Multiscale Electrophysiology Data Format

Version 1.0

(MED 1.0)

Feature Overview:

Feature	Characteristics

Format	• One directory per channel
	• Channels are segmented in time (single segment channels are supported)
	• Extensible channel types (currently, time series & video)
	• Time series channel:
	  • 32 bit resolution (integer)
	  • Independent channel sampling frequencies
	  • Any time series data can be encoded (e.g. transforms of original data)

Time Series Compression	• Decreased data storage • Increased network transfer, read/write speeds • Variable block sizes • Channel-specific sampling rates supported reduce data volume • Adaptive lossless or lossy compression • Improved compression ratio with decreased signal variance (e.g. filtering) • Independent blocks allow parallel compression / decompression • Variable sampling rates supported • Algorithm optimized for hardware implementation • Block headers contain information necessary to facilitate data transmission, including data loss detection and asynchronous transmission.
Encryption	• AES 128-bit • HIPAA compliant • Sharing of human data does not require de-identification procedures • Dual-tiered, single-password encryption scheme allowing differential access to the same file • Unauthorized copies have no access to creator-determined file regions: technical metadata, subject-identifying metadata, specific records, time series data • Times are optionally offset, preserving true time of day, but obscuring actual recording date and time zone. • No encryption level is required

Feature	Characteristics
Access	• Rapid random access via indices files • Field alignment facilitates direct variable access after data read
Analysis	• Separate directory for each channel to facilitate parallel processing • Independence of time series blocks support asynchronous and parallel processing • Multiple precalculated fields facilitate various common analyses
Real-time	• The structure of MED files allows real-time reading and writing. • Catastrophic failure during an acquisition will leave an intact valid MED structure

Redundancy & Damage mitigation	• 32-bit CRC checksums for detection of file, individual record, & time series block corruption
	• Time Series Channels:
	  • Block independence limits extent of data loss if damage occurs
	  • Block alignment facilitates file recovery
	  • Multiple fields duplicated in block header and indices file
	  • Entire indices file can be reconstructed from data file

Time	• Time discontinuities supported and indexed • μUTC time provides globally accurate date & time of day to microsecond resolution • μUTC time is easily converted to UTC time for use with standard Unix / Posix time functions
Events	• Stored in binary records file • User-defined event types readily accommodated by records format
Video	• Video channels are explicitly supported
Support	• Open source (Apache software license) • Freely available C, Matlab, & Java functions and software

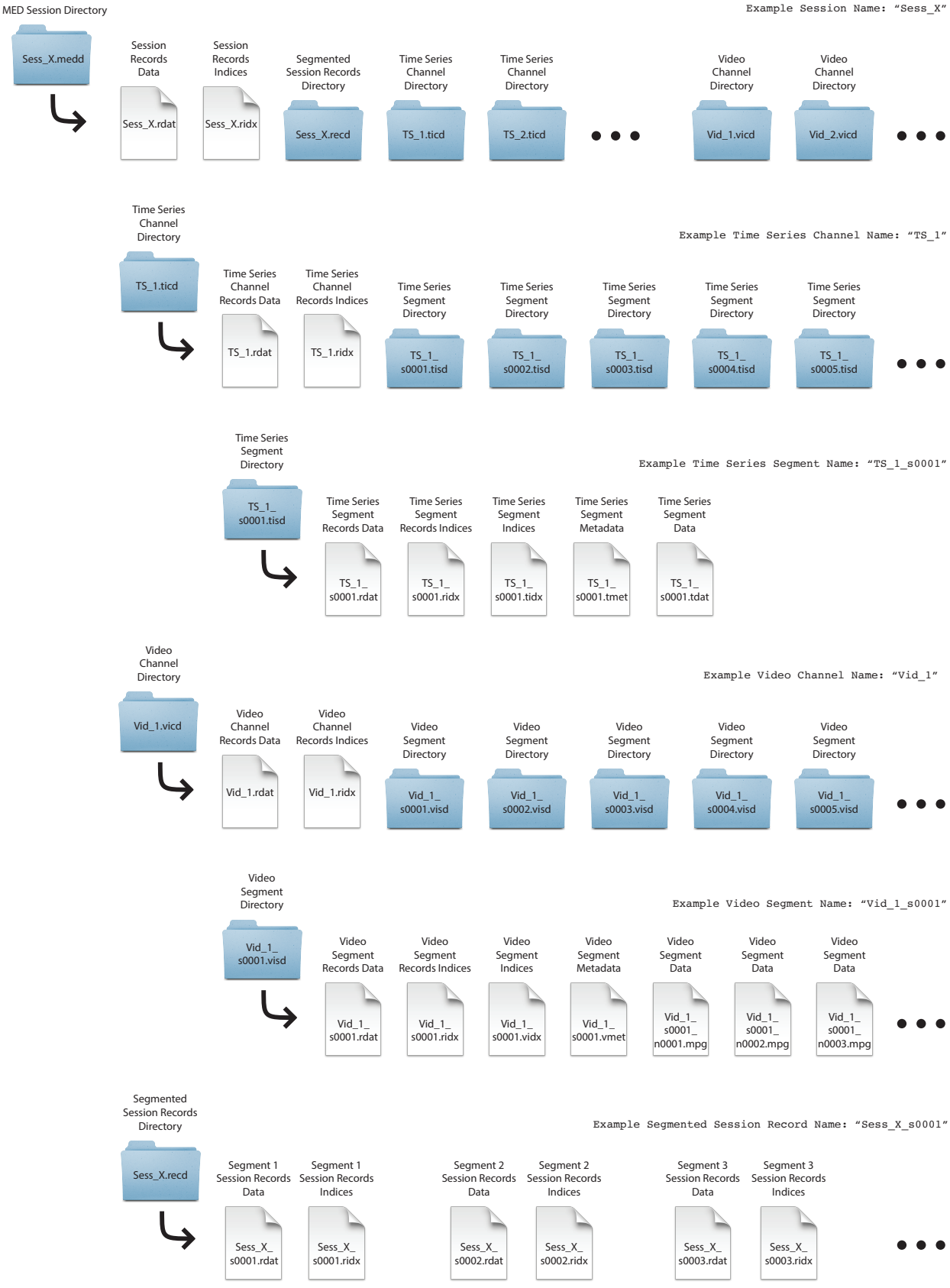
MED Data Hierarchy (See Figure 1)

