MINUTES OF MEETING

esa

FIRST/Planck Project

date		reference SCI-PT/–MN–08189	page 1/3
meeting date 19-9-2000		meeting place ESTEC	
chairman S. Thürey			
participants see below		copy T.P., A.H., P.E	
subject 4th Data Management WG Meeting (F/P)			

description		action	due date
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[signatures]

ESTEC
Keplerlaan 1 - NL 2201 AZ Noordwijk ZH - The Netherlands

description	action	due date

Agenda:
see page 1 of attachment 1
(ESA-handout)

Tentative next meeting:
3-11-2000 in Orsay

1) PS-ICD:
detailed points: attachment 1
AI 1: see page 3

2) Satellite Data Bus Protocol
TN ASTRIUM-SI-1042-TN-0001
has been handed over to
Instrument representatives
(attachment 2)
AI 2: see page 3

3) Common procurement of SDB-I/F-Simulator, incl. SDB-Protocol: see page 11 of attachment 1.
The instrument groups intend to ask for quotations from industry

description	action	due date
Action Items		
EGSE-APIDs: Instrument groups are asked to define (in a sufficient level of detail) how S/C-level EGSE-setups are structured, for AVM-, CQM-, and FM-activities. Important point: which Instrument-EGSE-elements are (still) involved, which EGSE-related APIDs.	AI1, all Instr.-groups	19-10-2000
MIL-Bus I/F connectors: ESA to specify the type of connector that shall be used for the Instrument/Stub interface.	AI2, ESA	10-10-2000

3) Common procurement of I/F, continued:

The instrument groups will update ESA about their approach.
The instrument teams expect ESA to give advice and review procurement spec's and test procedures for the items above, and to approve the I/F-Test, which is carried [illegible] the I/F-simulator.

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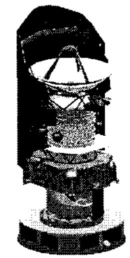


FIRST / Planck Instruments to CDMS Interfaces Working Group

Meeting 4, 19-9-2000, ESTEC

Stefan Thürey SCI-PXI

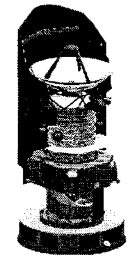
- **Agenda:**

  - 1) Packet Structure ICD: review and clarifications
  - 2) Mil 1553B data bus I/F: status of HW and protocol developments
  - 3) Open issues, action items,AOB

Attachment 1 (11 pages)

1) Packet Structure ICD: Review and Clarifications

- **Comments on selected subjects:**
  - 1) **TC Packet Length:**
    - As **all** Telecommands are potentially released via the Mission Timeline, and an MTL TC header is added to each Telecommand in this case, all Telecommands must **not exceed a total length of 228 octets, TBC.**
  - 2) **TC Verification and Event Packets:**
    - The maximum length for the parameter field shall not exceed 42 octets, for a **total length of the TC packet of less than 64 octets**, in order to allow for fast routing of these packets.

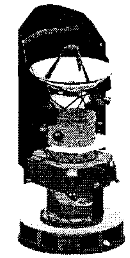


1) Packet Structure ICD: Review and Clarifications, 2

- **In certain areas simplifications will be introduced, as an outcome of an ESA-internal review.**

  - 3) Task Management (Service 7) and Function Management (Service 8):
    - It is now baselined that a certain unit or application shall be able to fulfil all required functionality by interfacing with other applications or the ground by utilising **Service 8 (and 18) only**. In this sense the **Service 7 shall not be used** (for all activities on S/C- and Mission-level).

  - 4) Parameter Fields for Function Management and equivalent services:
    - Variable-length Parameter Fields will no longer be allowed. There are either no parameters delivered in a data field (N = 0), or the nominal set of parameters (with a fixed structure) is sent in a TC or TM packet (N = no. of parameters that follow). In some cases a Structure-ID, SID, will be used, (Perform Activity of Function (8,3)) and Load Function Parameters (8,4)).



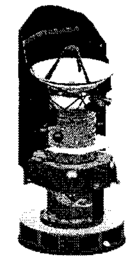
1) Packet Structure ICD:
Review and Clarifications, 3

- 5) Time Management, Service 9:

  - The basic principle will be that a **TM packet with time information** will be handed over to an instrument, **followed by a on-board synchronisation event**/pulse/message, at which this time information is valid.
    - This is different from the way and timing, in which the time synchronisation was done for example on -board XMM, Integral, ENVISAT (using a certain RBI I/F chip), but corresponds more to the way, time synchronisation id performed in various other applications.

  - Independently, **a similar mechanism has been specified on Data Link Layer level** as part of the data bus protocol (SDBP). It is foreseen to distribute a time message each second to all users, which is valid/exact at the start of each next second. A user may or may not pick up this time information for comparison or re-synchronisation. Details are provided in para. 4.3 of Appendix 9 of the PS-ICD.

  - Which of the methods will be adopted as the nominal means of time synchronisation is currently under assessment.



1) Packet Structure ICD: Review and and Clarifications, 4

- 6) On-board Scheduling Service (Service 11):

  - This service will be significantly simplified. No conditional branching within Telecommand sequences will be possible. The only means to test on-board conditions and to react on them according to the outcome of the test will be confined to OBCPs.

    - Instruments are not affected from this change.

- 7) Monitoring Service (Service 12):

  - The principle of this service is that, if a limit, which has been defined for a certain parameter, is exceeded, an Event packet becomes generated by the service, which in turn triggers a TC packet via the Event/Action Service. With this TC packet a corrective action can be executed.
  - This service will be simplified. Instruments are not affected from this change (CDMS-service).

1) Packet Structure ICD: Review and and Clarifications, 5

- 8) Packet Transmission Control, Service (Service 14):
  - Clarification: In contrast to the PUS, which defines the service for "controlling" the routing of TM packets to the Transponder I/F to the downlink, the requirements within the PS-ICD specify how **the generation of TM packets at the source** shall be controlled.
    - A basic principle on-board FIRST and Planck will be that once a TM/TC packet is generated, it will be routed on-board, stored, and eventually downlinked (under nominal conditions).

- 9) On-board Control Procedure Service (Service 18):
  - On-Board Control Procedures (OBCPs) are flight procedures, which are resident on-board of the FIRST or Planck satellite. After activation they are interpreted and executed in the CDMS, and potentially in instrument control units. They serve for controlling processes, which may be active for an extended period of time and which may involve the (conditional) execution of a (longer) sequence of commands.

- **OBCPs have to comply with common requirements on structure, syntax, operability, and maintainability!**

- **Details of the capabilities of OBCPs, their structure and language / interpreter, etc. are TBD.**

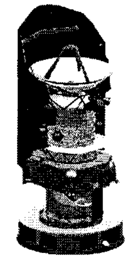
1) Packet Structure ICD: Review and and Clarifications, 6

- 10) **APIDs coded on unit connector (e-mail, K. King, 18-9-2000):**

  - There is no requirement for hardwiring APIDs in a coding-connector of DPUs.
  - However, **this requirement exists for the Remote Terminal Address Field for the data bus**. This address (for all on-board units on the bus) will be specified and frozen only after all usersare known, and the data bus topology, including the physical routing on the spacecraft, is known.

- 11) **Limited number of APIDs for EGSE-use (e-mail, K. King, 18-9-2000):**

  - **APIDs are** per definitionem to be used **for on-board addressing only.**
  - A small range has been made available for EGSE-related use for Instrument-level test activities.
  - These "**EGSE"-APIDs shall not be used during S/C-level integration and test activities**, including potentially AVM- or CQM-activities.
  - If a conflict can be identified between requirements of the space-segment and SCOS-2000 or EGSE-designs, the S/C-related requirements take precedence. Addressing conflicts shall be resolved on EGSE / SCOS 2000 -level, without impact on existing definitions.



2) MIL 1553B Data Bus I/F : Protocol Development

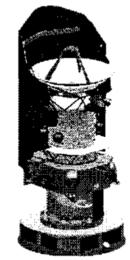
- 1) The **Satellite Data Bus Protocol Specification**.

  - Could be released as Appendix 9 of the PS-ICD on 1-9-2000.

- 2) A **Technical Note on the "Common Data Bus Protocol",** ASTRIUM-SI-IO42-TN-0001, issue 2B, is handed over to instrument groups. It provides a description of the protocol (identical to the SDBP), together with performance assessments, implementation hints, and suggestions for testing and verification.

- 2) An overview of the technical approach, using this document, will discuss:

  - Timing of the bus protocol
  - Packet Transfer
  - Supporting Lower Layer Control Functions



Satellite Data Bus Protocol, Basic Structure

- Three communication protocol layers (in reference to ISO - OSI) are covered:
  - 1) **Physical Layer:**
    - All electrical characteristics like signal levels, waveform timing, transformer parameters are directly according to MIL Std. 1553 B.
  - 2) **Data Link Layer**: All relevant parameters are specified in the Protocol Spec:
    - Timing on message level
    - RT addresses, subaddresses
    - Command Words, Mode Commands and their usage
    - Structures of Data and Status Words, Flag bits
    - FDIR for this layer
  - 3) **Transfer Layer:**
    - Synchronisation and timing for message and block / packet transfer
    - Buffer allocations
    - Handling of special TM / TC packets like Event packets.
- The basic timing is designed around a periodic scheme with **64 subframes each second / frame**. In most of them one maximum-length TM packet can be transferred, and other activities like TC packet delivery, polling, handling of short packets, etc. take place additionally.

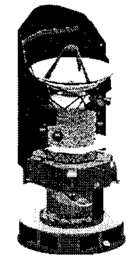
3) Open Issues, Action Items

1) The Project Office has updated para. 5.11.1 of the IID-A:

"Instruments, which are not the prime instrument for a certain observation, shall not exceed a TM rate of 2kbps each. "

> **AI from last WG-meeting: Instrument groups to comment / approve**

2) Mission Control will ensure in any case that the allocated average data rate per user, i.e. the agreed fraction of **100kbps over 24 hours for FIRST (Planck: currently under review) is not exceeded**. This may be done by stopping the science mode of a certain instrument or by terminating the recording/retrieval of Science TM packets.



3) Open Issues, Action Items

3) Central Procurement of a CDMS I/F Simulator

- **Considerations:**
  - ⇨ All instruments need this simulator as Instrument-level EGSE I/F.
  - ⇨ It would help to avoid miss-interpretations in the actual I/F implementations.
  - ⇨ Requirements for this unit: It has to act as an interface between SCOS 2000 and the instrument.
  - ⇨ For practical reasons it can consist of commercially available hardware like a PC with a 1553 plug-in board, which can be bought by each experimenter.

