A Tale of Two EDLs
(from a Telecom Point of View)

MER's Entry, Descent, and Landing

DESCANSO SEMINAR
2/26/04

Polly Estabrook

EDL Telecom Team

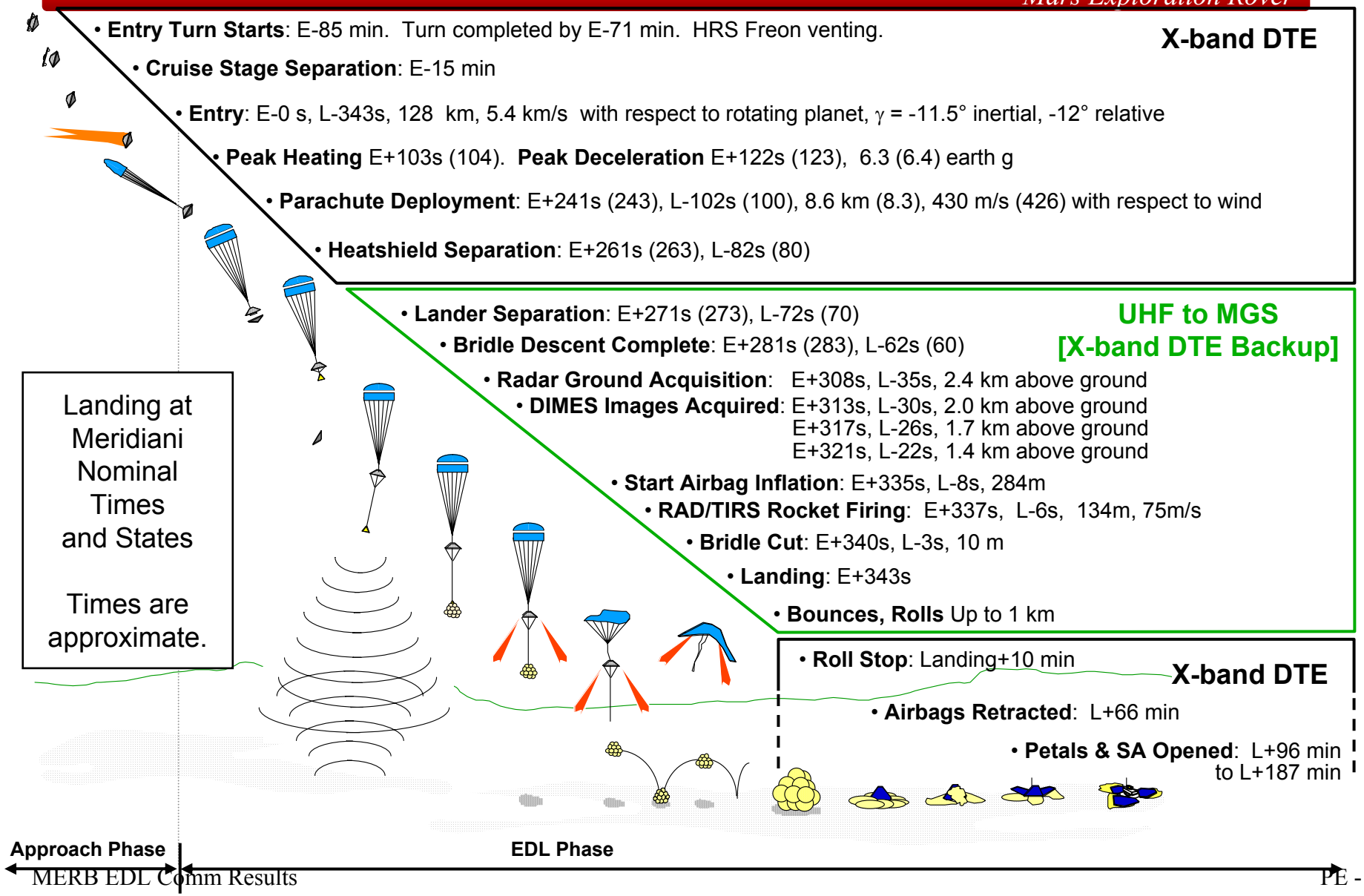
- EDA/ RSR People: Christine Chang, Sue Finley, Doug Johnston, Ed Satorius, Tim Pham, Sal Abbate, Sami Asmar
- UHF People: Andrea Barbieri, Peter Ilott, Monika Danos
- SU/SRI People: Arv Vaisnys, Brad Arnold, Chad Edwards
- DTT People: Chau Buu, Jeff Berner, Miguel Marina (at ROSA)
- Xband Telecom on Console: Jim Taylor, Peter Ilott
- RSR On Console: Aseel Anabtawi, Elias Barbinis

OUTLINE

- What is said about EDL ….
  - EDL Pictorial Timeline
  - 6 Minutes of Terror
- What we expected from EDL …..
  - Frequency Profile (Rates and Accelerations)
  - Power predictions
  - Dynamics predictions
- DSN Configuration during EDL ….
- What happened during EDL in Real Time ….
  - MERB EDA 'Movie'
  - MERA RSR Movie
  - DSN Closed-Loop Receiver Performance
  - UHF Performance
- Reconstruction ….

MER EDL Timeline (from MER Mission Plan)

Mars Exploration Rover



Opportunity (MER B) X Band Direct to Earth Overview

Mars Exploration Rover

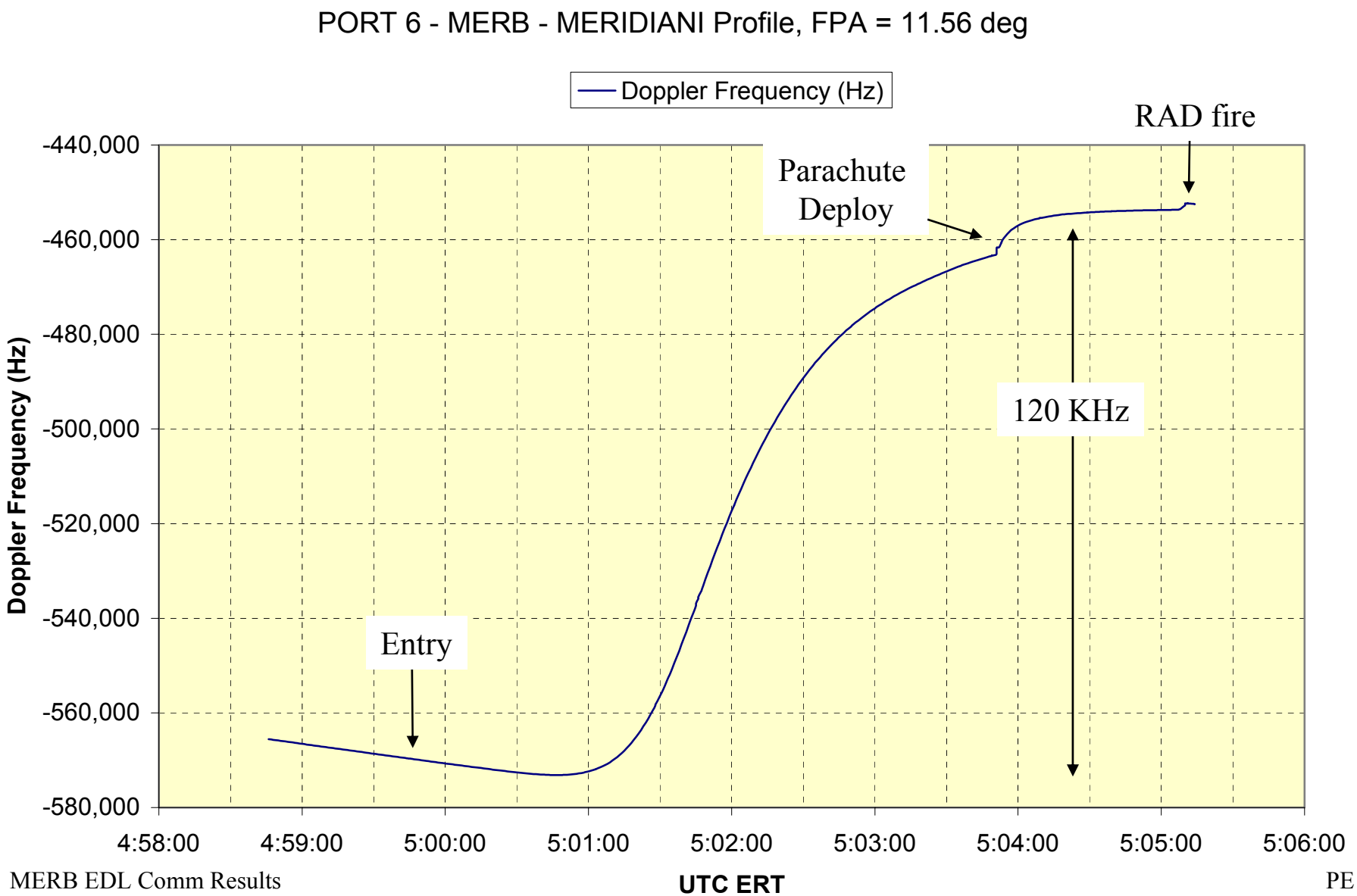
Event	EDL Phase	Phase Start Time	Nominal Duration (sec)	Worst case Margin (dB) on DSS-14,43	Comm. Observables
1	Transition to CLGA (D/L non-coherent, 10 bps)	Entry - 105 min	Instantaneous	8.0 dB	DTT out of lock (all) D/L freq. transition (AUX OSC warmup)
2	Turn to Entry Start & Stop	E - 85 min, E - 71 min	14 min (nom); 44 min (max)	4.0 dB	4 dB change is discernable in Pc/No
3	1st MFSK Tone (cal_sem_1)	E - 15min 50 sec	10 sec	>3.0 dB	Tone detect by DSS-14, -43 EDA;
4	Cruise Stage Separation	E - 15 min	30 sec (MPF heritage)	Loss of Signal	RSR & EDA detect LOS;
5	CSS to Entry	E - 15 min; E - 0 min	15 min	>4 dB	DSS-14, -43 EDA detect carrier and tones;
6	Entry to Parachute Deploy	E - 0 min; E + 240 sec	4 min	3 dB (at hypersonic entry)	DSS-14, -43 EDA detect carrier and tones;
7	Parachute Deploy to Lander Separation	E + 240 sec; E + 270 sec	30 sec	< 1 dB	DSS-14, -43 EDA detect intermittent carrier and possible tones;
8	Lander Separation to RAD Ignition	E + 270 sec; E + 340 sec	70 sec	Sporadic link avail. (4 dB to <0 dB)	DSS-14, -43 EDA INTERMITTENT carrier detection
9	RAD Ignition to S/C Rollstop	Landing (E + 343 sec); Landing + 5 min	5 min	Sporadic link avail. (geom. dependent)	DSS-14, -43 EDA INTERMITTENT carrier detection;
10	S/C Rollstop to Landed Tone Start	Landing + 5 min; Landing + 10 min	5 min	Geom. Dependent (unpredictable)	DSS-14 and -43 EDA intermittent carrier detection possible
11	Landed Tones via RLGA	L + 10 min; L + 13 min	3 min	40% chance of detection	DSS-14 and -43 EDA carrier and tone detection (Gemetry dependent)
12	CW on Lander Antenna	L + 13 min; L + 14 min	1 min	40% chance of detection (Geom. Dependent)	DSS-14 and -43 EDA intermittent carrier detection possible
13	Landed Tones via Lander Antenna	L + 14 min; L + 17 min	3 min	40% chance of detection	DSS-14 and -43 EDA carrier and tone detection (Gemetry dependent)
14	CD tones on Sol 2	10 AM LSTA	10 min	Rover Geometry Dependent	DSS-14 and -43 EDA carrier and tone detection (Gemetry dependent)

Two way downlink frequency = 8,435,346,093 Hz
One way downlink frequency = 8,435,368,400 Hz

6 Minutes of Terror Movie

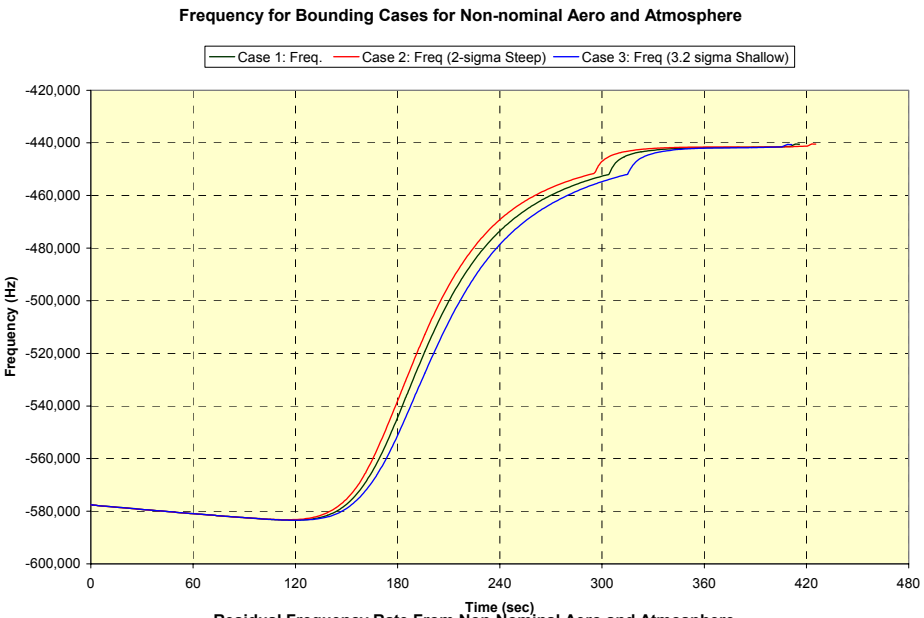
EDL Doppler Signature

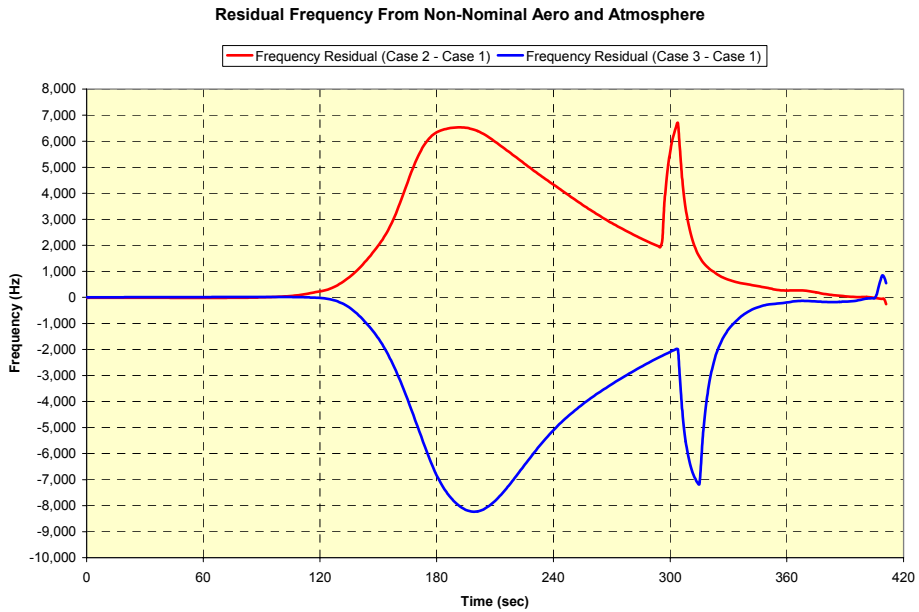
(MERB PORT6 Frequency Predict)

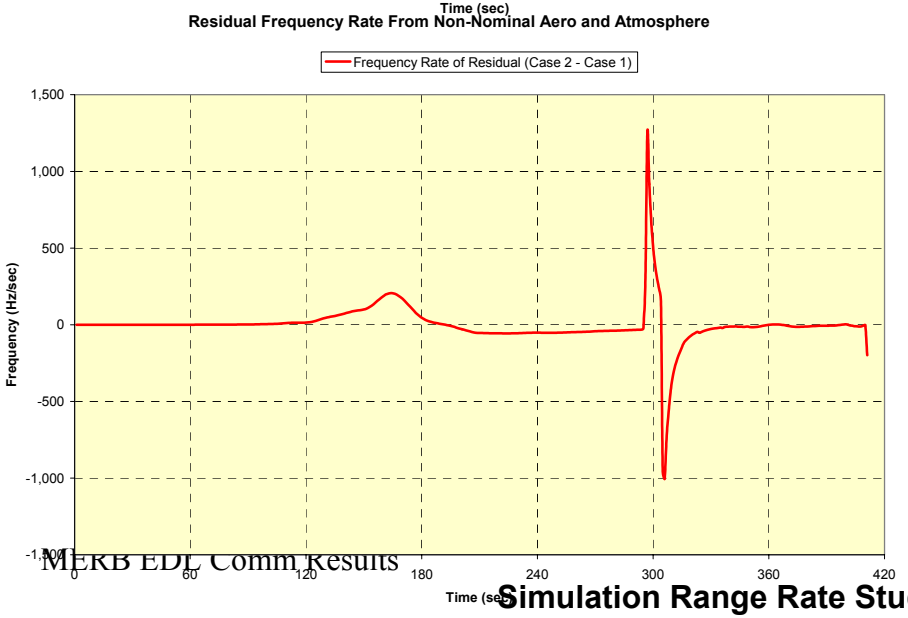


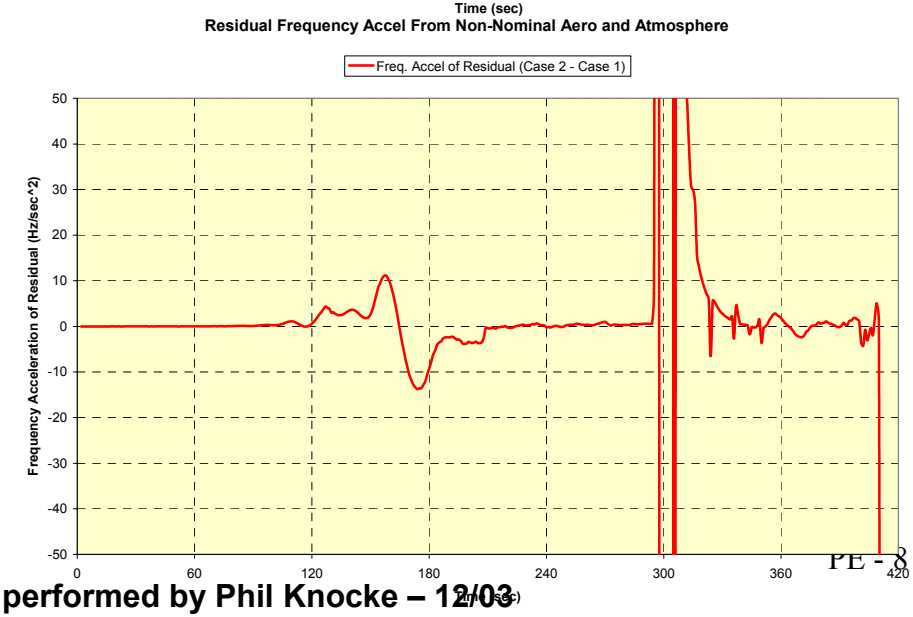
Frequency Signatures due to Nominal Range of Aeronautic, Atmospheric, and Flight Path Angle Changes

Mars Exploration Rover









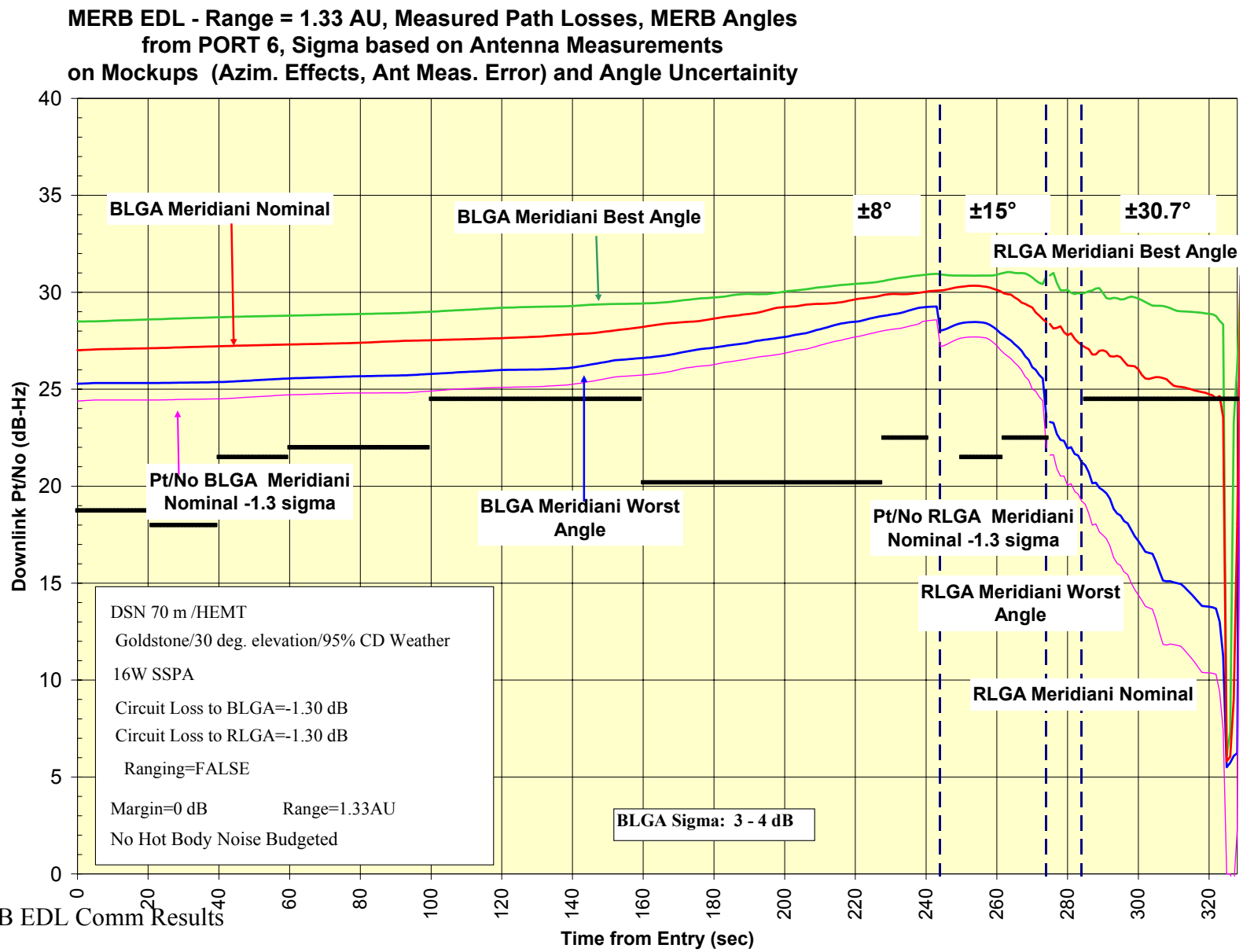
Simulation Range Rate Study performed by Phil Knocke – 12/03

RSR Bandwidth

- **During EDL, received X band signal is recorded at DSN by RSR (Radioscience Spectrum Recorder). RSR Bandwidth chosen to be:**
  - **100 KHz – usable –flat bandwidth = +/- 40 KHz**
  - **Allocation:**
    - **+/- 20 KHz for possible tone spectrum**
    - **+/- 10 KHz navigation**
    - **+/- 10 KHz oscillator frequency change due to temp. change**

