DSPSE LTT OPERATIONS

Major Activities Planned For This Phase: (Page 1 of 2)

• Phase 1A (TTI to TA1)
  - Post TTI Burn Activities
  - Subsystem Turn On & Checkout
  - Star Tracker Accuracy Measurements
  - Sensor Turn On, Checkout, & Calibration
  - Kick Motor Observation
  - Apogee ΔV Adjust Using RCS Motor (If Required)

• Phase 1B (TA1 to TP1)
  - Star Tracker Accuracy & Precision Measurements
  - Sensor Checkout & Calibration
  - Sensor Observations To Measure Sensor Sensitivity, Pointing Stability, Light Scattering, & Baffle Efficiency
  - Stars Will Be Used To Provide Reference Images For Calibration & To Measure Optical Distortions.
  - Autonomous Navigation: Sensors Will Be Used To Determine Spacecraft Position & Provide R3000 Processed Image & Navigation Data To The Ground
  - Image Earth & Moon At Various Phase Angles
Major Activities Planned For This Phase: (Page 2 of 2)

- Earth Flyby #1 & #2 (TP1 & TP2)
  - Minimal Power Mode
  - Radiation Experiments
    -- Single Upsets
    -- Cover Sensors & Take Dark Field Images Before & After Radiation Zones

- Phasing Loops 2A, 2B, & 3A
  - Orbit Determination, Trajectory Corrections (As Required), & Planning For Lunar Insertion Burn
  - Star Tracker Accuracy & Precision Measurements
  - Sensor Observations To Measure Sensor Sensitivity, Pointing Stability, Light Scattering, & Baffle Efficiency
  - Stars Will Be Used To Provide Reference Images For Calibration & To Measure Optical Distortions.
  - Image Earth & Moon At Various Phase Angles
  - Autonomous Navigation: Sensors Will Be Used To Determine Spacecraft Position & Provide Resulting Data To The Ground
  - Laser To Earth Communications Demo (TBD): Spot Size & Pointing Measurements
  - Lunar Orbit Insertion & Lunar Mapping Orbit Rehearsals

- Lunar Insertion
# DSPSE LTT OPERATIONS

## LTT Experiment Schedule

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<th>Sub Phase</th>
<th>Sensors</th>
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<th>Experiments</th>
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<th>Autonomous Operations (power approach)</th>
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<tr>
<td>lunar Transfer</td>
<td>Post-Kick Motor Burn</td>
<td>One of two for attitude &lt; 12 hours after TT burn</td>
<td>Powered Off &amp; Covered</td>
<td>Powered Off &amp; Covered</td>
<td>Powered Off &amp; Covered</td>
<td>Sensor off for all - off (TBD) for mission time</td>
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<tr>
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<td>Sensor Handling System Checkout</td>
<td>Both On</td>
<td>Powered On</td>
<td>Powered On</td>
<td>Powered On</td>
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<tr>
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<td>Kick Motor Observation</td>
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<td>Powered Off</td>
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<tr>
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<td>Both On</td>
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<tr>
<td>Lunar Transfer</td>
<td>Phasing Loop 3A</td>
<td>Both On</td>
<td>Powered Off</td>
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<td>Powered Off</td>
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Power profiles are TBD. They will be developed based on the information and timelines provided in this briefing.
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Post TTI Burn Activities: (Page 1 of 2)

- Kick Motor Ignition & Burn (60 - 63 Sec)
- Post TTI Burn Activities:
  - Enable Active Nutation Control (ANC) (Up To 5 Min)
    -- Damp Out Any Nutation Present At End Of The Burn
  - Disable ANC
  - Spin Down Spacecraft To ~ 5 RPM (~ 2 Min)
    -- Open Loop Via Stored Command
    -- Need Some Spin In Case Nutation Angles Induced During Spin Down
  - Enable Active Nutation Control (ANC) (Up To 5 Min)
    -- Damp Out Any Nutation Present
  - Disable ANC
  - Spin Down Spacecraft To 0 RPM
    -- Closed Loop Via Stored Command
  - Enable Command Receiver AGC (Per Stored Command)
  - Establish 2-Axis Attitude Control Mode
    -- Using Current (Post Burn & Spin Down) Attitude State, Sun Sensors, & IMU Data To Estimate Proper Pointing To The Sun - Method Is TBD
    -- Star Trackers Will Remain Covered To Prevent Contamination From Kick-Motor For 12 Hours Following The Kick Motor Burn
DSPSE LTT OPERATIONS