- Each collection of recorded channels is called a “Session”. A session is a directory at the top level of the hierarchy.
- A session directory is not required, MED channels or segments can be acquired and used independently.
- Channel Directories: Channels are any data stream. Currently time-series and video data are supported, but other channel types may be incorporated in the future.
- All channels are divided into segments. All channels are required to have at least one segment.
- Every level of the hierarchy may have records associated with that level.
- Each Session Directory contains:
    - Record Data File *(if present, a session Record Indices file must be present)*
    - Record Indices File *(if present, a session Record Data file must be present)*
    - Segmented Records Directory *(if present)* containing:
        - Record Data Files *(if present, corresponding Record Indices file must be present)*
        - Record Indices Files *(if present, corresponding Record Data files must be present)*
    - Time Series Channel Directories containing:
        - Record Data File *(if present, a channel Record Indices file must be present)*
        - Record Indices File *(if present, a channel Record Data file must be present)*
        - Segment directories containing:
            - Metadata File
            - Data File
            - Indices File
            - Record Data File *(if present, a segment Record Indices file must be present)*
            - Record Indices File *(if present, a segment Record Data file must be present)*
    - Video Channel directories containing:
        - Record Data File *(if present, a channel Record Indices file must be present)*
        - Record Indices File *(if present, a channel Record Data file must be present)*
        - Segment directories containing:
            - Metadata File
            - Indices File
            - Data Files (native video format file - e.g. MPEG; there can be multiple video files per segment - see naming convention below)
            - Record Data File *(if present, a segment Record Indices file must be present)*
            - Record Indices File *(if present, a segment Record Data file must be present)*

MED Naming Conventions (See Figure 1)

- Session Directories are named according to user preference and carry the ".medd" extension.
- Segmented Session Record Directories are named with the session name appended by ".recd". As with all record entities, this directory is optional.
- Record Data Files are named as the level (session, channel, segment) name appended by ".rdat".
- Record Indices Files are named as the level name appended by ".ridx".
- Record files within a Segmented Session Record directory are named with the session name, appended with an underscore and the letter "s", and a sequential fixed-width (4 digit) numbers starting from 1 (e.g. 0001, 0002, …) corresponding to the segment number with which they are associated (e.g. "Sess_X_s0001.rdat" & "Sess_X_s0001.ridx").
- Time Series Channel Directories are named as the channel name appended by ".ticd".
- Video Channel Directories are named according to user preference appended by ".vidd".
- Segments are named with the channel name, appended with an underscore and the letter "s", and a sequential fixed-width (4 digit) numbers starting from 1 (e.g. 0001, 0002, …). (e.g. "Chan_01_s0001").
- Time Series Segment Directories are named with the segment name, appended with the extension ".segd". (e.g. "Chan_01_s0001.tisd").
- Video Segment Directories are named with the segment name, appended with the extension ".segd". (e.g. "Chan_01_s0001.visd").
- Time Series Metadata Files are named as the segment name appended by ".tmet".
- Time Series Indices Files are named as the segment name appended by ".tidx".
- Time Series Data Files are named as the segment name appended by ".tdat". There is only one time series data file per segment (as opposed to Video Data Files).
- Video Metadata Files are named as the segment name appended by ".vmet".
- Video Indices Files are named with the video directory name appended by ".vidx".
- The Video Data Files are named with the segment name, appended with an underscore and the letter "n", and a sequential fixed-width (4 digit) video file numbers starting from 1 (e.g. "Vid_1_s0001_n0001"). They are appended by their native data format extension (e.g. "Vid_1_s0001_n0001.mpeg"). There can be multiple video data files per segment (as opposed to Time Series Data Files).

Figure 1: MED 1.0 Data Hierarchy & Naming Conventions



MEF Data Type Definitions:

Type Name	Description
ui1	1 byte unsigned integer
si1	1 byte signed integer
ui4	4 byte unsigned integer
si4	4 byte signed integer
sf4	4 byte signed floating point number
ui8	8 byte unsigned integer
si8	8 byte signed integer
sf8	8 byte signed floating point number
sf16	16 byte signed floating point number
utf8[n]	zero-terminated UTF-8 encoded string of maximum length “n” characters (not including terminal zero)
ascii[n]	zero-terminated ascii encoded string of maximum length “n” characters (not including terminal zero)

MED Time Series Data Format

- Data are stored in compressed (CMP) blocks, compressed with any of the following algorithms:
  - Range Encoded Differences (RED): best for real-time and hardware implementations
  - Predictive Range Encoded Differences (PRED): best compression ratio for standard CPU-based implementations (default)
  - Minimal Bit Encoding (MBE): best for degenerate data
- MED can encode signed integer data with 32-bit resolution, giving a full range of $-(2^{31})$ to $+(2^{31} - 1)$. [decimal -2,147,483,648 to +2,147,483,647] [hex 0x80000000 to 0x7FFFFFFF]
- -2^{31} is reserved to represent NaN (not a number). [decimal -2,147,483,648] [hex 0x80000000]

- $+(2^{31} - 1)$ is reserved to represent positive infinity. [decimal 2,147,483,647] [hex 0x7FFFFFFF]
- $-(2^{31} - 1)$ is reserved to represent negative infinity. [decimal -2,147,483,647] [hex 0x80000001]
- The unreserved range is therefore $-(2^{31} - 2)$ to $+(2^{31} - 2)$. [decimal -2,147,483,646 to +2,147,483,646] [hex 0x80000002 to 0x7FFFFFFE]
- Data blocks are indexed in the Time Series Indices File for random access.

MED Data Alignment

- All fields in all files in the format are aligned such that their values align to a multiple of their size from the beginning of the file. This allows for data read to be cast directly into data structures and for memory mapping of files.
- This alignment also facilitates recovery in the event of file damage.
- Pad bytes are added, if necessary, to maintain alignment, at the end of CMP Blocks, and Record Bodies. The value of the the pad byte is specified to be 0x7E, the ascii tilde ("~"). Specification of this value is done to facilitate reproducible CRCs and may be useful in the case of data recovery if file damage were to occur.

MED Strings

- All strings related to naming and descriptive data use UTF-8 encoding to allow for international character sets.
- UTF-8 encoding:
  - variable length characters
  - up to 4 bytes per character
  - not endian-sensitive
  - strings are null-terminated
- Unused bytes in MED string fields are set to zero to promote reproducibility of CRC values.
- Library string functions facilitate all of the above.