  - ESA assumes that each instrument consortium has made an allocation for funding and other resources, within the allocation for the EGSE development, for the design and production of this I/F simulator and associated (protocol-) SW.

  - Up to mid-1999 there was no confirmed baseline existing for this interface; for the data protocol not even a working assumption could be made. ESA therefore assumes that the resource allocations include a sufficiently large margin for the involved development risk.

- **Recommendations:**
  - The instrument groups should combine their efforts and agree on a common approach for the development of this EGSG I/F unit, among others covering:
    - ⇨ common requirement specification
    - ⇨ funding from each party, procurement, subcontracts
    - ⇨ lead-function, responsibility for design, etc., up to timely delivery.

  - **ESA would like to ask the PI or PM of each instrument group to make a proposal how each group intends to proceed.**

Attachment 2
(44 pages)

astrium

Dok. Nr./No:	ASTRIUM-SI-IO42-TN-0001		
Ausgabe/Issue:	2	**Datum/Date:**	07.08.2000
Überarbtg./rev:	B	**Datum/Date:**	04.09.2000

(cover page only attached to MoM)
SCI-PT-08191

Titel:
Title: Common Data Bus Protocol

Dokumenten Typ:
Document Type: Technical Note

Dokumentenklasse:
Document Class:

Dokumentenkategorie:
Document Category:

Klassifikations-Nr.:
Classification No.:

Konfigurations-Nr.:
Configuration Item No.:

Produktklassifizierungs-Nr.:
Classifying Product Code:

Freigabe Nr.:
Release No.:

Bearbeitet: A. Hein Prepared by:	**Org. Einh.:** IO42 Organ. Unit:	**Unternehmen:** Astrium Bremen Company:
Geprüft: R. Kledzik Agreed by:	**Org. Einh.:** IO42 Organ. Unit:	**Unternehmen:** Astrium Bremen Company:
Genehmigt: Approved by:	**Org. Einh.:** Organ. Unit:	**Unternehmen:** Company:
Genehmigt: Approved by:	**Org. Einh.:** Organ. Unit:	**Unternehmen:** Company: Agency:

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Dokumentenklasse:
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Klassifikations-Nr.:
Classification No.:

Dokumentenkategorie:
Document Category:

Konfigurations-Nr.:
Configuration Item No.:

Produktklassifizierungs-Nr.:
Classifying Product Code:

Freigabe Nr.:
Release No.:

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DCR Daten/Dokument-Änderungsnachweis/Data/Document Change Record

Überarbeitung Revision	**Datum** Date	**Betroffener Abschnitt/Paragraph/Seite** Affected Section/Paragraph/Page	**Änderungsgrund/Kurze Änderungsbeschreibung** Reason for Change/Brief Description of Change
1	19.07.2000	all	Draft
2	7.08.2000	all	New issue
2A	15.08.2000	Footer Figure 5.4-1 Chapter 3.1.1 Chapter 3.1.2 Table 4.5.3-1	Change see DAR 2 Change see DAR 2 Update of Reference to Specification column Update of Reference to Specification column Asterisk was missing
2B	04.09.2000	Table 4.5.2-1, Chapter 4.9: new paragraph, Editorals, various pages	Revew by ESA

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1. Introduction

1.1 Scope

The environment for the Common Data Bus Protocol (CDBP) is a spacecraft carrying several instruments which are connected via a serial data bus according to MIL-STD-1553B Bus to the Data Management Subsystem.

A common interface specification is established within this document, which is binding for all units on-board, that exchange data across the data bus. This document is the basis for covering all necessary aspects, which enables a party to design, develop, and test this interface as part of a certain unit in a way, that it communicates properly together with other units of the spacecraft after integration.

This specification is made applicable for the corresponding S/C interfaces of the experiments, for S/C Service Module units the corresponding details of the data bus and the protocol are to be agreed upon during Phase B activities. As all detailed I/F requirements for these units are naturally TBD at the time of the release of the FIRST/Planck ITT, the protocol specification below must be incomplete and has placeholder requirements in several cases.

1.2 Purpose

This TN will propose a detailed technical concept for a synchronous data transfer protocol which is in line with the system-level requirements and compliant with the MIL 1553 B standard.

It implements an analysis of the system level requirements and converts them into detailed requirements for the three main protocol levels (Physical, Data Link, and Transfer Layer)

It provides an analysis in order to demonstrate that the performance requirements are met, and identifies critical areas and implementation alternatives with their consequences for performance.

As a result of this TN a detailed design of the protocol specification will be described.

Furthermore a test and validation approach for the protocol, which can be applied by each independent user, will be given with this TN.

Requirements, which are to be covered in an electrical I/F specification separately from the protocol specification will be identified.

1.3 Conventions

- **Subaddresses**

Subaddress naming in the following chapters is done by using this arrangement:

Subaddress + Number (used range 1-30) + **T**ransmit or **R**eceive

Example :
SA 10 R - has the meaning: Subaddress Number 10 Receive

- **Meaning of RT**

The meaning of RT (Remote Terminal), which is according to the MIL STD 1553B only the bus I/F, encloses in the following chapters the RT and also the attached subsystems, host controllers and so on. Exceptions are explicitly mentioned.

- **Meaning of BC**

The meaning of BC (Bus Controller), which is according to MIL STD 1553B the bus master only, encloses in the following chapters the BC bus I/F and the Host Controller, and the applications and services behind the BC bus I/F.

1.4 Acronyms

ACMS, AOCS	Attitude & Orbit Control Subsystem
AD	Applicable Document
BC	Bus Controller
CCSDS	Consultative Committee for Space Data Systems
CDBP	Common Data Bus Protocol
CDMS	Command and Data Management Subsystem
ESA	European Space Agency
FDIR	Fault Detection, Isolation and Recovery
H/K	House Keeping
H/W	Hardware
I/F	Interface
ICD	Interface Control Document
kbps	kilobits per second
LSB	Least Significant Bit
MSB	Most Significant Bit
PDU	Power Distribution Unit
PSS	Procedures, Specifications and Standards
RD	Reference Document
RT	Remote Terminal
S/C	Spacecraft
SA	Subaddress
TBC	To Be Confirmed
TBD	To Be Determined
TC	Telecommand
TCS	Thermal Control System
TM	Telemetry

2. Applicable and Reference Documents

2.1 Reference Documents

RD 1

FIRST / PLANCK Instrument Interface Document – Part A F/P –IID, Part A

PT-IID-A-04624, Draft 0 / 2   15/02/2000

RD 2

FIRST / PLANCK Packet Structure Interface Control Document PS-ICD

SCI-PT-ICD-07527, Draft 1   22/05/2000

RD 3

ESA Packet Telemetry Standard

PSS-04-106, Issue 1, 1988

RD 4

ESA Packet Telecommand Standard

PSS-04-107, Issue 2, 1992

2.2 Applicable Documents

AD 1

MIL STD 1553 B, Notice 2

DIGITAL TIME DIVISION COMMAND/RESPONSE MULTIPLEX DATA BUS

AD 2

MIL-HDBK-1553A, Multiplex Data Bus Applications Handbook (Section 100)

Department of Defense, 1.11.1988

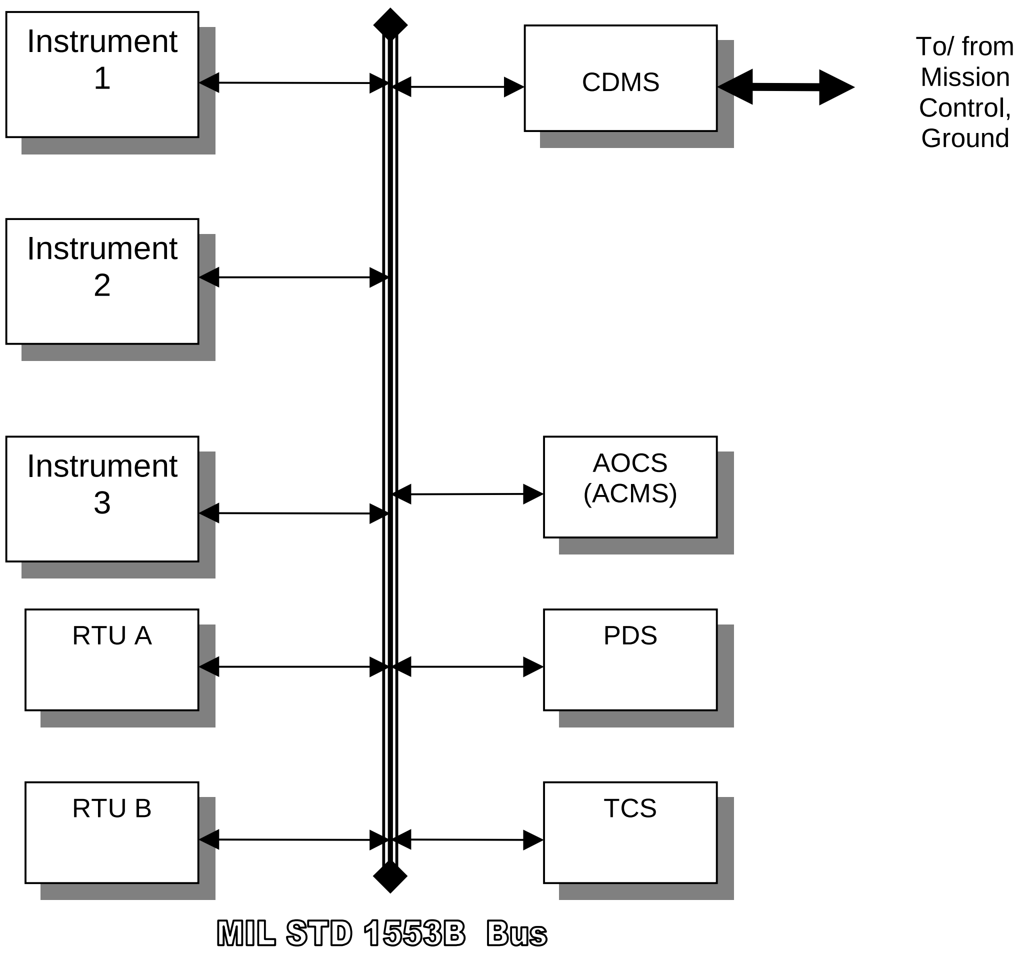
3. Technology Description

This document defines a data transfer protocol for a common on-board communication architecture, which is based on a serial data bus according to MIL-STD 1553 B. A typical reference architecture is shown below in figure 3-1.

