



Phoenix EDL Communications Reconstruction

*International Planetary Probe Workshop
Barcelona, Spain
June 2010*

Richard Kornfeld

**with major support of Kris Bruvold, Lynn Craig, Peter Ilott, Sami Asmar,
Danny Kahan, Dave Morabito, Gene Bonfiglio, Marla Thornton, Jeff Lewis
(LMA), Erik Bailey, Dave Skulski, Olivier Reboud (MEX), Dave Eckart (LMA),
Tim Priser (LMA)**

*Copyright 2010 California Institute of Technology. Government sponsorship acknowledged.
CL#10-1623*

Phoenix EDL Comm - A few "firsts"



- 4 parallel pipelines for EDL Comm
 - via Mars Reconnaissance Orbiter (MRO)
 - via Mars Odyssey (ODY)
 - via ESA's Mars Express (MEX)
 - Direct-to-Earth (DTE) to Green Bank Radio Telescope
- 32kbits/s - highest data rate so far (see table below)
- Open-loop recording and subsequent TLM extraction (for MRO only)
- International participation (ESA's Mars Express)

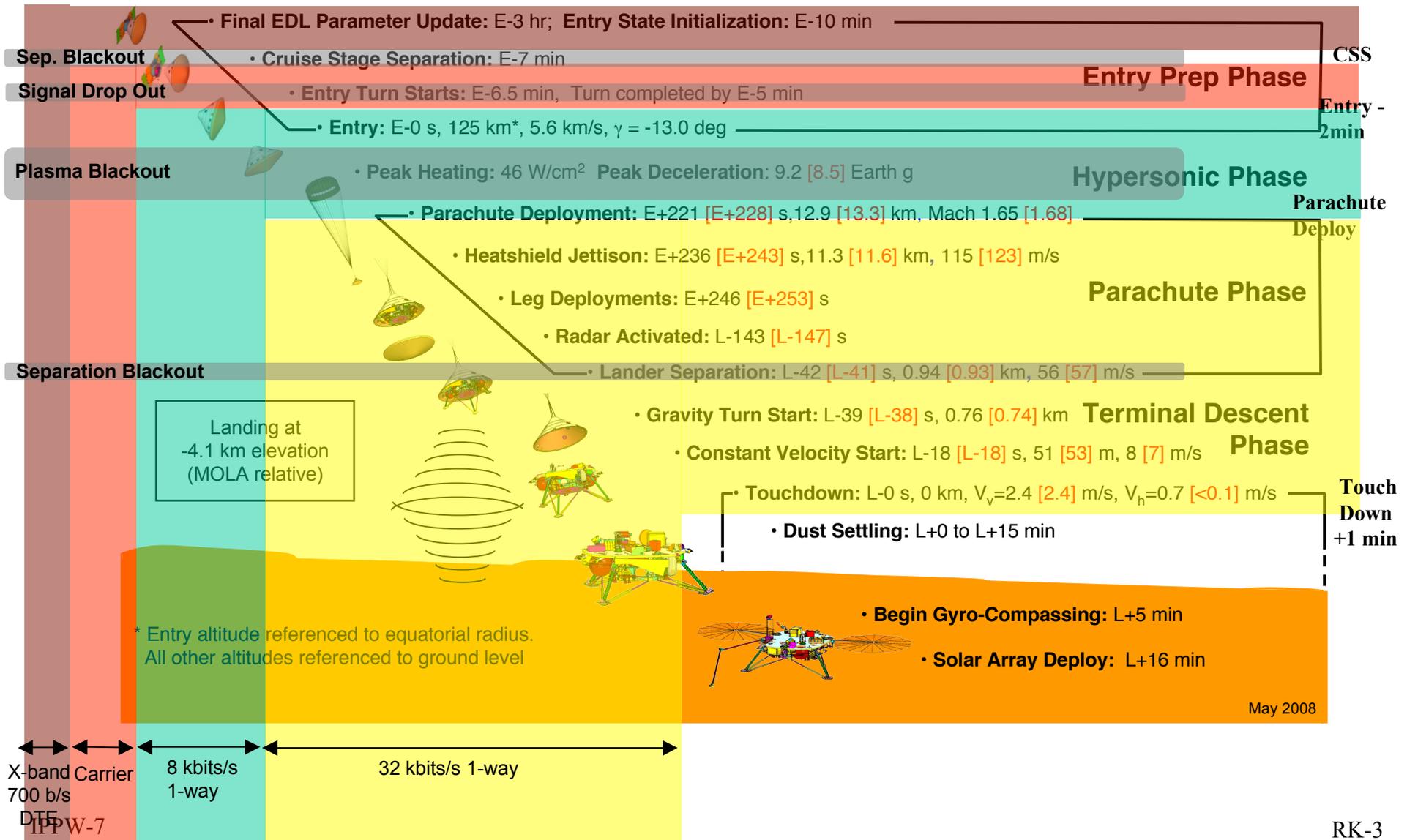


EDL Comm Capabilities

Missions	CSS to Entry	Hypersonic	Parachute	Terminal Descent
Viking	UHF 4 kbits/s	UHF 4 kbits/s	UHF 4 kbits/s	UHF 4 kbits/s
MPF	X-Band Carrier/ Semaphores	X-Band Carrier/ Semaphores	X-Band Carrier/ Semaphores	X-Band Carrier/ Semaphores
MER	X-Band Carrier / Semaphores	X-Band Carrier / Semaphores	X-Band Carrier / Semaphores	X-Band Carrier / Semaphores / UHF 8 kbits/s
Phoenix	UHF Carrier	UHF 8 kbits/s	UHF 32 kbits/s	UHF 32 kbits/s



Phoenix EDL Timeline (actual times in parenthesis)



Spectral Data (Doppler and Power)

ODY Canister Recording (RT)	CSS + 5 s to PD - 26 s
ODY AGC Data (RT)	CSS + 5 s to TD + 1 min
MRO Open-Loop Recording	CSS + 5 s to TD + 1 min
MEX Canister Recording	CSS + 5 s to TD + 1 min
Green Bank DTE Recording via RSR (RT)	CSS + 5 s to TD + 1 min
Green Bank DTE Recording via SWR (RT)	CSS + 5 s to TD + 1 min

Phoenix Telemetry

8 kbits/s extracted from MRO Open Loop Recording	E - 115 s to PD
32 kbits/s extracted from MRO Open Loop Recording	PD + 5 s to TD + 1 min
32 kbits/s relayed by ODY in real-time during EDL (RT)	PD + 5 s to TD + 1 min

Other EDL & EDL Comm Data

200 Hz IMU captured during EDL and stored onboard	E - 10 s to TD + 12 sec
Radar Data captured during EDL and stored onboard	LS - 25 s to TD
	TD - 67 s to TD