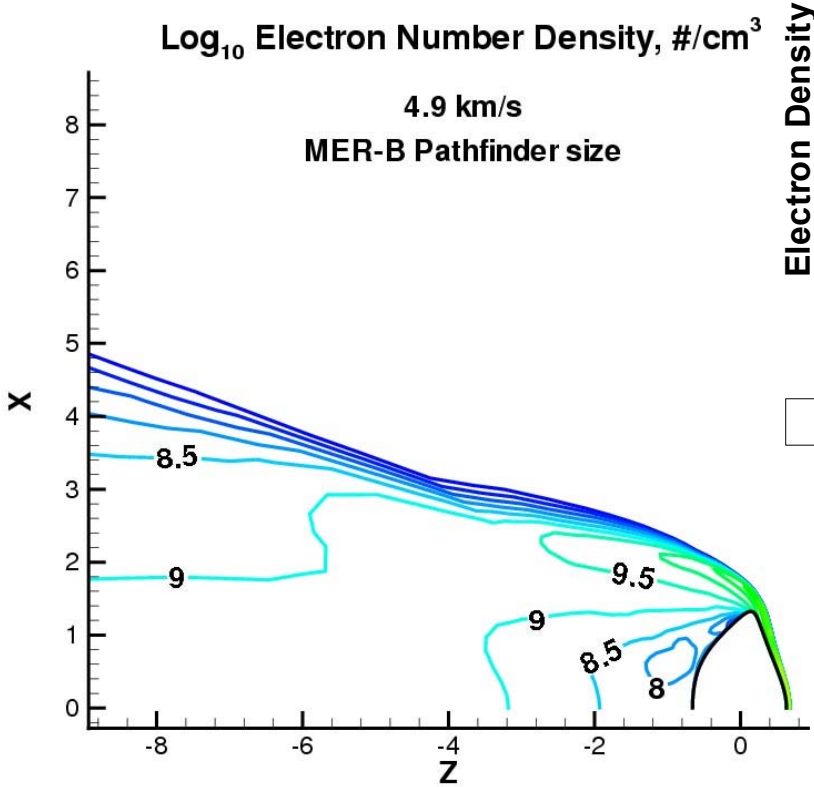
MER B - GDSCC Link Performance (30 deg elev)

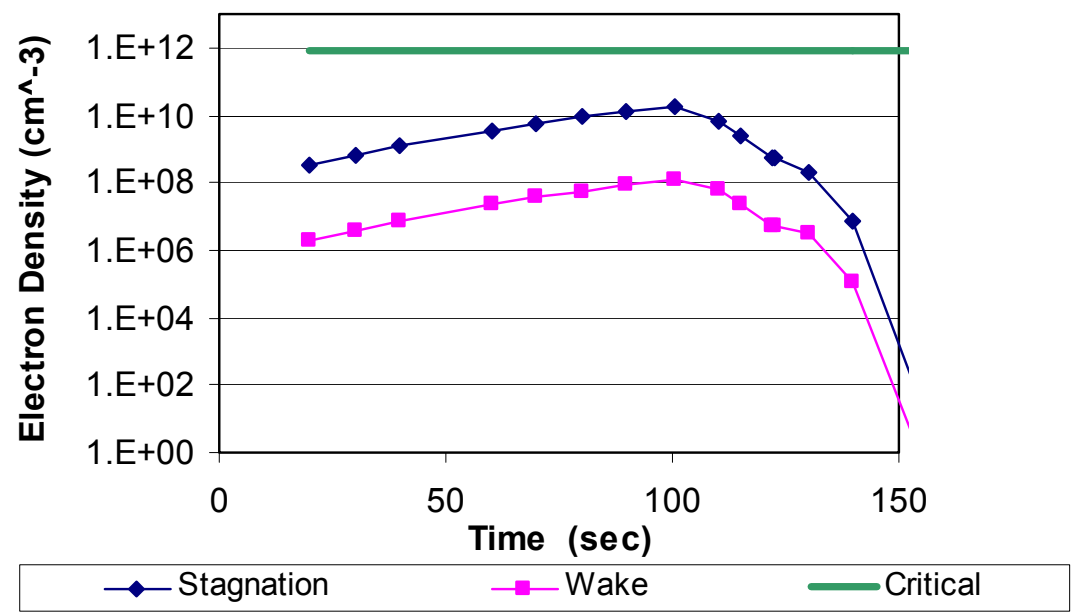
Mars Exploration Rover



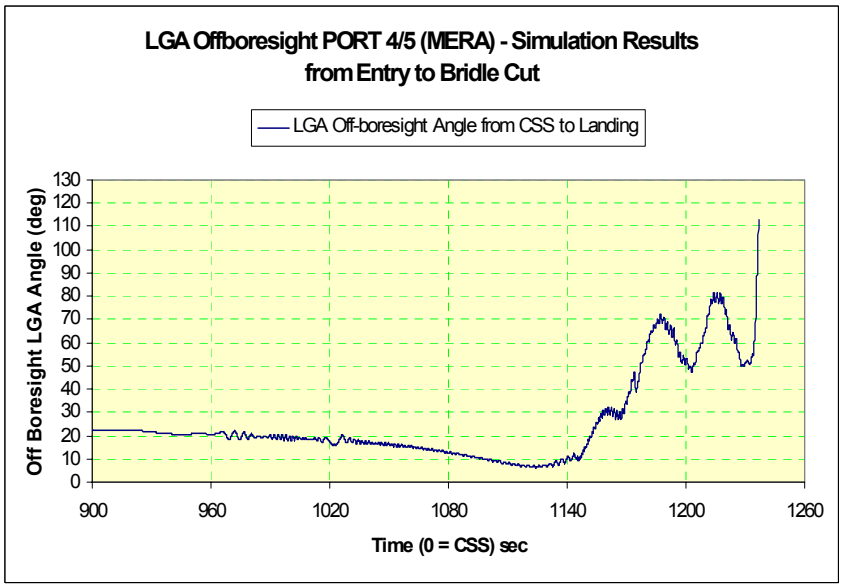
Plasma Predictions

Plasma outage at X band if Electron Density > 10^12

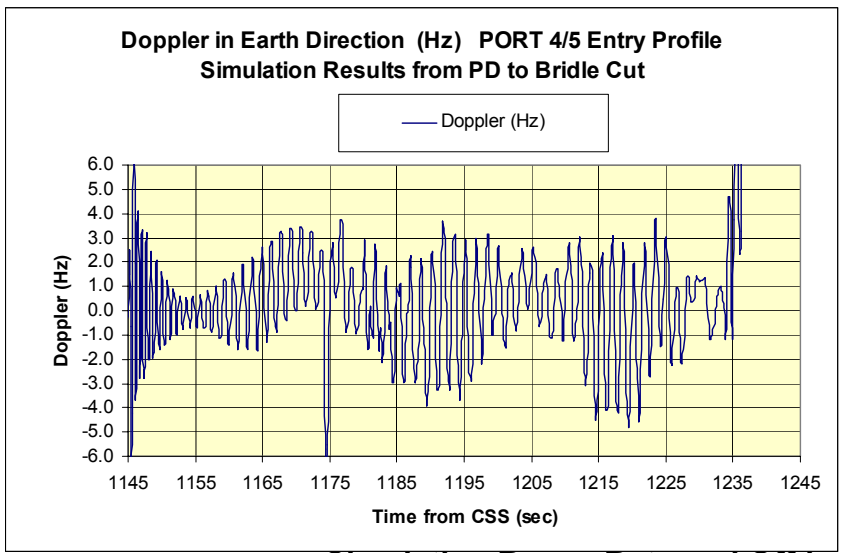


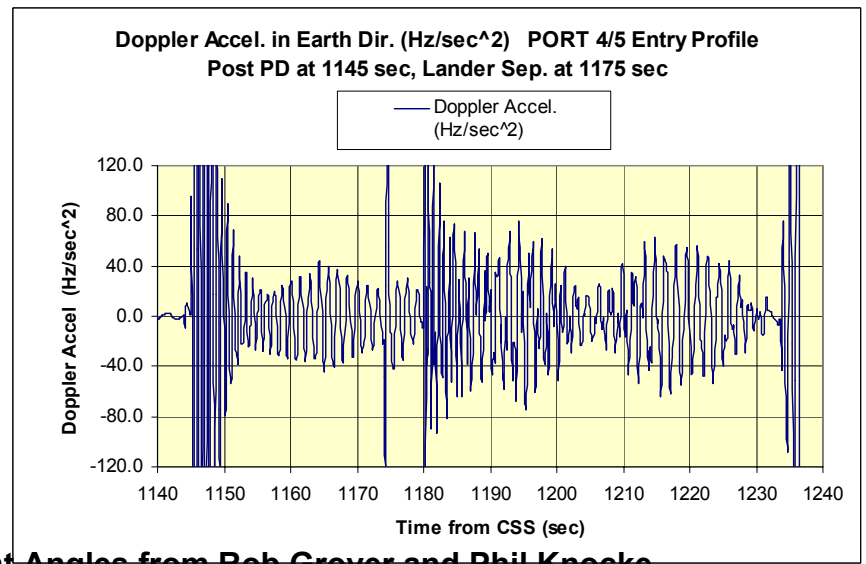


X band Carrier Signal Characteristics expected from PD to Bridle Cut



- Signal dynamics predicted by POST simulation show:
- PD to Bridle Separation:
  - High frequency Doppler post PD – 1Hz period
  - Carrier detection DIFFICULT but expected by RSR and EDA due to Pc/No > 18 dB Hz
- Bridle Separation to Bridle Cut
  - >40 Hz/sec^2 Doppler acceleration (1sec period) and large variation in Pc/No due to "Swinging on bridle" effect (30 sec period) make signal detection difficult
  - Carrier Detection by RSR UNLIKELY
  - Occasional Carrier Detection by EDA possible
  - UHF PRIME Comm Path

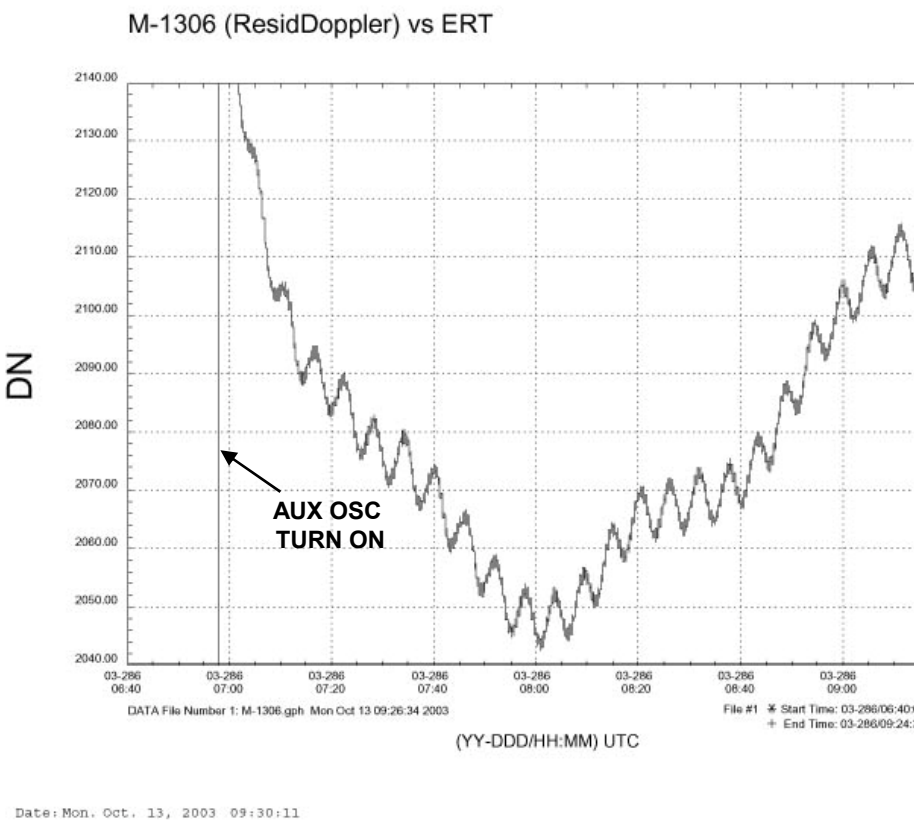


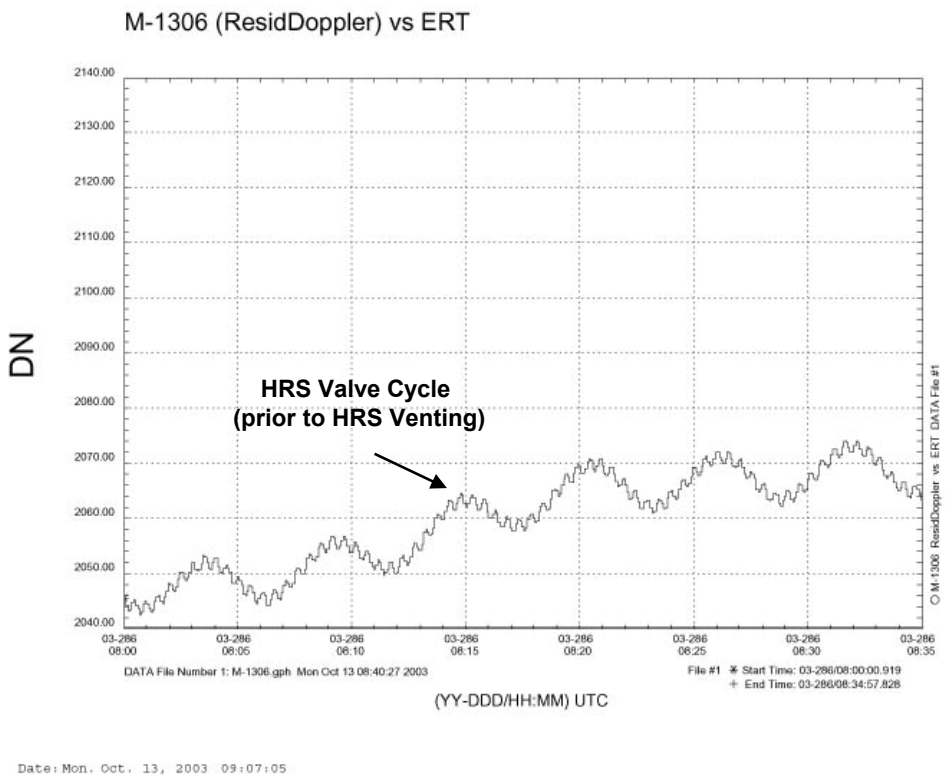


Simulation Range Rate and Off-boresight Angles from Rob Grover and Phil Knocke

X band Carrier Signal Characteristics at E- 1:45 - AUX OSC turn-on at MGA / LGA Switch

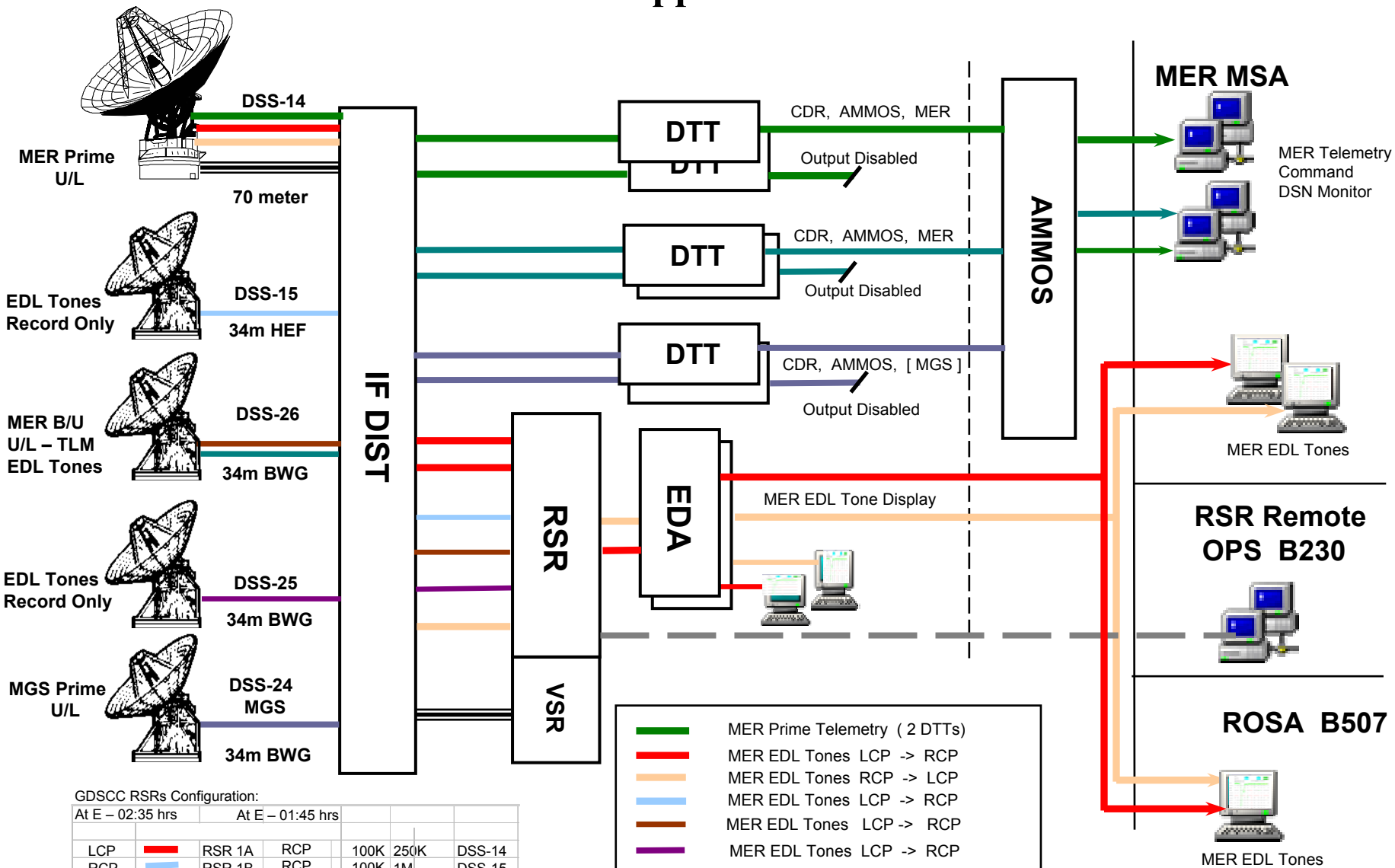
Residual Doppler Data from DSS Monitor Data during In Flight EDL Comm. Test





Data taken from In Flight Test on 10/17/03 on MGA;
2 rpm s/c spin expected to be <1 Hz on LGA
Freq variation due to HRS temp variation seen with 5-6 min period

Goldstone EDL Support Data Flow: MER-B



GDSCC RSRs Configuration:

At E – 02:35 hrs		At E – 01:45 hrs				
LCP		RSR 1A	RCP	100K	250K	DSS-14
RCP		RSR 1B	RCP	100K	1M	DSS-15
RCP		RSR 2A	LCP	100K	1M	DSS-14
RCP		RSR 2B	RCP	100K	1M	DSS-25
RCP		RSR 3A	RCP	100K	1M	DSS-26
LCP		RSR 3B	RCP	100K	1M	DSS-14

Courtesy Byron Yetter

EDL Data Analysis Configuration

Mars Exploration Rover

- **EDA divides the EDL Timeline into 7 segments:**
  - **Cruise, Entry, Parachute, Predict Recovery, Bridle Bounce, Landed Carrier only, Landed (Carrier and Tones)**

	Segment 3: Parachute				Segment 7: Landed			
	Segment Duration		70.0	sec	Segment Duration		788.0	sec
Event Relative Time	**Tstart (PD earliest - 5 sec)**	**5**	**Tstop (PD latest + 5 sec)**	**5**	**Tstart (1st MFSK Tone)**	**0**	**Tstop (Entry + 33 min)**	**1980**
UTC Time (hh:mm:ss)		**5:03:14**		**5:04:24**		**5:19:38**		**5:32:46**
EDA Time (sec)		**3794**		**3864**		**4778**		**5566**
EDA Configuration Parameters	Acquisition	Tracking / Backtrack	Refine	Tone Detection	Acquisition	Tracking / Backtrack	Refine	Tone Detection
Delta f (Hz)	10	5	5	5	1	1	1	1
Tcoherent, Tau (sec)	0.1	0.2	0.2	0.2	1	1	1	1
m	10	5	5	5	10	10	15	10
Tnoncoherent, T = m * Tau	1	1	1	1	10	10	15	10
Nf	1,650,165	39,765	3,150	768	4,500,225	3,015	765	768
Max Acceleration (Hz/sec^2) = (2 * delta f)/ T^2	20.00	10.00	10.00	10.00	0.020	0.020	0.009	0.020
Noise Floor (dB-Hz)	**13.7**	**11.6**	**10.5**	**9.8**	**3.9**	**1.6**	**-0.2**	**0.9**
Prob. of Correct Estimate (1 - Prob(error))	95	95	95	99.9	95	95	95	95
Pt/No Threshold (w/o implement'n loss)	**20.5**	**17.9**	**17.3**		**10.4**	**8**	**6.4**	

MER B EDA ‘Movie’

MERB Event Timeline

Mars Exploration Rover

Event	UTC-ERT	
MGA - LGA Transition	1/25/2004	3:14:46
Turn to Entry Start	1/25/2004	3:34:46
Turn to Entry Stop	1/25/2004	3:53:06
HRS Venting	1/25/2004	4:19:46
Cruise Stage Separation	1/25/2004	4:44:45
First Deceleration Tone	1/25/2004	4:47:46
Atmospheric Entry - ETLF	1/25/2004	4:59:46
Peak Heating (predict)	1/25/2004	5:01:28
Max Deceleration (6.3 Gs) 5:03:49 expected	1/25/2004	5:01:47
Chute Deploy (13393 lb)	1/25/2004	5:03:56
Heat Shield Jettison	1/25/2004	5:04:16

Event	UTC-ERT	
Lander Separation	1/25/2004	5:04:26
RAS Acquire (2523.1 m)	1/25/2004	5:04:50
RAD Fire	1/25/2004	5:05:22
Bridle Cut	1/25/2004	5:05:25
Landing (Approximate)	1/25/2004	5:05:28
Rollstop (Bounce 26 times total, bounce, roll into crater, bounce, roll)	1/25/2004	5:07:15
SCM transition from EDL to CD - UHF Transceiver OFF	1/25/2004	5:15:25
Begin Landed Tones on RLGA (1 KHz)	1/25/2004	5:18:53
End Landed Tones on RLGA	1/25/2004	5:22:08
Switch to Lander Antenna - CW only	1/25/2004	5:22:09
Begin Landed Tones on Lander Antenna (1 KHz)	1/25/2004	5:24:23
End Landed Tones on Lander Antenna	1/25/2004	5:27:38

Key Items in Reconstruction Timeline from Erik Bailey

MERB EDL Real Time Results: DSS-14 Tones (UNABRIDGED!)

