The version code length shall be the total number of bytes in the Version Code data block excluding this field. If the STIM manufacturer does not implement this function, then either a 00000000_{16} or a $FFFFFFFF_{16}$ shall be returned.

The version code shall be defined by the manufacturer and contains information used to identify the version of the firmware in the STIM.

The checksum shall be the one's complement of the sum (modulo 2^{16}) of all the data structure's preceding bytes, including the initial length field and excluding the checksum field.

5. Transducer Electronic Data Sheet (TEDS) specification

This clause defines the format of the TEDS data blocks of which only the Meta-TEDS and the Channel TEDS are mandatory. All other TEDS data blocks are optional. All fields in the mandated TEDS data blocks shall be filled, unless a length field that applies to them is zero. If a field is not applicable to the implementation, its value shall be

— A null string for string data types
— A NaN for single-precision real and double-precision real data types
— A zero for integers, enumeration, and field length data types
— "Digital data," as specified in Table 5, for physical units data types

The following TEDS data blocks may have their length field set to zero:

— Meta-Identification TEDS
— Channel-Identification TEDS
— Calibration-Identification TEDS
— Calibration TEDS
— End-Users' Application-Specific TEDS
— Industry Extensions TEDS

A TEDS length field of $FFFFFFFF_{16}$ shall be interpreted as a length of zero.

The specification of the TEDS given here places requirements only on the logical format and content of the TEDS. No restriction is placed upon the physical embodiment of the TEDS or upon the particular form of any internal physical interface between the TEDS and any other part of the STIM. It is required, however, that the TEDS shall remain physically associated with the transducer(s) it describes during normal operation of the STIM while connected to an NCAP and while disconnected from an NCAP for purposes such as storage, transportation, or calibration. It is not required that this physical association be maintained during periods in the life-cycle of the STIM outside the scope of this standard (e.g., during manufacture, repair, refurbishment, or decommissioning).

5.1 Meta-TEDS data block

5.1.1 Access

Functional address 160 applied to CHANNEL_ZERO shall access this data.

5.1.2 Function

The function of the Meta-TEDS shall be to make available at the interface all of the information needed to gain access to any channel, plus information common to all channels. Meta-TEDS bytes are constant and read only.

5.1.3 Data structure

Table 23 shows the data structure. Subsequent subclauses explain each data field in the structure. Serial transmission of data shall occur msb first. When serial data is divided into bytes, such as in the transmission of multi-byte TEDS fields, the most significant byte shall be transmitted first.

Table 23—Data structure of Meta-TEDS data block

Field no.	Description	Type	No. of bytes
TEDS version constant related data sub-block			
1	Meta-TEDS Length	U32L	4
2	IEEE 1451 Standards Family Working Group Number	U8E	1
3	TEDS Version Number	U8E	1
Identification related data sub-block			
4	Globally Unique Identifier	UUID	10
Data structure related data sub-block			
5	CHANNEL_ZERO Industry Calibration TEDS Extension Key	U8E	1
6	CHANNEL_ZERO Industry Nonvolatile Data Fields Extension Key	U8E	1
7	CHANNEL_ZERO industry TEDS extension key	U8E	1
8	CHANNEL_ZERO End-Users' Application-Specific TEDS key	U8E	1
9	Number of Implemented Channels	U8C	1
10	Worst-Case Channel Data Model Length	U8C	1
11	Worst-Case Channel Data Repetitions	U16C	2
12	CHANNEL_ZERO writable TEDS length	U32C	4
Timing related data sub-block			
13	Worst-Case Channel Update Time (t_{wu})	F32	4
14	Global Write Setup Time (t_{gws})	F32	4
15	Global Read Setup Time (t_{grs})	F32	4
16	Worst-Case Channel Sampling Period (t_{wsp})	F32	4
17	Worst-Case Channel Warm-Up Time	F32	4
18	Command Response Time	F32	4
19	STIM Handshake Timing (t_{hs})	F32	4
20	End-Of-Frame Detection Latency (t_{lat})	F32	4
21	TEDS Hold-Off Time (t_{th})	F32	4
22	Operational Hold-Off Time (t_{oh})	F32	4
23	Maximum Data Rate	U32C	4
Channel grouping related data sub-block			
24	Channel Groupings Data Sub-block Length	U16L	2
25	Number of Channel Groupings = G	U8C	1

Table 23—Data structure of Meta-TEDS data block (continued)

Field no.	Description	Type	No. of bytes
Fields 26–28 are repeated G times, once for each group			
26	Group Type	U8E	1
27	Number of Group Members = N	U8C	1
28	Member Channel Numbers List = M(N)	Array of U8E	N
Data integrity data sub-block			
29	Checksum for Meta-TEDS	U16C	2

5.1.3.1 Meta-TEDS Length

Meta-TEDS data field number 1

Data type: unsigned integer used for field length (U32L, 4 bytes)

This field specifies the total number of bytes in the Meta-TEDS data block excluding this field.

5.1.3.2 IEEE 1451 Standards Family Working Group Number

Meta-TEDS data field number 2

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

This field shall be set to two for devices conforming to this standard. This field shall be used by other members of the IEEE 1451 standards family to indicate to an NCAP that a different data structure follows.

