MilCAN Working Group

MilCAN B Specification

MWG-MILB-001

Revision 2

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R Connor/L Koikeroinen

To request clarification of any information contained in this specification or to report any errors please contact :

L.Koikeroinen
BAE Systems Bofors AB
SE-691 80
Karlskoga,
Sweden
Tel: +46 (586) 733 284
Fax: +46 (586) 733 009
Email: Leo.Koikeroinen@baesystems.se

Record of changes

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Subsystem Control, Integration & Diagnostics

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1 Introduction

1.1 Scope

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

To this end, the Basic MilCAN B Interface is intended to provide an initial interconnect specification that can be used in the near term by system and equipment developers, whilst being compatible with the additional elements that will be included in the full MilCAN B specification.

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

MilCAN B is compatible with CANopen will define a specification for 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 MilCAN messages based upon MilCAN A.

MilCAN B is intended to be easily bridgeable to other CAN based protocols, specifically MilCAN A, SAE J1939 and CANopen. Indeed, it should be possible to mix CANopen devices with MilCAN B devices on the same bus. J1939 devices must be segmented via a bridge.

The philosophy of this document is to make reference to ISO11898[2] wherever possible, detailing only the specific deviations or additions required for MilCAN B 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.

1.2 Related Documents

This document supercedes the following documents:

- Basic MilCAN B Physical Layer Specificastion – IHSDB-APP-GEN-D-033
- Basic MilCAN B Data Link Layer Specification – IHSDB-APP-GEN-D-034
- Basic MilCAN B Application Layer Specification – IHSDB-APP-GEN-D-035

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/devices 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/devices 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 as 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