Mars Exploration Rover

YEAR	DOY	HH:MM:SS	TONE_ DURATION	TONE	Tone_Mnemonic	Pc/No	Pd/No	Pc/No-TH	Pd/No-TH	
2004	25	4:00:00	2641			23.91	LOW	13.01	14.51	
2004	25	4:44:01	30	1	mfsk_cal_sem_1	23.87	23.34	13.01	14.51	
2004	25	4:44:31	14	256	mfsk_cal_sem_2	24.14	22.78	13.01	14.51	
2004	25	4:44:45	2			LOW	LOW	9.51	11.01	
2004	25	4:44:47	14	256	mfsk_cal_sem_2	23.68	22.46	13.01	14.51	
2004	25	4:45:01	10	8	mfsk_css_event	23.21	22.74	13.01	14.51	
2004	25	4:45:11	160	256	mfsk_cal_sem_2	24.02	22.87	13.01	14.51	
2004	25	4:47:51	800	57	mfsk_accel_1	23.61	22.87	13.01	14.51	
2004	25	5:01:11	10	58	mfsk_accel_2	23.26	22.19	13.01	14.51	
2004	25	5:01:21	10	59	mfsk_accel_3	23.24	22.74	13.01	14.51	
2004	25	5:01:31	10	60	mfsk_accel_4	23.07	22.09	13.01	14.51	
2004	25	5:01:41	10	62	mfsk_accel_6	23.65	22.8	13.01	14.51	
2004	25	5:01:51	10	63	mfsk_accel_7	23.5	22.26	13.01	14.51	
2004	25	5:02:01	11	62	mfsk_accel_6	21.19	20.23	13.01	14.51	
2004	25	5:02:12	1	61	mfsk_accel_5	15.19	LOW	13.01	14.51	← Not valid
2004	25	5:02:13	3	62	mfsk_accel_6	20	19.43	13.01	14.51	
2004	25	5:02:16	1	62	mfsk_accel_6	15.71	LOW	13.01	14.51	
2004	25	5:02:17	4	62	mfsk_accel_6	21.86	21.18	13.01	14.51	
2004	25	5:02:21	1	62	mfsk_accel_6	14.53	LOW	13.01	14.51	
2004	25	5:02:22	9	61	mfsk_accel_5	21.72	20.85	13.01	14.51	
2004	25	5:02:31	5			15.06	LOW	12.01	13.51	
2004	25	5:02:36	15	60	mfsk_accel_4	23.28	22.62	13.01	14.51	
2004	25	5:02:51	10	59	mfsk_accel_3	24.11	23.36	13.01	14.51	
2004	25	5:03:01	50	58	mfsk_accel_2	25.4	24.71	13.01	14.51	
2004	25	5:03:51	5	57	mfsk_accel_1	25.48	24.28	13.99	15.49	
2004	25	5:03:56	1	57	mfsk_accel_1	16.28	LOW	13.99	15.49	
2004	25	5:03:57	10	81	mfsk_para_deploy_event	22.06	21.56	13.99	15.49	
2004	25	5:04:07	10	58	mfsk_accel_2	22.96	21.87	13.99	15.49	
2004	25	5:04:17	9	94	mfsk_ht_shield_deploy_event	25.42	24.48	13.99	15.49	
2004	25	5:04:26	1	120	mfsk_spare_53	15.17	LOW	13.99	15.49	← Not valid
2004	25	5:04:27	3	107	mfsk_lander_drop_event	24.19	22.72	13.99	15.49	
2004	25	5:04:30	1	65	mfsk_accel_9	LOW	LOW	11.49	12.99	← Not valid
2004	25	5:04:31	6	107	mfsk_lander_drop_event	23.96	23.49	13.99	15.49	
2004	25	5:04:37	10	57	mfsk_accel_1	23.05	21.97	13.99	15.49	
2004	25	5:04:47	7	226	mfsk_rad_sol_matrix_4	20.38	19.18	13.99	15.49	
2004	25	5:04:54	1	226	mfsk_rad_sol_matrix_4	14.91	LOW	13.99	15.49	
2004	25	5:04:55	6	226	mfsk_rad_sol_matrix_4	18.2	17.14	13.99	15.49	
2004	25	5:05:01	1	226	mfsk_rad_sol_matrix_4	17.8	LOW	13.99	15.49	
2004	25	5:05:02	1	226	mfsk_rad_sol_matrix_4	17.96	16.31	13.99	15.49	
2004	25	5:05:03	8			LOW	LOW	11.49	12.99	
2004	25	5:05:11	2	98	mfsk_rad_sol_matrix_21	18.35	16.79	13.99	15.49	
2004	25	5:05:13	2	98	mfsk_rad_sol_matrix_21	17.29	LOW	13.99	15.49	
2004	25	5:05:15	7	98	mfsk_rad_sol_matrix_21	20.15	19.31	13.99	15.49	
2004	25	5:05:22	839			LOW	LOW	3	4.5	
2004	25	5:19:35	28	1	mfsk_cal_sem_1	15.64	16.63	5	6.5	
2004	25	5:20:03	30	160	mfsk_landed_accel_3	21.54	21.71	5	6.5	
2004	25	5:20:33	31	140	mfsk_no_fault	23.78	23.74	5	6.5	
2004	25	5:21:04	30	194	mfsk_plus_y_petal_down	22.3	22.26	5	6.5	
2004	25	5:21:34	33	185	mfsk_no_event_to_report	17.95	17.19	5	6.5	
2004	25	5:22:07	81			LOW	LOW	3	4.5	

MERA RSR Movie

MERA EDL Timeline

Mars Exploration Rover

Event	Reconstruction Team Timeline
	UTC ERT
Cruise Stage Separation	04:14:20
Atmospheric Entry - ETLF	04:29:20
Peak Heating (Predict)	04:31:04
Max Deceleration (5.8 Gs)	04:31:24
Chute Deploy (12985 lb)	04:33:32
Heat Shield Jettison	04:33:52
Lander Separation	04:34:02
RAS Acquire (2509.7 m)	04:34:27
RAD Fire	04:35:00
Bridle Cut	04:35:03
Landing	04:35:06 (?)
End of Bouncing - (28 bounces	04:36:07
End of Rolling	04:37:00
Rollstop	
RLGA Tones	
Beginning of 1 KHz	04:48:08
Beginning of 5 KHz	04:48:53
End of Last Tone	04:51:23
Carrier Only on Lander Ant.	04:51:29
Lander Antenna Tones	
Beginning of 1 KHz	04:53:38
Beginning of 5 KHz	04:54:23
End of Last Tone	04:56:53
Start Airbag Retraction	4:57:03
Complete Airbag Retraction	5:42:18
Earth Set	6:01:00

MERA EDL Real Time Results: DSS-43 Tones (UNABRIDGED!)

Mars Exploration Rover

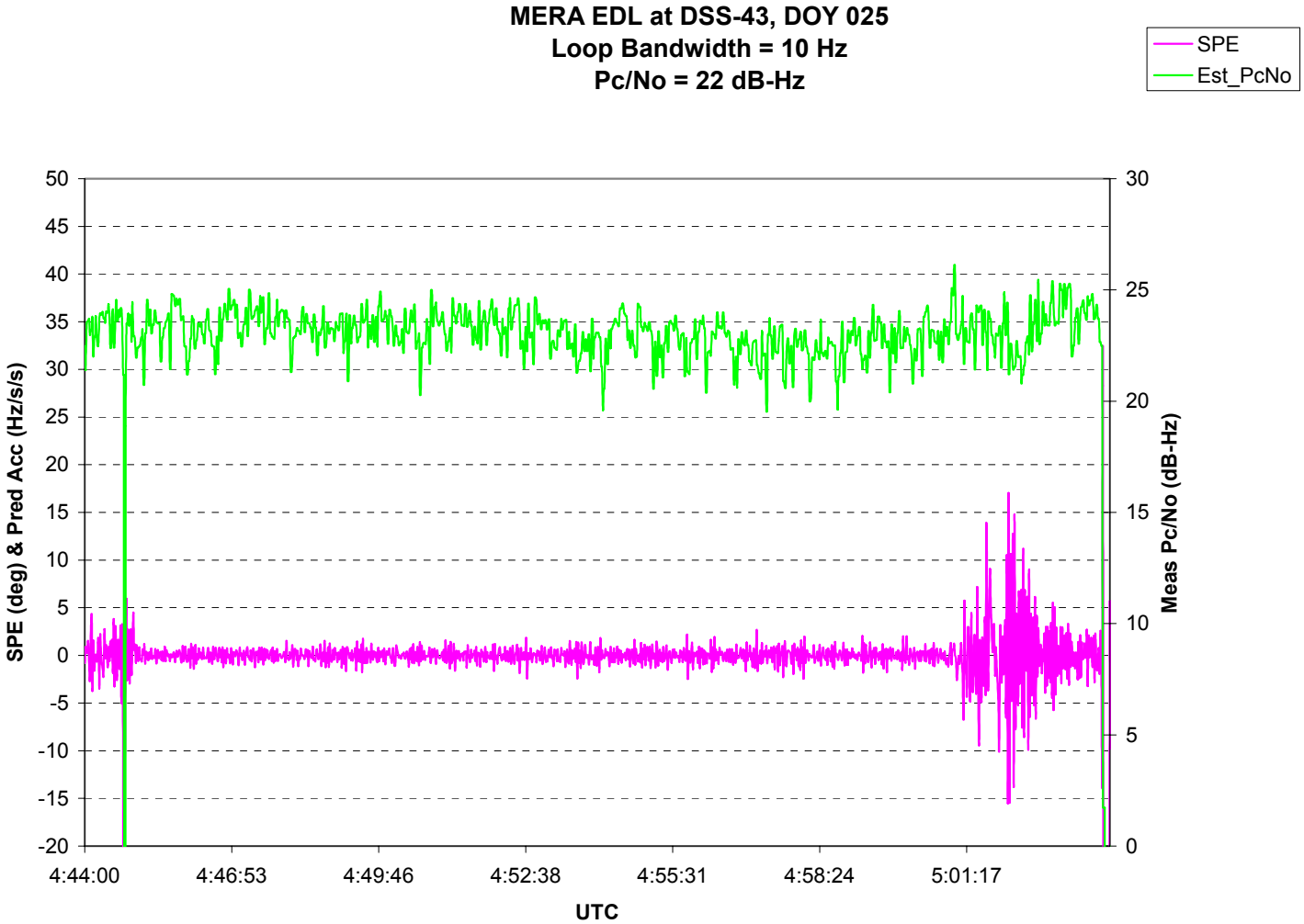
YEAR	DOY	HH:MM:SS	Seconds past EDA Start Time	TONE_DURATION (sec)	EDA TONE Number	Tone_Mnemonic	Pc/No	Pd/No	Pc/No-TH	Pd/No-TH
2004	4	3:14:00	0	3576			24.87	LOW	13.01	14.51
2004	4	4:13:36	3576	30	1	mfsk_cal_sem_1	26.11	24.06	13.01	14.51
2004	4	4:14:06	3606	10	155	mfsk_rover_batt_low_temp_fault	26.07	23.99	13.01	14.51
2004	4	4:14:16	3616	4	256	mfsk_cal_sem_2	25.62	23.39	13.01	14.51
2004	4	4:14:20	3620	4		Cruise Stage Separation	LOW	LOW	9.51	11.01
2004	4	4:14:24	3624	12	256	mfsk_cal_sem_2	26.14	24.47	13.01	14.51
2004	4	4:14:36	3636	10	8	mfsk_css_event	27.75	25.5	13.01	14.51
2004	4	4:14:46	3646	160	256	mfsk_cal_sem_2	27.81	26	13.01	14.51
2004	4	4:17:26	3806	800	57	mfsk_accel_1	28.09	26.04	13.01	14.51
2004	4	4:30:46	4606	10	58	mfsk_accel_2	28.78	26.58	13.01	14.51
2004	4	4:30:56	4616	10	59	mfsk_accel_3	28.48	26.37	13.01	14.51
2004	4	4:31:06	4626	10	60	mfsk_accel_4	28.22	26.32	13.01	14.51
2004	4	4:31:16	4636	10	61	mfsk_accel_5	28.82	26.78	13.01	14.51
2004	4	4:31:26	4646	30	62	mfsk_accel_6	28.65	26.65	13.01	14.51
2004	4	4:31:56	4676	10	61	mfsk_accel_5	29.03	26.96	13.01	14.51
2004	4	4:32:06	4686	20	60	mfsk_accel_4	29.18	27.15	13.01	14.51
2004	4	4:32:26	4706	20	59	mfsk_accel_3	29.12	27.12	13.01	14.51
2004	4	4:32:46	4726	40	58	mfsk_accel_2	29.28	27.2	13.01	14.51
2004	4	4:33:26	4766	7	57	mfsk_accel_1	27.43	24.94	13.99	15.49
2004	4	4:33:33	4773	10	81	mfsk_para_deploy_event	25.32	23.32	13.99	15.49
2004	4	4:33:43	4783	10	58	mfsk_accel_2	25.55	23.63	13.99	15.49
2004	4	4:33:53	4793	10	94	mfsk_ht_shield_deploy_event	22.75	20.53	13.99	15.49
2004	4	4:34:03	4803	7	107	mfsk_lander_drop_event	24.07	22.21	13.99	15.49
2004	4	4:34:10	4810	3			LOW	LOW	11.49	12.99
2004	4	4:34:13	4813	5	57	mfsk_accel_1	17.99	16.21	13.99	15.49
2004	4	4:34:18	4818	1	57	mfsk_accel_1	19.32	LOW	13.99	15.49
2004	4	4:34:19	4819	4	57	mfsk_accel_1	21.12	19.01	13.99	15.49
2004	4	4:34:23	4823	10	226	mfsk_rad_sol_matrix_4	22.87	20.64	13.99	15.49
2004	4	4:34:33	4833	2	227	mfsk_rad_sol_matrix_8	20.79	17.74	13.99	15.49
2004	4	4:34:35	4835	5			LOW	LOW	11.49	12.99
2004	4	4:34:40	4840	3	227	mfsk_rad_sol_matrix_8	19.45	17.15	13.99	15.49
2004	4	4:34:43	4843	16	97	mfsk_rad_sol_matrix_17	21.23	19.04	13.99	15.49
2004	4	4:34:59	4859	524			LOW	LOW	3	4.5
2004	4	4:53:29	5969	37	1	mfsk_cal_sem_1	21.87	7.18	3.52	5.02
2004	4	4:54:06	6006	3	1	mfsk_cal_sem_1	20.46	LOW	3.52	5.02
2004	4	4:54:09	6009	39	1	mfsk_cal_sem_1	21.51	19.05	3.52	5.02
2004	4	4:54:48	6048	30	160	mfsk_landed_accel_3	17.57	15.72	3.52	5.02
2004	4	4:55:18	6078	25	140	mfsk_no_fault	11.86	9.89	3.52	5.02
2004	4	4:55:43	6103	32	15	mfsk_base_petal_down	17.62	16.04	3.52	5.02
2004	4	4:56:15	6135	38	185	mfsk_no_event_to_report	22.51	19.52	3.52	5.02
2004	4	4:56:53	6173	45			LOW	LOW	2.12	3.62

LOS Due to CSS

EDA locked up to 5th harmonic of 1 KHz vestigial tone

DSN Closed Loop Performance

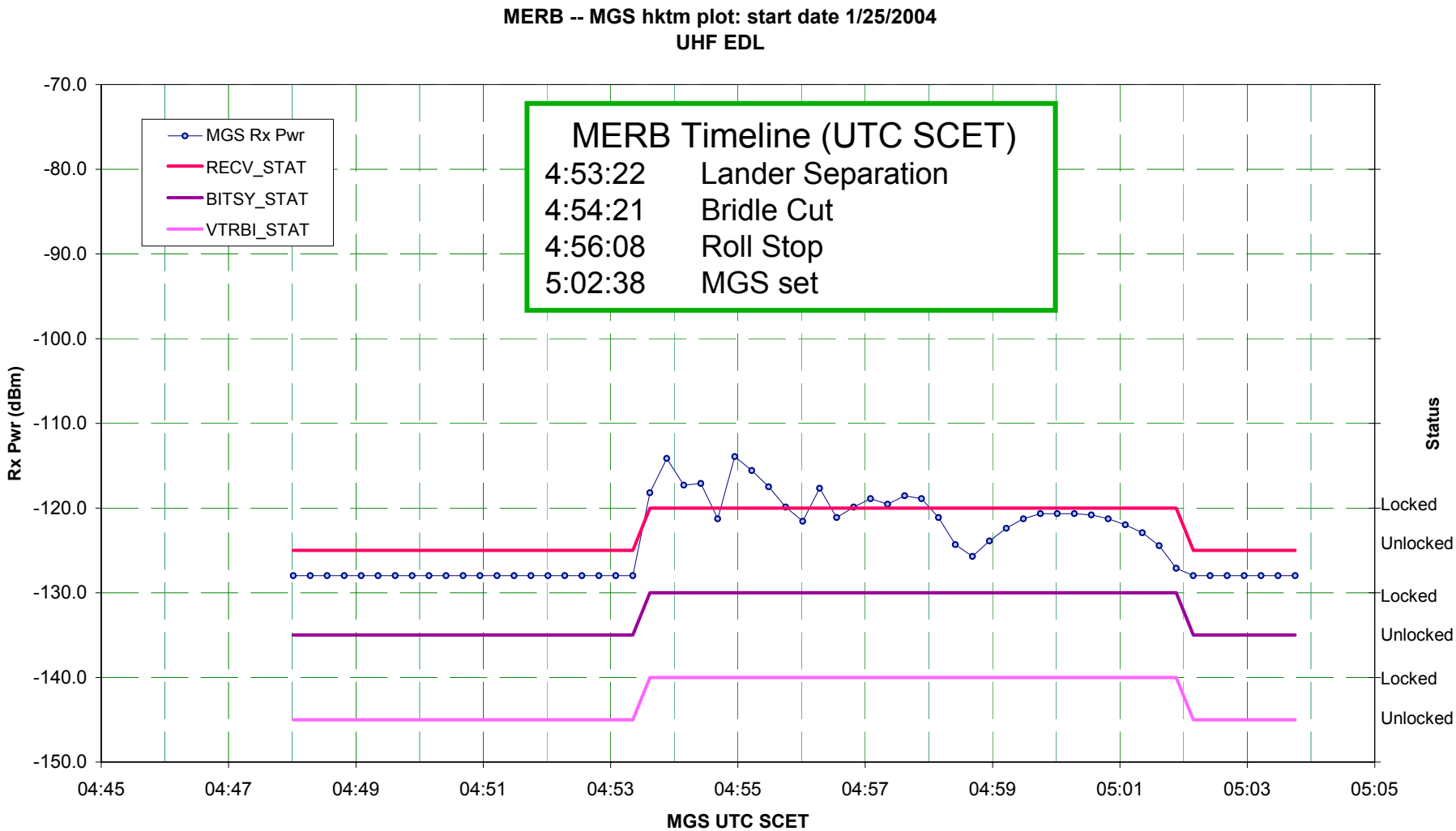
Mars Exploration Rover



DSS-43 DTT Remained in Lock till Parachute Deploy

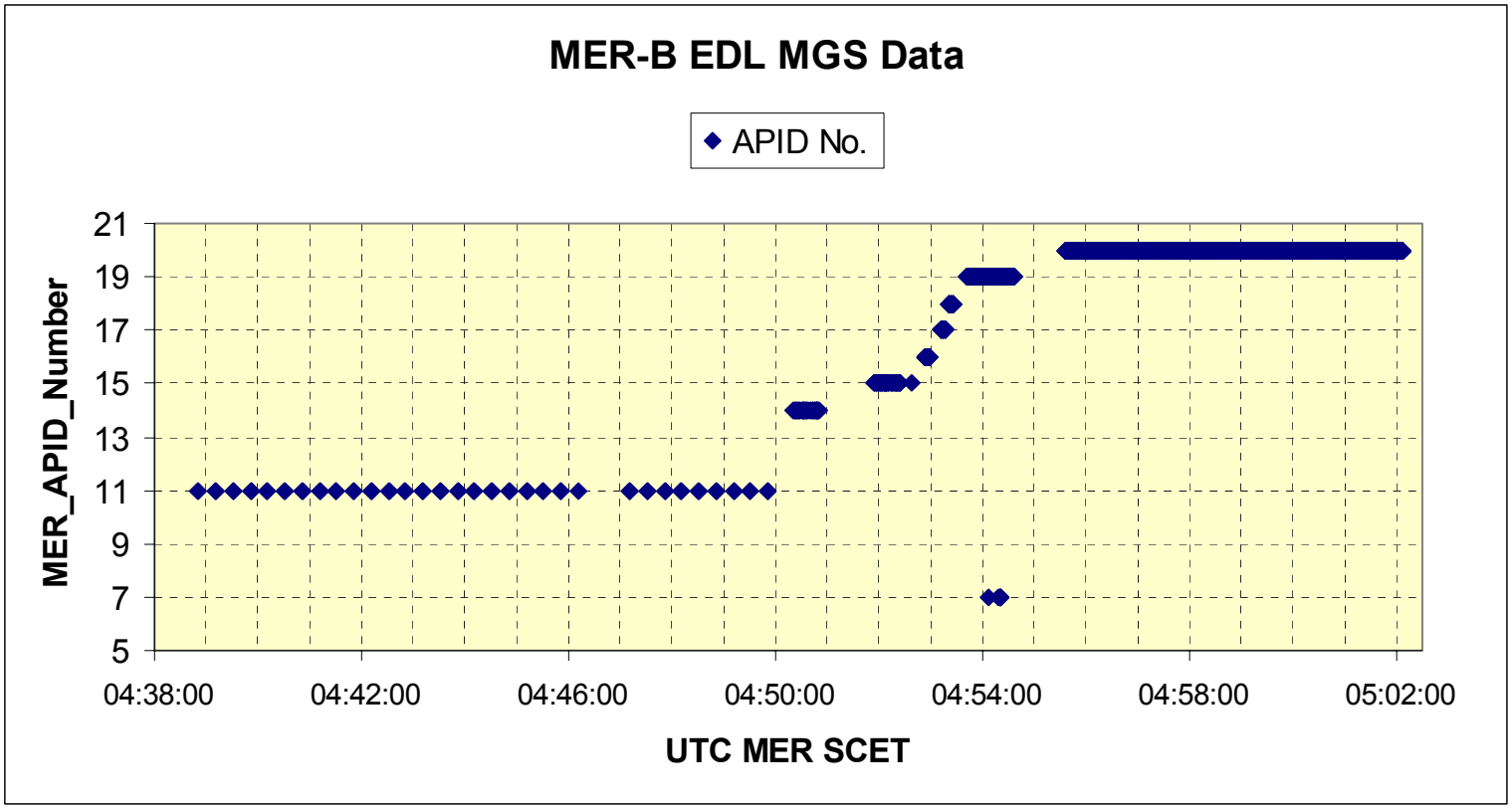
MERA&B UHF Performance

MGS Mars Relay Telemetry (sampled every 12 sec)



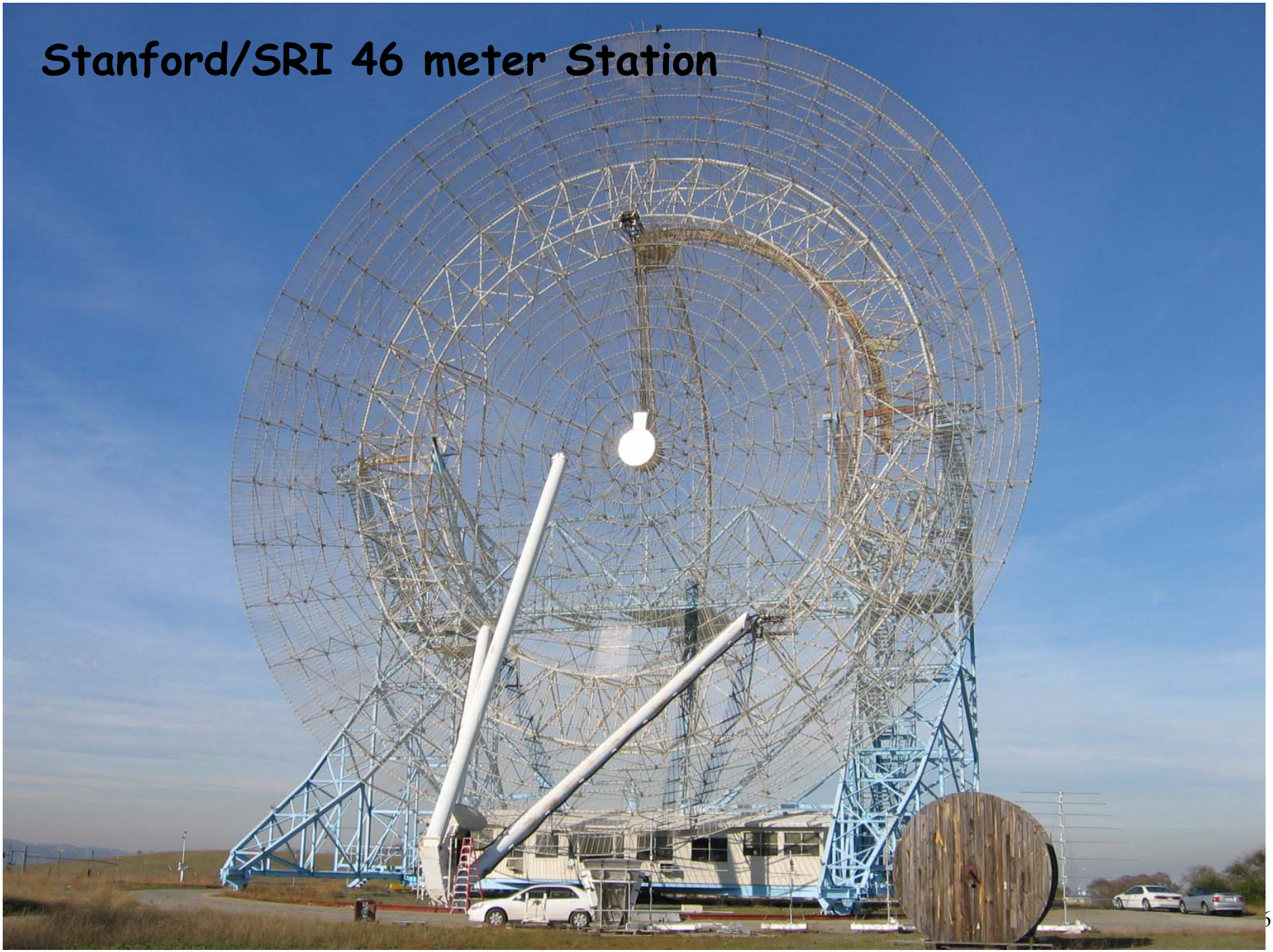
MGS-MR locked to MER UHF Signal from 4:53:37 to 5:01:53 MGS SCET although Rx Pwr low at 4:58:30 MGS SCET

