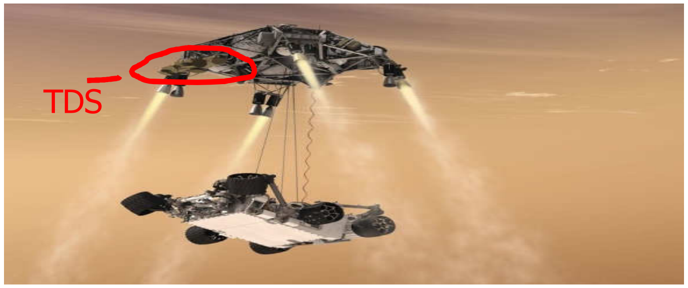
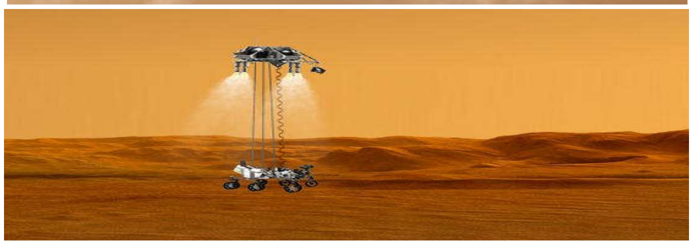
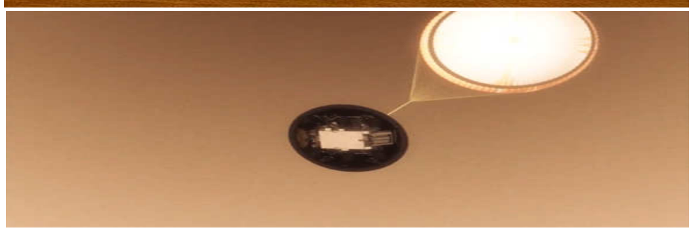
IEEE MEETING NOTICE **Buenaventura MTT-S Chapter**







Date and Time: Thursday, June 16th, 2016 (6:30PM)

Location : Skyworks (Conference Room), 649 Lawrence Drive, Newbury Park, CA 91320

Agenda: 6:30PM Reception & Networking;
7PM Presentation

M2020/MSL: TDS (Terminal Descent Sensor) DEA (Digital Electronics Assembly)”

Presenter : Dr. Mohammad Ashtijou
JPL/California Institute of Technology

Abstract : TDS is the radar used in MSL mission to land Curiosity rover on Mars. TDS will be used again in M2020 mission. DEA is the brain of the TDS where it serves as the controller and digital signal processor. The DEA commands TDS to cycle through the antenna beams making measurements using one of the 6 antenna beams at a time. DEA uses beam sequences and parameter tables to generate measurements. The most important measurements are velocity and range that are used to guide the landing of Curiosity rover. DEA performs these measurement tasks using radar signal processing FPGA firmware and radar microprocessor ‘s hardware and software.

Bio: : Mohammad Ashtijou is a seasoned Electronics Engineer at Jet Propulsion Laboratory. His interest is on novel radars and electronics systems that enable NASA/JPL to access new places in space , unfold new knowledge about space and earth, and to pave the road for travel to beyond solar system. He received B.S.E.E. from Clemson University, M.S. and Ph.D. degrees in Electrical Engineering from University of Alabama.

M2020/MSL TDS (Terminal Descent Sensor) DEA (Digital Electronics Assembly)

Presenter: Mohammad Ashtijou

Note: All the information in this presentation are gathered from public web sites and/or JPL documents and tried to modify to the extent to make them generic if not already generic. The intent of this power point is to present generic concepts about DEA in a lunch time radar section forum. This is not for publication.

The Authors of the JPL documents were:

Andy Berkun, Elain Chapin, DJ Byrne, Bryan Pollard, Curtis Chen, and Igor Kuperman

See You Tube: NASA Mars Science Laboratory (Curiosity Rover) Mission Animation

Outline

- **Introduction: Get to know TDS**
- **DEA Overview**
- **DEA SPARC Processor and Software**
- **DEA Functions**
  - **Velocity and Range Measurement Algorithm**
  - **Telemetry Generation**
  - **Commands**
- **Tests**
- **Summary**

