Jet Propulsion Laboratory
California Institute of Technology

Schiaparelli UHF Signal Reception at GMRT

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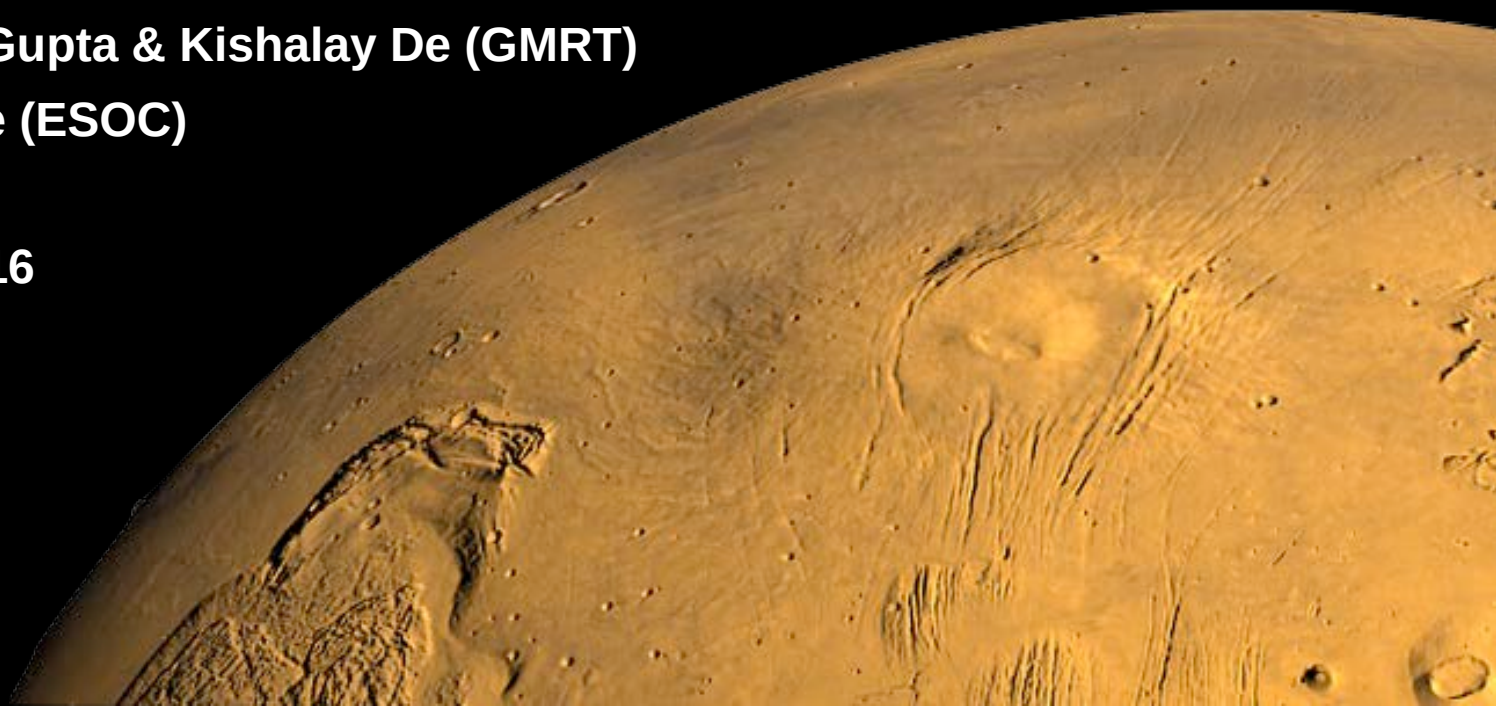
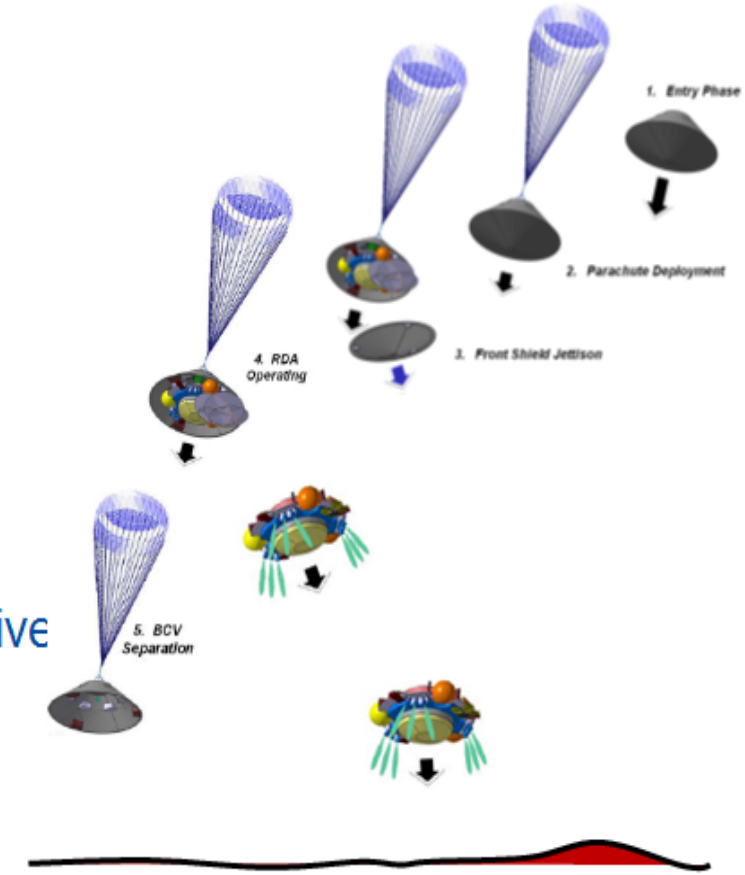