MER EDL Packets Received via MGS

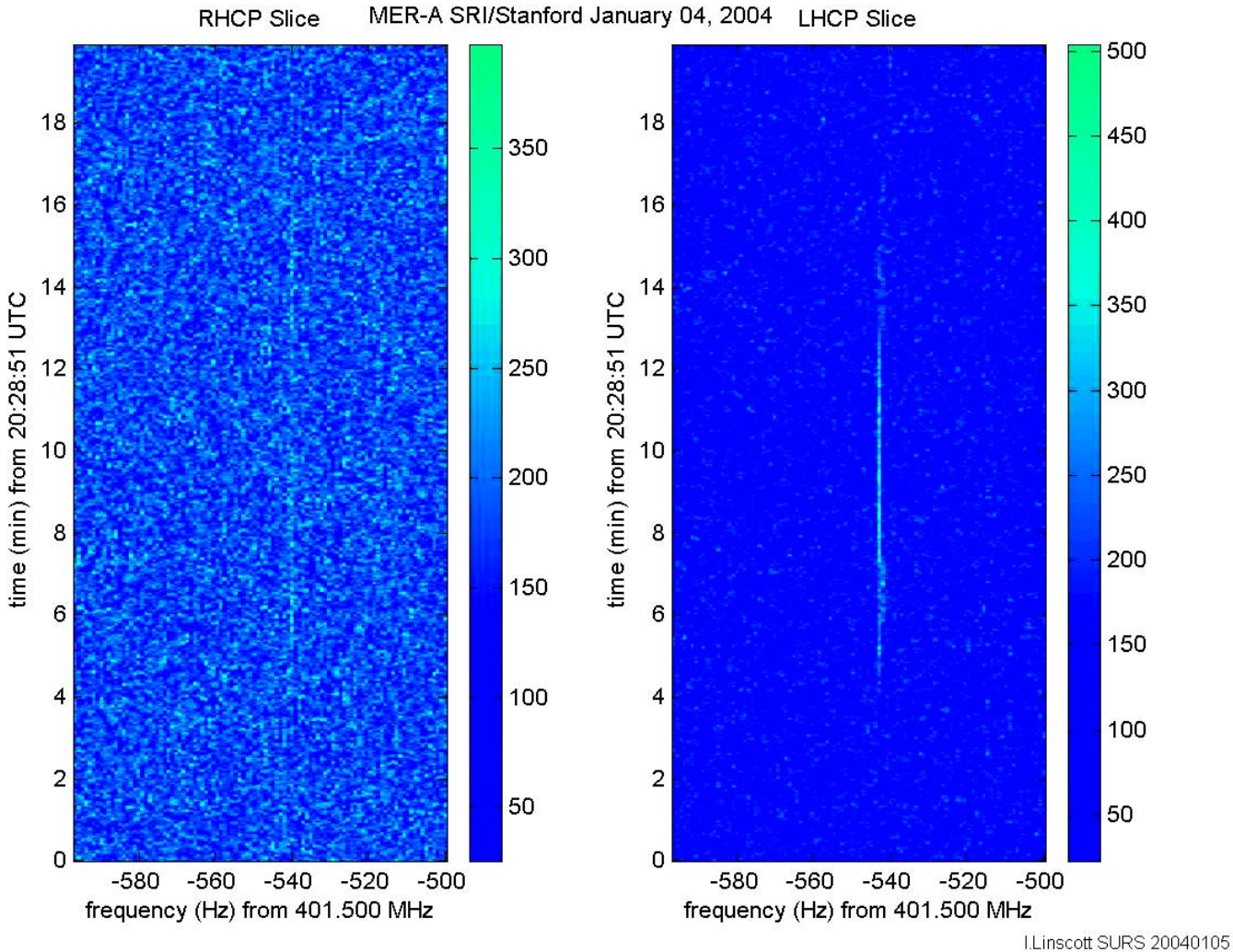


TIMELINE INFO:
UHF Data Collection Start at CSS to SCM transition (4:33:41 to 5:01:53 MER SCET)
APIDs 11, 13 – 20 used; APID 7: evr_warning_rt
MGS-MR locked to MER UHF Signal from 4:53:37 to 5:01:53 MGS SCET

Stanford/SRI 46 meter Station



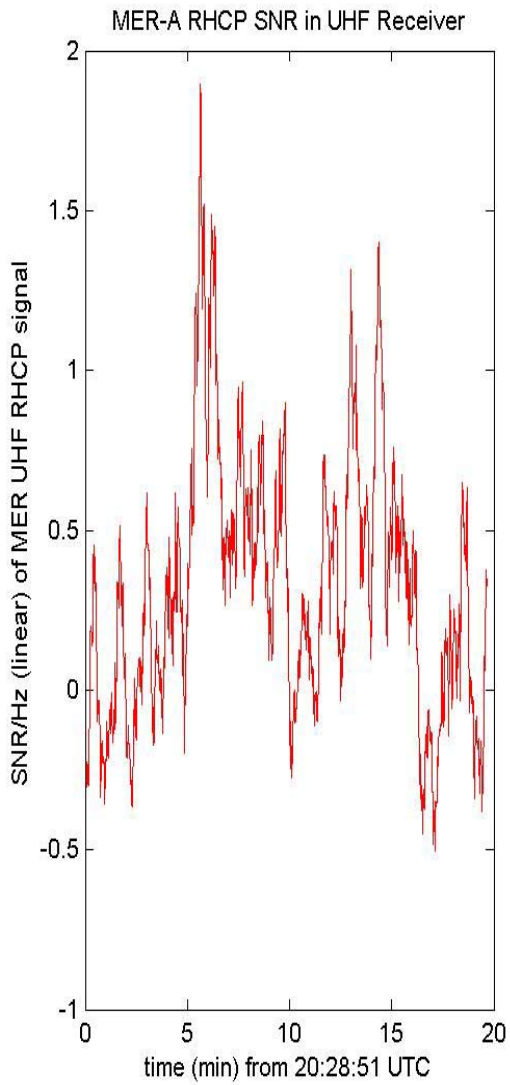
Spectrogram of MER A EDL Signal

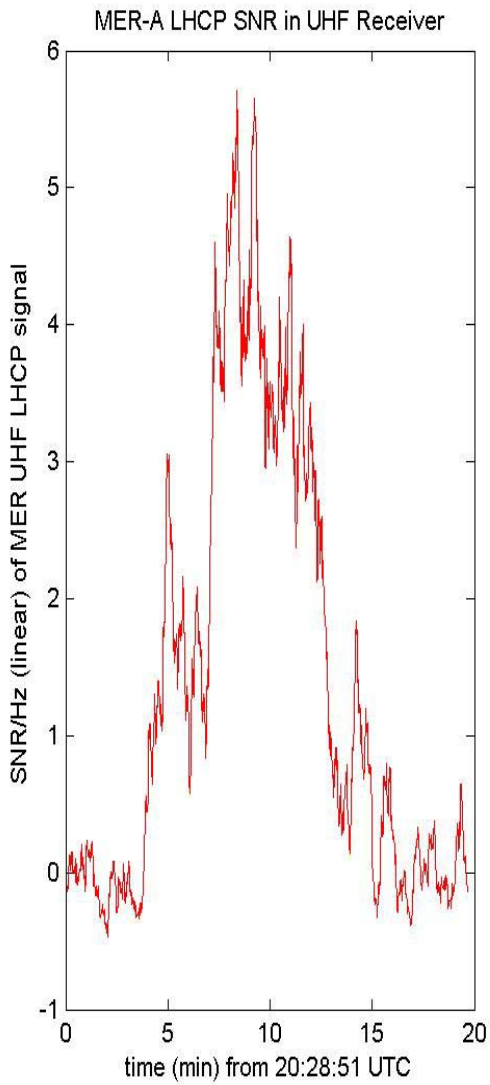


Stanford Detection of MER-A UHF EDL

Mars Exploration Rover

LINK BUDGET		MER A EDL
Reeiving by SRI Antenna		1/3/2004
Xmitter power watts	watts	12.0
Xmitter power dBw	dBW	10.8
Frequency	GHz	0.401
Transmit antenna gain	dB	-3
Polarization	CP/LP	CP
Circuit Loss (dB)	dB	-0.6
EIRP (dBW)	dBW	7.2
Range (AU)	AU	1.1
Range	km	1.7E+08
Free space loss	dB	-248.8
Atmospheric attenuation	dB	0
Receive antenna diameter	meters	45.7
Antenna Efficiency	%	52.5
Receive antenna gain	dB	42.9
Receive Antenna Polarization		cp
Polarization Loss	dB	0
Antenna pointing loss	dB	0
Circuit Loss	dB	-0.35
Received signal power	dBW	-199.1
Rcv.NF	dB	0.32
Tsky (1)	K	20.0
Tsys	K	63.1
Tsys dB K	dBK	18.0
Receive G/T	dB/K	24.9
No	dBw/Hz	-210.6
Pt/No	dBHz	11.5
Pc/No with modulation	dBHz	5.5
(1) Variable		



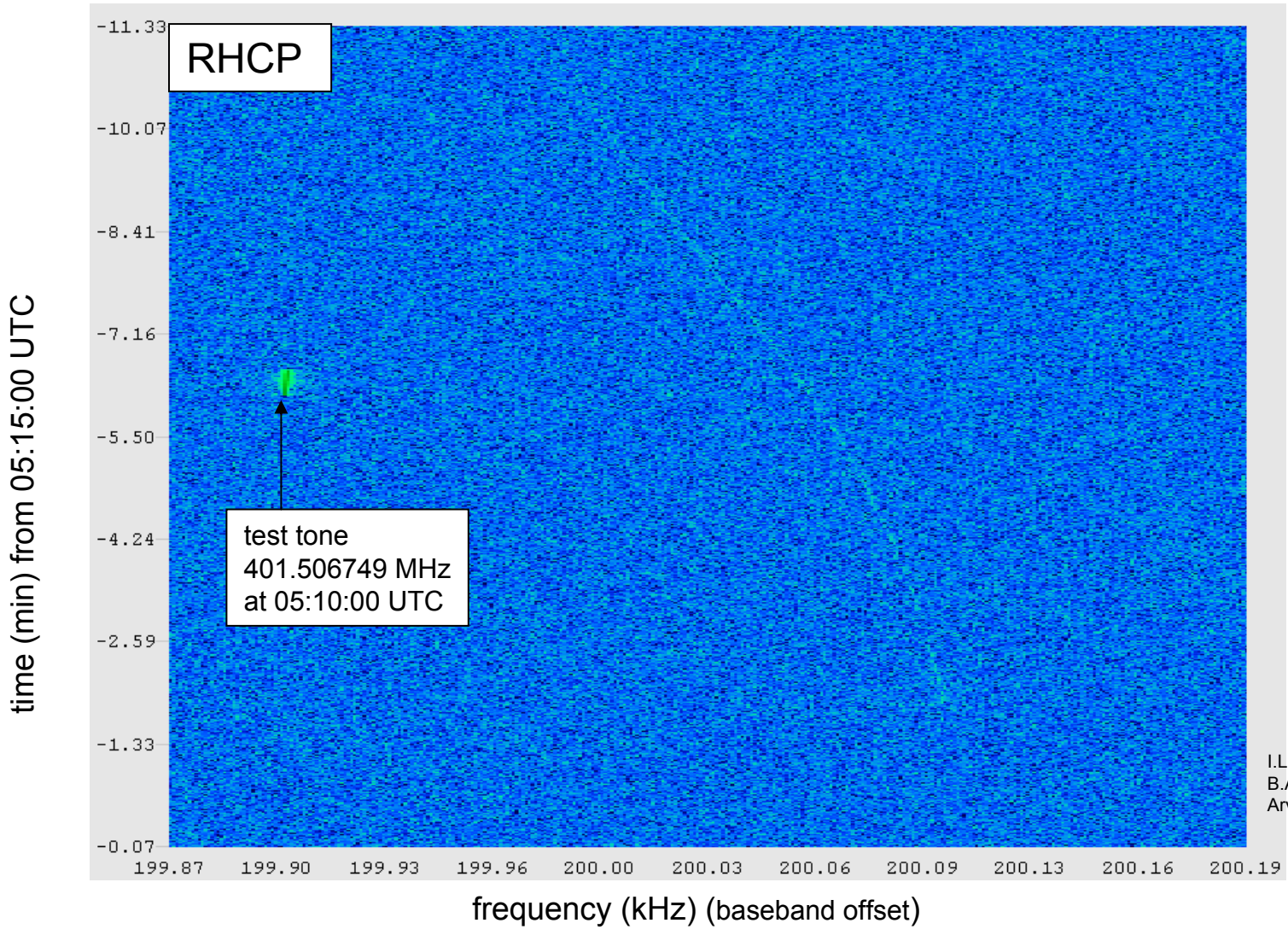


I.Linscott SURS 20040105

Spectrogram of MER B EDL Signal

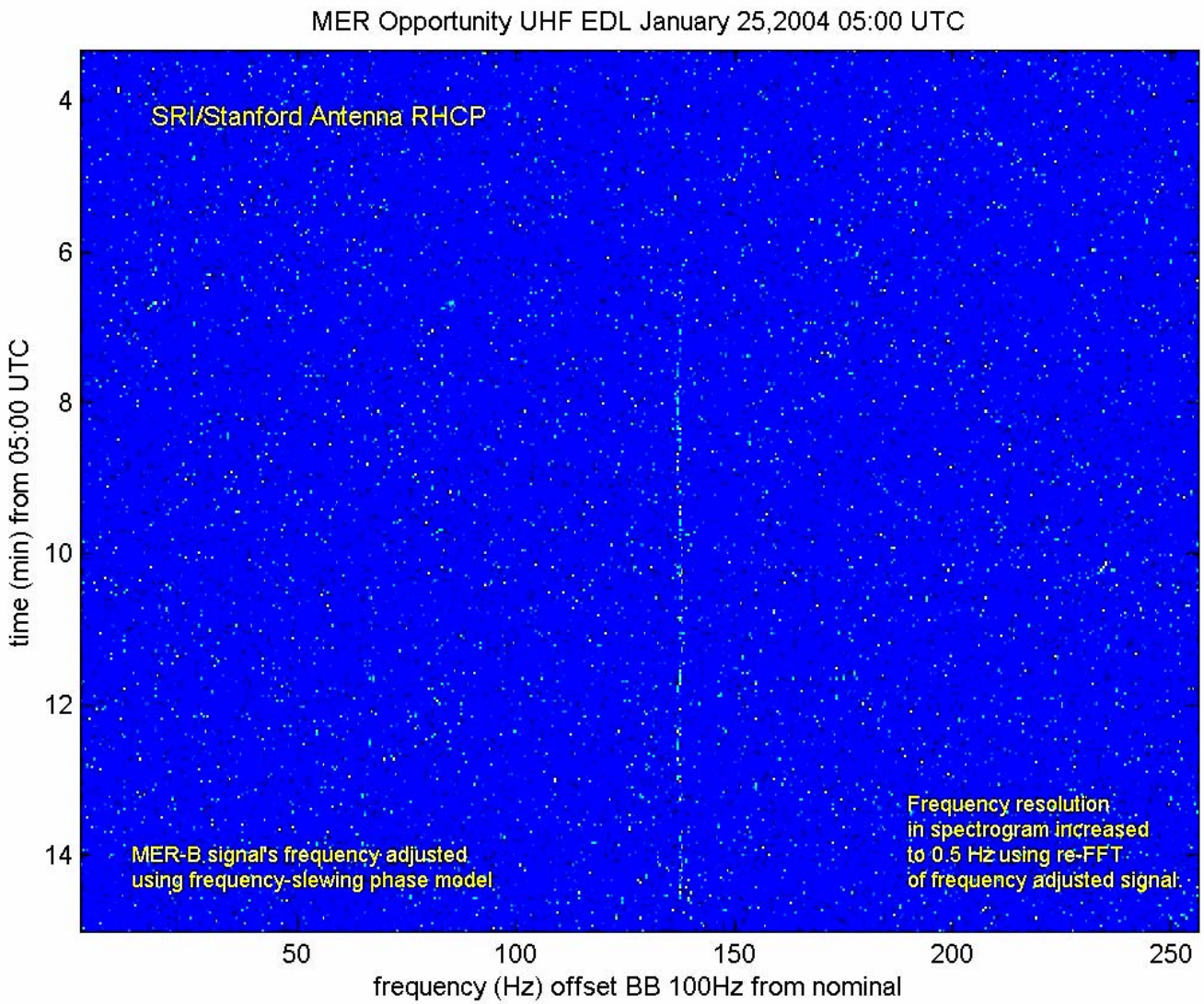
Mars Exploration Rover

Stanford/SRI Dish January 25, 2004 05:15 UTC



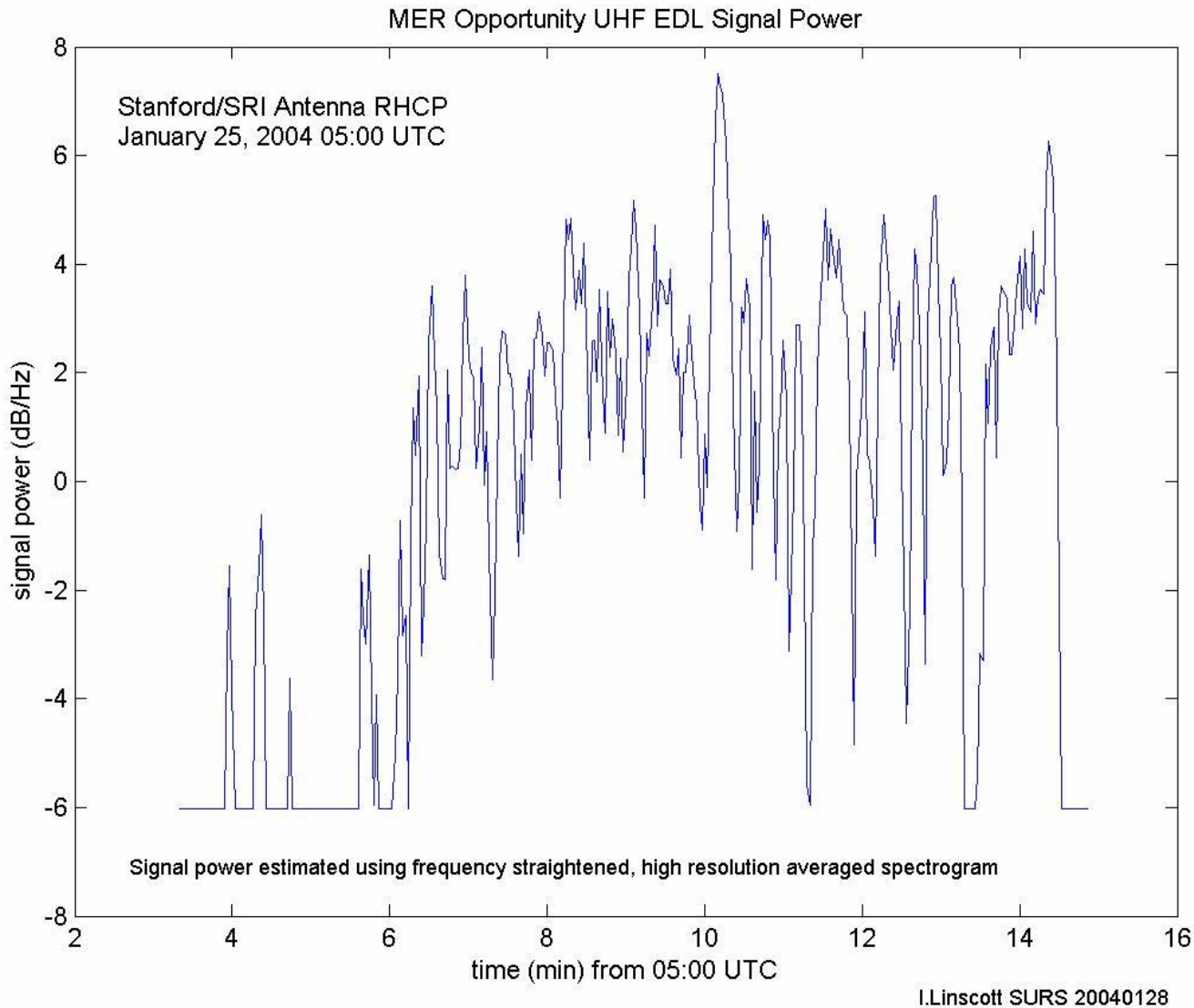
I.Linscott SURS 20040125
B.Arnold JPL
Arv Vaisnys JPL