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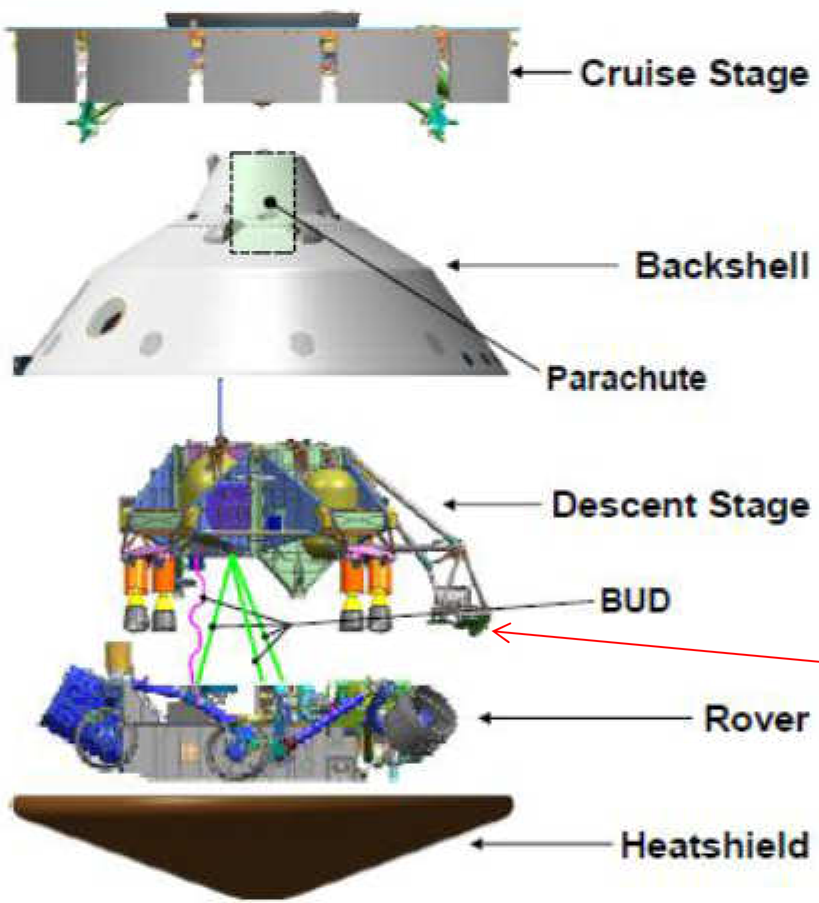
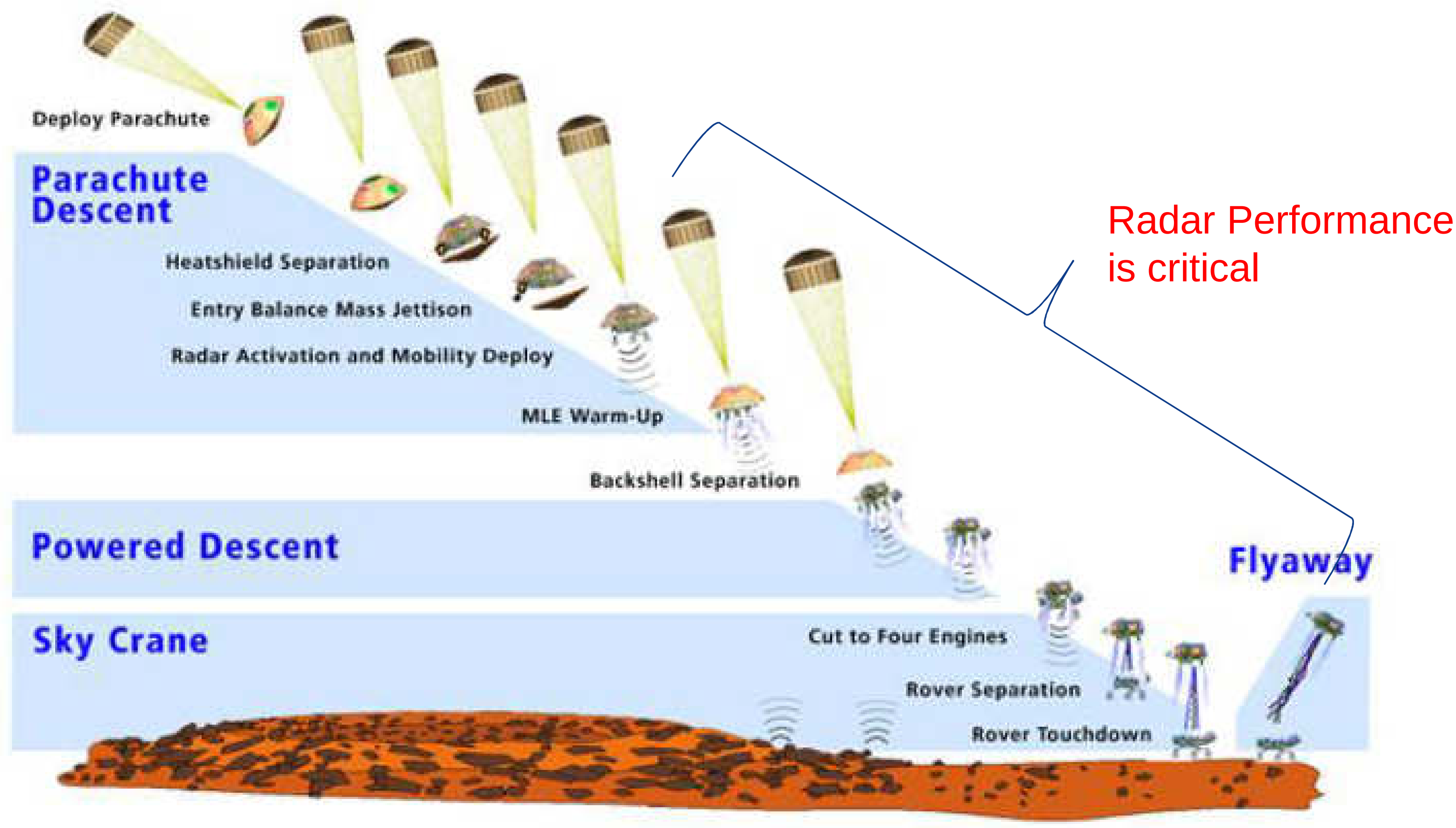
MSL Spacecraft Components



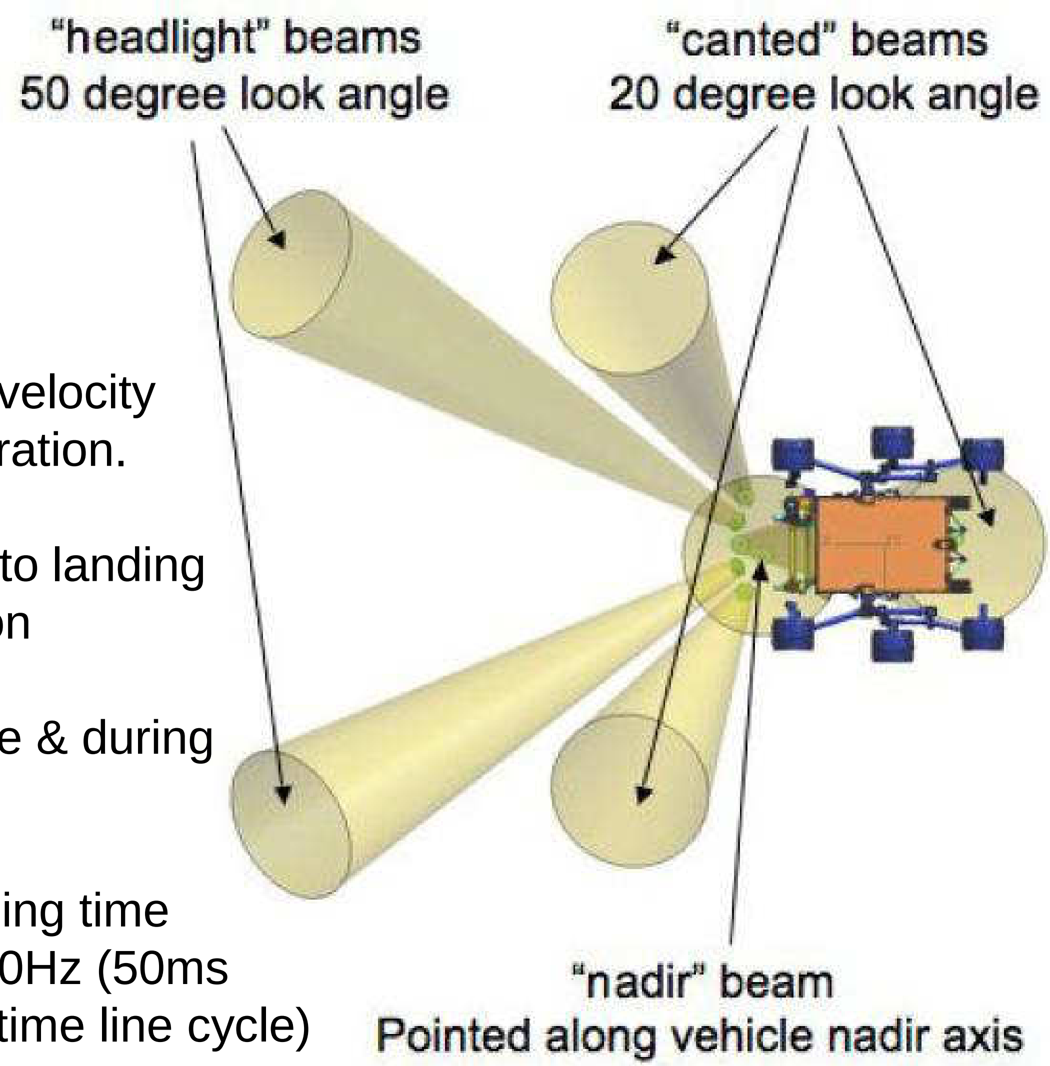
Entry Descent & Landing (EDL)

