MilCAN Working Group

MilCAN A Specification

MWG-MILA-001

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Record of changes

Issue	Date	Detail of Changes
1	March 2006	Initial publication. Merger of the following documents: MilCAN A Physical Layer Specification (IHSDB-APP-GEN-D-030 Rev 3) MilCAN A Data Link Layer Specification (IHSDB-APP-GEN-D-031 Rev 4) MilCAN A Application Layer Specification (IHSDB-APP-GEN-D-032 Rev 2)
2	May 2007	Includes the following Change Requests: CR009 – this change allows for an additional connector option CR010 – this change updates the Mil Spec Standard to latest issue for connector style 38999 CR002 – this changes the mandating of CAN controllers to avoid automatic re-transmission on error CR004 – this change allows an additional Baud rate of 500Kbps CR006 – this change clarifies any potential confusion between Fig 2.3 & Fig 3.1 CR024 – this change corrects an error in angle direction parameter scaling/resolution.
Draft 3	May 2009	Includes the following Change Requests: CR025 – Adds a completion time for enter configuration mode. CR026 – specifies a timeout value for system configuration mode.

		CR027 specifies how a node handles message transmission of a multi-frame message containing a payload of 8 bytes or less. CR028 specifies how a node should handle the destruction of multi-frame messages. CR031 removes all previous reference to multi-instance addressing. CR033 differentiates between compulsory requirements and those that are system specific/optional enhancements by changing font of the latter to 50% Gray.

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1 Introduction

1.1 Scope

The aim of the MilCAN A specification is to define and ratify an open standard interface to the CAN databus technology. The MilCAN A specification is intended to support implementation in all application areas of military vehicles, where the performance requirements of specific implementations are commensurate with that of CANbus.

As with all such initiatives, the MilCAN A specification will be subject to change to keep pace with experience and technical advances.

MilCAN is intended to be easily bridgeable to other CAN based protocols, specifically CUP [1], SAE J1939 [3] and CANopen. Indeed, it should be possible to mix J1939 node/device with MilCAN node/device on the same bus provided that baud rate and message priority requirements for the two protocols are observed. CUP and CANopen node/device must be segmented via a bridge.

MilCAN B defines the superimposition of the MilCAN communication architecture on top of CANopen, using a system developed by BOFORS as the foundation. This specification will include CANopen device profiles for military devices using the same MilCAN B messages.

The philosophy of this document is to make reference to ISO 11898[2] wherever possible, detailing only the specific deviations or additions required for MilCAN to satisfy the requirements of its military vehicle application.

Each MilCAN requirement has a classification marked against it; these are defined as follows:

- Compulsory:

  Compulsory to gain accreditation as MilCAN compliant.

- Optional enhancement:

  Optional enhancement to MilCAN, which need not be implemented in order to gain accreditation. However if implemented, the implementation should adhere to the MilCAN specification.

- System specific:

  System specific item that is not constrained by MilCAN and is left to the system developer to optimise for any specific system.

The system designer is responsible for tailoring those requirements identified in this specification as Optional enhancement or System specific for the system under consideration.

1.2 Related Documents

This document should be read in conjunction with the following documents:

- MilCAN A System Management Specification - IHSDB-APP-GEN-D-036 Rev 1

2 Physical Layer

2.1 Physical Connectivity

2.1.1 Physical Topology - System Specific

Two physical topologies are recommended:

- Linear multi-drop
- Daisy chain

Multi-drop nodes/devices require a single bus connector and may be linked to the main bus using a drop cable and a T-piece connector as shown in Figure 2-1. It is possible to avoid the use of T-piece connectors by replacing them with bifurcated cables as shown in Figure 2-2.

Daisy chain node/device require one input bus connector and one output bus connector and are connected in series as shown in Figure 2-3.

Both topologies can be employed exclusively or in combination.

Nodes/devices supporting the daisy-chain topology should also be capable of use in the multi-drop topology, utilising only the input bus connector.

Equal cable lengths between node/device should be avoided to minimise standing waves. Similarly, drop cable lengths should not generally be equal.

The optional implementation of in-cable power supply should feed into one end of the bus via a female connector, such that no male connectors carry live power or signals when exposed.

A single terminating resistor should be installed at each extreme end of each bus segment.

2.1.2 Connector Gender Assignments - Compulsory

Recommended connector gender assignments are shown in Figure 2-1, Figure 2-2 and Figure 2-3.

Cables:	Male one end, female other end
Devices, multi-drop:	Male
Devices, daisy-chain:	Male in, female out
T-pieces, multi-drop:	Male in, 2*female out

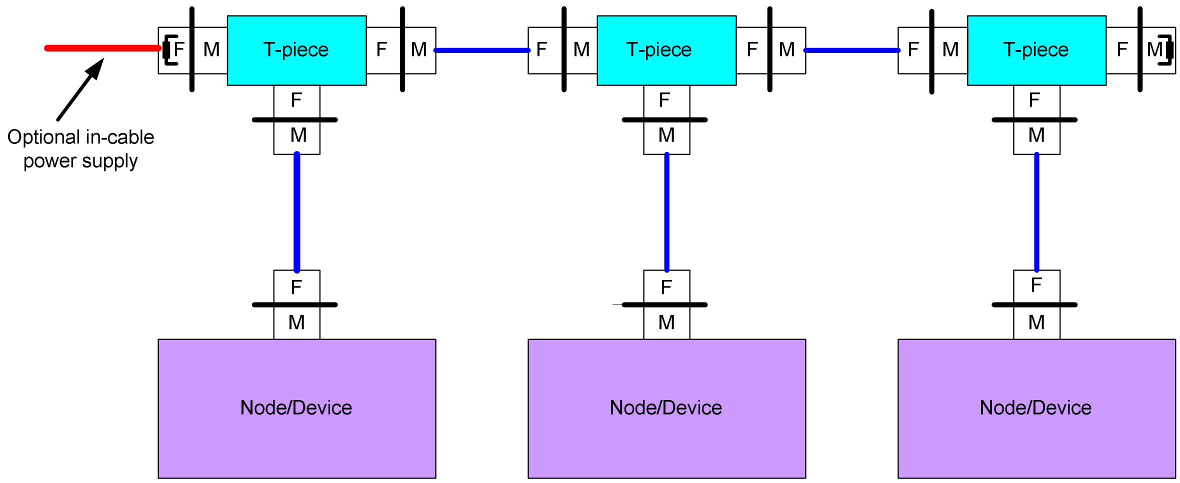


Figure 2-1 - Linear multi-drop topology

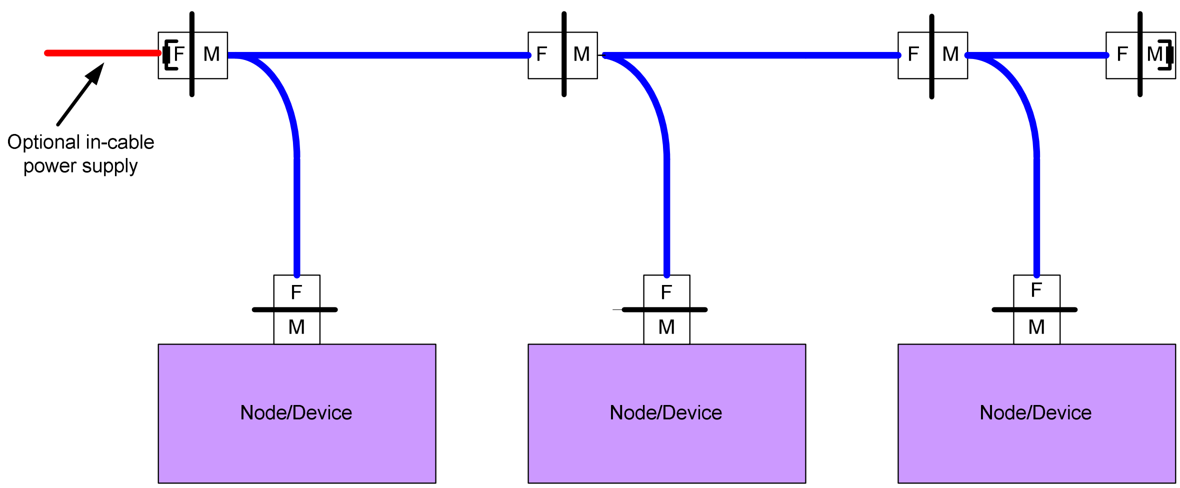


Figure 2-2 - Linear multi-drop topology using bifurcated cables

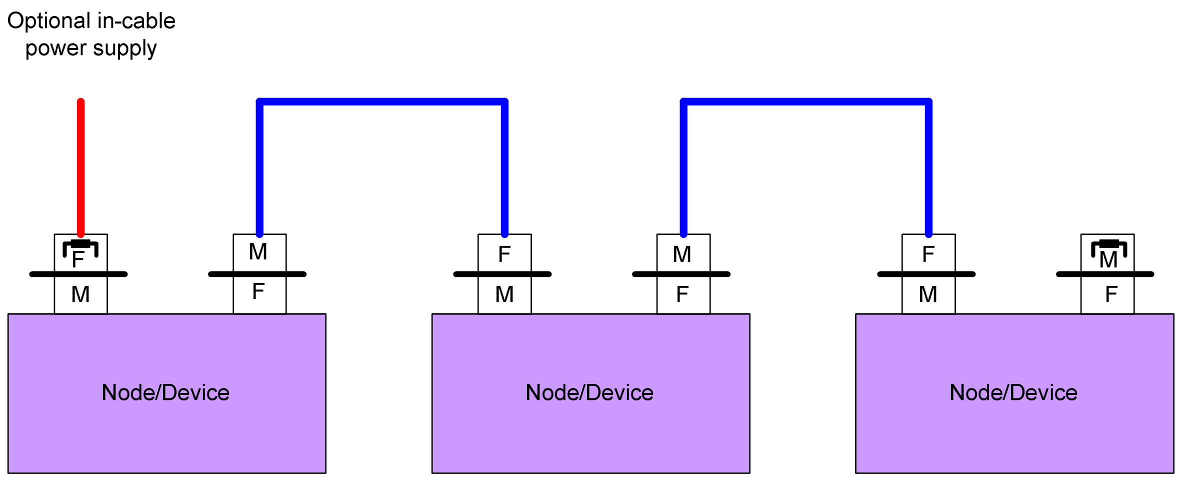


Figure 2-3 - Daisy-chain topology

<u>Note</u>

N-level media redundancy is not specifically addressed in the MilCAN specification, but obviously these topologies must support its future implementation. There are a number of topology options depending on the criticality of the system and the perceived places of vulnerability. A fully redundant system would operate two or more identical networks side-by-side, however if only the media is considered vulnerable then a single node/device may be attached to two or more redundant busses. It is recommended, at this stage, that media redundancy is carried right up to each node/device using two or more redundant connectors at each node/device.

2.1.3 Maximum Bus Length And Drop Length - Compulsory

As ISO 11898 [2] plus additional requirements. Guidance on the specification of this parameter can be obtained through reference to an Application Note from Philips components [5].

2.1.4 Maximum Number Of Network Node/device - Compulsory

As ISO 11898 [2].

2.2 Medium

2.2.1 Cable Requirements

2.2.1.1 CAN Signal A - Compulsory

There shall be provision to carry one CAN signal according to the physical medium specification of ISO 11898 [2].

2.2.1.2 CAN Signal B - Optional Enhancement

If implemented, a second CAN signal can also be carried according to the physical medium specification of ISO 11898 [2].

2.2.1.3 Shield - System Specific

It is recommended that all implementations employ shielded cables. The specific details of each implementation are left to the system designer to satisfy specific system requirements. However, the recommendation is to shield each CAN signal pair and each power pair with individual shields, there should also be an overall cable shield.

2.2.1.4 In-Cable Power - Optional Enhancement

If implemented, the in-cable power supply shall be carried on a shielded twisted pair capable of bearing the maximum current load specified by the systems integrator, whilst satisfying the power signal specification.

2.2.1.5 Reserved - Compulsory

Any lines designated as ‘Reserved’ shall not be used by system designers, as they may be assigned a specification in the future.

2.2.2 Connector

In the connector pinouts in the following sections it may be necessary to allocate those pins labelled ***Shield: Can (a)*** or ***Shield: Can (b)*** as ***Can 0V*** and ensure they are connected to the Can Transceiver Gnd pin to avoid high common mode voltage between nodes. In this case the system designer must ensure that the terminantion of the can shields does not impair the system grounding & shielding policy.