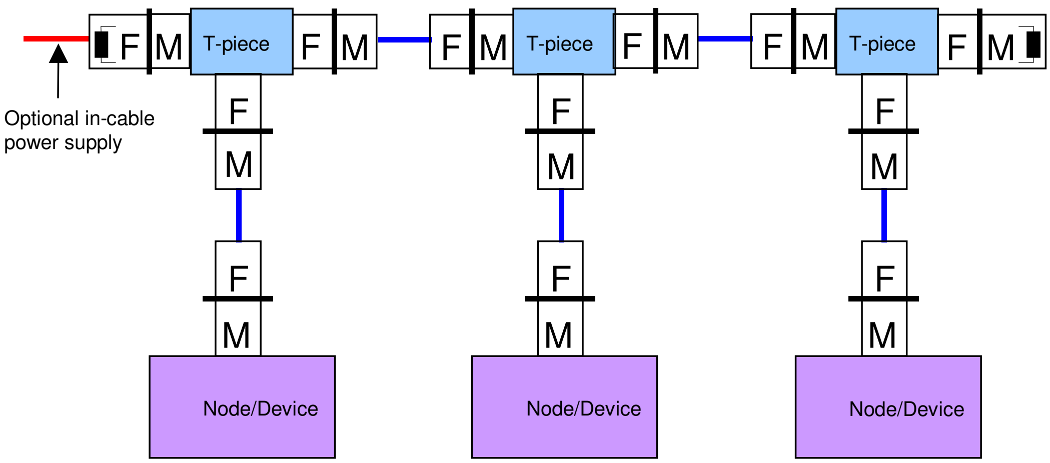

Figure 2-1: Linear multi-drop topology

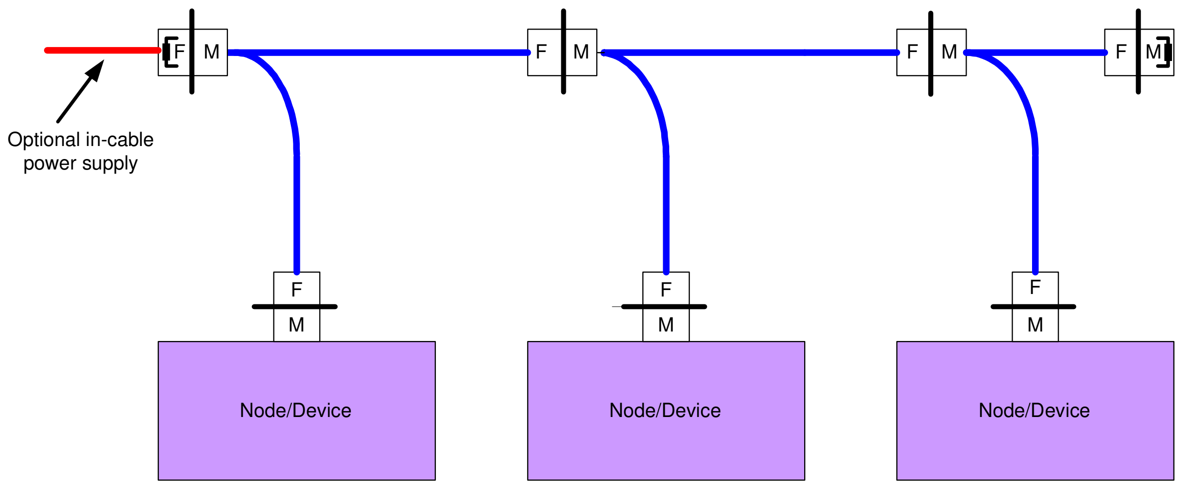

Figure 2-2: Linear multi-drop topology using bifurcated cables

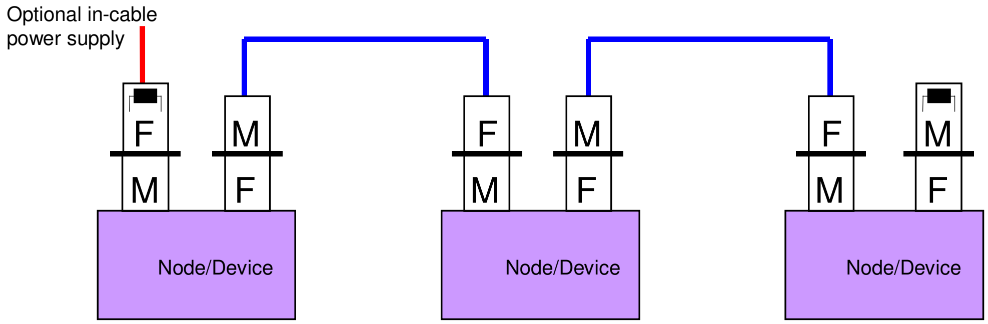

Figure 2-3: Daisy-chain topology

Note

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 – System Specific

As ISO11898[2] plus additional requirements, see section 2.4.2.

2.1.4 Maximum Number Of Network Devices – System Specific

As ISO 11898[2]

2.2 Medium

2.2.1 Cable Requirements

2.2.1.1 CAN Signal A – Compulsory

There should be provision to carry one CAN signal according to the physical medium specification of ISO11898[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 ISO11898[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 should 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

2.2.2.1 Connector Type – System Specific

To define a connector to suit all applications is not practical. Therefore, MilCAN B 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 B configuration of that connector.

Two connector types are listed, MIL-DTL-D38999 and Bayonet style series 1 ½ circular connector complying with VG96912 specification referenced to LN29729.

2.2.2.1.1 MIL-DTL-38999 Configuration A: Dual CAN Bus With In-Cable Power

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 'z' is specified in section 2.1.2.

The key orientation is N.

Connector specification: Connector specification VG96912 bayonet style series 1 ½ circular connector.

There is no fixing restriction or exterior finish.

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

The appropriate gender selection 'z' 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 MIL-DTL-38999 Configuration B: Dual CAN Bus, No In-Cable Power

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 ‘z’ is specified in section 2.1.2.

The key orientation is A.

Connector specification: Connector specification VG96912 bayonet style series 1 ½ circular connector.

There is no fixing restriction or exterior finish.

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

The appropriate gender selection ‘z’ 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 MIL-DTL-38999 Configuration C: Single CAN Bus With In-Cable Power

Connector specification: MIL-DTL-38999/ffeA35zN 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 ‘z’ is specified in section 2.1.2.

The key orientation is N.

Connector specification: Connector specification VG96912 bayonet style series 1 ½ circular connector.

There is no fixing restriction or exterior finish.

The shell size is 12 and the pin layout is 35 (6 pin).

The appropriate gender selection 'z' 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 MIL-DTL-38999 Configuration D: Single CAN Bus, No In-Cable Power

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 'z' is specified in section 2.1.2.

The key orientation is N.

Connector specification: Connector specification VG96912 bayonet style series 1 ½ circular connector.

There is no fixing restriction or exterior finish.

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

The appropriate gender selection 'z' 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 ISO11898[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.

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 to be 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, regulated, in the range 18V to 32V DC without spikes and dropouts.

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 ISO11898[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 unpowered.

2.3.2 Resistance To Electrical Bus Faults – System Specific

As ISO 11898[2].

2.3.3 Opto-Isolation – Optional Enhancement

It is recommended that opto-isolation of the CAN signal is always 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 shall support one or more of these bit rates:

- 1Mbps
- 800Kbps
- 500Kbps
- 250Kbps
- 125Kbps
- 50Kbps
- 20Kbps
- 10Kbps

See also ref 6.

2.4.2 Bit Timing – Compulsory

MilCAN B bit timing parameters are specified to maintain compatibility with node/device implementing parameters specified in the CANopen specification, see ref 6, and in the SAE J1939/11 standard.

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

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

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

For the 800, 500, 125, 50, 20 and 10 Kbps option, see ref 6 according to the bit sample point.

The synchronisation jump width must 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 250Kbps the round trip propagation time of a CAN interface shall be less than 300ns.

For the 800, 500, 125, 50, 20 and 10 Kbps option, see ref 6 according to the round trip propagation time.