Entry Descent & Landing (EDL)



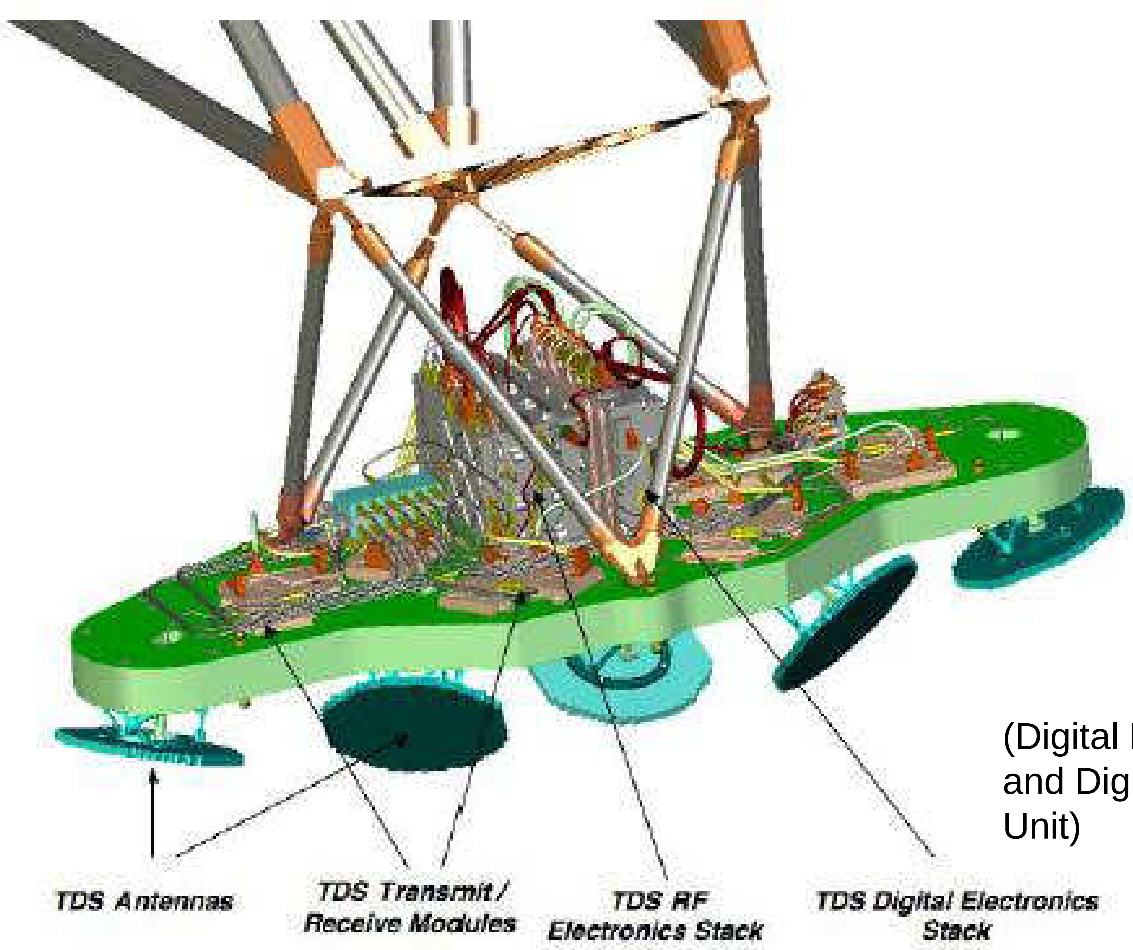
Radar Beams

- Headlight beams are critical for velocity measurements after rover separation.
- Nadir beam measures distance to landing site during constant deceleration
- All beams used during parachute & during most of descent
- Radar makes measurements using time multiplexed beams at a rate of 20Hz (50ms Per beam or per measurement time line cycle)