2.2.2.1 Connector Type - System Specific

To define a connector to suit all applications is not practical. Therefore, MilCAN will maintain a list of recommended connector configurations that will allow a system developer to select a suitable connector for his application and thereby maintain compatibility by implementing the MilCAN configuration of that connector.

Two connector styles are listed:

- MIL-DTL-38999
- Bayonet style series 1 1/2 circular connector complying with VG96912 specification referenced to LN29729

2.2.2.1.1 Configuration A: Dual CAN Bus With In-Cable Power - System Specific

Connector specification: MIL-DTL-38999/ffeC98zN Series 3.

There is no restriction on fixing type 'ff' or exterior finish 'e'.

The shell size is C and the pin layout is 98 (10 pin).

The appropriate gender selection is specified in Section 2.1.2.

The Key orientation is N.

Connector specification: VG96912 Bayonet style series 1 1/2 circular connector.

There is no fixing restriction or exterior finish.

The shell size is 12 and pin layout 98 (10 contacts).

The appropriate gender selection is specified in Section 2.1.2.

The Key orientation is N.

Pin	Function
A	Power 0V
B	Power +24V
C	CAN_L (a)
D	CAN_H (a)
E	CAN_L (b)
F	CAN_H (b)
G	Reserved
H	Shield: Power
J	Shield: CAN (a)
K	Shield: CAN (b)

Table 2-1- Connector pin assignment - Dual CAN bus with in-cable power

2.2.2.1.2 Configuration B: Dual CAN Bus, No In-Cable Power - System Specific

Connector specification: MIL-DTL-38999/ffeA35zA Series 3.

There is no restriction on fixing type 'ff' or exterior finish 'e'.

The shell size is A and the pin layout is 35 (6 pin).

The appropriate gender selection is specified in Section 2.1.2.

The Key orientation is A.

Connector specification: VG96912 Bayonet style series 1 1/2 circular connector.

There is no fixing restriction or exterior finish.

The shell size is 8 and pin layout 35 (6 pin).

The appropriate gender selection is specified in Section 2.1.2.

The Key orientation is A.

Pin	Function
1	CAN_H (a)
2	CAN_L (a)
3	Shield: CAN (a)
4	CAN_H (b)
5	CAN_L (b)
6	Shield: CAN (b)

Table 2-2 - Connector pin assignment - Dual CAN bus, no in-cable power

2.2.2.1.3 Configuration C: Single CAN Bus With In-Cable Power - System Specific

Connector specification: MIL-DTL-38999/ffeA35zN Series 3.

There is no restriction on fixing type ‘ff’ or exterior finish ‘e’.

The shell size is 8 and the pin layout is 35 (6 pin).

The appropriate gender selection ‘is specified in Section 2.1.2.

The Key orientation is N.

Connector specification: VG96912 Bayonet style series 1 1/2 circular connector.

There is no fixing restriction or exterior finish.

The shell size is 8 and pin layout 35 (6 pin).

The appropriate gender selection is specified in Section 2.1.2.

The Key orientation is N.

Pin	Function
1	CAN_H (a)
2	CAN_L (a)
3	Shield: CAN (a)
4	Power 0V
5	Power +24V
6	Shield: Power

Table 2-3 - Connector pin assignment - Single CAN bus, with in-cable power

2.2.2.1.4 Configuration D: Single CAN Bus, No In-Cable Power - System Specific

Connector specification: MIL-DTL-38999/ffeA98zN Series 3.

There is no restriction on fixing type ‘ff’ or exterior finish ‘e’.

The shell size is A and the pin layout is 98 (3 pin).

The appropriate gender selection is specified in Section 2.1.2.

The Key orientation is N.

Connector specification: VG96912 Bayonet style series 1 1/2 circular connector.

There is no fixing restriction or exterior finish.

The shell size is 8 and pin layout 98 (3 pin)

The appropriate gender selection is specified in Section 2.1.2.

The Key orientation is N.

Pin	Function
1	CAN_H (a)
2	CAN_L (a)
3	Shield: CAN (a)

Table 2-4 - Connector pin assignment - Single CAN bus, no in-cable power

2.2.2.2 Bus Terminator - Compulsory

As ISO 11898 [2], with the following additional requirements:

Terminating resistors shall be incorporated inside a bus connector. Terminating resistors may be incorporated into network node/device only where a mechanism for switching them into and out of the network is also implemented. The switching mechanism shall be operable manually but may additionally be automated as part of an intelligent network management system.

At present, split terminations, as recommended for Philips TJA1040 High Speed CAN Transceivers, are not specified for MilCAN.

2.2.3 In-Cable Power Distribution - Optional Enhancement

The in-cable power supply is an optional enhancement that may be used for any purpose that the system designer considers being advantageous.

It shall be sourced from one location only, as shown in Figure 2-1, Figure 2-2 and Figure 2-3.

The in-cable power supply/filter shall be compliant with an input voltage as specified in Mil-Std-1275B and provide a nominal output voltage in the range 18V to 32V.

Each individual node/device that uses the in-cable power shall consume no more than 500mA.

If the in-cable power supply is brought into a node/device then it shall be electrically isolated from all other external signals, power supplies, ground returns and shields being used by that node/device.

2.2.4 Shielding - System Specific

It is recommended that all implementations employ shielded cables. The specific details of each implementation are the responsibility of the system designer in order to meet specific system requirements. However, the recommendation is to shield each CAN signal pair and each power pair with individual shields, there should also be an overall cable shield.

General principles for consideration are:

- The overall cable shield should be connected to the case of each node/device.
- There should be a connection of the CAN shield at the digital ground of each node/device's interface circuitry.

2.3 Transceiver Characteristics

2.3.1 Transceiver Electrical Characteristics - Compulsory

Transceivers should conform to the physical medium attachment sub-layer as specified in ISO 11898 [2].

Transceivers may be used in conjunction with filter circuits. However, the increased signal slope times and propagation delays associated with filters shall be included in the CAN interface propagation delay time and the total shall comply with the bit timing specification of section 2.4.2.

Transceiver bus connections should enter a high impedance state when not powered.

2.3.2 Resistance To Electrical Bus Faults - Compulsory

As ISO 11898 [2].

2.3.3 Opto-Isolation - Optional Enhancement

It is recommended that opto-isolation of the CAN signal is implemented, and that an isolated supply powers the interface circuitry.

Opto-isolators impose a propagation delay that restricts potential bus length. They shall be chosen such that the maximum round trip interface delay time for a node/device is compliant with the bit timing requirements of section 2.4.2.

2.4 Bit Timing

2.4.1 Bit Rates - Compulsory

Nodes/devices may support one or more of these bit rates:

- 1Mbps
- 500Kbps
- 250Kbps

A mechanism for selection of the bit rate for a node/device is described in the System Management Layer specification.

2.4.2 Bit Timing - Compulsory

MilCAN bit timing parameters are specified to maintain compatibility with node/device implementing parameters specified in the CANopen specification and in the SAE J1939/11 standard.

The bit time oscillator tolerance shall be better than +/- 0.1%

For the 1Mbps option, the bit sample point shall be at 75% of the bit time or later; preferably 80% or later.

For the 500Kbps & 250Kbps option, the bit sample point shall be at 87.5% of the bit time or later (e.g. Tsyncseg=1 time quanta, TSEG1=13 time quanta, TSEG2=2 time quanta).

The synchronisation jump width shall be 1-time quanta.

Sampling mode shall be single sampling.

Synchronisation shall be ‘recessive to dominant’ edges only.

At 1 Mbps, the round trip propagation time of a CAN interface shall be less than 210ns.

At 500Kbps & 250Kbps , the round trip propagation time of a CAN interface shall be less than 300ns.

Some points for consideration:

- The large amount of propagation time in the 250 Kbps configurations facilitates slower slopes and input filtering.
- Implementations of the 1Mbps option must have fast signal slopes, requiring low internal capacitance of CAN interfaces and appropriate EM shielding.
- It is possible to use MilCAN compliant node/device on the same bus as node/device that use an earlier sample point. However, the maximum bus length must be shortened accordingly.

- It is possible to use MilCAN compliant node/device on the same bus as node/device that use CAN interfaces with larger propagation delays. In this case, the bus length must be shortened accordingly.

- It is not possible to use MilCAN compliant node/device on the same bus as node/device that have wider oscillator tolerances than the MilCAN tolerance.

3 Data Link Layer

3.1 Media Access Control

3.1.1 Priority Based Bus Access Arbitration - Compulsory

As ISO 11898 [2].

3.1.2 Framing - Compulsory

As ISO 11898 [2], extended (29 bit identifier) format.

3.1.3 Link Layer Acknowledgement - Compulsory

As ISO 11898 [2].

3.1.4 Link Layer Communication Error Detection - Compulsory

As ISO 11898 [2].

3.1.5 Link Layer Communication Error Signalling - System Specific

Reporting of link layer communication errors from the CAN controller is system specific. If implemented, corrective procedures appropriate for the system application may then be executed by the node/device application software.

3.1.6 Fault Confinement - Compulsory

As ISO 11898 [2].

3.2 Logical Link Control

3.2.1 Frame Format - Compulsory

The 29-bit frame identifier shall be formatted as shown in Figure 3-1. The format is based on that of SAE J1939 shown in Figure 3-2. The two formats may be used on the same bus (provided a baud rate of 250 Kbps has been selected for MilCAN) and are differentiated by the Protocol Type bit, bit 25.

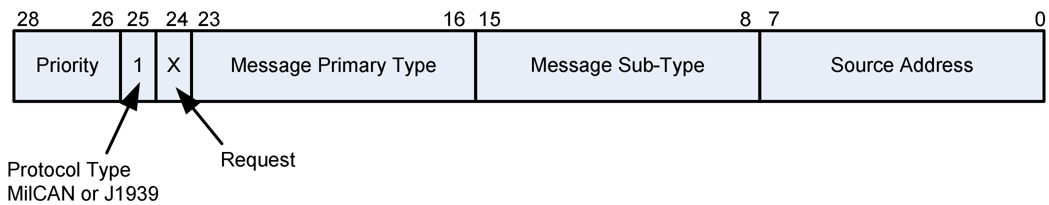


Figure 3-1 - Frame identifier structure as per MilCAN

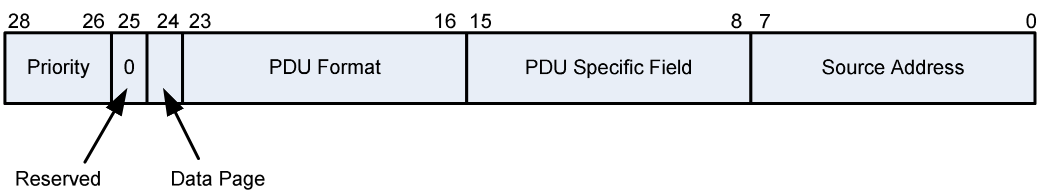


Figure 3-2 - Frame identifier structure as per SAE J1939

3.2.1.1 Source Address Field - Compulsory

Bits 0 to 7 shall denote the source address (physical network address) of the node/device that transmits the frame. Each node/device on the network shall have a unique source address assigned to it. This shall ensure that identical operational messages sourced from different nodes or devices do not have the same identifier.

Source address 0x00 is reserved and shall not be used by any node/device.

3.2.1.2 Message Primary-Type, Message Sub-Type fields - Compulsory

Bits 16 to 23 shall represent the primary-type field and bits 8 to 15 shall represent the sub-function field of the message type identifier. A possible definition of the message types and their identifiers is specified in the Section 4 Application Layer.

3.2.1.3 Request Bit - Compulsory

Bit 24 shall denote that the frame is either a request message (bit value ‘1’) or a Status/Command message (bit value ‘0’).

3.2.1.4 Protocol Type Bit - Compulsory

Bit 25 shall denote that the message is either a MilCAN message (bit value '1') or an SAE J1939 message (bit value '0'). Bit 25 is currently 'reserved' in the J1939 standard and hence this distinction between the two protocols shall remain valid until such time as the SAE specify another use for this bit.

3.2.1.5 Priority Level Field - Compulsory

Bits 26 to 28 shall represent the MilCAN priority level (0 to 7) for the message. The CAN media access control protocol operates such that priority code '0' has highest bus access priority, whilst code '7' has the lowest.

The mechanism for defining priority levels for messages is specified in Section 4 Application Layer.

3.2.2 Link Layer Communication Error Reporting - System Specific

Where appropriate, functionality may be incorporated to take errors signalled by the CAN controller (transmission failures and other bus errors) and report them to higher protocol layers within the node/device. If implemented, corrective procedures appropriate for the system application may then be executed by the application software for the node/device.

No further action shall be taken at the LLC level.