Micro-UTC Time (μUTC or UUTC)

- All times in MED are represented as offset μUTC times.

- A μUTC time is an si8 containing the elapsed microseconds since January 1, 1970 at 00:00:00 in the UTC (Coordinated Universal Time) (also GMT time zone).
- μUTC is simply converted to UTC (Coordinated Universal Time: seconds since 1/1/1970 at 00:00:00 GMT. Referred to as "The Epoch", defined by the International Telecommunications Union) by dividing by 1,000,000.
- In MED all μUTC times are stored and utilized as offset μUTC times by subtracting a recording time offset. If the recording time offset is zero, the times are effectively not offset. If the recording time offset is known, when reading a file, it will be used when displaying times and dates.

Recording Time Offsets

- All times in the MED format are obfuscated with a value called the "Recording Time Offset" which is stored in Section 3 of the Metadata files. Data are stored with the recording time offset applied and represent times based in the UTC timezone such that the recording start day is January 1, 1970. and the recording start time of day is the same as the true local recording start time. This mechanism allows preservation of time of day information, without providing any true date or timezone information. True time & date values are retrieved by removing the "Recording Time Offset" value.
- No Daylight saving time correction is used in the offset mechanism; it is based on standard local time. To include this DST corrections accurately would require knowledge of the true recording location and start time, which this mechanism is designed to obscure.
- The Recording Time Offset is included in Section 3 of the Metadata files, and if times are not offset this field is set to zero.
- As recording time offsets are stored in section 3 of the Metadata files, to remove offsets, Metadata files should be read first when reading a segment.

Tiered Encryption

- Three levels of encryption are available, referred to as Level 0**, Level 1, & Level 2.
- **Level 0 encryption indicates no encryption.
- Level 1 and Level 2 encryption can be selected in various places:
    - Sections 2 and 3 of Metadata Files
    - Individual records of Record Data Files
    - Individual CMP blocks of the Time Series Data Files
- Level 2 decryption ability guarantees Level 1 decryption ability, but not the converse.

- Level 1 encryption is typically used for technical data, and Level 2 encryption for potentially subject identifying data. This way technical data can be shared with collaborators with out violating subject privacy. *However, encryption levels can be designated in any way desired by the file creator.*
- Level 2 encryption requires specification of a Level 1 password, even if Level 1 encryption is not employed anywhere in the file.
- Password hints can be specified for Level 1 & Level 2 passwords.
- An *optional* Level 3 password can be specified during file creation which will allow retrieval of the Level 1 and Level 2 passwords. Level 3 is not an encryption level in itself, however. The intention of the Level 3 password is to allow for a *broad failsafe* against password loss. Obviously, if used, Level 3 passwords should be carefully guarded. A typical usage might be: All EEG studies collected by an institution are encoded with the same Level 3 password (perhaps changed on a fixed schedule), known only to system administrators.
- The encryption / decryption algorithm is the 128-bit Advanced Encryption Standard (AES). [http://www.csrc.nist.gov/publications/fips/fips197/fips-197.pdf], which satisfies the Health Insurance Portability and Accountability Act (HIPAA) 112-bit requirement for symmetric encryption of human data.

UTF-8 passwords

- AES-128 requires a 16 byte key. Therefore multibyte UTF-8 password characters are used internally in MED by taking the last (most unique) byte in each character of the UTF-8 encoding.
- The password length limit is 16 (UTF-8) characters.
- Programming Note: Because MED passwords are required to be null terminated strings, the string buffer length must accommodate a terminal zero (typically 17 bytes, but up to 65 bytes (= (16 * 4) + 1) for UTF-8 passwords).

Time Series Compression

- At the time of this writing, compression is done by one of three lossless algorithms:
    - RED (Range Encoded Differences) differences the data, and then range encodes the differences.
    - PRED (Predictive Range Encoded Differences) uses 3 separate models to predictively encode the data using the RED algorithm. This algorithm is more computationally expensive on encoding, but produces higher compression ratios.

    - MBE (Minimal Bit Encoding) simply encodes each raw sample with the minimum bits required for the range of the block. This is typically used when a RED or PRED encoded block would exceed the compression ratio of MBE. This is useful for blocks that contain very noisy (uncorrelated) data.

- Data can optionally be detrended prior to applying compression. This operation is lossless, but is generally more useful in lossy compression routines.
- Lossy compression is permitted in time series data by scaling data prior to compression with the RED or PRED algorithms. Scaling is adaptive and may vary from block to block. The scaled values must be rounded to the nearest integer, introducing the loss. Lossy compression is not required, but can produce substantial storage savings with negligible data differences in data streams whose sample-value specificities exceed their information content. Compression can also be useful in speeding transmission and viewing of data.
- Four compression modes are currently supported:
    1. Lossless (default)
    2. Fixed Scale Factor: a user-specified scale factor is applied to the block (1.0 results in lossless compression)
    3. Fixed Compression Ratio: the scale factor is adjusted until the block compression ratio (block_bytes / input_array_size [as si4s]) is this number plus or minus a tolerance. e.g. 20% of the original si4 size with a 1% tolerance is 0.19 to 0.21. If lossless compression can achieve or exceed the desired ratio (plus the tolerance), lossless compression will be applied. This option may add noticeable processing time to compression, but once done, adds negligible time to decompression.
    4. Mean Residual Ratio: the scale factor is adjusted until the mean(abs((scaled_data - original_data) / original_data)) for the values in the block, is this number plus or minus a tolerance. e.g. 0.5% difference with a 0.1% tolerance is 0.004-0.006. This option may add noticeable processing time to compression, but once done, adds negligible time to decompression.

Protected and Discretionary File Regions

- The protected region is reserved for possible future additions to the MED format and should not be modified by end users.
- The discretionary region is reserved for end user use so that custom data can be conveniently added to the files without interfering with the specified format fields.
- Protected and discretionary regions can be found in the universal header, each section of the metadata files, and optionally in CMP block headers.

Encryption Level Schema

- The following table contains codes for encryption that are useful in processing as well as in file encoding.