Post TTI Burn Activities: (Page 2 of 2)

- Post TTI Burn Activities: (Continued)
  - Deploy Solar Panels
  - Turn On Solar Array Drives & Enable Autotrack
  - Turn On Reaction Wheel Controller
  - Enable Momentum Dump Mode
  - Turn On Heaters For Remaining 6 ACS Thrusters
  - Charge Batteries
    - Using Solar Panel & Sun Sensor Telemetry, Adjust Vehicle Attitude To Acceptable Energy Balance Performance While Maintaining Communications With The Ground Stations
  - TBD Hours After TTI Burn, Lower Downlink Bit Rate To TBD BPS (Per Stored Command)
  - Maintain Proper Attitude For Communications, Power, & Thermal Subsystems
  - 12 Hours After Kick Motor Burn, Uncover Star Trackers
  - Turn On R3000
  - Update Attitude Using Star Tracker Data
  - Go To Normal 3-Axis Attitude Control Mode
  - Uncover Mission Sensors
    -- Delay 2 - 4 Days After Kick Motor Burn To Allow Residue From The Kick Motor Burn To Dissipate & For Outgassing
DSPSE LTT OPERATIONS

Kick Motor Observation Overview:

- Experiments Involving The Departing Kick Motor Components Will Include Imaging, Active Ranging & Closed Loop Tracking
- Turn On Of Sensors Containing High Voltage Components, Such As The HiRes Camera & The Laser For The Laser Ranging System, Will Be Delayed 2 - 4 Days After The Kick Motor Burn To Allow Adequate Outgassing To Prevent Arcing
  - Separation Path Is More Linear If Kick Motor Is Jettisoned Closer To The Midpoint Between Apogee & Perigee
- The Kick Motor Must Be Jettisoned Prior To Reaching Apogee (Day 5).
  - If A Mid Course Correction Prior To The Apogee Burn Is Required, The Kick Motor Will Have To Be Jettisoned Early. If That Is The Case, The Decision Whether To Accomplish The Kick Motor Observation Will Be Made
- Prior To The Observation:
  - Sensors Will be Checked Out & Data Downlinked Via Omni Antennas (Kick Motor Covers The High Gain Antenna)
  - Command Plan Will Be Developed, Validated, & Rehearsal Performed
- Upon Jettison Of The Kick Motor @ .3 m/s (1 ft/sec), The Spacecraft Will Be Rotated To Point Sensors Toward The Kick Motor, The Observation Will Take Place Until The Kick Motor Is No Longer Visible, The High Gain Antenna Feed Will Be Deployed, & The Data Dumped Via The High Gain Antenna
  - Kick Motor Will Be Visible Up To 24 Hours
DSPSE LTT OPERATIONS

Kick Motor Observation: (Page 1 of 5)

- Objectives
  - Test Closed Loop Acquisition & Tracking
  - Test Ability To Change Primary Mission Sensor (Handoff) From UV/Vis To HiRes Camera
  - Test Laser Ranger
  - Image Kick Motor With All Cameras Using A Variety Of Filters
  - Test Ability To Perform Precision Attitude Control (Tracking)

- Test Conditions
  - Kick Motor Jettison Will Be As Close To Directly Away From Sun As Possible For Maximum Reflected Light But Still Maintaining Required Real-Time Communications With Pomonkey
    - Need Real-time Downlink Via Omni Antennas, Point -Z Axis Within ± 50° Of Earth (Best Antenna Pattern - May Get Up To 8 Kbs Downlink)
  - Real-time Command Capability (Abort, Contingency, Etc.) Pomonkey In View
  - Separation Velocity Is Estimated At 1 f/s (.3 m/s)