Introduction

- **JPL's *Interplanetary Network Directorate* (IND) is responsible for Cross Support and International Collaboration for deep space tracking and communications**
  - **Cross Support Agreement between NASA and ESA**
- **Also responsible for brokering and establishing collaboration with assets outside the agency as needed**
- **Reached agreement with GMRT leadership for support of EDM UHF reception on best efforts basis**
  - **InSight 2016 EDL was initial driver**
- **Fact Finding visit last December and in communications since**
  - **Primary concern was local interference**
- **Objective: detect & report UHF signal carrier for lander aliveness**

Main events of the EDM EDL phase

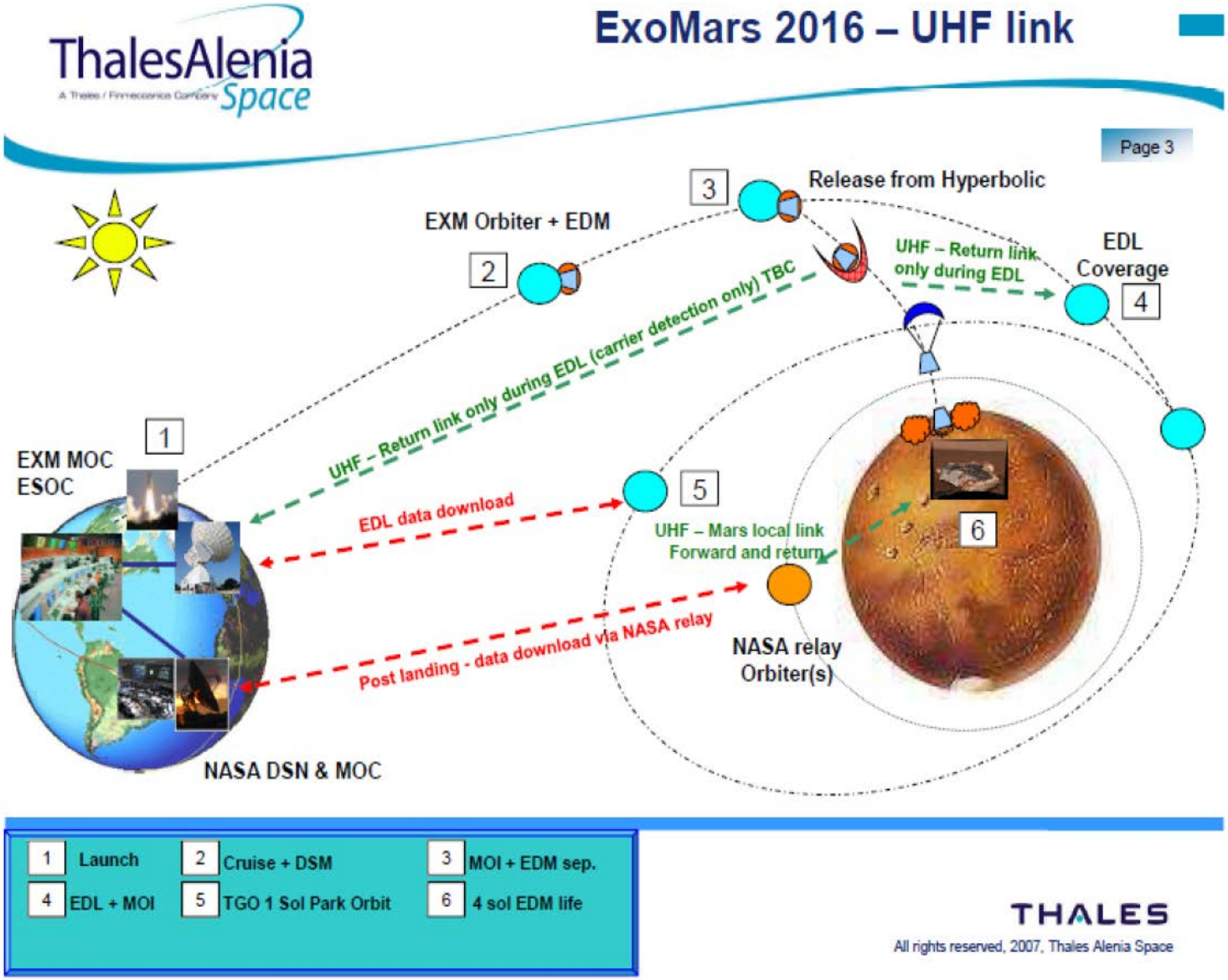
- EIP – 3 days → EIP : Coast phase
- EIP → EIP + 4 min: Hypersonic entry
- EIP + 4min → EIP + 6 min: Parachute phase
  - ✓ Parachute opening at Mach 1.8
  - ✓ Front shield release
  - ✓ Radar altimeter acquisition
- EIP + 6 min → EIP + 6.5 min: Propulsive braking
- EIP + 6.5 min: (semi-soft) Landing