Reconstructed Spectrogram of MER B EDL Signal

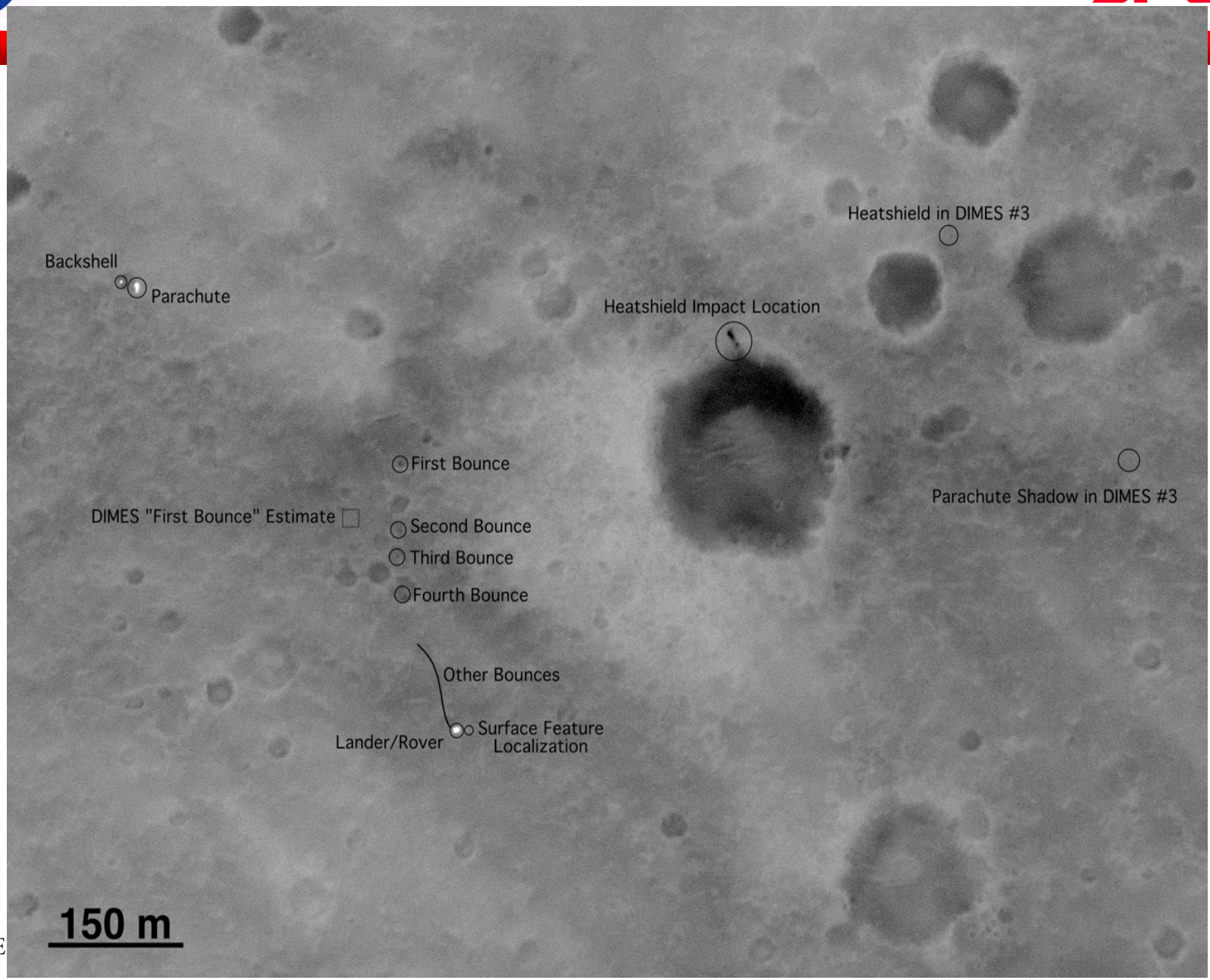


I.Linscott SURS 20040128

Stanford Detection of MER-B UHF EDL

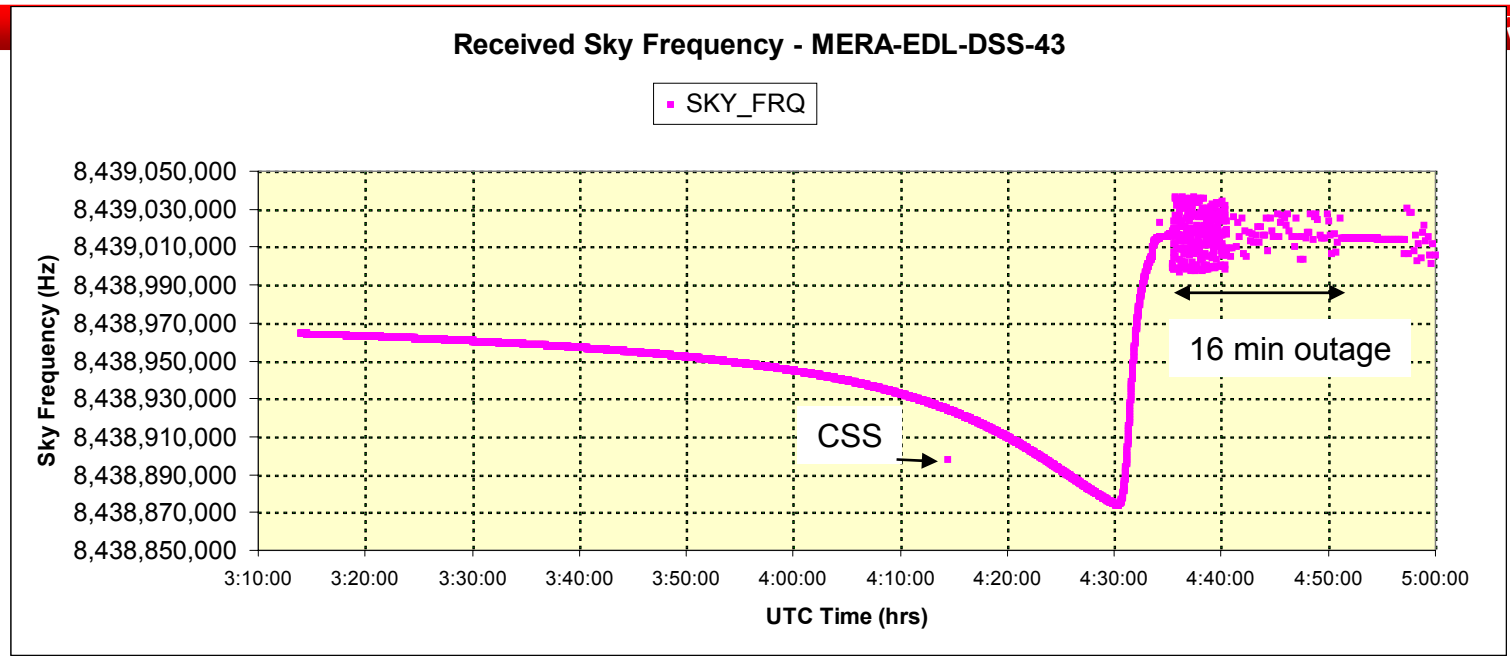


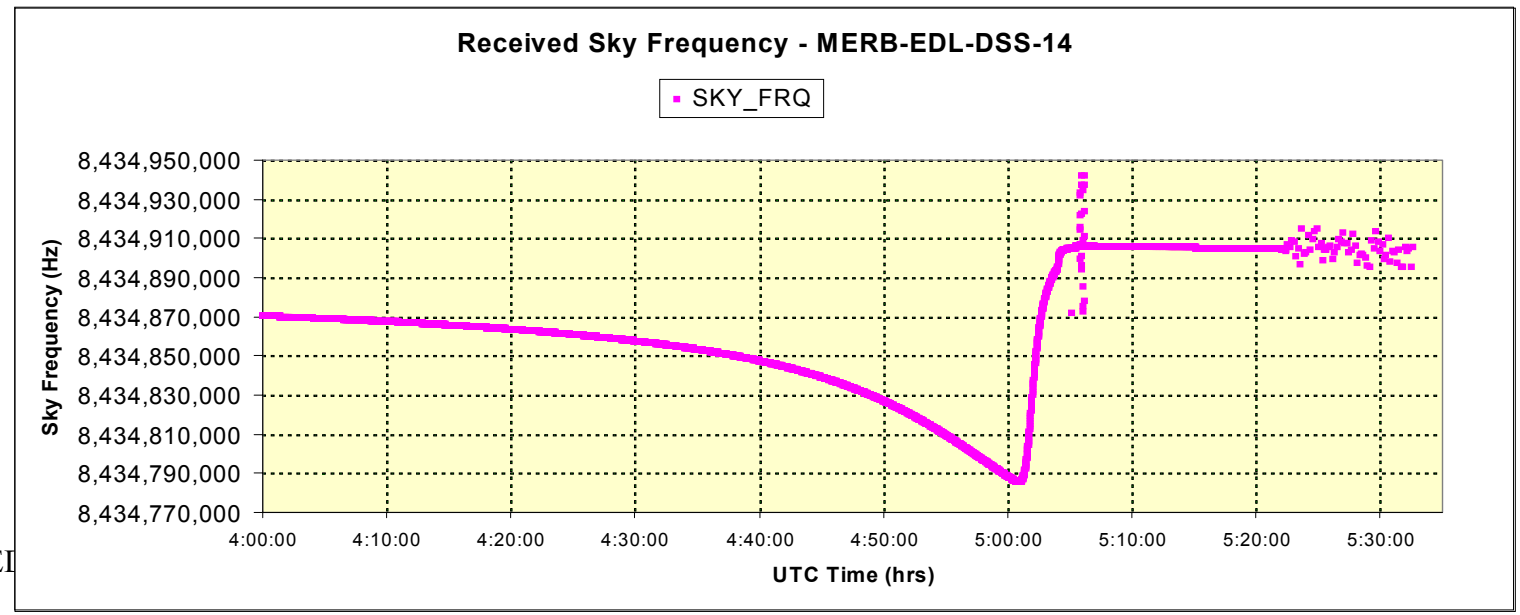
Spirit Reconstruction Movie



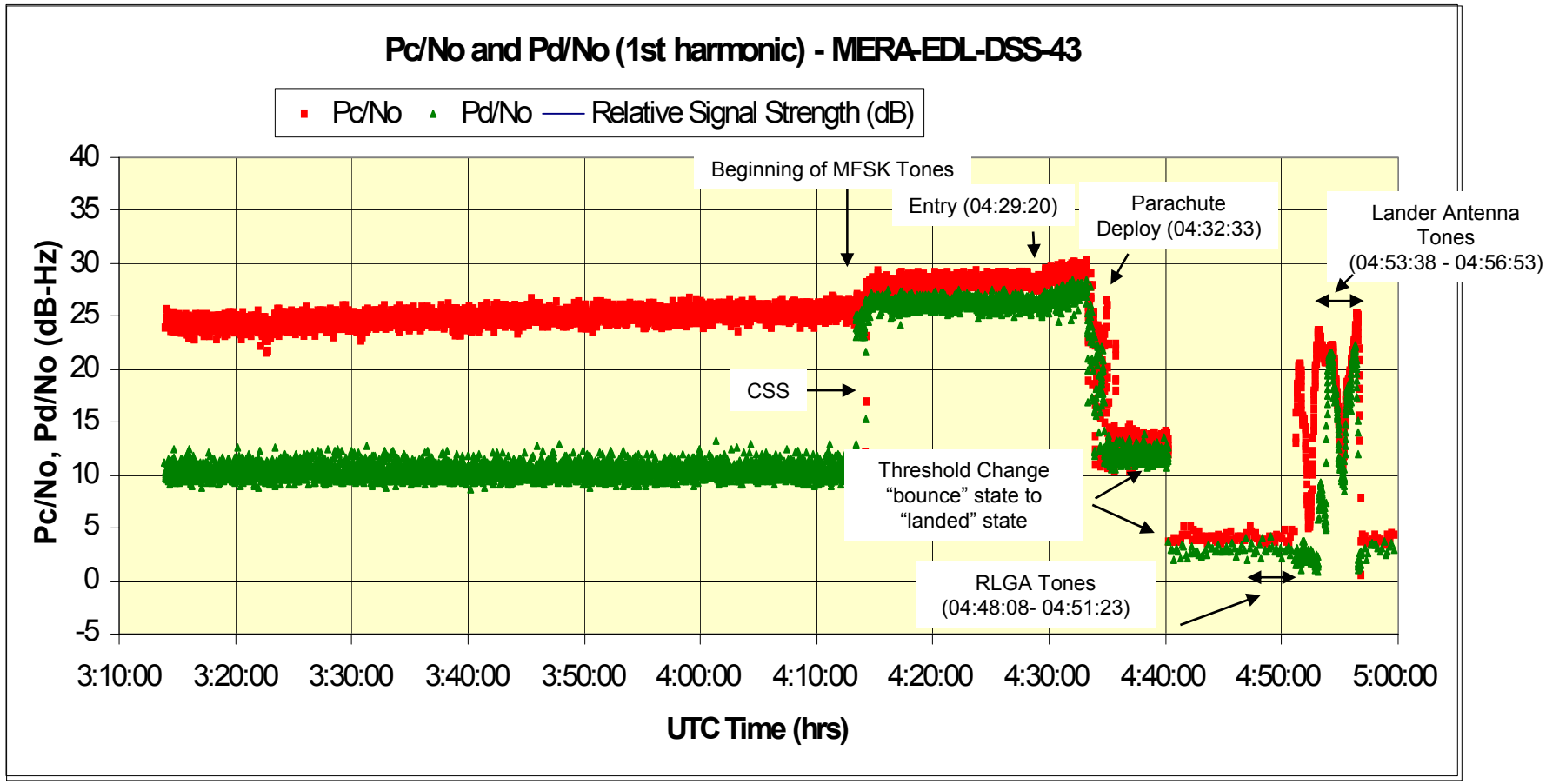
Reconstruction Data

EDA Real Time Results: Sky Frequency



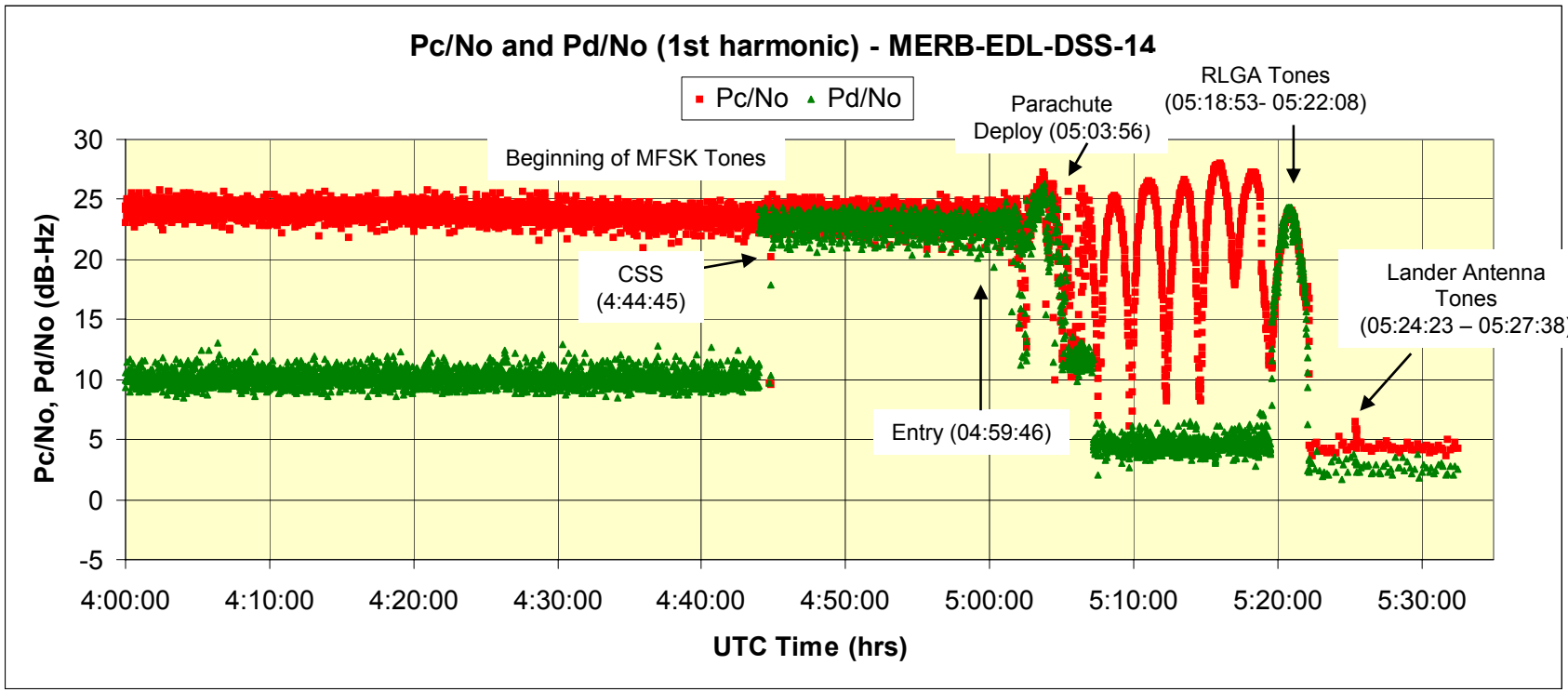


MERA EDL Real Time Results: Pc/No and Pd/No from DSS-43

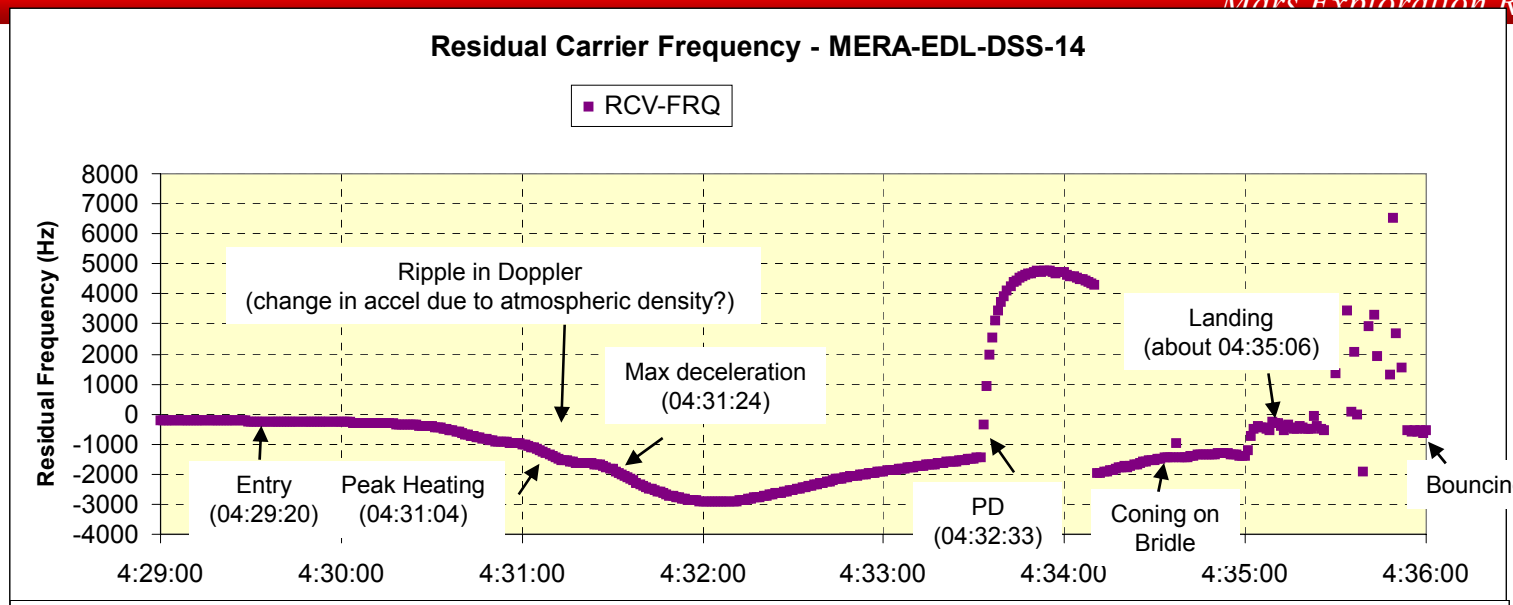


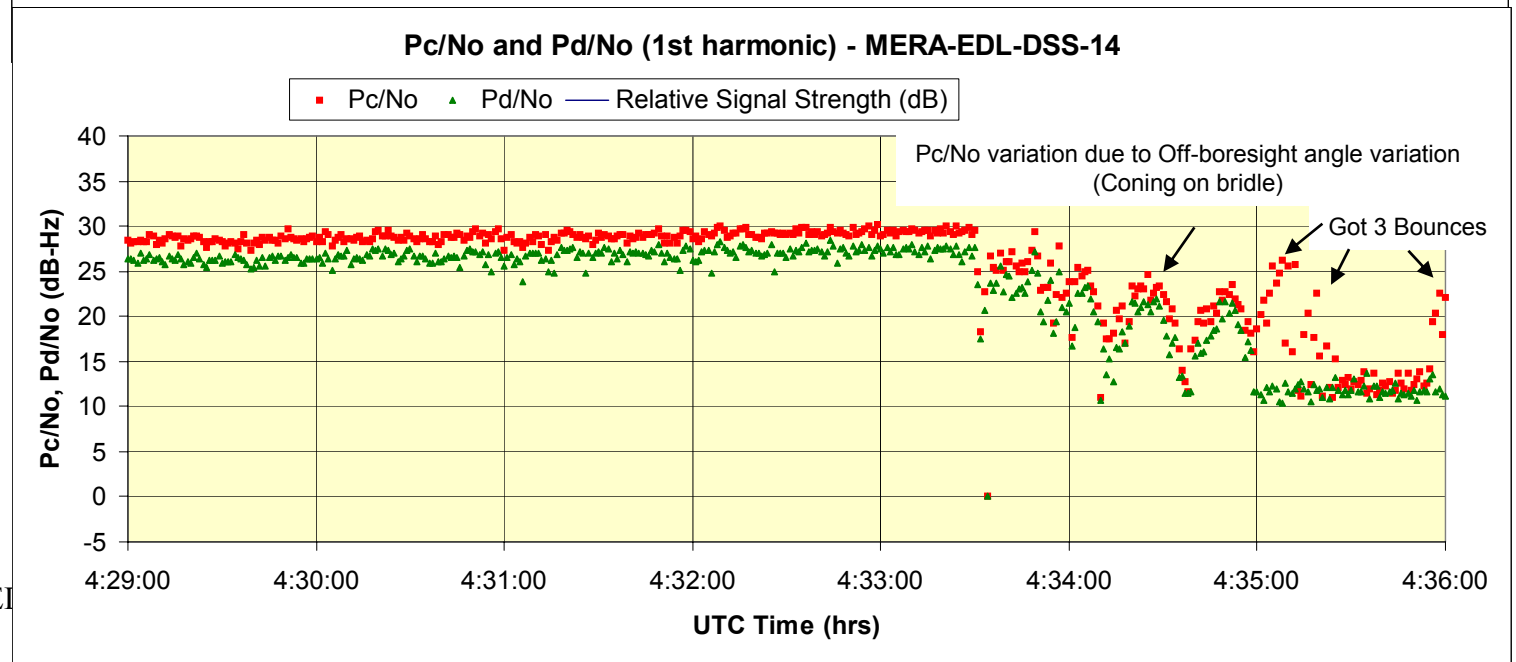
EDA is configured for Bouncing State until 4:41:00, then "landed" state

MERB EDL Real Time Results: Pc/No and Pd/No from DSS-14

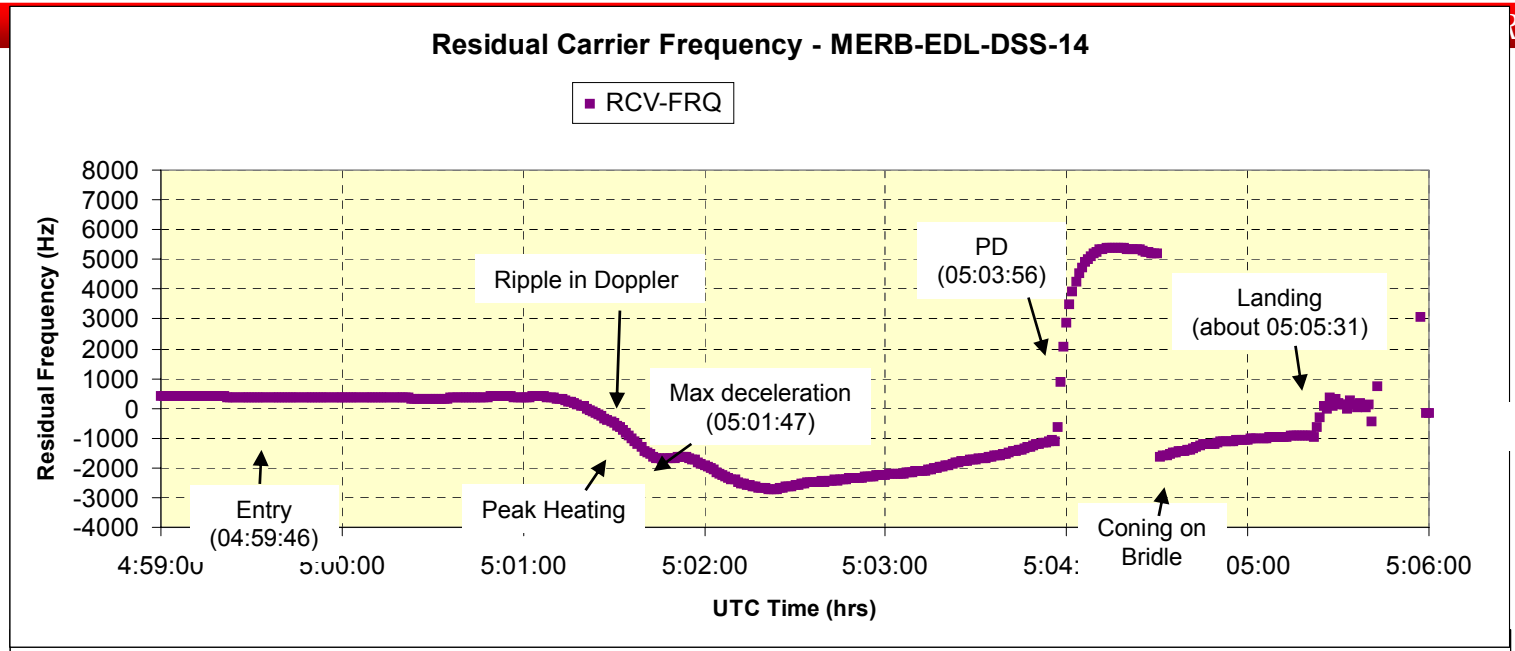


MERA EDL Real Time Results: Entry to Landing (Frequency and Power)