3.2.3 Network Interface Error Detection And Reporting - System Specific

Where appropriate, software may be incorporated into a node/device to detect the failure of its network interface hardware and report this to higher protocol layers. If implemented, corrective procedures appropriate for the system application may then be executed by the application software for the node/device.

No further action shall be taken at the LLC level.

3.2.4 Addressing System - Compulsory

Operational messages shall use logical addressing i.e. based solely on the message primary-type & sub-type conveyed in the message identifier. The source address contained in the message identifier shall not be used in the interpretation of operational messages.

Non-operational messages may be supported by special identifiers that use physical addressing.

3.2.5 Message types

3.2.5.1 Operational Messages

3.2.5.1.1 Status/Command Messages - Compulsory

Status/Command messages shall be the primary mode of communication during normal system operation. The frame identifier shall contain the message priority, the message primary-type & sub-type and source address of the transmitting node/device.

Status/Command messages may be either periodic or event triggered.

3.2.5.1.2 Request Messages - Optional Enhancement

Request messages shall be used to request data from a specific message primary-type & sub-type. The frame identifier shall contain the message priority, the message primary-type & sub-type and the source address of the requesting node/device. The request bit (bit 24 of the identifier) shall be set to '1'. No data shall be placed in the payload of a request message.

The receiving node(s)/device(s) associated with the requested function shall return the required data by transmitting a message identifier with the requested message primary-type & sub-type. The response message identifier will be modified as follows:

- The source address shall be changed to reflect that of the node/device returning the requested data;
- The request bit shall be set to '0' to reflect that this is not a request message.

The response message shall adopt the priority of the request message.

The response message data is placed in the payload.

3.2.5.2 Non operational Messages - Optional Enhancement

Physically addressed messages shall use the primary-type value 0x31 in the message identifier. The identifier sub-type shall convey the physical address of the destination node/device. A physical destination address of 0x00 signifies a broadcast message.

The data payload shall convey the message data.

3.2.5.3 Sync Frame Message - Compulsory

The transmission of messages by synchronous nodes/devices shall be co-ordinated by the Sync Frame message as described in Section 4 Application Layer.

The Sync Frame message shall be transmitted by the currently elected Sync Master node/device. There shall be at least one potential Sync Master per bus segment. The procedure for electing a Sync Master is described in the Section 4 Application Layer.

The Sync Frame message shall use identifier primary-type value 0x00, identifier sub-type value 0x80 and priority level '0'.

The data payload of the Sync Frame message shall contain a Sync Slot counter. This counter shall repeatedly cycle from 0 to 1023 and be incremented for every Sync Frame message. The definition of the Sync Frame message is contained in Section 4 Application Layer.

The frequency of the Sync Frame message is system specific. Recommended Sync Frame frequencies are:

- 512Hz +/-1% for 1 Mbps
- 128Hz +/-1% for 500Kbps
- 64Hz +/-1% for 250 Kbps

The System Management specification [9] describes a mechanism for altering the frequency of the Sync Frame.

The definition of the payload of this message is described in the Section 4 Application Layer.

3.2.5.4 System Configuration Mode Messages

3.2.5.4.1 Enter Configuration Mode Message - Compulsory

The Enter Configuration Mode message shall be used to broadcast a request to all nodes/devices on the bus to suspend operational mode and enter system configuration mode. The request to enter system configuration mode shall consist of an ordered sequence of three Enter Configuration Mode messages. Each Enter Configuration Mode message shall be identical with the exception of the single byte data payload. The single byte data payload for the first, second and third messages in the sequence are the ASCII data characters 'C', 'F' and 'G' respectively.

The Enter Configuration Mode message shall use identifier primary-type value 0x00, identifier sub-type value 0x81 and priority level 0.

The definition of the payload and the use of this message is described in Section 4 Application Layer.

3.2.5.4.2 Exit Configuration Mode Message - Compulsory

The Exit Configuration Mode message shall be used to broadcast a request to all nodes/devices on the bus to exit configuration mode. The request to exit configuration mode shall consist of an Exit Configuration Mode message containing the three-character ASCII data code 'OPR' in the data payload.

The Exit Configuration Mode message shall use identifier primary-type value 0x00, identifier sub-type value 0x82 and priority level 0.

The definition of the payload and the use of this message is described in the Section 4 Application Layer.

3.2.5.5 Alive Message - Compulsory

All nodes/devices on the bus shall transmit an Alive message to indicate the overall status of the node/device. The Alive message shall contain, as a minimum, a single byte payload to indicate the healthy / not healthy status of the node/device. More detailed status information on the node/device and its functions may be broadcast in additional user defined diagnostic messages or in the remaining payload bytes of the Alive message. The definition of the payload of this message is described in Section 4 Application Layer.

The Alive message identifier primary-type 0x62 shall be allocated to each node/device. Each node/device shall be allocated a unique node ID that shall be contained within the Alive message identifier sub-type. The valid range for the node ID shall be 1-255 (0x01 to 0xff). The message identifier 0x6200 is reserved and shall not be used by any node/device. The system designer is free either to allocate a unique node ID number for each node/device or to allocate the source address of the node/device to the node ID field for ease of identification.

The minimum transmission frequency of the Alive message by each node/device shall be 1 Hz.

3.2.6 Bus Access Timing

3.2.6.1 Nodes/Devices Operating Synchronous to the Bus - Compulsory

Nodes/devices shall incorporate a mechanism that reports the arrival of Sync Frame Messages and the value of the sync counter to higher layers within the node/device.

The operation of the synchronous message triggering is described in Section 4 Application Layer.

3.2.6.2 Nodes/Devices Operating Asynchronous to the Bus - Compulsory

Asynchronous nodes/devices attached to the network shall be Sync Frame aware in order to transition between the system modes as described in Section 4 Application Layer.

Nodes/devices that transmit asynchronous periodic messages shall ensure that these messages are triggered at the appropriate rate.

3.2.6.3 Asynchronous Messages - Compulsory

Periodic asynchronous messages shall be transmitted with priority 2 or lower.

The transmission of the Sync Frame message and the Enter & Exit Configuration mode message are exceptions to this restriction and are defined as priority 0 messages.

3.2.7 Prioritised Access Queue Manager

3.2.7.1 Prioritised Queuing - Compulsory

To prevent low priority messages queued within a node/device from blocking the transmission of other higher priority messages behind them, each node/device shall present its messages to the bus in order of priority.

New messages of higher priority shall be queued ahead of previously queued messages of lower priority. This includes any lower priority message that may already have been written into the CAN controller transmit buffer. This is required in order to prevent 'priority inversion' occurring within a node/device that transmits messages with a range of priorities.

Nodes/devices that trigger messages, all of which have equal priority, need not make any provision for this requirement.

3.2.7.2 Destruction of Timed-out Messages - Compulsory

In times of heavy busload or disruption, some queued messages may become stale, or even incorrect, before being transmitted.

All messages shall be defined with a 'mortal' attribute. Where this attribute has the value TRUE, a 'time to live' value shall be specified. Where the 'mortal' attribute has the value FALSE, messages shall not expire and no value for 'time to live' need be specified.

Nodes/devices shall ensure messages that have been waiting in the bus access queue for longer than their 'time to live' values are destroyed. Where appropriate, software may be incorporated into a node/device to signal the destruction of messages that have exceeded their 'time to live' value and report this to higher protocol layers within the node/device.

The action of destroying messages that have exceeded their 'time to live' value will facilitate recovery from bus interruptions.

3.2.8 Message Acceptance Filtering - System Specific

Nodes/devices should utilise message acceptance filtering wherever possible to reduce the load on the node/device processor.

3.2.9 Link Layer Flow Control - Compulsory

The 'overload' frame of the ISO11898 CAN standard should never be invoked by the CAN controller LLC sub-layer of a node/device. CAN controllers should be selected such that they can accommodate the maximum level of bus activity.

3.2.10 Link Layer Re-transmission on Error - Compulsory

The LLC sub-layer of the ISO11898 CAN standard includes amongst its functions the re-transmission of frames that have been disrupted by errors during transmission. This process can result in an unpredictable number of re-transmissions of the same frame in the event of errors.

Automatic re-transmission on error shall be prohibited where this would violate the requirements of prioritised queuing as stated in section 3.2.7.1. Corrective procedures appropriate for the system application may then be executed by the node/device application software.

3.2.11 Remote Frame Request - Compulsory

This function of the ISO 11898 [2] CAN standard shall not to be used.

The source node/device would be dependent on destination node/device to complete the frame. This is not compatible with logically addressed systems (i.e. the identifiers for both the request frame and the response frame would be identical).

3.2.12 Transport Layer functions

3.2.12.1 Multi-Frame Messages - Optional Enhancement

Messages requiring a data payload of greater than 8 bytes may be transmitted as multi-frame messages. A multi-frame message is defined as a group of related CAN frames, each frame having an identical 29 bit identifier, that contain a combined payload of greater than 8 bytes.

Multi-frame messages are not time critical messages and are governed by the maximum message trigger rate that restricts frames with identical 29 bit identifiers from being triggered more than once per primary time unit. Time critical messages would normally be defined as a group of single frame messages each with unique function identifiers.

Nodes/devices using multi-frame messages should implement a service that manages the process of triggering each individual frame and issuing it to the data link layer. Where applicable this service shall not restrict the transmission and reception of multiple multi-frame messages at the same time. The only restriction on the service is that it shall ensure multi-frame messages with the same message identifier are not transmitted at the same time by the node/device. In this instance, nodes/devices shall wait until the previous multi-frame message has been successfully transmitted.

Multi-frame messages shall be identified as such within the message set. Each frame of a multi-frame message shall use the normal Status/Command message format.

The structure of the payload of a multi-frame message is defined below (see Figure 3-3).

		Byte No							
		0	1	2	3	4	5	6	7
Frame No.	0	Message Count	Byte Count			Reserved			
	1	Message Count	Data						
	↓	↓	Data						
	249	Message Count	Data						
	250	Message Count	CRC (Optional)		Reserved				

Figure 3-3 - Multi-frame Message Structure

Multi-frame messages are divided into three segments, the first frame, intermediate frames and the last frame.

3.2.12.1.1 First Frame

The first frame of a multi-frame message shall be transmitted first and shall contain control information only. The frame is comprised of the following fields:

- Message Count Field - this field (payload byte 0) shall be used to ensure the chronology of data being transmitted as a multi-frame message. In the first frame, the message count shall always be set to 0 to indicate the start of a multi-frame message. The field structure of the message count shall be as defined in Table 3-1.

Data	Byte No	No. Bits	Limits / Range	Comments
Message Count	0	8	0 to 250	The message count can take any value between 0 and 250 in a multi-frame message but shall always be 0 for the first frame of a multi-frame message.

Table 3-1 - Message Count field for first frame of a multi-frame message

- Byte Count Field - this field (payload bytes 1 to 3) shall be used to identify the size of the data block being transmitted as part of the multi-frame message. The byte count shall represent the exact size of the data block and shall exclude any padding bytes that might be required to populate the data field. The field structure of the byte count shall be as defined in Table 3-2. Payload byte 3 shall represent the most significant byte of the byte count and payload byte 1 the least significant byte.

Data	Byte Order	No. Bits	Limits / Range	Comments
Byte Count	3-1	24	0 to 16,449,535 (0xFAFFFF)	Note max value is not 16,777,215

Table 3-2 - Byte Count field for first frame of a multi-frame message

- Reserved Field - Payload bytes 4 to 7 are reserved by MilCAN for future use.

3.2.12.1.2 Intermediate Frames

The intermediate frames of a multi-frame message are transmitted in message count order and contain both control information and data. Each intermediate frame is comprised of the following fields:

- Message Count Field - for all intermediate frames of the multi-frame message, the message count field (payload byte 0) shall be a counter that operates in the range 1 to 249. The count shall always start at 1 for the first intermediate frame and count upward for each subsequent frame. If the count overflows, it shall be reset to 1. The field structure of the message count shall be as defined in Table 3-3.

Data	**Byte No**	**No. Bits**	**Limits / Range**	**Comments**
Message Count	0	8	0 to 250	The message count can take any value between 0 and 250 in a multi-frame message but shall always be in the range 1 to 249 for intermediate frames of a multi-frame message. On reaching the value 249 the message count will be reset to 1 for the next frame

Table 3-3 - Message Count field for intermediate frames of a multi-frame message

- Data Field - intermediate frames contain the message data (payload bytes 1 to 7).

  Bytes 0 to 6 of the data block shall be stored in bytes 1 to 7 of the first intermediate frame for multi-frame. Subsequent frames shall contain the remainder of the data block. Where insufficient data is available to populate the data field of the last intermediate frame, padding bytes shall be used to populate the remainder of the data field.