- Pre-Jettison Phase - Sensor Checkout (TBD Hours Before Kick Motor Jettison)
  - Power Up Cryo Coolers 30 Minutes Before Powering Up Sensors
  - Power Up Sensors 10 Minutes Before Imaging & Verify Heath & Welfare
  - Take Dark Images With All Sensors & Downlink Images Via Omni Antennas
  - Uncover Sensors, Image Moon (Verify Autoexposure Algorithm) & Downlink Images Via Omni Antennas
DSPSE LTT OPERATIONS

Kick Motor Observation: (Page 2 of 5)

- Rotate Spacecraft To Jettison Attitude
  - Assumed The The Spacecraft X-Z Plane Is In The Earth-Moon Plane & Attitude Changes Would Mainly Involve Rotations About The Y Axis
    - This Allows Good Solar Incidence Angle For Solar Arrays
    - Actual Jettison Direction Is TBD Pending Analysis To Avoid Recontact
    - Should Jettison Be In Spacecraft Orbital Plane Or Earth Moon Plane? (Spacecraft Orbital Plane Is @ 70° Inclination In Respect To Earth)

- Jettison Kick Motor (.3 m/s)

- Pre-Acquire Phase
  - Deploy High Gain Antenna Feed
  - Wait 10 sec (TBD) For Kick Motor To Clear Spacecraft
  - Rotate Spacecraft 90° To Point Sensors (+Z Axis) Towards Kick Motor Location
    - How Long To Rotate? Wheels Or Jets? Distance Traveled During Time To Rotate?
  - Select Highest Possible Downlink Rate (8 kbps ?) For Omni Antennas
    - Will Store Images On Solid State Recorder & At The Same Time Will Continuously Downlink Processed Image Data Via The Omni Antennas
DSPSE LTT OPERATIONS

Kick Motor Observation: (Page 3 of 5)

- Acquisition Phase (UV/Vis Primary Sensor - I.E. UV/Vis Image Used By R3000 To Compute Centroid)
  - Begin Imaging Using Clear Filter @ TBD Images per (second ?)
  - Process Image Using Algorithm In R3000, Attempt To Compute Centroid
  (Assume Kick Motor Is Found When It Is In The Camera Image & A Centroid Can Be Computed),
  - If Not Found After 3 Images, Use Different Exposure (In Case Motor Dim)
  - If Still Not Found After 4 More Images (@ Different Exposure), Begin 3x3 Conical Scan Centered On Starting Point Obtaining 4 Images Per Location
  - If Not Found After Conical Scan, Use NIR Camera As Primary Sensor & Repeat Above Process
  - If Still Not Found, Ground Will Implement Contingency Procedures
  - When Kick Motor Found:
    -- Pass Centroid Data To Guidance Module On 1750A Processor; Guidance Will Compute Desired Quaternions & Rates & Pass This Data To ACS Who Will Maintain The Desired Attitude
    -- Dump Image To Ground (Along With Centroid & Range)
    -- Obtain Range With Laser Ranging System @ 1 Hz Rate (TBD)
    -- Laser Ranging Data Not Used By Acquisition Algorithm
    -- Begin Initial Tracking Phase
DSPSE LTT OPERATIONS

Kick Motor Observation: (Page 4 of 5)

• Initial Tracking Phase
  - Begin Imaging With All Cameras Using Autoexposure Control (Rate TBD)
  - Continue Laser Ranging @ 1 Hz Rate (TBD)
    -- Include Laser Ranging & Centroid Data In Real-time Omni Downlink
  - Perform Precision Attitude Check (PAC) - While Keeping Kick Motor In The FOV, Perform A Spiral Scan About Centroid & Then Re-Center Image In FOV
    -- PAC Tests ACS Precision Control & Tests Size Of Radar Cone
    -- May Need To Disable Tracking Algorithm During PAC
  - Continue Imaging With UV/Vis (or NIR) Until Image Is < 1.25 mr (25% of HiRes FOV (Range ≈ 1 km)) Then Begin Final Tracking Phase