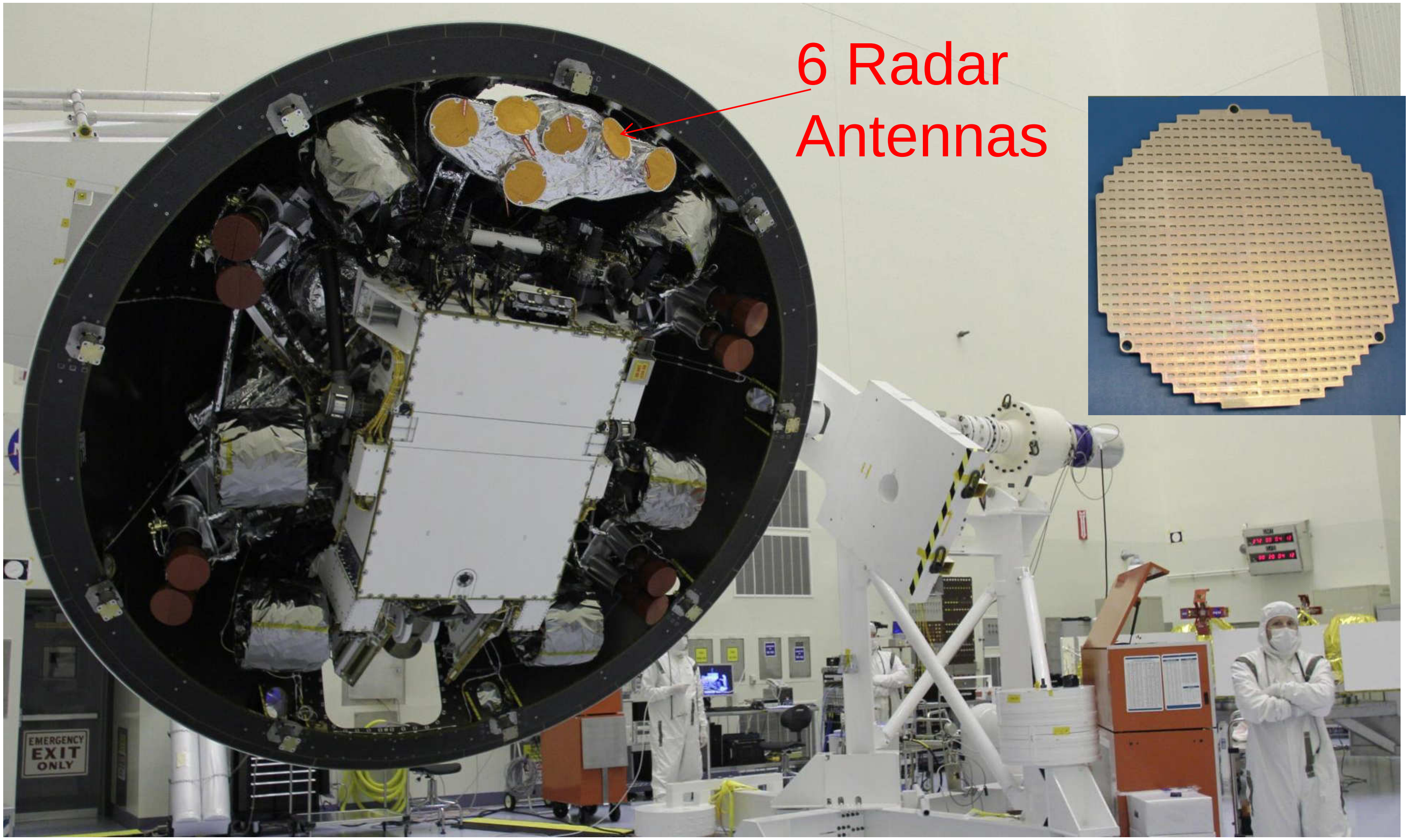
TDS (Terminal Descent Sensor) Radar System Model

20.8” by 52”



(Digital Electronics Assembly and Digital Power Distribution Unit)