3.2.12.1.3 Last Frame

The last frame of a multi-frame message shall be transmitted last and shall contain control information only. The frame is comprised of the following fields:

- Message Count Field - In the last frame, the message count field (payload byte 0) shall always be set to 250 to indicate the end of a multi-frame message. The field structure of the message count shall be the same as the message count defined in Table 3-4.

Data	Byte No	No. Bits	Limits / Range	Comments
Message Count	0	8	0 to 250	The message count can take any value between 0 and 250 in a multi-frame message but shall always be 250 for the last frame of a multi-frame message.

Table 3-4 - Message Count field for last frame of a multi-frame message

- Cyclic Redundancy Check (CRC) Field - this field (payload bytes 1 and 2) shall be used to provide an optional user-defined 8 or 16-bit CRC for the data block being transmitted as part of the multi-frame message. The CRC shall exclude any padding bytes that might be required to populate the data field. The use of the CRC shall be specified as part of the message set as part of system design.

- Reserved Field - payload bytes 3 to 7 are reserved by MilCAN for future use.

4 Application Layer

4.1 Communication Architecture

4.1.1 Message Payload Data Byte Order - Compulsory

Where reference is made to a message payload in this specification, the byte ordering shall conform to the following definition:

- Message payload bytes are transmitted in Intel format (i.e. least significant byte first). The first payload byte received shall be designated Byte 0 and the last payload byte received (for a maximum 8 byte payload) shall be designated Byte 7.
- Bits within the message payload bytes are transmitted most significant first. The first bit received is designated Bit 7 and the last bit received is designated Bit 0.

4.1.2 Message Acknowledgements - System Specific

MilCAN messages shall not generally require an acknowledgement message from any recipient node/device. This is in keeping with the spirit of CANbus as a broadcast bus and will reduce unnecessary traffic on the bus.

In some applications it may be necessary to obtain confirmation from the receiving device(s) application process that the message has been successfully received and processed. In this case, the systems designer shall specify the mechanism for acknowledgement.

4.1.3 Multi-instance addressing - System Specific

This is no longer supported by MilCAN A. System designers are free to implement a protocol to support this function if required.

4.1.4 Message Identifier Assignment - Compulsory

28 – 26	25	24	23 – 16	15 – 8	7 – 0
Priority	1	X	Message Primary Type	Message Sub-Type	Source Address

The CAN frame 29bit identifier, shall be divided as follows:

- Bits 26 - 28 convey the message priority level (see 4.1.5.3).
- Bit 25 identifies the message as a MilCAN message. In J1939 this bit is reserved and set to 0, in MilCAN this bit is set to 1.
- Bit 24 - is the Request bit set to 0 for normal message, set to 1 for requested data.
- Bits 16 -23 define the message primary-type.

- Bits 8 -15 define the message sub-type.

- Bits 0 - 7 define the node/device source address. This must be unique for each node/device on the network. The value 0x00 is reserved and must not be used.

The message priority is assigned according to whether the message is Hard real time, Soft real time or Non real time and the maximum message latency (see 4.1.5.3).

The message primary-type and message sub-type allow coarse message filtering (using only the primary-type byte) and fine message filtering (using the combined primary and sub-type bytes).

Messages are grouped by virtue of their primary-type - see Appendix A for discussion of identifier assignment and a table containing a suggested allocation.

4.1.5 Support for deterministic message transmission

4.1.5.1 Protocol Requirements

The primary goal of MilCAN is to provide deterministic communications between those devices connected to a platform network that require such a capability and yet support non-deterministic communications for other devices as required.

Implementation of a Prioritised Bus Access with Bounded Throughput protocol will achieve the need for determinism for those devices that require it while providing sufficient flexibility to accommodate those devices that do not.

The primary requirements for this protocol are:

- Message priority assignment is dependent on the required delivery deadline (latency) of each message. The shortest delivery deadline messages will be assigned the highest priority (lowest value) in order to meet their required maximum latency.
- Sync Frames should be issued by a Sync Master at a rate determined by messages with the shortest delivery deadline.
- Provision of a number of Sync Frame Masters and an associated election protocol to ensure that only one Sync Frame Master can output Sync Frames at any given time. The election protocol should ensure that a new master is elected after the failure of the current Sync Frame Master is detected.
- Each message has a minimum inter-arrival rate that must be greater than or equal to the primary time unit.
- If all the messages in the system and their inter-arrival times are known then a schedule of all messages can be determined at the system design stage. This is achieved by allocating messages to be triggered in the numbered slots as indicated by the Sync Frame.
- The protocol must accommodate HRT, SRT and NRT messages. This is achieved by allocating message priority values 0 through 7 to messages.
- Since the protocol does not employ a global timebase and each node/device is responsible for the timing of it's own message triggering there will be some timing inaccuracies between nodes/devices. The protocol must make allowance for these timing inaccuracies.
- The protocol must support fault recovery in the event of failures.

4.1.5.2 Maximum message trigger rate - Compulsory

No single-frame message or an individual frame of a multi-frame message, whether synchronous or asynchronous to the Sync Frame message, shall be triggered more than once per PTU.

It is the responsibility of the application layer within each node/device to ensure that this requirement is met.

Non-compliance with this requirement can result in the failure of other messages to meet their delivery deadlines.

4.1.5.3 Message priority assignment - Compulsory

Message priority assignment is dependent on the required delivery deadline (latency) of each message. The shortest delivery deadline messages will be assigned the highest priority (lowest value) in order to guarantee meeting their required maximum latency.

In the table that follows, the stated maximum latency requirements for each priority refer to either a single-frame message or to each frame of a multi-part message.

Priority	Message Transfer Performance Criteria	Comments
0	Messages assigned this priority are termed HRT0 and will gain immediate access to the bus subject to the following constraints: • If a message of any priority is being transmitted on the bus at the point in time when a message of this type is triggered, access to the bus will be delayed until the message being transmitted is complete. • If another HRT0 message with a lower value of the 29 bit ID is being queued by another device, access to the bus will be delayed until that message has completed. • If a device transmits more than 1 HRT0 message, they will be queued in the order in which they are triggered.	This priority is reserved for either protocol operation messages (e.g. Sync Frame message) or for messages that cannot tolerate a maximum latency value of 1 PTU. The system designer is free to specify other messages of this priority provided that: • No operational HRT0 messages are assigned an Identifier that results in a priority that is higher than the Sync Frame message • Constraints on message latency are taken into account. The Sync Frame message, EnterConfigMode & ExitConfigMode messages are the only messages currently defined by MilCAN A that are assigned an HRT0 priority.
1	Messages assigned this priority are termed HRT1 and should have maximum latency requirements that do not exceed 1 x PTU. The latency requirement can only be guaranteed if the following conditions are true: • The systems designer has ensured that sufficient time is available to transmit all HRT1 messages allocated to the PTU in which the message is triggered. • The network is error free at the time when the message is transmitted.	This priority should be assigned to HRT operational messages that must be delivered within one PTU of being triggered by a node/device.
2	Messages assigned this priority are termed HRT2 and should have maximum latency requirements that do not exceed 8 x PTU. The latency requirement can only be guaranteed if the following conditions are true: • The systems designer has ensured that sufficient time is available to transmit all HRT2 messages allocated to the period of 8 x PTU in which the message is triggered • The network is error free at the time when the message is transmitted.	This priority should be assigned to HRT operational messages that must be delivered within 8 x PTU of being triggered by a node/device.

Priority	Message Transfer Performance Criteria	Comments
3	Messages assigned this priority are termed HRT3 and should have maximum latency requirements that do not exceed 64 x PTU. The latency requirement can only be guaranteed if the following conditions are true: • The systems designer has ensured that sufficient time is available to transmit all HRT3 messages allocated to the period of 64 x PTU in which the message is triggered • The network is error free at the time when the message is transmitted.	This priority should be assigned to HRT operational messages that must be delivered within 64 x PTU of being triggered by a node/device.
4	Messages assigned this priority are termed SRT1 and should have latency requirements that do not exceed 8 x PTU. Messages assigned this priority will be transmitted using bus capacity not consumed by HRT0, HRT1, HRT2 & HRT3 messages during an 8 x PTU period beginning with the Sync frame message in which this SRT1 message is triggered. Latency requirements can not be guaranteed for this priority.	This priority should be assigned to SRT operational messages that have a high probability of being delivered within 8 x PTU of being triggered by a node/device.
5	Messages assigned this priority are termed SRT2 and should have latency requirements that do not exceed 64 x PTU. Messages assigned this priority will be transmitted using bus capacity not consumed by HRT0, HRT1, HRT2, HRT3 & SRT1 messages during a 64 x PTU period beginning with the Sync frame message in which this SRT2 message is triggered. Latency requirements can not be guaranteed for this priority.	This priority should be assigned to SRT operational messages that have a high probability of being delivered within 64 x PTU of being triggered by a node/device.
6	Messages assigned this priority are termed SRT3 and should have latency requirements that do not exceed 1024 x PTU. Messages assigned this priority will be transmitted using bus capacity not consumed by HRT0, HRT1, HRT2, HRT3, SRT1 & SRT2 messages during a 1024 x PTU period beginning with the Sync frame message in which this SRT3 message is triggered. Latency requirements can not be guaranteed for this priority.	This priority should be assigned to SRT operational messages that have a high probability of being delivered within 1024 x PTU of being triggered by a node/device.

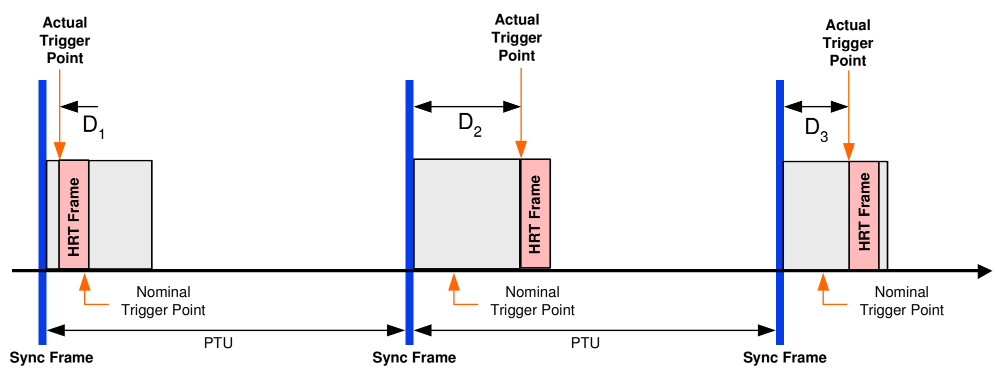
Priority	Message Transfer Performance Criteria	Comments
7	Messages assigned this priority are termed NRT and have no latency requirement. These messages may use any available spare bus capacity.	

Table 4-1 - Message priority assignment

4.1.5.4 Synchronous Device Response Time to Sync Frame - Compulsory

Devices operating synchronously to the network will trigger messages on receipt of a Sync Frame message that indicates the slot number within the major cycle in which the message is scheduled to be triggered.

Devices must respond to the Sync Frame message by triggering the appropriate messages for that slot within a defined period of time. Since this time is a function of the processing time within the device, a fixed amount of time equal to the worst case response time to Sync Frame must be reserved in each PTU to ensure that all messages allocated to a particular slot can be transmitted in that slot. Refer to Figure 4-1. It is the responsibility of the system designer to define the maximum allowable time to respond to Sync Message for all devices on the network and to ensure that this time is reserved in each slot when designing the message schedule.



$D_1 > D_3 > D_2$

D_2 represents the worst case response of a node/device to a Sync Frame

Figure 4-1 - Synchronous Devices response to Sync Frame

4.1.5.5 Asynchronous Message Triggering - System Specific

In the case where a message is triggered in response to an event, from either an asynchronous or a synchronous device, such a message may be triggered in any slot forcing the systems designer to allocate a fixed amount of time in each slot to accommodate it, even though the message may be triggered infrequently. For this reason it is recommended that the systems designer should consider the following:

- eliminate event driven messages
- minimise the use of event driven messages
- lower the priority of event driven messages

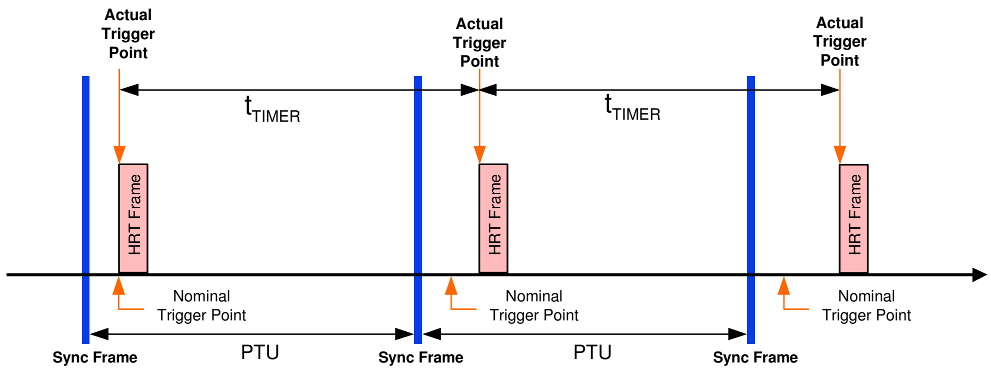
Devices operating asynchronously to the network must be aware of the Sync Frame message in order to transition from pre-operational to operational modes and vice versa. However, in order to transmit messages on to the bus, asynchronous nodes/devices are not mandated to trigger messages on receipt of the Sync Frame, instead they may trigger periodic messages in response to an internal timer.