CSS: Cruise Stage Separation

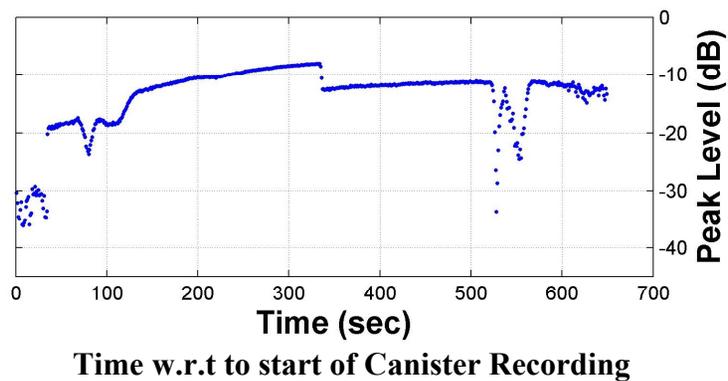
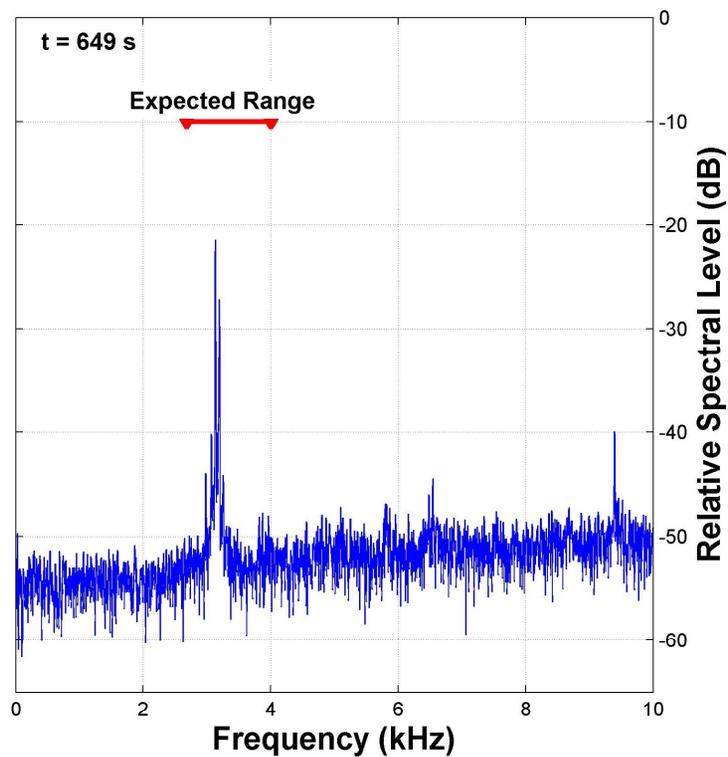
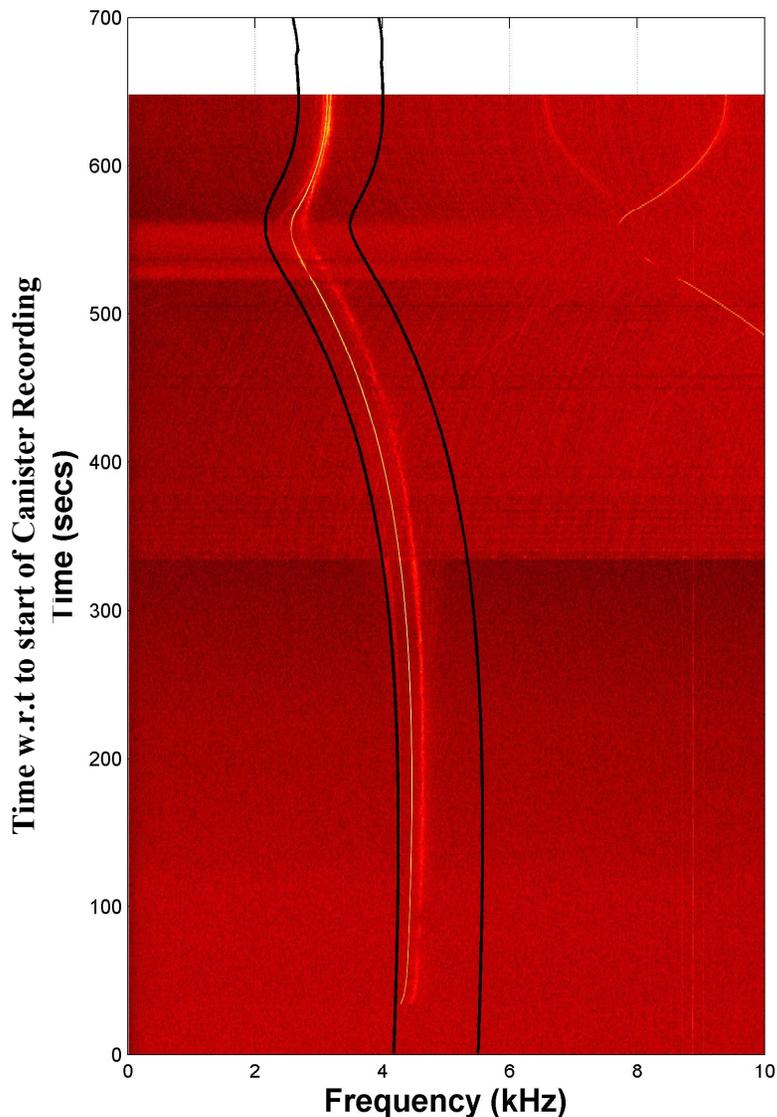
E: Entry

