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Bench Checkout Equipment for Spaceborne Laser Altimeter Systems

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LIST OF FIGURES

ACRONYM LIST

A/D	Analog to Digital
ATU	Alitmetry Test Unit
BCE	Bench Checkout Equipment
CCD	Charge Coupled Device
D/A	Digital to Analog
DSA	Digital Signal Analyzer
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
GPS	Ground Power Supply
GSFC	Goddard Space Flight Center
JPL	Jet Propulsion Laboratory
LDU	Laser Diagnostics Unit
LEC	Laser External Cooler
LED	Light Emitting Diode
MB	Mega Byte
MO	Mars Observer
MOLA	Mars Observer Laser Altimeter
MOSCS	Mars Observer Spacecraft Checkout Station
MSB	Most Significant Bit
NASA	National Aeronautics and Space Administration
OTS	Optical Test Source
PC	Personal Computer
PDS	Payload Data Sub-systems
RX	Receive
S/C	Spacecraft
SCS	Spacecraft Checkout Station
Si-APD	Silicon Avalanche photo-diode
TBD	To Be Determined
TBS	To Be Specified
TIU	Time Interval Unit
T/V	Thermal Vacuum
TX	Transmit

INTRODUCTION

This paper addresses the requirements for testing and characterizing spaceborne laser altimeter systems. The Bench Checkout Equipment (BCE) system, test requirements and flow-down traceability from the instrument system's functional requirements will also be presented. Mars Observer Laser Altimeter (MOLA) and the MOLA BCE are presented here as representative of a 'typical' laser altimeter and its corresponding test system. The testing requirements of other or future laser altimeter systems may vary slightly due to the specific spacecraft interface and project requirements.

MOLA, the first solid-state interplanetary laser altimeter, was designed to be operational in Mars orbit for two Earth years (687 days). MOLA transmits a 7.5 ns pulse at a wavelength of 1.064 μm with a 0.25 mr beam divergence and a pulse repetition rate of 10 Hz. The output energy is specified at 45 mj at the beginning of mapping orbit and 30 mj at the end of one Martian year (687 Earth days). MOLA will measure the laser pulse transit time from the spacecraft to the Mars surface and return to a resolution of 1.5 meters.

BCE FUNCTIONAL REQUIREMENTS

Functional requirements of an instrument and the associated performance specifications are generated to accomplish specific scientific requirements of a project. The science team or principal investigator work closely with the system engineer to develop instrument functional requirements that will collect the necessary data to address the science requirement. These functional requirements are usually a compromise between the best instrument that can be built and what is minimally acceptable to obtain the required science data.

Typical functional requirements for a laser altimeter will address range resolution, laser energy, pointing accuracy, etc.. Verifying that an instrument meets these functional requirements becomes the Bench Checkout System (BCE) system functional requirements.

"A set of bench checkout equipment (BCE) is identified as that hardware equipment and software, if applicable, necessary for performing a complete functional checkout of a flight instrument. The BCE must be capable of simulating all functional spacecraft electrical interfaces, exercising all normal instrument operating modes, and providing a hard copy record of instrument output data in a form suitable for determining whether or not the instrument is performing consistent with the environment in which it may be operating. The BCE also includes all cables and instrument stimuli necessary for performing these functions.

The BCE will interface with the instrument primarily through those electrical connectors that normally interface with the spacecraft. The BCE may, in addition, interface with special test-access connectors located on the instrument.

The BCE also consist of stimuli (if applicable), stimuli controls, and whatever equipment is necessary for monitoring essential internal instrument functions that cannot be monitored via spacecraft telemetry when mounted on the spacecraft. The BCE also consist of all cables between the instrument and/or stimuli and the system test complex. When on the spacecraft, the BCE may interface with the instrument directly only through special test-access connectors located on the instrument."[1]

In addition, the BCE should be capable of " ... isolating equipment (instrument) faults or malfunctions to an assembly level. Monitor and evaluate equipment performance during spacecraft systems tests."[2] The BCE should also continuously monitor Health and Welfare of the instrument during spacecraft level testing via instrument telemetry data provided by the Spacecraft Checkout Station (SCS).

Given the above project specific formal definition of the BCE , the following is a grouping of the BCE functional requirement categories. These should be addressed individually with regard to thoroughness and required complexity as separate requirements at the onset of the BCE design. These tasks must be weighed against practical considerations such as instrument schedule, budgets, and required project and spacecraft interfaces. Above all, the agreed upon BCE design and performance specifications must be consistent with the requirement to validate the instrument system functional requirements.

1) Validate the Instrument System Functional Requirements - This is the primary reason for instrument system level testing and therefore is the primary BCE system requirement.

2) Perform Instrument calibration and/or performance characterization - The level of precision and accuracy required of the BCE System performance will dictate the overall system cost and complexity.

3) Provide system interfaces during all phases of testing (EMI/EMC, T/V, S/C integration., etc.) - This mostly involves cabling, connectors and logistics of the BCE system. Particular attention must be given to interfacing with the EMI/EMC and thermal vacuum test facilities. These facilities often have very specific and unique requirements, but these interfaces are usually straight forward and can be well defined in advance.

4) Monitor instrument sub-system performance - In a situation when instrument performance severely degrades during system level testing it is extremely useful to know exactly which sub-system is malfunctioning. This knowledge will be crucial in determining the strategy for any corrective engineering efforts.

[1]Mars Observer Payload Policies and Requirements Document, JPL 642-40, Appendix C, pp. C-1
[2]Mars Observer Spacecraft General Interface Specification Document, JPL 642-SE-001, Section 4.1.a.1,2, & 3

Instrument (MOLA) Functional Requirements and BCE Testing Requirements flow-down:

The following is a representative list of how the MOLA Functional Requirements flowed-down to form the BCE Functional Requirements (i.e. Testing Requirement traceability).

I. Instrument Functional Requirement:

Maintain a laser non-operating lifetime of two years and a operational lifetime of three years. The three years operational lifetime is allocated to two years Mars orbit operation plus pre-launch testing.

Testing Requirement: Monitor the MOLA laser output energy with an integration sphere and energy meter combination. Monitor MOLA packet data and recover the Laser Start-Detector readings. Average these readings over TBD shot intervals. Record and monitor laser transmit energy to establish an output energy trend to validate an "expectation" of >30 mj laser output at end of Mars mission. In order to track total accumulated laser shots, a Laser Shot Record Book will be maintained to record all laser "on" times. To help manage and conserve laser life, each test will have a specific run-time allocation .

II. Instrument Functional Requirement:

Maintain an approximate 100 meter Mars surface laser illuminated footprint.

Testing Requirement: Monitor the far-field energy pattern of the laser output beam with a CCD camera system. Record the laser beam divergence, and energy uniformity (peak-to-average). These data and statistical readings will be taken as required.

III. Instrument Functional Requirement:

Maintain a laser firing rate of 9.9999 Hz in order to achieve a greater than 30% along-track coverage; assume nominal spacecraft orbit altitude of 380 km and orbital velocity of 3.3 km/sec..