Encryption Level Schema:

Value	Meaning
0	No encryption
1	Level 1 encrypted
-1	Level 1 encryption specified, currently decrypted
2	Level 2 encrypted
-2	Level 2 encryption specified, currently decrypted
-128	No entry

Universal Header

- Each file in the MED structure begins with a universal header
- The only current exception is video data files whose content is determined entirely by their specific video format (e.g. MPEG).
- The universal header is not encrypted.
- Design concepts:
    - Contains the minimum information required to read a file in the absence of any other files (e.g. indices or metadata). Appropriate interpretation of the data may still require metadata and passwords.
    - Contains the minimum information to uniquely identify a file, its place in a MED hierarchy, and its provenance.
    - Contains the minimum information required to detect file corruption.
    - Facilitates decryption of potentially encrypted information.
    - Fields whose values may change with each file write operation are clustered at the beginning of the universal header in the “Robust Mode Region”, so termed because if they are updated with every write (a choice which has its pros & cons), MED files are robust to catastrophic failure during file creation.

Universal Header:

Field	Offset	Bytes	Type	Contents
Robust Mode Region Start				
Header CRC	0	4	ui4	• CRC of the universal header after this field • 0 indicates no entry
Body CRC	4	4	ui4	• CRC of the entire file after the universal header • 0 indicates no entry
File End Time	8	8	si8	• File end time in offset μUTC format • If segment file, this is segment end time • 0x8000000000000000 indicates no entry • *In the ephemeral SESSION, CHANNEL, & SEGMENT library structures, this is the latest end time of all its contents*
Number of Entries	16	8	si8	• Number of entries in the file • See **Universal Header Number of Entries** table (below) for the specific meaning for each file type • -1 indicates no entry
Maximum Entry Size	24	4	ui4	• Maximum size of an entry in the file • See **Universal Header Number of Entries** table (below) for the specific meaning for each file type • 0 indicates no entry
Robust Mode Region End				
Segment Number	28	4	si4	• Number of the segment (if applicable) • Numbering starts at 1 • -1 indicates no entry • -2 indicates channel level • -3 indicates session level

Field	Offset	Bytes	Type	Contents
Type String or Type Code	32	5	ascii[4] or ui4	• 4 ascii characters of file name extension, null terminated or used as ui4 value • 0 (all zeros = zero-length string) indicates no entry • In the ephemeral SESSION & CHANNEL library structures, this is the directory type
MED Version Major	37	1	ui1	• numeric value: 1, currently • 0xFF indicates no entry
MED Version Minor	38	1	ui1	• numeric value: 0, currently • 0xFF indicates no entry
Byte Order Code	39	1	ui1	• 0 ==> big-endian • 1 ==> little-endian • 0xFF indicates no entry • *Only little-endian byte order is supported by the library at this time*
Session Start Time	40	8	si8	• Session start time in offset μUTC format • 0x8000000000000000 indicates no entry
File Start Time	48	8	si8	• File start time in offset μUTC format • If segment file, this is segment start time • 0x8000000000000000 indicates no entry • *In the ephemeral SESSION, CHANNEL, & SEGMENT library structures, this is the earliest start time of all its contents*
Session Name	56	256	utf8[63]	• Session name without path or extension • Zero-length string indicates no entry

Field	Offset	Bytes	Type	Contents
Channel Name	312	256	utf8[63]	• Channel name without path or extension • Zero-length string indicates no entry
Anonymized Subject ID	568	256	utf8[63]	• Anonymized subject ID • Anonymized name or number is typical • Zero-length string indicates no entry
Session UID	824	8	ui8	• Unique Identifying Number • 8 random bytes shared by all files in the session • zeros indicate no entry
Channel UID	832	8	ui8	• Unique Identifying Number • 8 random bytes shared by all files in the channel • zeros indicate no entry
Segment UID	840	8	ui8	• Unique Identifying Number • 8 random bytes shared by all files in the segment • zeros indicate no entry
File UID	848	8	ui8	• Unique Identifying Number • 8 random bytes unique to the current file • zeros indicate no entry
Provenance UID	856	8	ui8	• Unique Identifying Number • Typically **File UID** of originating file • Identity with current file **File UID** indicates that this is the originating file • zeros indicate no entry
Level 1 Password Validation Field	864	16	ui1[16]	• First 16 binary bytes of a SHA-256 hash of the Level 1 password • zeros indicate no entry

Field	Offset	Bytes	Type	Contents
Level 2 Password Validation Field	880	16	ui1[16]	• Exclusive-or of first 16 bytes of a SHA-256 hash of the Level 2 password with the unhashed Level 1 password • zeros indicate no entry
Level 3 Password Validation Field	896	16	ui1[16]	• Intended as ***optional*** password recovery mechanism (decided by file creator) • Allows extraction of Level 1 & Level 2 passwords, if specified • Level 3 is not a valid encryption level itself • Exclusive-or of first 16 bytes of a SHA-256 hash of the Level 3 password with the unhashed Level 1 or 2 password (if specified) • zeros indicate no entry
Protected Region	912	56		• Filled with zeros • Reserved for potential future use
Discretionary Region	968	56		• Filled with zeros if unused • Discretionary end-user use

Universal Header: Number of Entries

File Type	Extension(s)	*Number of Entries* Contents	*Maximum Entry Size* Contents
Record Data File	rdat	• Number of records in the file • -1 indicates no entry	• Number of **bytes** (including record header and pad bytes) in the largest record in the file • -1 indicates no entry
Record Indices File	ridx	• Number of records indices in the file (= number of records) • -1 indicates no entry	• Number of **bytes** in a record index (a constant) • -1 indicates no entry
Metadata Files	tmet vmet	1	• Number of **bytes** in a metadata file (a constant) • -1 indicates no entry
Time Series Data File	tdat	• Number of CMP blocks in the file • -1 indicates no entry	• Number of **bytes** in the largest CMP block in the file • -1 indicates no entry
Time Series Indices File	tidx	• Number of time series indices in the file, including (extra) terminal index • -1 indicates no entry	• Number of **bytes** in a time series index (a constant) • -1 indicates no entry
Video Indices File	vidx	• Number of video indices in the file(s), including (extra) terminal indices • -1 indicates no entry	• Number of **bytes** in a video index (a constant) • -1 indicates no entry
Ephemeral SESSION Metadata FPS		• Maximum number of Records/Record Indices in the Channel directories and Session level records • -1 indicates no entry • Note that the SESSION Universal Header structure is ephemeral (never written to disk)	• Maximum number of **bytes** in a Record in the Channel directories and Session level records • -1 indicates no entry • Note that the SESSION Universal Header structure is ephemeral (never written to disk)