PD: Parachute Deployment

LS: Lander Separation

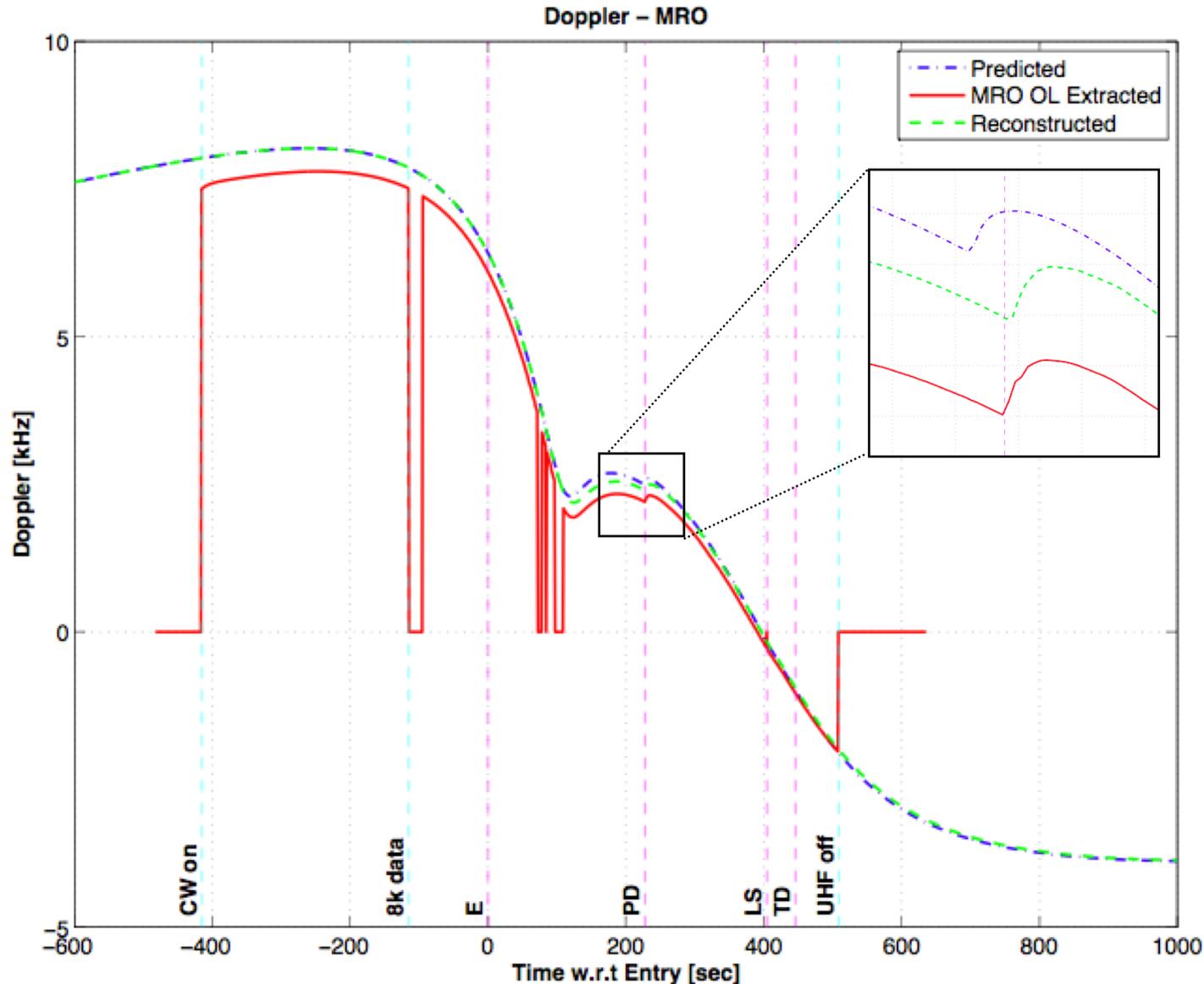
TD: Touchdown

RT: Real-Time (i.e. available during EDL, delayed only by one-way light-time)

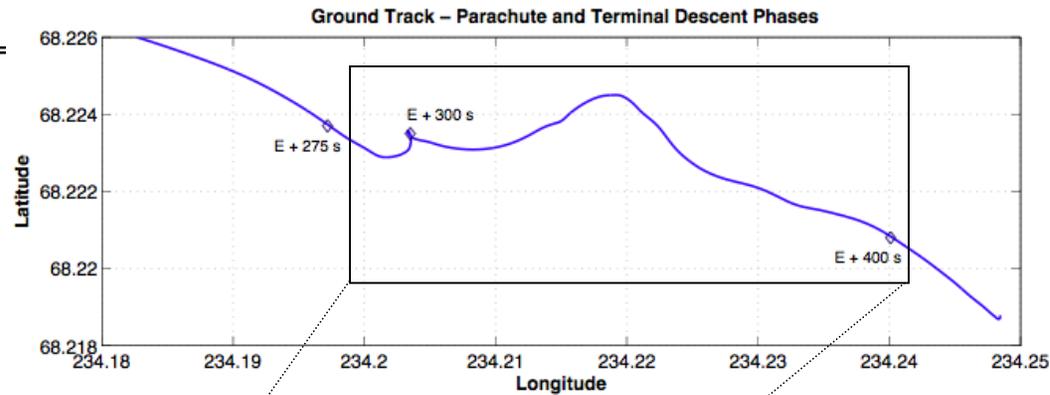




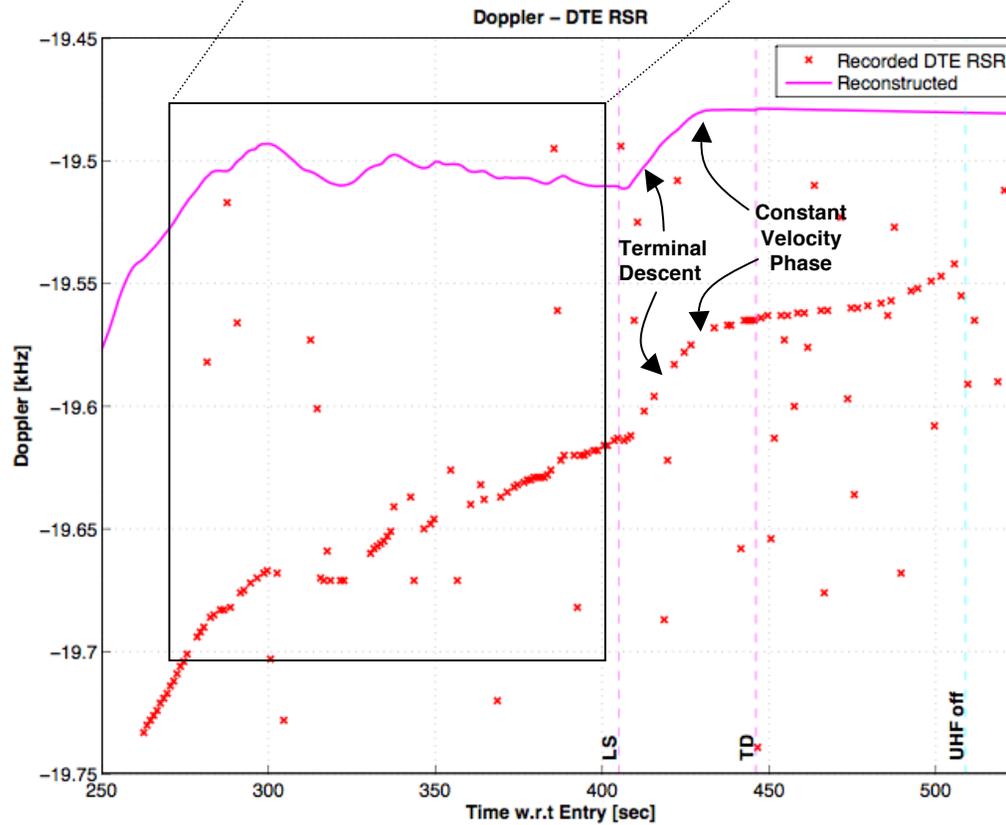
Phoenix Example of Spectral Data: MRO Doppler Profiles