Descent Stage without Heat Shield



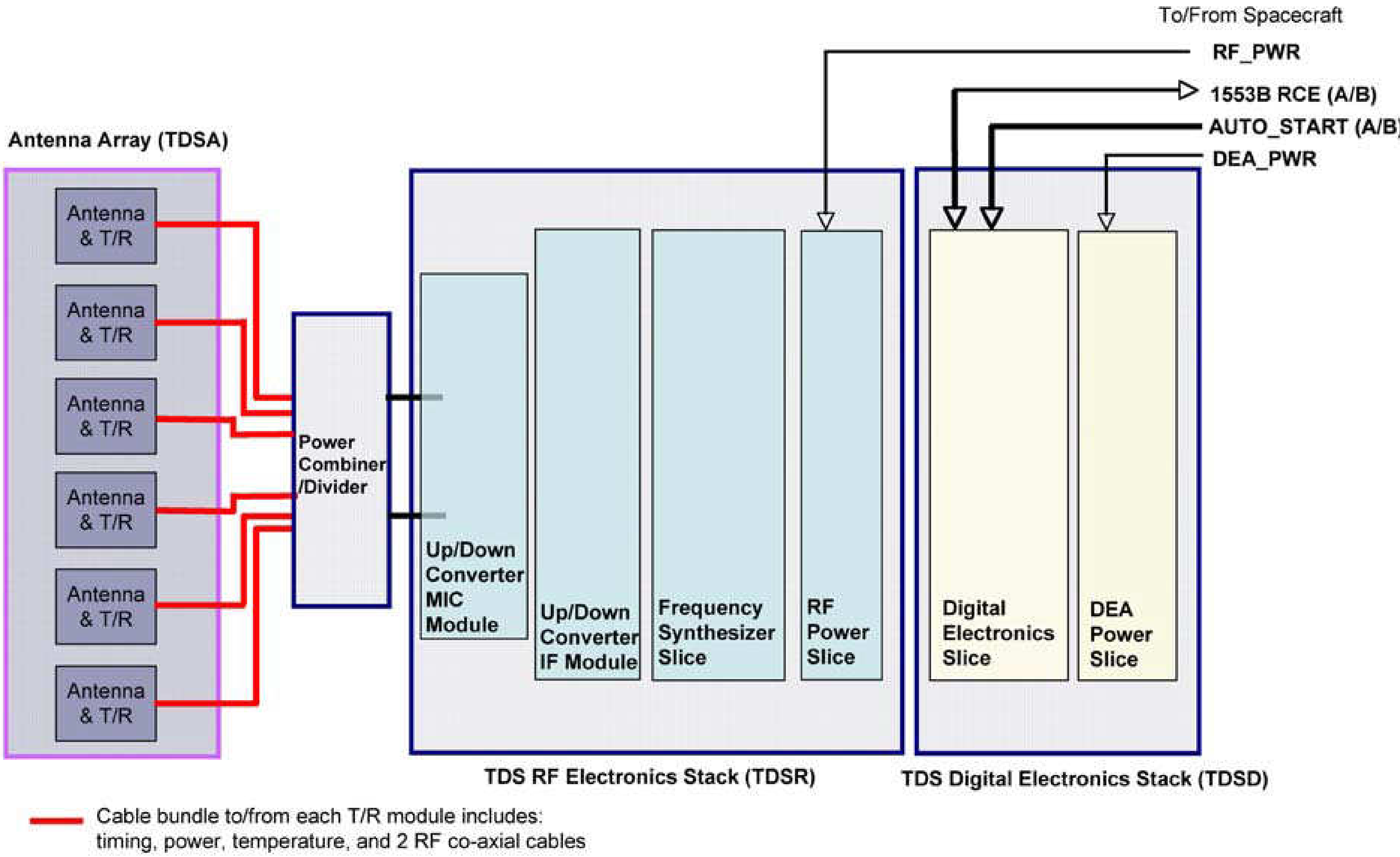
TDS a Pulse-Doppler Rader

- The TDS is a multiple-beam Ka-band pulse-Doppler radar designed to measure the 3-axis velocity and altitude of the MSL spacecraft from about 100 m/s and 4 km altitude to rover touchdown. The radar provides velocity and range for each radar beam to the spacecraft's navigation system, which computes the 3-axis velocity and altitude of the descent stage.
- Beam LOS Range by Time of Flight of Pulse
- Doppler Shift Estimated by Phase Shift Between Successive Echos
- TDS Allows Adaptive Selection of Parameters with no Knowledge of Previously Acquired Data and No Sharing of Information Between Beams
  - Pulse width
  - Pulse repetition interval
  - Pulse pair separation
  - Measurement sensitivity

Key Radar Parameters

Parameter	Value
Number of Beams / Antennas	6
Center Frequency	35.75 GHz
Wavelength	8.39 mm
Antenna Diameter (per beam)	220 mm
Peak Radiated Power (per beam)	2 W
Measurement Update Rate	20 Hz
Range of Pulse Widths	4 – 16000 ns
Range of Pulse Repetition Intervals	75-250 us

TDS High Level Block Diagram



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Simplified DEA Block Diagram

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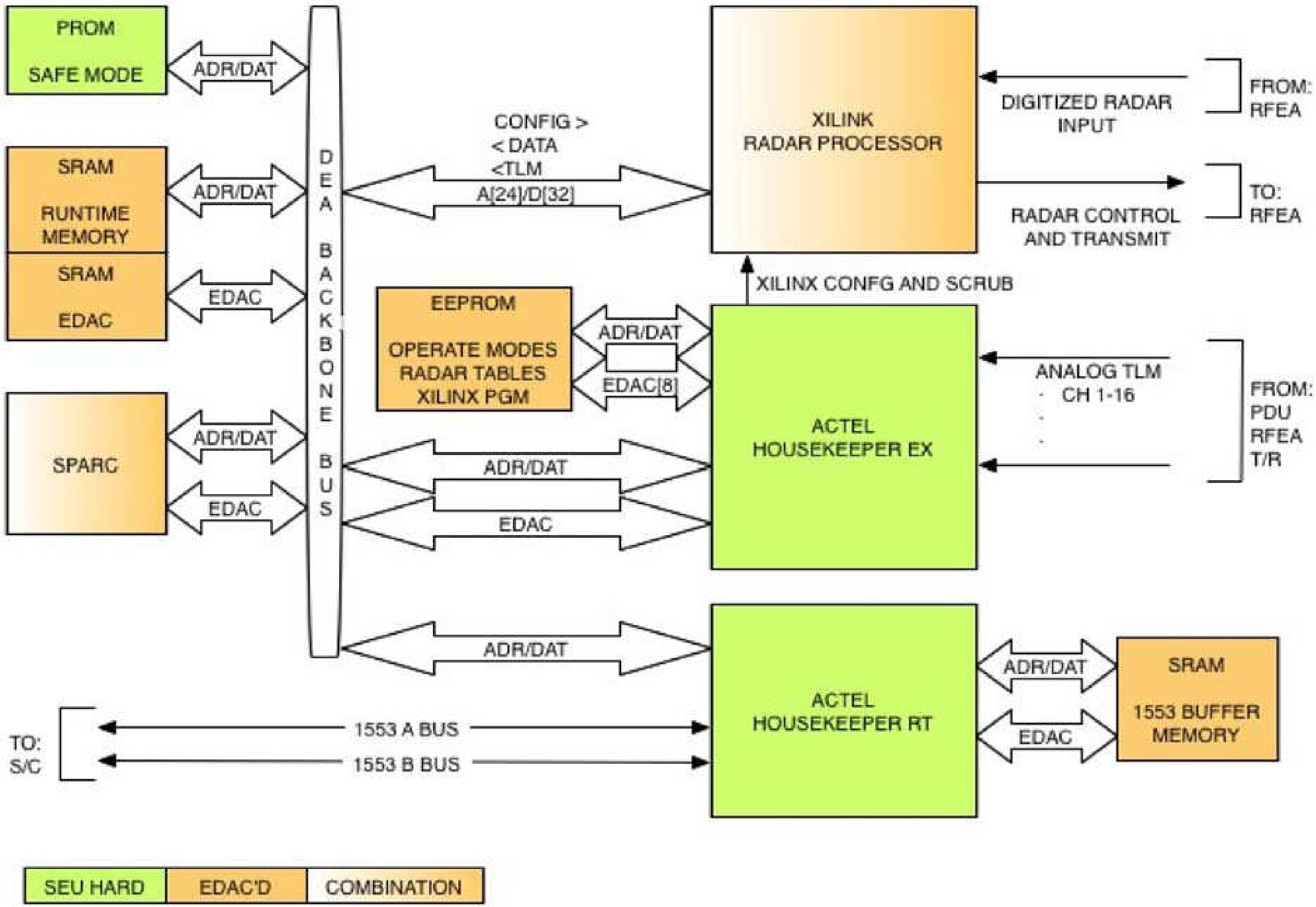

DEA Functional Blocks

- The DEA serves as the controller and digital signal processor.
- The DEA consists of a 1553 transceiver chip supporting 1553B link for command and telemetry transfers and a large reprogrammable FPGA referred to as the radar processor (RP) for generating timing signals for the TDS and handling all the digital signal processing of radar data.
- An 8-bit analog-to-digital converter is utilized to digitize radar video signal with a bandwidth as high as 500 MHz and center frequency of 250Mhz.
- A radiation-hardened Sparc based microcontroller serves as the radar controller (RC) where it handles spacecraft commands, time tagging, packaging of telemetry messages, etc.

DEA Functional Blocks

- The Radar Processor (RP) design implementation is a pulse Doppler based Radar. As opposed to the RC, the function of the RP is to be the signal processing “co-processor”, with limited signal processing functions that are performed as directed through registers accessed from the RC.