File Type	Extension(s)	*Number of Entries* Contents	*Maximum Entry Size* Contents
Ephemeral CHANNEL Metadata FPS		• Maximum number of Records/Record Indices in the Segment directories and Channel level records • -1 indicates no entry • Note that the CHANNEL Universal Header structure is ephemeral (never written to disk)	• Maximum number of **bytes** in a Record in the Segment directories and Channel level records • -1 indicates no entry • Note that the CHANNEL Universal Header structure is ephemeral (never written to disk)

Metadata Files

- One for each channel segment in the MED hierarchy
- The metadata files share an identical format, but most section 2 fields are specific to the channel data type.
- Currently there are 2 types of metadata files specified: time-series and video. The first four fields of section 2 are common to all section 2 types: *Session Description, Channel Description, Segment Description, and Equipment Description.*
- Each type of metadata file has its own file type, which also serves as its file name extension.
- Ephemeral metadata files are not part of the stored MED file hierarchy, but are created while reading data. They contain summary metadata for the levels below them: an ephemeral channel metadata file is created to summarize the data in a selected set of segments it contains. Likewise an ephemeral session metadata file is created to summarize the data in a selected set of channels it contains. In the case of ephemeral *session* metadata files, one is created for each channel type in the session (e.g. time series, video)

Metadata Files:

Field	Offset	Bytes	Type	Contents	Encryption
Universal Header	0	1024		See “Universal Header” description	None
Section 1					
Level 1 Password Hint	1024	256	utf8[63]	• Zero-length string indicates no entry	Level 1 Password Hint
Level 2 Password Hint	1280	256	utf8[63]	• Zero-length string indicates no entry	Level 2 Password Hint
Section 2 Encryption Level	1536	1	si1	see Encryption Level Schema table	None
Section 3 Encryption Level	1537	1	si1	see Encryption Level Schema table	None
Protected Region	1538	254		• Filled with zeros • Reserved for potential future use	None
Discretionary Region	1792	256		• Filled with zeros if unused • Discretionary end-user use	None
Section 2 (technical data)					
Metadata Section 2 Channel Type Specific Fields	2048	10240		See channel type specific tables below	As specified in Section 1
Section 3 (subject specific data)					
Recording Time Offset	12288	8	si8	• Value to add to all μUTC times to adjust them to true UTC time • Zero indicates no entry	As specified in Section 1

Field	Offset	Bytes	Type	Contents	Encryption
Daylight Time Start Code	12296	8	*Daylight Time Change Code* (si1[8] / si8)	• See Daylight Time Change Code Table below • Zero in regions that do not observe DST • (si8) -1 indicates no entry • *Note that this code reflects the regional rules at the time of the recording only*	As specified in Section 1
Daylight Time End Code	12304	8	*Daylight Time Change Code* (si1[8] / si8)	• See Daylight Time Change Code Table below • Zero in regions that do not observe DST • (si8) -1 indicates no entry • *Note that this code reflects the regional rules at the time of the recording only*	As specified in Section 1
Standard Timezone Acronym	12312	8	ascii[7]	• Daylight Saving or Summer Time is not included in this acronym • e.g “MST” for United States Mountain Standard Time • Zero-length string indicates no entry	As specified in Section 1
Standard Timezone String	12320	64	ascii[63]	• Daylight Saving or Summer Time is not included in this string • e.g “Mountain Standard Time” for United States Mountain Standard Time • Zero-length string indicates no entry	As specified in Section 1

Field	Offset	Bytes	Type	Contents	Encryption
Daylight Timezone Acronym	12384	8	ascii[7]	• Daylight Saving or Summer Time version of the Standard Timezone Acronym • e.g “MDT” for United States Mountain Daylight Time • Zero-length string indicates no entry for regions that do not observe DST	As specified in Section 1
Daylight Timezone String	12392	64	ascii[63]	• Daylight Saving or Summer Time version of the Standard Timezone String • e.g “Mountain Daylight Time” for United States Mountain Daylight Time • Zero-length string indicates no entry for regions that do not observe DST	As specified in Section 1
Subject Name 1	12456	128	utf8[31]	• Typically subject first name • Zero-length string indicates no entry	As specified in Section 1
Subject Name 2	12584	128	utf8[31]	• Typically subject middle name • Zero-length string indicates no entry	As specified in Section 1
Subject Name 3	12712	128	utf8[31]	• Typically subject last name • Zero-length string indicates no entry	As specified in Section 1
Subject ID	12840	128	utf8[31]	• Subject ID • Zero-length string indicates no entry	As specified in Section 1

Field	Offset	Bytes	Type	Contents	Encryption
Recording Country	12968	256	utf8[63]	• Country in which the recording occurred • Zero-length string indicates no entry	As specified in Section 1
Recording Territory	13224	256	utf8[63]	• Territory, Province, State, etc. in which the recording occurred • Zero-length string indicates no entry	As specified in Section 1
Recording Locality	13480	256	utf8[63]	• City, Township, Village, etc. in which the recording occurred • Zero-length string indicates no entry	As specified in Section 1
Recording Institution	13736	256	utf8[63]	• Organization, Institution, etc. in which the recording occurred, or other description of where recording occurred • Zero-length string indicates no entry	As specified in Section 1
GeoTag Format	13992	32	ascii[31]	• GeoTag data format, e.g. “Exif”, “XMP”, “GeoSMS” • Zero-length string indicates no entry	As specified in Section 1
GeoTag Data	14024	1024	ascii[1023]	• GeoTag data • Zero-length string indicates no entry	As specified in Section 1

Field	Offset	Bytes	Type	Contents	Encryption
Standard UTC Offset	15048	4	si4	• File recording time zone *expressed in seconds* ahead or behind UTC (GMT), in **Standard Time** • Daylight Saving or Summer Time is not included in this field • Added to μUTCs to get local time of day. (e.g. example, 0 indicates GMT, -18000 [-5 * 60 * 60] indicates US Eastern Standard Time) • -86401 indicates no entry (-24 hours and 1 second behind UTC (GMT))	As specified in Section 1
Protected Region	15052	668		• Filled with zeros • Reserved for potential future use	As specified in Section 1
Discretionary Region	15720	664		• Filled with zeros if unused • Discretionary end-user use	As specified in Section 1