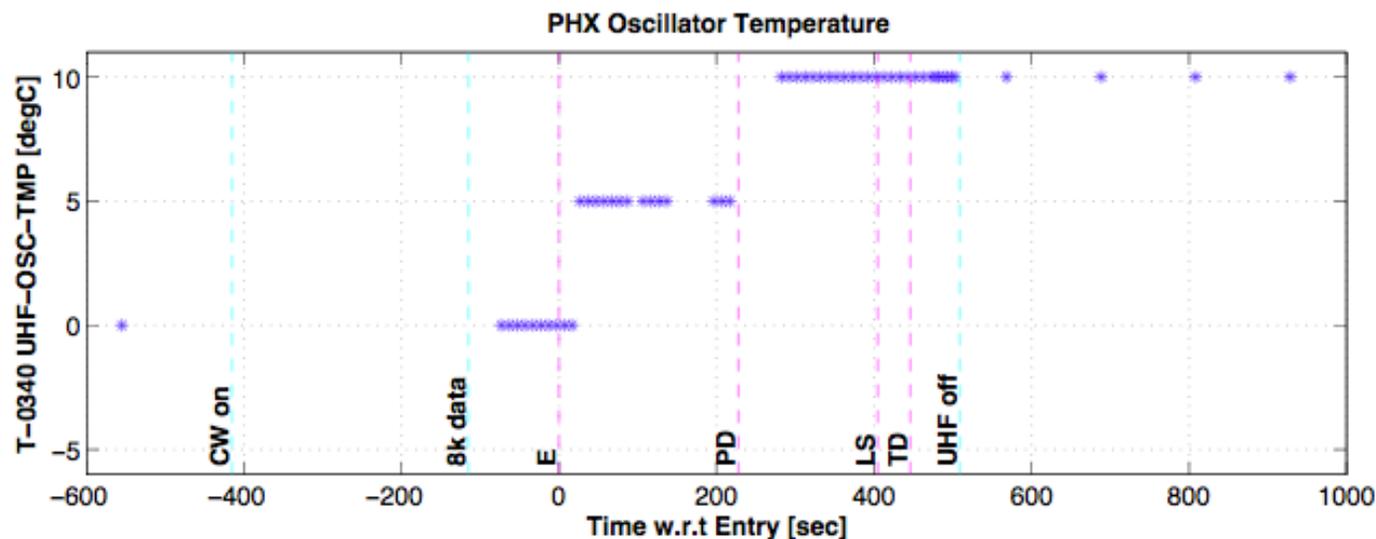
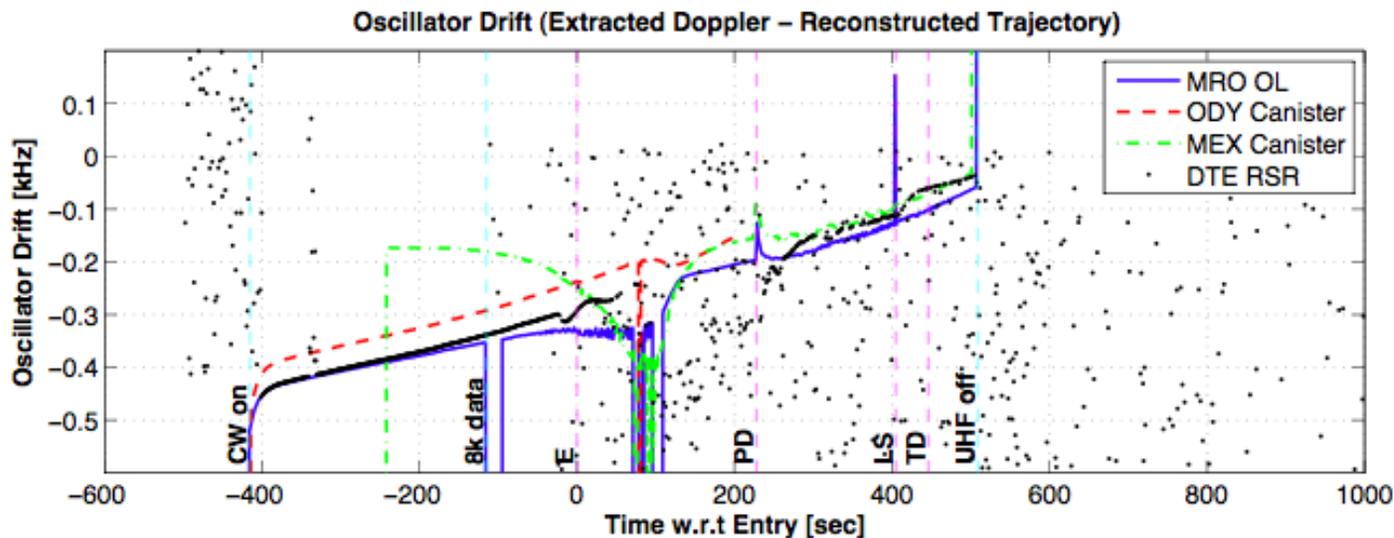


Reconstructed Ground Track



Direct-To-Earth Doppler Profiles during Parachute and Terminal Descent Phases







Phoenix EDL Comm Results



- Successfully established EDL Comm links to ODY, MRO, ESA's MEX and direct-to-Earth (DTE) to Green Bank Radio Telescope
 - ODY and DTE were real-time links
 - Obtained Doppler & Power data for all four links
 - Link performance was as expected
 - “Bent-pipe” real-time 32 kbits/s telemetry via ODY from Parachute Deployment to touch down + 1 minute (5.3 Mbits)
 - highest data rate so far for Mars EDL
 - Recorded & played-back 8 kbits/s and 32 kbits/s telemetry via MRO from Entry - 2 min to touch down + 1 min (6.6 Mbits)
 - Observed a short brownout during the period around peak heating (consistent with level of charged particles)
 - Employed for the first time open-loop recording and subsequent telemetry extraction (for MRO)
 - Provided extra robustness for periods of marginal UHF links
- AND**



MRO HiRISE images the Phoenix Spacecraft during EDL



Phoenix References & Additional Material to Phoenix EDL Comm



- Kornfeld, R.P. et al., *"Entry, Descent, and Landing Communications for the 2007 Phoenix Mars Lander"*, AIAA Journal of Spacecraft and Rockets, Vol. 45, No. 3, May-June 2008.
- Kornfeld, R.P. et al., *"Reconstruction of Entry, Descent and Landing Communications for the Phoenix Mars Lander"* submitted to the AIAA Journal of Spacecraft and Rockets, lined up for a special edition of the journal dedicated to the Phoenix EDL to be published in 2010/2011.
- David Morabito, et al., *"The Mars Phoenix Communications Brownout during Entry into the Martian Atmosphere"*, IPN Progress Report 42-179 November 15, 2009.
- Edwards, C. D. et al., *"Telecommunications Relay Support of the Mars Phoenix Lander Mission"*, IEEE Big Sky Conference, March 5-12, 2010.
- Jim Taylor et al., *"Phoenix Telecommunications"*, JPL DESCANSO Design and Performance Summary Series, Article 15, March 2010, submitted for publication.