5.1.3.3 TEDS Version Number

Meta-TEDS data field number 3

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

This field specifies the version number of the TEDS that corresponds to the particular IEEE 1451 standard of the working group that specifies the TEDS data structure as shown in Table 24.

Table 24—Enumeration of TEDS Version Numbers

TEDS version	IEEE 1451.2 standard version
0	Reserved
1	This will correspond to the first official version of the standard: IEEE Std 1451.2-1997.
2–255	Reserved

The meaning and structure of the first three fields (the first 6 bytes) of the Meta-TEDS shall never be changed in any subsequent TEDS version.

5.1.3.4 Globally Unique Identifier

Meta-identification TEDS data field number 4

Data type: Universally unique identification (UUID, 10 bytes)

The UUID field is provided to allow better management of STIM components in a distributed system (e.g., tracking and traceability of STIMs for operational and maintenance purposes). The UUID must be guaranteed to be unique in the universe of all STIMs. The algorithm for computing a unique UUID without recourse to an administrative agency is defined in 3.3.9.

5.1.3.5 CHANNEL_ZERO Industry Calibration TEDS Extension Key

Meta-TEDS data field number 5

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

The value in this field indicates the highest functional address for writing the industry-implemented Calibration TEDS extension that is available in the STIM for CHANNEL_ZERO. Acceptable values and their meanings are defined in Table 25.

Table 25—Enumeration of CHANNEL_ZERO Industry Calibration TEDS Extension Keys

Key value (K)	Meaning
0	No extensions implemented in STIM
1–79	Invalid
80–95	Valid, TEDS extension(s) implemented for: —Functional addresses used for writing: between 80 and (K); and —Functional addresses used for reading: between 208 and (K+128)
96–255	Invalid

5.1.3.6 CHANNEL_ZERO Industry Nonvolatile Data Fields Extension Key

Meta-TEDS data field number 6

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

The value in this field indicates the highest functional address for writing the industry-implemented nonvolatile data field extensions that is available in the STIM for CHANNEL_ZERO. Acceptable values and their meanings are defined in Table 26.

Table 26—Enumeration of CHANNEL_ZERO Industry Nonvolatile Data Fields Extension Keys

Key value (K)	Meaning
0	No extensions implemented in STIM
1–111	Invalid
112–127	Valid, TEDS extension(s) implemented for: —Functional addresses used for writing: between 112 and (K); and —Functional addresses used for reading: between 240 and (K+128)
128–255	Invalid

5.1.3.7 CHANNEL_ZERO Industry TEDS Extension Key

Meta-TEDS data field number 7

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

The value in this field indicates the highest functional address for writing the industry-implemented TEDS extensions that is available in the STIM for CHANNEL_ZERO. Acceptable values and their meanings are defined in Table 27.

Table 27—Enumeration of CHANNEL_ZERO Industry TEDS Extension Keys

Key value (K)	Meaning
0	No extensions implemented in STIM
1–175	Invalid
176–191	Valid, TEDS extension(s) implemented for: —Functional addresses used for reading: between 176 and (K)
192–255	Invalid

5.1.3.8 CHANNEL_ZERO End-Users' Application-Specific TEDS Key

Meta-TEDS data field number 8

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

This field indicates the presence of End-Users' Application-Specific TEDS function in CHANNEL_ZERO as defined in Table 28.

Table 28—Enumeration of End-Users' Application-Specific TEDS Keys

Key value	Meaning
0	End-Users' Application-Specific TEDS is not implemented on CHANNEL_ZERO.
1	End-Users' Application-Specific TEDS is implemented on CHANNEL_ZERO.
2–255	Reserved.

5.1.3.9 Number of Implemented Channels

Meta-TEDS data field number 9

Data type: unsigned byte integer used for counting (U8C, 1 byte)

This field specifies the number of channels implemented in the STIM. If the number is one, this shall be a single variable transducer. Numbers greater than one identify multiple variable transducers, perhaps consisting of both sensor and actuator elements. There can be up to 255 channels on a STIM, thus the value of this field shall be M such that $1 \leq M \leq 255$.

A STIM can provide TEDS without having to produce data. This is specified by setting the following Channel TEDS fields:

— Channel Data Model to “N-byte”
— Channel Data Model Length to zero
— Channel Model Significant Bits to zero
— Channel Data Repetitions to zero

For details on these Channel TEDS fields, see 5.2.3.

5.1.3.10 Worst-Case Channel Data Model Length

Meta-TEDS data field number 10

Data type: unsigned byte integer used for counting (U8C, 1 byte)

This field specifies the maximum value of the Channel Data Model Length for all the implemented channels. See also the description of the Channel Data Model Length in the Channel TEDS description, 5.2.3.15.

5.1.3.11 Worst-Case Channel Data Repetitions

Meta-TEDS data field number 11

Data type: unsigned 16 bit integer used for counting (U16C, 2 bytes)

This field specifies the maximum value of the Channel Data Repetitions for all the implemented channels. See also the description of the Channel Data Repetitions in the Channel TEDS description, 5.2.3.17.