Daylight Time Change Code Table:

si1 Union Values		
Byte	Field	Values
0	Code Type	(DST end / DST Not Observed / DST start) == (-1 / 0 / +1)
1	Day of Week	(No Entry / [Sunday : Saturday]) == (-1 / [0 : 6]) *Unix time functions encode the days of the week in the range [0 : 6]*
2	Relative Weekday of Month	(No Entry / [First : Fifth] / Last) == (0 / [1 : 5] / 6)
3	Day of Month	(No Entry / [1 : 31]) == (0 / [1 : 31]) *Unix time functions encode the days of months in the range [1 : 31]*
4	Month	(No Entry / [January : December]) == (-1 / [0 : 11]) *Unix time functions encode months in the range [0 : 11]*
5	Hours of Day	[-128 : +127] hours relative to 0:00 (midnight)
6	Reference Time	(Local / UTC) == (0 / +1) *Any entry can be encoded in either, but local is usually more intuitive*
7	Shift Minutes	[-120 : +120] minutes *Typically +60 for DST start & -60 for DST end*
si8 Union Values		
0 indicates DST is not observed		
-1 indicates no entry		

Time Series Metadata Section 2:

Field	Offset	Bytes	Type	Contents	Encryption
Section 2 (technical data): Channel Type Independent Fields					
Session Description	2048	2048	utf8[511]	• Description of recording session • Zero-length string indicates no entry • Present in all section 2 metadata types	As specified in Section 1
Channel Description	4096	1024	utf8[255]	• Description of recording channel • Zero-length string indicates no entry • Present in all section 2 metadata types	As specified in Section 1
Segment Description	5120	1024	utf8[255]	• Description of recording segment • Zero-length string indicates no entry • Present in all section 2 metadata types	As specified in Section 1
Equipment Description	6144	2044	utf8[510]	• Description of recording equipment • Zero-length string indicates no entry • Present in all section 2 metadata types	As specified in Section 1
Acquisition Channel Number	8188	4	si4	• Number of the time series channel in the original recording • -1 indicates no entry • *Library default numbering is from 1, but zero-based or other numbering schemes may be used*	As specified in Section 1
Section 2 (technical data): Channel Type Specific Fields					

Field	Offset	Bytes	Type	Contents	Encryption
Reference Description	8192	1024	utf8[255]	• Description of recording reference channel • Zero-length string indicates no entry	As specified in Section 1
Sampling Frequency	9216	8	sf8	• Sampling frequency • -1.0 indicates no entry • This is the acquisition sampling frequency: individual blocks may be subsampled from this	As specified in Section 1
Low Frequency Filter Setting	9224	8	sf8	• High-pass filter setting, in Hertz • -1.0 indicates no entry	As specified in Section 1
High Frequency Filter Setting	9232	8	sf8	• Low-pass filter setting, in Hertz • -1.0 indicates no entry	As specified in Section 1
Notch Filter Frequency Setting	9240	8	sf8	• Notch filter setting, in Hertz • -1.0 indicates no entry	As specified in Section 1
AC Line Frequency	9248	8	sf8	• AC line frequency, in Hertz • -1.0 indicates no entry	As specified in Section 1
Amplitude Units Conversion Factor	9256	8	sf8	• Value to multiply sample values by to get native units (“Units Description” field) • 0.0 indicates no entry • Negative values indicate values are inverted	As specified in Section 1
Amplitude Units Description	9264	128	utf8[31]	• String describing units (e.g. “microvolts”) • Zero-length string indicates no entry	As specified in Section 1

Field	Offset	Bytes	Type	Contents	Encryption
Time Base Units Conversion Factor	9392	8	sf8	• Value to multiply time values by to get μUTC time • 0.0 indicates no entry • Allows format to accommodate time bases coarser or finer than microseconds	As specified in Section 1
Time Base Units Description	9400	128	utf8[31]	• String describing time base units (e.g. "μUTC") • Zero-length string indicates no entry	As specified in Section 1
Absolute Start Sample Number	9528	8	si8	• Number of the first sample in the CMP block data relative to all samples in the channel (*not the segment*) • The number of the first sample number in *first* segment is zero • 0x8000000000000000 indicates no entry	As specified in Section 1
Number of Samples	9536	8	si8	• Total recorded samples in the segment • -1 indicates no entry	As specified in Section 1
Number of Blocks	9544	8	si8	• Total recorded CMP blocks in the file • -1 indicates no entry • Duplicated in Universal Header of Time Series Indices and Data Files	As specified in Section 1
Maximum Block Bytes	9552	8	si8	• Maximum bytes, including header & pad bytes, in any CMP block in the file • -1 indicates no entry	As specified in Section 1

Field	Offset	Bytes	Type	Contents	Encryption
Maximum Block Samples	9560	4	ui4	• Maximum number of samples in a CMP block • 0xFFFFFFFF indicates no entry • Duplicated (as an si8) in Universal Header of Time Series Data Files	As specified in Section 1
Maximum Block Difference Bytes	9564	4	ui4	• Maximum bytes required for the difference data in the compressed blocks • 0xFFFFFFFF indicates no entry	As specified in Section 1
Maximum Block Duration	9568	8	sf8	• Duration of CMP blocks (*intended*) • Units described in Time Base Units Description (default units are microseconds) • -1.0 indicates no entry • -2.0 indicates variable block durations (*intentional, not due to discontinuities*)	As specified in Section 1
Number of Discontinuities	9576	8	si8	• Number of discontinuities in the segment • Does not includes first and last sample is a discontinuity indices (which are required, but not true discontinuities) • -1 indicates no entry	As specified in Section 1
Maximum Contiguous Blocks	9584	8	si8	• Maximum number of contiguous CMP blocks between discontinuities in the segment • -1 indicates no entry	As specified in Section 1

Field	Offset	Bytes	Type	Contents	Encryption
Maximum Contiguous Block Bytes	9592	8	si8	• Maximum number of contiguous compressed bytes between discontinuities in the segment (including block headers and pad bytes) • -1 indicates no entry	As specified in Section 1
Maximum Contiguous Samples	9600	8	si8	• Maximum number of contiguous samples between discontinuities • -1 indicates no entry	As specified in Section 1
Protected Region	9608	1344		• Filled with zeros • Reserved for potential future use	As specified in Section 1
Discretionary Region	10952	1336		• Filled with zeros if unused • Discretionary end-user use	As specified in Section 1