On this data bus all data are to be routed between instruments, the Attitude Control and Measurement Subsystem (ACMS), RTUs for commanding and monitoring, PDUs for power distribution and the CDMS, as required for the various types of data. The bulk of these data will be formatted into TM- or TC-Packets according to the relevant ESA / PSS Standards (see chapter 2 RD list) , additionally several control and status messages are to be exchanged.

This TN covers all necessary aspects, which enable the design, development and test of the bus interface.

Figure 3-1: Reference Spacecraft Architecture



3.1 Requirements

Requirement ID numbering in order to separate requirements for RT and BC. Requirement ID 1xxx numbering for RT and BC , 2xxx numbering for BC and 3xxx numbers for RT only.

3.1.1 Functional requirements

Require-ment ID	See Specif.	SOW Ref.	
1000	2005	1.1	The on-board data bus interface circuits shall be according to MIL Std. 1553B
1010	2005 2010	1.2	The spacecraft data bus shall provide redundant, AC-coupled signals to the instruments.
2000	3005	1.3	The (redundant) Command and Data Management System (CDMS) shall act as Bus Controller (BC),
3000	3040	1.3	All other instruments connected to the data bus shall act as Remote Terminals (RTs).
Headl.	-	1.4	The CDMS shall at least support the following services across the data bus:
2020	4245	1.4.1	Routing of TM and TC Packets according to FIRST/Planck PS-ICD (SCI-PT-ICD-07527) and control messages
2030	4305	1.4.2	Distribution of time synchronisation and time information to all users.
2040	4445	1.4.3	Sending of short asynchronous TC-Packets for special instruments control functions
2050	3020	1.4.4	Sending of Broadcast Messages for system ancillary data.
2060	3385	1.4.5	Monitoring of the bus traffic and associated reporting is high level CDMU function. The bus protocol shall provide FDIR messages and other status information
2070	3025	1.5	All packet transfers on the data bus shall be controlled by the CDMS (BC).
Headl.	-	1.6	All other users shall support the services listed above as Remote Terminals, and to the extent the services are needed by a certain user. Optional RT services are:
3020	3180	1.4.1	Routing of TM and TC Packets according to FIRST/Planck PS-ICD (SCI-PT-ICD-07527) and control messages
3030	4310	1.4.2	Processing of time synchronization and time information.
3040	4450	1.4.3	Receiving of short asynchronous TC-Packets for special instruments control functions
3050	3075	1.4.4	Receiving of Broadcast Messages for system ancillary data.
3060	3270	1.4.5	Providing of FDIR messages and other status information
3070	4450	1.6.1	Reception of asynchronous short TC-Packets *(64 octets)*,
3080	3052	1.6.2	Reception of Broadcast Messages.
2080	4100	1.7	The data bus protocol shall have a deterministic, periodic structure, which is synchronised with the central on-board time, implemented in the CDMS.
1020	4085	1.8	Each on-board user shall be served in a quasi-periodic way for at least two times per second.

3.1.2 Performance Requirements

Require-ment ID	See Specif.	SOW Ref.	
1030	2015 2020	2.1	Coupling of users to the data bus via stubs longer than 30 cm shall be possible.
1040	4010	2.2	Maximum throughput for all users shall be at least 350 kbps on TM/TC packet level.
1050	see below	2.3	The minimum latency for a single user between the end of a packet transfer and the start of a new transfer of the same type (TM or TC) shall be 4 ms.
1051	4015		change of requirement 1050. See chapter 4.2
1060 1061	4020 4025 4030	2.4	The maximum size of TM-Packets shall be 1024 octets, for TC-Packets the maximum size is 248 octets. - The TM/TC-Packets may have variable length.
1070	4040	2.5	One complete packet shall be exchanged with a user without interruptions for the user (Remote Terminal).
1080	4045	2.6.1	The Data Bus Interface Protocol shall support each second the exchange of at least 50 TM-Packets
1090	4050	2.6.2	The Data Bus Interface Protocol shall support each second the exchange of at least 16 TC-Packets
1100	4060	2.6.3	The Data Bus Interface Protocol shall support each second the exchange of at least 1 time synchronization
1110	4065	2.6.4	The Data Bus Interface Protocol shall support each second the exchange of at least 2 asynchronous TC-Packets, with a maximum length of 64 octets, addressed independently to dedicated buffers within RTs.
1120	4070	2.7	The accuracy for timing and synchronization across all on-board systems up to the data interface of users shall be better than 100 microseconds TBC
1130	see below	2.8	The routing latency of an asynchronous TC-Packet, according to Req. 2040, from the CDMS to the input buffer of a RT shall be below 100 microseconds.
1131	4075		change of requirement 1130. See chapter 4.2
1140	4910	2.9	The CDMS shall control the TM data rate of a maximum of ten users by adjusting the actual data rates according to allocated bandwidths on a 2 second timescale. The bus protocol has to generate the necessary support information for the high level bus traffic control function of the CDMS (example: packet length of all transfers).No further capabilities needed.

3.2 Operational modes

For sizing of the bus traffic the maximum throughput requirements are relevant.

Typical scenarios for operation are given in table 3.2-1, see below. The maximum data rates are listed, the average values are about 20% smaller.

User / Case	AOCS	RTU A	RTU B	PDS	TCS	Instrument 1	Instrument 2	Instrument 3
A	4	2	2	1	1	120	20	20
B	4	2	2	1	1	60	60	20
C	4	2	2	1	1	300	20	20
D	4	2	2	1	1	150	150	20

Table 3.2-1: Bus load scenarios A to D. All values in kbps.

Independently from the maximum data rates, the maximum number of TM-Packet transfers per second is important for the layout of the data bus protocol.

Not all TM packets have maximum size and requirement 1020 must be taken into account for the allocation of subframes to users.

The table below shows the quantity of packets per user. This will be taken as baseline for data bus throughput calculations.

Beside the data TM packets the capability of sending two Event Messages per second must be supported.

User / Case	AOCS	RTU A	RTU B	PDS	TCS	Instrument 1	Instrument 2	Instrument 3
A	1	1*	1*	1**	1**	16	3	3
B	1	1*	1*	1**	1**	8	8	3
C	1	1*	1*	1**	1**	40	3	3
D	1	1*	1*	1**	1**	20	20	3

Note: Only TM packets are shown (all cases include two Event Messages).

1*) one packet in 2 seconds, 1**) one packet in 4 seconds

Table 3.2-2: Bus load scenarios A to D. Data packets per second.

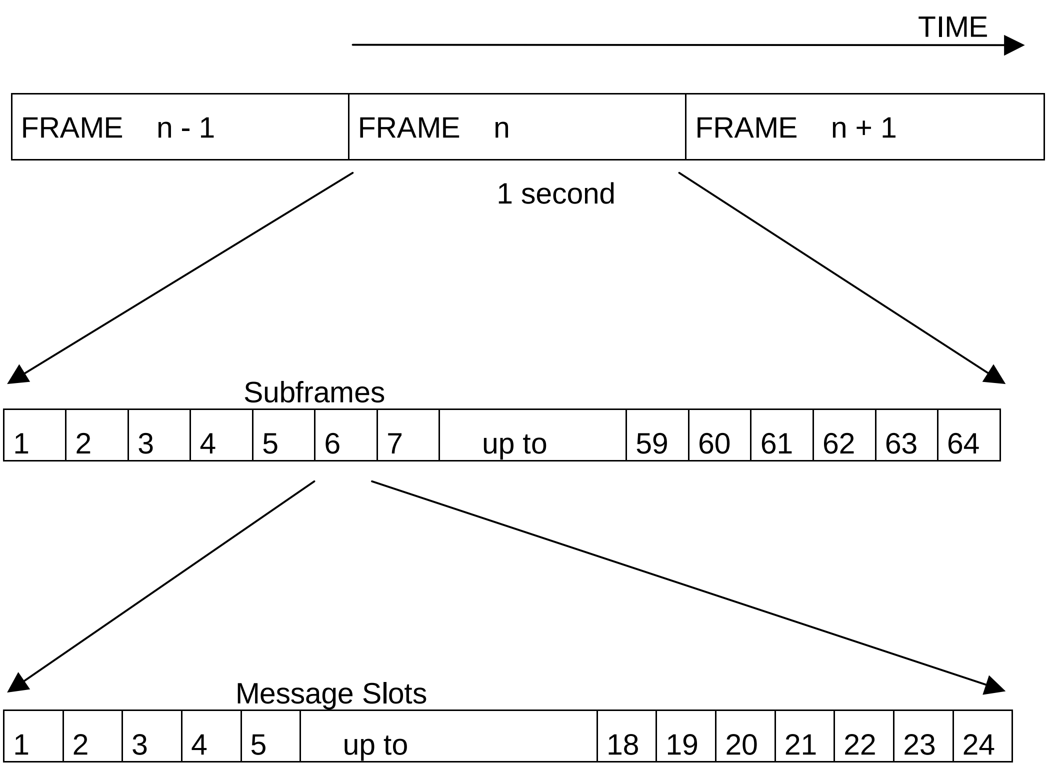
4. CDBP Basic consideration and definitions

4.1 Timing

The CDBP is based on a 1 second period called frame. This frame is divided into 64 subframes, each containing a number of MIL STD 1553B messages. These messages will occur in a subframe within a defined timing structure called message slots.

The TM packet transfer from instrument to the CDMU is subframe oriented. This means the Instrument data packet shall fit into the subframe boundaries.

Figure 4.1-1: Data Bus profile



Definition:

1 FRAME = 64 SUBFRAMES; 1 SUBFRAME = 24 MESSAGE SLOTS

1 FRAME = 1 second long

1 SUBFRAME = 1/64 second long

1 Slot = see table 4.1-1

Table 4.1.-1: Message Slot allocation Table

SLOT No.	Content/ Purpose	Duration in micro seconds
1	Subframe synchronisation *1)	150
2	Command/ Acquisition Slot	750
3	Command/ Acquisition Slot	750
4	Command/ Acquisition Slot	750
5	Packet transfer	750
6	Packet transfer	750
7	Packet transfer	750
8	Packet transfer	750
9	Packet transfer	750
10	Packet transfer	750
11	Packet transfer	750
12	Packet transfer	750
13	Packet transfer	750
14	Packet transfer	750
15	Packet transfer	750
16	Packet transfer	750
17	Packet transfer	750
18	Packet transfer	750
19	Packet transfer	750
20	Packet transfer	750
21	Packet control (e.g. polling)	150
22	Packet control	150
23	Packet control	150
24	Regulation Slot *2)	$\leq$ 775

Notes:

*1) Subframe synchronization: In the first Subframe every second the Mode Command Sync distributed as broadcast message will be used. In all other subframes the broadcast message Mode Command Sync with Data Word will be utilized.