Testing Requirement: Monitor MOLA packet data to correlate the spacecraft time and the laser fire offset interval timer with the 140 shots per packet constant rate (9.9999 Hz) to identify long or short term drifts between the expected offset constants. This data will be averaged over the total time for any given test length. Monitor the oscillator temperature data within the MOLA packet to correlate timing changes due to temperature.

IV. Instrument Functional Requirement:

Acquire range timing measurements with 10 ns resolution (1.5 m).

Testing Requirement: Provide simulated range delay pulse returns (1.064 μm) over the expected Mars orbital values corresponding to distances of 360-410 km. Provide range delay pulse returns to simulate various Mars topographic profiles. These simulated topographies will vary in range delays between suitable for evaluating the function of the time interval unit (TIU), TIU counter transition boundaries, range gate, and acquisition/tracking software.

V. Instrument Functional Requirement:

Employ four (4) receiver channel filters matched to 20 ns, 60 ns, 180 ns, and 540 ns pulse returns which correspond to Mars terrain variations of 3 to 80 meters over the laser footprint.

Testing Requirement: Utilize a light emitting diode (LED) source and programmable pulse generator to simulate variable laser pulse width and pulse amplitude return signals. Generate a sufficient number amplitude and pulse width combinations to verify proper four channel discrimination. These LED pulse inputs will also provide a data base necessary to address the time-walk correction factors for each channel at different background thresholds and return energy levels.

VI. Instrument Functional Requirement:

Measure laser transmit and received pulse amplitudes.

Testing Requirement: Utilize a fiber optic pick-off and integration sphere combination to monitor the MOLA laser output beam pulse width and energy values. The MOLA start detector value and the BCE data will be independent measurements for correlation of laser transmit energy. The BCE pulsed 1.06 um laser source will supply variable receiver pulse amplitudes that will encompass the Mars expected conditions. The MOLA packet data will be reviewed for proper receive energy readings and correlated with the energy monitor readings within the BCE data.

VII. Instrument Functional Requirement:

Provide a 90% orbit average ranging probability - Ch#1 and Ch#2 only. Provide 50% orbit average ranging probability for Ch#3 and 10% orbit average ranging probability for Ch#4. These probabilities are valid only during non-disturbing atmospheric conditions (no dust storms, etc.).

This functional requirement encompasses a variety of hardware and software design features which require testing. Listed below are the functions which will require specific verification

A. Bore-sight alignment - maximum deviation ±100 μr

Testing Requirement: Monitor the far-field energy pattern of the laser output beam with the BCE CCD camera. Record the laser energy centroid location (bore-sight alignment stability), centroid pointing jitter, divergence, and energy uniformity (peak-to-average). These data and statistical readings will be taken on shot averages as required. Also, the Ch#1 and #2 energy readings obtained during the "zero range delay" operation mode will also be compared with the Laser Start Detector energy reading contained in the MOLA packet data to help correlate alignment status.

The "absolute" laser-to-detector alignment verification will be performed with a set of adjustable Risley wedges and a retro-reflector corner-cube combination (BCE hardware).

B. 3 dB link margin at Mars orbit

Testing Requirement: Provide simulated expected Mars background day/night 1.06 μm power levels and associated return pulse energies using the BCE test hardware. The test hardware will provide expected Mars signal conditions (with margin). The MOLA laser , electronics box and detector assembly operating temperatures will be varied over the expected operational ranges to verify adequate link margin.

C. Maximization of detection probabilities

Testing requirement: Provide the instrument with simulated return stimulus necessary to verify proper discriminator threshold settings, range delays (360-410 km orbit altitude), range windows (+/- 10 km tracking) and validate the flight software acquisition/tracking algorithms.

Ranging profiles, background power and return pulse energies will be varied to simulate loss of signal and verify correct re-acquisition software algorithms. Also "within norm" terrain profiles, background power and expected return pulse energies will be tested to validate the normal tracking software algorithms.

MOLA Flight software algorithms and parameters will be modified via up-link commanding to verify software "patch" capabilities. Science and Maintenance Mode operations will be validated.

D. General Housekeeping Data

Testing Requirement: These data will normally be retrieved within the MOLA packet data during all MOLA "on" testing states and generally require no special testing requirements other than periodic monitoring. These data need only be verified for proper levels/contents for the given test conditions. All current, voltage and temperature monitors will be cataloged into an appropriate trend files establishing the "norms". This data will also be used to establish temperature correction factors for energy readings, time-walk corrections, timing drifts, internal optical test source (OTS) output levels, all D/A threshold levels, A/D conversions, detector responsivity, etc..

VIII. Instrument Functional Requirement:

Comply with Mars Observer Project Requirements

A. Spacecraft Interfaces - Software

Testing Requirements: The packet data will be reviewed to verify the packet format and validate proper MOLA Science and Maintenance Mode packet data contents. All MOLA commands will be sent and validated by reviewing the MOLA packet data (Science and Maintenance Modes) that the command has been properly executed. All MOLA packet status data will be validated against the expected values particular to the test conditions. All Spacecraft broadcast commands will be relayed to MOLA and packet reviewed to validate the required action or no-action was taken.

B. Spacecraft Interfaces - Electrical

Testing Requirements: The MOLA +28V power consumption will be measured to verify compliance with the power allocation as specified in the Interface Control Document (ICD). The MOLA +28V power bus transient and ripple content will be measured to verify compliance with the ICD.

C. Spacecraft Interfaces - Mechanical

Testing Requirements: The MOLA will be weighed to verify compliance with the mass allocation specified in the ICD. MOLA will also be measured to determine mass, center of gravity, and mass moment of inertia to verify compliance with the ICD.

D. Spacecraft Interfaces - Thermal

Testing Requirements: The MOLA instrument must be fully functional according to the S/C environment specified by the ICD. The MOLA cruise phase replacement and operational heaters along with the associated quad-redundant KLIXON thermostats will be tested during system level thermal testing.

TESTING OBJECTIVES

The MOLA Instrument System consist of several sub-systems. These sub-systems have certain performance specifications that need to be monitored and validated in order to ensure the instrument meets it functional requirements and in the case of the power sub-system, the spacecraft bus interface.

The following is the list in outline form of sub-systems for the MOLA instrument and the associated parameters requiring testing, validation, and characterization.