5.1.3.12 CHANNEL_ZERO Writable TEDS Length

Meta-TEDS data field number 12

Data type: unsigned 32 bit integer used for counting (U32C, 4 bytes)

This field specifies the length in bytes available for each CHANNEL_ZERO user-writable TEDS. The only structure currently defined in this standard is the CHANNEL_ZERO End-Users’ Application-Specific TEDS. An entire writable TEDS, including the length field and checksum, must fit within this maximum length.

5.1.3.13 Worst-Case Channel Update Time

Meta-TEDS data field number 13

Data type: single-precision real (F32, 4 bytes)

This field specifies the maximum value of the Channel Update Time (t_{wu}) for all the implemented channels in seconds. See also the description of the Channel Update Time in the Channel TEDS description, 5.2.3.21.

For a STIM without enabled event sequence channels, this parameter is used to determine if a STIM is failing to respond to a global trigger. If such a STIM is fully functional, the time between trigger and trigger acknowledge shall never exceed this time. For a STIM with at least one enabled event sequence sensor, this parameter indicates the additional time that must pass after a global trigger acknowledgment before all other channels may be assumed to have acknowledged the virtual triggering associated with the event. See 4.6.10.2 for further explanation.

5.1.3.14 Global write setup time

Meta-TEDS data field number 14

Data type: single-precision real (F32, 4 bytes)

This field specifies the minimum time (t_{gws}), in seconds, between the end of a global write frame and the application of a global trigger. This shall be at least as great as the maximum value of the Channel Write Setup Time (5.2.3.22) for all implemented channels.

5.1.3.15 Global Read Setup Time

Meta-TEDS data field number 15

Data type: single-precision real (F32, 4 bytes)

This field specifies the minimum time (t_{grs}), in seconds, between the receipt of a global trigger acknowledge and the beginning of a global read frame. This shall be at least as great as the maximum value of the Channel Read Setup Time (5.2.3.23) for all implemented channels.

For STIMs with enabled event sequence sensors, the NCAP shall wait for the duration of the Worst-Case Channel Update Time plus the Global Read Setup Time before beginning a global read frame. See 5.1.3.13 and 4.6.10.2 for further explanation.

5.1.3.16 Worst-Case Channel Sampling Period

Meta-TEDS data field number 16

Data type: single-precision real (F32, 4 bytes)

This field specifies the maximum value (t_{wsp}), in seconds, of the channel sampling period for all implemented channels. See also the description of the Channel Sampling Period (5.2.3.24) in the Channel TEDS description.

5.1.3.17 Worst-Case Channel Warm-Up Time

Meta-TEDS data field number 17

Data type: single-precision real (F32, 4 bytes)

This field specifies the minimum time, in seconds, that is necessary between application of power to the STIM and instigation of the first transducer data transfer. This is the maximum value of all the Channel Warm-Up Times. See also the description of the Channel Warm-Up Time in the Channel TEDS description (5.2.3.25).

5.1.3.18 Command Response Time

Meta-TEDS data field number 18

Data type: single-precision real (F32, 4 bytes)

This field specifies the longest time, in seconds, that the STIM takes to process any command in Table 19.

5.1.3.19 STIM Handshake Time

Meta-TEDS data field number 19

Data type: single-precision real (F32, 4 bytes)

This field specifies the longest time (t_{hs}), in seconds, for the STIM to remove the trigger acknowledge signal after the trigger signal is removed by the NCAP, or for the STIM to remove the data transport acknowledge signal after the data transport is inactivated by the NCAP.

5.1.3.20 End-Of-Frame Detection Latency

Meta-TEDS data field number 20

Data type: single-precision real (F32, 4 bytes)

This field specifies the longest time (t_{lat}), in seconds, that a STIM shall take to detect the removal of the data transport enable signal. If the data transport enable signal is removed for this period or longer, then the STIM shall be ready to detect another assertion of the data transport enable signal, which the STIM shall understand to be the start of a new data transport frame.

5.1.3.21 TEDS Hold-Off Time

Meta-TEDS data field number 21

Data type: single-precision real (F32, 4 bytes)

This field specifies the maximum individual hold-off time, in seconds, imposed by the STIM before the first byte, or between bytes, of any data transfer addressed to TEDS functions, (i.e., functional addresses in the ranges of 32–127 or 160–255, inclusive).

5.1.3.22 Operational Hold-Off Time

Meta-TEDS data field number 22

Data type: single-precision real (F32, 4 bytes)

This field specifies the maximum individual hold-off time, in seconds, imposed by the STIM before the first byte, or between bytes, of any data transfer addressed to operational functions, (i.e., functional addresses in the ranges of 1–31 or 129–159, inclusive).

5.1.3.23 Maximum Data Rate

Meta-TEDS data field number 23

Data type: unsigned 32 bit integer used for counting (U32C, 4 bytes)

This field specifies the maximum data rate, in bits per second, supported by the STIM interface.

5.1.3.24 Channel Groupings Data Sub-Block Length

Meta-TEDS data field number 24

Data type: unsigned 16 bit integer used for field length (U16L, 2 bytes)

This field specifies the total number of bytes in the Channel Grouping data sub-block. The Channel Groupings Data Sub-Block Length field shall not include the length of the length field itself. The length shall be the number of relevant bytes following the length field.