• Final Tracking Phase
  - Switch Primary Mission Camera To HiRes (R3000 Uses HiRes Images To Compute Centroid)
    -- Continue Imaging With All Cameras Using Autoexposure Control
    -- LWIR & NIR Camera Data Not Used For Tracking & Can Be Turned Off After TBD Image Sequences Have Been Obtained
    -- HiRes Images For Centroid Computation Required @ TBD Rate But Only Every N (TBD) Images Will Be Stored On The SSR
  - Repeat PAC Tests Every 2 Km (≈ Every 1.85 Hours)
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Kick Motor Observation: (Page 5 of 5)

- Final Tracking Phase (Continued)
  - To Simulate Asteroid Flyby Operations, May Want To Point High Gain Antenna To Earth, Dump The SSR (30 - 60 Min), & Re-acquire The Kick Motor. Repeat Every TBD Hours.
  - Continue Laser Ranging @ 1 Hz Rate (TBD)
    -- Include Laser Ranging Data In Real-time Omni Downlink
    -- Discontinue Laser Ranging When Ranging Data No Longer Available
    -- When Ranging Data Drop Outs Occur May Want To Perform PAC Test So Can Determine Capability Of The Laser Ranger
  - Continue Imaging Until Kick Motor Is No Longer Visible In The HiRes Images & The R3000 Can No Longer Compute A Centroid But No Longer Than 24 Hours (TBD)
- End Of Test - Turn Off All Sensors & Cryo Coolers, Rotate Spacecraft To Point High Gain Antenna Towards Earth (± 0.2° Of Earth Center) & Dump Solid State Recorder. (≈3 Hours For Full 1.2 GByte SSR)
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Kick Motor Observation Issues & Concerns:

- How Soon Can The Observation Be Accomplished Vs. Outgassing Requirements?
- Use Of The Omni Antennas Vs. High Gain Antenna For Real-time Downlink
  - Omni Antennas Require Only ±40° - 50° Pointing Accuracy
  - High Gain Antenna Requires ±2° - 3° Pointing Accuracy. Do We Want To Try To Maintain This Pointing While Tracking The Kick Motor?
- Can The CT & DH Subsystem Support Real-time Centroid Computations, Real-time Downlink, & Data Compression & Storage On The SSR @ The Same Time?
- How Long Should The Test Last (12 - 24 Hours)
- Can The Thermal Control Systems Support The Cameras Being On This Length Of Time? (Will Be Pointing Away From Sun)
- What Imaging Schedule Will Be Used For Each Camera & Filter?
- What Schedule Should Be Used For The Laser Ranger Over The 12 - 24 Hours Of The Tests So It Can Still Support The Rest Of The Mission Within Its Stated Lifetime?
- In What Direction Should The Kick Motor Be Jettisoned To Minimize Effects On Spacecraft Orbit & To Prevent Possible Re-Contact?

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Kick Motor Observation

Geometry:


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Earth Flyby Operations:

- Will Fly By The Earth Twice, Passing Through The Earth's Radiation Belts Each Time.
- Orbit Adjust Burns Have Priority Over All Other Operations
- For The Worse Case The Inner Van Allen Belt Is Centered @ ≈ 3000 km & Is ≈ 5000 km Thick. The Outer Belt Begins @ 15,000 - 20,000 km & Is 6,000 km - 10,000 km Thick
  - Thickest Portion Of The Van Allen Belts Is Centered About The Magnetic Equator. This Thickness Varies With The Amount Of Solar Activity
    - For Worst Case, This Limits Activities To When The Spacecraft Is < 500 km
    - The Actual Inclination Is ≈70° So We Will Not Pass Through The Worsk‡ Portion Of The Belts On The Approach Or Departure
  - Altitude @ Perigee #1 Is ≈ 586 km, Altitude @ Perigee #2 Is ≈1429 km Which May Limit Operations During The Earth Flybys To Radiation Effects Experiments
Earth Flyby #1 Altitude Vs. Time Chart:

Note: Radiation Belt Boundaries Shown are at Geomagnetic Equator

- Outer Electron Zone Upper Boundary (32000 km)
- Outer Electron Zone Lower Boundary (20000 km)
- Proton Zone Upper Boundary (10000 km)
- Inner Electron Zone Upper Boundary (7600 km)

Lower Boundary of Inner zones - approx 500 km
Altitude @ perigee = 586 km

TIMELINE ACTIVITIES/LSW/10/22/92.25

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Earth Flyby #1 Ground Track:

Altitude @ Perigee = 586km

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Earth Flyby #2 Altitude Vs. Time Chart:

Note: Radiation Belt Boundaries Shown are at Geomagnetic Equator

- Outer Electron Zone Upper Boundary (32000 km)
- Outer Electron Zone Lower Boundary (20000 km)
- Proton Zone Upper Boundary (10000 km)
- Inner Electron Zone Upper Boundary (7600 km)
- Lower Boundary of Inner zones - approx 500 km
- Altitude @ perigee = 1429 km
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Earth Flyby #2 Ground Track:

Perigee #2

Altitude @ Perigee = 1429 km
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Lunar Mapping Rehearsals:

- There Will Be Full Rehearsals Of The Lunar Insertion Burn & A 5 Hour Lunar Mapping Orbit
  - The Simulation Objectives Are:
    -- To Familiarize Operations Personnel With The Activities & Sequences Needed To Support The Lunar Orbit Insertion Burn
    -- To Ensure The Activities & Sequences Can Be Smoothly & Accurately Executed.
    -- To Learn The Spacecraft & Ground System Idiosyncrasies
    -- To Allow For Modifications To Ensure The Software Algorithms, Procedures, Command Plans, Spacecraft, Sensors, Ground Operations Team, Etc. Are Ready For The Lunar Portion Of The Mission
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Key Operations & Engineering Team Activities:

• A Comprehensive Check Of All Spacecraft Subsystems
• Determination Of The Spacecraft's Trajectory; Planning & Executing Trajectory Corrections
• Experiment Support (Command Plans, Real-time Support, Etc.)
• Maintaining Synchronization Of Spacecraft Clock With UTC
• Managing Communications Opportunities With DSN & RTS Sites
• Managing Large Distance To Spacecraft & Associated Transmission Times
• Communicating Using The High Gain & Omni Antennas
• Managing Operations Using A Single Commanding Station (Pomonkey)
• Processing, Displaying, & Managing Large Quantities Of Transmitted Image Data
• Determining Time & Spacecraft Orientation For Injection Into Lunar Orbit
• Preparing For The Lunar Orbit Injection Burn
• Preparing, Validating, & Rehearsing Command Plans For Conducting Lunar Mapping & Other Experiments
DSPSE LTT OPERATIONS

Issues & Concerns: (Page 1 of 2)

- Contamination Of Sensors From Kick Motor Residue
- Time For Electrical Components To Outgas Before Turn On To Prevent Arcing
- Need To Turn Off Sensor & Spacecraft Systems While Passing Through The Van Allen Belts
- How Do We Manage The SSR Dumps So We Don't Lose Data During Blind Downlinks?
- Coordination With DSN & RTS When They Are Needed For Uplink.
  - Interfaces & Procedures For Interfacing With The DSN Are TBD.
- Engineering Data Storage Formats & Downlink Schedule Needs To Be Developed
  - Will Not Have Continuous Downlink At All Times
  - Not Practical To Require Continuous Downlink - A Store & Dump Method Of Operations Is More Practical
- Kick Motor Observation Issues/Questions Need To Be Resolved
DSPSE LTT OPERATIONS

Issues & Concerns: (Page 2 of 2)

- How Will The Activity Scenarios Be Carried Out? I.E. What Scenario Will Be Used For Structuring & Uploading Command Scripts?
  - Event Driven Or Time Driven
  - Events & Times Via Upload Or Based On On-Board Computed Data? Or Combination Of Both?
- How Much On-Board Processing Is Required?
  -- Star Tracker
  -- Moon, Earth, TGS, Sun Pointing Vector Propagation
  -- Camera Integration Times & Gains
  -- Closed Loop Tracking