Altimetry Electronics:

I. Define acquisition and tracking performance
   A. under simulated Mars conditions
      1. wide test parameters to show performance margins past expected Mars day/night conditions
   B. limited test conditions
      1. parameters suited for collecting data to characterize corrections for range walk
      2. TX and RX pulse energy calibration

II. Define operational parameters
   A. acquisition
      1. probability of measurement
      2. probability of false alarm (miss)
   B. tracking
      1. tracking window sensitivity
   C. altimetry
      1. altimetry accuracy (timing)
      2. return pulse width discrimination
      3. time walk variations (pulse width and amplitude)
   D. reflectance measurement
      1. start/stop pulse energy readings (pulse width and amplitude)
      2. background noise counters

III. Temperature monitors - (packet data)

Computer:

I. Spacecraft commands
   A. command execution
      1. single word
      2. multi-word

II. Science and Maintenance mode commands (MOLA)
   A. command execution
      1. single word
      2. multi-word

III. Temperature monitors - (packet data)

IV. Current and Voltage monitors - (packet data)

Power Supply:

- I. MOLA power usage - +28V
  - A. turn on transient (250 kHz sampling)
  - B. total power
    - 1. steady state
      - a. science mode
      - b. maintenance mode
  - C. ripple spec
    - 1. steady state
      - a. science mode
      - b. maintenance mode
- II. Temperature monitors - (packet data)

Laser:

- I. Spatial characteristics
  - A. divergence
  - B. energy uniformity
  - C. shot-to-shot jitter (pointing)
- II. Pulse parameters
  - A. energy
  - B. width
  - C. repetition rate
- III. Power consumption
  - A. science mode
  - B. maintenance mode
- IV. Temperature monitors - (packet data)

Optics:

- I. Laser and receiver boresight alignment stability
  - A. acceptance/verification level testing
  - B. thermal vacuum testing

Thermal:

- I. Allowable temperature ranges - Instrument on and off states
  - A. launch and earth orbit
  - B. inner and outer cruise phase
  - C. anomalous spacecraft safe hold conditions
  - D. transition and mapping orbits

BCE SYSTEM DESCRIPTION

BCE System Block Diagram:

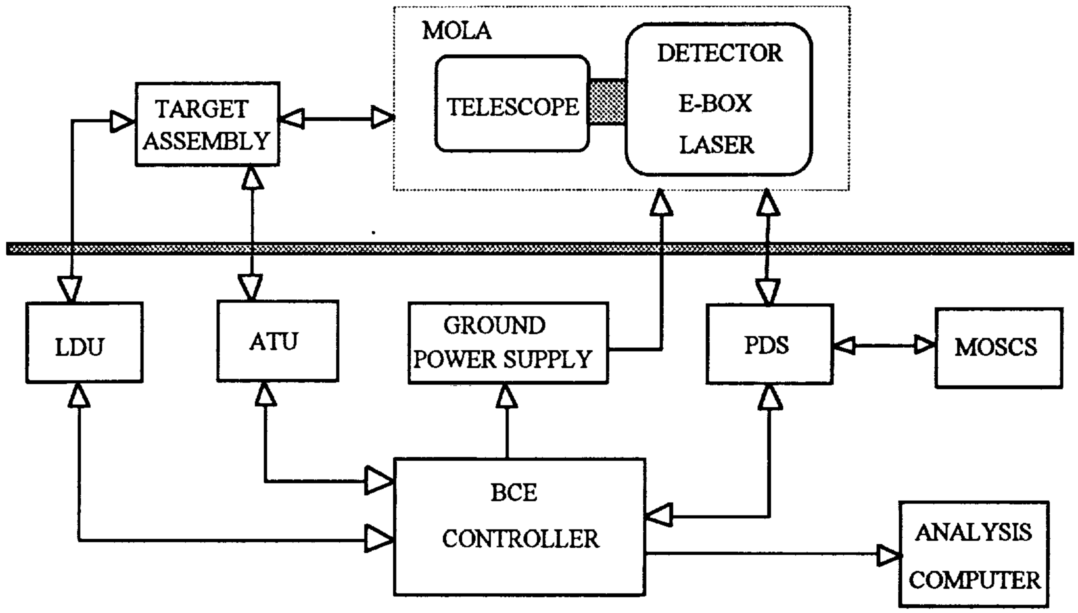

Fig. 1 (BCE System Block Diagram)

Figure #1 shows the MOLA BCE system block diagram. The central point of the BCE system is the BCE Controller which coordinates the testing stimulus provided by the BCE sub-systems and the MOLA instrument. In test configurations where power is not provided by the spacecraft, the MOLA operational power (+28V) is supplied via the Ground Power Supply (GPS). The Altimetry Test Unit (ATU) provides MOLA with simulated expected Mars background and range delay return signals. The Laser Diagnostic Unit (LDU) monitors the MOLA laser beam energy, temporal and spatial characteristics. During instrument testing the BCE controller commands and receives data from the ATU and the LDU. The Target Assembly is positioned directly over MOLA and provides the ATU and LDU optical interface to MOLA. MOLA packet telemetry data is collected and transmitted to the BCE Controller by the Payload Data Sub-system (PDS). The BCE controller commands and coordinates data exchanges to MOLA via the PDS and/or directly to the Mars Observer Spacecraft Checkout Station (MOSCS).

Target Assembly:

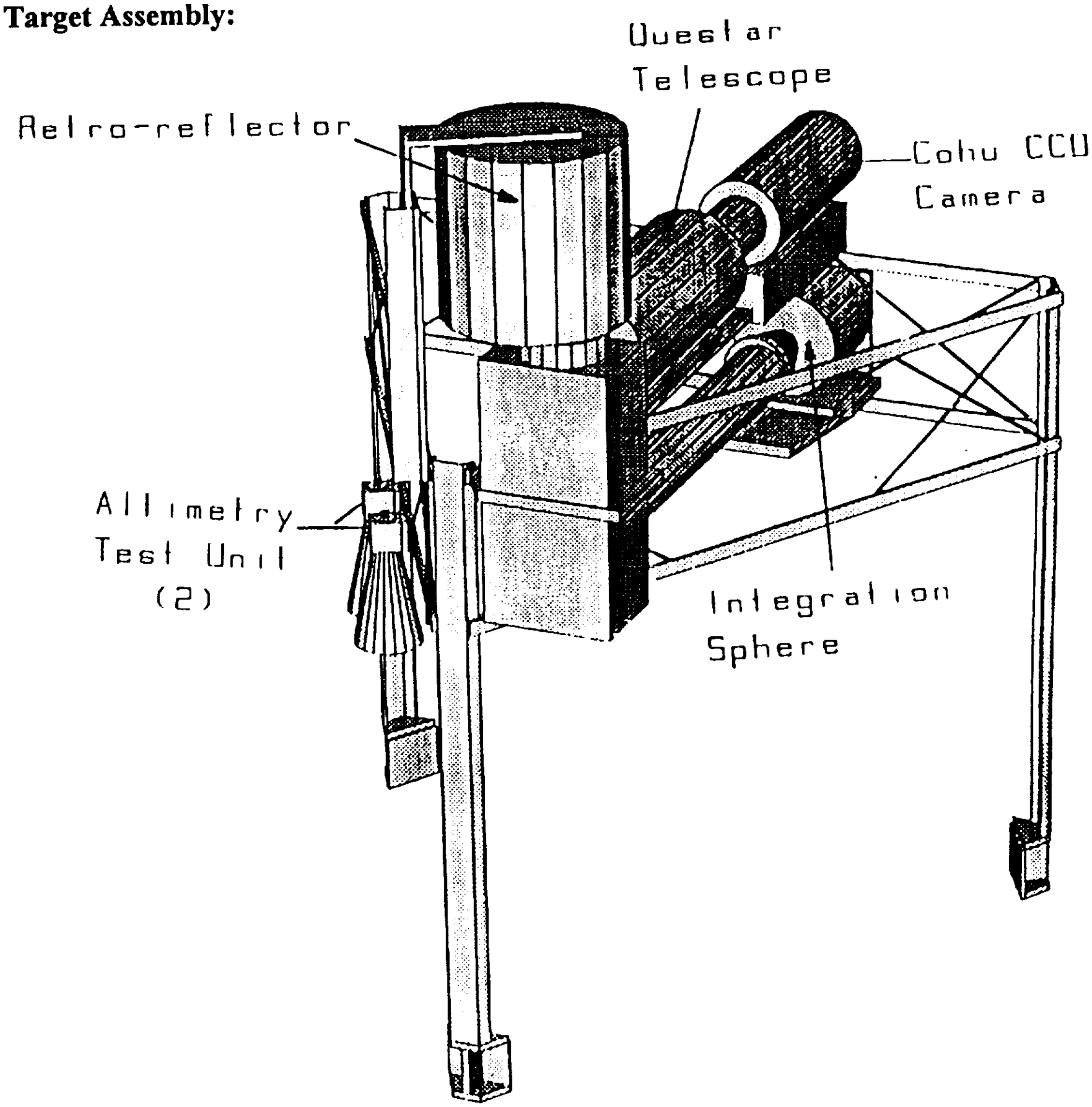

Fig. 2 (BCE Target Assembly)

The BCE Target Assembly is a mechanical test fixture (figure #2) that is mounted over the MOLA instrument and holds the ATU and LDU testing apparatus. These apparatus will be discussed in more detail under the ATU and LDU sections that follow. The three legs of the Target Assembly are designed to have a ball-and-cup mounting interface with the MOLA instrument. The MOLA instrument has three cup-like holding sockets located at the perimeter corners of the instrument base mounting plate. The ends of the Target Assembly legs are rounded to provide a ball mounting surface. This ball-and-cup mounting arrangement provide an easy and self-aligning mechanism to ensure alignment repeatability over the MOLA instrument. The Target Assembly is constructed of Invar and was designed for use within the thermal vacuum chamber over wide ambient temperature ranges (+60 °C to -30 °C). The Target Assembly also houses a combination of retro-reflector corner-cube and Risley adjustment wedges that are used to verify the MOLA laser transmitter and telescope receiver boresight alignment.

Altimetry Test Unit (ATU):

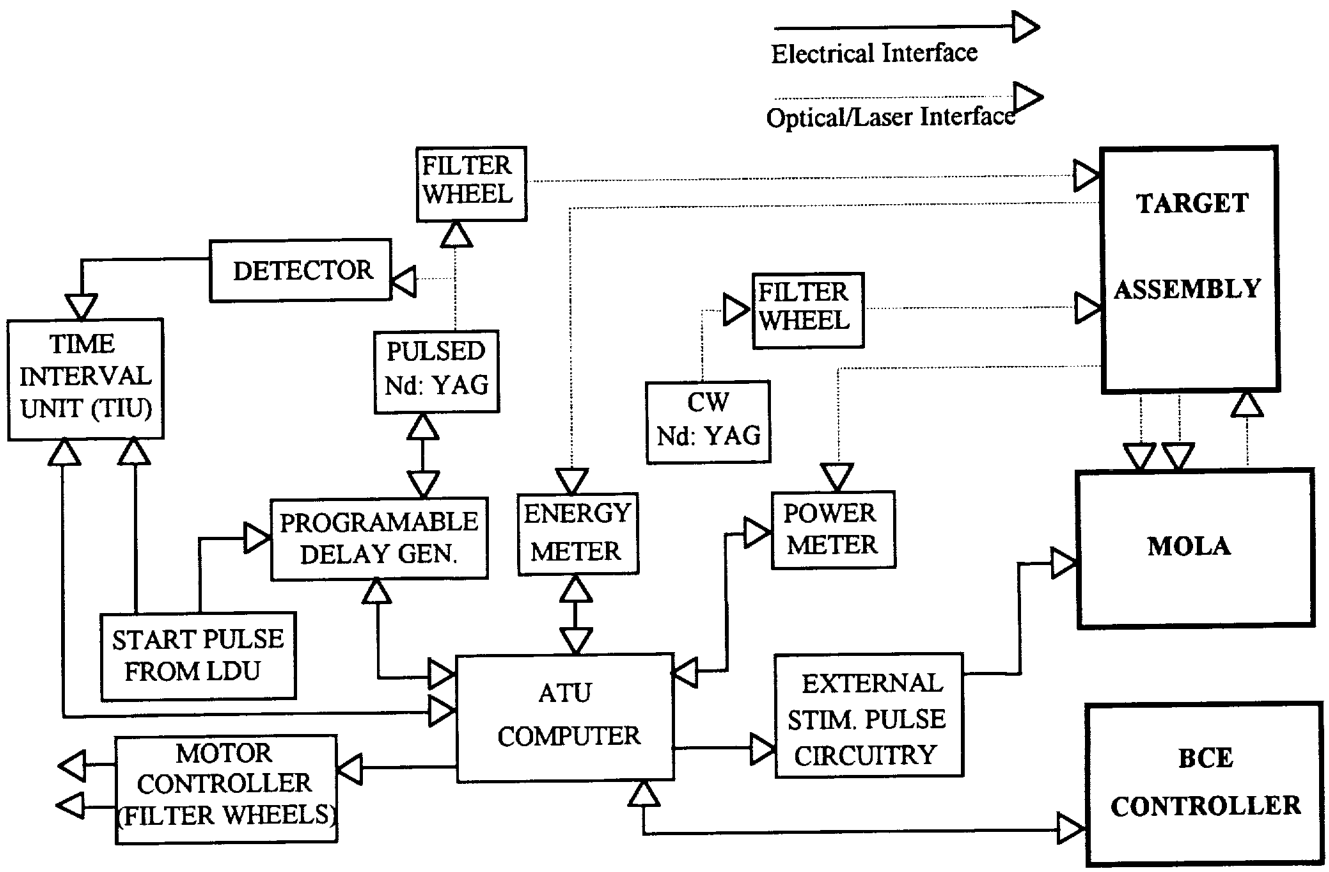

Fig. 3 (ATU Functional Block Diagram)

Figure #3 shows the ATU sub-system block diagram. As stated earlier, the primary ATU function is to provide the MOLA with simulated Martian flight conditions which include stimuli that tests the instrument's ranging electronics, range gate, discriminator thresholds, return pulse energy and background noise counters.

The ATU has three main sub-systems. The first is the background simulator, a CW laser (1.064 μm) that is directed into the MOLA telescope and simulates the reflected sunlight from the surface of Mars that would be in the MOLA receiver field of view (Fig. 3b). The luminance level of this signal can be selected, via commands from the BCE controller, from 16 discrete levels on a shot-to-shot basis. This is accomplished by passing the laser light through a sixteen position neutral density filter wheel driven by a stepper motor (Fig. 3a).