National Aeronautics and Space
Administration
Jet Propulsion Laboratory
**California Institute of
Technology**

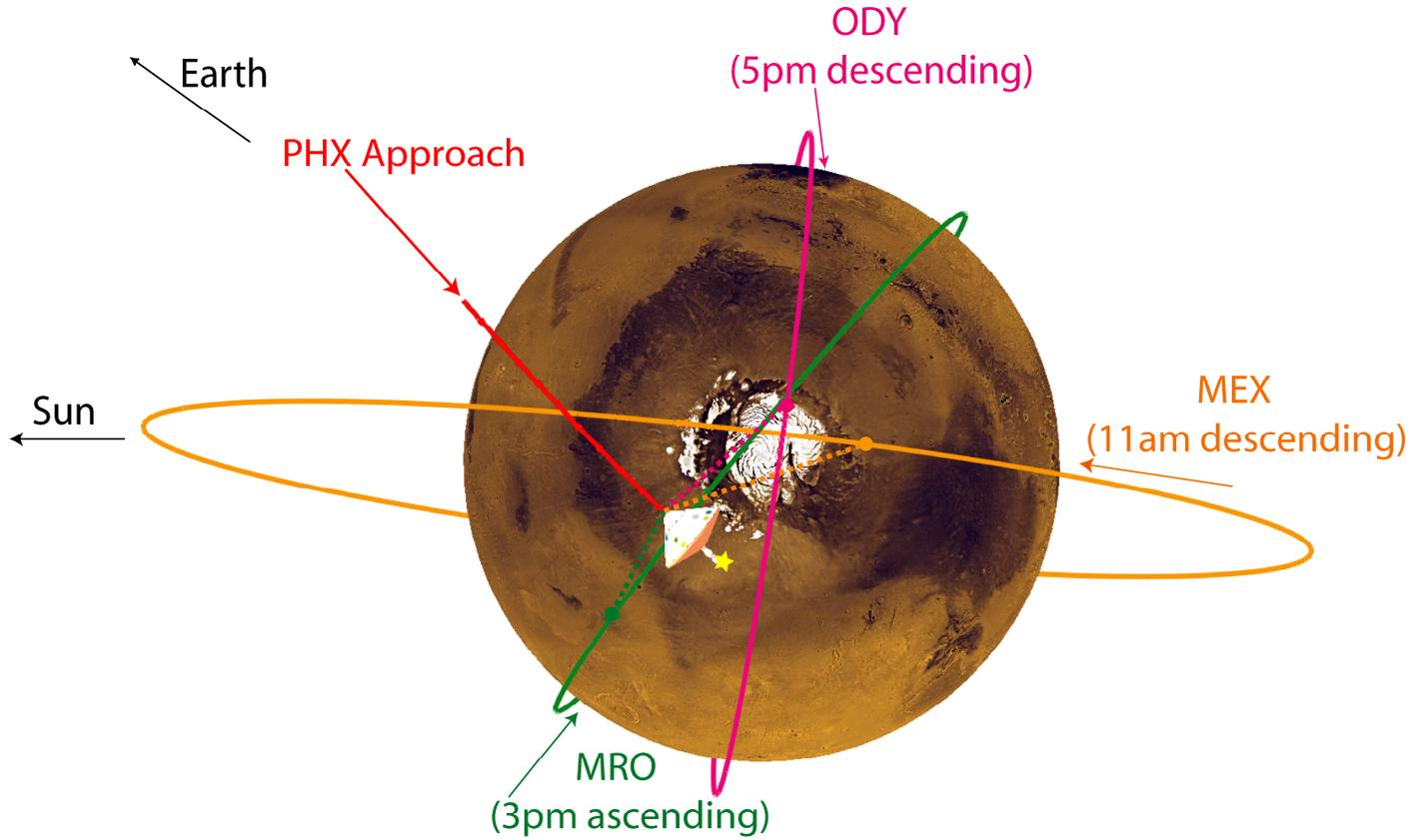


LOCKHEED MARTIN

Appendix

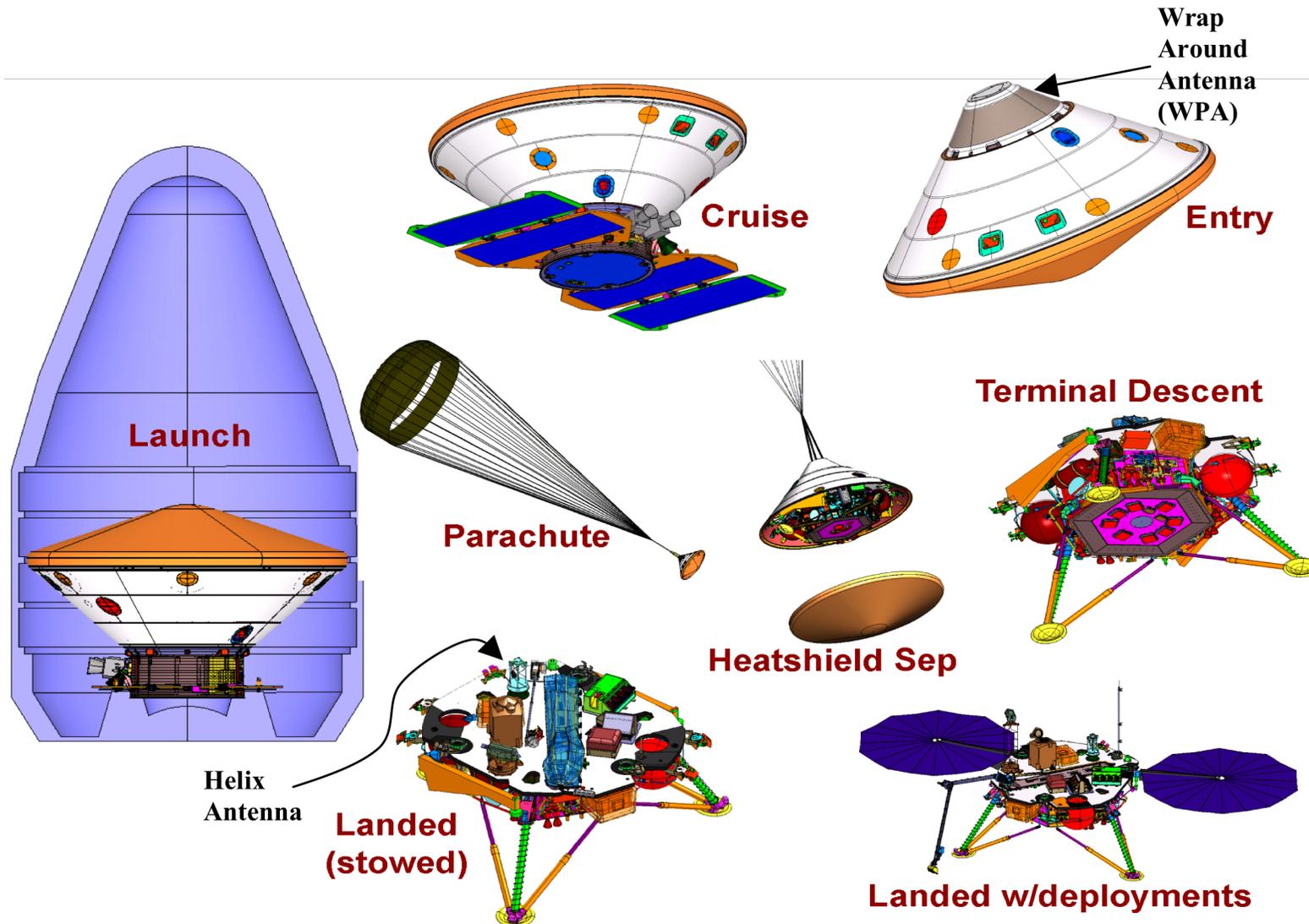


