DSN Capabilities To Support Multi-Purpose Crew Vehicle (MPCV) Program - Exploration Missions (EM-1 & EM-2) -

ESA-JPL TIM
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Wallace Tai, Caltech/JPL
<table>
<thead>
<tr>
<th><strong>Forward Link Data Service – Key Attributes</strong></th>
<th><strong>Remark</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency Bands</strong></td>
<td>Near-Earth S-band</td>
</tr>
<tr>
<td><strong>Antenna Types</strong></td>
<td>34m BWG, 34m HEF</td>
</tr>
<tr>
<td><strong>Polarizations</strong></td>
<td>RCP or LCP; No RCP/LCP simultaneity</td>
</tr>
<tr>
<td><strong>Modulation Types</strong></td>
<td>BPSK directly on carrier (no ranging); SS-UQPSK (with ranging)</td>
</tr>
<tr>
<td><strong>Forward link Data Rate</strong></td>
<td>Maximum 256 kbps; Minimum 7.8 bps</td>
</tr>
<tr>
<td><strong>Forward Error Correction Code</strong></td>
<td>LDPC rate 1/2; CCSDS Synchronization and Channel Coding (ref. CCSDS 131.0-B-2)</td>
</tr>
<tr>
<td><strong>Data from MOC to DSN</strong></td>
<td>• Stream of AOS frames over a TCP/IP interface; • CCSDS Space Link Extension (SLE) Enhanced Forward CLTU Service (ref. CCSDS 912.11-O-1);</td>
</tr>
<tr>
<td><strong>Data from DSN to Spacecraft</strong></td>
<td>• Encoded AOS frame per CCSDS AOS Space Data Link Protocol (ref. CCSDS 732.0-B-2)</td>
</tr>
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<td><strong>Return Link Data Service - Key Attributes</strong></td>
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<td><strong>Antenna Types</strong></td>
<td>34m BWG, 34m HEF</td>
</tr>
<tr>
<td><strong>Polarizations</strong></td>
<td>RCP or LCP; RCP/LCP simultaneity at some stations</td>
</tr>
<tr>
<td><strong>Modulation Types</strong></td>
<td>OQPSK/SQPSK (no ranging)</td>
</tr>
<tr>
<td></td>
<td>SS-UQPSK, SQPN (with ranging)</td>
</tr>
</tbody>
</table>
| **Return link Data Rate**                   | Maximum: 6 Mbps  
Minimum: 10 bps (> 40 bps recommended for timely acquisition) | Present capability. We understand the EM-1 &-2 maximum rate is 3 Mbps |
| **Forward Error Correction Code**           | LDPC rate 1/2  
CCSDS Synchronization and Channel Coding (ref. CCSDS 131.0-B-2) | New capability, in the DSN plan, but yet to be funded |
| **Data from DSN to MOC**                    | • Stream of AOS frames over a TCP/IP interface;  
• CCSDS Space Link Extension (SLE) RAF/RCF (ref. CCSDS 911.1-R-1.7 and 911.2-R-1.7); On-line timely/On-line complete/Off-line | Present capability |
<p>| <strong>Data from Spacecraft to DSN</strong>             | • Encoded AOS frame per CCSDS AOS Space Data Link Protocol (ref. CCSDS 732.0-B-2) | Present capability |</p>
<table>
<thead>
<tr>
<th>Radiometric Data Service - Key Attributes</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Bands</td>
<td>Present capability</td>
</tr>
<tr>
<td>Antenna Types</td>
<td>Present capability</td>
</tr>
<tr>
<td>Tracking Data Types</td>
<td>Range, Doppler, Angle (mainly for initial acquisition during LEOP)</td>
</tr>
<tr>
<td>Modulation Types</td>
<td>SS-UQPSK, SQPN</td>
</tr>
<tr>
<td>Ranging Type</td>
<td>Pseudo-noise</td>
</tr>
<tr>
<td>Range Accuracy (1σ Error)</td>
<td>1 meter</td>
</tr>
<tr>
<td>Doppler Accuracy (1σ Error)</td>
<td>0.2 mm/s, 60s Compression</td>
</tr>
<tr>
<td>Doppler Measurement Rate</td>
<td>0.1 second</td>
</tr>
<tr>
<td>Data Latency</td>
<td>Doppler/Range: 5 minutes (95%)</td>
</tr>
<tr>
<td>Data Modes (DSN to MOC)</td>
<td>Stream data mode</td>
</tr>
<tr>
<td>Delivery Modes (DSN to MOC)</td>
<td>On-line; Off-line</td>
</tr>
<tr>
<td>Interface standards</td>
<td>CCSDS Tracking Data Messages (TDM) for data contents/format, over NDM (Ref. 1: CCSDS 505.0-B-1 XML specification for navigation data messages);</td>
</tr>
<tr>
<td></td>
<td>Present capability.</td>
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</tbody>
</table>
DSN Support To HSF MPCV
Lunar Missions Coverage Analysis Conclusions

• Requested by JSC MPCV project, a coverage analysis was performed on SCaN network support to MPCV lunar missions: EM1, EM2, L2Flyby, and L2 Waypoint.

• Two sets of most feasibly ground station sites are considered:
  – DSN3: DSN Goldstone, Canberra, and Madrid
  – DSN6: DSN3 plus Usuda, Santiago, and Hartebeesthoek (HBK) stations

• Given the various mission trajectories, the coverage gap is less than 5%:
  – EM-1: DSN3 = 2%, DSN6 = 1.1%
  – EM-2: DSN3 = 4.39%, DSN6 = 3.92%
  – L2Flyby: DSN3 = 0.9%, DSN6 = 0.1%
  – L2Waypoint: DSN3 = 0.4%, DSN+HBK = 0% (100% coverage)

• The difference in coverage gap between DSN3 and DSN6 is less than 1%. The added benefit by additional stations is relatively minor.

• Only one critical event, TCM-4 in EM-2, would fall into the DSN gap. This gap can be eliminated by augmenting the DSN3 with HBK.

• The optimal choice of ground stations to support lunar missions is the 3 DSN sites augmented by HBK. The existing CSIR 13.2m station at HBK seems to be a good candidate.