If this value is zero, there are no channel groupings defined, and there shall be no data bytes in the subsequent fields of the channel groups data sub-block.

5.1.3.25 Number of Channel Groupings

Meta-TEDS data field number 25

Data type: unsigned byte integer used for counting (U8C, 1 byte)

This field specifies the number of discrete channel groupings defined in this STIM's Meta-TEDS. The subsequent fields in the channel grouping data sub-block shall be repeated in that order for the Number of Channel Groupings.

5.1.3.26 Group Type

Meta-TEDS data field number 26

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

The relationship between the channels comprising the specific group shall be defined by the enumeration in Table 29.

The arbitrary relation, when the enumeration value is equal to zero, shall be used to convey grouping semantics not specifically enumerated by this subclause, but deemed necessary by the transducer manufacturer, for the correct operation or interpretation of the data related to the channels that are members of the group.

The arbitrary relation may be used to redundantly convey, in a more compact form than the Calibration TEDS fields defined in 5.3, that correct behavior of channels with coupling terms in the calibration assumes that all channels involved are triggered at the same time.

Table 29—Enumeration of Group Types

Value	Meaning
0	An arbitrary relation
1	x, y, z right-hand rectangular spatial coordinates
2	ρ, ϕ, z, right-hand cylindrical spatial coordinates
3	r, θ, ϕ right-hand spherical spatial coordinates
4	Latitude, longitude, altitude planetary coordinates
5	In-phase, quadrature temporal coordinates
6	Red, green, blue color coordinates
7	Analog event sequence sensor channel, analog input sensor channel, upper threshold virtual actuator channel, hysteresis virtual actuator channel
8	Sensor channel (any type), high-pass filter virtual actuator channel, low-pass filter virtual actuator channel, scale factor virtual actuator channel
9	Transducer (any type), sample interval virtual actuator channel
10	Digital event sequence sensor channel, digital input sensor channel, event pattern virtual actuator channel
11–127	Reserved for future expansion
128–255	Open to industry

Enumerations 7 and 10 may be used to identify the virtual actuator channels used to set up an event sequence sensor. They also identify a sensor channel that may be used to read the level of the signal in an analog event sequence sensor or the current pattern input to a digital event sequence sensor.

Enumeration 8 may be used to identify the virtual actuator channels used to set the high-pass filter, low-pass filter, and scale factor associated with a sensor of any type.

Enumeration 9 may be used to identify the virtual actuator channels used to set the channel sampling period in a data sequence sensor or buffered sequence sensor. It may also be used to set the channel sampling period in sensors, buffered sensors, and actuators with Channel Data Repetitions greater than zero and Series Increment and Series Units indicating that a time sequence of samples is to be processed on a trigger.

5.1.3.27 Number of Group Members

Meta-TEDS data field number 27

Data type: unsigned byte integer used for counting (U8C, 1 byte)

This field specifies the number of channels comprising the specific group.

5.1.3.28 Member Channel Numbers List

Meta-TEDS data field number 28

Data type: an array of unsigned byte integers used for enumeration (U8E, 0 to 255 bytes)

This field specifies a one-dimensional array (list) of 1 byte elements. Each element is the channel address for a member channel in the specific group. The values of the elements in this list shall be in the sequence specified by the group type.

An element with value zero shall indicate that the transducer does not implement this particular element of the enumerated relationship. For example, a two-axis vector measurement implemented by channels 1, x, and 2, y, may be specified by designating the Group Type (5.1.3.26) as 1 (x, y, z) with the Member Channel Numbers List (1, 2, 0). The value zero shall not appear in the Member Channel Numbers List for a group of group type "arbitrary relation."

Note that a channel can be represented in multiple groups.

5.1.3.29 Checksum for Meta-TEDS

Meta-TEDS data field number 29

Data type: unsigned 16 bit integer used for counting (U16C, 2 bytes)

This field contains the checksum for the complete Meta-TEDS data block. The checksum shall be the one's complement of the sum (modulo 2^{16}) of all the data structure's preceding bytes, including the initial length field and excluding the checksum field.

5.2 Channel TEDS Data Block

5.2.1 Access

Functional address 160 applied to channels 1–255 shall access this data.

5.2.2 Function

The function of the Channel TEDS shall be to make available at the interface all of the information concerning the channel being addressed to enable the proper operation of the channel. Channel TEDS bytes are constant and read-only.

5.2.3 Data structure

Table 30 shows the data structure. Subsequent subclauses explain each data field in the structure. Serial transmission of data shall occur msb first. When serial data is divided into bytes, such as in the transmission of multi-byte TEDS fields, the most significant byte shall be transmitted first.