*2) The remaining slot time is sufficient to provide one asynchronous command insertion between any other slot without discarding the following slots. The slot time of slot No. 24 will be reduced in accordance with the asynchronous event.

4.2 Discussion on requirements

See Requirements list, table 4.1-1 and table 4.1-2.

Requirements:

1000, 1010, 1030, 2000, 2070, 3000

Discussion:

These requirements are related to the physical layer . This is covered by the MIL STD 1553B.

Conclusion: These Requirements will be covered by reference to MIL STD 1553B.

Requirement:

1080	2.6.1	The Data Bus Interface Protocol shall support each second the exchange of at least 50 TM-Packets

Discussion:

There are 64 subframes in one second, each one is able to carry one TM packet with maximum size.

Assuming: for system internal use there are 4 subframes reserved and not available for TM packet transfers.

The remaining 60 subframes allow for the insertion of 60 TM packets in total. Low-level command capability and RT polling is possible besides TM data transfer within the same subframes.

Conclusion: Design is compliant to requirement No. 1080

Requirements:

1040	2.2	Maximum throughput for all users shall be at least 350 kbps on TM/TC packet level.

1060 1061	2.4	The maximum size of TM-Packets shall be 1024 octets, for TC-Packets the maximum size is 248 octets. - The TM/TC-Packets may have variable length.

Calculation:

- For TM packets:

60 subframes out of 64 subframes are available for TM packet transfer.

60 subframes X 1 packet = 60 subframes X 1024 Byte X 8 Bit = 491,520 kbps

Additional possible Low Level commanding:

60 frames X 3 Command Slots = 64 frames X 3 X 32 words X 16 Bit = 98,304 kbps

- For TM packets:

At least 4 subframes out of 64 subframes are reserved for TC packet transfer.

4 frames X 16 Command Slots = 4 frames X 16 X 32 words X 16 Bit = 32,768 kbps

In total the (theoretical) values for packet transfer are:

- TM packets = 491,520 kbps and
- TC packet = 32,768 kbps.

Required throughput capability is 350 kbps on TM/TC packet level.

Conclusion: Design will be compliant to requirement No Req. 1040 .

Requirement:

1050	2.3	The minimum latency for a single user between the end of a packet transfer and the start of a new transfer of the same type (TM or TC) shall be 4 ms.

Calculation:

A packet of 1024 Bytes fit into 16 MIL Bus messages (each with 64 Bytes).

The duration of a 32 word message is 750 micro seconds.

Remaining time in a subframe: 15,625 msec - (16 messages X 0,750 msec) = 3,625 msec

The required latency is 4 msec but the remaining time in a subframe is only 3,625 ms.

This is too short to allow an user the packet transfer within consecutive subframes.

So data transfer for one user is only possible in every second frame.

But this will reduce a user dedicated data rate of 262,144 kbps.

<u>This is not sufficient for scenario C</u> (see chapter3.2).

Astrium recommended to change the minimum latency time and the requirement 1050.

New value shall consider the insertion of:

- one asynchronous command (750 µs)
- allowed jitter (+- 5 µs TBD)

Calculation: 3,625 ms - 0,75 msec - 0,005 msec = 2,87 msec

<u>New value shall be smaller 2,87 msec</u>

Conclusion: Change of requirement 1050 necessary. Changed requirement has Req. ID 1051.

1051	2.3	The minimum latency for a single user between the end of a packet transfer and the start of a new transfer of the same type (TM or TC) shall be 2,5 ms.

Requirement:

1120	2.7	The accuracy for timing and synchronisation across all on-board systems up to the data interface of users shall be better than 100 microseconds TBC

Discussion:

Equipment which is BC shall be designed that the internal Master Clock shall trigger the BC framing. (E.g. the DDC MIL Bus I/F hybrids do support this feature.)

For testing purpose the BC shall provide the Master Clock pulse to a test I/F.

Conclusion:

Proposed change of wording: The BC shall send a Broadcast Mode command (Sync) latest 100 (TBD) micro seconds after the trigger event (1sec) from master clock.

Requirement:

1130	2.8	The routing latency of an asynchronous TC-Packet, according to Req. 2040, from the CDMS to the input buffer of a RT shall be below 100 microseconds.

Discussion:

This requirement is supporting the distribution of asynchronous events.

100 microseconds is shorter than the duration of a 32 words MIL bus message slot.

Therefore it is not possible to fulfill this requirement.

It has been agreed with ESA that requirement is changed from 100 microsecond to 1 millisecond.

1131	2.8	The routing latency of an asynchronous TC-Packet, according to Req. 2040, from the CDMS to the input buffer of a RT shall be below **1 milliseconds**.

Assuming the AOCS is the source of the event, which may be the spin flag or the target flag event. These events are not predictable!

To acquire this event via 1553 Bus the BC has to poll the AOCS and has to process the answer. Then the BC has to distribute it on the Bus. This has to be done faster than 1 millisecond

Note: A message slot duration is 750 micro seconds.

This will block the whole data transfer on the bus. No other communication is possible!

Another model is possible.

If this asynchronous event is known to the BC by any other scenario except acquisition via the bus, the BC has to insert this command into the bus communication immediately, provided an ongoing message is not aborted. The BC must have the capability to insert a message in an current transfer sequence very fast.

Assuming the designer will make use of a DDC Chip (ACE/ Mini ACE Series BC/RT/MT Advanced Communication Engine Integrated 1553 Terminal (used in enhanced mode)), implemented in the BC Bus I/F, and he will use the BC stop-on-message feature, it shall be possible to insert an asynchronous message in an current frame.

But it must be investigated by the BC designer if it is possible to meet the 1 ms requirement and if it is possible to continue the interrupted frame without a corrupted packet transfer. See requirement 1070.

From the bus protocol side it is possible to reserve a message slot for asynchronous commands. Based on the timing there will be an accuracy of 1 frame (15,625 ms).

This is above the required value, and if this command distribution is time critical it is recommend not to use the MIL Bus and provide a dedicated I/F, or implement an additional signal via the clock I/F. The MIL Bus communication is based on a deterministic behavior and unpredictable command insertion is a difficult operation.

Requirements:

1070, 1140, 2020, 2030, 2040, 2050, 3020, 3030, 3040, 3050, 3060, 3070, 3080

Discussion:

These requirements will be introduced to the CDBP specification.

Conclusion:

No relevant impact to throughput or performance expected. Will be covered in physical and data link layer.

Requirements:

1020, 1080, 1100, 1110, 2080

Discussion:

Due to the 64 subframe transfer model there are available message slots for:

Low Level commanding 64 x 3 = 192 message slots = 12288 Byte/s

TM/TC packet data transfer 64 x 16 = 1024 message slots = 65536 Byte/s

polling 64 x 3 = 192 message slots

others (e.g. time message) are using the services above.

Conclusion:

The bus throughput capability and performance will be sufficient.

Requirement:

1090		2.6.2	The Data Bus Interface Protocol shall support each second the exchange of at least 16 TC-Packets

Discussion:

Due to the size of TC packets it is possible to transfer up to 4 TC packet within one subframe.

Because there are 4 subframes reserved for TC packet transfer it is guaranteed that 4 x 4 = 16 TC packets can be transferred within one second.

Conclusion: Design is sufficient for requirement No. 1090.

4.2.1 Summary on Requirement Review

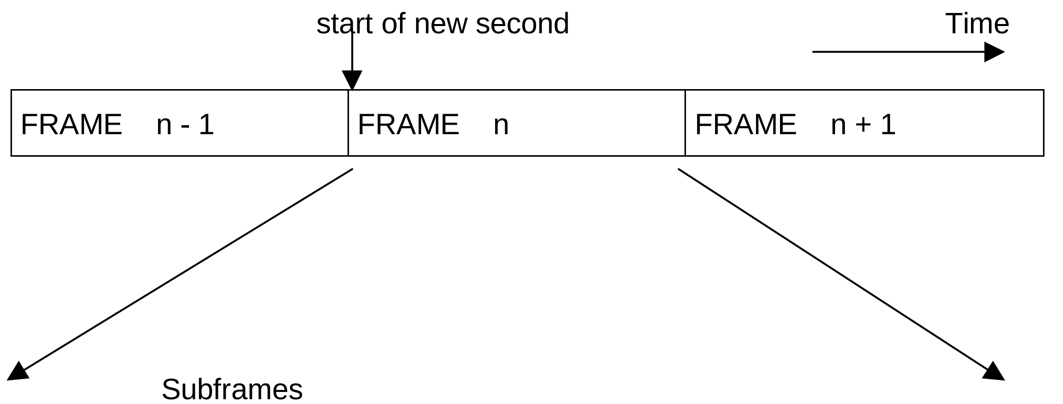
The CDBP is a adequate way to fulfill the given requirements see chapter 3.1.

Because of MIL Bus timing restrictions the requirements No. 1050 and 1130 are changed after discussion with ESA. After these changes it can be stated that the CDBP is compliant to the mission requirements.

4.3 CDBP description

4.3.1 Framing

One second is divided into 64 Subframes.



1.*	2.	3.	...	16.	**17.**	18.	...	32.	**33.**	34.	...	48.	**49.**	50.	...	64.
0	1	2		15	**16**	17		31	**32**	33		47	**48**	49		63

Subframe Count

Figure 4.3.1-1: Subframe and Subframe count

*) The first subframe every second start with the Mode Command "Sync without Data word" in the first message slot. This subframe is reserved and no instrument TM data transfer is allowed.

This provides time for the instrument internal processes like clock/ time maintenance.

Subframes 1, 17, 33,49 are reserved for TC packet transfer.

In Subframe 33 the time information is distributed.

The remaining Subframes (60 out of 64) are used for packet transfers etc.

The mode command "Sync with Data word" is inserted into the first message slot of Subframes 2 to 64.

The data word is containing the RT Address of the instrument data which will be acquired in this frame .

4.3.2 Frame synchronization by BC

The first subframe starts with the Broadcast *Mode Command Synchronize* transmitted in the first message slot .

All other subframes start with the Broadcast Mode Command *Synchronize with Data Word* transmitted in the first message slot .

The attached data word format is as shown below.

Figure 4.3.2-1 : Subframe Synchronize messages

<u>Broadcast *Mode Command Synchronize*</u>

MIL BUS COMMAND

Sync	*RT Address*	*T/R*	*SA*	*Mode code*	*Parity*
	11111	1	00000	00001	

<u>Broadcast *Mode Command Synchronize with Data Word*</u>

MIL BUS COMMAND

Sync	*RT Address*	*T/R*	*SA*	*Mode code*	*Parity*
	11111	0	00000	10001	

DATA WORD

Sync	Subframe user	Reserved bits	Subframe count	*Parity*
	5 bit	6 bit	5 bit	

- Subframe user

In the Subframe user field the RT address of the RT is transmitted to which this subframe is allocated. This is only additional information and should not be interpreted as command or enable signal by a RT.