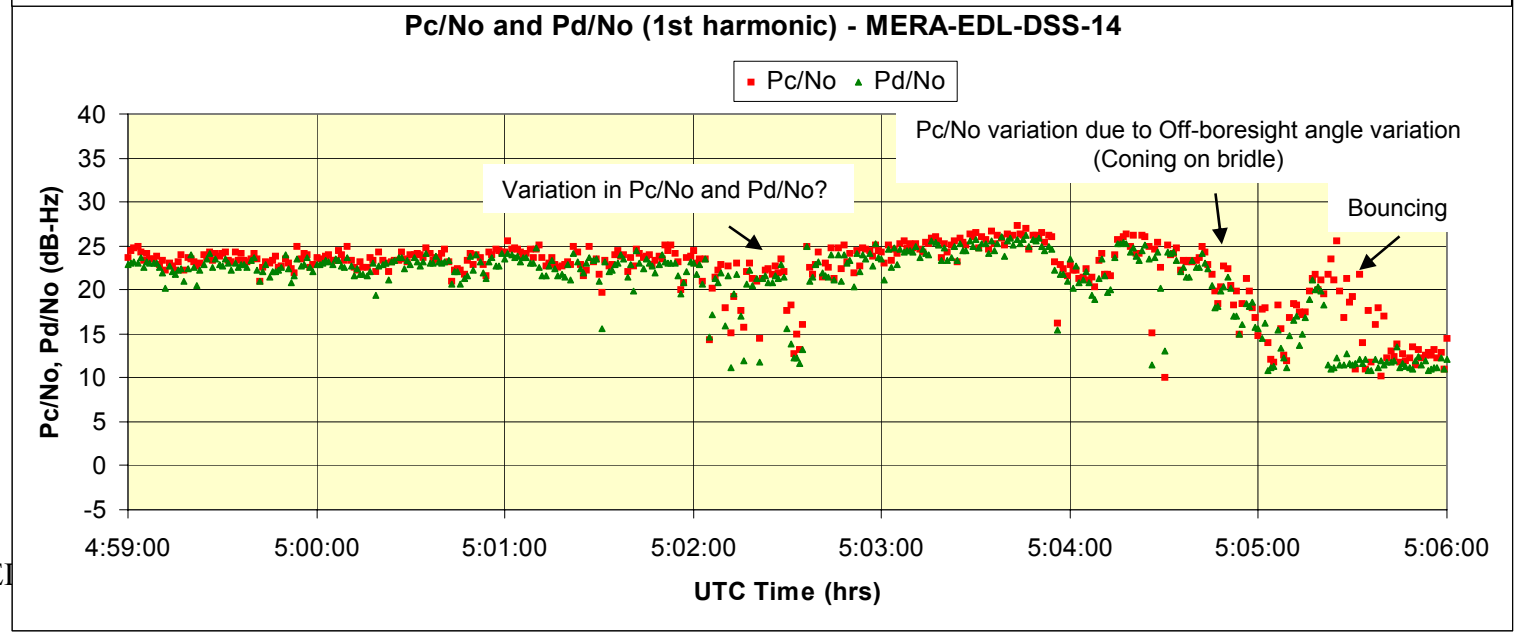




MERB EDL Real Time Results: Entry to Landing (Frequency and Power)

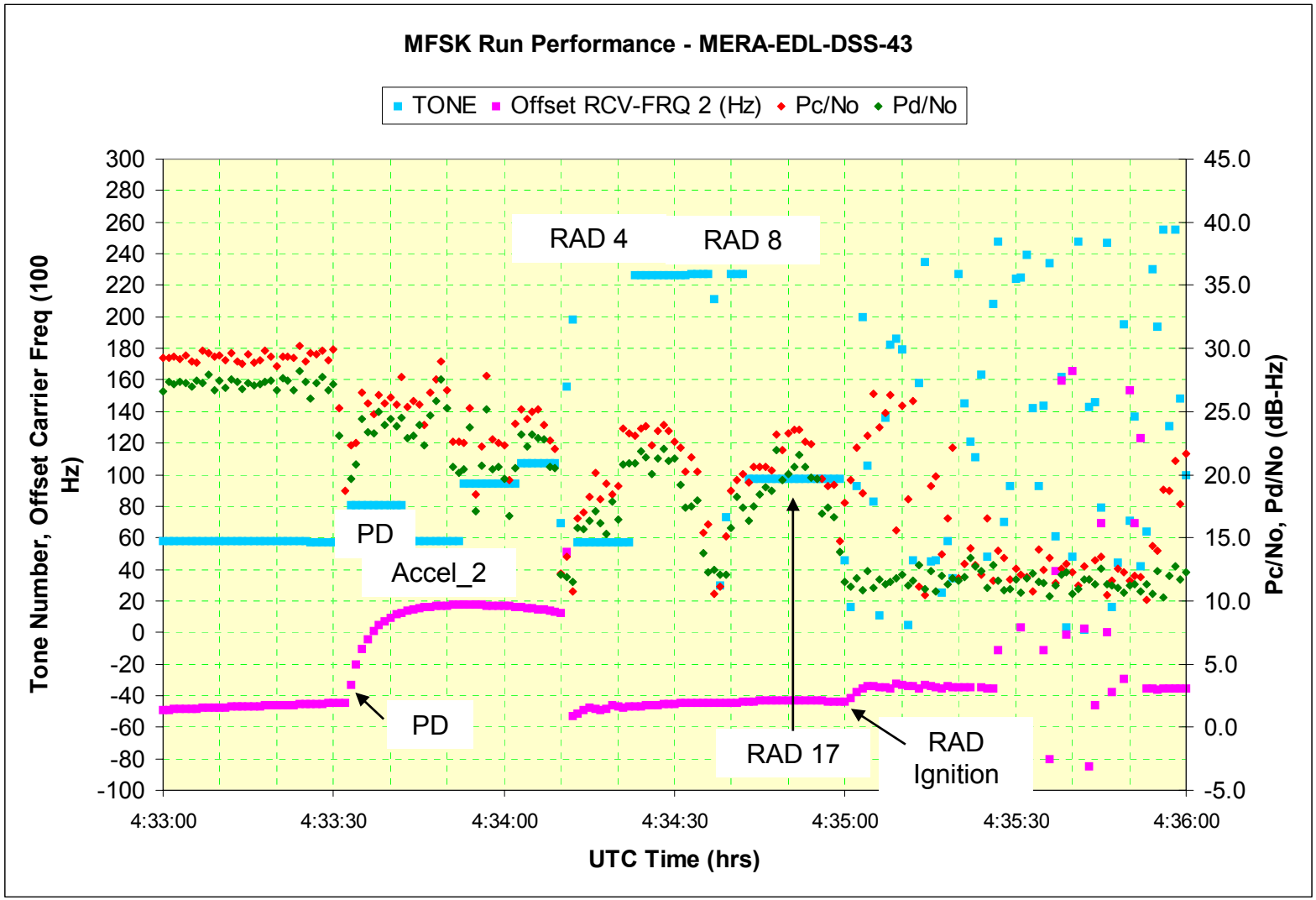


Bouncing



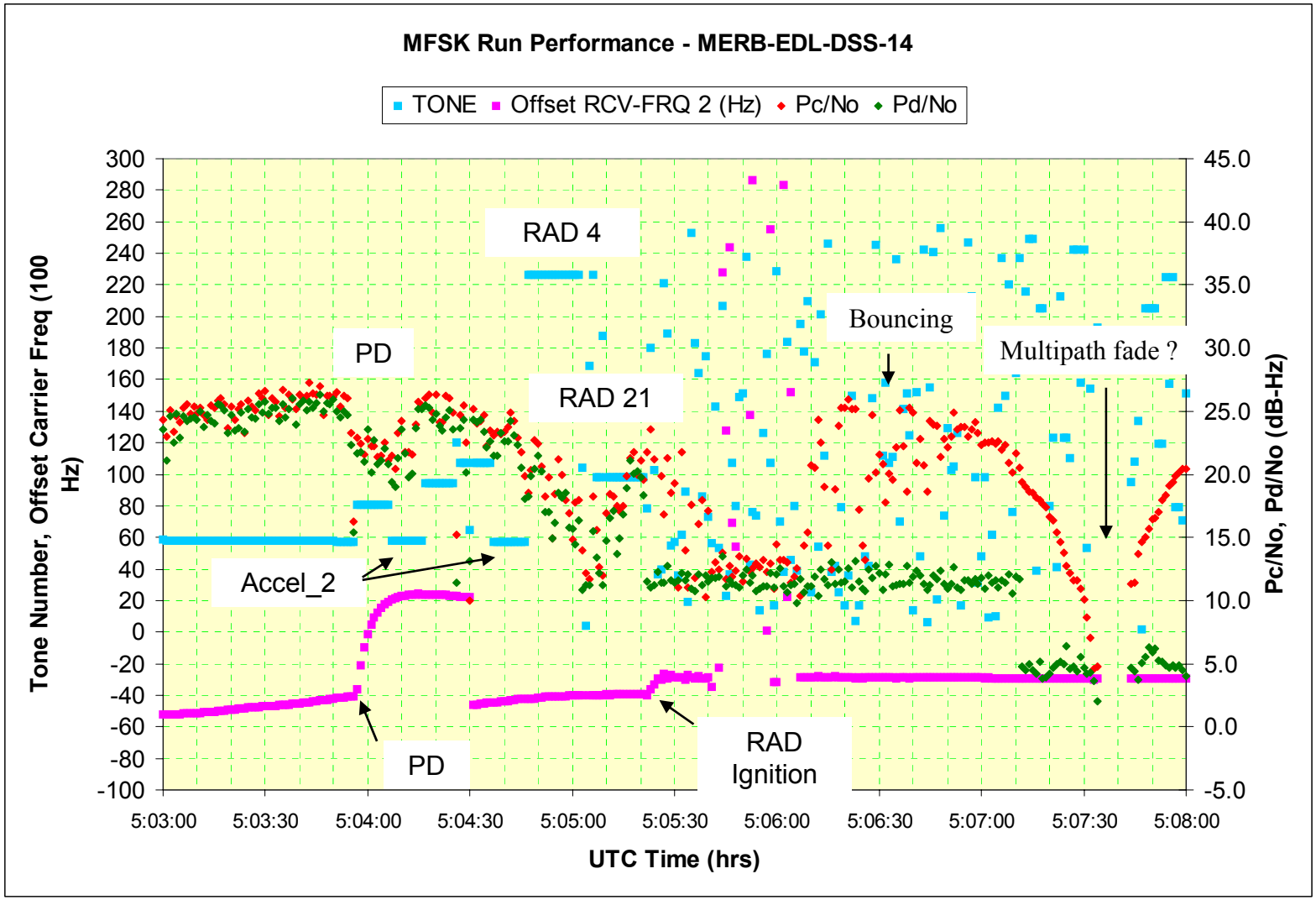
MERA EDL Real Time Performance: From PD to Landing (DSS-43)

Mars Exploration Rover

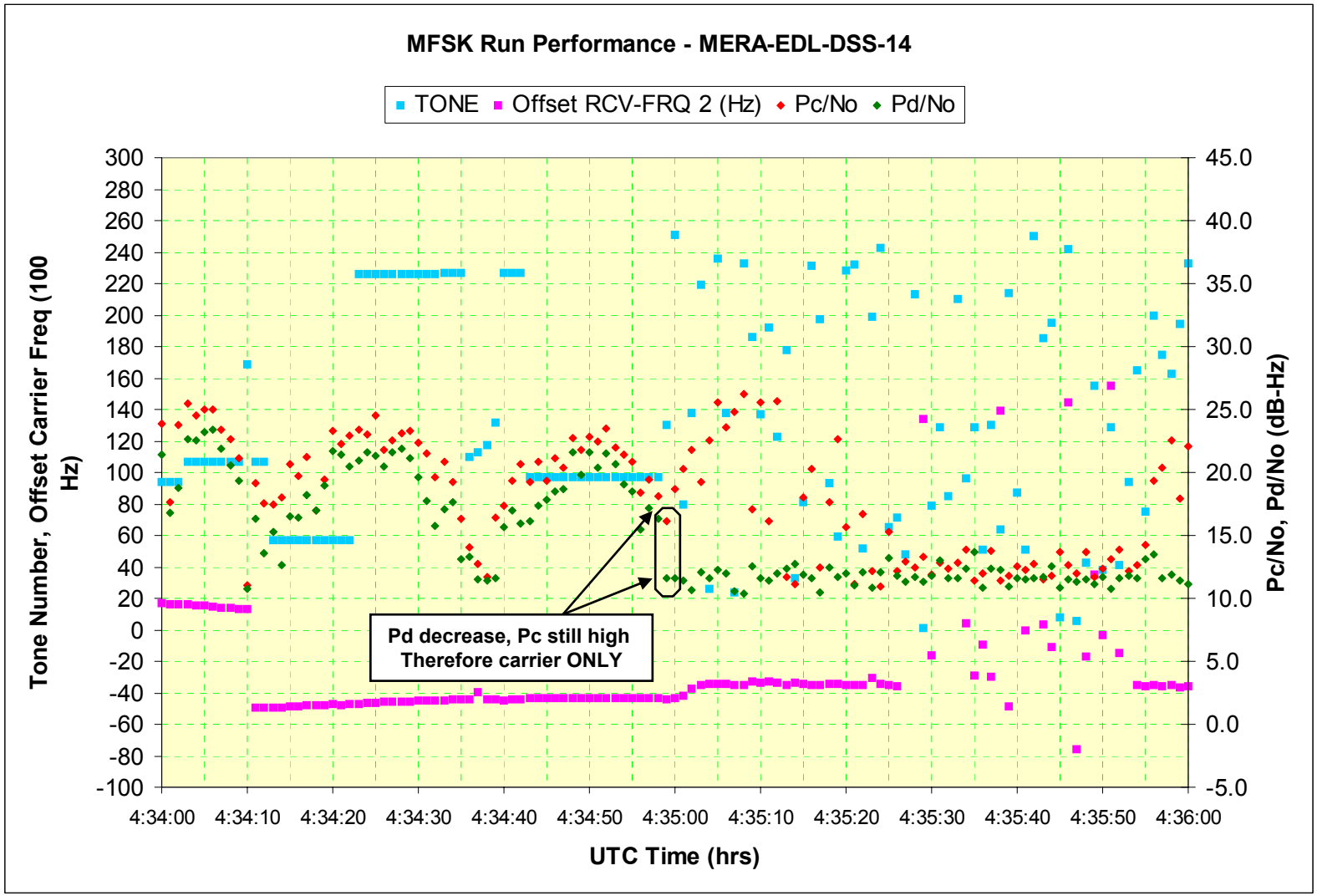


MERB Real Time Performance: From PD to Landing (DSS-14)

Mars Exploration Rover

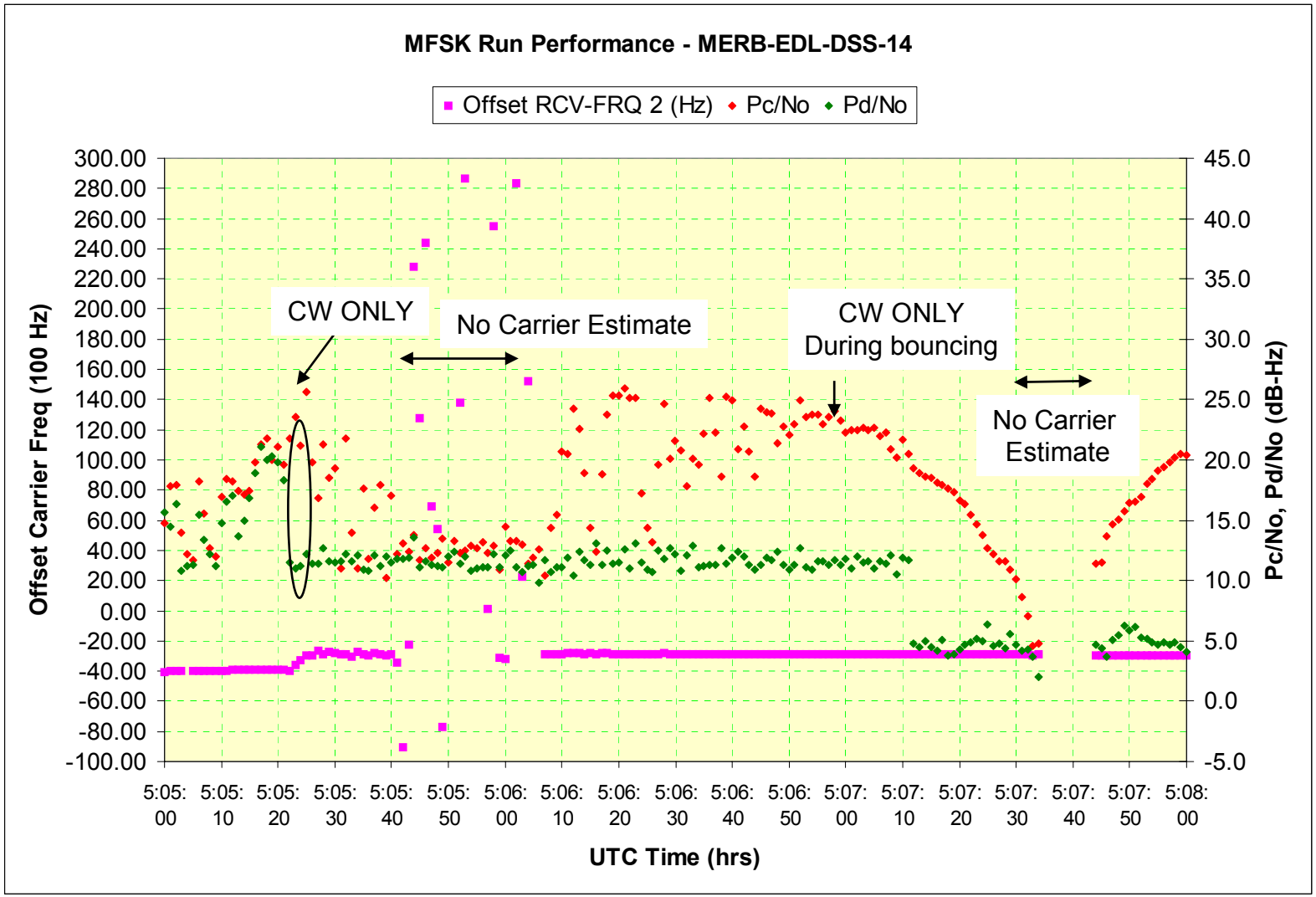


MERA EDL Event Detection: RAD Ignition Time (DSS-14) 04:34:59



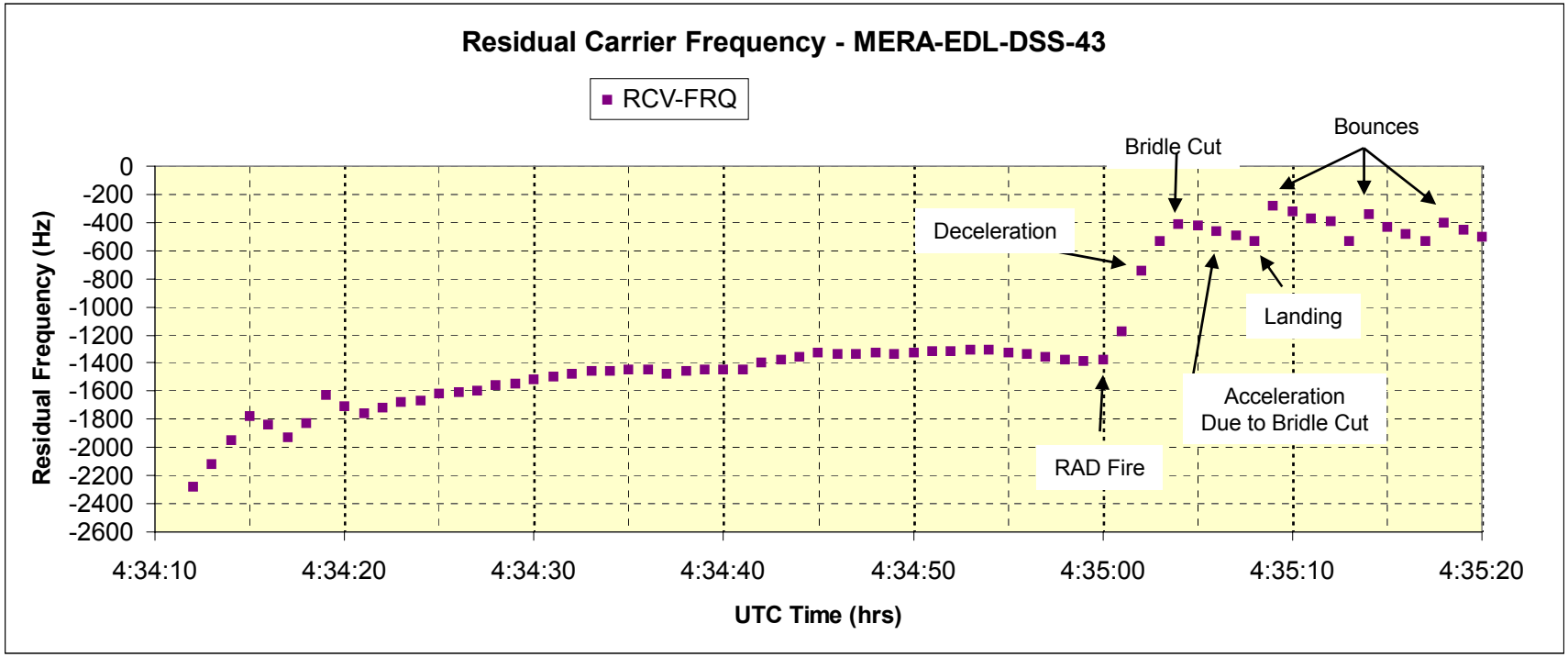
RAD Ignition Time or Time of CW ONLY Signal = 04:34:59 UTC ERT (Predict = 04:35:11 UTC ERT)

MERB Real Time Results: Bouncing on Surface – Signal from RLGA – Carrier ONLY post RAD ignition