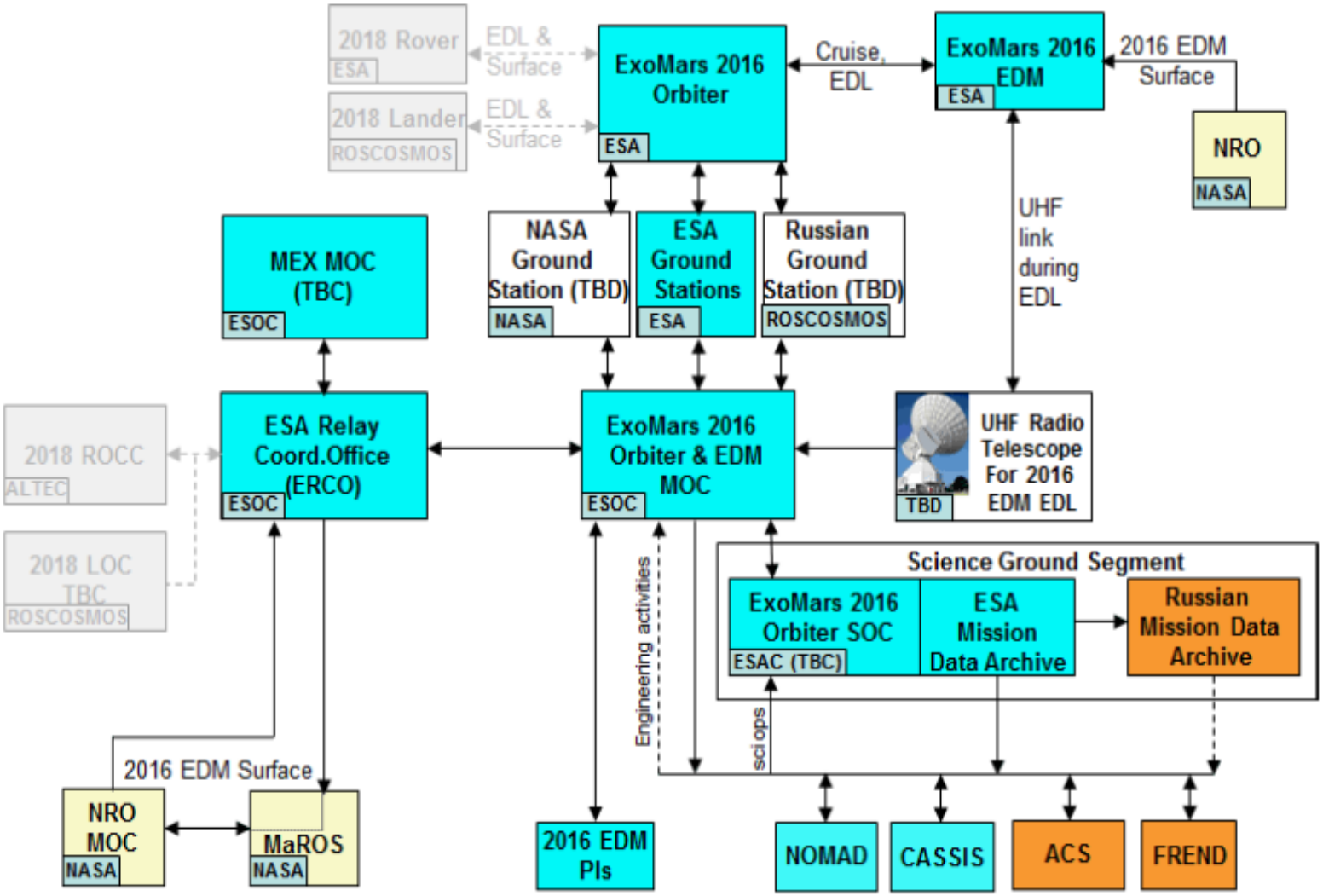
EDL Communications Overview

- From -30 min. to +10 min.
  - Direct UHF coverage by Mars Orbiters
  - TGO (ExoMars Orbiter) UHF radio receiver in open loop recording mode
  - Direct-to-Earth UHF to Earth (GMRT) in open loop carrier detection mode
  - EDM transceiver set to TX force mode to broadcast UHF signal
  - Transmitter: 5W, circuit losses to BackShell antenna ~2.6dB, to Surface Platform antenna ~1dB
  - BackShell antenna gain min. -10dBic / max. 0dBic; Surface Platform antenna gain min. dBic -8dBic / max. +6dBic
  - Frequency: 401.585 MHz (Return link)
  - Physical Layer set to SP-L Modulation, Residual Carrier (mod. index 60°)
  - CCSDS Prox-1 Expedited Mode, Return data rate set to 8kbps