- Subframe count field

The Subframe count field is transmitted by the BC in accordance to chapter 4.3.1.

4.4 Time distribution

The BC provide system time information via the MIL bus. The time information is a broadcast message (received by all RTs) send to SA 8.

The layout of this message is shown in figure 4.4-1.

The time information send in the 33.subframe, Subframe count is equal to 32. The time information is in compliance to the time at beginning of the next frame. Reference is the beginning mid of sync pattern of the mode command *Synchronize*.TBC
The relative accuracy of the Bus Distributed Time is max. 100 micro second w.r.t. the system time of the BC.

The time format is CUC-TAI, Coarse Time using 4 octets and 2 octets for Fine Time (subseconds).
Bit times :

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20

Bit # (Bit Position) :

S	S	S	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	P

MIL 1553 B Command Word:

Sync	RT Address (= 31)	T/ R =0	Subaddress (= 8)	Data Word Count (= 4)	P

Data Words:

	MSB	LSB	
Sync	reserved set to "0000 0000"	P-Field "0010 1110"	P
Sync	T-Field : Coarse Time	T-Field : Coarse Time	P
Sync	T-Field : Coarse Time	T-Field : Coarse Time	P
Sync	T-Field : Fine Time	T-Field : Fine Time	P

Figure 4.4-1 : Time Distribution Broadcast Message

4.5 General rules for RTs

4.5.1 Subframe counter

Each RT shall support an internal subframe counter and shall provide the value for BC access .

By receiving of the first subframe of the 1 second frame the subframe counter shall be set to 0 and the RT shall increment this value by one with every received Sync with Data Word command.

This function is TBC, depending on instrument performance.

Note: This feature is useful for at least following reasons:

- By using this feature the BC is informed if a RT with the unit behind is alive or not. The presence of MIL Bus communication gives only information about the bus I/F being running but no information about the host behind the I/F.
- A Broadcast Sync message, which was corrupted during its transmission on the bus, can not be detected by the BC. Each RT which receive an invalid message will ignore it. But by comparing of an RT internal subframe count value with the distributed one the missing Subframe Sync can be detected an associated procedures can be started. The implementation is instrument/user-dependant.

4.5.2 Subaddress (SA) allocation

Each RT shall support this common SA allocation.

Table 4.5.2-1: SA utilization table

Subaddress (dez)	Transmit **T**	Receive **R**
0	reserved for Mode command	reserved for Mode command
1	Unit status data	Unit control
2	Data send	Data receive
3	Data send	Asynchronous Short Command 1
4	Data send	Asynchronous Short Command 2
5	Event Message TM - A	Event Message TM - A acknowledge
6	Event Message TM - B	Event Message TM - B acknowledge
7	Data send	Data receive
8	Internal Time TBD	Time Messages
9	Data send	Data receive
10	TM Packet Transfer Request	TM Packet Transfer Confirmation
11	TM Data send MSB	TC Data receive MSB
12	TM Data send	TC Data receive
13	TM Data send	TC Data receive
14	TM Data send	TC Data receive LSB
15	TM Data send	Data receive
16	TM Data send	Data receive
17	TM Data send	Data receive
18	TM Data send	Data receive
19	TM Data send	Data receive
20	TM Data send	Data receive
21	TM Data send	Data receive
22	TM Data send	Data receive
23	TM Data send	Data receive
24	TM Data send	Data receive
25	TM Data send	Data receive
26	TM Data send LSB	Data receive
27	TC Packet Transfer Confirmation	TC Packet Transfer Descriptor
28	Low Level Command - Status	Low Level Command
29	Data send	Data receive
30	Data Wrap read	Data Wrap write
31	reserved for Mode command	reserved for Mode command

4.5.2.1 Mode command (SA 0, 31)

Mandatory for all RTs, shall be compliant to AD 1 (MIL STD 1553B).

4.5.2.2 Unit status data (SA 1T)

Via this SA the H/K data and status data about the unit and its provided data is transmitted.

4.5.2.3 Unit control (SA 1R)

Via this SA unit related commands are transferred.

4.5.2.4 Asynchronous Short Command 1, 2 (SA 3R, 4R)

Small Asynchronous Telecommand Packets, only one message long, are send to this SA.

4.5.2.5 Event Message TM - A, B (SA 5T, 6T)

If the instruments generates Event TM packets with a length not longer than 64 octets, these SAs are used for the exchange.

4.5.2.6 Event Message TM - A, B acknowledge (SA 5R, 6R)

The BC informs the RT about the Event messages acquisition by sending an acknowledge message to this SA.

4.5.2.7 Internal Time (SA 8T)

This SA is reserved for a read of the internal time and RT clock status of a unit. Note: This function may be only for troubleshooting purpose, TBC.

4.5.2.8 Time messages (SA 8R)

By using this SA the time information is distributed on the bus. The time message is send as broadcast message to all RTs.

4.5.2.9 TM Packet Transfer Request (SA 10T)

The RT provides via this SA its request for a TM packet transfer.

4.5.2.10 TM Packet Transfer Confirmation (SA 10R)

The BC places here, after reading the TM packet from the RT, the handshake message.

4.5.2.11 TM Data send (SA 11 - 26T)

This SA is containing the TM data.

4.5.2.12 TC Data receive (SA 11 - 14R)

This SA is containing the TC data.

4.5.2.13 TC Packet Transfer Descriptor (SA 27R)

To this SA the BC send the control words to inform the RT about the presence of a new TC packet.

4.5.2.14 TC Packet Transfer Confirmation (SA 27T)

The RT places here, after reading the TC packet from the BC, the handshake message.

4.5.2.15 Low Level Command (SA 28R)

This SA is used for low level commanding of RTs.

4.5.2.16 Low Level Command - Status (SA 28T)

This SA is reserved for supporting a low level command execution status.

4.5.2.17 Data send (SA 2, 3, 4, 7, 9, 29T)

Not used Transmit SA.

4.5.2.18 Data receive (SA 2, 7, 9, ,15 – 26, 29R)

Not used Receive SA.

4.5.2.19 Data Wrap read (SA 30T)

SA used for test purpose, see AD1and AD2.

4.5.2.20 Data Wrap write (SA 30R)

SA used for test purpose, see AD1 and AD2.

4.5.3 Mode Commands

Table 4.5.3-1 shows a list of Mode Commands with the corresponding patterns. For description and meaning of mode commands see AD1.

Table 4.5.3-1 Mode Commands

Mode Command	Pattern (bin)	Assigned SA (bin)	See AD 1 § No.:	Supported by : BC	S/C RTs non intelli-gent	S/C RTs	Instru-ment RTs
Dynamic Bus Control	00000	00000	4.3.3.5.1.7.1	NO	NO	NO	NO
Synchronize (without data word) *)	00001	00000	4.3.3.5.1.7.2	YES	YES	YES	YES
Transmit Status Word	00010	00000	4.3.3.5.1.7.3	YES	YES	YES	YES
Initiate Self-test **)	00011	00000	4.3.3.5.1.7.4	YES	YES	YES	YES
Transmitter (TX) Shut-Down	00100	00000	4.3.3.5.1.7.5	YES	YES	YES	YES
Override TX Shut-Down	00101	00000	4.3.3.5.1.7.6	YES	YES	YES	YES
Inhibit Terminal Flag	00110	00000	4.3.3.5.1.7.7	YES	YES	YES	YES
Override Inhibit Terminal Flag Bit	00111	00000	4.3.3.5.1.7.8	YES	YES	YES	YES
Reset Remote Terminal **)	01000	00000	4.3.3.5.1.7.9	YES	YES	YES	YES
Transmit Vector Word	10000	00000	4.3.3.5.1.7.11	YES	YES	YES	YES
Synchronize (with data word) *)	10001	00000	4.3.3.5.1.7.12	YES	YES	YES	YES
Transmit Last Command	10010	00000	4.3.3.5.1.7.13	YES	YES	YES	YES
Transmit BIT (Built-In Test data) Word **)	10011	00000	4.3.3.5.1.7.14	YES	YES	YES	YES
Selected TX Shut Down (SD)	10100	00000	4.3.3.5.1.7.15	NO	NO	NO	NO
Override Selected TX SD	10101	00000	4.3.3.5.1.7.16	NO	NO	NO	NO
Remaining Possible Command pattern (reserved for future use)	all other	00000	4.3.3.5.1.7.10 4.3.3.5.1.7.17	N/A	N/A	N/A	N/A

*) These Mode Commands are used as Broadcast Commands

**) According to the MIL1553B Standard, the Remote Terminal on the bus is not the total unit/equipment connected to a MIL Bus, but the interfacing circuitry only (e.g. MIL Bus chip set or H/W including the necessary buffers). E.g. the ‚Reset Remote Terminal‘ command described in the MIL 1553B Standard, does not reset the unit/equipment itself, but the interface only. The MIL Bus chip set only is affected, not the host unit.

4.6 TM Packet Transfer

4.6.1 General

The CDMS BC will be commanded by ground to activate one of several predefined fixed bus profiles. Each bus profile defines the function of all 64 subframes, which belong to a cyclic 1 second frame. Each profile is capable to handle the data throughput of one of the traffic scenarios A,B,C or D (and their permutations), see chapter 3.2.

Each set-up is static for a longer period of time (typically static for some hours). All instruments will be commanded independently into modes, in which they stay below their allocated maximum data rates.

The actual size of TM packets (and TC packets) may vary from packet to packet (within limits of max size and max rate).

The key event for RT activities (and BC activities) for each packet transfer is the Subframe Sync (with or w/o Data Word), which may start RT internal cyclic processing.

Each packet transfer is controlled by the exchange of a Packet Transfer Request and a Packet Transfer Confirmation message.

Each sender, BC or RT, of data provides two parameters together with the packet:

- The number of needed messages for the transfer of a packet
- The number of words in the last message (equal to the word count pattern of a MIL Bus Command).

Each receiver utilizes this information to re- assemble the packet.

Congruent TM packet transfers of a single user are not allowed. If there is more than one packet to be send they have to be queued and send sequentially by the RT.

Event packets/messages are independent from nominal TM transfers and are possible in parallel with TM packet transfers, provided they are shorter than or equal to 64 octets in length.

All messages belonging to one TM packet are transferred within one subframe. Packets with maximum size (1024 octets) should be used for high throughput efficiency, if possible.