EDL Communications Geometry





Phoenix Spacecraft Configurations





Phoenix

End-to-end Data Flow

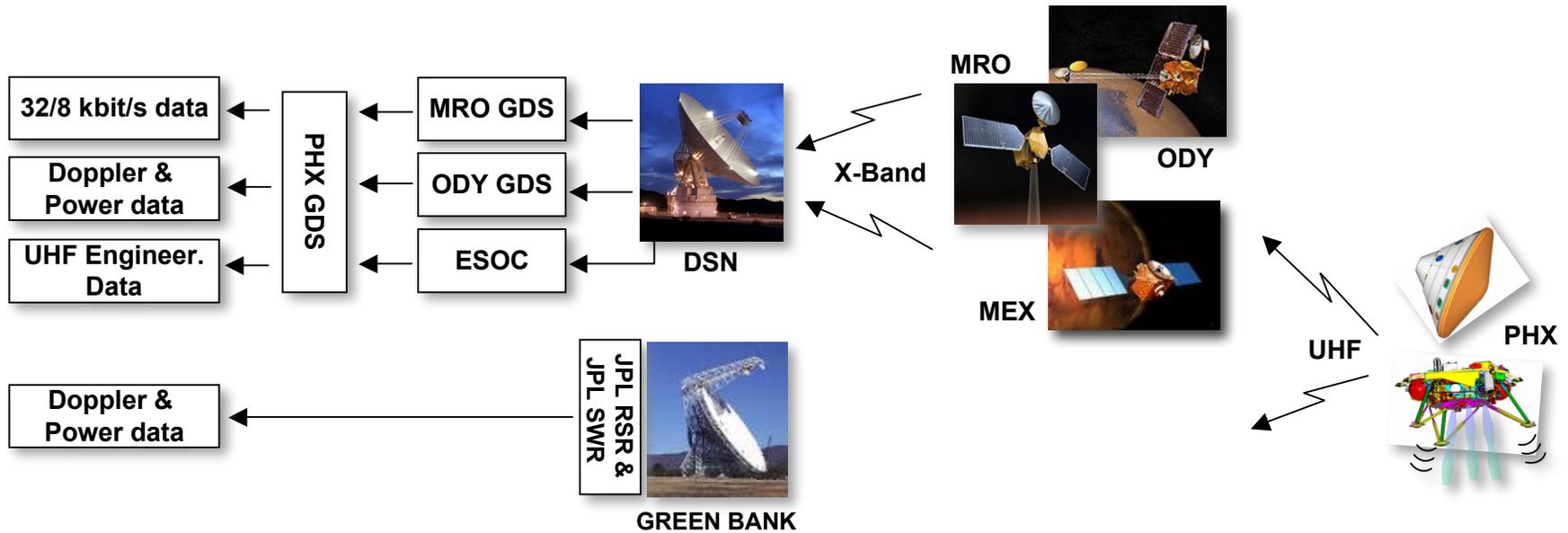
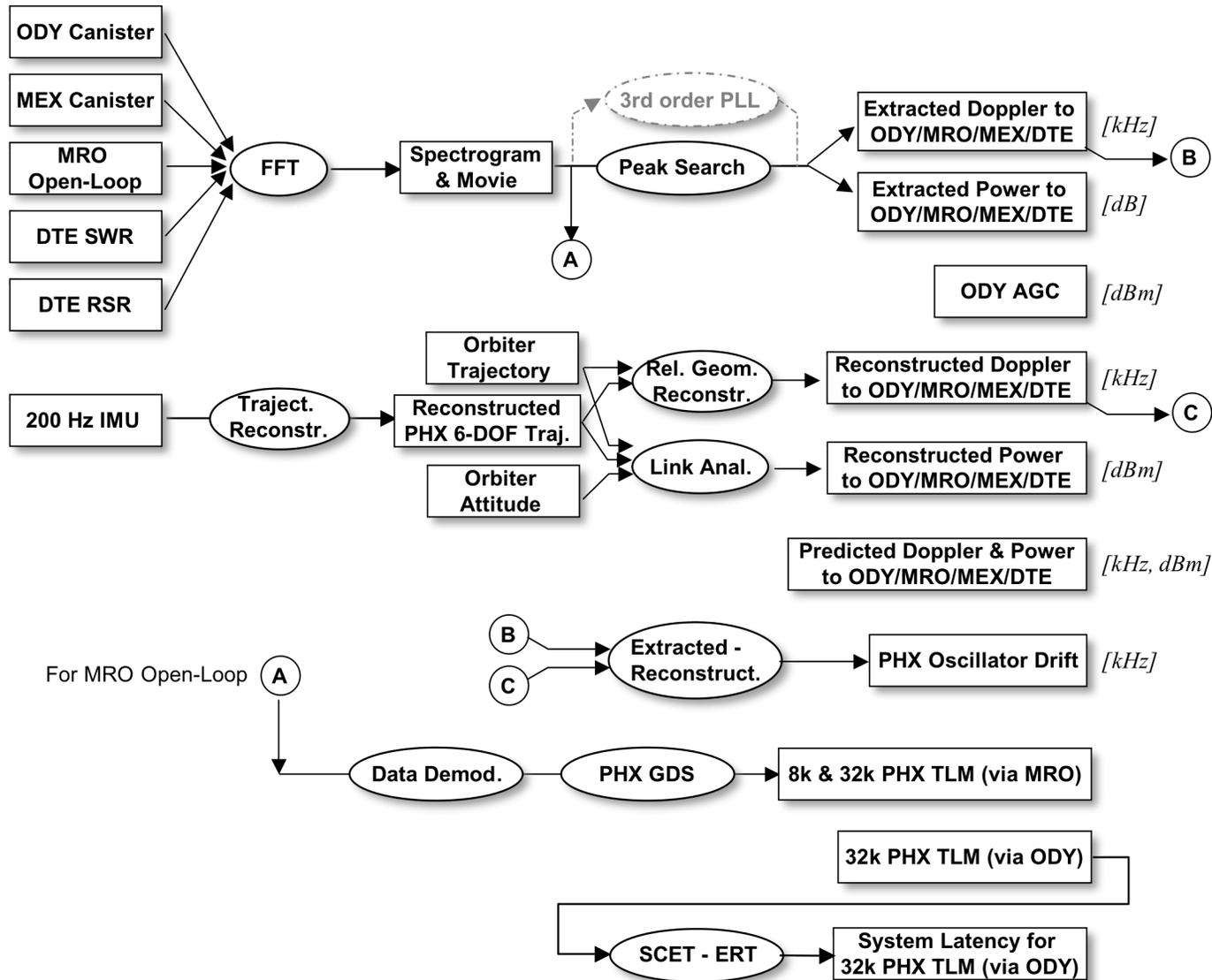