Some points for consideration:

- The large amount of propagation time in the 250Kbps configurations facilitate 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 B compliant node/devices on the same bus as devices that use an earlier sample point. However, the potential maximum bus length is shortened accordingly.
- It is possible to use MilCAN B compliant node/devices on the same bus as devices 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 B compliant node/devices on the same bus as node/devices that have wider oscillator tolerances than the MilCAN B tolerance.

Maximum Bus Length and Drop Length are considered to be system specific parameters that are not constrained by MilCAN B and are therefore left to the system developer to optimise for any specific system. Guidance on the specification of these parameters can be obtained through reference to an Application Note from Philips components, see ref 5.

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3 Data Link Layer

3.1 Media Access Control

3.1.1 Priority Based Bus Access Arbitration – Compulsory

As ISO11898[2].

3.1.2 Framing – Compulsory

As ISO 11898[2], 11 bit identifier format and CAN Specification 2.0 Part B Passive.

3.1.3 Link Layer Acknowledgement – Compulsory

As ISO11898[2].

3.1.4 Link Layer Communication Error Detection – Compulsory

As ISO11898[2].

3.1.5 Link Layer Communication Error Signaling – 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 ISO11898[2].

3.2 Logical Link Control

3.2.1 Frame Format – Compulsory

As for CANopen 11 bit frame identifier, see Ref 5.

3.2.2 Link Layer Communication Error Reporting – System Specific

As specified in ISO 11898, see Ref 2.

3.2.3 Network Interface Error Detection And Reporting – System Specific

As specified in ISO 11898, see Ref 2.

3.2.4 Addressing System – Compulsory

MilCAN B is optimised for logical/function-based addressing for operational messages. Logical addressing is based solely on the function type conveyed in the message identifier.

3.2.5 Message Types

3.2.5.1 Sync Frame Message – Compulsory

The transmission of messages by synchronous nodes/devices shall be coordinated by the sync frame message as described in the 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 definition of the Sync Frame message is contained in the Section 4 Application Layer. Sync Frame message shall use identifier value 0x80. The frequency of the Sync Frame message is system specific.

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

The default tolerance of the sync period trigger timing should be +/-1%.

3.2.6 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 Alive message identifier is system specific.

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

3.2.7 Bus Access Timing

3.2.7.1 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 trigger system is described in the Section 4 Application Layer.

3.2.7.2 Nodes/Devices Operating Asynchronous To The Bus - Compulsory

Nodes/devices shall not transmit asynchronous messages on the bus, except for emergency messages.

3.2.8 Prioritised Access Queue Manager

3.2.8.1 Prioritised Queuing – Compulsory

Nodes/devices in a MilCAN B system shall respond to the sync frame message by triggering the appropriate message/s for the slot. The design of the bus traffic with low priority messages and higher priority messages in a MilCAN B system are prepared early in the project. The system designer shall distribute all messages to different slots and minimise the busload. That makes it possible for both low priority messages and higher priority messages to have access to the bus.
In times of disruption, some messages may be transmitted in a later slot. How a system should respond to this behaviour must be left to the system developer to optimise.

3.2.9 Message Acceptance Filtering – System Specific

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

3.2.10 Link Layer Flow Control – Compulsory

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

3.2.11 Link Layer Re-Transmission On Error – Compulsory

The LLC sub-layer of the ISO11898 CAN standard includes amongst its functions the retransmission of frames that have been disrupted by errors during transmission.
This process can result in an unpredictable number of retransmissions 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 3.2.8

3.2.12 Remote Frame Request – Compulsory

This function of the ISO11898 CAN standard is not to be used.

3.2.13 Transparent Data Streams

Not defined in MilCAN B.

3.2.14 Transport Layer Functions

3.2.14.1 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 identifier, that contain a combined payload of greater than 8 bytes.

Data is distributed (sources broadcast data) on a publisher/user basis in MilCAN B. Devices or nodes will extract data of interest from broadcast messages. It is recommended to send a System mode command which activate the receiver node of Multi-frame messages. The System mode command carry the information of which node is the receiver of Multi-frame messages. The System mode command shall use the standard CAN protocol with 11 bit identifier and shall be periodic.
Multi-frame messages shall be identified as such within the message set and they can be event triggered.

Multi-frame messages are not time critical messages and are governed by the maximum message trigger rate that restricts frames with identical 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.