EDL UHF Overview

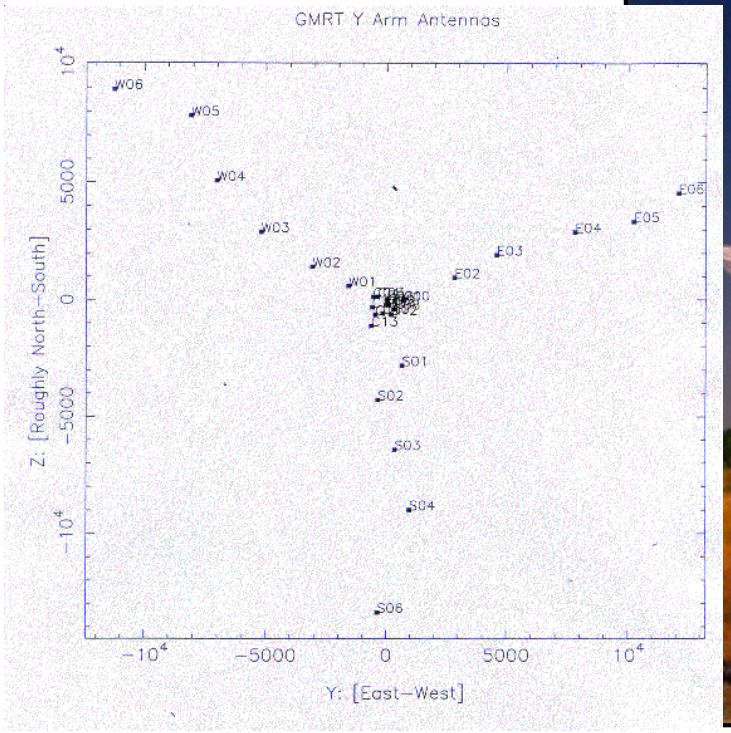


Ground Segment

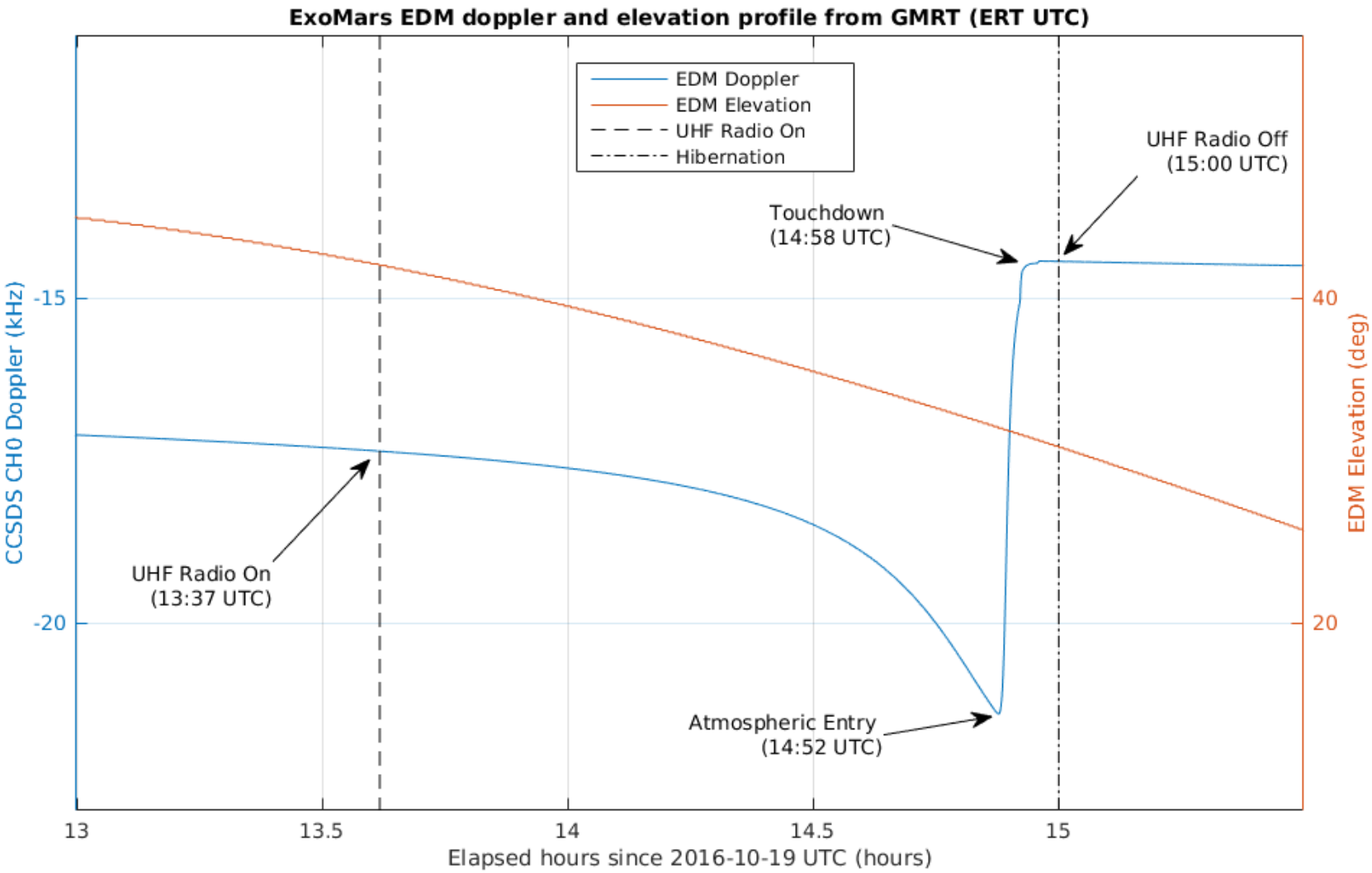


GMRT

- **The Giant Metrewave Radio Telescope, outside Pune, India**
- **Tata Institute of Fundamental Research - The National Centre for Radio Astrophysics**
- **30 dishes, 45-m diameter each, in Y-shape configuration**



