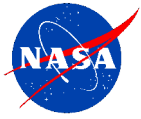


# **Lunar Reconnaissance Orbiter (LRO)**

## **CRaTER Technical Interchange Meeting C&DH Flight Software**

**April 14, 2005**

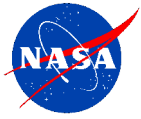


# C&DH Software Overview

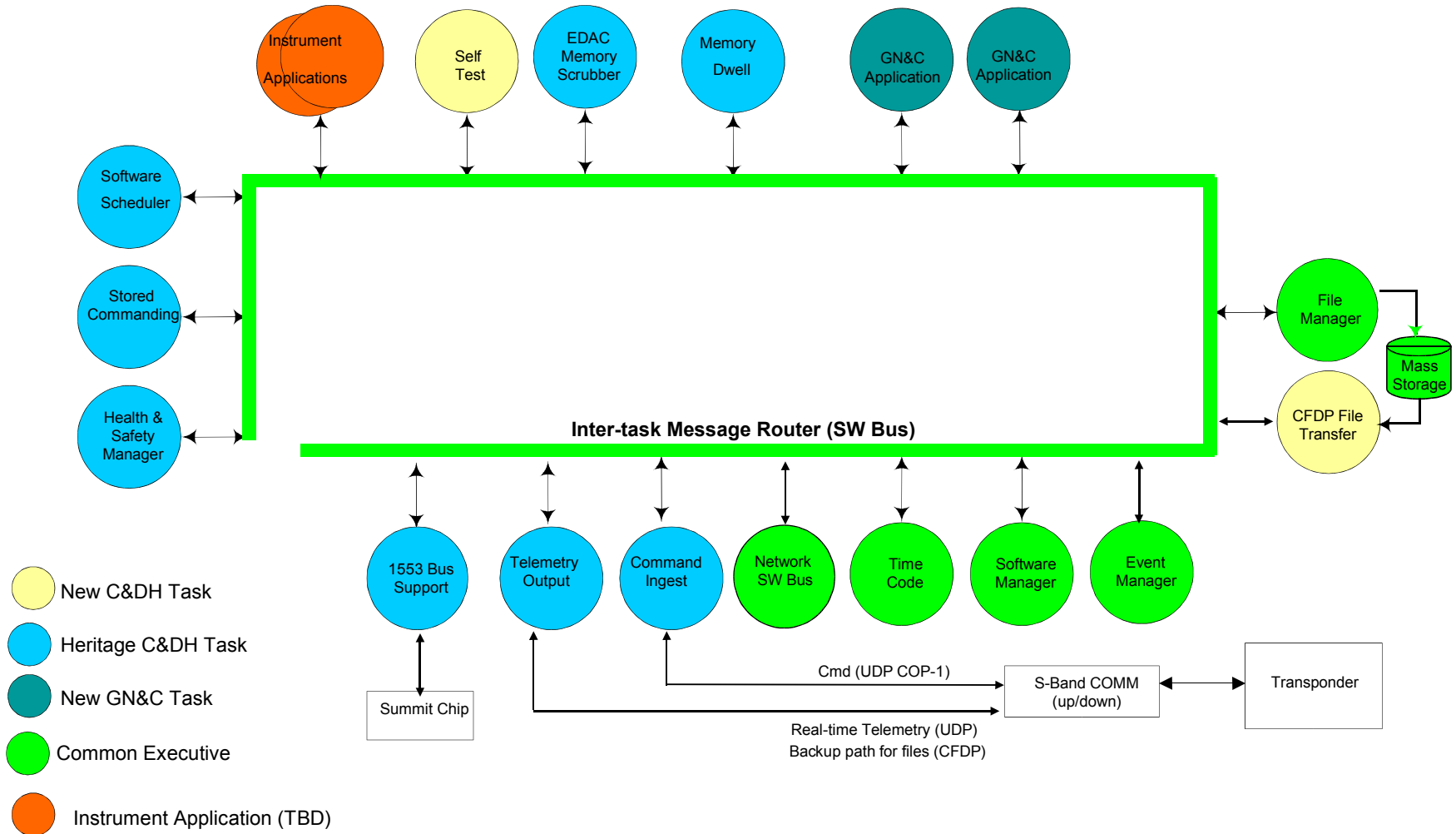


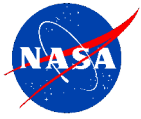
- Command and Data Handling (C&DH) includes the following functions:
  - Decoding ground commands and distributing them to other subsystems
  - Running time-tagged command sequences
  - Collecting housekeeping data from other subsystems
  - Sending HK data to the ground in real-time telemetry and to the SSR for storage
  - Collecting science data from instruments and formatting it (if necessary) for storage in the SSR
  - Distributing time information to other subsystems
  - Monitoring HK telemetry for problems and initiating recovery actions
  - Hosting the GN&C software applications





# LRO Flight Software Architecture



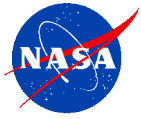


# C&DH Services (1)



- Commanding
  - Commands come in CCSDS packets from the ground in real-time or as time-tagged command sequences
  - Flight software validates cmd's integrity and forwards them to the correct subsystem based on the CCSDS packet's application ID
  - Stored commands may have an absolute time tag or a delay from the previous command (relative time)



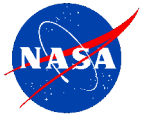


# C&DH Services (2)



- Telemetry
  - Real-time telemetry (housekeeping data) will be formatted as CCSDS packets
  - C&DH can accept and forward packets from other subsystems, or can collect raw data and format it into packets
  - Stored telemetry will be collected into files on the SSR
  - Files may be formatted as a collection of CCSDS packets, or as raw data, or whatever format the users want
  - C&DH can (if desired) add some formatting to data collected from the instruments before it is stored in files
  - Files will be transferred to the ground station and then to the MOC and/or ISC in the same format as they were stored on the SSR



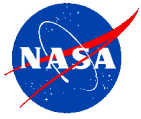


# C&DH Services (3)



- Timing
