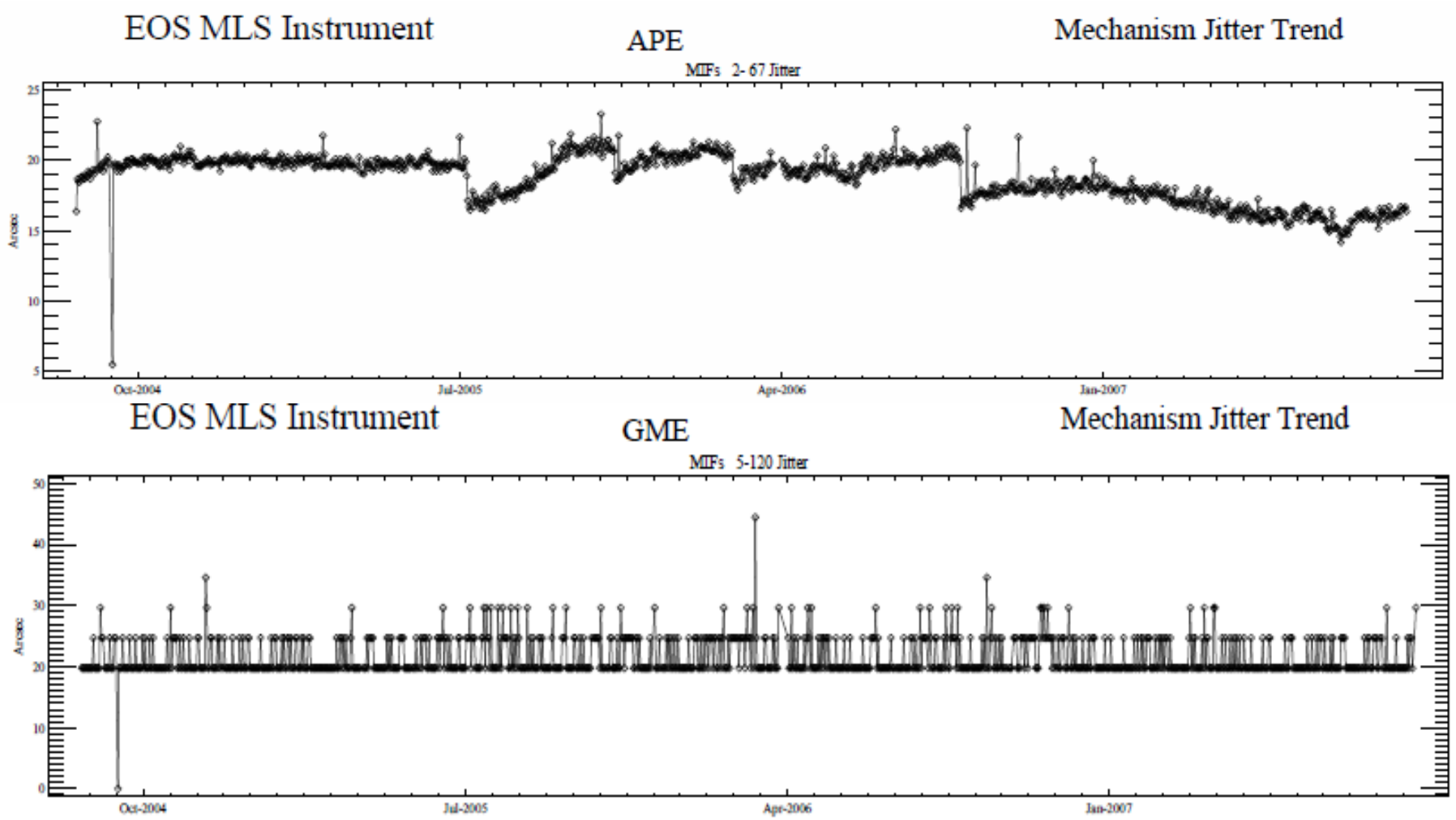
MLS Nominal Trends

Additional Signal Chain Trends



MLS Nominal Trends

Mechanism Jitter Trends APE and GME



MLS Nominal Trends

Mechanism Jitter Trends