Table 1 Orbiter Sampling and Downlink Rates

Orbiter	Sampling Frequency	Number of Bits	X-Band Downlink Rate	Real-time Downlink
ODY canister	83.6 kHz	1	124 kbits/s	Yes
MRO open-loop	150 kHz	16 (complex)	2.6 Mbits/s	No
MEX canister	42.1 kHz	1	91.4 kbits/s	No

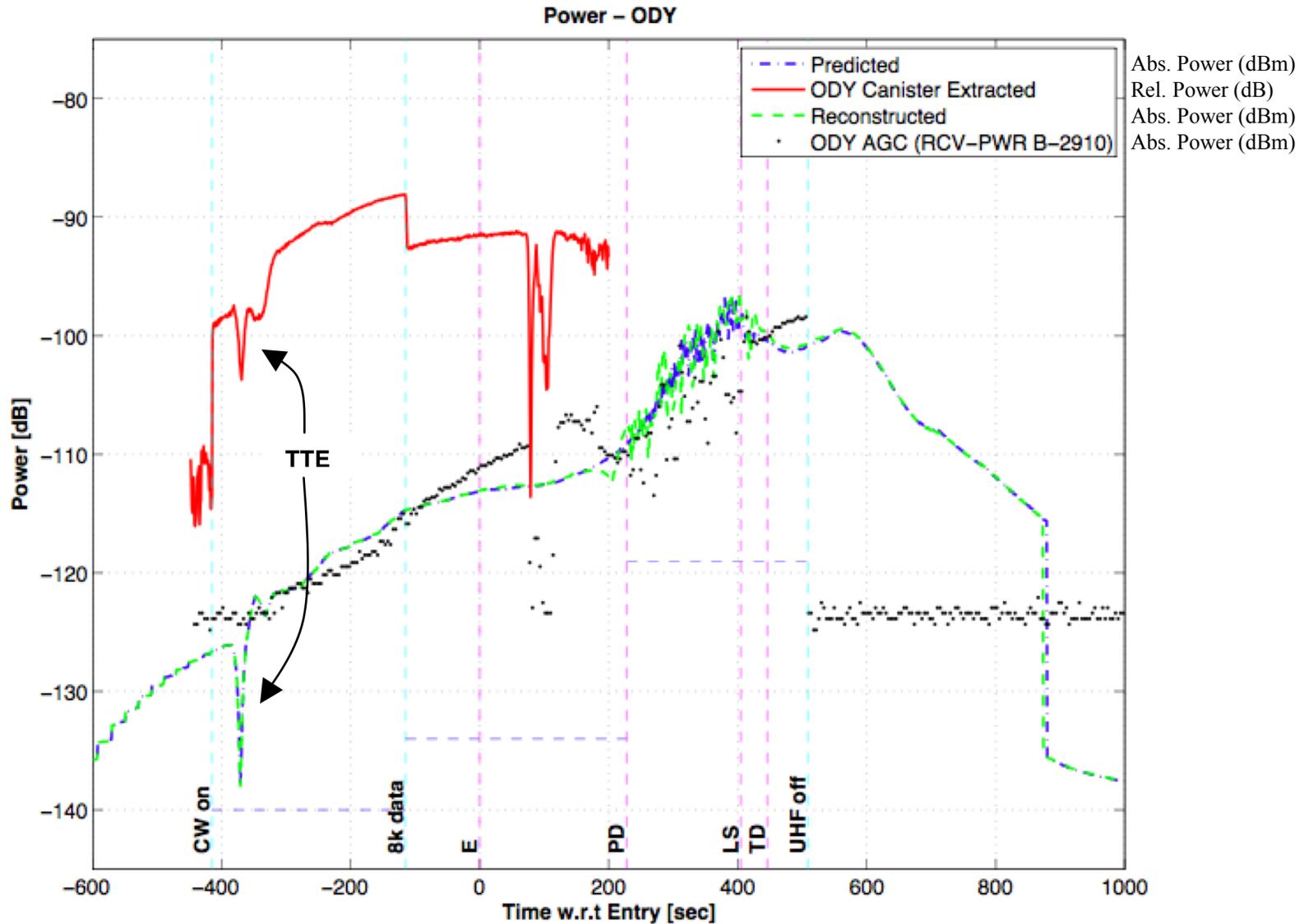


EDL Comm Reconstruction Approach