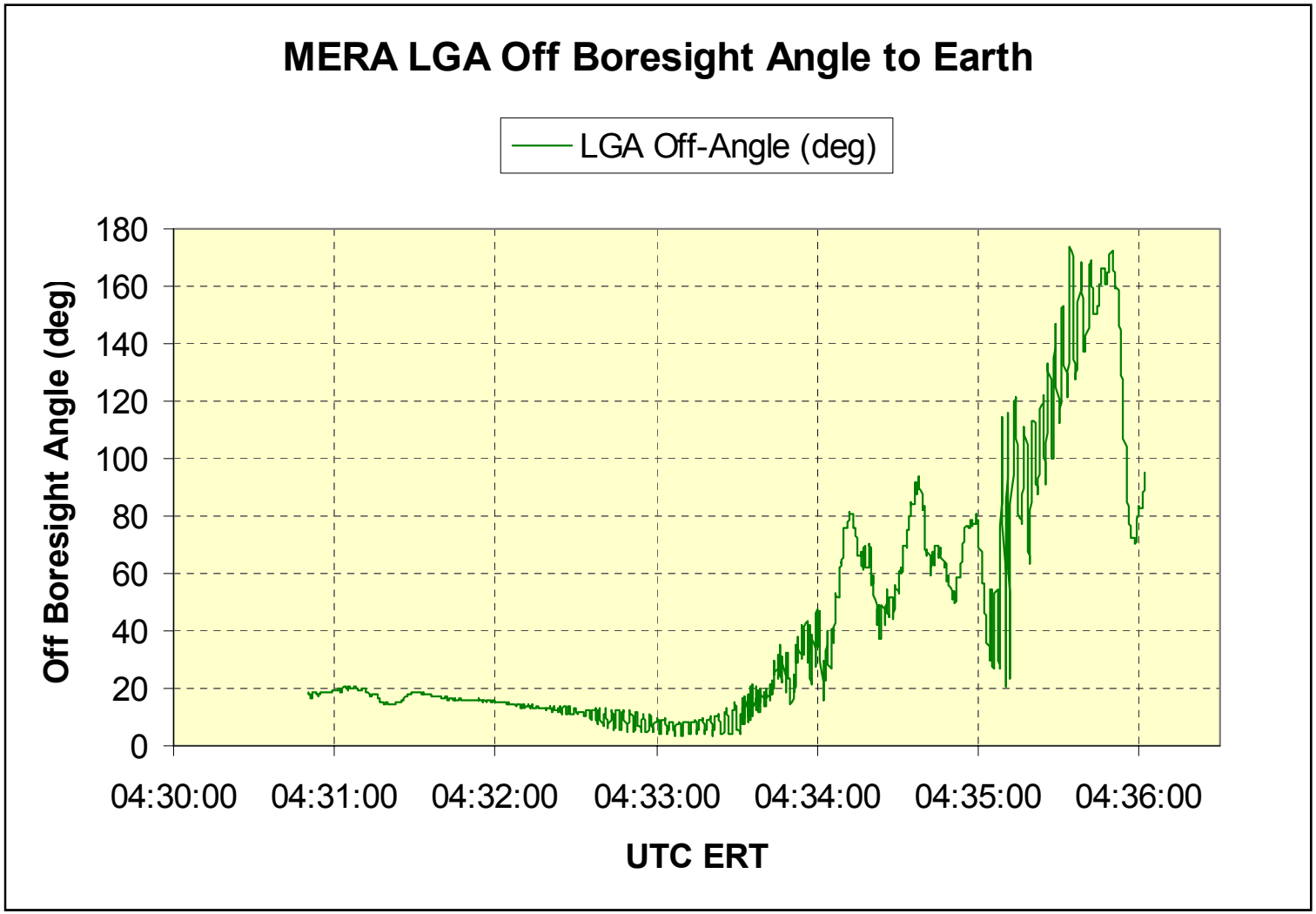


MERA Event Detection: Landing

Mars Exploration Rover

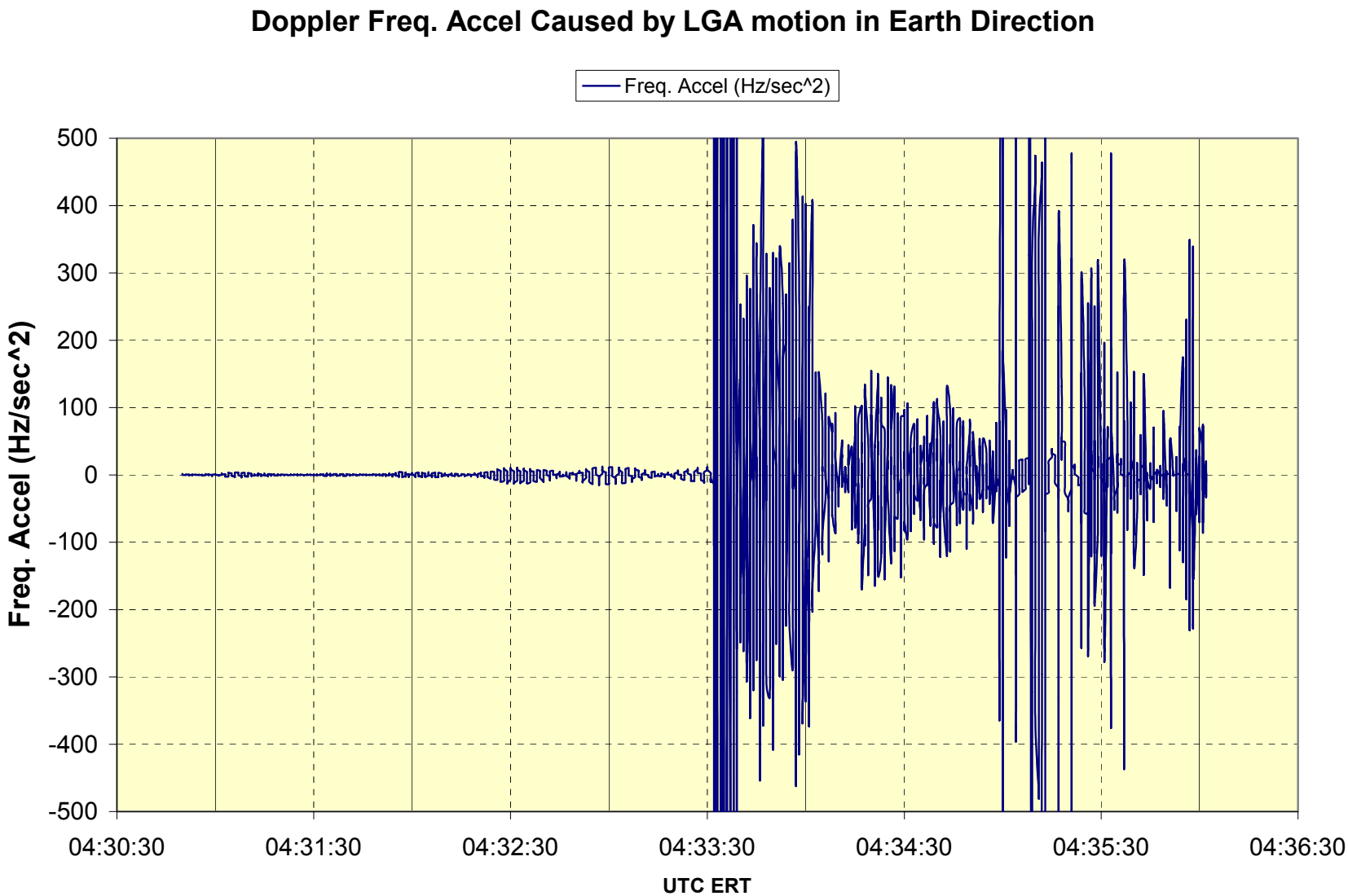


MERA LGA Off Boresight Angle: Entry to Rollstop (MERA EDL)



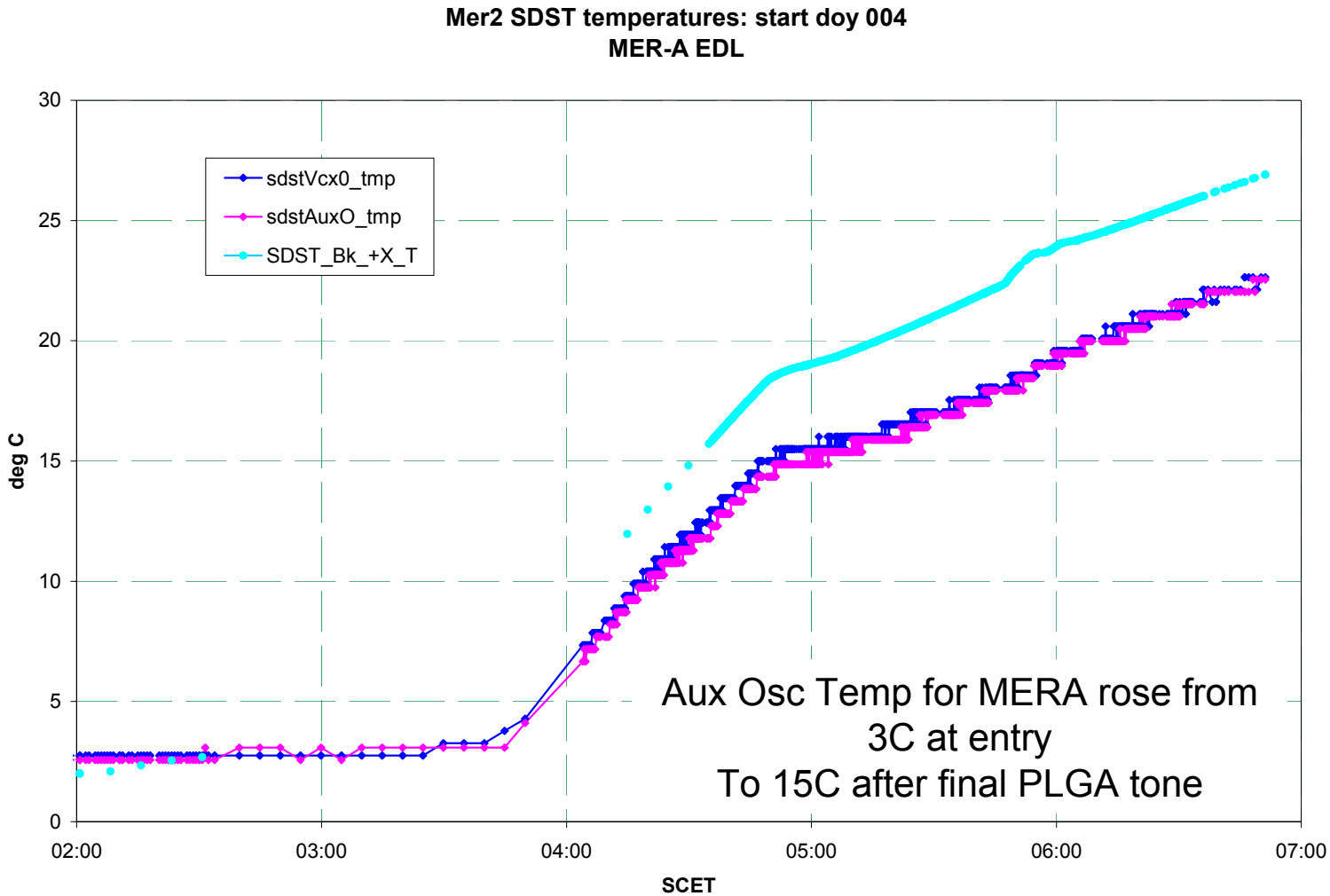
Courtesy: Rob Grover and Reconstruction Team

MERA Frequency Accel. caused by LGA motion as seen in Earth direction from Entry to Rollstop (from MERA)



Courtesy: Rob Grover and Reconstruction Team

MERA AUX OSC Temp Increase from Entry to Final PLGA Tone



From: R. Tung, Mer2_sdst_EDL_SDSTauxoscT

Summary

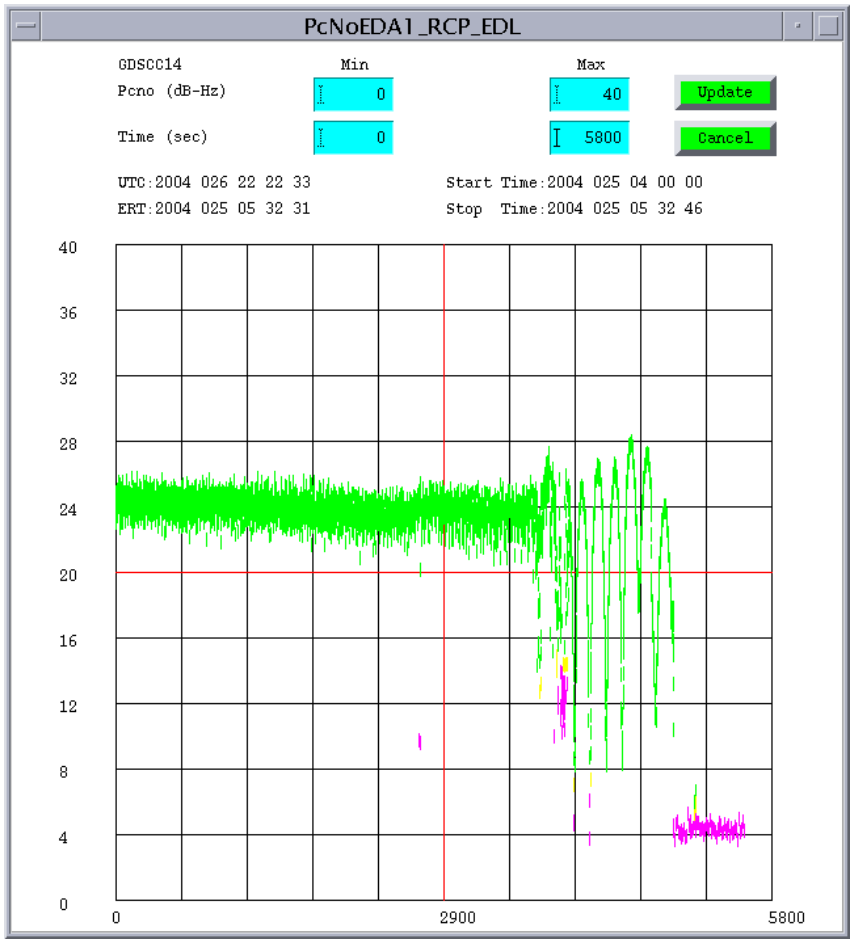
- **EDA Real Time Results**
  - **Receipt of Carrier Frequency ALONE allows major event detection (PD, RAD ignition, Bridle Cut, Landing)**
  - **EDA performance for Tone Detection better than anticipated given expected post bridle deploy dynamics**
  - **No plasma outage during max. heating / max. deceleration as predicted**
  - **Signal reception and tone detection on surface possible due to landing orientation – multipath worked for us!!!**

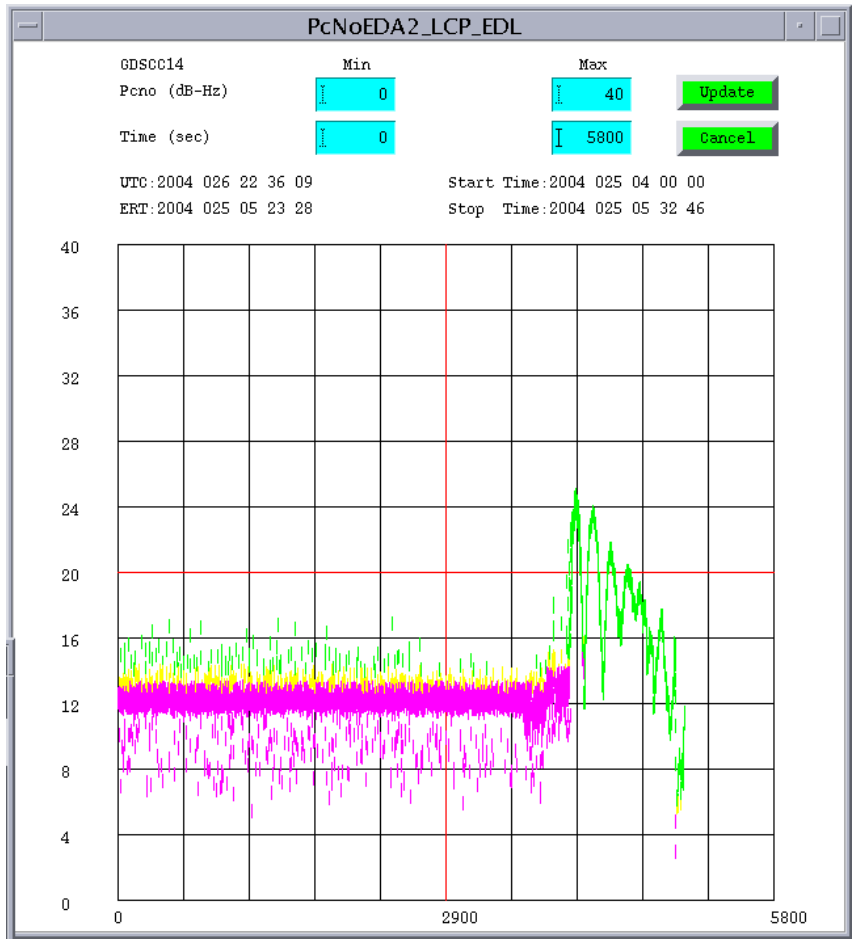
- **UHF EDL Performance – outstanding**
  - **DUHF survived airbag inflation AND bouncing on surface**

- **Presence of MER UHF Signal detected at Stanford Univ with SRI 46m antenna**

MER B EDL Results

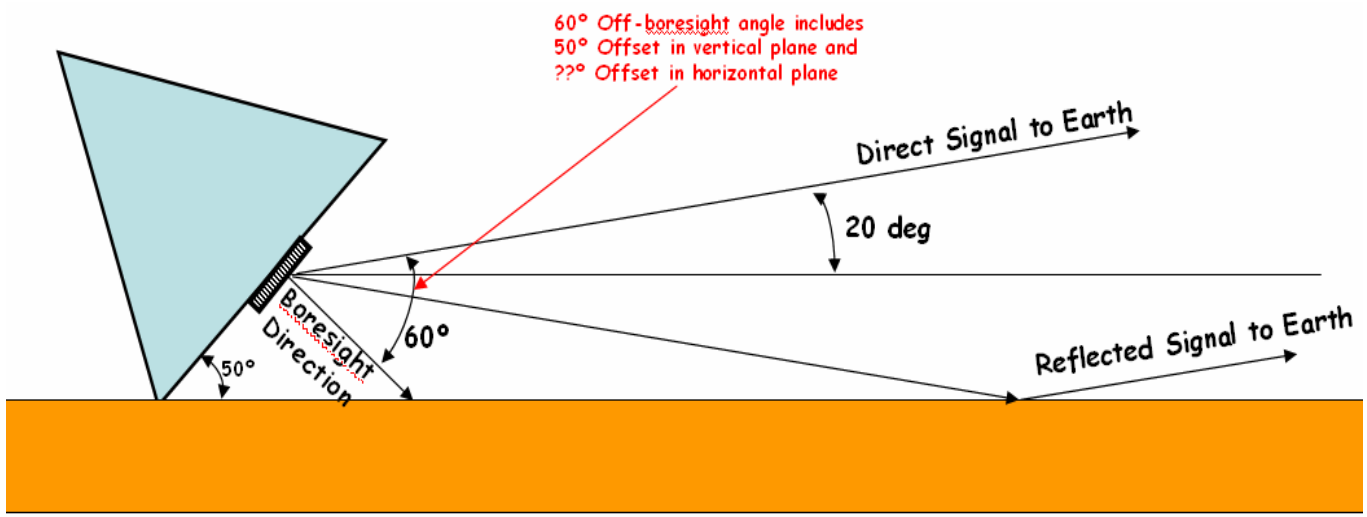
Mars Exploration Rover





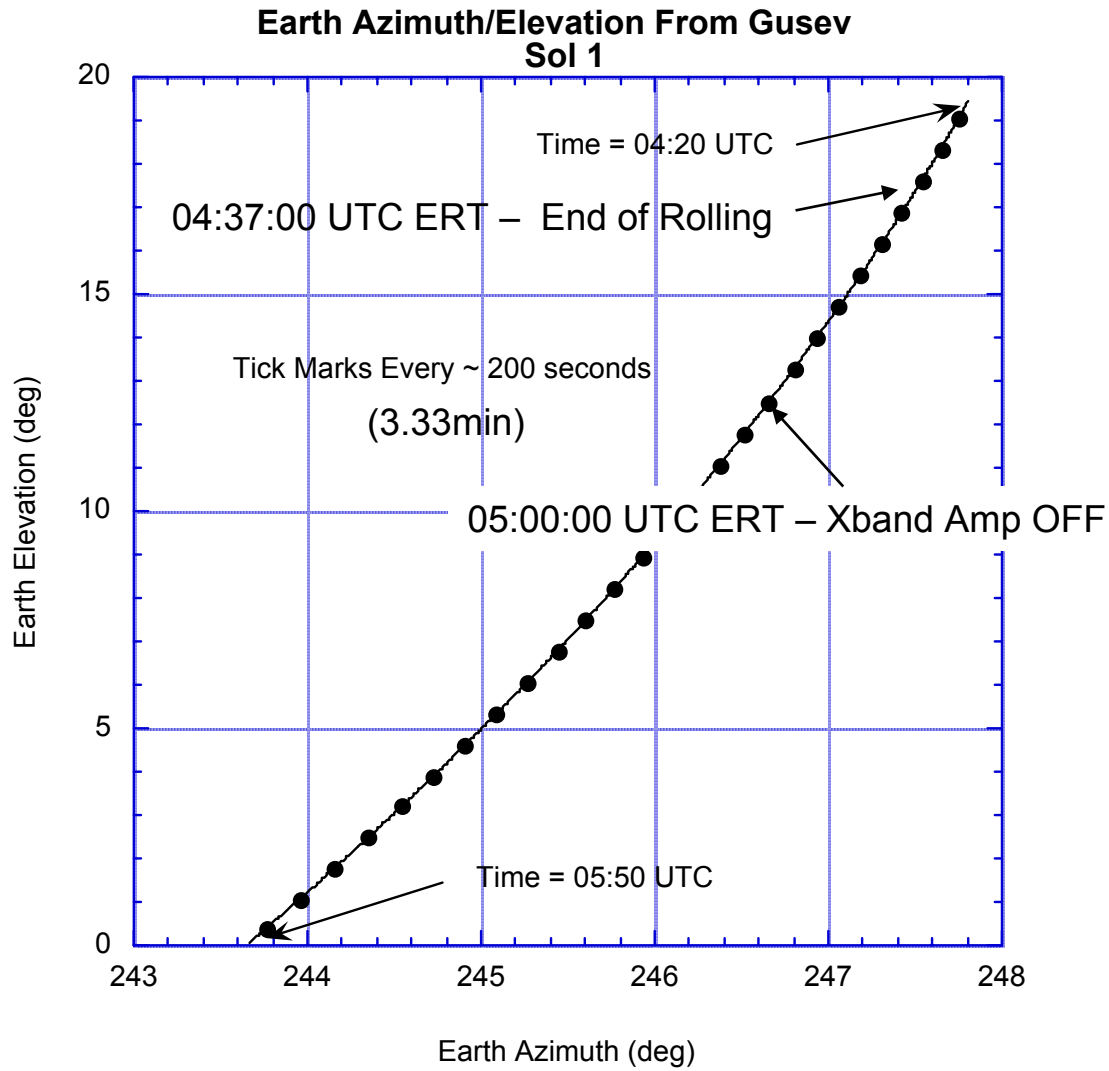
MERA RLGA and PLGA Signal Strengths

- Max Gain from RLGA and PLGA similar
- Pc/No can be 30 dB Hz if all power is carrier (ie. No tones) and Earth is on boresight of RLGA or PLGA if little airbag signal degradation
- 60 deg off boresight, RLGA Pc/No (no tones) = 24 dB Hz
- 90 deg off boresight RLGA Pc/No (no tones) = 13 dB Hz
- 130 deg off boresight RLGA is equally RCP and LCP
- RLGA and PLGA have similar patterns and maximum gains