- The RP is the direct interface to the RFEA through the receiver analog input. The RP receives an echo signal from the RF UDCM, digitizes it, performs filtering, decimation, calculates range and velocity sub-products for use by the RC. The RP is also responsible for collection of time tags for this information.

DEA Functional Blocks

- The Housekeeper (HK-RT and HK-EX) is a virtual controller with the responsibility to maintain some low-level fundamental functions of the DEA. The Housekeeper is responsible for functions including time keeping, clock generation and distribution for all DEA components, monitoring of analog health indicators, and monitor and scrub of upset errors in the RP. The Housekeeper will in normal operation allow the RC to control of such things as readout of analog health data, and permission to scrub RP memory.
- The primary functions of the Housekeeper include (but are not limited to):

(1) Timing

a. Capture of spacecraft time word upon clock valid signal received

b. Transfer of time word to RP upon strobe

c. Generation of all clocks required by DEA components

(2) Analog monitoring

a. Monitoring of DEA and TDS analog parameters.

(3) Xilinx Configuration

a. Both program and scrub modes

(4) 1553 RT

a. Perform all the functions of the 1553 RT

b. Maintain external memory for 1553 message buffers

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DEA SPARC Processor (RC)and Software

(1) Provide the host spacecraft interface software via 1553 link:

- a. Accept and process commands from the host spacecraft HK-RT MIL-STD-1553B interface
- b. Monitor Radar health and status and report back to host spacecraft
- c. Provide for clock synchronization on command through the 1553 interface

(2) Perform detailed control of TDS modes and operation

- a. Radar Parameter configuration file
- a. Provide interface to control and status data of the RP
- b. Provide control (through HK) for actively operating DEA components

(3) Produce radar measurement packet

- a. Program RP’s control memory and/or registers
- b. Read and perform unit conversions on RP’s status and measurement data
- c. Secondary Processing (e.g., range and velocity final products and uncertainty flags)
- d. Deliver radar measurement packets back to host spacecraft via 1553 interface

- The RC will accomplish these functions through direct, register-driven control of the Housekeeper and RP FPGA functions. The RC software will have sole responsibility for managing the central bus of the DEA, there will be no shared or DMA access modes.

DEA SPARC Processor and Software Continued

- Other than the basic boot code, the RC will be completely reprogrammable, with the code able to be modified at any time, including after launch. The primary restriction on this reprogrammability will be the EEPROM (non-volatile memory) used. This memory will typically have a limited number of write cycles.
- EEPROM holds images of RCSW, RP FPGA, and configuration files.
- The RCSW inherits significant portions of its architecture, design, and source code from the ElectraLite software (MSL software defined radio), which in turn inherits from the MRO Electra software. The flight software is coded primarily in ANSI C, with some targeted assembly code.

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DEA Most Important Operations

- The DEA is the brain of the TDS where it serves as the controller and digital signal processor.
- The DEA commands TDS to cycle through the antenna beams making measurements using one of the 6 antenna beams at a time.
- The beam measurements are made at 20Hz (50 ms intervals).
- A limited number of beam sequences are pre-stored in the DEA EEPROM memory and can be recalled by using a beam sequence table ID command.
- Eight radar mode configuration block set exist in EEPROM memory: three of them are for radar normal operation and each mode configuration block includes a parameter table. The parameter table consists of max 15 radar parameter sets: S0, S1, S2, …... S14.
- DEA uses beam sequences and parameter tables to generate measurements: the beam velocity, range, measurement validity, time tag, and other related information are packaged into a 64-byte radar measurement packet for the spacecraft computer to pick up via the 1553 bus at up to 64 Hz. DEA performs this measurement task using Radar Signal Processing FPGA firmware called RP and Radar Microprocessor software.

Radar Controller Software (RCSW) Modes

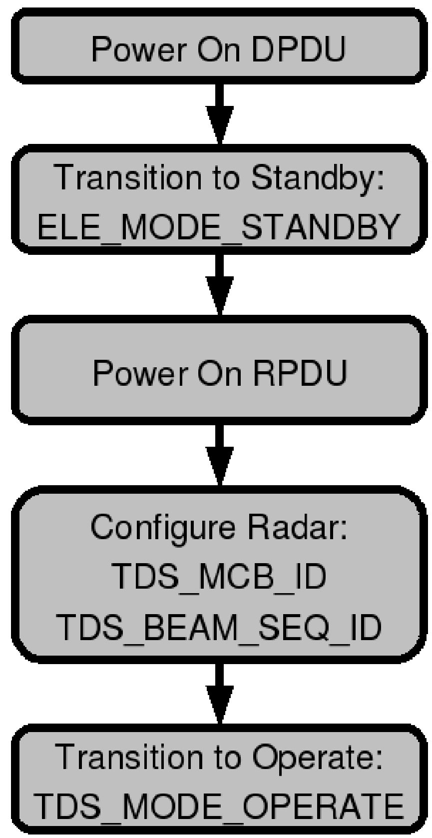
The core activities performed in each of the powered-on RCSW modes are:

- Safe: Troubleshoot the DEA, RCSW, and RP.
- Standby:
  - Safely power on or off the RFEA.
  - Configure radar to collect data.
  - Configure RCSW and RP.
- Operate:
  - Collect range and velocity data.
  - All radar modes happen in this software mode

Radar Power up to Software Operate Mode

- During software operate mode TDS functions as Radar where it measures range and velocity

Nominal Power Up



Power State	RCSW Mode	Transmitting?
Off	Off	No
Low	Safe	No
Low	Standby	No
Quiescent	Standby	No
Full	Operate	Yes