In the case where messages from an asynchronous device are triggered periodically in response to an internal timer, the period of the timer for all asynchronous devices should be set to a value greater than one PTU. In this way, the maximum message trigger rate constraint contained in section 4.1.5.2 may be maintained for asynchronous devices. See Figure 4-2.

Messages from an asynchronous device that are triggered in response to an internal timer may be triggered in any slot again forcing the systems designer to allocate a fixed amount of time in each slot to accommodate them. For this reason it is recommended that the systems designer should consider the following:

- where possible, eliminate asynchronous devices
- minimise the use of asynchronous devices
- lower the priority of asynchronous messages

The systems designer is also constrained by section 3.2.6.2, which states that asynchronous devices shall be restricted to the transmission of messages of priority 2 or lower.



t_{TIMER} > PTU

t_{TIMER} = Period of message trigger timer for Asynchronous Device

Figure 4-2 - Asynchronous Devices Message Trigger Timer Period

In general, both event driven messages and asynchronous devices connected to the bus introduce an uncertainty in the triggering of messages and can therefore impact on latency requirements of the overall system.

4.1.5.6 Sync Frame message generation - Compulsory

Military vetronic systems will predominantly be distributed real-time systems providing deterministic message transfer to ensure predictable performance. This requires some form of co-ordination of message generation at each network node/device and this is achieved within MilCAN by employing one of the network nodes/devices as a Sync Frame message generator (or Sync Master) to provide this co-ordination. However, since a single Sync Frame message generator makes the system vulnerable to its failure, a protocol is required that will allow other nodes/devices to assume this role in the event of a failure of the current Sync Master.

The generation of Sync Frame messages is the responsibility of the node/device that has won the arbitration for the role of Sync Master that takes place at system start up and in the event of a failure in the currently elected Sync Master.

The number of nodes/devices designated as Potential Sync Masters within a system is the responsibility of the systems designer.

Nodes/devices designated as Potential Sync Masters shall adhere to the following process:

- Each node/device that has been designated as a Potential Sync Master shall check for receipt of a Sync Frame message. If a Sync Frame message is not received within the sync slave timeout period then the node/device shall assume the role of Sync Master by transmitting a next Sync Frame message containing the next Sync Frame counter value. If the Sync Frame counter value is undefined then the node/device shall transmit the first Sync Frame message with a Sync Frame counter value of zero. The sync slave timeout period shall be greater than one PTU plus the time to transmit two messages of maximum length (considering worst case bit stuffing).

- If a Potential Sync Master receives a Sync Frame message that has a higher priority (lower source address), the node/device shall maintain the role of a Potential Sync Master.
- If a Potential Sync Master receives a Sync Frame message that has a lower priority (higher source address), the node/device shall assume the role of Sync Master by transmitting a takeover Sync Frame message containing the next Sync Frame counter value after a sync arbitration timeout period. The sync arbitration timeout period shall be 0.8 PTU (±12.5%).
- If the Sync Master receives a takeover Sync Frame message that has a higher priority (lower source address), then the node/device shall assume the role of a Potential Sync Master by ceasing its own Sync Frame message transmission.
- The Sync Master shall maintain Sync Frame message transmission if it does not receive a Sync Frame message within the Sync Master timeout period or if it receives a takeover Sync Frame message that has a lower priority (higher source address). The Sync Master timeout period shall be equal to the system PTU.

This protocol will ensure that the Potential Sync Master with the highest priority will eventually become the system Sync Master. If the Potential Sync Master with the highest priority is non-functional then the next highest priority potential Sync Master will become the system Sync Master for the system.

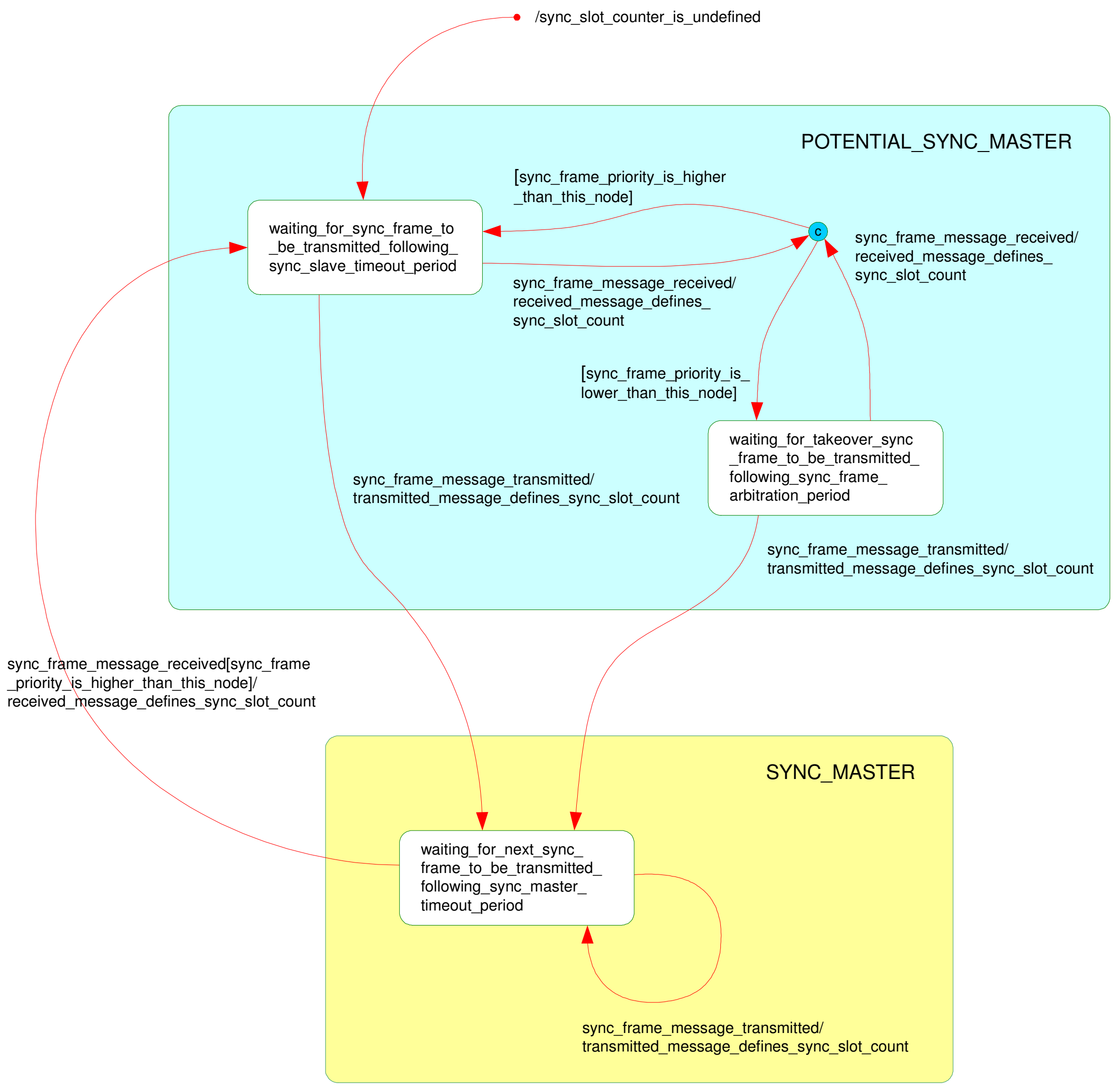


Figure 4-3 - Sync Frame Arbitration

4.2 System Modes - Compulsory

All devices shall implement, as a minimum, the modes and transitions shown in the state diagram given in Figure 4-4. The details of how a node/device will respond while in system configuration mode are defined in the System Management Layer Specification [9].

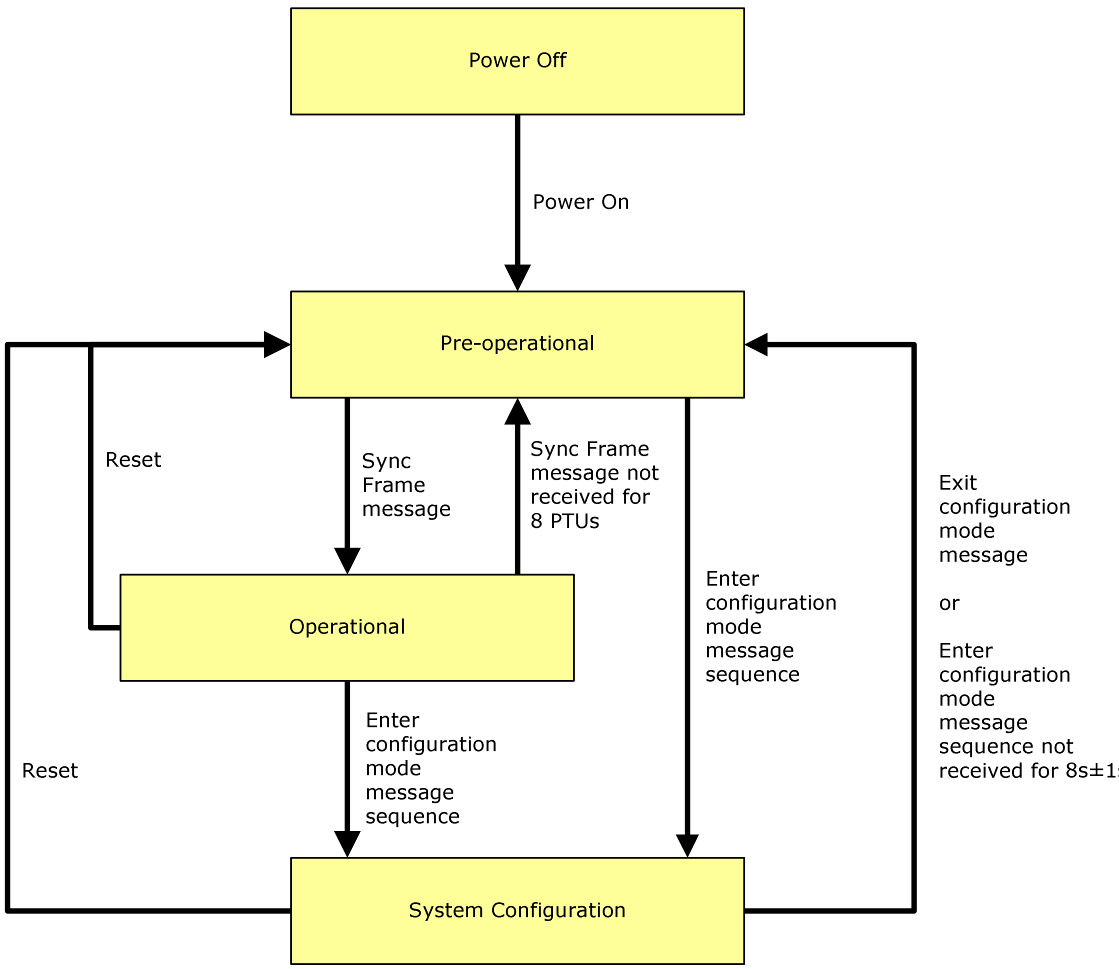


Figure 4-4 - System Modes

4.2.1 Pre-Operational Mode

Following the application of power, a reset, loss of Sync Frames or upon exiting system configuration mode, devices connected to the bus shall automatically enter pre-operational mode. In this mode of operation, message transmission is restricted to Sync Frame and enter/exit configuration mode messages only.

Having entered pre-operational mode, devices designated as potential Sync Masters arbitrate for the role of Sync Master. The procedure for electing the Sync Master is described in section 4.1.5.6.