The structure of the payload of a multi-frame message is defined below (see Figure 3-1 and Figure 3-2 below). Two payload structures are defined, one for multi-frame (non multi-instance) messages and the other for multi-frame (multi-instance) messages:

		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 3-1: Multi-frame (Non Multi-instance) Message Structure

<table>
<tr><td colspan="2"></td><td colspan="8">Byte No</td></tr>
<tr><td colspan="2"></td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td rowspan="5">Frame No</td><td>0</td><td>Message Count</td><td colspan="3">Byte Count</td><td colspan="3">Reserved</td><td>Multi-instance No.</td></tr>
<tr><td>1</td><td>Message Count</td><td colspan="6">Data</td><td>Multi-instance No.</td></tr>
<tr><td>↓</td><td>↓</td><td colspan="6">Data</td><td>Multi-instance No.</td></tr>
<tr><td>249</td><td>Message Count</td><td colspan="6">Data</td><td>Multi-instance No.</td></tr>
<tr><td>250</td><td>Message Count</td><td colspan="2">CRC (Optional)</td><td colspan="4">Reserved</td><td>Multi-instance No.</td></tr>
</table>

Figure 3-2: Multi-frame (Multi-instance) Message Structure

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

3.2.14.1.1 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 chronological order 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 6 are reserved by MilCAN for future use.
- Multi-Instance Reserved Field – this field (payload byte 7) shall be reserved for multi-frame, multi-instance messages. The field shall be used to identify a particular instance of a function where more than one instance of the function exists on the platform (i.e. two hand controllers). For multi-frame, non multi-instance messages this byte shall not be used. The field structure of the multi-instance-reserved field shall be as defined in Table 3-3.

Data	**Byte No**	**No. Bits**	**Limits / Range**	**Comments**
Multi-instance reserved	7	8	0 to 250	Identifies a particular instance of a function where more than one instance of the function exists on the platform

Table 3-3: Multi-instance Reserved field for first frame of a multi-frame message

3.2.14.1.2 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 3-4.

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 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 3-4: Message Count field for intermediate frames of a multi-frame message

- Data Field - intermediate frames contain data in the payload. Two definitions exist for the data payload. For multi-frame, non multi-instance messages, payload bytes 1 to 7 shall be used to transmit data. For multi-frame, multi-instance messages only payload bytes 1 to 6 shall be used to transmit data. Payload byte 7 in this instance shall be used as the multi-instance-reserved field (see multi-instance reserved field definition below).

  Bytes 0 to 6 of the data block shall be stored in bytes 1 to 7 of the first intermediate frame for multi-frame, non multi-instance messages. Bytes 0 to 5 of the data block shall be stored in bytes 1 to 6 of the first intermediate frame for multi-frame, multi-instance messages. Subsequent frames for both message types 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

- Multi-Instance Reserved Field - this field (payload byte 7) shall be reserved for multi-frame, multi-instance messages. The field shall be used to identify a particular instance of a function where more than one instance of the function exists on the platform (i.e. two hand controllers). For multi-frame, non multi-instance messages this byte shall be used as an additional data field byte (see data field definition above). The field structure of the multi-instance-reserved field shall be the same as the multi-instance reserved field in the first frame.

3.2.14.1.3 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 3-5.

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 3-5: 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 6 are reserved by MilCAN for future use.
- Multi-Instance Reserved Field – this field (payload byte 7) is reserved for multi-frame, multi-instance messages. The field shall be used to identify a particular instance of a function where more than one instance of the function exists on the platform (i.e. two hand controllers). For multi-frame, non multi-instance messages this byte shall not be used. The field structure of the multi-instance-reserved field is the same as the multi-instance reserved field in the first frame.

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 from any recipient node/device. This is in keeping with the spirit of CANbus as a broadcast bus and will reduce unecessary 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 Support For Deterministic Message Transmission - Compulsory

The primary goal of MilCAN B is to provide deterministic communications between those devices connected to a platform network.

The primary requirements for this protocol are:

- Provision of a number of Sync Frame Masters and an associated election protocol to ensure that only one master can output Sync Frames at any given time. The election protocol ensures 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 adhered to by ensuring that each message is triggered no more than once per time unit.
- If all the messages in the system and their trigger periods are known then a schedule of all messages can be determined at the system design stage by allocating messages to Sync Slots as indicated by the Sync Frame.
- The protocol must accommodate Hard Real Time (HRT) messages.
- The protocol must support fault recovery in the event of failures.

4.1.3.1 Maximum Message Trigger Rate - Compulsory

No message shall be triggered more than once per Primary Time Unit (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.

4.1.3.2 Message Priority Assignment

Not included in MilCAN B.

4.1.3.3 Synchronous Device Response Time To Sync Frame - Compulsory

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.