Table 30—Data structure of Channel TEDS data block

Field No.	Description	Type	No. of bytes
Data structure related data sub-block			
1	Channel TEDS Length	U32L	4
2	Calibration Key	U8E	1
3	Channel Industry Calibration TEDS Extension Key	U8E	1
4	Channel Industry Nonvolatile Data Fields Extension Key	U8E	1
5	Channel Industry TEDS Extension Key	U8E	1
6	Channel End-Users' Application-Specific TEDS Key	U8E	1
7	Channel Writable TEDS Length	U32C	4
Transducer related data sub-block			
8	Channel Type Key	U8E	1
9	Physical Units	UNITS	10
10	Lower Range Limit	F32	4
11	Upper Range Limit	F32	4
12	Worst-Case Uncertainty	F32	4
13	Self-Test Key	U8E	1
Data converter related data sub-block			
14	Channel Data Model	U8E	1
15	Channel Data Model Length	U8C	1
16	Channel Model Significant Bits	U16C	2
17	Channel Data Repetitions	U16C	2
18	Series Origin	F32	4
19	Series Increment	F32	4
20	Series Units	UNITS	10
Timing related data sub-block			
21	Channel Update Time (t_u)	F32	4
22	Channel Write Setup Time (t_{ws})	F32	4
23	Channel Read Setup Time (t_{rs})	F32	4
24	Channel Sampling Period (t_{sp})	F32	4
25	Channel Warm-Up Time	F32	4
26	Channel Aggregated Hold-Off Time (t_{ch})	F32	4
27	Timing Correction	F32	4
28	Trigger Accuracy	F32	4
Event sequence options field			
29	Event Sequence Options	U8E	1
Data integrity data sub-block			
30	Checksum for Channel TEDS	U16C	2

5.2.3.1 Channel TEDS length

Channel TEDS data field number 1

Data type: unsigned 32 bit integer used for counting (U32L, 4 bytes)

This field specifies the total number of bytes in the channel TEDS data block excluding this field.

5.2.3.2 Calibration Key

Channel TEDS data field number 2

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

The calibration capabilities of the STIM are defined in Table 31.

Table 31—Enumeration of Calibration Keys

Value	Name	Function
0	CAL_NONE	No calibration information needed or provided. No correction is performed by the NCAP on transducer data associated with this channel. If the value is CAL_NONE, this implies that there is no calibration TEDS associated with this block. If the Calibration TEDS is accessed, the Calibration TEDS Length shall be zero.
1	CAL_FIXED	Fixed calibration information provided. This information cannot be modified. Correction is performed in the NCAP or elsewhere in the system.
2	CAL_MODIFIABLE	Calibration information provided. This information can be modified by writing to the Calibration TEDS. Correction is performed in the NCAP or elsewhere in the system.
3	CAL_SELF	Calibration information provided. Adjusted by a self-calibration capability. Correction is performed in the NCAP or elsewhere in the system.
4	CAL_CUSTOM	Calibration information is provided through an industry extension. Correction is performed in the NCAP or elsewhere in the system.
5	STIM_CAL_FIXED	Fixed calibration information is provided to be applied in the STIM. This information cannot be modified. See 5.2.3.2.2 for additional details.
6	STIM_CAL_MODIFIABLE	Calibration information is provided to be applied in the STIM. This information can be modified by writing to the Calibration TEDS. See 5.2.3.2.2 for additional details.
7	STIM_CAL_SELF	Calibration information is provided to be applied in the STIM. Adjusted by a self-calibration capability. See 5.2.3.2.2 for additional details.
8–255	Reserved	Reserved for future expansion.

5.2.3.2.1 NCAP corrections

Calibration key enumerations CAL_FIXED, CAL_MODIFIABLE, CAL_SELF, and CAL_CUSTOM are to be used when the correction is performed in the NCAP or elsewhere in the system.

5.2.3.2.2 STIM corrections

Calibration key enumerations STIM_CAL_FIXED, STIM_CAL_MODIFIABLE, and STIM_CAL_SELF are to be used when the correction is performed in the STIM using the correction method specified in 5.3 and information stored in the Calibration TEDS (5.3).

5.2.3.3 Channel Industry Calibration TEDS Extension Key

Channel TEDS data field number 3

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

The value in this field indicates the highest functional address for writing the industry-implemented Calibration TEDS extension that is available in the STIM for this channel. Acceptable values and their meanings are defined in Table 32.

Table 32—Enumerations of Channel Industry Calibration TEDS Extension Keys

Key value (K)	Meaning
0	No extensions implemented in STIM
1–79	Invalid
80–95	Valid, TEDS extension(s) implemented for: —Functional addresses used for writing: between 80 and (K); and —Functional addresses used for reading: between 208 and (K+128)
96–255	Invalid

5.2.3.4 Channel Industry Nonvolatile Data Fields Extension Key

Channel TEDS data field number 4

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

The value in this field indicates the highest functional address for writing the industry-implemented nonvolatile data field extensions that is available in the STIM for this channel. Acceptable values and their meanings are defined in Table 33.

Table 33—Enumerations of Channel Industry Nonvolatile Data Fields Extension Keys

Key value (K)	Meaning
0	No extensions implemented in STIM
1–111	Invalid
112–127	Valid, TEDS extension(s) implemented for: —Functional addresses used for writing: between 112 and (K); and —Functional addresses used for reading: between 240 and (K+128)
128–255	Invalid

5.2.3.5 Channel Industry TEDS Extension Key

Channel TEDS data field number 5

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

The value in this field indicates the highest functional address for writing the industry-implemented TEDS extensions that is available in the STIM for this channel. Acceptable values and their meanings are defined in Table 34.