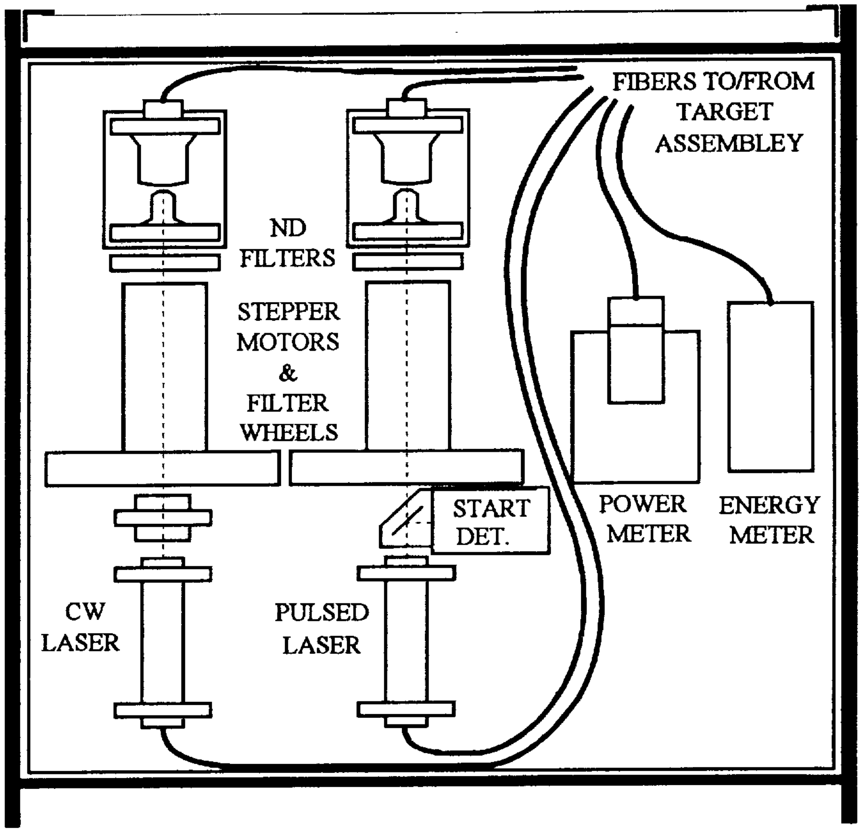

Fig. 3a (ATU Optical Bench Layout)

These filter wheel positions are programmed to provide simulated background levels ranging from Mars night to twice the Mars expected daylight (average) levels. This feature exercises the MOLA background noise counters, adjustable threshold discriminators, and the flight software that autonomously adjust the receiver discriminator threshold levels to provide a predetermined constant false alarm rate.

The second ATU sub-system provides a 35 ns laser pulse (1.064 μm) directed into the MOLA telescope and is also located on the Target Assembly adjacent to the background simulator (Fig. 3b).

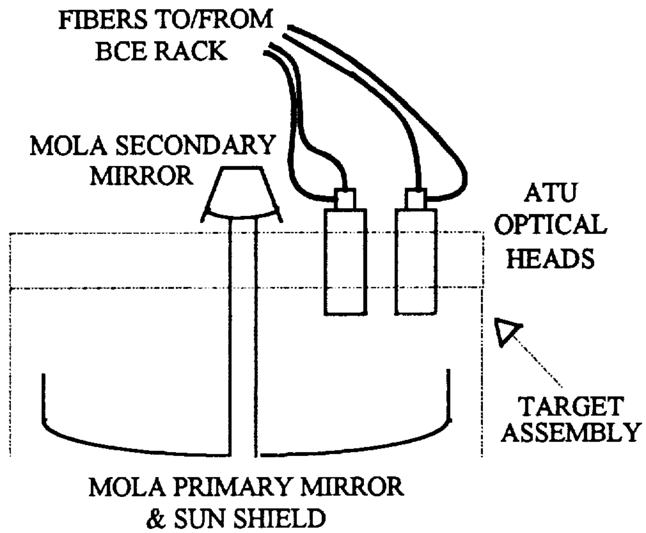

Fig. 3b (ATU Optical Head Position on the Target Assembly)

This pulse simulates the laser return signal from the surface of Mars and exercises the altimetry electronics return pulse energy monitors and ranging related functions. The luminance of this signal can also be selected from 16 discrete levels on a shot-to-shot basis in the same manner as the background simulator (Fig. 3a).

The third sub-system involves hardware and software programming that coordinates and synchronizes these two laser test sources. This feature allows for simulated 'real-time' Mars terrain topography profile data to be input into the MOLA receiver telescope thus providing an end-to-end system functional test. This is accomplished by using a digital programmable delay generator providing the pre-programmed fire control signals to the pulsed laser. This 'canned' topographic profile provides a means to evaluate MOLA range tracking performance, time interval counter (TIU), range gate, and the flight software signal acquisition and tracking algorithms.

The ATU also monitors and records the test laser output power and energy that is sent into the MOLA telescope on a shot-to-shot basis (Fig. 3c). It also measures the actual delay of the pre-programmed delay times of the simulated return pulses.

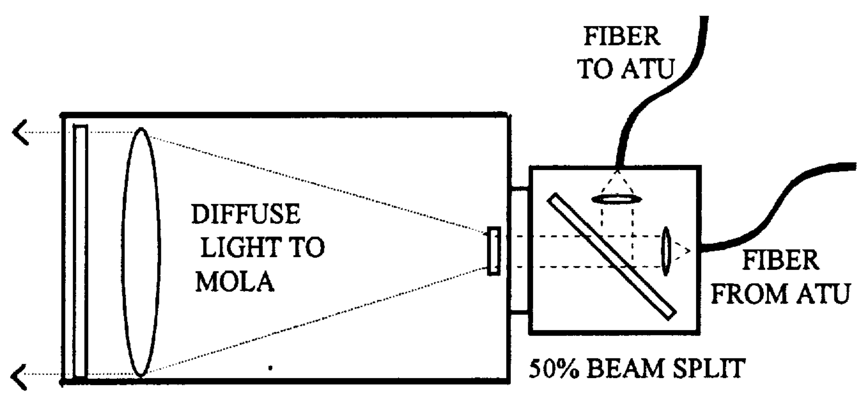

Fig. 3c (ATU Optical Head Detail)

The simulated Mars return pulses, background stimuli, and monitor data are relayed to and from the ATU optical heads located on the BCE Target Assy and the ATU instrument rack via 200 ft. fiber optic cables (200 μm core diameter n = 1.4997 @ 1.064 μm).

The control and data acquisition of the ATU sub-systems are performed by the ATU computer which interfaces to the BCE controller. The ATU computer translates test parameters sent by the controller into a coordinated process of setting delays to simulate terrain patterns, moving motors to set the filter wheels simulating different terrain albedos and reading the monitored data. The ATU computer then organizes the stimulus and monitor data in a shot-to-shot format so that it can be aligned and compared against the MOLA performance results thereby providing a means of characterizing and calibrating the MOLA instrument altimetry electronics performance for each test environment.