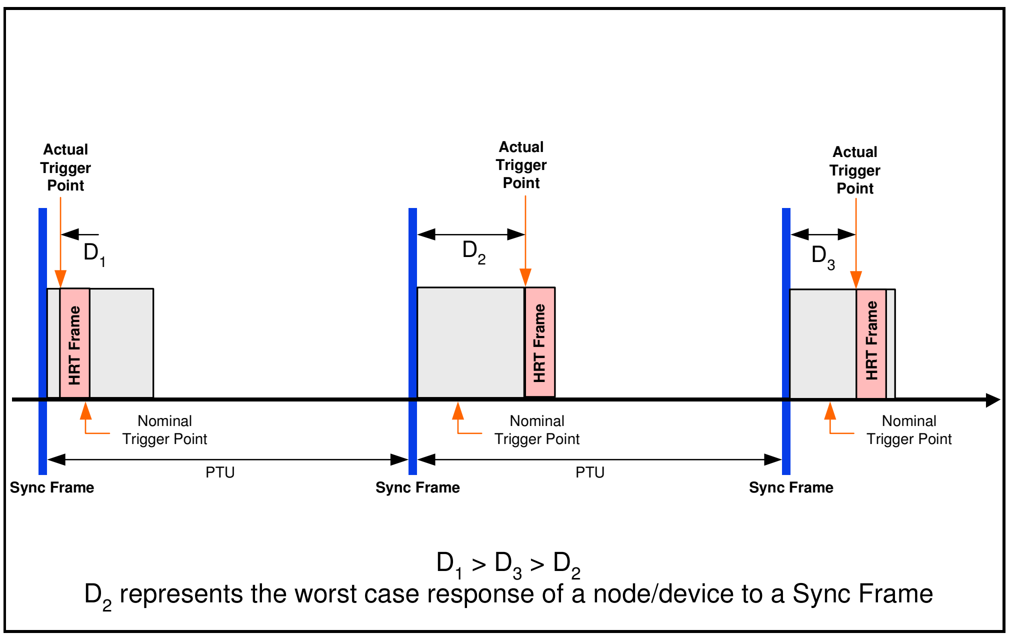

Figure 4-4-1: Synchronous Devices response to Sync Frame

4.1.3.4 Sync Frame Message Generation - Compulsory

Military vetronic systems will predominantly be distributed real-time systems providing deterministic messages transfer to ensure predictable performance. This requires some form of co-ordination of message generation at each network node and this is achieved within MilCAN B by employing one of the network nodes 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 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 or 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 or devices designated as potential Sync Masters within a system is the responsibility of the systems designer. Message ID 120-127 has been reserved for the Sync Request message, allowing up to eigth potential Sync masters in the same system.
Following a reset or lost Sync Frame, a node or device that has been designated as a potential Sync Master shall send a Sync Request message on the bus. The node then must check if a Sync Request has been sent by another node or device. If a Sync Request is not received within the expected period (timeout period) then this node will assume the role of Sync Master and start an initialization process to make CANopen components to be NMT slaves and to switch them into operational mode. This is effectuated by sending a message ID0 (zero), consisting of two databytes with value (1,0). This message means node start. After the CANopen intialization sequence, the elected Sync master send out a Sync Frame message on the bus.

If a Sync Master has started to generate Sync Frames it is not allowed for another potential Sync Master to interrupt this even if it has higher Sync Request priority. All potential Sync Masters shall continously check if there are any Sync Frame present, if not the Sync Request procedure shall start after a timeout period.

The Sync Frame timeout period and Sync Request timeout period are the system designers responsibility.