Table 34—Enumerations of Channel Industry TEDS Extension Keys

Key value (K)	Meaning
0	No extensions implemented in STIM
1–175	Invalid
176–191	Valid, TEDS extension(s) implemented for: —Functional addresses used for reading: between 176 and (K)
192–255	Invalid

5.2.3.6 Channel End-Users' Application-Specific TEDS Key

Channel TEDS data field number 6

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

This field indicates the presence of End-Users' Application-Specific TEDS function for this channel as defined in Table 35.

Table 35—Enumeration of End-Users' Application-Specific TEDS Keys

Key value	Meaning
0	End-Users' Application-Specific TEDS Function Is Not Implemented On This Channel.
1	End-Users' Application-Specific TEDS function is implemented on this channel.
2–255	Reserved

5.2.3.7 Channel Writable TEDS Length

Channel TEDS data field number 7

Data type: unsigned 32 bit integer used for counting (U32C, 4 bytes)

This field specifies the length in bytes available for each individual user-writable TEDS associated with this channel, such as Calibration TEDS, Calibration Identification TEDS, or End-User's Application-Specific TEDS. An entire writable TEDS, including the length field and checksum, must fit within this maximum length.

5.2.3.8 Channel Type Key

Channel TEDS data field number 8

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

This field specifies the channel transducer type. The values for Channel Type Key are defined in Table 36.

Table 36—Enumeration of Channel Type Keys

Key value	Meaning
0	Sensor
1	Actuator
2	Event sequence sensor
3	Data sequence sensor
4	General transducer
5	Buffered sensor
6	Buffered data sequence sensor
7–255	Reserved for future expansion

5.2.3.9 Physical Units

Channel TEDS data field number 9

Data type: Physical units (UNITS, 10 bytes)

This field defines the physical units that apply to the transducer data, however, if the Calibration Key is CAL_FIXED, CAL_MODIFIABLE, CAL_SELF, or CAL_CUSTOM the physical units apply only to the transducer data *after* correction for the case of sensors, or *before* correction for the case of actuators.

See 3.3.8 for details on the Physical Units Fields.

5.2.3.10 Lower Range Limit

Channel TEDS data field number 10

Data type: single-precision real (F32, 4 bytes)

For sensors, this shall be the lowest valid value for transducer data after correction is applied, interpreted in the units specified by the Physical Units field of the Channel TEDS. If the corrected transducer data lies below this limit, it may not comply with STIM specifications set by the manufacturer.

For actuators, this shall be the lowest valid value for transducer data before correction is applied, interpreted in the units specified by the physical units field of the channel TEDS. Writing corrected transducer data below this limit may result in behavior outside the STIM specifications set by the manufacturer.

In cases where no correction is applied and the data is expressed in a different format than single-precision real, conversion to single-precision real is necessary before making the comparison.

An example of this is data from a channel whose Calibration Key is CAL_NONE and whose Data Model is N-byte integer. Note that this conversion may limit the practical range or precision of the converted transducer data.

When this parameter is not applicable it shall be NaN.

An example of a number for which Range Limits do not apply is N-byte data representing a bank of switches. In this case the field shall be set to NaN. On the other hand, Range Limits may apply to N-byte data that represents a 12 bit integer with no expressed units, such as raw analog-to-digital convertor (ADC) output. In either case, the physical units will be “digital data.”

If the Channel Data Repetitions field of this channel is nonzero, then the value of this field shall be interpreted to apply to all of the repetition instances.

5.2.3.11 Upper Range Limit

Channel TEDS data field number 11

Data type: single-precision real (F32, 4 bytes)

For sensors, this shall be the highest valid value for transducer data after correction is applied, interpreted in the units specified by the Physical Units field of the Channel TEDS. If the corrected transducer data lies above this limit, it may not comply with STIM specifications set by the manufacturer.

For actuators, this shall be the highest valid value for transducer data before correction is applied, interpreted in the units specified by the Physical Units field of the Channel TEDS. Writing corrected transducer data above this limit may result in behavior outside the STIM specifications set by the manufacturer.

In cases where no correction is applied, and the data is expressed in a different format than single-precision real, conversion to single-precision real is necessary before making the comparison.

An example of this is data from a channel whose Calibration key is CAL_NONE and whose Data Model is N-byte integer. Note that this conversion may limit the practical range or precision of the converted transducer data.

When this parameter is not applicable it shall be NaN.

An example of a number for which Range Limits do not apply is N-byte data representing a bank of switches. In this case the field shall be set to NaN. On the other hand, Range Limits may apply to N-byte data that represents a 12 bit integer with no expressed units, such as raw ADC output. In either case, the physical units will be "digital data."

If the Channel Data Repetitions field of this channel is nonzero, then the value of this field shall be interpreted to apply to all of the repetition instances.

5.2.3.12 Worst-Case Uncertainty

Channel TEDS data field number 12

Data type: single-precision real (F32, 4 bytes)

This field specifies the "Combined Standard Uncertainty" defined in Appendix C, Section 2.2 of [B2]. The value of this field shall be expressed in the same units as the transducer data as specified in the Physical Units field of the Channel TEDS, 5.2.3.9.

5.2.3.13 Self-Test Key

Channel TEDS data field number 13

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

This field defines the self-test capabilities of the transducer as shown in Table 37.