Having entered pre-operational mode, devices shall remain in this mode until they have received a valid Sync Frame message or a valid enter system configuration mode message sequence. Following receipt of a valid Sync Frame, all devices shall enter operational mode and start normal message transmission. Following receipt of a valid enter system configuration mode message sequence, all devices shall enter system configuration mode.

4.2.2 Operational Mode

Devices shall suspend pre-operational mode and enter operational mode following receipt of a valid Sync Frame. In operational mode normal message transmission is allowed.

All devices shall suspend operational mode and enter pre-operational mode following a reset or in the event that Sync Frame messages cease to be generated on the bus within 8 PTUs of the last received Sync Frame.

All devices shall suspend operational mode and enter system configuration mode following receipt of a valid enter system configuration mode message sequence.

4.2.3 System Configuration Mode

All devices shall suspend pre-operational/operational mode and enter system configuration mode on request by a Configuration Master node/device. Whilst in system configuration mode, devices shall only respond to system configuration mode messages, all operational messages, including Sync Frames, shall be suspended.

The Configuration Master node/device is likely to be a normally offline tool, such as a laptop or similar test equipment, which is used specifically for system configuration. However, this does not preclude a device such as a crewstation from being employed as the Configuration Master Node, should a system designer so wish.

System configuration mode shall be invoked by the Configuration Master Node, attached to the bus, transmitting a sequence of three messages with the same ID but with a different defined payload for each message. The configuration mode message sequence shalll be transmitted within 400ms. Note that the minimum message transmission time is limited by the maximum message trigger rate of the system i.e 3 PTUs..

On receipt of the correct sequence of messages all devices attached to the bus shall suspend operational mode and enter system configuration mode. The sequence of messages is intended to prevent accidental entry into system configuration mode.

Devices must receive the message sequence in the correct order before entry into system configuration mode. If any message is received out of sequence, the sequence must be restarted before entry into system configuration mode can be achieved.

If an exit configuration mode message is received before the enter system configuration mode message sequence is completed, the sequence must be restarted before entry into system configuration mode can be achieved.

The sequence of enter configuration mode messages must be received within a timeout of 500ms ±5% from receipt of the first message in the sequence. If the sequence is not completed within this time all devices shall remain in their current mode.

In system configuration mode message transmissions shall not be restricted by the maximum message trigger rate of the system.

In system configuration mode the Configuration Master Node shall continually transmit the enter system configuration mode message sequence at a rate of once per second. This ensures that devices, which come on-line when the bus is in system configuration mode, also enter into system configuration mode.

In system configuration mode the Configuration Master Node shall immediately transmit the enter system configuration mode message sequence if unexpected bus traffic is detected. This ensures that devices e.g. potential Sync Masters, which come on-line when the bus is in system configuration mode, are prevented from transmitting operational messages while the network is in system configuration mode.

Devices shall exit configuration mode and enter pre-operational mode if the enter configuration mode message sequence has not been received for 8s ±1s, on request by the Configuration Master Node or following a system reset. Pre-operational mode shall be entered following receipt of a single, exit configuration mode message with a defined payload.

Data distribution architecture - Compulsory
Data shall be distributed on a publisher/user basis. i.e. data sources broadcast data messages to the system and users read data of interest from the system. Nodes/devices will extract data of interest from broadcast messages by filtering messages using the message identifier (see 4.1.4). Data shall be communicated either by event driven or periodic broadcast messages.

4.3 Command distribution architecture - Compulsory

Command shall be issued in one of two forms:

- Implicit commands - an implicit command is a data message that conveys a change in a system parameter resulting in a function responding in an appropriate manner. (e.g. an engine start switch issues a status message conveying a change in the switch state and the engine controller acts accordingly by starting the engine).
- System mode commands - a system mode commands will inform a node/device how data that it receives should be interpreted e.g. data received may be interpreted differently depending on the operational (or non-operational) mode of the system. A node/device would also be informed of the data source to use in this manner. Similarly, a system mode command would also indicate to a node/device the data that it should issue in a particular operational (or non-operational) mode.

The majority of command messages used in a system will be ‘implicit’. This avoids tight associations between functions, such as control devices requiring precise knowledge of actuating devices. System mode change commands will normally only be issued by crewstations and stand-alone MMI devices.

4.4 Processing/control topology - Compulsory

The processing topology shall be distributed.

5 References

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4. CAN Specification, Version 2.0, 1991, Bosch GmbH, R, Stuttgart, Germany

5. Bit Timing Parameters for CAN Networks – Application Note KIE 07/91 ME, 20 March 1991, Philips Concept and Application Laboratory, Hamburg, Germany.

6. MilCAN A Physical Layer Specification – IHSDB-APP-GEN-D-030- Rev3

7. MilCAN A Data Link Layer Specification – IHSDB-APP-GEN-D-031- Rev 4

8. MilCAN A Application Layer Specification – IHSDB-APP-GEN-D-032 Rev 2

9. MilCAN A System Management Specification – IHSDB-APP-GEN-D-036 Rev 1

List of Definitions

Arbitration	The process by which the CAN protocol controls access to the transmission medium for simultaneously generated messages.
Asynchronous message	A message that is transmitted by a device without dependence upon the receipt of a Sync Frame message.
Automatic Re-transmission	Retransmission of a message that was previously reported as containing an error(s).
Device	A subsystem containing an interface to the bus.
Event Driven Message	A message that is transmitted by a device in response to the occurrence of a particular event.
Hard Real Time (HRT) Message	A message that must meet its delivery deadline (maximum latency) in order to avoid unacceptable consequences.
Ideal PTU	The interval between consecutive Sync Frames for a perfect bus i.e. one that is not subject to any variation in time between Sync Frames.
Latency	The allowable time between a message being triggered and it being received. No account of processing time in either the transmitting node or the receiving node is included in this time.
Message	A single CAN frame comprising a unique 29-bit identifier and a payload of between 0 and 8 bytes. This is known as a single-frame message. Or, A group of related CAN frames, each frame having an identical 29-bit identifier that contains a combined payload of greater than 8 bytes. This is known as a multi-frame message.
Message Inter-Arrival Time	The time between messages comprising identical 29 bit identifiers gaining access to the bus.
Message Priority	The value given by bits 26-28 of the 29-bit Identifier of a message. 8 levels of priority (values 0 – 7) are possible with the value 0 being the highest priority.
Message Transmission	The point in time when a message wins the arbitration process and is successfully transmitted on the bus.

Message Triggering	The point in time when a message is placed in either the priority queue system if implemented within a device or in the transmit buffer of the CAN controller of a device that does not implement a priority queue system. This may be different from the point in time when it gains access to the bus.
Multi-frame message	A group of related CAN frames, each frame having an identical 29-bit identifier that contains a combined payload of greater than 8 bytes.
Node	An interface to the bus for one or more subsystem.
Non Real Time (NRT) Message	A message that will be delivered on a 'best effort' basis.
Periodic Message	A message that is transmitted by a device at regular intervals.
Primary Time Unit (PTU)	The interval between the arrival of consecutive Sync Frame messages.
Soft Real Time (SRT) Message	A message that will have a high probability of meeting it's delivery deadline but the consequences of occasionally missing the deadline will be acceptable.
Synchronous message	A message that is transmitted by a device in response to the receipt of a Sync Frame message by that device.

List of Abbreviations

ASCII	American Standard Code for Information Interchange
BIT	Built in Test
BMS	Battle Management System
bps	bits per second
BWB	Bundesamt für Wehrtechnik und Beschaffung
CAN	Controller Area Network
CRC	Cyclic Redundancy Check
CUP	CAN Utilities Protocol
DAS	Defence Aids System
FDSS	Fire Detection & Suppression System
HRT	Hard Real-Time
HVAC	Heating, Ventilation, and Air Conditioning
IEC	International Electrotechnical Commission
IHSDB	International High Speed Data Bus
ISO	International Standards Organisation
LLC	Logical Link Control
MMI	Man Machine Interface
NBC	Nuclear Biological & Chemical
NRT	Non Real-Time
PDU	Protocol Data Unit
PTU	Primary Time Unit
SAE	Society of Automotive Engineers

SRT	Soft Real-Time
STA	Surveillance & Target Acquisition
TBD	To Be Decided
Tx	Transmit

A Message Identifier Assignment – System Specific

A.1 It would be ideal if a master message dictionary for all implementations of MilCAN could be maintained such that systems designers and device manufacturers had a single source of information, which they could consult (this is effectively the approach of the SAE J1939 standard). However, the diversity of military vehicles and their equipment fit makes it difficult to achieve this ideal.

A.2 The approach to message identifier assignment is therefore to allow the system designer the freedom to assign identifiers according to the needs of a particular system with the exception that some Primary-type and Sub-type values have been pre-allocated. These Primary-type and Sub-type values are:

a. Identifiers 0x0000-0x007F (hexadecimal value of bits 8 to 23 of the 29 bit identifier) are reserved for possible future network management use.
b. The identifier 0x0080 is reserved for the Sync Frame message. See Table A-2.
c. The identifier 0x0081 is reserved for the Enter Configuration Mode message. See Table A-3.
d. The identifier 0x0082 is reserved for the Exit Configuration Mode message. See Table A-4.
e. Identifiers 0x0083-0x00BF are reserved for possible future network management use.
f. The identifier 0x62nn (hexadecimal value of bits 16 to 23 of the 29 bit identifier) is reserved for the Alive message. See Table A-5.

A.3 In order to assist the systems designer a suggested set of message primary type identifiers is given in Table A-1.

Hex Value	**Message Primary-Type**		
0x00	System Management / Ultra low latency		
		Hex Value	**Message Sub-Type**
		0x00-0x7F	Reserved
		0x80	Sync Frame
		0x81	Enter Config Mode
		0x82	Exit Config Mode
		0x83-0xBF	Reserved
		0xC0-0xCF	Low-jitter/High-frequency Operational Messages (system specific)
		0xD0-0xFF	Reserved
0x01-0x30	Reserved		
0x31	Physically addressed messages		

Hex Value	Message Primary-Type
0x32	System Configuration
0x33	Reserved
0x34	Special to Role / Application specific
0x35	Special to Role / Application specific
0x36	Special to Role / Application specific
0x37	Special to Role / Application specific
0x38	Special to Role / Application specific
0x39	Special to Role / Application specific
0x3A	Special to Role / Application specific
0x3B	Special to Role / Application specific
0x3C	System Command and Control
0x3D	Reserved
0x3E	Motion Control
0x3F	Reserved
0x40	STA
0x41	Reserved
0x42	Fire Control
0x43	Reserved
0x44	Automotive
0x45	Reserved
0x46	Navigation
0x47	Reserved
0x48	Special to Role / Application specific
0x49	Special to Role / Application specific
0x4A	Special to Role / Application specific
0x4B	Special to Role / Application specific
0x4C	Special to Role / Application specific
0x4D	Special to Role / Application specific
0x4E	Special to Role / Application specific
0x4F	Special to Role / Application specific
0x50	Power Management
0x51	Reserved
0x52	DAS
0x53	Reserved
0x54	Communications/BMS

Hex Value	Message Primary-Type
0x55	Reserved
0x56	HVAC/NBC
0x57	Reserved
0x58	Vision Sensor Control
0x59	Reserved
0x5A	Generic MMI devices
0x5B	Reserved
0x5C	FDSS
0x5D	Reserved
0x5E	Lighting
0x5F	Reserved
0x60	Body Electronics
0x61	Reserved
0x62	Alive Message
0x63	Diagnostics
0x64	Diagnostics
0x65	Diagnostics
0x66	Diagnostics
0x67-0xFF	Undefined

Table A-1 - Suggested Message Identifiers

A.4 The Sync Frame Message will have the following identifier 0x020080xx, this corresponds to the following:

Priority value:	0
Protocol type:	MilCAN
Message primary type value:	0x00
Message sub-type value	0x80

The payload of the Sync Frame message shall be 2 Bytes and is defined in Table A-2 below.

Data	Byte Order	No. Bits	Limits / Range	Comments
Sync slot counter	1-0	16	0 to 1023	Provides an index to identify the current sync slot number within the major cycle. The valid range for the Sync slot counter is 0 to 1023. The Sync slot counter repeatedly cycles from 0 to 1023 and is incremented for each Sync Frame message transmitted on the bus.

Table A-2 - Sync Frame Message Payload Definition

A.5 The Enter Configuration Mode message shall have the following identifier 0x020081xx, this corresponds to the following:

Priority value:	0
Protocol type:	MilCAN
Message primary type value:	0x00
Message sub-type value	0x81

The payload of the Enter Configuration Mode message shall be 1 Bytes and is defined in Table A-3.