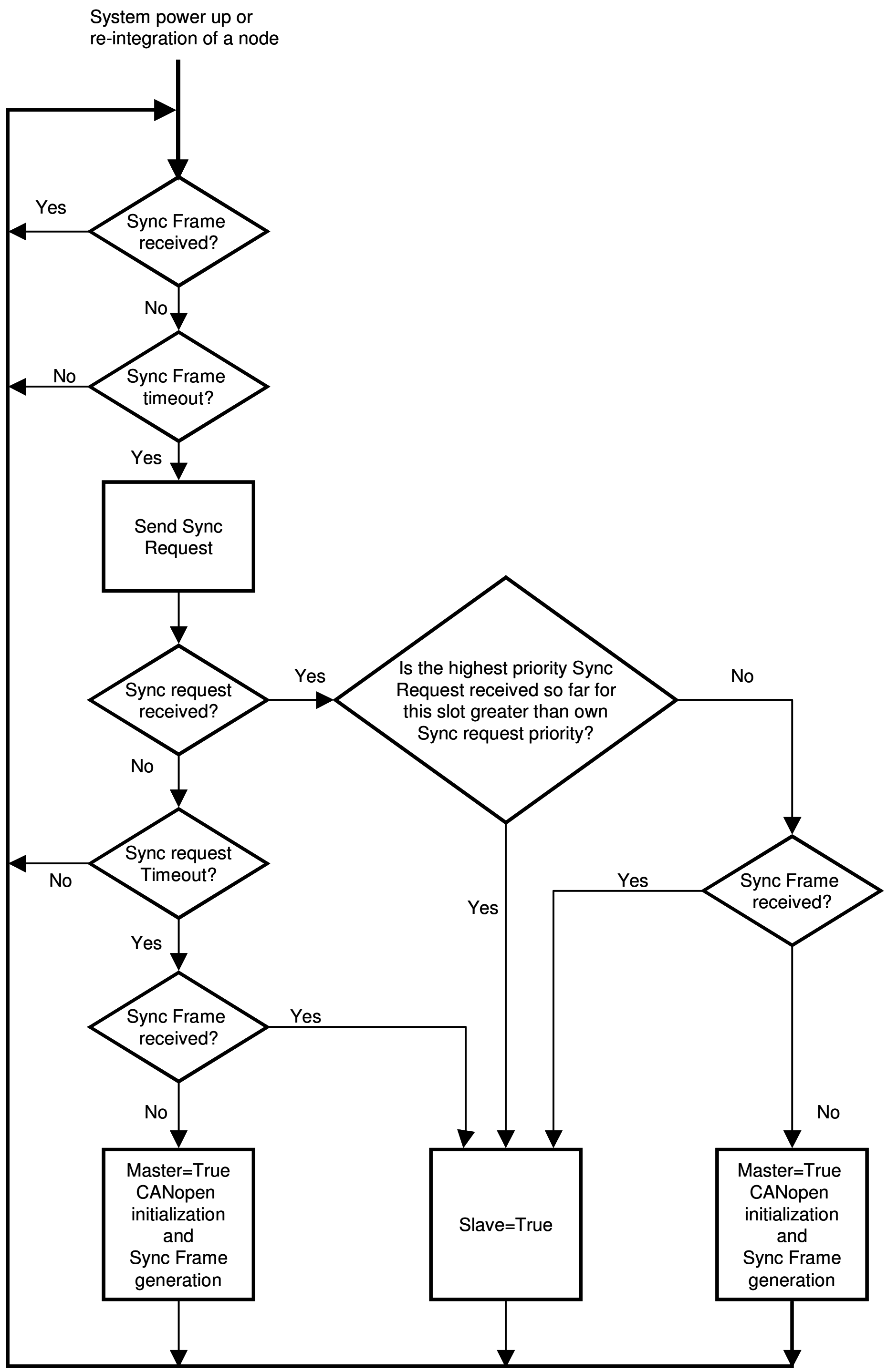

Figure 4-2: Sync Frame Arbitration

4.2 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. Devices or nodes will extract data of interest from broadcast messages by filtering messages using the message identifier. Data shall be communicated by 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 device or node 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 system mode command would also indicate to a device or node 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.

4.5 Device/Process Failure Detection And Reporting

TBA

5 References

1. CUP protocol (Message Handling + Interface definitions), WTD41 Coblenz, Germany, April 2000, Doc. No.:729711.400.000

2. ISO 11898 Road vehicles – Interchange of digital information – Controller area network (CAN) for high-speed communication, First Edition 1993 (Amended 1995), International Organisation for Standardisation, Geneva, Switzerland, ISO, ISO 11898:1993(E)

3. Data Link Layer – SAE J1939/21, 1994, Society of Automotive Engineers, Warrendale, USA, SAE, J1939/21

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 & Application Laboratory, Hamburg, Germany

6. CAN OPEN Communication Profile, CIA DS-301 V. 3.0, October 1996

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 node/device without dependence upon the receipt of a Sync Frame message.
Device	A subsystem containing an interface to the bus.
Event Driven Message	A message that is transmitted by a node/device in response to the occurrence of a particular event.
Message	A single CAN frame comprising a unique MilCAN B: 11 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 MilCAN B: 11 bit identifier that contains a combined payload of greater than 8 bytes. This is known as a multi-frame message
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 node/device or in the transmit buffer of the CAN controller of a node/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 MilCAN B: 11 bit identifier that contains a combined payload of greater than 8 bytes.
Node	An interface to the bus for one or more subsystem.
Periodic Message	A message that is transmitted by a node/device at regular intervals.
Primary Time Unit (PTU)	The interval between the arrival of consecutive Sync Frame messages.
Synchronous message	A message that is transmitted by a node/device in response to the receipt of a Sync Frame message by that node/device
Multi-instance message	A message that can be transmitted from more than one source. Multi-instance messages are identified within the message set for the system.

List Of Abbreviations

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
EM	Electromagnetic
FDSS	Fire Detection & Suppression System
HRT	Hard Real-Time
HVAC	Heating, Ventilation and Air Conditioning
IHSDB	International High Speed Data Bus
ISO	International Standards Organisation
LLC	Logical Link Control
MMI	Man Machine Interface
NBC	Nuclear Biological & Chemical
PTU	Primary Time Unit
SAE	Society of Automotive Engineers
STA	Surveillance & Target Acquisition

A Message Identifier Assignment – System Specific

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

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 albeit with some minor constraints. The constraints are given in Table A-1.