  - The C&DH will distribute time information to the instruments in two parts
  - A discrete 1Hz pulse will be sent to all users
    - A timing accuracy of 1ms is guaranteed
  - An accompanying message will be sent across the instrument interfaces according to the negotiated ICD
    - “at the tone the time will be....”
    - The message will arrive at the interface to the instrument no later than 100ms before the accompanying pulse
  - We could also distribute pointing and ephemeris info to the instruments, if necessary
- Safing
  - The C&DH can monitor any data point from housekeeping tlm for high/low limit violations
  - Detected violations can trigger a sequence of recovery commands – any commands, with time delays between them
  - More complicated triggers and actions are possible if we include command scripts on LRO





# Solid State Recorder (SSR)



- SSR Hardware
  - The SSR will have a memory capacity of at least 300 Gbits
  - The SSR will handle input rates of 10Mbps(average) and 50Mbps (peak)
  - The SSR's only physical layer interface is 1355b (Spacewire)
- SSR Software
  - The SSR will be a “file manager” and will store all instrument and telemetry data as files
    - Will manage its own memory locations making the absolute address of data transparent to users
    - Will respond to commands such as “create directory”, “open file”, “close file”, etc.
    - Will employ the CCSDS File Delivery Protocol (CFDP) standard for transferring data to the ground





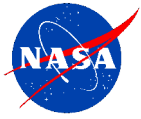
# Instrument-SSR Interface



- Solid State Recorder (SSR) Instrument Options:
  - An instrument with a Spacewire interface can use the services of the SSR directly
    - Adhere to the user interface (“open file”, “write to file”, “close file”, etc
    - Contents of the file is user specific with no format restrictions imposed by the SSR
  - An instrument with no Spacewire interface will employ the services of the C&DH according to an agreed-upon ICD
    - The C&DH will be responsible for storing the files on the SSR
    - File format negotiated between Inst. team and C&DH SW