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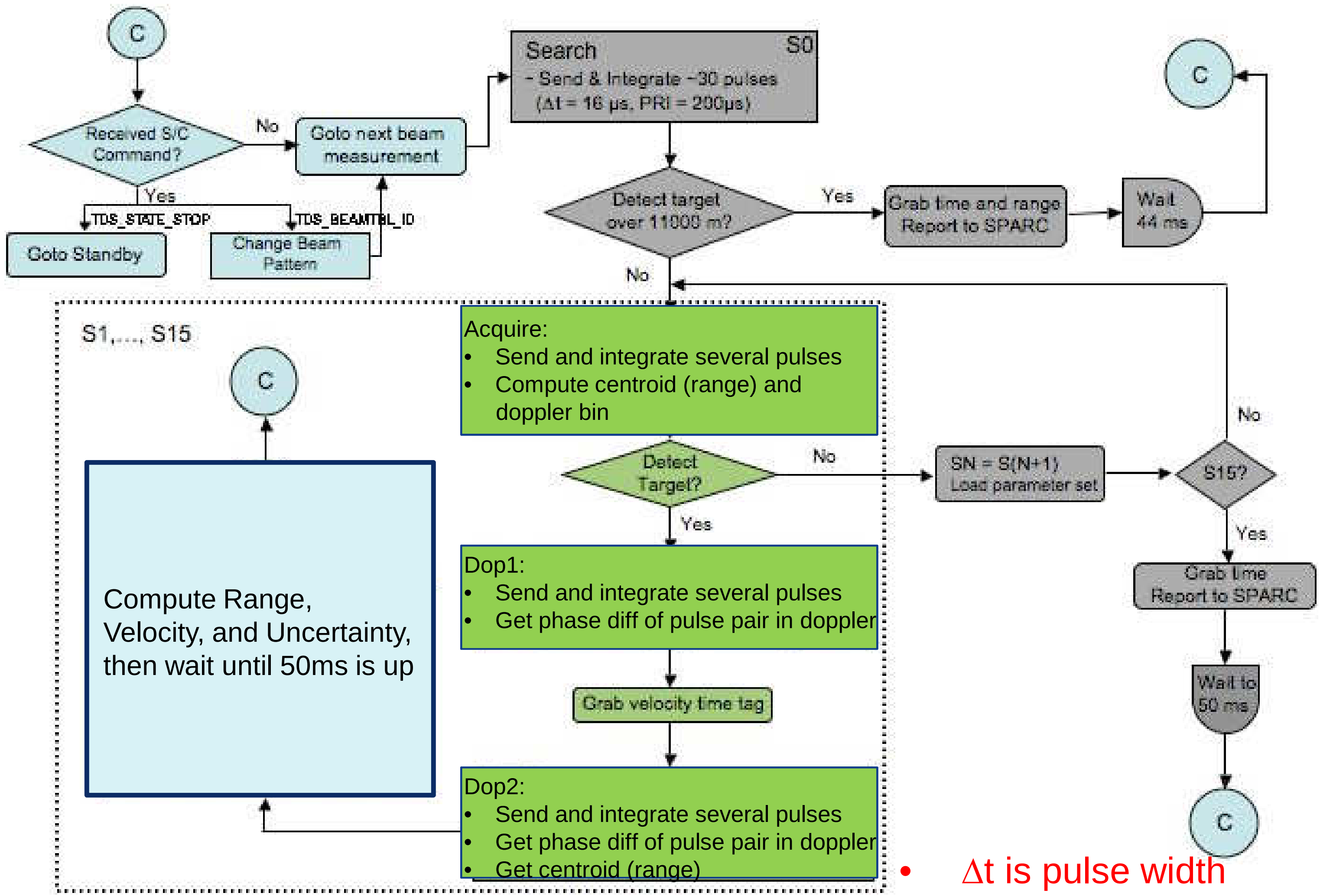
An Example TDS Radar Nominal Mode of Operation



- Δt is pulse width
- PRI is pulse repetition interval

An Example Beam Measurement Time Line

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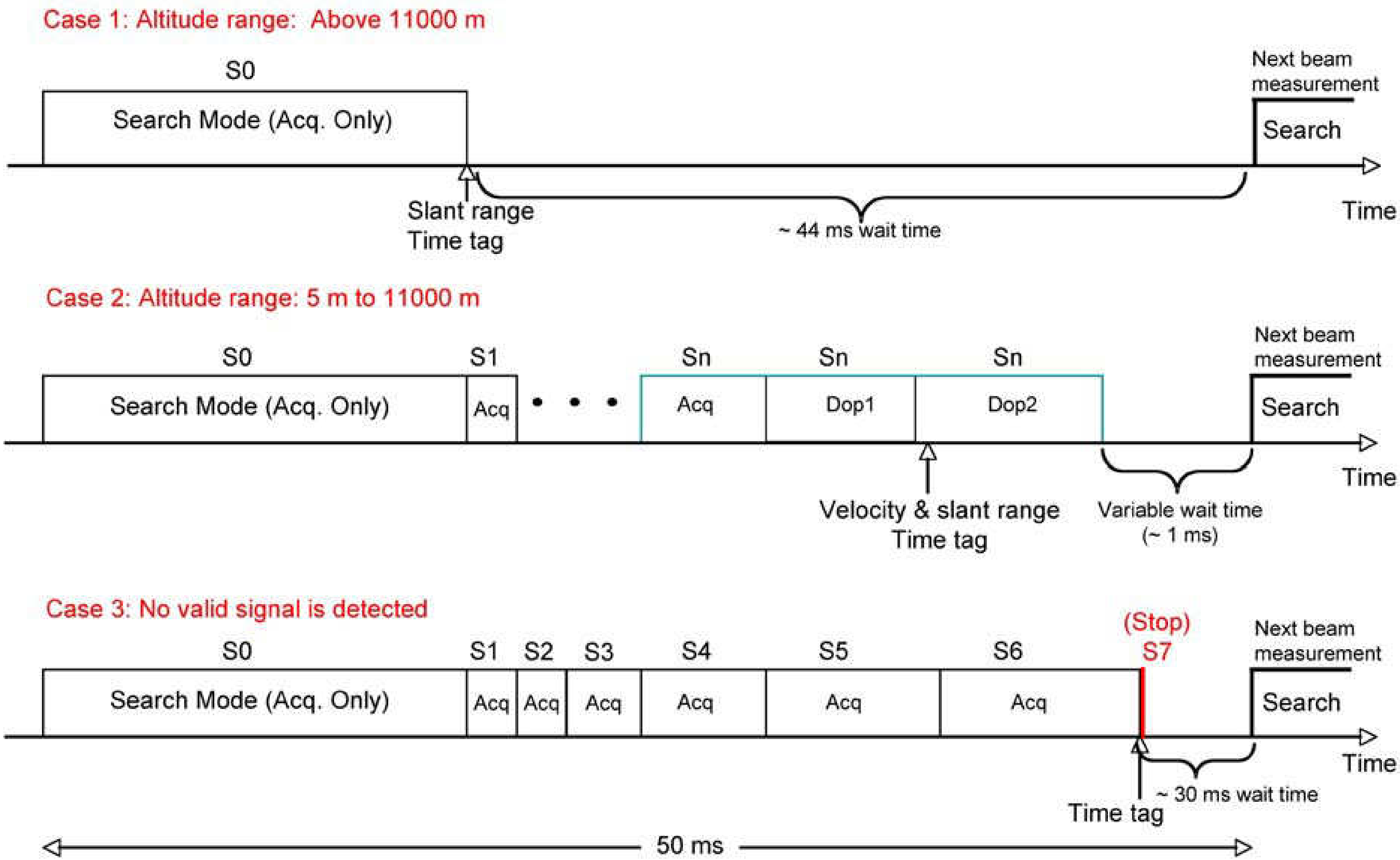