4.6.2 Transfer Request from the RT

The RTs are indicating their need for a TM Packet transfer by utilizing SA 10T.

Table 4.6.2-1: Layout of the Packet Transfer Request words

1. Data word (Packet size)				2. Data word (Packet Control, Event handling)					
(3 Bit)	(5 Bit)	(3 Bit)	(5 Bit)	(1 Bit)	(1 Bit)	(1 Bit)	(2 Bit)	(3 Bit)	(8 Bit)
Reserved ´000´	No. of messages for next packet	Reserved ´000´	No. of Data Words in the last message of next packet	Event A	Event B	Burst Mode	Flow control	Reserved ´000´	Packet count

- Reserved bits

These bits are reserved for later use. The bits are set to zero.

- No. of messages for next packet

This data field indicates the number of messages needed for the packet the RT is intending to send in the next subframe. The first message of a TM Packet is always stored at SA 11T, in accordance to table 4.5.2-1: SA allocation.

- No. of Data Words in the last message of the next TM Packet

This data field indicates the number of data words transmitted in the last message of the TM Packet. In case of 32 words this field is set to "00000"B.

Data packets always have a size of n x 16 Bit. Because they are build out of a even number of bytes there is no fill area foreseen.

- Event fields

Event A:

0 - no event message pending

1 - event message is pending, BC is asked to read associated SA and to confirm the acquisition.

Event B:

0 - no event message pending

1 - event message is pending, BC is asked to read associated SA and to confirm the acquisition.

- Burst Mode

0 - Nominal Mode

1 - Burst Mode

- Flow control

Meaning of Flow Control pattern:

00 - No transfer pending

01 - Transfer is pending

10 - reserved

11 - Transfer is finished (this pattern is used by BC only)

- Packet count

This field is used to support a RT-generated counter. By using a counter, which is incremented with every new request, and which is returned to the RT after a successful transfer, the RT is able to detect the completion of a specific TM packet transfer, even if successive packets are identical in size.

To avoid that after a RT initialisation or reset an identical packet number will be used (causing a deadlock), there is one number foreseen for that case. This number does never appear in the cyclical transmission; it is skipped in the normal sequence.

No check on (the completeness of) the sequence will be performed by the BC depending on the Packet Count value.

4.6.3 TM Packet Transfer Confirmation from BC

The RT, which request a packet transfer, must be able to make a decision if the packet transfer was performed and the next packet data can be load to the message buffers. The RT can be informed about every bus transfer from its bus I/F, but this method produces considerable effort (additional interrupts and polling of I/F). Also, an invalid data transfer to the BC will not be recognized.

More reliable is the “packet transfer with handshake” method. After a successful packet transfer the BC sends a handshake signal to the sending RT. This handshake informs the RT which packet was transmitted, even in the case of consecutive transfers of packets with identical size, by returning the Packet Count Field of the last RT TM Packet Transfer Request.

The layout is shown in the table 4.6.3-1, see below.

Table 4.6.3-1: Layout of the TM Packet Transfer Confirmation words

1. Data word (Packet size)				2. Data word (Packet Control)					
(3 Bit)	(5 Bit)	(3 Bit)	(5 Bit)	(1 Bit)	(1 Bit)	(1 Bit)	(2 Bit)	(3 Bit)	(8 Bit)
Reserved ´000´	No. of messages of the last TM packet	Reserved ´000´	No. of Data Words in the last message of the last packet	Reserved ´0´	Reserved ´0´	Burst Mode	Flow control	Reserved ´000´	Packet count

The first data word is a duplication of the first Packet transfer request control word from the RT:

- Reserved bits
- No. of messages of the last TM Packet =
  RT: Number of messages for next packet

- No. of Data Words in the last message of the last packet =
  RT: Number of Data Words in the last message of the next TM Packet

The second data word contains all necessary information for the handshake purpose:
No event handling is performed via this data word. All other bits are set to zero.

- Burst Mode

This bit will not be changed by the BC. It stays as it was set by the RT.

- Flow control

The Flow Control pattern is set by the BC to:
11 - Transfer is finished

- Packet count

This field is identical to the packet count field of the last correctly acquired TM Packet.

4.6.4 TM Packet acquisition mechanism (RT to BC)

- Initialization

The Ground/ Mission Control prepares the BC for a predefined bus traffic profile, thereafter the BC starts the polling of the RTs.

The polling rate is depending on the operational modes, see 3.2.

At least one subframe before the next scheduled packet transfer from a certain RT starts, the RT is asked if there is a need for a transfer. This will be done by reading the RT TM Packet Transfer Request message from (SA 10T).

The RT requests a TM packet transfer (RT to BC) by setting the Flow control bits in the TM Packet Transfer Request.

- Packet Delivery

If a packet transfer request was issued, the BC will acquire this TM packet within the next subframe, using as many transmit message commands as requested by the RT. After the valid transmission (no error occurred) the BC sends the predefined confirmation message to the RT, see chapter 4.6 .

The RT will check the content of the confirmation message at the latest after beginning of the next Subframe (receiving of the next *Mode Command Synchronize with or without data word*).

If the transfer is confirmed by the BC ,the RT prepares the next data packet transfer.

- End of Transfer

In case there is no new TM packet pending the RT will set the first word of the Packet Transfer Request message to ´0000 0000´B. The packet count value of the second word stays unchanged. The Burst Mode bit and the Flow Control Field bits are set to zero.

- Burst Mode

In the case of traffic scenario C, see chapter 3.2, the needed data throughput for one RT is so high that several consecutive subframes will be used to acquire the TM data from this RT. This reduces the time for command sequence generation by the BC and for the buffer management of the RT (During normal transfers there is always at least one subframe in between two transfer-subframes for a certain RT.)

The RT uses a special mode with fixed TM packet sizes. Due to the need of a high throughput these TM packets shall have their maximum size (No time needs to be spent to determine the actual length of a last message).

To indicate this special mode and to inform the BC that no dynamic packet size allocation will happen for the next transfers, the Burst Mode is indicated by setting the bit in the Burst Mode Field of the TM Packet Transfer Request Words (see chapter 4.6).

After the BC has acquired a TM Packet Transfer Request message, the BC will acquire in one of the following subframes the TM packet (SA 11T to SA 26T) and will copy the RT TM Packet Transfer Request Words belonging to this TM packet to SA 10R as a confirmation. In the Burst Mode, the BC polls the RT by reading the RT TM Packet Transfer Request Words (SA 10T) immediately after the confirmation of the last TM packet.

The BC will not check the validity of the packet transfer and will not support any retry on packet level.

In the Burst Mode the RT provides an updating of the TM Packet Transfer Request (SA 10T) and the TM Packet Transfer messages (SA 11T to SA 26T) according to following timing.

In the Burst Mode the TM Packet Transfer Request SA is updated either after:

- The subframe has started and the RT address of the RT in Burst Mode, was transmitted in the Data word of the Synchronization message (see chapter 4.3.2) TBC.

Or

- The pending TM Packet Transfer has actually started in this subframe. This is detected by the BC access to SA 11T.

In the Burst Mode the TM Packet output buffers (SA 11T to SA 26T) are updated either after

- Receiving of the BC TM Packet Transfer Confirmation message (SA 10R)

Or

- The next subframe has started and the RT address of the RT in Burst Mode has been delivered in the Synchronization message (see chapter 4.3.2) TBC.

4.6.5 TM Packet Transfer Scenarios

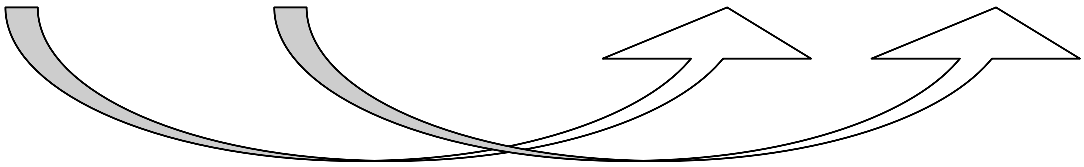
After the BC has been configured by ground control for a predefined bus profile the BC generates all necessary messages for this profile.

The given bus profile will cover the maximum allocated throughput capability of each RT. The actual data rates will be equal or below these maximum rates. The BC will ignore transfer requests above allocated maximum rates.

At least one subframe before a subframe, which is allocated for one RT TM packet transfer, the RT is asked by the BC if a packet is pending, and about its size.

Figure 4.6.5-1: Example of bus profile for modes A, B and D

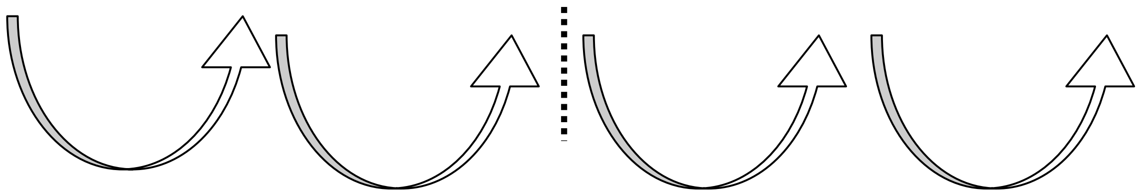
Subframe N - 1	Subframe N	Subframe N + 1	Subframe N + 2
Acquisition of Instrument 1	Acquisition of Instrument 2	**Acquisition of Instrument 3**	**Acquisition of Instrument 1**
Polling of Instrument 3	**Polling of Instrument 1**	Polling of Instrument 2	Polling of Instrument 3



In the operational modes A, B and D (see chapter 3.2) this scenario is sufficient for any TM packet acquisition. Operational mode C requires a different scenario. This burst mode for instrument 1 is shown in figure 4.6.3-2.

Figure 4.6.5- 2: Example of bus profile for Mode C (Burst Mode)

Subframe M - 1	Subframe M	Several subframes	Subframe N	Subframe N + 1
Acquisition of Instrument 3	**Acquisition of Instrument 1**	**Acquisition of Instrument 1**	**Acquisition of Instrument 1**	Acquisition of Instrument 2
Polling of Instrument 1	**& Polling of Instrument 1**	**& Polling of Instrument 1**	Polling of Instrument 2	Polling of Instrument 3



An **example** of a Message sequence reflecting scenario A is shown in table 4.6.5-1 below.

System RTs (AOCS, RTU A, RTU B, PDS and TCS) are also listed in this model scenario, however the associated polling is not shown, although they should be polled before their scheduled acquisition-subframes. because no new TM packet may be available. If these units generate TC packet confirmations and Event packets the number of subframes allocated to them should be increased.