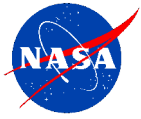


# Stored Data File Transfer



- CCSDS File Delivery Protocol (CFDP)
  - A proven CCSDS Standard employed by LRO for the purpose of the reliable transfer of files to the ground
    - A “negative acknowledge”, or NAK, concept is utilized for the purpose of preserving band-width
    - Multiple files can be transferred concurrently
    - Files are automatically removed on-board once they have been successfully transferred to the ground
  - A CFDP “entity”, or task, resides in the SSR along with a corresponding entity at each ground station
- Internet file transfer protocols (FTP, etc.) will be used once the file is received on the ground
  - File data and format will be maintained through all transfer steps back to the MOC and/or ISC





# ICD Questions



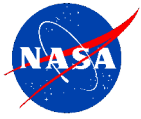
- C&DH-Instrument ICD Questions
  - Command Format
  - Commanding Protocol (timing, #of cmds, RTSs)
  - HK Telemetry Format
  - Data Collection Protocol
  - Stored Data File Format
  - Timing Accuracy
  - Instrument Safing Requirements
  - Additional Processing of Inst Data by C&DH SW





# CRaTER Specifics



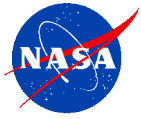


# CRaTER Command Interface



- Physical Interface: Mil-Std-1553, RT Address 16 (TBD)
- Command Size: 2 or 4 bytes
- Command Format:
  - Raw data sent to subaddress 1,8, 16, 17, 18, or 19
  - Sent at 200ms offset from the 1Hz, but only if needed
- Command Rate: 1Hz (max)
- Code/Memory Load Method: N/A
  - No code or memory that can be loaded
- Time Sync Method: 1Hz pulse and time tone message
  - Time Msg sent to SA#1 at 600ms after pulse
  - 32 bit seconds, no subseconds



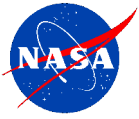


# CRaTER Housekeeping Interface



- Physical Interface: Mil-Std-1553, RT Address 16 (TBD)
- HK Collection Method:
  - S/C reads subaddress 9(TBD) at 400ms offset from the 1Hz
- Housekeeping Size: 44 bytes
- Housekeeping Data Format from Instrument:
  - CCSDS packet header + 32 bytes data
- Housekeeping Data Format to ground:
  - CCSDS packet exactly as read from instrument
- Housekeeping Collection Rate: 1 packet every 16 seconds
- Housekeeping Telemetry Rate: 1 packet every 16(TBD) seconds
- Housekeeping Storage Rate: 1 packet every 64(TBD) seconds



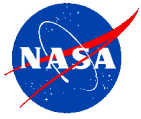


# CRaTER Primary Science Interface

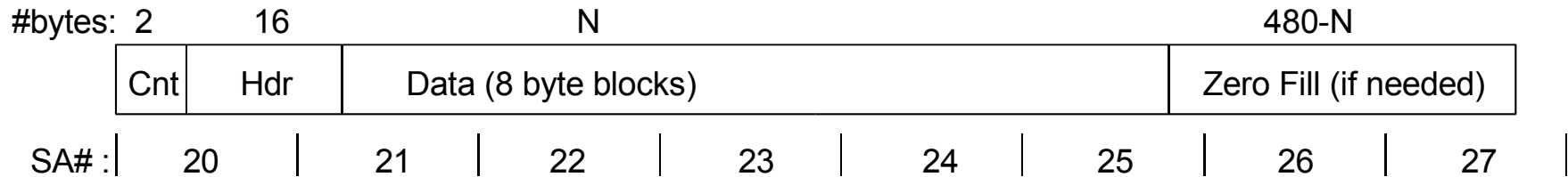


- Physical Interface: Mil-Std-1553, RT Address 16 (TBD)
- Data Collection Method:
  - S/C reads subaddresses 20-27 (TBD) every 40ms
  - First read at 20ms after 1Hz pulse
- Data Format from Instrument:
  - Counter + CCSDS packet header + 480 bytes of data
  - S/C discards data until counter value changes
- Data Size: 498 bytes
- Data Rate: 25Hz
- Data Directory: SSR/CRATER/
- Data File Names: CRnnnnnnn.DAT
- Data Storage Format:
  - CCSDS packets with counter value stripped (mixed with sec. sci. pkts)
  - File closed when it reaches 1MB
  - Can be closed early by command





