DSPSE Asteroid Flyby Operations

Command & Control:

- Visibility Between The Spacecraft & A Given Ground Station Averages ~13 Hours
  - There Will Be No RF Blockages
  - There Will Be No Sun Shadow Transversals

- The Pomonkey Ground Station Will Continue To Be The Primary Command & Control Ground Station With DSN & The AFSCN Asset As Possible Secondary Sites Until The Spacecraft Is ≈ 2 Million Km From The Earth (About June 15).

- Beyond ≈ 2 Million Km, NASA's DSN Will Provide Telemetry, Tracking, & Command Communication Links.
  - The DMOC Will Send Its Command Sequences To The DSN For Uplink To The Spacecraft. (Interfaces & Procedures Are TBD)
  - The DSN Sites Will Also Receive Telemetry Via The Omni & High Gain Antennas & Route This Data To The DMOC.
    -- To Avoid Continuous DSN Support, The S/C Will Store Engineering Data For TBD Interval & Then Dump The Stored Data
    -- Range & Range Rate Data Will Be Obtained Whenever Omni Uplink or Omni/High Gain Downlink Is Scheduled
    -- Starting At 5 Hours Before The Flyby, Will Receive Continuous Omni Downlink Data AT 125 BPS (Except ± 10 Minutes Of The Actual Flyby)
  - The TGSs Will Not Be Able To Receive Telemetry Nor Command The Spacecraft Directly
Pre-Flyby To Flyby Overview:

- The Transition From The Transfer Trajectory Phase To The Approach Phase Will Occur \( \approx 5 \) Days Before The Spacecraft's Closest Approach To Geographos.

- The Main Task To Be Performed Is The Acquisition Of Images & Range Data Immediately Before & After The Time Of Closest Approach Of The Spacecraft & Geographos.

  - The Spacecraft Sensors Will Be Used To Take Images & Collect Laser Ranging Data As The Spacecraft Approaches & Recedes From The Asteroid.

  - The Distance Of Closest Approach Between The Spacecraft & Geographos Will Be Between 80 Km & 200 Km.

  - Based On A Closing Velocity Magnitude Of \( \approx 11 \) Km/Sec, & Sensors Characteristics, The Total Time Interval During Which The Sensors Can Be Used To Make Resolved Images Will Be \( \approx +/\!-600 \) Seconds & \( \approx +/\!-60 \) For Laser Ranging

- The Spacecraft Will Flyby Geographos On About 31 August 1994, At A Distance From Earth Of \( \approx 8 \) Million Km.

Flyby Rehearsals:
- There Will Be 2 Flyby Rehearsals Covering The Final 4 Hours Of Activity To Test Operations Procedures & Measure The S/C Response To Slew Rates.
  - The S/C Will Be Oriented So The +Z Axis Is Pointed At A Simulated Geographos Location, & Will Rotate About Y Axis During The Flyby.
  - Simulated Images From UV/Vis & LWIR Are Routed To The R3000 For Processing. (New Software Requirement?)
  - Simulated Image Centroids From The R3000 Are Given To The 1750A Guidance Processor To Compute Required Attitude (Quaternions & Body Rates) Which Are Then Passed On To The ACS Which Compares Commanded Vs Actual Attitude & Generates Required Torquing Commands
  - The Spacecraft Will Record Sensor Images Of The Region Around The Simulated Geographos Location, Point The High Gain Antenna (-X Axis) Towards Earth, & Dump The Images Along With Stored Engineering Telemetry
  - Ground Operations Personnel Will Process & Analyze The Images & Telemetry To Assess The Flyby Geometry
  - The Flyby Imaging Sequence For The Sensors Occurs +/- 600 Sec Around The Simulated Point of Closest Approach
  - The Flyby Imaging Sequence For Laser Ranging Occurs +/- 60 Sec Around The Simulated Point of Closest Approach, At A 1 Hz Rate
  - After The Batteries Have Charged, Data Will Be Dumped To Earth
DSPSE Asteroid Flyby Operations