User Case A	AOCS	RTU A	RTU B	PDS	TCS	Instrument 1	Instrument 2	Instrument 3
No. of TM Packets per second	1 P/sec	1P/2 sec	1P/ 2 sec	1 P/4 sec	1 P/4 sec	16 P/sec	3 P/sec	3 P/sec
expected real data rate	4 kbps	2 kbps	2 kbps	1 kbps	1 kbps	120 kbps	20 kbps	20 kbps

Table 4.6.5-1: Example of a Message Sequence

Subframe Count	Action	Action
0	Reserved for Commanding	
1	Acquisition of TM Packet # 1 of instrument 1	Polling of Instrument 3
2	Acquisition of TM Packet # 1 of instrument 2	Polling of Instrument 1
3	Acquisition of TM Packet # 1 of instrument 3	Polling of Instrument 2
4	Acquisition of TM Packet # 2 of instrument 1	Polling of Instrument 3
5		Polling of Instrument 1
6		Polling of Instrument 2
7	Acquisition of TM Packet # 3 of instrument 1	Polling of Instrument 3
8		Polling of Instrument 1
9		Polling of Instrument 2
10	Acquisition of TM Packet # 4 of instrument 1	Polling of Instrument 3
11		Polling of Instrument 1
12		Polling of Instrument 2
13	Acquisition of TM Packet # 5 of instrument 1	Polling of Instrument 3
14	Acquisition of TM Packet # 2 of instrument 2	Polling of Instrument 1
15	Acquisition of TM Packet # 2 of instrument 3	
16	Reserved for Commanding	
17	Acquisition of TM Packet # 6 of instrument 1	Polling of Instrument 3
18	Acquisition of AOCS data	Polling of Instrument 1
19		Polling of Instrument 2
20	Acquisition of TM Packet # 7 of instrument 1	
21		Polling of Instrument 1
22	Acquisition of RTU A data	
23	Acquisition of TM Packet # 8 of instrument 1	Polling of Instrument 3
24	Acquisition of RTU B data	Polling of Instrument 1

25		Polling of Instrument 2
26	Acquisition of TM Packet # 9 of instrument 1	Polling of Instrument 3
27		Polling of Instrument 1
28		Polling of Instrument 2
29	Acquisition of TM Packet # 10 of instrument 1	Polling of Instrument 3
30		Polling of Instrument 1
31		Polling of Instrument 2
32	Reserved for Commanding	& Time distribution
33	Acquisition of TM Packet # 11 of instrument 1	Polling of Instrument 3
34	Acquisition of PDS data	Polling of Instrument 1
35		
36	Acquisition of TM Packet # 12 of instrument 1	Polling of Instrument 3
37	Acquisition of TCS data	Polling of Instrument 1
38		Polling of Instrument 2
39	Acquisition of TM Packet # 13 of instrument 1	Polling of Instrument 3
40	Acquisition of TM Packet # 3 of instrument 2	Polling of Instrument 1
41		Polling of Instrument 2
42	Acquisition of TM Packet # 14 of instrument 1	Polling of Instrument 3
43		Polling of Instrument 1
44		Polling of Instrument 2
45		Polling of Instrument 3
46		Polling of Instrument 1
47		Polling of Instrument 2
48	Reserved for Commanding	
49		Polling of Instrument 3
50		Polling of Instrument 1
51		Polling of Instrument 2
52	Acquisition of TM Packet # 15 of instrument 1	Polling of Instrument 3
53		Polling of Instrument 1
54	Acquisition of TM Packet # 3 of instrument 3	Polling of Instrument 2
55	Acquisition of TM Packet # 16 of instrument 1	Polling of Instrument 3
56		Polling of Instrument 1
57		Polling of Instrument 2
58		Polling of Instrument 3
59		Polling of Instrument 1
60		Polling of Instrument 2
61		Polling of Instrument 3
62		Polling of Instrument 1 *
63		Polling of Instrument 2 *

* = polling for next subframe

4.6.6 Event Handling

TM-Events are small TM data packets which have to be specified to fit into one MIL bus message. These Event messages are independent from the scheduled TM Packet Transfer.

The RT will request the need for a TM event transfer by setting the Event flag in the Packet Transfer Request control words.

This TM Event transfer request is inserted into the TM Packet Transfer Request to reduce the need for polling messages on the bus. To avoid that an TM Event is overwritten by a more actual one before the BC has acquired the event message, an event handshaking has been introduced. Additionally a second Event SA is reserved in case there are multiple important events at the same time.

Because of the asynchronous behavior of TM packets and especially of the TM Events, a combined handshake is not advisable.

Therefore the event handshake is performed by a duplication of the Event message coming from the RT Transmit SA back to the Receive SA. By comparing the contents of these SAs, the RT is able to detect that the BC has acquired this event message.

The BC has to take care that an event flag, which is processed, will initializes only once the associated transfer. The same event flag will be ignored until the event is acquired and confirmed by the BC. Additionally, the BC shall ignore any change of this event flag for the period of one additional subframe. This provides for time for resetting of this flag within the RT.

The RT checks at least after every subframe sync if the event packet transfer was confirmed, and it shall then reset the corresponding event flag immediately.

A new event flag setting of the same kind (A or B) is only allowed after waiting for at least 2 subframes.

4.6.7 Timing of Internal Processes within a Subframe

Start of (Frame) Subframe	Command / Acquisition period	TM Data Acquisition TC Data Delivery period	Polling and confirmation period	Regu-lation
Message Slot 1	Message Slots 2 - 4	Message Slots 5 – 20	Message Slots 21 – 23	Message Slot 24

Figure 4.6.7-1: Message Slots within a subframe

Description :

Start of (Frame) Subframe

In the first Subframe in each Frame / second a user / instrument may do an update or comparison of its internal clock.

With every subframe start the user / instrument has to check if its last packet transfer was processed by looking at the acknowledge message data words from the BC.

Command / Acquisition period

These Message Slot are utilized for:

- Low Level Commanding
- H/K Data acquisition
- FDIR messages
- TBD

TM Data Acquisition , TC Data Delivery period

Here the BC acquires the TM data packet from the RTs according to the Bus Profile which is active. Also the BC transmits the TC Packet messages by using these message slots in Subframes no. 0, 16, 32, and 48.

Polling and confirmation period

Here the TM Packet Transfer Confirmation message is send to the RT from which a TM packet transfer was performed. Additionally, the BC has to acquire the next TM Packet Transfer Request messages from another RT.

Regulation Slot

This slot/ time is normally unused. In case of Asynchronous TC message insertion by the BC (at any time at the end of a message slot) all consecutive activities are shifted into the next slot and the Regulation Slot is used to maintain the proper timing of subframes.

4.7 Commanding

4.7.1 General

The commanding of users / instruments is supported by the BC using the TC packet delivery procedure, see chapter 4.6.1. On 1553-protocol level there is only the command exception status via the RT *Status Word*, which provides an information about the valid transmission.

A TC Packet verification is supported by using transfers of TC Verification packets. This is covered within the Application Layer.

4.7.2 TC Packet Delivery mechanism (BC to RT)

The BC sends in one subframe all messages belonging to the TC packet, followed by the TC Packet Transfer Descriptor message to SA 27 R. For the layout see table 4.7.2-1. The command packet is send to TC Packet receive SAs, starting with SA 11R.

Table 4.7.2-1: Layout of the TC Packet Transfer Descriptor (BC to RT)

1. Data word (Packet size)				2. Data word (Packet Control)		
(3 Bit)	(5 Bit)	(3 Bit)	(5 Bit)	(6 Bit)	(2 Bit)	(8 Bit)
Reserved ´000´	No. of messages for next packet	Reserved ´000´	No. of Data Words in the last message of the next packet	Reserved, set to ´00 0000´	set to ´01´	Packet count

At least after the next Subframe Sync the RT stores the TC Packet and copies the just received Transfer Descriptor wordss to SA 27T, as TC Packet Transfer Confirmation.

Table 4.7.2-2: Layout of the TC Packet Confirmation (from RT)

1. Data word (Packet size)				2. Data word (Packet Control)		
(3 Bit)	(5 Bit)	(3 Bit)	(5 Bit)	(6 Bit)	(2 Bit)	(8 Bit)
Reserved ´000´	No. of messages of the last packet	Reserved ´000´	No. of Data Words in the last message of the last packet	Reserved, ´00 0000´	Reserved ´01´	Packet count

To provide sufficient bus throughput capability there are at least 4 subframes reserved for commanding. These are the 1.,17.,33. and 49. subframe in each Frame of one second (subframe count: 0,16, ...).
In each of these subframes a maximum of 4 TC Packets to different RTs can be delivered.

4.7.3 Asynchronous Short Commands

Asynchronous Short Commands are event-driven TC Packets with a maximum size of 64 octets.
The BC sends Asynchronous Short TC-Packets for special RT control functions to RTs which support this service.
The routing latency of an asynchronous TC-Packet from the CDMS to the input buffer of a RT shall be equal or below 1 millisecond.
The BC inserts Asynchronous TC Packet messages in the ongoing message sequence.
Asynchronous Short Commands are send to RT SA 3R or SA 4R.
Only one insertion of an Asynchronous Short Command per subframe is allowed.

Note: This command insertion shall not corrupt the nominal TM Packet or TC Packet transfer in the affected subframe, only the timing shall be shifted by one message slot.

4.7.4 Low Level Commanding

Sending of TBD Low Level Commands to non-intelligent RTs is possible by using the SA 28R.

For Low Level Command verification a separate SA is foreseen (SA 28T).

Low Level Commands are TBD.

4.8 Protocol stability

This Common Data Bus Protocol shall be able to transfer data in sequence, free of errors, and without loss or duplication. It shall be stable in all nominal and known non-nominal situations.

To illustrate this a number of potential problem cases are listed below with the discussion of the CDBP behavior.

- Problem: Is it possible that a packet is available in a RT, but will not be acquired?

Due to the systematic polling of the control words the system / RT will take the request into account. Polling of all instruments / users must be implemented adequately in each of the predefined bus profiles.

To avoid that after an instrument reset an identical packet number will be used in the RT and BC, and therefore no packet transfer starts, there is one number foreseen that will never appear during the nominal transfers

Problem: Is it possible that an event packet is available but not acquired?

Because of the systematic control word polling the system will take this request into account.

- Problem: Is it possible that a packet transfer request leads to a duplicated transfer?

This is not possible because the packet count number is used by the BC to recognize a new request. If this number is unchanged w. r. t. the previous transfer request no additional transfer takes place.

- Problem: Is it possible that an event packet transfer request leads to a duplicated transfer?