Laser Diagnostic Unit (LDU):

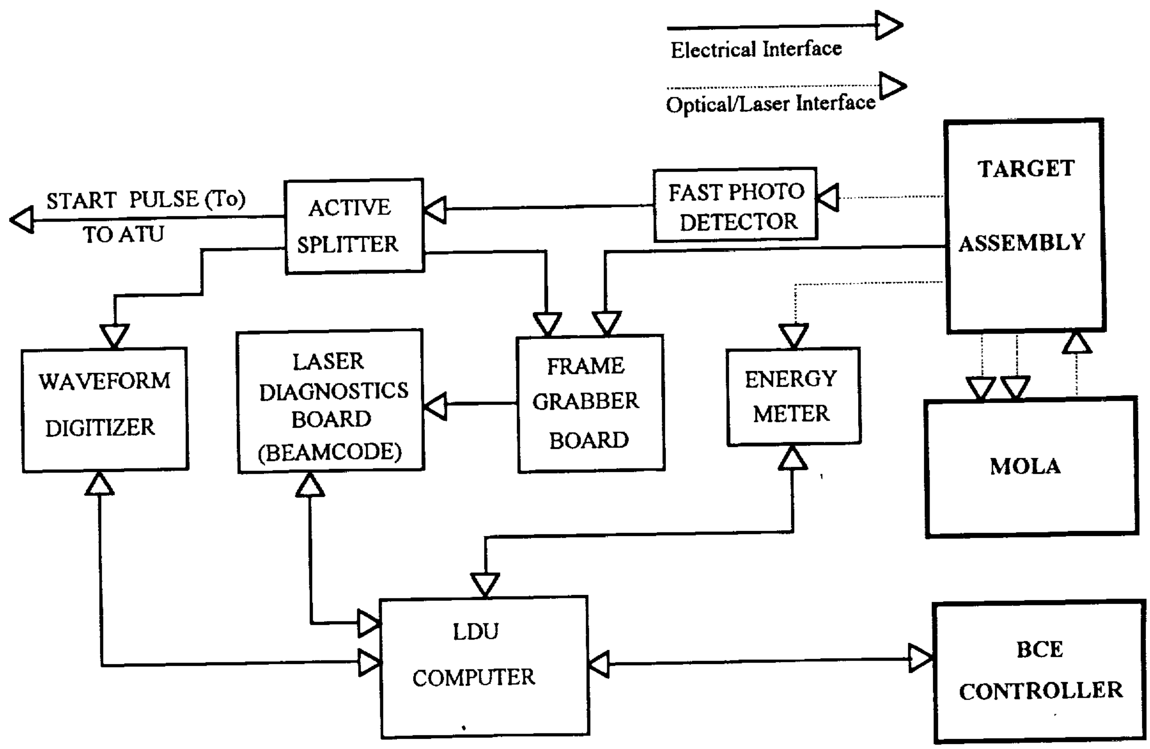

Fig. 4 (LDU Functional Block Diagram)

The LDU system block diagram is shown in Figure #4. The primary purpose of the LDU is to acquire data detailing the performance of the MOLA laser transmitter output. These data consist of laser pulse spatial and temporal characteristics as well as laser pulse energy. Optical and electronic instrumentation to sample the transmitted laser pulse is mounted on the MOLA Target Assembly. The Target Assembly itself is attached to the MOLA instrument during testing and evaluation (see Target Assembly section). Signals from the Target Assembly instruments are transmitted via optical fibers, coax and wire cables to the data acquisition hardware which may be located up to 45 meters away from the MOLA instrument. The data acquisition instruments are housed in a 19" electronics rack. All data acquisition hardware is connected to the LDU computer, a Compaq™ 386/20 MHz PC.

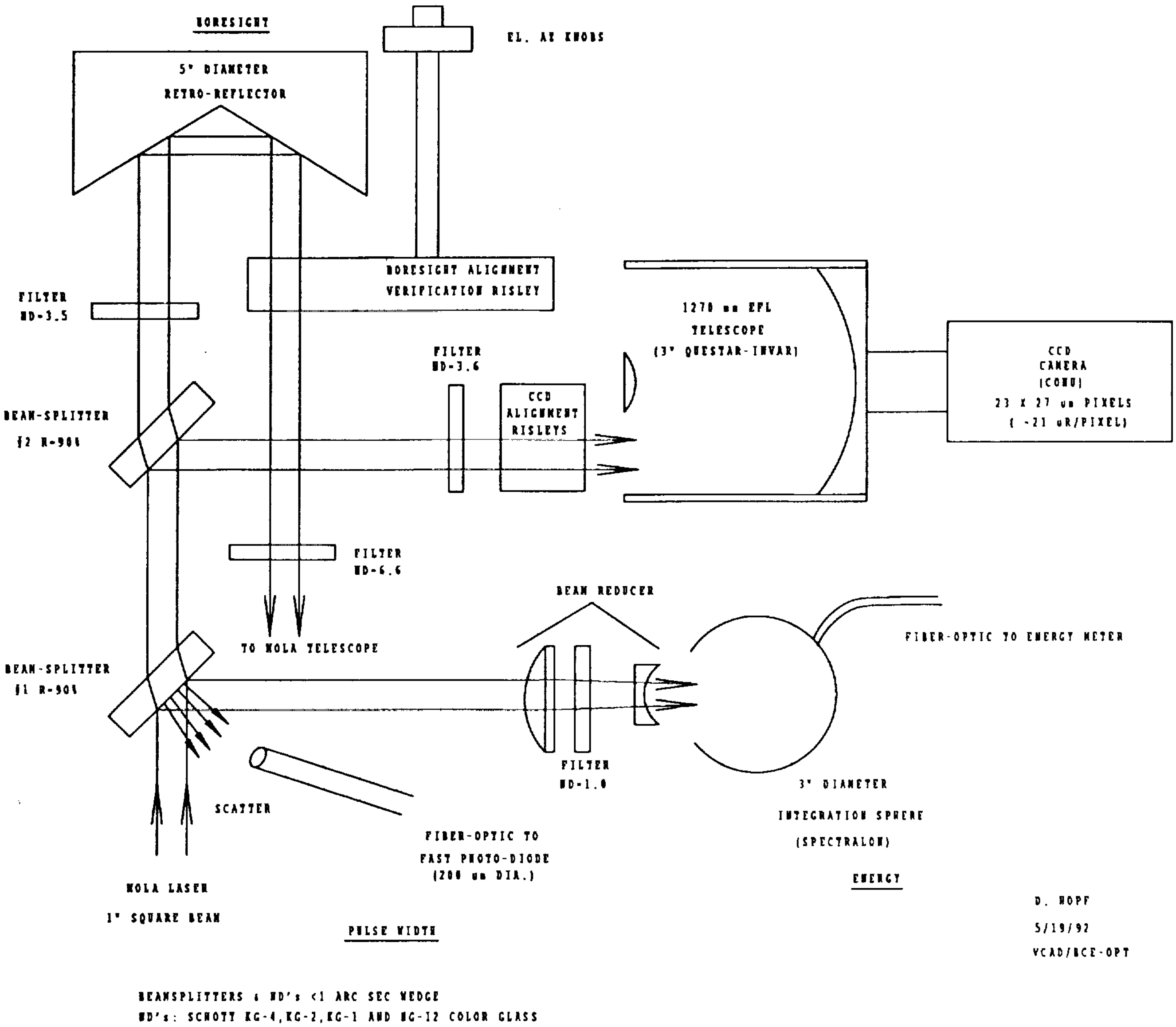

Fig. 5 (LDU Optical Path Layout)

Referring to figure #5, beam-splitter #1 directs 90% of the transmitted energy through beam attenuation and reduction optics and into a Spectralon™ integrating sphere manufactured by Labsphere™. The sphere is utilized to remove spatial non-uniformity in the laser beam while sampling the pulse energy. An optical fiber (200 µm core, n = 1.5, length = 45 m) is coupled to the integrating sphere and transmits a portion of the energy to a Molectron™ J3S 10 mm silicon photo diode connected to a Molectron™ JD2000 energy meter. The JD2000 computes the average and standard deviation of 99 laser pulse energy readings for transmission to the LDU computer.