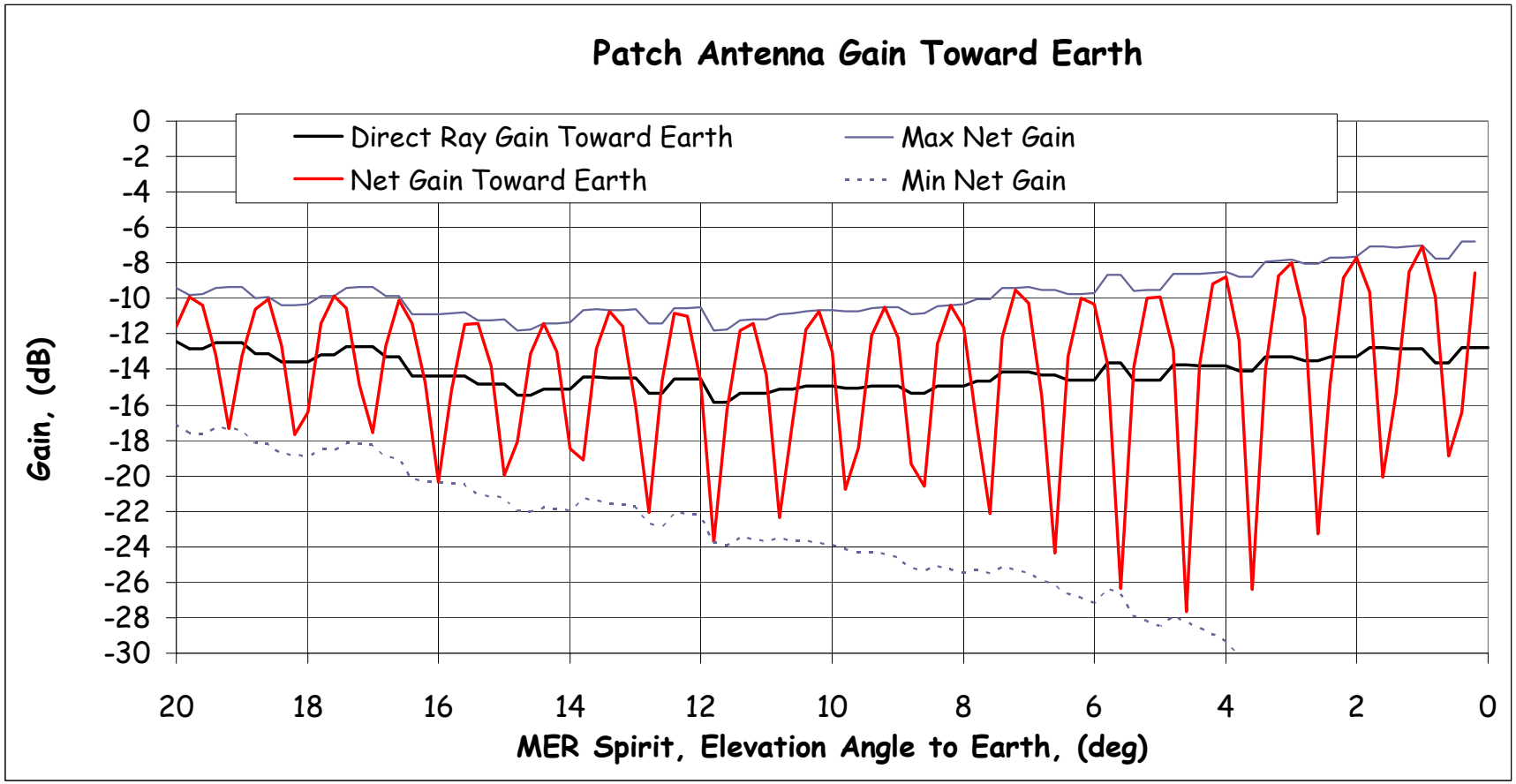
Analysis performed by Dave Bell

Earth Elevation at Mars
(UTC SCET – add 9:30 mm:ss for UTC ERT)



04:37:00 UTC ERT – End of Rolling – 17.5 deg elev
05:00:00 UTC ERT – Xband Amp OFF – 12.5 deg elev

Simple Multipath Result for PLGA (height off Mars Soil 1 m)



Analysis performed by Dave Bell

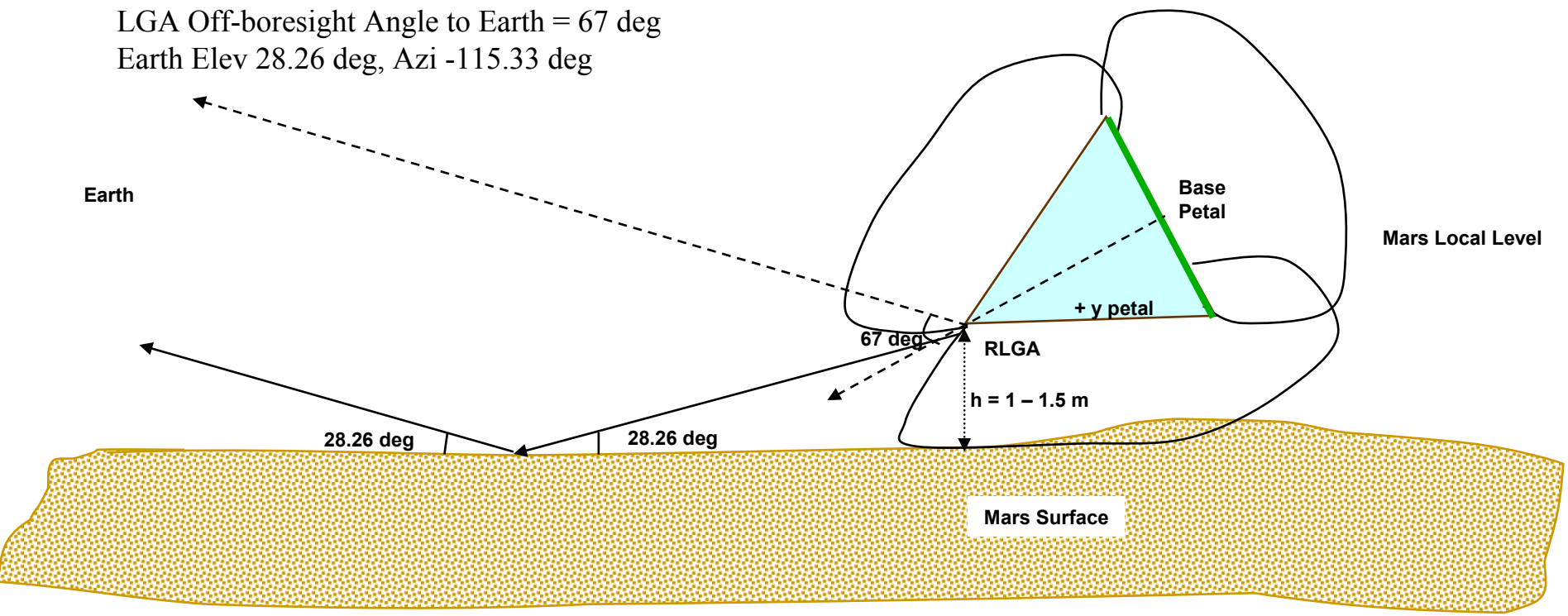
MERB Landed Geometry

At 1/25/04 5:07:15 UTC ERT

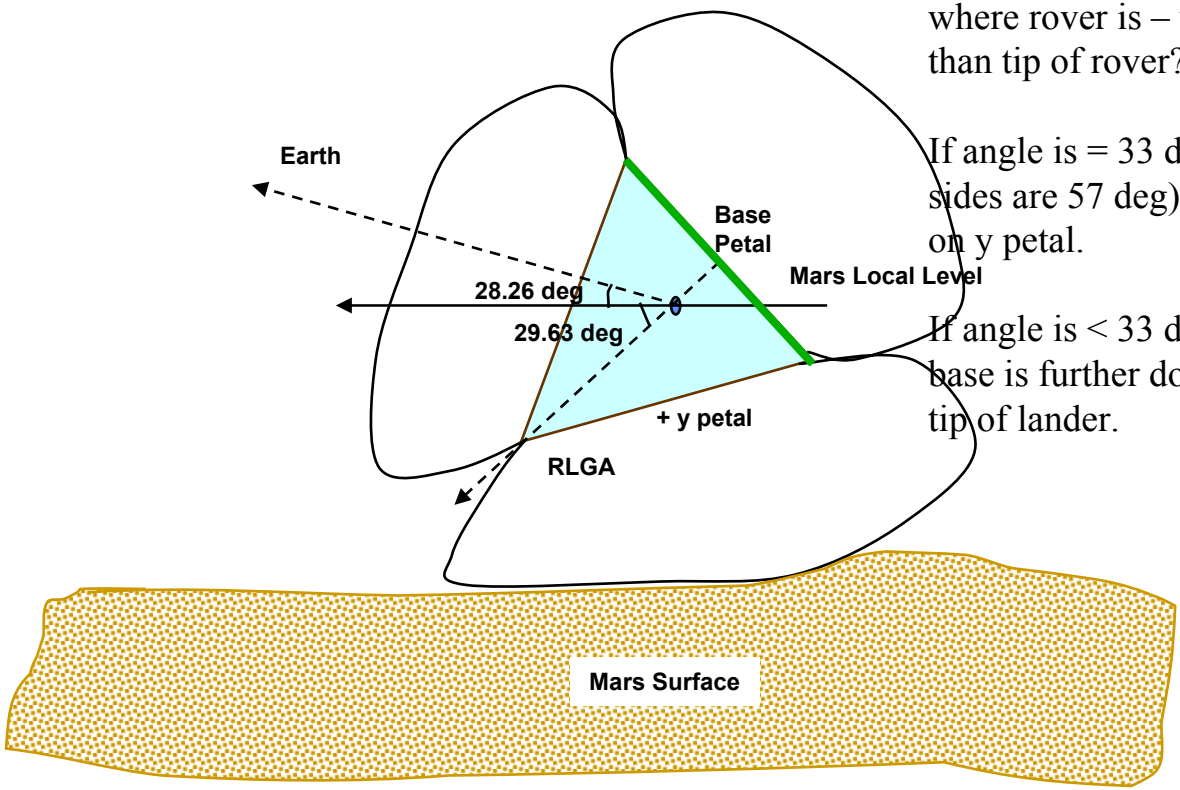
Unit Vector of RLGA in Local Level Frame:
North, East, down: -0.718, -0490, 0.494

Unit Vector of Earth in Local Level Frame:
North, East, down: -0.377, -0.798, -0.469

LGA Off-boresight Angle to Earth = 67 deg
Earth Elev 28.26 deg, Azi -115.33 deg



Cross-sectional View Elevation

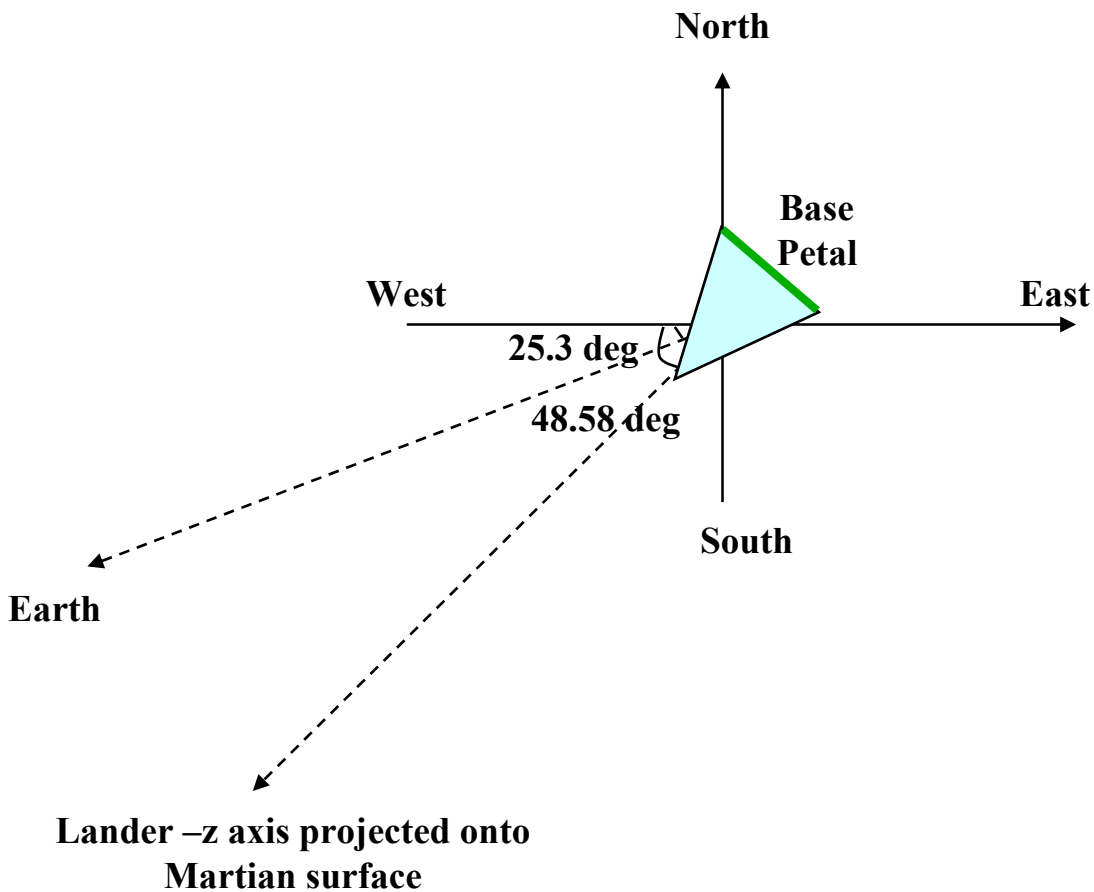


Why doesn't back of lander – where rover is – weigh down more than tip of rover?

If angle is = 33 deg (assuming sides are 57 deg) then rover is flat on y petal.

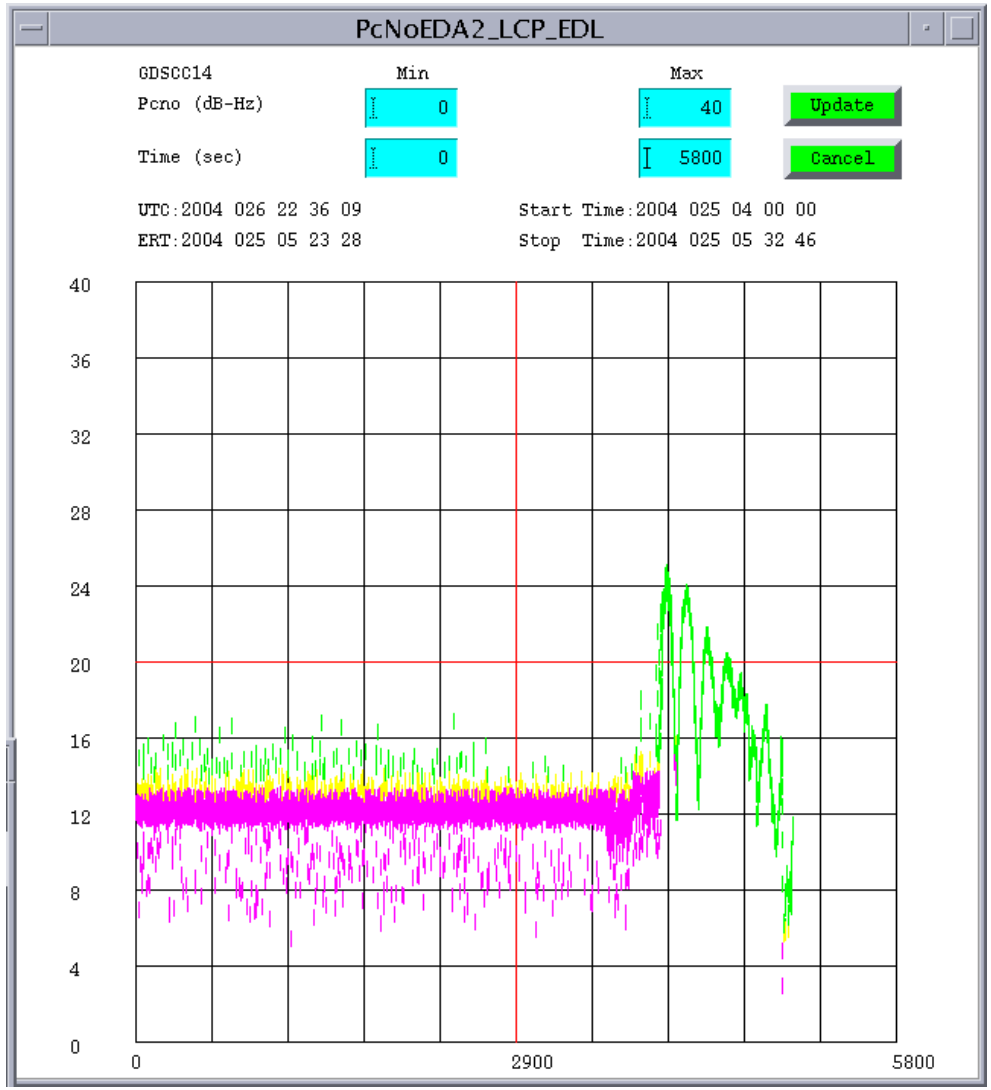
If angle is < 33 deg, then rover base is further down on airbag then tip of lander.

Top View of Lander

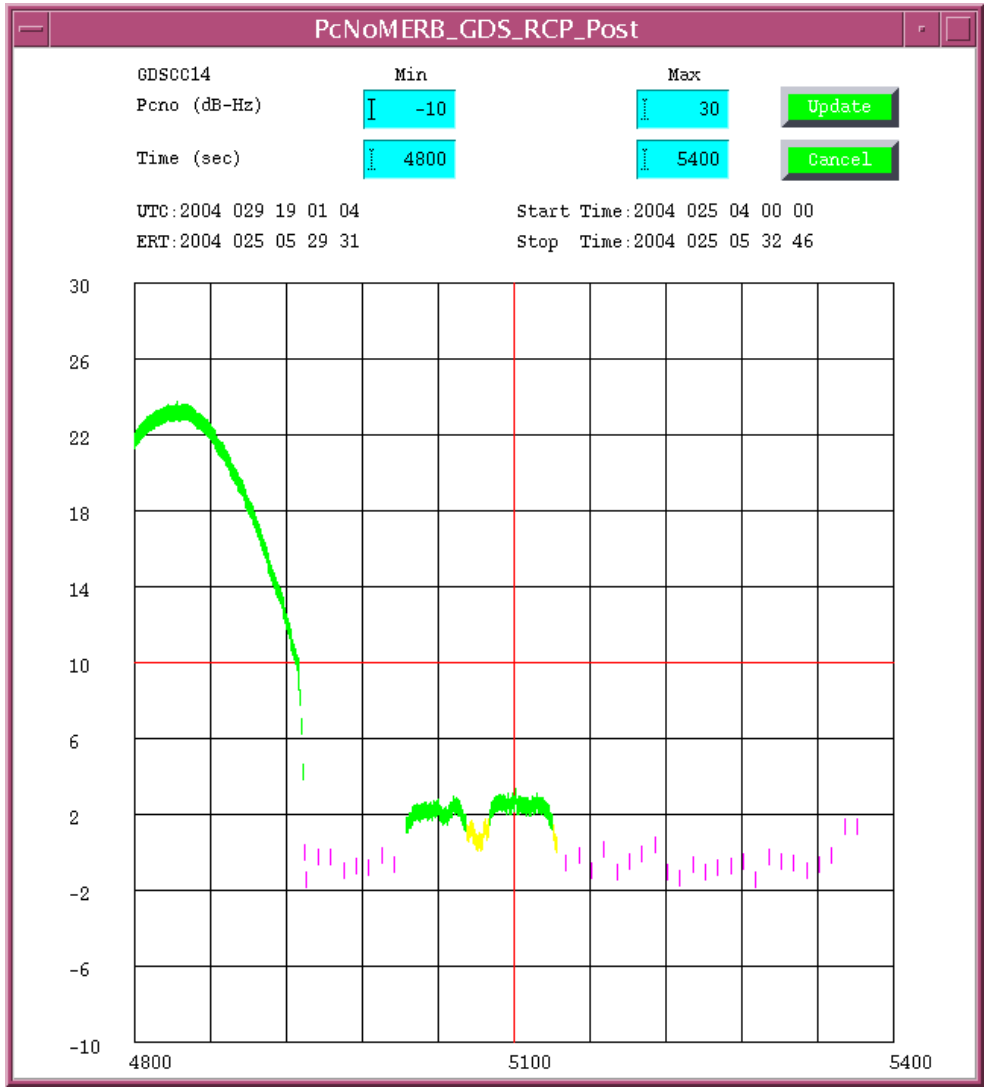
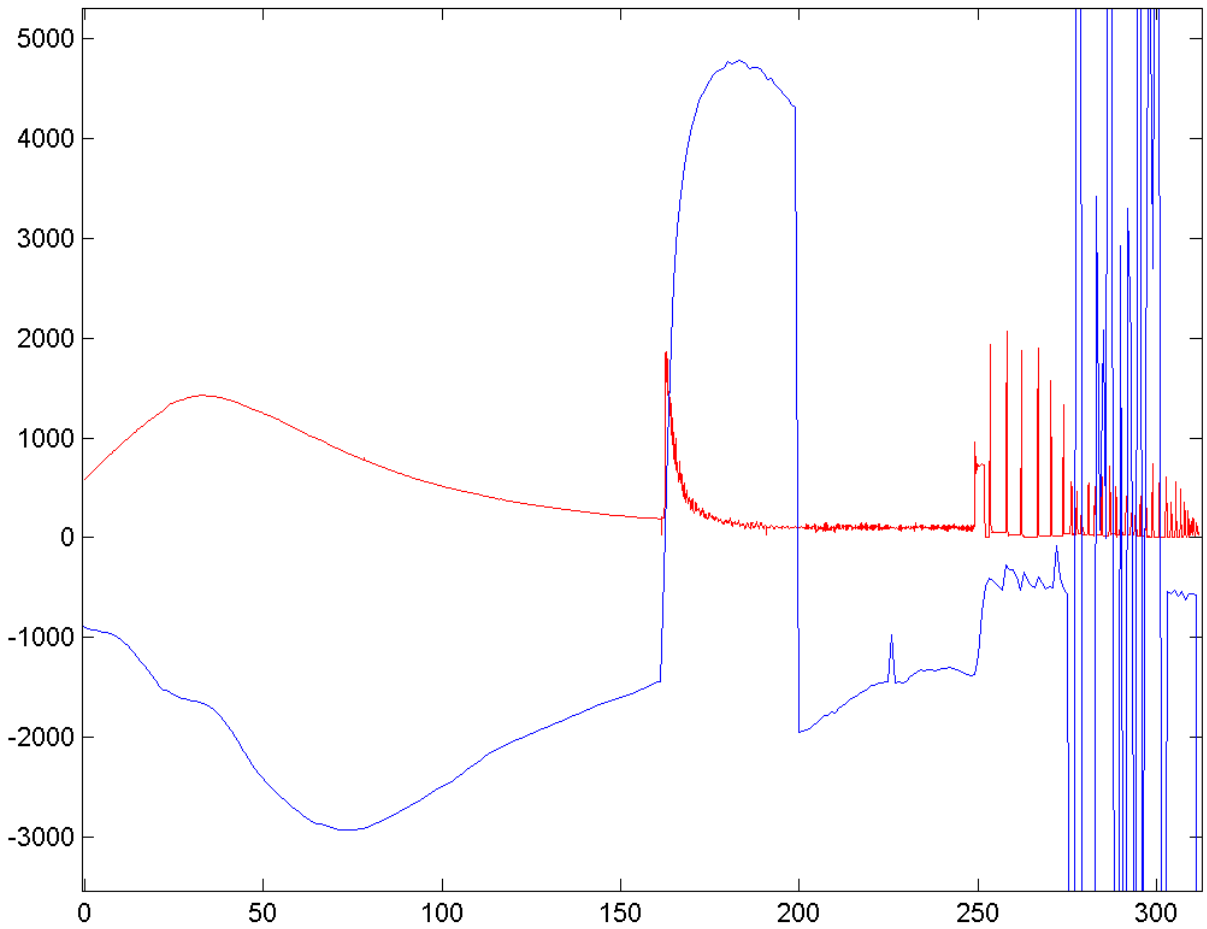


MERB LCP Signal throughout EDL

Mars Exploration Rover



MERB RCP Signal Post Processed during Carrier ONLY from Lander Antenna



MERA Frequency DSS-43 (RCP) and Accelerometer Data