CAN Identifier decimal	CAN Identifier hexadecimal	Communication Objects	Source
0	0x000	NMT Services	CANopen
1 ... 119	0x001…0x077	Reserved for future use	MilCAN
120-127	0x078…0x07F	Sync request message	MilCAN
128	0x080	Sync Message	CANopen
129 ... 255	0x081…0x0FF	Emergency Messages	CANopen
256	0x100	Time-Stamp Message	CANopen
257 ... 272	0x101…0x101	System Command and Control	MilCAN
273 …288	0x111…0x120	Free	MilCAN
289 …304	0x121…0x130	Motion Control	MilCAN
305 …320	0x131…0x140	Free	MilCAN
321 …336	0x141…0x150	STA	MilCAN
337 …352	0x151…0x160	Free	MilCAN
353 …368	0x161…0x170	Fire Control	MilCAN
369 …384	0x171…0x180	Free	MilCAN
385 ... 511	0x181…0x1FF	Transmit Process Data Objects	CANopen
512	0x200	Free	MilCAN
513 ... 639	0x201…0x27F	Receive Process Data Objects	CANopen
640	0x280	Free	MilCAN
641 ... 767	0x281…0x2FF	Transmit Process Data Objects	CANopen
768	0x300	Free	MilCAN
769 ... 895	0x301…0x37F	Receive Process Data Objects	CANopen
896 ... 911	0x380…0x38F	Automotive	MilCAN
912 …927	0x390…0x39F	Free	MilCAN
928 …943	0x3A0…0x3AF	Navigation	MilCAN
944 …959	0x3B0…0x3BF	Free	MilCAN

CAN Identifier decimal	CAN Identifier hexadecimal	Communication Objects	Source
960 …975	0x3C0…0x3CF	Power Management	MilCAN
976 …991	0x3D0…0x3DF	Free	MilCAN
992 …1007	0x3E0…0x3EF	DAS	MilCAN
1008 …1023	0x3F0…0x3FF	Free	MilCAN
1024 …1039	0x400…0x40F	Communications/BMS	MilCAN
1040 …1055	0x410…0x41F	Free	MilCAN
1056 …1071	0x420…0x42F	HVAC/NBC	MilCAN
1072 …1087	0x430…0x43F	Free	MilCAN
1088 …1103	0x440…0x44F	Vision Sensor Control	MilCAN
1104 …1119	0x450…0x45F	Free	MilCAN
1120 …1135	0x460…0x46F	Generic MMI devices	MilCAN
1136 …1151	0x470…0x47F	Free	MilCAN
1152 …1167	0x480…0x48F	FDSS	MilCAN
1168 …1183	0x490…0x49F	Free	MilCAN
1184 …1199	0x4A0…0x4AF	Lighting	MilCAN
1200 …1215	0x4B0…0x4BF	Free	MilCAN
1216 …1231	0x4C0…0x4CF	Body Electronics	MilCAN
1232 …1247	0x4D0…0x4DF	Free	MilCAN
1248 …1279	0x4E0…0x4FF	Diagnostics	MilCAN
1280 …1295	0x500…0x50F	Free	MilCAN
1296 ...1404	0x510…0x57C	Special to role/Application specific	MilCAN
1405 ...1535	0x57D…0x5FF	Service Data Objects	CANopen
1536	0x600	Special to role/Application specific	MilCAN
1537 ...1663	0x601…0x67F	Service Data Objects	CANopen
1664 ...1792	0x680…0x700	Special to role/Application specific	MilCAN
1793 ...1919	0x701…0x77F	Node Guarding (Boot-Up) Messages	CANopen
1920 ...2014	0x780…0x7DE	Special to role/Application specific	MilCAN
2015 ...2031	0x7DF…0x7EF	Reserved for NMT, LMT, and DBT Services	CANopen

Table A-1: Suggested Message Identifiers

Before messages can be allocated to 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-2 through Table A-7 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
	0xFF	0xFFxx	0xFFxxxx	0xFFxxxxxx

Table A-2 : 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-3 : 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-4 : 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-5 : 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-6 : 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
	$2Pi/2^{16}$	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

Parameter	Scaling / Resolution	Limits / Range	Offset	Parameter Size	Origin
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
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

Parameter	Scaling / Resolution	Limits / Range	Offset	Parameter Size	Origin
	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
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-7: 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	
Brake Air Pressure	Byte	kPa	0 to 4000 kPa	0	16 kPa/bit		
Fuel Level	Byte	%	0 - 100%	0% offset	0.4%/bit		

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
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	2kPa/bit	n/a	
Engine Speed	Uword	rpm	0 to 8031.875	0	0.125rpm/bit	n/a	
Engine Temperature	Byte	degs C	-40 to 210	-40 deg C	1deg C/bit	n/a	
Exhaust Temperature	Uword	degs C	-273 to 1775 deg C	-273 deg C	0.01325 deg C/bit	n/a	

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Engine Oil Pressure	Byte	kPa	0 to 1000	0	4 kPa/bit	n/a	
Transmission Oil Pressure	Byte	kPa	0 to 4000	0	16 kPa/bit	n/a	
Hydraulic Oil Pressure	Uword	kPa	0 to 32127.5	0	0.5 kPa/bit	n/a	
Transmission Speed	Uword	rpm	0 to 8031.875	0	0.125rpm/bit	n/a	
Set Cooling Fan Drive	Uword	%	0 to 100	0	0.001556%/bit	n/a	
Measure Cooling Fan Drive	Uword	%	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	