GMRT Doppler & Elevation Profiles



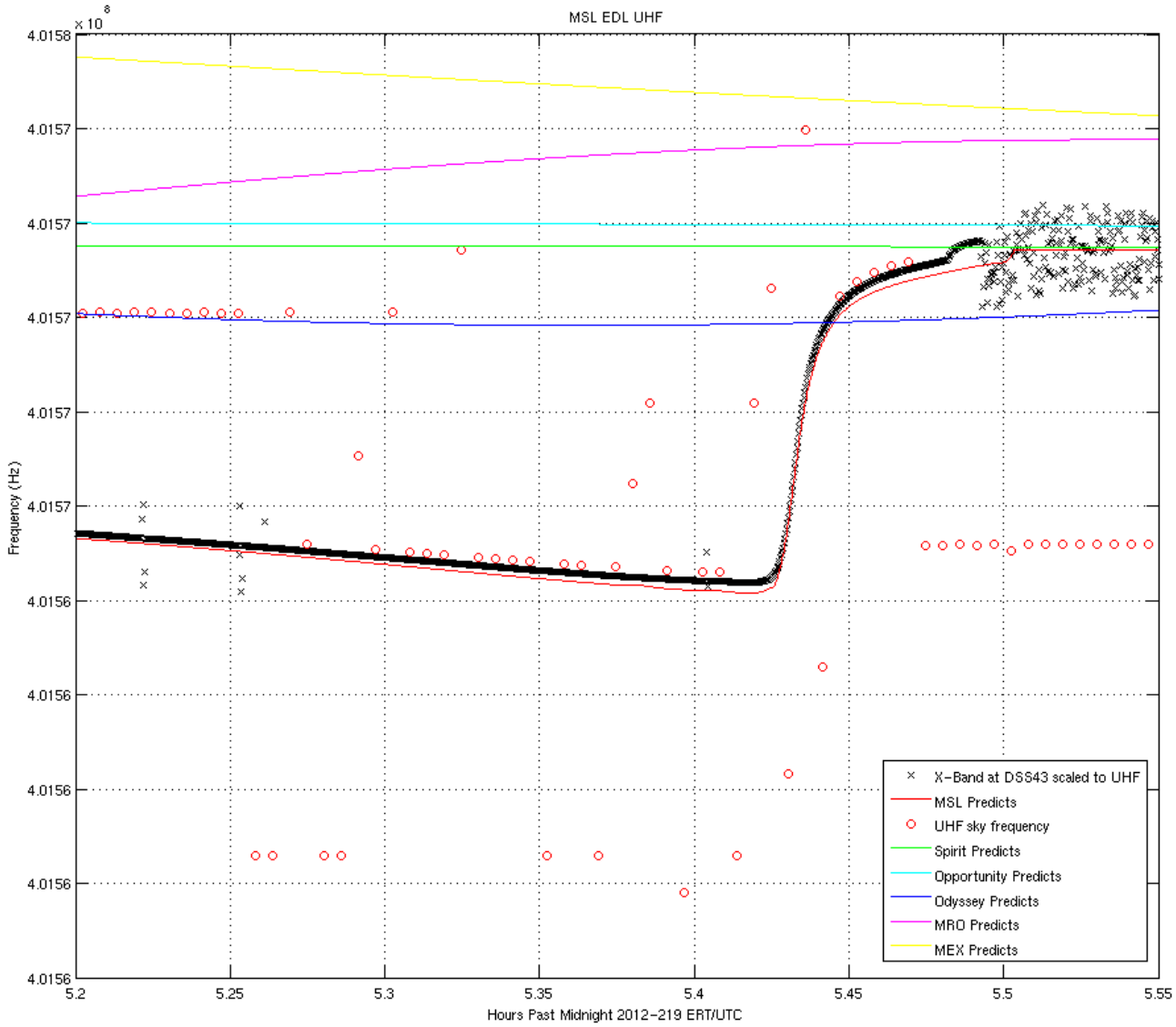
UHF DTE Link Performance

- During December 2015 site visit, 16 dishes were instrumented with UHF
- By October 2016, all 30 dishes will be ready
  - We assume 25 dishes for link analysis:
  - Effective Area: 19,880 m^2 (25 dishes, 45m, 50% efficiency)
  - Expected Pc/No: 17.2 dB-Hz (+6 dBiC) to 1.3 dB-Hz (-10 dBiC)
    - Depending on EDM antenna pattern
- Spacecraft-Earth range at arrival ~ 1.16 AU
- Frequency = 401.585 MHz; transmitted power = 5 W
- System Temperature = 106K (Mars ~10 degrees off galactic plane)
- Previous work managed to detect carrier at ~3 dB-Hz in open-loop mode
- Target sensitivity at GMRT ~3 dB-Hz

Expected Operations

- **One JPL specialist at GMRT**
- **One JPL specialist at ESOC**
- **No specialized hardware needed to be transported to GMRT**
- **Voice communications & coordination by phone**
- **Real-time plots via internet conference protocol (e.g., Webex)**
- **On best-efforts basis, to advice project**
- **No communications with the press or public**
  - **Only project office make announcements**
- **If successful, GMRT can take credit for participation at a later time**
- **Raw data can be available to GMRT, JPL, and ESOC at a later time**
- ***After the event, GMRT is willing to help with additional support as needed but will not make blanket schedule-clearing commitment***

MSL Parkes UHF Big Picture



Performed & Planned Tests

- Performed radiated and injected tone testing
  - Tested entire signal processing chain in post processing
  - Tones appeared at expected frequency
  - Radiated and injected tone power exhibit periodic fading, likely due to experimental setup since other "RFI" tones tracked did not show this fading
- Next tests:
  - MSL to GMRT test during two overflight opportunities
  - MSL,MRO : 2016-08-12T10:28:57, 9 minutes, CCSDS CH2
  - MSL,MRO : 2016-08-17T13:54:55, 10 minutes CCSDS CH2
  - TGO/EDM in flight test on 21 Sep.
  - Run real time test on tones to ensure no dropped data

GMRT Data Collection

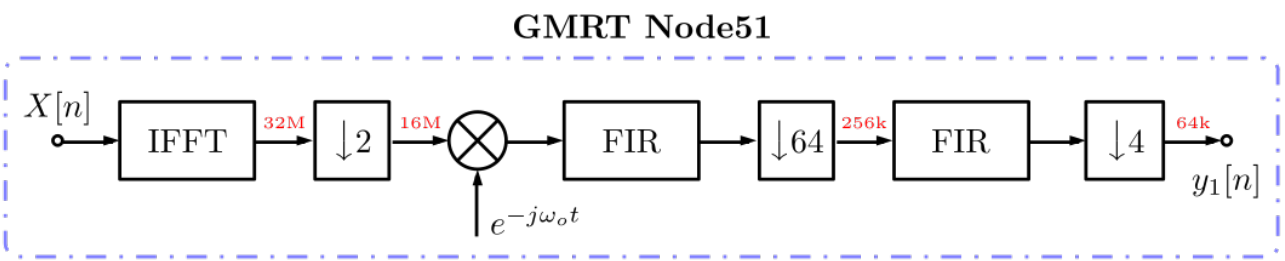
- During 15 December 2015, JPL visited GMRT
- Phased 16 antennas, pointed at Mars
- GMRT in PA Voltage mode
  - Records Phased Array raw voltage spectrum
  - Used GMRT's IFFT code to convert spectrum voltage to time domain voltage
- RF Center frequency: 401.5 MHz, Span: 6 MHz (+-3 MHz)
- All GMRT data shown below is from the 15 December 2015 test
- No actual Mars asset UHF signal recorded due to lack of opportunities (other side of Mars) during limited test time

GMRT Digital Signal Processing

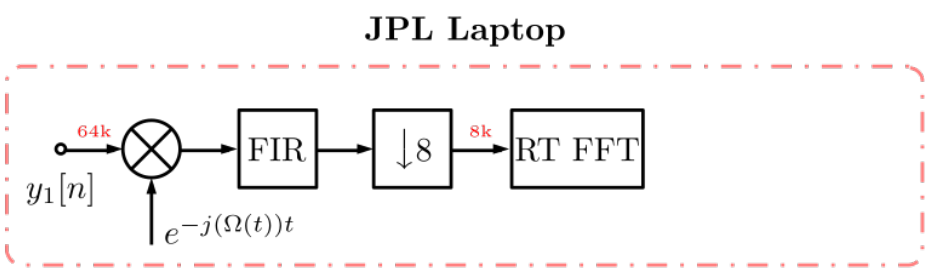
Signal Processing Implemented for EDL support:

- IFFT (GMRT-provided) to convert voltage spectrum to voltage time-domain data.
- Various stages of Mixers, Filters, Decimation to reduce resolution bandwidth to ~1 Hz for weak signal detection.
- Software to apply predicted Doppler corrections
- Real Time FFT/Waterfall software to create spectrogram

GMRT PA Voltage Spectrum



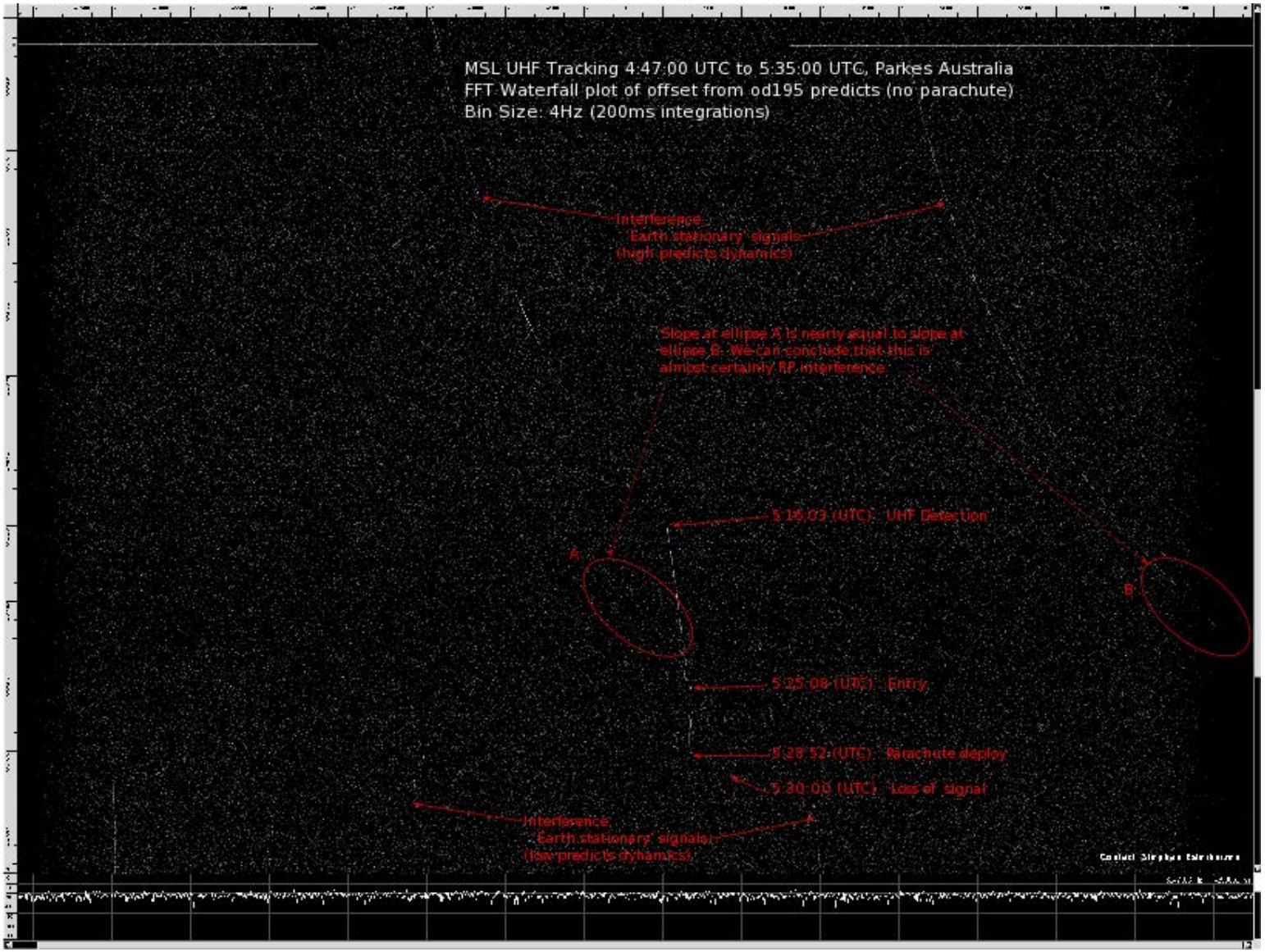
64 kHz bandwidth data to JPL laptop



Doppler Correction

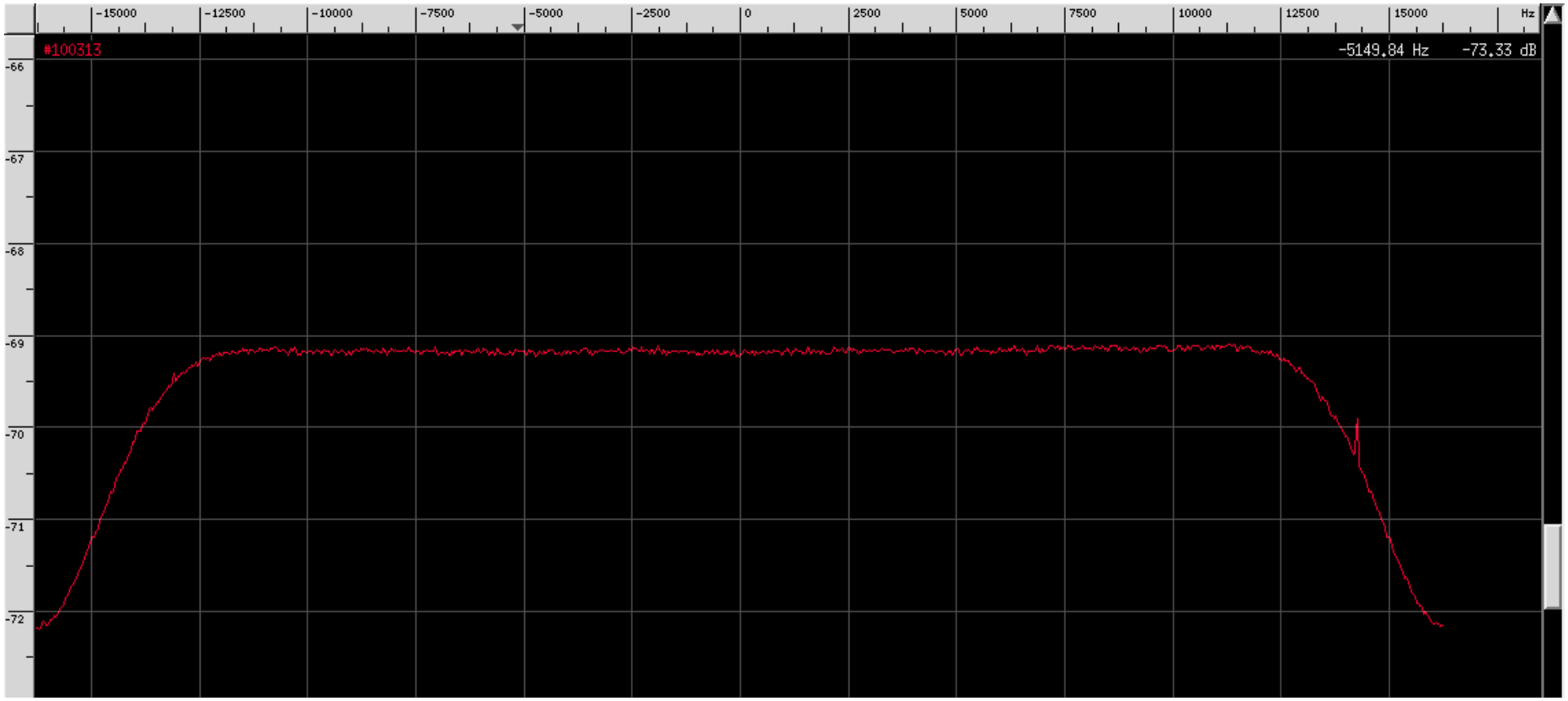
JPL laptop applies doppler correction and computes real time FFT and Spectrogram with ~1 Hz Resolution BW

Spectrogram from MSL EDL at Parkes (8/5/2012)



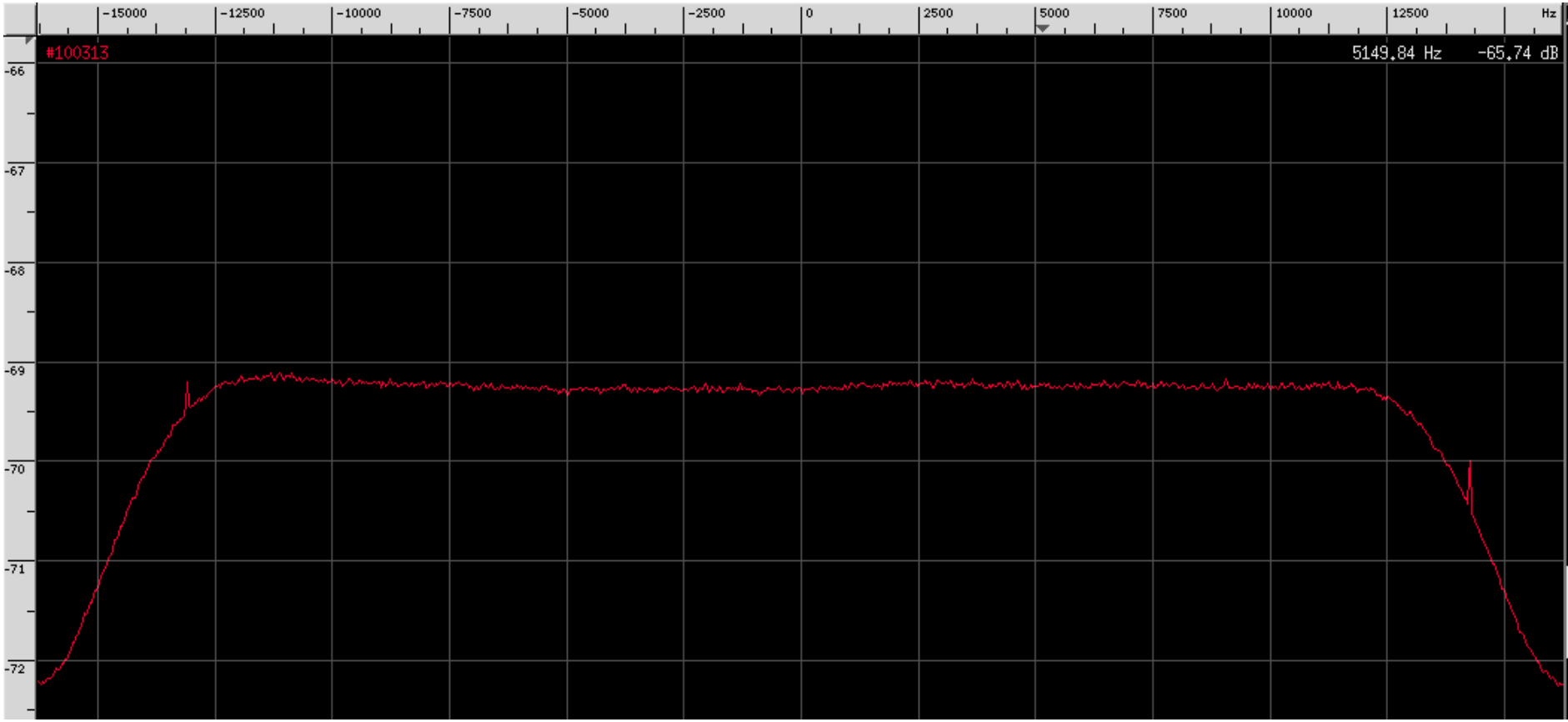
GMRT RFI (Pol: RCP)