A second optical fiber (200 μm core, n = 1.5, length = 45 m) transmits a portion of the diffuse reflection from beam-splitter #1 to a high speed silicon avalanche photo-diode (Si-APD) and amplifier manufactured by OptoElectronics™ Inc.. A screw-type attenuator is used to adjust the optical throughput to the Si-APD. The Si-APD and amplifier bandwidth is 1 GHz. The pulse output of this detector is digitized at 2 GSamples/s and stored with a Tektronix™ DSA 602 Signal Analyzer. The DSA 602 averages 100 pulses and calculates pulse width, peak voltage, rise time and fall time.

The Si-APD signal is split after the amplifier to provide a T_0 reference for the ATU and a trigger for the Molectron™ JD2000 energy meter.

Beam splitter #2 again splits the remaining energy. 90% of this energy is directed into a 1270 mm EFL Invar Schmidt Cassegrain telescope manufactured by Questar™. The telescope focuses the far-field beam pattern onto a 8.7 x 6.4 mm COHU™ CCD camera. Neutral density filters are used to limit the beam intensity and a Risley alignment prism assembly adjusts the beam displacement. A typical beam cross section illuminates approximately 30 x 30 pixels on the camera (each pixel is 23 x 27 μm). Power, synchronization and video signals are transferred to the LDU rack over a 45 meter long wire cable. Camera scans are captured at the LDU computer with an AT Vista™ video frame grabber and Big Sky Beamcode™ software. The software computes diameter, centroid and peak positions of the beam cross section.

The remainder of the pulse energy is transmitted through beam splitter #2 to a five inch retro-reflector which displaces and reflects the pulse back into the MOLA telescope. The MOLA receiver detects this pulse and the signal is used to verify alignment of the MOLA receiver and transmitter. A Risley prism assembly is used to manually translate this return pulse across the detector field-of-view for alignment verification. This alignment check procedure is performed each time after the instrument has been significantly relocated, vibration, thermal vacuum testing etc. to verify the internal laser-to-detector alignment is still within specification.

Ground Power Supply (GPS):

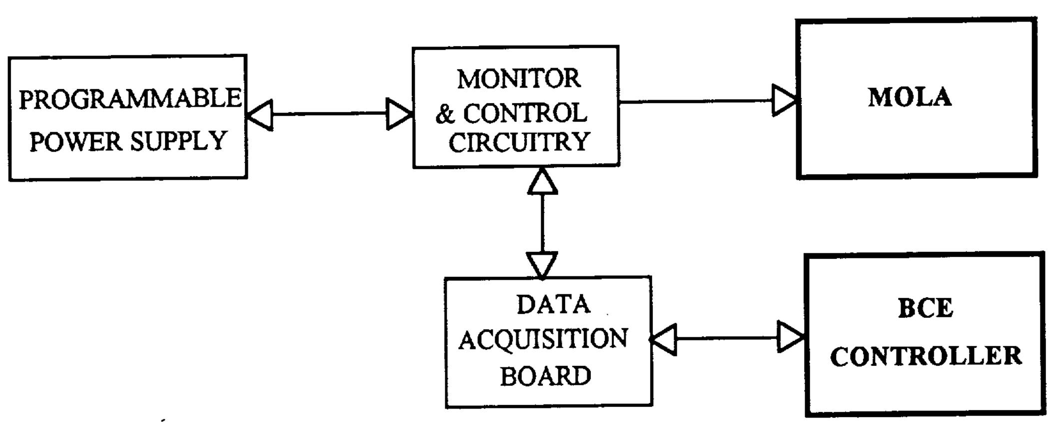

Fig. 6 (GPS Functional Block Diagram)

A block diagram of the BCE GPS is shown in Figure #6. The GPS system consists of a programmable power supply controlled and monitored (voltage and current) by custom circuitry consisting of a current sensor, latching relay and accompanying electronics interfaced to a Data Translation™ 2821 data acquisition board. The GPS system provides adjustable DC power to MOLA, captures the instrument's current and voltage turn-on transients, and simulates over/under voltage surges on the spacecraft power bus due spacecraft events such as battery switching, etc..

The GPS is used to verify that MOLA functions as designed over the possible range of spacecraft over/under voltage levels and transient events.

BCE Controller:

The BCE Controller consists of PC based hardware and custom menu driven software that coordinates and controls the operation of the other BCE sub-systems with the related spacecraft systems. The BCE Controller software provides the primary interface between a test conductor/operator and the sub-systems shown in figure #1. Resident in the BCE Controller software is a series of standard instrument tests.

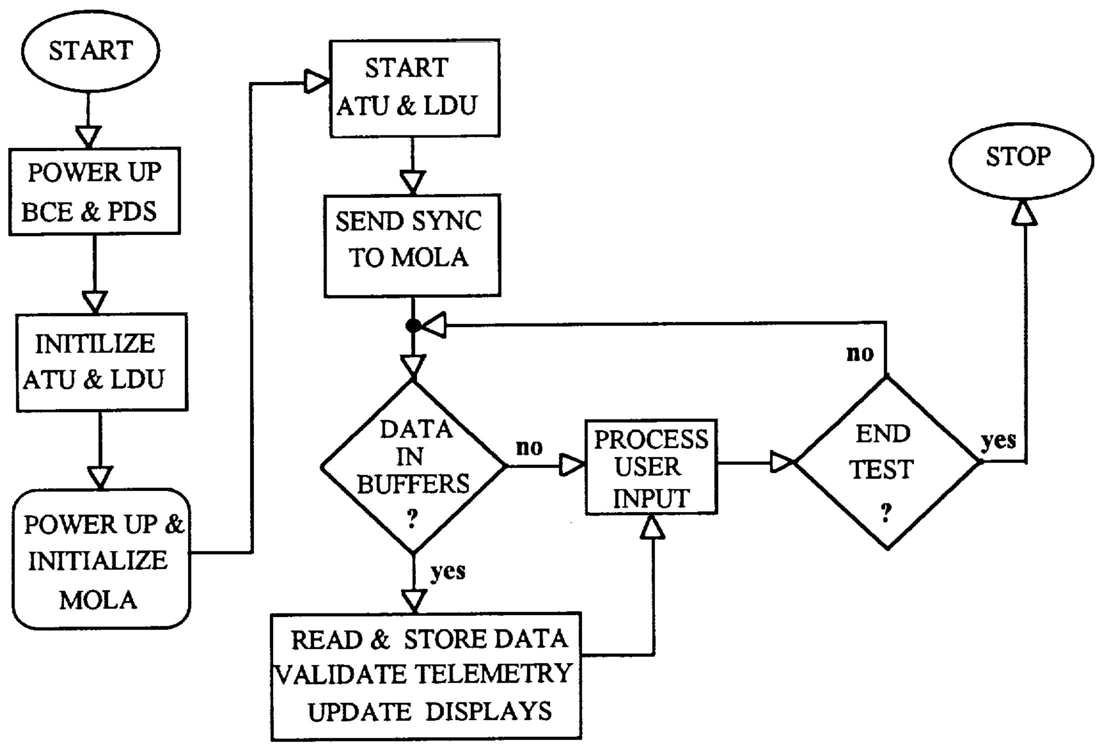

Fig. 7 (BCE Controller Operation Flow Diagram)