Overview of Radar Processor (RP) FPGA Algorithm

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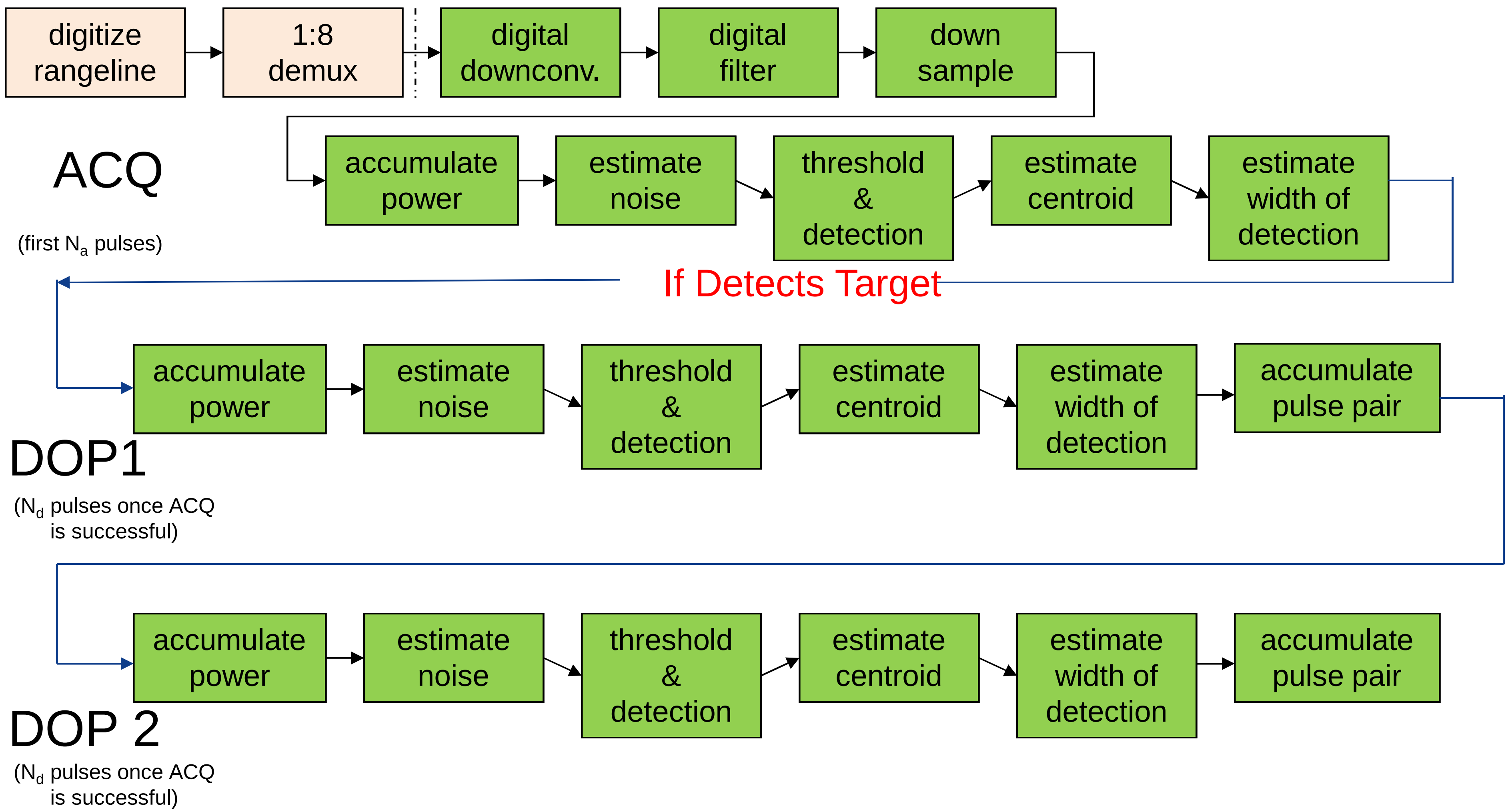
Mars 2020 Project



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DEA Telemetry Generation

- Heartbeat telemetry provides status of the TDS HW and SW and is generated at rate of 1Hz (once per second) in all software modes.
- Radar measurement packet provides beam measurements (range, velocity, time tag, etc..) at rate 20Hz only in SW operate mode.
- Diagnostic telemetry packet are generated at rate of 20Hz during SW operate mode. This telemetry packet provides additional insight about radar measurements for development and debugging.
- Command response and analysis packet provides feedback to S/C about the type of command that radar received . It is used during software and hardware development and interfacing to S/C flight system. It is available as soon as TDS is powered.

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DEA Conceptual Commands

- Mode: sets the operating mode of the radar to safe, stand by or operate
- Load: loads or copies a number of bytes to a set of memory locations
- SW Parameters: sets or reads various software parameters for software operation
- Time_S/C: informs or sets SW of S/C time, or it could get Radar time for S/C
- Peek: Reads a memory address provided
- Poke: Writes a value in a memory address
- Heartbeat: Gets health status telemetry
- Test: Diagnostic commands used for testing and troubleshooting
- TDS_OPS_PARA: Selects which beam sequence to be loaded into RP, or it could also select which mode configuration block (a set of S0….S14 parameters) gets to be loaded into RP.
  - TDS_BEAM_SEQ_ID
  - TDS_MCB_ID

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Tests

- Interface
- Functional
- Performance
- Characterization
- Calibration
- Software
- Fault tolerance
- RF timing
- Telemetry
- BIT and Diagnostic
- Thermal and Vibration

Summary

- Successful performance testing of DEA in ambient, thermal and vib is critical for M2020 project
- It will require technically a strong team to perform diligent testing
- DEA got Curiosity to MARS once under MSL project
- It is expected that DEA will again perform well under M2020 project