Major Pre-Flyby & Flyby Activities: (Page 1 of 4)

- ≈ 24 (TBD) Hours Before Flyby, A Final Trajectory Correction Will Be Made Based On Radiometric & Ground Based Analysis of S/C Camera Images Along With Geographos Orbit Updates.
  - Prior To This Time, Other Mid Course Corrections Will Have Been Made
  - The Plan Is To Make An 80%ΔV Burn, Determine New Trajectory, & Make A Final 20% ΔV Burn
  - Actual Time Of Final Burn Sequence Depends On Fuel Budget, Availability Of Geographos Orbit Updates, & Time Required For JPL To Determine New Trajectory Between the 80% & 20% ΔV Burns

- Starting At ≈ 24 Hours Before Flyby, The Spacecraft Will Collect 10 - 20 Image Sequences Of The Region Around Geographos' Expected Location Using All Non-Star Tracker Sensors For ≈ 10 Minutes, Change Its Attitude To Point The High Gain Antenna To The Earth, & Downlink These Images.
  - This Sequence Will Be Repeated ≈ Once An Hour Until ≈ 12 Hours Before Closest Approach When The Interval Will Be Decreased To ≈ Once Every 30 Minutes
  - Rotation Will Be ≈ 50° About The Y Axis To Point High Gain Antenna (-X Axis) To Earth. This Will Take Between 100 To 200 Seconds Using Reaction Wheels Only
  - Because Rotation Is About Y Axis, The Solar Incidence Angle Will Be Maximized During This Time
DSPSE Asteroid Flyby Operations

Major Pre-Flyby & Flyby Activities: (Page 2 of 4)

• Geographos Is Expected To Be First Visible In The LWIR Camera At \(\approx 10\) To 12 Hours Before Closest Approach.
  
  - Narrow Field Of View May Preclude Adequate Star Backgrounds For Identification.

  - After Geographos Is Identified By The LWIR, Its Location From Other Sensors Images Will Be Examined.

  - Changes In Its Size & Intensity From Different Camera Images Will Be Monitored To Provide Final Information For The Closed Loop Tracking During The Closest Approach.

  - Early Attempts To Determine Range To Geographos Will Be Based On Intensity Changes.

• At \(\approx 4\) Hours, The UV/Vis Camera Should Begin To Be Able To See Geographos

  - A Gradual Handoff Will Take Place Between The LWIR & UV/Vis Cameras; Comparing R3000 Computed Centroid Data.

  - When Satisfied With The UV/Vis Geographos Location, Then It Will Be Prime For Close Loop Tracking

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DSPSE Asteroid Flyby Operations

Major Pre-Flyby & Flyby Activities: (Page 3 of 4)

• Combined LWIR, HiRes, & UV/Vis Image Centroids From The R3000 Are Given To The 1750A Guidance Processor To Compute Required Attitude (Quaternions & Body Rates) Which Are Then Passed On To The ACS Which Compares Commanded Vs Actual Attitude & Generates Required Torquing Commands
  - Beginning 3 Hours Before Flyby, Frequent (≈ Once Every 15 To 20 Minutes - TBD) Image Taking & Dumping Sequences Will Occur To Verify Closed Loop Tracking Robustness & The Reacquisition Of Geographos
  - Engineering Data Will Contain The Computed Relative State.