# Primary Science Format



CRaTER sets Cnt to 0 and fills in Pkt Hdr on initialization

S/C discards data until Cnt changes

CRaTER adds data blocks as events occur

When Pkt is full, CRaTER increments Cnt

Also, at 1Hz pulse, CRaTER fills remaining blocks with 0s, adjusts pkt length field, and increments Cnt

Maximum data rate: 25pkts/sec, 12000 bytes/sec, 96000 bits/sec





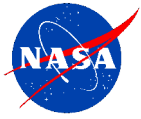
# CRaTER Secondary Science I/F



- Physical Interface: Mil-Std-1553, RT Address 16 (TBD)
- Data Collection Method:
  - S/C reads subaddresses 10 (TBD) every second
  - Occurs at 800ms after 1Hz pulse
- Data Format from Instrument:
  - CCSDS packet header + 8 bytes of data
- Data Size: 20 bytes
- Data Rate: 1Hz
- Data Directory: SSR/CRATER/
- Data File Names: CRnnnnnn.DAT
- Data Storage Format:
  - CCSDS packets (mixed with primary sci. pkts)
  - File closed when it reaches 1MB
  - Can be closed early by command



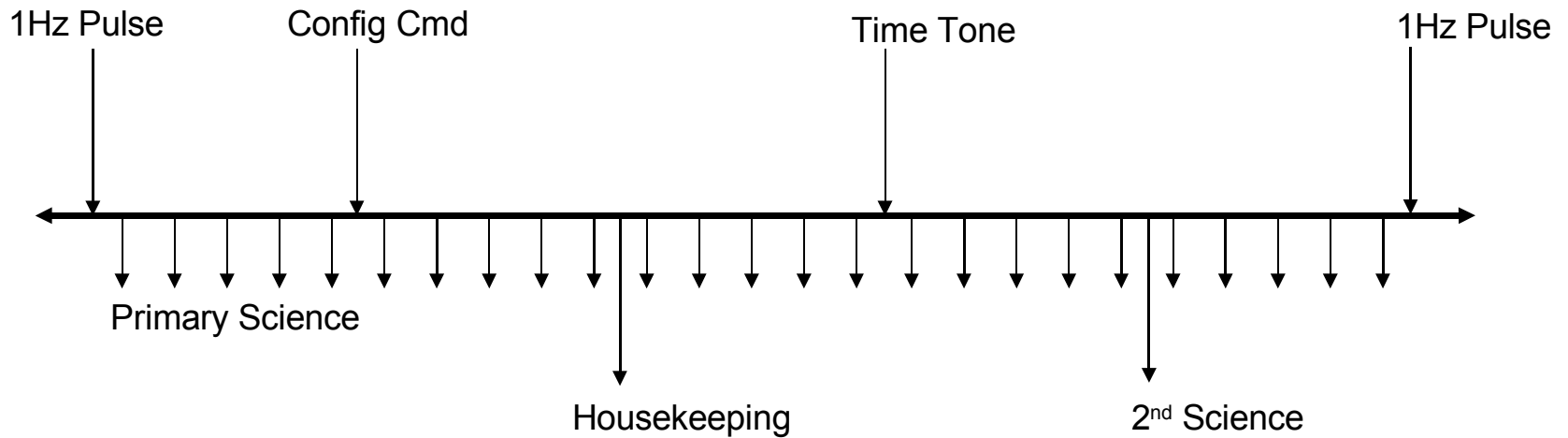


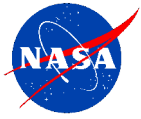


# CRaTER Timing Diagram



## Timing of 1 Second Worth of Transfers:





# Issues to be Worked



- Will CRaTER use ITOS for instrument-level testing?
- Do you need a spacecraft simulator? If so, how soon?
  - Note: The S/C simulator will use ITOS
- Splinter meeting for ICD details?
- Any desired safing actions on the S/C side?