As shown in Figure #7, a typical test scenario begins with the power-up and initialization of all of the BCE systems and the PDS. The BCE controller software sends test setup information to the ATU and LDU software. After acknowledging the controllers setup commands the ATU and LDU initialize their various components and then wait for a start command from the controller. At this time the controller will either energize a relay to provide power to MOLA via the GPS or monitor the MOLA telemetry data packets from the PDS to determine whether MOLA is operational. Once MOLA is turned on and in the correct configuration the controller will command the ATU and LDU to start and execute a test. Immediately after the start command is received the ATU sends a pre-defined ranging pattern to MOLA which provides a means to align the BCE stimulus (ATU) and laser monitor (LDU) data with the MOLA packet telemetry data. The ATU software then sets its filter wheels, delay circuits and pulse generators to the settings required for the specific test. As the test continues the controller acquires and processes the stimulus, laser monitor and telemetry data from the ATU, LDU and PDS. The controller continues to acquire, monitor telemetry and archive test data until the end of the test is reached or until the test is stopped by an operator. At the end of a test the BCE Controller software updates test logs and creates backup copies of all the data files generated from that test. The BCE test data can then be fully processed off-line by the Analysis Computer.

Analysis Computer:

The Analysis Computer sub-system consist of data processing hardware and performance assessment software. This BCE sub-system receives MOLA and BCE sub-system testing data from the BCE Controller on 20 MB removable hard disk media (Bernoulli®). Raw test packet data from MOLA and BCE sub-system stimulus data is then merged and aligned by post-processing software on the analysis computer to form spreadsheet data files. These data files are then processed to form summary data product files and hardcopy performance sheets (graphs and tables). These summary performance data files are archived to form the data base for the instrument performance trend analysis. The summary data products are used to quantitatively determine the MOLA performance and determine that MOLA is meeting the instrument functional requirements during that specific series of instrument tests. The instrument performance trend data is continuously monitored for anomalous indications. The performance data base will allow the MOLA data analysis team to evaluate mission data and predict instrument performance trends (i.e. laser energy output, etc.).

Shown in figure #8 below is a representative data analysis performance chart displaying the MOLA range and range gate tracking performance to a triangular topographic profile provided by the BCE/ATU stimulus.

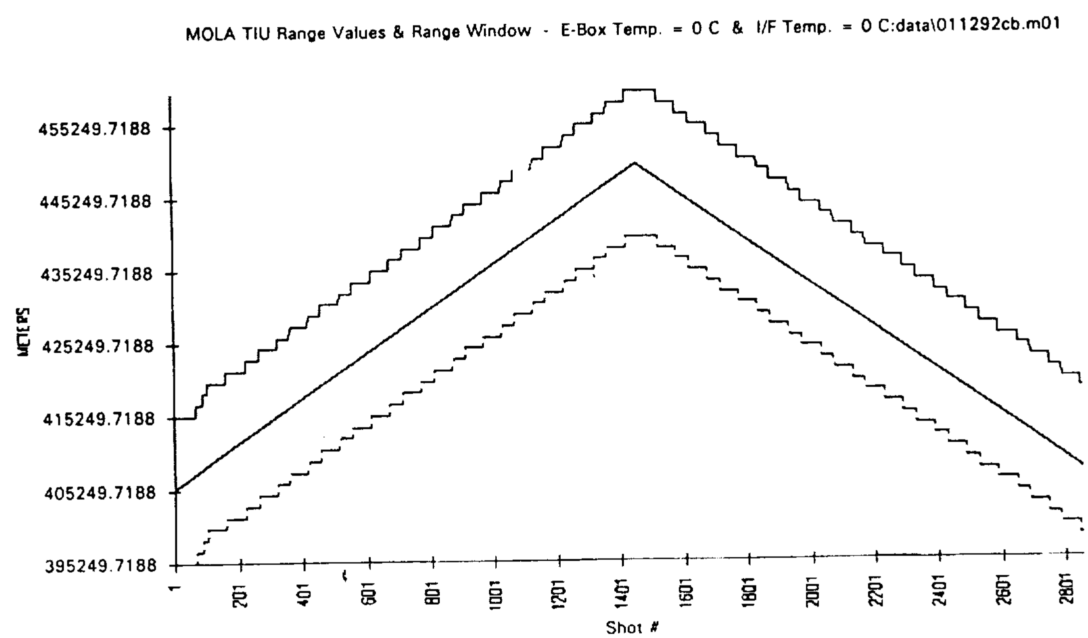

Fig. 8 (Data Analysis Performance Chart)

FINAL COMMENTS

There are a few BCE sub-systems that were used with the MOLA instrument that bear mentioning. These were not include in the main text of this paper because they were too MOLA specific and may not be necessary or of the same design (implementation) on future altimeter instrument systems.

The Laser External Cooler (LEC) was an off-the-shelf chiller that we used to cool a plate that was used to conductively couple (clamped) to the side of the laser box to remove the heat generated by the laser pumping diodes. This allowed operation the laser at or above normal room temperatures preventing the overheating of the diodes and subsequent lifetime degradation. Also, by varying the chiller temperature over a small range we were able to characterize the laser output energy and pulse width as a function of temperature. For future spaceborne solid state laser instruments, consideration should be given to having the cooling manifold integral to the laser box. The added mass overhead will more than be compensated for by the increased operational flexibility, simplification of hookup, and added system level safety considerations.

The laser cavity purge system was used on MOLA to prevent a laser cavity burst disk assembly from rupturing during system level thermal vacuum testing. The burst disk assembly was designed into the box wall of the laser cavity and is intended to rupture during the spacecraft launch and thus venting the laser cavity to deep space. This is necessary to avoid the critical pressure region because of the high voltage used to operate the Lithium Niobate Q-switch. The Class 100 cleanliness requirements of the laser cavity made this a very difficult task to manage. Consideration should be given to future applications to implement a totally sealed laser cavity box - fully pressurized or totally evacuated and maintained for the life of the system.

In conclusion, it is important to maintain an overall BCE system that is fairly flexible and modular. There will always be testing anomalies and BCE component failures that will occur. The ability of the BCE to absorb and accommodate these events must be planned for in advance. In the end, this will greatly reduce testing cost and schedule impacts.

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