Table 37—Enumeration of Self-Test Keys

Key value	Meaning
0	No self-test function needed or provided
1	Self-test function provided
2–255	Reserved for future expansion

5.2.3.14 Channel Data Model

Channel TEDS data field number 14

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

This field describes the data model used when addressing read transducer data or write transducer data for this channel as shown in Table 38.

There are two differences between N-byte-integer (enumeration zero) and N-byte-fraction (enumeration three), as follows:

a) The radix point (which divides integer from fractional bits) is to the right of the lsb for N-byte-integer. It is immediately to the right of the msb for N-byte-fraction.

b) Justification of the significant bits differs (see 5.2.3.16).

Table 38—Enumeration of Channel Data Models

Value	Model	Length
0	N-byte integer (unsigned)	0≤N≤255
1	Single-precision real	4 bytes
2	Double-precision real	8 bytes
3	N-byte fraction (unsigned)	0≤N≤255
4–255	Reserved for future expansion	_

The N-byte fraction type may be used to keep the multinomial coefficients (see 5.3.3.11) within representable bounds.

5.2.3.15 Channel Data Model Length

Channel TEDS data field number 15

Data type: unsigned byte integer used for counting (U8C, 1 byte)

This field specifies the number of bytes in the representation of the selected Channel Data Model.

For N-byte integer	the value in this field shall be N, where 0 ≤ N ≤ 255.
For N-byte fraction	the value in this field shall be N, where 0 ≤ N ≤ 255.
For single-precision real	the value in this field shall be 4.
For double precision real	the value in this field shall be 8.

5.2.3.16 Channel Model Significant Bits

Channel TEDS data field number 16

Data type: unsigned 16 bit integer used for counting (U16C, 2 bytes)

When the Channel Data Model is N-byte integer (enumeration zero) or N-byte fraction (enumeration three), the value of this field is the number of bits that are significant. The value of this field shall be between zero and 2040.

For example, if data from a transducer channel comes from a 12-bit ADC, then

Channel Data Model	= N-byte integer (field enumeration value of zero)
Channel Data Model Length	= 2 (the number of bytes to hold 12 bits)
Channel Model Significant Bits	= 12

When the Channel Data Model is N-byte integer or N-byte fraction, the Channel Model Significant Bits shall not exceed eight times the Channel Model Data Length.

When the Channel Data Model is N-byte integer, the significant data bits shall be right-justified within the byte stream.

When the Channel Data Model is N-byte fraction, the significant data bits shall be left-justified within the byte stream.

When the Channel Data Model is single- or double-precision real (enumerations one or two), the value of this field is the number of bits in the STIM's signal converter.

5.2.3.17 Channel Data Repetitions

Channel TEDS data field number 17

Data type: unsigned byte integer used for counting (U16C, 2 bytes)

The number *L* of repetitions of the transducer value produced or required by a single trigger. Each repetition represents an additional measurement or actuation value produced or consumed by the transducer at each trigger, which shall be spaced apart from the initial value associated with the trigger along some axis (for example, time) by an amount defined by the Channel TEDS fields Series Increment and Series Units, respectively. When *L* is zero, the values of Series Origin, Series Increment, and Series Units may be ignored. The purpose of this structure shall be to enable the specification of transducers that produce an array of data with the application of a single trigger such as a time series or a mass spectrum.

When reading or writing data with Channel Data Repetitions greater than zero, the order of transmittal shall be with the 0^{th} data sample transmitted first, the first repetition transmitted second, etc.

5.2.3.18 Series Origin

Channel TEDS data field number 18

Data type: single-precision real (F32, 4 bytes)

For the case where the Channel Data Repetitions is greater than zero, the Series Origin represents the value of the independent variable associated with the first datum returned in a data set. The Series Origin is expressed in units defined by the Series Units field in the Channel TEDS, 5.2.3.20.

5.2.3.19 Series Increment

Channel TEDS data field number 19

Data type: single-precision real (F32, 4 bytes)

For the case where the Channel Data Repetitions is greater than zero, the series increment represents the spacing between values of the independent variable associated with successive members of the data set. The series increment is expressed in units defined by the Series Units field in the Channel TEDS, 5.2.3.20.

5.2.3.20 Series Units

Channel TEDS data field number 20

Data type: Physical units (UNITS, 10 bytes)

This field specifies the physical units associated with the series origin, 5.2.3.18, and series increment, 5.2.3.19 fields in the Channel TEDS.

5.2.3.21 Channel Update Time

Channel TEDS data field number 21

Data type: single-precision real (F32, 4 bytes)

This field specifies the maximum time (t_u), in seconds, between the receipt of a trigger and the issue of trigger acknowledge for this channel. This parameter allows NCAPs to determine time-out values, if appropriate.

For data sequence and buffered data sequence sensors, this parameter only applies when they are enabled.

For event sequence sensors, this parameter shall be NaN.

5.2.3.22 Channel Write Setup Time

Channel TEDS data field number 22

Data type: single-precision real (F32, 4 bytes)

This field specifies the minimum time (t_{ws}), in seconds, between the end of a write frame and the application of a trigger. (For most devices this will be a setup time characteristic of the transducer electronics. For more complex transducers, particularly those with a microprocessor, there could be additional time needed that can be specified by this constant.)