• Final Instructions Will Be Transmitted To The Spacecraft ≈ 1 Hour Before Closest Approach.
  - The Autonomy Will Occur Through The Closed Loop Tracking Control Of The Orientation Of The Spacecraft.
    -- Orientation Of The Spacecraft For Flyby Will Be Such That Rotation About Only One Axis (Y Axis) Is Required.
  - Delayed Execution Commands Will Control The Sensors & Data Storage.
DSPSE Asteroid Flyby Operations

Major Pre-Flyby & Flyby Activities: (Page 4 of 4)

- Onboard Control of Tracking Will Use The UV/Vis Camera, With Possible Hand-Over Between Sensors (HiRes Or LWIR)
  - Filter Wheel Movements For The Controlling Camera Will Be Coordinated During Portions Of The Fly By So They Will Not Disrupt Tracking
  - Imaging Will Be Carried Out By All Cameras With Image Sequencing Driven by Science and Pointing
  - Solar Array Autotrack Will Be Disabled For \( \approx 10 \) Minutes During The Imaging Sequence
  - The Flyby Imaging Sequence For The Sensors Occurs +/- 600 Sec Around The Point of Closest Approach
  - The Flyby Imaging Sequence For Laser Ranging Occurs +/- 60 Sec Around The Point of Closest Approach, At A 1 Hz Rate
  -- If Valid Ranging Data Is Obtained, It Will Be Used By The Onboard Pointing Control To Predict Required Slew Rates & Use These Predictions In The Control Algorithms.

- If Expected Slew Rates Are Too High, The Spacecraft Will Be Commanded To Point At The Selected Spot That Geographos Is Expected To Fly Through & Take Images & Try To Reestablish Closed Loop Tracking There.
## DSPSE Asteroid Flyby Operations

### Timeline (1 of 2)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Days to Flyby</th>
<th>Date</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Lunar Swingby</td>
<td>96</td>
<td>5/27/94</td>
<td>Determine orbit</td>
</tr>
<tr>
<td>Tracking Of S/C</td>
<td>96</td>
<td>5/27/94</td>
<td>Correction burn as needed</td>
</tr>
<tr>
<td>Trajectory Correction</td>
<td>95</td>
<td>5/28/94</td>
<td>Rehearse for the 1st flyby simulation.</td>
</tr>
<tr>
<td>Test Bed Simulation</td>
<td>90</td>
<td>6/1/94</td>
<td>Simulate flyby operations activity &amp; exercise S/C dynamics</td>
</tr>
<tr>
<td>Flyby Simulation Using S/C</td>
<td>89</td>
<td>6/2/94</td>
<td>Based on simulation change S/C models, image sequence, etc.</td>
</tr>
<tr>
<td>Update Test Bed &amp; Flyby Planning</td>
<td>89</td>
<td>6/3/94</td>
<td>Determine orbit</td>
</tr>
<tr>
<td>Tracking Of S/C</td>
<td>88</td>
<td>6/4/94</td>
<td>Correction burn as needed</td>
</tr>
<tr>
<td>Trajectory Correction</td>
<td>88</td>
<td>6/4/94</td>
<td>Determine limit of detectability for each camera</td>
</tr>
<tr>
<td>Instrument Sensitivity Tests</td>
<td>86</td>
<td>6/6/94</td>
<td></td>
</tr>
<tr>
<td>Background Star Survey</td>
<td>85</td>
<td>6/7/94</td>
<td>Examine area around Geographos, compare with Customized Catalogue</td>
</tr>
<tr>
<td>DSN Communication Only</td>
<td>77</td>
<td>6/15/94</td>
<td>After 2 million Km only DSN can Communicate.</td>
</tr>
<tr>
<td>Test Bed Simulation</td>
<td>55</td>
<td>7/7/94</td>
<td>Rehearse for the 2nd flyby simulation.</td>
</tr>
<tr>
<td>Flyby Simulation Using S/C</td>
<td>54</td>
<td>7/8/94</td>
<td>Simulate flyby operations activity &amp; exercise S/C dynamics</td>
</tr>
<tr>
<td>Update Test Bed &amp; Flyby Planning</td>
<td>53</td>
<td>7/9/94</td>
<td>Based on simulation, change S/C models, image sequence, etc.</td>
</tr>
<tr>
<td>Tracking Of S/C</td>
<td>53</td>
<td>7/9/94</td>
<td>Determine orbit</td>
</tr>
<tr>
<td>Trajectory Correction</td>
<td>52</td>
<td>7/10/94</td>
<td>Correction burn as needed</td>
</tr>
</tbody>
</table>