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
ME Run Start	field		2 bits			00 = Off 01 = Run 10 = Start 11 = No Change	
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		

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Vehicle Direction	field		3 bits			000 = Neutral 001 = Forward 010 = Reverse 011 = Unused 100= Error 101= Unused 110 =Unused 111= Unavailable	Null, Forward, Reverse
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		

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
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			0=Open 1=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 degC/bit		
Surrounding Temp	Word	deg C	-273 to +1735	-273	0.03125 degC/bit		
Rel Humidity	Word	%	0-100	0	0.4		
Wind speed	Word	m/s	0 to 6425.5	0	0.1		
Wind direction	Word	radians	0-2pi	0	$Pi/2^{15}$		
Ammunition type	Byte		0 to 250				
Ammunition mode	Byte		0 to 250				

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
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				
On target	field	1 bit				0 = false 1 = true	
Boresight offset	Byte		-16 to +16 mrad	-16 mrad	0.128 mrad/bit		

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
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		

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Superelevation	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	3 byte	radians	± pi		$Pi/2^{23}$		
Gun roll	3 byte	radians	± pi		$Pi/2^{23}$		
Gun yaw	3 byte	radians	± pi		$Pi/2^{23}$		
Gun speed traverse	3 byte	radians/second	± 83.88608		0.00001		
Gun speed elevation	3 byte	radians/second	± 83.88608		0.00001		
Palm_Sw	Field		1 bit			0 = Off 1 = On	
Az & EL Handles	Word	rad/sec	± 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/sec @ gun			2^{-15}		

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Az & EL Torque	Word	amps			(Full Scale)/2^{-15}		Depends on motor
Az & El Gyros	Word	rad/sec	± 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 Lattitude	32 bit	deg	-210 to +211.1	-210	10e-7 / bit		(ref WGS 84)
Vehicle Alltitude (ref mean sea level)	16 bit	m	-1000 to 7031.875	-1000	0.125 m / bit		(ref mean sea level)
Vehicle Heading (True)	16 bit	deg	-200 to +301.99	-200	1/128 deg / bit		
Vehicle Heading (Mag)	16 bit	deg	-200 to +301.99	-200	1/128 deg / bit		
Waypoint ID	byte						
Bearing to Waypoint	16 bit	deg	-200 to +301.99	-200	1/128 deg / bit		
Distance to waypoint	16 bit	m	0 to +322550	0	10 m / bit		+ve values only

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	
Distance along track to	16 bit	m	-320000 to +322550	-320000	10 m / bit		+ve values distance to waypoint, -ve values past waypoint
Cross Track	16 bit	m	-4000 to 4031.875	-4000	0.125 m / bit		(-ve values LEFT of track)
Time to waypoint	16 bit	seconds	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	16 bit 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) Conditition	field		2 bits			00 = Charge low 01 = Charge ok 10 = Error 11 = unavailable	
Battery Current (Ibatt)	16 bit word	amps	±1605.35 A	-1605.35A	0.05A/bit		
Battery State of Health (SOH) Condition	field		2 bits			00 = Failiure/ Imminent Failiure 01 = OK 10= Error 11 = unavailable	
Battery temperature (Tbatt)	byte	°C	-40 to +210	-40	1°C/bit		

B.11 STA Parameters

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Sight pitch	3 byte	radians	± pi	- pi	$Pi/2^{23}$		
Sight roll	3 byte	radians	± pi	- pi	$Pi/2^{23}$		
Sight yaw	3 byte	radians	± pi	- pi	$Pi/2^{23}$		
Sight speed traverse	3 byte	radians/second	± 83.88608		0.00001		
Sight speed elevation	3 byte	radians/second	± 83.88608		0.00001		
Laser distance	3 byte	m	0 to 167,772.15		0.01		
Tracking mode command	Byte		0-255				
Tracking mode response	Byte		0-255				
Target 1 X position	3 byte	m	±83,886.08		0.01		
Target 1 Y position	3 byte	m	±83,886.08		0.01		

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Target 1 Z position	3 byte	m	±83,886.08		0.01		
Target 2 X position	3 byte	m	±83,886.08		0.01		
Target 2 Y position	3 byte	m	±83,886.08		0.01		
Target 2 Z position	3 byte	m	±83,886.08		0.01		
LOS Azimuth	3 byte	radians	±pi	- pi	$Pi/2^{23}$		
LOS elevation	3 byte	radians	±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	

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
Set Defaults	Field		2 bits			00 = Off 01 = On 10 = Reserved 11 = No change	
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 = reserverd 11 = No change	

Parameter Name	Data Type	Units	Range	Offset	Resolution	Coding	Comments/Notes
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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