5.2.3.23 Channel Read Setup Time

Channel TEDS data field number 23

Data type: single-precision real (F32, 4 bytes)

This field specifies the minimum time (t_{rs}), in seconds, between the trigger acknowledge and the beginning of a read frame. (For most devices this will be a setup time characteristic of the transducer electronics. For more complex transducers, particularly those with a microprocessor, there could be additional time needed that can be specified by this constant.)

5.2.3.24 Channel Sampling Period

Channel TEDS data field number 24

Data type: single-precision real (F32, 4 bytes)

The Channel Sampling Period (t_{sp}) shall be the minimum sampling period of the channel transducer unencumbered by read or write considerations (since there is no requirement to read or write with each trigger).

Typically, for sensor, buffered sensor, and actuator channels this time will be limited by A/D or D/A conversion times, STIM processor speed, etc., but in more complex transducers it may reflect transducer or sample handling times as well (e.g., a pH sensor that on each trigger extracts a new fluid sample using a pump). If reads or writes are involved, then the actual sampling rates will be further limited by setup and data transfer times depending on the transducer type.

In the case of data sequence and buffered data sequence transducers, this parameter shall represent the sequence sampling time determined by the STIM implementation.

In the case of event sequence transducers, this parameter shall represent the minimum event resolution time.

The Channel Sampling Period shall be expressed in seconds.

5.2.3.25 Channel Warm-Up Time

Channel TEDS data field number 25

Data type: single-precision real (F32, 4 bytes)

This field specifies the period of time, in seconds, in which the device stabilizes its performance to predefined tolerances after the application of power to the transducer.

5.2.3.26 Channel Aggregated Hold-Off Time

Channel TEDS data field number 26

Data type: single-precision real (F32, 4 bytes)

This field specifies the maximum aggregated time (t_{ch}) that the STIM will spend holding off the data transport during a complete data transfer addressed to *read transducer data* or *write transducer data* and this channel, assuming the Maximum Data Rate is used. This time shall include the time between the NCAP activating the data transport and the STIM acknowledgment.

5.2.3.27 Timing Correction

Channel TEDS data field number 27

Data type: single-precision real (F32, 4 bytes)

This field specifies the time offset, in seconds, between the issue of global trigger acknowledge and when this channel actually sampled the sensor or updated the actuator. See 4.6.10 for recommendations on the use of this field.

If the channel itself is addressed, then the trigger acknowledge defines the actuation or sensing point in time, and the timing correction field does not apply.

5.2.3.28 Trigger Accuracy

Channel TEDS data field number 28

Data type: single-precision real (F32, 4 bytes)

This field specifies the accuracy, in seconds, of the Timing Correction.

5.2.3.29 Event Sequence Options

Channel TEDS data field number 29

Data type: unsigned byte integer used for enumeration (U8E, 1 byte)

An event sequence sensor has the option of changeable pattern, upper threshold, and/or hysteresis. It also has the option of detecting inconsistencies in settings of these parameters as described in 4.6.9. This enumeration defines, for the NCAP, the ability of the STIM to detect and report these inconsistencies. The options are defined in Table 39.

Table 39—Event sequence options

Value	Meaning
0	Not applicable
1	Pattern/threshold/hysteresis not changeable
2	Changeable and inconsistencies detected
3	Changeable and inconsistencies not detected
4–255	Reserved

5.2.3.30 Checksum for Channel TEDS

Channel TEDS data field number 30

Data type: unsigned 16 bit integer used for counting (U16C, 2 bytes)

This field contains the checksum for the complete Channel TEDS data block. The checksum shall be the one's complement of the sum (modulo 2^{16}) of all the data structure's preceding bytes, including the initial length field and excluding the checksum field.

5.3 Calibration TEDS data block

5.3.1 Access

Functional addresses 64 and 192 applied to channels 1–255 shall access this data.

5.3.2 Function

The function of the Calibration TEDS shall be to make available at the interface all of the information used by correction software in connection with the channel being addressed.

The Calibration TEDS shall be read and write capable if the value of the Calibration Key Field is CAL_MODIFIABLE or STIM_CAL_MODIFIABLE. The Calibration Identification TEDS shall be read only in all other cases of the Calibration Key field. The Calibration Identification TEDS may be modified by the STIM in response to a "calibrate channel" control command if and only if the value of the Calibration Key field is CAL_SELF or STIM_CAL_SELF.

5.3.2.1 Method

Correction is the application of a specified mathematical function upon transducer data from one or more STIM channels and/or data delivered from other software objects. This subclause gives an overview of how the correction process is modeled, in order to aid understanding of how to develop and use the entries in the Calibration TEDS for correction.

Correction is intended to reconcile two different numbers associated with a transducer channel, as follows:

— The NCAP-side number: This number represents the channel's value expressed in the Physical Units (5.2.3.9) recorded in the Channel TEDS. The Lower and Upper Range Limits (5.2.3.10, 5.2.3.11) apply to this number. This is the number used in the NCAP and elsewhere to represent the channel transducer data.
— The transducer-side number: This number is read from or written to the channel hardware.