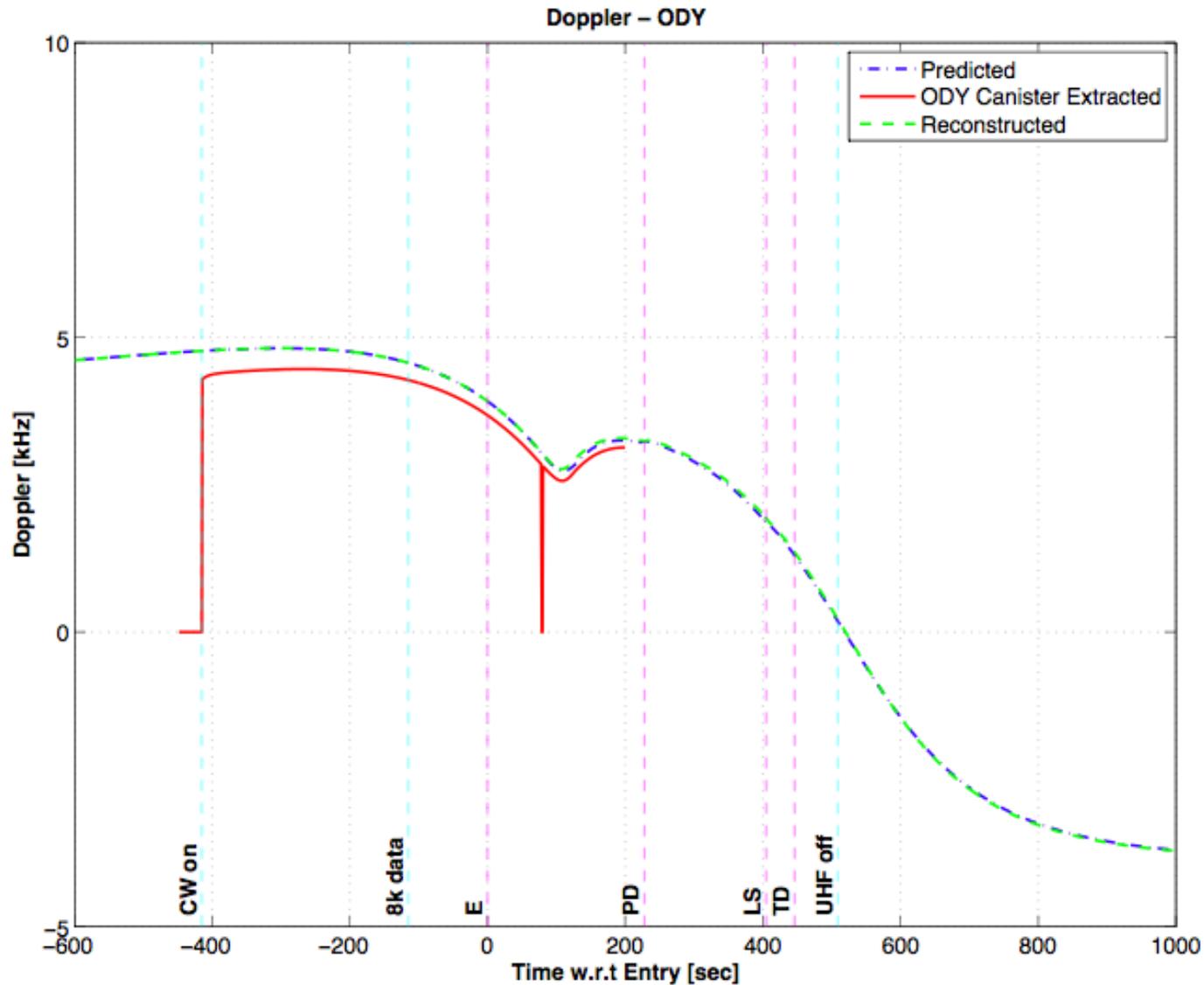


Example of Spectral Data: ODY Power Received Profiles



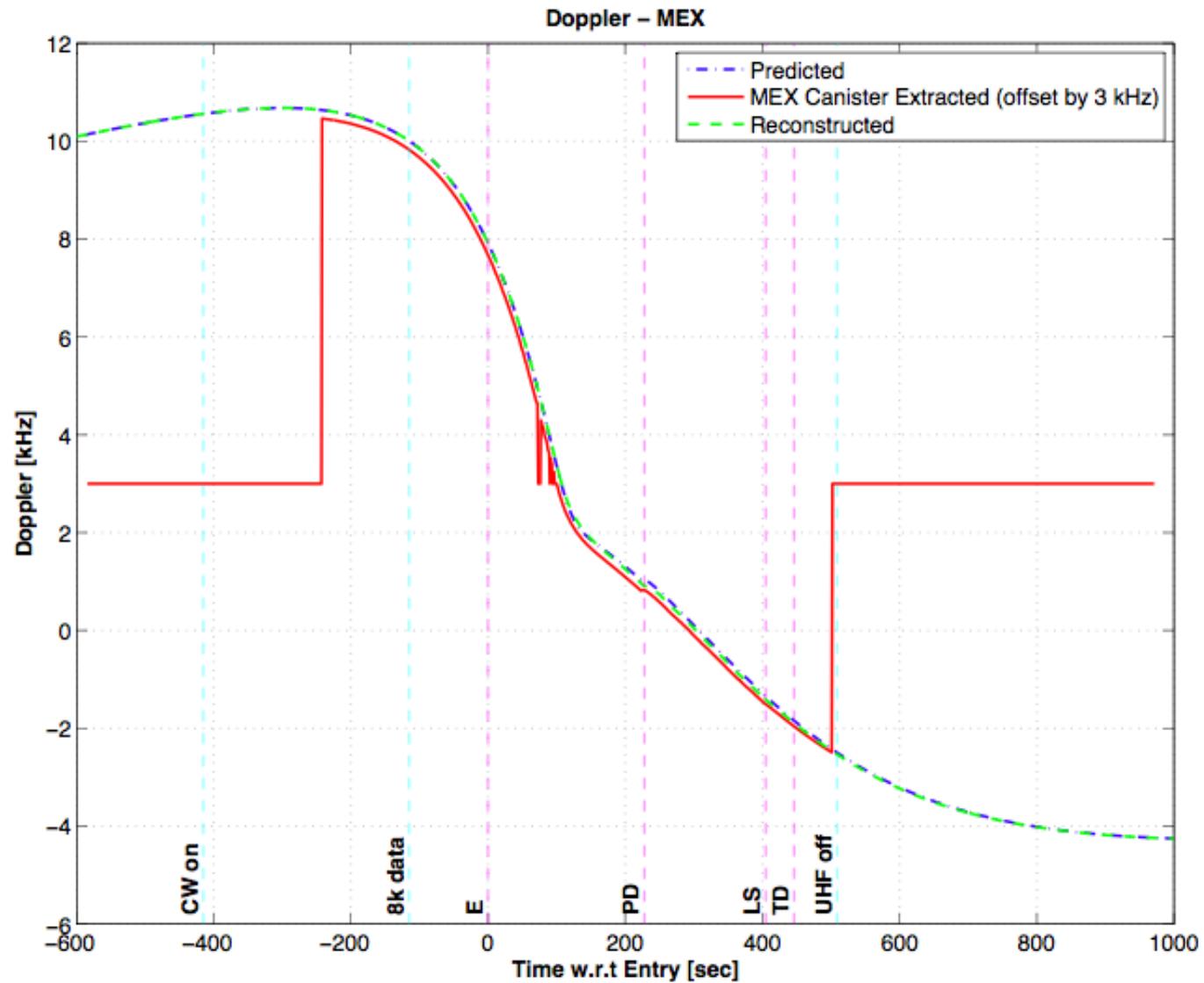


Phoenix Example of Spectral Data: ODY Doppler Profiles





Example of Spectral Data: MEX Doppler Profiles



MEX Doppler
was offset by 3
kHz (corrected
in the plot)