Data	Byte Order	No. Bits	Limits / Range	Comments
Enter Configuration Mode	0	8	N/A.	Provides a single ASCII data character as part of a coded sequence to place all devices on the bus into system configuration mode. Valid ASCII data characters in the sequence are 'C' (43h), 'F' (46h) and 'G' (47h). ASCII character data are encoded as defined in ISO/IEC 8859-1-1998 Information processing – 8-bit single byte coded graphic character sets - Part 1: Latin alphabet No. 1

Table A-3 - Enter Configuration Mode Message Payload Definition

A.6 The Exit Configuration Mode message shall have the following identifier 0x020082xx, this corresponds to the following:

Priority value:	0
Protocol type:	MilCAN
Message primary type value:	0x00
Message sub-type value	0x82

The payload of the Exit Configuration Mode message shall be 3 Bytes and is defined in Table A-4.

Data	Byte Order	No. Bits	Limits / Range	Comments
Exit Configuration Mode	2-0	24	N/A	Provides a three-character ASCII string to place all devices on the bus into pre-operational mode. The valid three-character ASCII string is ‘OPR’ (4Fh, 50h and 52h). ASCII character data are encoded as defined in ISO/IEC 8859-1-1998 Information processing – 8-bit single byte coded graphic character sets - Part 1: Latin alphabet No. 1

Table A-4 - Exit Configuration Mode Message Payload Definition

A.7 The Alive Mode message shall have an identifier that corresponds to the following:

Priority value:	TBD by Systems Designer
Protocol type:	MilCAN
Message primary type value:	0x62
Message sub-type value	TBD by Systems Designer

The payload of the Alive message shall be a minimum of 1 Byte and is defined in Table A-5.

Data	**Byte No.**	**Bit Index**	**LSB loc.**	**Range Name**	**Definition**
Device Status	0	1-0	0	Disabled (BIT not run)	00
				Enabled (BIT pass)	01
				Error indicator (BIT failed)	10
				Not available or not installed (BIT not available)	11
Not used	0	7-2	n/a	n/a	Reserved

Table A-5 - Alive Message Payload Definition

More detailed status information on the device and its functions may be broadcast in additional user defined diagnostic messages or in bytes 1-7 of the Alive message

A.8 Before messages can be allocated an identifier, the systems designer must decide on the content of the messages. A message will consist of a mixture of commands, status information and parameter data. To this end Table A-6 through Table A-11 below can be used to assist the systems designer in specifying commands, status information and parameters.

Range Name	1 Byte	2 Byte	3 Byte	4 Byte
Valid Signal	0 to 250	0 to 64255	0 to 16,449,535	0 to 4,211,081,215
	0x00 to 0xFA	0x0000 to 0xFAFF	0x000000 to 0xFAFFFF	0x00000000 to 0xFAFFFFFF
Parameter Specific Indicator	251	64256 to 64511	16,449,536 to 16,515,071	4,211,081,216 to 4,227,858,431
	0xFB	0xFB00 to 0xFBFF	0xFB0000 to 0xFBFFFF	0xFB000000 to 0xFBFFFFFF
Reserved range	252 to 253	64512 to 65023	16,515,072 to 16,646,143	4,227,858,432 to 4,261,412,863
	0xFC to 0xFD	0xFC00 to 0xFDFF	0xFC0000 to 0xFDFFFF	0xFC000000 to 0xFDFFFFFF
Error Indicator	254	65024 to 65279	16,646,144 to 16,711,679	4,261,412,864 to 4,278,190,079
	0xFE	0xFExx	0xFExxxx	0xFExxxxxx
Not available or Not requested	255	65280 to 65535	16,711,680 to 16,777,215	4,278,190,080 to 4,294,967,295

Table A-6 - Suggested parameter range values

Range Name	Transmitted Measured Value
Disabled (Off)	00
Enabled (On)	01
Error Indicator	10
Not Available or Not Installed	11

Table A-7 - Suggested range values for 2 bit status fields

Range Name	Transmitted Measured Value
Disabled (Off)	000
Enabled State 1 (On)	001
Enabled State 2 (On)	010
Enabled State 3 (On)	011
Error Indicator	100
Reserved	101
Reserved	110
Not Available or Not Installed	111

Table A-8 - Suggested range values for 3 bit status fields

Range Name	Transmitted Command Value
Command to disable function (turn off)	00
Command to enable function (turn off)	01
Reserved	10
Don't care / take no action (leave function as is)	11

Table A-9 - Suggested range values for 2 bit command fields

Range Name	Transmitted Command Value
Command to disable function (turn off)	000
Command to enable function state 1	001
Command to enable function state 2	010
Command to enable function state 3	011
Reserved	100
Reserved	101
Reserved	110
Don't care / take no action (leave function as is)	111

Table A-10 - Suggested range values for 3 bit command fields

Parameter	Scaling / Resolution	Limits / Range	Offset	Parameter Size	Origin
Angle Direction	$Pi/2^{23}$	-pi to +pi radians	-pi	24 bits	MilCAN
	$Pi/2^{15}$	0 to 2pi radians	0	16 bits	MilCAN
	10^{-7} deg/bit	-210 to +211.108122 deg	-210	32 bits	J1939
	1/128 deg/bit	-200 to 301.9921875 deg	-200	16 bits	J1939
	1/128 deg/bit	0 to 501.9921875 deg	0	16 bits	J1939
	1/8 mil/bit	0 to 8031.875mils		16 bits	MilCAN
Distance	0.01 m/bit	0 to 167,772.15 m	0	24 bits	MilCAN
	0.01 m/bit	-83,886.08 to +83,886.08 m	-83,886.08	24 bits	MilCAN
	0.125 km/bit	0 to 526,385,151.875 km	0	32 bits	J1939
	1/12.5m/bit	-2500 to 2640.4	-2500	16 bits	J1939
	0.125m/bit	0 to 526,385.151875 km	0	32 bits	MilCAN
	4 km/bit	0 to 1000 km	0	8 bits	MilCAN
Economy	1/512 km/L per bit	0 to 125.498 km/L	0	16 bits	J1939
Electrical Current	1 A/bit	-125 to 125.498 A	125	16 bits	J1939
	1 A/bit	0 to 250.498 A	0	16 bits	J1939
Electrical Potential	50mV/bit	0 to 3212.75 V	0	16 bits	J1939
Flow Rate	50mL/h per bit	0 to 3212.75 mL/h	0	16 bits	J1939
Force	5 N/bit	0 to 321275 N	0	16 bits	J1939
Mass	0.5 kg/bit	0 to 32,127.5 kg	0	16 bits	J1939
	2 kg/bit	0 to 128,510 kg	0	16 bits	J1939
Percent	0.4 %/bit	0 to 100 %	0	8 bits	J1939
	1 %/bit	-125 to +125 %	-125	8 bits	J1939
	0.001556 %/bit	0 to 100 %	0	16 bits	MilCAN
Power	0.5 kW/bit	0 to 32,127.5	0	16 bits	J1939

Parameter	Scaling / Resolution	Limits / Range	Offset	Parameter Size	Origin
Pressure	0.05 kPa/bit	0 to 12.5 kPa	0	8 bits	J1939
	0.5 kPa/bit	0 to 125 kPa	0	8 bits	J1939
	2 kPa/bit	0 to 500 kPa	0	8 bits	J1939
	4 kPa/bit	0 to 1000 kPa	0	8 bits	J1939
	16 kPa/bit	0 to 4000 kPa	0	8 bits	J1939
	0.5 kPa/bit	0 to 32127.5 kPa	0	16 bits	J1939
	1/128 kPa/bit	-250 to 251.99 kPa	-250	16 bits	J1939
	1/256 Mpa/bit	0 to 250.996 MPa	0	16 bits	J1939
Ratio	0.001/bit	0 to 64.255	0	16 bits	J1939
	0.1/bit	0 to 25	0	8 bits	J1939
	1/bit	0 to 250	0	8 bits	J1939
Revolutions	1000 revs/bit	0 to 4,211,081,215,000 revs	0	32 bits	J1939
Temperature	1 °C/bit	-40 to +210 °C	-40	8 bits	J1939
	0.03125 °C/bit	-273 to 1735 °C	-273	16 bits	J1939
Time	0.25s/bit	0 to 62.5 s	0	8 bits	J1939
	1 min/bit	0 to 250 min	0	8 bits	J1939
	1 h/bit	0 to 250 h	0	8 bits	J1939
	0.25 day/bit	0 to 62.5 days	0	8 bits	J1939
	1 month/bit	0 to 250 months	0	8 bits	J1939
	1 year/bit	1985 to 2235	+1985	8 bits	J1939
	1 s/bit	0 to 64,255 s	0	16 bits	J1939
	0.05h/bit	0 to 210,554,060.75 h	0	32 bits	J1939
Torque	1 Nm/bit	-32000 to +32255 Nm	-32000	16 bits	J1939
	1 Nm/bit	0 to 64255 Nm	0	16 bits	J1939
Velocity (linear)	0.1 m/s/bit	0 to 6425,5 m/s	0	16bits	MilCAN
	1/256 kph/bit	0 to 250.996 kph	0	16 bits	J1939
	1/128 kph/bit	-250 to +250.996 kph	-250	16 bits	J1939
	1 kph/bit	0 to 250 kph	0	8 bits	J1939

Parameter	Scaling / Resolution	Limits / Range	Offset	Parameter Size	Origin
Velocity (angular)	0.00001 radians/second	-83,886.08 to +83,886.08 radians/second	-83.88608	24 bits	MilCAN
	0.125 rpm/bit	0 to 8031.875 rpm	0	16 bits	J1939
	4 rpm/bit	0 to 265051.875 rpm	0	16 bits	J1939
	0.5 rpm/bit	0 to 32127.5 rpm	0	16 bits	J1939
	10 rpm/bit	0 to 2500 rpm	0	8 bits	J1939
Volume	0.5 L/bit	0 to 2,105,540,607.5 L	0	32 bits	J1939

Table A-11 - Suggested parameter definitions

B Defined Parameters

The parameters contained in this appendix have been defined by the MilCAN group members and are included for reference. This set of parameters is by no means complete and it is expected that users of MilCAN will define their own application specific parameters. In addition, the combination of parameters to form message payloads is a task to be performed by the systems designer.

B.1 Automotive Parameters

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Transmission oil temperature	Word	deg C	-273 to 1775 deg C	-273 deg C	0.03125 deg C/bit		
Hydraulic oil temperature	Word	deg C	-273 to 1775 deg C	-273 deg C	0.03125 deg C/bit		
Brake fluid level state	Field		2 bits			00 = Level low 01 = Level normal 10 = Error 11 = Unavailable	
Set Parking brake	Field		2 bits			00 = Set brake off 01 = Set brake on 10 = Unused 11 = No Change	
Parking brake state	Field		2 bits			00 = Brake off 01 = Brake on 10 = Error 11 = Unavailable	

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Brake Air Pressure	Byte	kPa	0 to 4000 kPa	0	16 kPa/bit		
Fuel Level	Byte	%	0 - 100%	0% offset	0.4%/bit		
Set Differential High/Low state	Field		2 bits			00 = Set low 01 = Set high 10 = Unused 11 = No Change	
Differential High/Low state	Field		2 bits			00 = Low 01 = High 10 = Error 11 = Unavailable	
Set Drive state	Field		2 bits			00 = Set 8*8 01 = Set 4*8 10 = Unused 11 = No Change	
Drive state	Field		2 bits			00 = 8*8 01 = 4*8 10 = Error 11 = Unavailable	
Set Rear Differential lock	Field		2 bits			00 = Set off 01 = Set locked 10 = Unused 11 = No Change	

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Rear Differential lock state	Field		2 bits			00 = Off 01 = Locked 10 = Error 11 = Unavailable	
Set Front Differential lock	Field		2 bits			00 = Set off 01 = Set locked 10 = Unused 11 = No Change	
Front Differential lock state	Field		2 bits			00 = Off 01 = Locked 10 = Error 11 = Unavailable	
Accelerator Pedal	Byte	%	0 - 100%	0	0.4%/bit	n/a	
Boost Pressure	Byte	kPa	0 to 500	0	2 kPa/bit	n/a	
Engine Speed	Word	rpm	0 to 8031.875	0	0.125rpm/bit	n/a	
Engine Temperature	Byte	deg C	-40 to 210	-40 deg C	1 deg C/bit	n/a	
Exhaust Temperature	Word	deg C	-273 to 1775 deg C	-273 deg C	0.01325 deg C/bit	n/a	
Engine Oil Pressure	Byte	kPa	0 to 1000	0	4 kPa/bit	n/a	