Center: 401.585625 MHz
Span: 32 kHz
RBW: 16 Hz

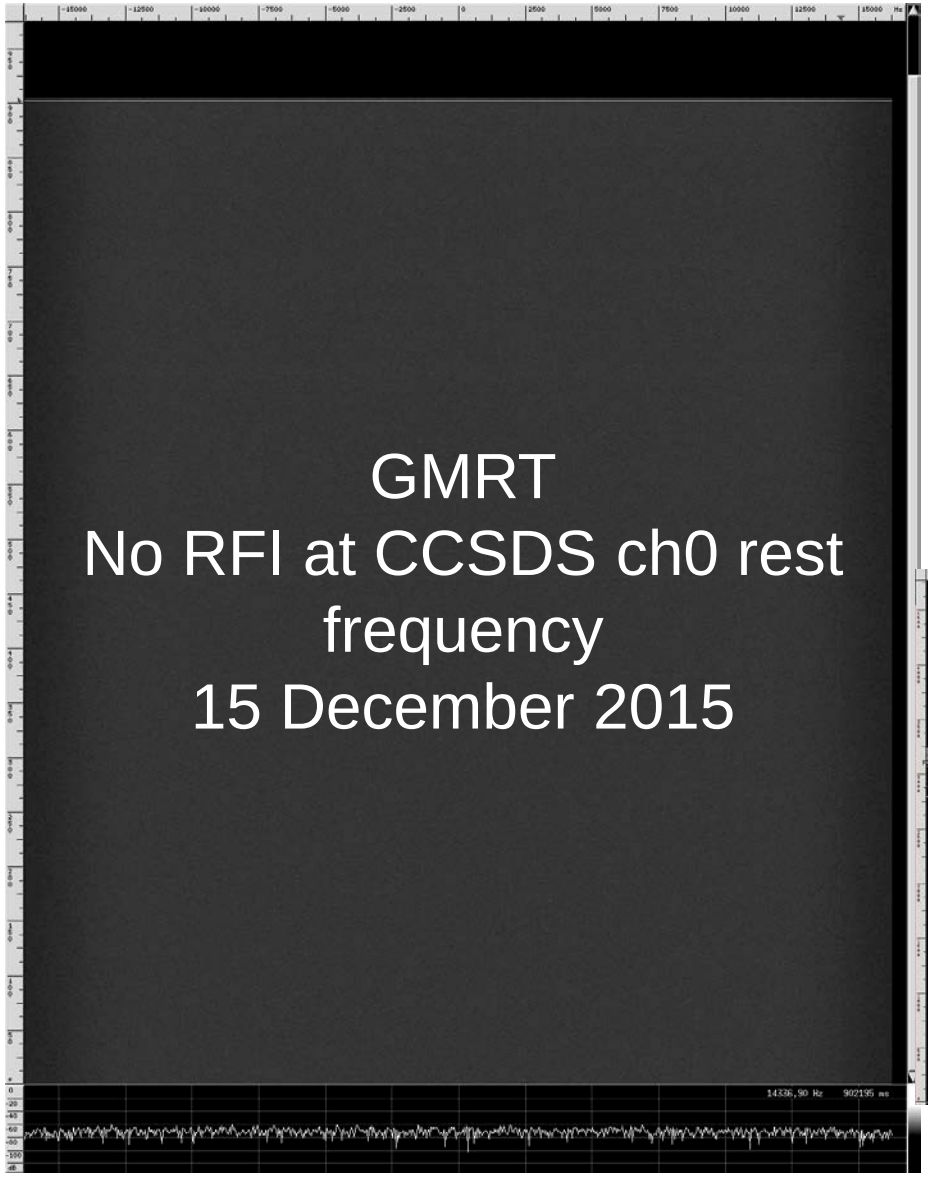


GMRT RFI (Pol: LCP)

Center: 401.585625 MHz
Span: 32 kHz
RBW: 16 Hz



GMRT Spectrum vs. Time



Center: 401.585625 MHz
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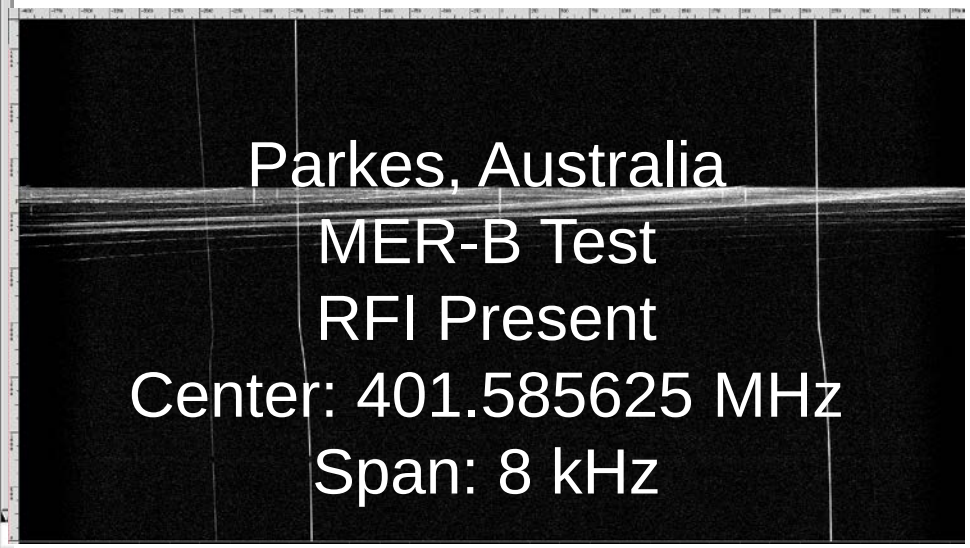
Parkes Radio Telescope



Conclusions

- JPL software work complete
- Signal processing is ready for EDL
- Still need to perform real time tests at GMRT
  1. Inject tones to ensure processing chain works in real time
  2. Observe MSL or MER-B UHF transmissions at GMRT
- The GMRT RFI plots showed clean spectrum at the UHF transmitter rest frequency. We should get an estimate of expected Doppler shift of ExoMars EDL Demonstrator and examine this frequency band for RFI.
- GMRT management and staff extremely cooperative and hospitable, which is much appreciated.

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