There is a dedicated mechanism foreseen to avoid this. The BC shall be able to react to a RT event packet transfer request and it shall take a new request into account only after a confirmation of the last request.

It should be guaranteed by the design of higher layers that identical event messages do not cause any problems.

Problem: What will happen in case of a corrupted Packet transfer control message?

If the transfer BC to RT was disturbed, this will be identified by the RT response and the BC can react accordingly.

If the transfer RT to BC was corrupted, the BC can perform a retry or the BC can acquire the data of a complete TM packet with the next polling.

- Problem: What will happen in case of a corrupted transfer of a packet message?

If the transfer BC to RT was disturbed, this will be identified by the RT response and the BC can react accordingly.

If the transfer RT to BC was corrupted, the BC can suppress the packet transfer confirmation and can perform a retry because the packet stays in the buffer until it is confirmed.

- Problem: What will happen in case of a corrupted transfer of a event message?

If the transfer RT to BC was corrupted, then the BC can suppress the event transfer confirmation and can perform a retry because the event stays in the buffer until it is confirmed.

- Problem: What will happen in case there is only an event and no packet transfer request or vice versa?

That is not a problem because the transfers are independent from each other. The polling is done within the same Data words to reduce effort and transfer time. Because of the different confirmation processes there is no influence between these services.

4.9 Margins in the Protocol

The CDBP is a transfer mechanism based on the assumption that all data traffic on-board stays within the boundaries of predefined mission scenarios. Each increase of flexibility or adoption to highly variable scenarios results in an increased effort for the BC in controlling the bus traffic, and for RTs to react properly and timely.

In the current version of the protocol the BC polls the instruments for a need for TM packet transfer, and shortly later the BC produces a command sequence, which is capable to acquire a block of data, which is tailored to the length of this TM packet.

This requires fast internal processing of the BC in order to (re-)configure its I/F controller chip. If it becomes obvious during the design phase that this is not feasible within an appropriate effort, there is some margin in the protocol to relax the constrains for the bus transfer services.

Reducing the calculation effort on the BC side is one possible way to reduce the I/F controlling effort.

- A first step on Transfer Layer could be to use only messages with a length of 32 words for Packet Transfer. Filler/random patterns at the end of each TM packet have to be removed by a higher layer service.
- A further way to reduce the workload of the BC is, to acquire only data blocks equivalent to maximum-length TM packets. By using this option only two predefined command sequences for the I/F circuit are needed. Again, extracting the valid TM packet data has to be done by a higher layer. For timing and throughput on the data bus (layers) there should be no penalty because a sufficient number of message slots per Frame to satisfy maximum throughput requirements, is allocated anyhow.

To which extent the throughput rates for nominal TM packets, TC packets, Event TM packets, and Asynchronous Short Commands, which have been discussed in this TN for 4 model cases (see para. 3.2), can actually be achieved or potentially extended to the theoretical limits for this protocol (see para. 4.2), depends on the architecture and performance of the host processor of the BC, and the I/F controller electronics. Taking the characteristics and performance of established and known I/F controller chips into account, the protocol, as defined, should work at the expected performance.

A trade-off should be made between processing time, which is needed for the bus protocol layers, higher TM/TC packet layers, and the processing time needed by the BC for all the other services and functions, it has to support.

If an architecture for the 1553 I/F and the host processor is selected for the RTs, which is comparable in performance with the BC, there should be no significant problem to implement the I/F function. The processing time needed by the RT for controlling its 1553 I/F should be a fraction only of the amount needed by the BC.

5. Bus-level FDIR

5.1 Scope of MIL Bus FDIR

The MIL Bus FDIR has the capability to manage the bus redundancy switch-over in case of a failure of the physical medium or an I/F circuit. This function collects the data necessary to monitor the status of the communications on the bus, isolates a bus medium failure, and performs an automatic reconfiguration of the bus from communication medium A to communication medium B, as necessary to maintain the integrity of the bus communication path.

The MIL Bus FDIR additionally collects FDIR data from the MIL Bus that is relevant to RT equipment FDIR. For example, if a RT does not answer anymore on the bus, this may be because the MIL Bus communication medium is cut, or because the RT itself has failed or has been powered OFF. The bus FDIR function will first try to isolate whether the error is caused by a bus failure or not. If a RT failure is confirmed instead, the failure shall be managed by a RT-related FDIR function. The bus FDIR will report the error to the equipment FDIR layer.

5.2 RT interfaces necessary to support FDIR

No specific RT interface is required to support MIL Bus FDIR. Only standard and mandatory features of MIL-STD-1553B protocol are used.

For failure detection, the MIL Bus FDIR relies on nominal data traffic, and does not generate additional specific data traffic. Only for failure isolation a specific data traffic is generated.
The following bus FDIR error conditions are collected by the MIL Bus communication service:

- RT message error bit, (from RT MIL-STD-1553B Status Word)
- RT Busy bit, (from RT MIL-STD-1553B Status Word)
- RT subsystem flag bit, (from RT MIL-STD-1553B Status Word)
- RT Terminal flag bit, (from RT MIL-STD-1553B Status Word)

- RT transmission error, (from BC Bus I/F)
- RT no response time-out, (from BC Bus I/F)
- BC loop back test fail, (from BC Bus I/F)

5.3 Ground command interfaces for bus FDIR

The following MIL Bus FDIR related commands shall be provided for usage by ground/ mission control

- Switch to bus medium A
- Switch to bus medium B
- Disable bus automatic reconfiguration function
- Enable bus automatic reconfiguration function

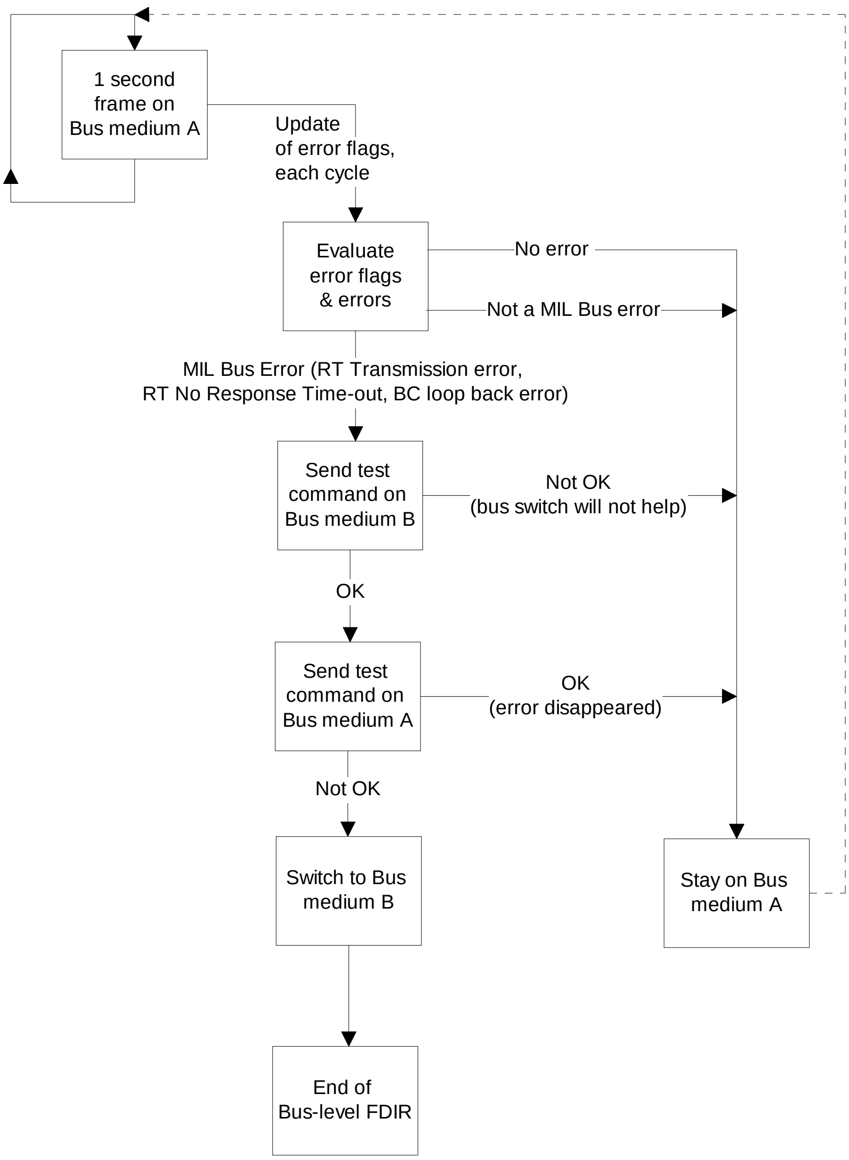
The format of these commands is TBD.

5.4 Functional Description of Bus-level FDIR

By default, the BC uses bus medium A. If the BC Bus FDIR isolates a failure on bus A, the whole MIL Bus traffic will be reconfigured to bus B. No automatic reconfiguration from bus B to bus A is implemented. In case a further failure occurs on bus B, no further recovery is triggered by the bus FDR function, and the traffic is maintained on bus B. The A/B switch status is reported to Ground/ Mission Control. The Ground/ Mission Control can override the MIL Bus A/B switching function by dedicated commands, see chapter 5.3.

The isolation of the bus failure is an automatic procedure performed by the BC. After detection of an anomaly on bus medium, a sampling of the status of bus B via dedicated asynchronous messages takes place, while the main traffic remains on bus A. A bus failure is confirmed if bus B is sampled OK, while bus A is sampled as failed, see figure 5.4-1.

Figure 5.4-1: MIL Bus failure isolation.



6. Testing

The testing of the MIL Bus interfaces of all RTs should be done according to AD 2: MIL-HDBK-1553A Section 100, RT Validation Test Plan. This document provides detailed specifications for test requirements, test procedures, and test setups. It is made applicable for I/F tests on Physical and Data Link Layer. Tests according to this document will provide a full validation of the basic MIL Bus performance of a RT.

The electrical characteristics of the MIL Bus interface of a Bus Controller should be tested in an equivalent test. Because the MIL-HDBK-1553A, Section 100, is for RT testing only, the interface of the BC has to be configured into RT Mode during the test, which is a nominal capability for most I/ controller chips .

The monitoring and testing of the bus traffic scenarios can be done by tracking and decoding the data words, which belong to the Mode Codes “Synchronize”. These data words will indicate which RT is selected for a TM Packet transfer in a certain subframe. Further data relevant for throughput measurements can the be decoded from the bus traffic.

Testing of the CDBP-specific requirements should be done according to the CDBP Specification, which defines the adequate test method for each requirement.