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Transmission Oil Pressure	Byte	kPa	0 to 4000	0	16 kPa/bit	n/a	
Hydraulic Oil Pressure	Word	kPa	0 to 32127.5	0	0.5 kPa/bit	n/a	
Transmission Speed	Word	rpm	0 to 8031.875	0	0.125 rpm/bit	n/a	
Set Cooling Fan Drive	Word	%	0 to 100	0	0.001556%/bit	n/a	
Measure Cooling Fan Drive	Word	%	0 to 100	0	0.001556%/bit	n/a	
Gear Select	Byte	Gear	-125 to +125	-125	1 Gear/bit	n/a	
Gear Engaged	Byte	Gear	-125 to 125	-125	1 Gear/bit	n/a	R2, R1, N, F1-F7
ME Fuel On	Field		2 bits			00 = Off 01 = On 10 = Unused 11 = No Change	
ME Run Start	Field		2 bits			00 = Off 01 = Run 10 = Start 11 = No Change	

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
ME Power	Field		2 bits			00 = Off 01 = On 10 = Unused 11 = No Change	
APU Fuel On	Field		2 bits			00 = Off 01 = On 10 = Unused 11 = No Change	
APU Run Start	Field		2 bits			00 = Off 01 = Run 10 = Start 11 = No Change	
Engine Cooling Fan Demand	Byte	%	0 to 100 %	0	0.4%/bit		
Vehicle Direction	Field		3 bits			000 = Neutral 001 = Forward 010 = Reverse 011 = Unused 100 = Error 101 = Unused 110 = Unused 111 = Unavailable	Null, Forward, Reverse

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Vehicle Total Distance	32 bit	km	0 to 526385.151875 km	0	0.125m/bit		
Vehicle Trip Distance	Byte	km	0 to 1000	n/a	4 km/bit	n/a	
Engine Alarm Stop	Field		2 bits			00 = Stop alarm 01 = Normal 10 = Error 11 = Unavailable	
Engine Alarm check	Field		2 bits			00 = Check alarm 01 = Normal 10 = Error 11 = Unavailable	
Engine Coolant temp	Byte	deg C	-40 to 210 deg C	-40 deg C	1 deg C/bit		
Engine Coolant status	Field		2 bits			00 = Level low 01 = Level normal 10 = Error 11 = Unavailable	
Vehicle Road Speed	Word	kph	0 - 256kph	0	1/256 kph/bit		

B.2 BMS Parameters

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Target or object grid position							As per Vehicle Current Position parameters
Left of arc	Word	mils	0 - 8031.875	0	1/8 mil/bit		Mils, relative to true north
Right of arc	Word	mils	0 - 8031.875	0	1/8 mil/bit		Mils, relative to true north
Centreline of arc	Word	mils	0 - 8031.875	0	1/8 mil/bit		Mils, relative to true north

B.3 Body Electronics

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Horn	Field		2 bits			00 = Off 01 = On 10 = Unused 11 = No Change	
Hatches	Field		2 bits			00 = Open 01 = Closed 10 = Unused 11 = No Change	Driver's, rear door

B.4 Diagnostics

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Fault Status	Field		2 bits			00 = No fault 01 = Fault 10 = Error 11 = Unavailable	
Fault Acknowledge	Field		2 bits			00 = No Ack 01 = Ack 10 = Error 11 = Unavailable	
Fault ID	Byte		0 - 250				

B.5 Fire Control

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Muzzle Velocity	Word	m/s	0 to 6425.5	0	0.1 m/s/bit		
Powder Temp	Word	deg C	-273 to +1735	-273	0.03125 deg C/bit		
Surrounding Temp	Word	deg C	-273 to +1735	-273	0.03125 deg C/bit		
Rel Humidity	Word	%	0 - 100	0	0.4		

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Wind speed	Word	m/s	0 to 6425.5	0	0.1		
Wind direction	Word	rads	0 - 2pi	0	$Pi/2^{15}$		
Ammunition type	Byte		0 to 250				
Ammunition mode	Byte		0 to 250				
Rate of fire A	Field		3 bits			000 = No rate 001 = Preset rate 1 010 = Preset rate 2 011 = Preset rate 3 100 = Error 101 = Reserved 110 = Reserved 111 = Not available	
Rate of fire B	Word	rounds/ min	0 to 642.55	0	0.01 rounds/min		
Weapon select A	Field	2 bits				00 = Main cannon 01 = Coax m/c gun 10 = Error 11 = Not available	
Weapon select B	Byte		0 - 250				

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
On target	Field	1 bit				0 = False 1 = True	
Bore sight offset	Byte		-16 to +16 mrad	-16 mrad	0.128 mrad/bit		
Zero offset	Byte		-16 to +16 mrad	-16 mrad	0.128 mrad/bit		
Rounds count	Word		0 to 64255	0	1 count/bit		
Atmos pressure			+700 to +1200 mbar	+700 mbar	2 mbar/bit		
Coincidence window	Field	1 bit				0 = Outside window 1 = Inside window	
Jump az./el.	Byte		-16 to +16 mrad	-16 mrad	0.128 mrad/bit		
Target mode	Field	2 bits				00 = Ground fixed 01 = Airborne 10 = Ground moving 11 = No target	
Security loop	Field	1 bit				0 = Open 1 = Closed	
Lead angle	Word	mrad	-400 to +403.1875 mrad	-400 mrad	0.0125 mrad/bit		
Super elevation	Word	mrad	-400 to +403.1875 mrad	-400 mrad	0.0125 mrad/bit		

B.6 Generic MMI

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Set Tachometer Display	Byte	%	0 to 100	n/a	0.4%/bit	n/a	
Display Lamp Control n	Field		2 bits			00 = Set Off 01 = Set On 10 = Unused 11 = No Change	
Display Lamp Status n	Field		2 bits			00 = Lamp Off 01 = Lamp On 10 = Lamp Error 11 = Unavailable	

B.7 Lighting Parameters

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Trafficator	Field		3 bits			000 = Off 001 = Left 010 = Right 011 = Hazards 100 = Unused 101 = Unused 110 = Unused 111 = No Change	
Headlights Off / Side / Head	Field		3 bits			000 = Off 001 = Side 010 = Head 011 = Unused 100 = Unused 101 = Unused 110 = Unused 111 = No Change	
Headlights Dip / Main	Field		2 bits			00 = Dip 01 = Main 10 = Unused 11 = No Change	

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Normal / Blackout / Convoy	Field		3 bits			000 = Normal 001 = Blackout 010 = Convoy 011 = Unused 100 = Unused 101 = Unused 110 = Unused 111 = No Change	
Fog Light	Field		2 bits			00 = Off 01 = On 10 = Unused 11 = No Change	
Work Lights	Field		2 bits			00 = Off 01 = On 10 = Unused 11 = No Change	
Intensity Light n	Byte	%	0 to 100 %	0	0.4% per bit		0% = Fully OFF 100% = Fully ON

B.8 Motion Control Parameters

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Gun pitch	24 bit	rads	± pi		$Pi/2^{23}$		
Gun roll	24 bit	rads	± pi		$Pi/2^{23}$		
Gun yaw	24 bit	rads	± pi		$Pi/2^{23}$		
Gun speed traverse	24 bit	rads/s	± 83.88608		0.00001		
Gun speed elevation	24 bit	rads/s	± 83.88608		0.00001		
Palm_Sw	Field		1 bit			0 = Off 1 = On	
Az & EL Handles	Word	rads/s	± 1		2^{-15}		
Stab enab	Field		1 bit			0 = Off 1 = On	
Gun Elev	Word	rads	±pi		$Pi/2^{15}$		
Turret azimuth	Word	rads	±pi		$Pi/2^{15}$		
Az & El Tach	Word	rads/s @ gun			2^{-15}		
Az & EL Torque	Word	amps			$(Full Scale)/2^{-15}$		Depends on motor
Az & El Gyros	Word	rads/s	± 1		2^{-15}		

B.9 Navigation

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	
Vehicle Longitude	32 bit	deg	-210 to +211.1	-210	10e-7 / bit		(ref WGS 84)
Vehicle Latitude	32 bit	deg	-210 to +211.1	-210	10e-7 / bit		(ref WGS 84)
Vehicle Altitude (ref mean sea level)	Word	m	-1000 to 7031.875	-1000	0.125 m / bit		(ref mean sea level)
Vehicle Heading (True)	Word	deg	-200 to +301.99	-200	1/128 deg / bit		
Vehicle Heading (Mag)	Word	deg	-200 to +301.99	-200	1/128 deg / bit		
Waypoint ID	Byte						
Bearing to Waypoint	Word	deg	-200 to +301.99	-200	1/128 deg / bit		
Distance to waypoint	Word	m	0 to +322550	0	10 m / bit		+ve values only

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	
Distance along track to	Word	m	-320000 to +322550	-320000	10 m/bit		+ve values distance to waypoint, -ve values past waypoint
Cross Track	Word	m	-4000 to 4031.875	-4000	0.125 m/bit		(-ve values LEFT of track)
Time to waypoint	Word	second	0 to 64255		1 sec/bit		
Waypoint threshold	Byte	m	0 to 250		1 m/bit		

B.10 Power Management

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Battery Voltage	Word	Volts	0 to 3276.8V		0.05V/bit		
Battery Charge	Byte	%	-125 to +125	-125	0.4% per bit		
Low State of Charge (SOC) Condition	Field		2 bits			00 = Charge low 01 = Charge OK 10 = Error 11 = Unavailable	
Battery Current (Ibatt)	Word	amps	±1605.35 A	-1605.35A	0.05A/bit		
Battery State of Health (SOH) Condition	Field		2 bits			00 = Failure/ Imminent Failure 01 = OK 10 = Error 11 = Unavailable	
Battery temperature (Tbatt)	byte	deg C	-40 to +210	-40	1 deg C/bit		

B.11 STA Parameters

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Sight pitch	24 bit	rads	± pi	- pi	$Pi/2^{23}$		
Sight roll	24 bit	rads	± pi	- pi	$Pi/2^{23}$		
Sight yaw	24 bit	rads	± pi	- pi	$Pi/2^{23}$		
Sight speed traverse	24 bit	rads/s	± 83.88608		0.00001		
Sight speed elevation	24 bit	rads/s	± 83.88608		0.00001		
Laser distance	24 bit	m	0 to 167,772.15		0.01		
Tracking mode command	Byte		0 - 255				
Tracking mode response	Byte		0 - 255				
Target 1 X position	24 bit	m	± 83,886.08		0.01		
Target 1 Y position	24 bit	m	± 83,886.08		0.01		
Target 1 Z position	24 bit	m	± 83,886.08		0.01		
Target 2 X position	24 bit	m	± 83,886.08		0.01		

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Target 2 Y position	24 bit	m	± 83,886.08		0.01		
Target 2 Z position	24 bit	m	± 83,886.08		0.01		
LOS Azimuth	24 bit	rads	± pi	- pi	$Pi/2^{23}$		
LOS elevation	24 bit	rads	± pi	- pi	$Pi/2^{23}$		
Laser trigger	Field					0 = Active 1 = Passive	
LRF select	Field		3 bit			000 = First echo 001 = Second echo 010 = Manual dist 011 = Combat dist. 100 = Not selected	

B.12 Vision Sensor Control Parameters

Parameter Name	**Data Type**	**Units**	**Range**	**Offset**	**Resolution**	**Coding**	**Comments/Notes**
Video channel n	Field		0 - 15		1		
All sources on	Field		2 bits			00 = Off 01 = On 10 = Reserved 11 = No change	
Zoom (incremental)	Field		2 bits			00 = Zoom Out 01 = Zoom In 10 = Zoom Normal 11 = No change	
Gain (incremental)	Field		2 bits			00 = -ve 01 = +ve 10 = Auto 11 = No change	
Contrast (incremental)	Field		2 bits			00 = -ve 01 = +ve 10 = Auto 11 = No change	
Set Defaults	Field		2 bits			00 = Off 01 = On 10 = Reserved 11 = No change	

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Commanders Sight Override	Field		2 bits	N/A		00 = Override 01 = Normal 10 = Unused 11 = Unavailable	
Wipe	Field		2 bits			00 = Off 01 = On 10 = Intermittent 11 = No change	
Wash & wipe	Field		2 bits			00 = Off 01 = On 10 = Reserved 11 = No change	
Pan	Field		2 bits			00 = Left 01 = Right 10 = Reserved 11 = No change	
Tilt	Field		2 bits			00 = Up 01 = Down 10 = Reserved 11 = No change	
Power save	Field		2 bits			00 = Off 01 = On 10 = Reserved 11 = No change	

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