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# DSPSE Asteroid Flyby Operations

## Timeline (2 of 2)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Days to Flyby</th>
<th>Date</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begin Geographos ID</td>
<td>5</td>
<td>8/26/94</td>
<td>Take frequent images in HiRes &amp; LWIR</td>
</tr>
<tr>
<td>Intense Tracking Of S/C</td>
<td>4</td>
<td>8/27/94</td>
<td>Produce best orbit based on ground obs.</td>
</tr>
<tr>
<td>Update Geographos Orbit</td>
<td>1</td>
<td>8/30/94</td>
<td>Based on ground based optical &amp; radar data.</td>
</tr>
<tr>
<td>Update Relative S/C To Geographos Position Using S/C Image Data</td>
<td>1</td>
<td>8/30/94</td>
<td>Combine S/C image data with radiometric &amp; Geographos data on the ground.</td>
</tr>
<tr>
<td>Perform Final S/C Targeting Maneuvers</td>
<td>1</td>
<td>8/30/94</td>
<td>Based on latest relative position calculations between S/C &amp; Geographos</td>
</tr>
<tr>
<td>Determine New S/C Trajectory</td>
<td>1</td>
<td>8/30/94</td>
<td>Based on results of burn &amp; range &amp; range rate DSN data</td>
</tr>
<tr>
<td>Update Geographos Orbit</td>
<td>1</td>
<td>8/30/94</td>
<td>Based on ground based optical &amp; radar.</td>
</tr>
<tr>
<td>Upload Latest State Of Relative Positions</td>
<td>1</td>
<td>8/30/94</td>
<td>Used for on board pointing</td>
</tr>
<tr>
<td>Flyby</td>
<td>0</td>
<td>8/31/94</td>
<td></td>
</tr>
</tbody>
</table>
DSPSE Asteroid Flyby Operations

Post Flyby Activities:

• Following The Flyby, Solar Panel Auto Track Will Be Enabled & Time Will Be Allowed For The Batteries To Be Charged

• After The Batteries Have Been Charged, The Spacecraft Will Be Commanded To Point The High Gain Antenna To Earth & Transmit The Stored Flyby Sensor & Engineering Data

• Additional Tests May Be Conducted For A Few Days Or Weeks After The Fly By. Details Of These Tests Are TBD
DSPSE Asteroid Flyby Operations

Power Profiles:

TBD
**Issues & Concerns: (Page 1 of 2)**

- **How Fast Can We Do The Orbit Determination & Get A New Ephemeris To The Mission planners Following Mid Course Corrections**
  - Time Is TBD, JPL To Supply Answer

- **Does The Spacecraft Need To Verify A DSN Site Is Ready To Receive Before Beginning The Wide Band Downlink?**
  - DSN Site Will Have Two Way Communications So Can Be Locked Up On The Carrier Before Commanding The Downlink

- **Can Commands Be Uplinked To The Spacecraft During A Wide Band Downlink Via The High Gain Antenna?**
  - Yes ??.

- **Coordination With DSN & RTS When They Are Needed For Uplink.**
  - Interfaces & Procedures For Interfacing With The DSN Are TBD.

- **Time Of Combined Sensor On Time & Transmitter On Time Is 3 - 4 Hours Prior To The Flyby. Can EPS & Thermal Subsystems Support This Length Of On Time?**
Issues & Concerns: (Page 2 of 2)

- How Will The Flyby Scenario 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 Is Closed Loop Tracking Accomplished?
- How Much On-Board Processing Is Required?
  -- Star Tracker
  -- Moon, Earth, TGS, Sun Pointing Vector Propagation
  -- Camera Integration Times & Gains
  -- Distance To Geographos
- Storage Of Engineering Data Formats & Downlink Schedule Needs To Be Developed
- Flight Software Capability To Supply Simulated Images & Resulting Centroid Data In Support Of Simulations