Video Metadata Section 2

Field	Offset	Bytes	Type	Contents	Encryption
Section 2 (technical data): Channel Type Independent Fields					
Session Description	2048	2048	utf8[511]	• Description of recording session • Zero-length string indicates no entry • Present in all section 2 types	As specified in Section 1
Channel Description	4096	1024	utf8[255]	• Description of the video stream • Zero-length string indicates no entry • Present in all section 2 types	As specified in Section 1
Segment Description	5120	1024	utf8[255]	• Description of the segment of the video stream • Zero-length string indicates no entry • Present in all section 2 types	As specified in Section 1
Equipment Description	6144	2044	utf8[510]	• Description of recording equipment • Zero-length string indicates no entry • Present in all section 2 metadata types	As specified in Section 1
Acquisition Channel Number	8188	4	si4	• Number of the video channel in the original recording • -1 indicates no entry • *Library default numbering is from 1, but zero-based or other numbering schemes may be used*	As specified in Section 1
Section 2 (technical data): Channel Type Specific Fields					

Field	Offset	Bytes	Type	Contents	Encryption
Horizontal Resolution	8192	8	si8	• Horizontal pixels • -1 indicates no entry	As specified in Section 1
Vertical Resolution	8200	8	si8	• Vertical pixels • -1 indicates no entry	As specified in Section 1
Frame Rate	8208	8	sf8	• Frames per second • -1.0 indicates no entry or variable frame rate	As specified in Section 1
Number of Clips	8216	8	si8	• Number of clips (= video non-discontinuity indices) in the video index file • -1 indicates no entry	As specified in Section 1
Maximum Clip Bytes	8224	8	si8	• Maximum bytes in a clip in the video file • -1 indicates no entry	As specified in Section 1
Video Format	8232	256	utf8[63]	• e.g. “MPEG-4” • Zero-length string indicates no entry	As specified in Section 1
Number of Video Files	8488	4	si4	• Number of video files in the segment • -1 indicates no entry	As specified in Section 1
Protected Region	8492	1900		• Filled with zeros • Reserved for potential future use	As specified in Section 1
Discretionary Region	10392	1896		• Filled with zeros if unused • Discretionary end-user use	As specified in Section 1

Records Data File

- Binary format described below
- Can be present at any level of the MED hierarchy, but is never required.

- Session Records can be segmented, and if they exist, are stored in the ".recd" directory at the Session level of the file hierarchy. Segmented Session Records do no preclude the existence of unsegmented session records: either, both, or neither can exist.
- If a Records Data File is present, a Records Index File must also be present, and vice versa.
- Each record begins with a record header
- Example record types include:
    - Electrode & probe descriptions
    - Electrode coordinates
    - Electrode diagrams
    - Spike records
    - Seizure marks
    - Event related study data
    - Sleep stage / behavioral state
    - Miscellaneous notes
    - Acquisition system log entries
    - Acquisition system configuration
    - End-user defined record types
- Records can also be compressed, but the specific compression algorithm (e.g. jpeg, png, bzip) should be defined in the record description documentation.
- The length of the body of each record must be padded to a multiple of 16 for encryption. The pad-byte value is 0xFE (ascii tilde, "~").

Records Data File:

Field	Offset	Bytes	Contents
Universal Header	0	1536	*See "Universal Header" description*
Records	1536		*See "Record Header Format" description*
…			

Record Header Format:

Field	Offset	Bytes	Type	Contents	Encryption
Record CRC	0	4	ui4	• Cyclically Redundant Checksum for record and remainder of Record Header • 0 indicates no entry	None
Total Bytes	4	4	ui4	• Record size in bytes, including record header and pad bytes if any. • 0 indicates no entry	None
Start Time	8	8	si8	• Record time in μUTC time format. • If recording time offset is used for the session it is applied here also. • 0x8000000000000000 indicates no entry	None
Type String or Type Code	16	5	ascii[4] or ui4	• 4 byte integer, typically representing 4 ascii characters, designating record type, null terminated, or used as ui4 value • 0 (all zeros = zero-length string) indicates no entry	None
Record Version Major	21	1	ui1	• Record type's major version • 0xFF indicates no entry	None
Record Version Minor	22	1	ui1	• Record type's minor version • 0xFF indicates no entry	None
Encryption Level	23	1	si1	• Changes sign when record is encrypted / decrypted • See "Encryption Level Schema" table	None

Record Indices File Format

- Universal header
- Sequential record index data
- 8-byte boundary aligned

Record Indices File:

Field	Offset	Bytes	Contents
Universal Header	0	1536	*See “Universal Header” description*
Record Index	1536	24	*See “Record Index Format” description*
…			

Record Index Format:

Field	Offset	Bytes	Type	Contents
File Offset	0	8	si8	• Record start file offset in bytes. • -1 indicates no entry • There is one terminal record index with **File Offset** equal to the record data file length
Start Time	8	8	si8	• Record time in μUTC time format. • If recording time offset is used for the session it is applied here also. • 0x8000000000000000 indicates no entry • There is one terminal record index with **Start Time** equal to the *segment* end μUTC + 1
Type String or Type Code	16	5	ascii[4] or ui4	• 4 byte integer, typically representing 4 ascii characters, designating record type, null terminated, or used as ui4 value • 0 (all zeros = zero-length string) indicates no entry • The **Type String / Type Code** is 0 (all zeros = zero-length string) in the terminal record index
Record Version Major	21	1	ui1	• Record type's major version • 0xFF indicates no entry • The **Version Major** is 0xFF in the terminal record index
Record Version Minor	22	1	ui1	• Record type's minor version • 0xFF indicates no entry • The **Version Minor** is 0xFF in the terminal record index

Field	Offset	Bytes	Type	Contents
Encryption Level	23	1	si1	• Does ***not*** change sign when corresponding record is encrypted / decrypted • See “Encryption Level Schema” table • The **Encryption Level** is 0 in the terminal record index

Segment (Sgmt) Records:

These records are not required, but are convenient when stored at the session or channel levels. They document segment start & end times and descriptions. Specifically they contain the following fields:

```
———————— Record Header START ————————
CRC:
Type Code/String: Sgmt
Version:
Encryption Level:
Total Bytes:
Start Time:
————————— Record Header END —————————
————————— Record Body START —————————
End Time:
Absolute Start Sample Number (or Frame Number):
Absolute End Sample Number (or Frame Number):
Segment UID:
Segment Number:
Acquisition Channel Number: (or REC_Sgmt_v10_CHANNEL_NUMBER_ALL_CHANNELS_m10)
Sampling Frequency:
Segment Description:
————————— Record Body END ——————————
```

They are useful (but not required) for finding a segment or range of segments based on time, or description. For example a segment may often be created within a longer continuous recording for the purpose of delimiting an experiment or other condition. Sgmt records stored in (non-segmented) ***session*** records are useful for this purpose. Sgmt records stored at the ***channel*** level make processing individual, or sharing subsets of channels, without session data simpler for finding segments of interest. Sgmt records at the channel level are also appropriate when segment breaks between channels are not temporally aligned. Because they are small and generally infrequent, they are often stored at both session & channel levels.

Sgmt records are of little utility in Segmented Session Records. If Segmented Session Records are implemented and Sgmt records are desired, Sgmt records should be kept in ***parallel*** non-segmented Session Records. This is the most efficient arrangement for long recordings with many segments and records.

Time Series Indices File Format

- Universal header
- Sequential time series index data
- The first sample in a recording is considered a discontinuity (but not necessarily a segment)
- The last index in each segment points to a virtual, non-existent block where:
    - File Offset = Time Series data file length
    - Start Time = estimated μUTC of the next sample (or segment end μUTC + 1)
    - Start Sample Number = number of samples in segment

Time Series Indices File:

Field	Offset	Bytes	Contents
Universal Header	0	1536	*See "Universal Header" description*
Time Series Index	1536	24	*See "Time Series Index Format" description*
...			

Time Series Index Format:

Field	Offset	Bytes	Type	Contents
File Offset	0	8	si8	• Offset to the beginning of the indexed CMP Block in the time series data file (in bytes). • Negative **File Offsets** indicate that the sample comes after a discontinuity. The file offset is the positive of this value. • The first sample in a *Channel (*but not necessarily a *Segment*) is always considered a discontinuity. • There is one terminal time series index with **File Offset** equal to the time series data file length
Start Time	8	8	si8	• *μ*UTC time of block start • If recording time offset is used for the session it is applied here also. • 0x8000000000000000 indicates no entry • There is one terminal time series index with **Start Time** equal to the estimated *μ*UTC of the next sample, assuming no discontinuity (or segment end *μ*UTC + 1)
Start Sample Number	16	8	si8	• Number of the first sample in the CMP Block relative to samples in the segment (*not the channel*). • 0x8000000000000000 indicates no entry • There is one terminal time series index with **Start Sample Number** equal to total segment samples

Video Indices File Format

- Universal header
- Sequential video index data
- The first frame in a recording is considered a discontinuity

- Frame numbering starts at zero for each segment, *but continues across video data file boundaries within a segment.*
- The last index in each segment points to a virtual, non-existent clip where:
    - File Offset = Video data file length
    - Start Time = estimated μUTC of the next frame (or segment end μUTC + 1)
    - Start Frame Number = number of frames in segment
    - Video File Number = -1 (no entry)

Video Indices File:

Field	Offset	Bytes	Type	Contents
Universal Header	0	1536		*See "Universal Header" description*
Video Index	1536	24		*See "Video Index Format" description*
...				

Video Index Format:

Field	Offset	Bytes	Type	Contents
File Offset	0	8	si8	• File offset to the start frame, typically a keyframe, depending on format • Negative **File Offsets** indicate that the frame comes after a discontinuity. The file offset is the positive of this value. • The first frame in a *Channel (*but not necessarily a *Segment*) is always considered a discontinuity. • There is one terminal video index with **File Offset** equal to the video data file length
Start Time	8	8	si8	• μUTC time of first frame in clip. • If recording time offset is used for the session it is applied here also. • 0x8000000000000000 indicates no entry • There is one terminal video index with **Start Time** equal to the estimated μUTC of the next frame, assuming no discontinuity (or segment end μUTC + 1)
Start Frame Number	16	4	si4	• Number of the first frame in the clip in this video file • The first frame in a file is always indexed • Frame numbering starts at zero *for the first video file in a segment;* • 0x80000000 indicates no entry • There is one terminal video index with **Start Frame Number** equal to total frames in the segment
Video File Number	20	4	si4	• Number of the video file within the segment • Combined with Segment Number and Base File Name to create the full file name of each video file • Numbering starts at one, *not zero* • -1 indicates no entry • There is one terminal video index with **Video File Number** equal to -1

Time Series Data File Format

- Universal header
- Sequential CMP blocks
- Each block is 8-byte boundary aligned

Time Series Data Encryption

- Optionally the time series data can be encrypted with either Level 1 or 2 encryption
- The encryption uses AES-128 to encrypt the first 16 (typically most significant) bytes of the statistical model in each CMP compressed block.
- Encryption / decryption adds negligible time to data processing.

Time Series Data File:

Field	Offset	Bytes	Type	Contents
Universal Header	0	1536		See “Universal Header” description
CMP Block	1536	varies		See “CMP Block Format” description
...				

CMP Blocks

- Data are stored in compressed independent blocks.
- Blocks are structured in the following hierarchy:
  - Block Header
    - Fixed Region: *always present*, cast into CMP_BLOCK_FIXED_HEADER_m10 structure
    - Variable Region: *sometimes present*, depending on user choices
      - Records Region: user defined records

        - Parameter Region: up to 32 4-byte parameters
        - Protected Region: unstructured space for future MED development
        - Discretionary Region: unstructured space for file creator user
      - Model Region: *always present*, contains details required by codecs
    - Compressed Data
- In RED/PRED, raw data are differenced. Differences are encoded in a single signed byte. If there is overflow, i.e > +127 or < -127, then a keysample is introduced, flagged by the reserved value -128 (0x80). The 4 bytes following the keysample flag contain the full undifferenced value of the (second) data point generating the overflow difference, as an si4.
- In RED/PRED, the differenced data are statistically modeled, the model is stored in the CMP block header. RED generates 1 model; PRED generates 3 models.
- In RED/PRED, Range Encoding is used to compress the differences, using the statistical model(s).
- In MBE, the minimal bits required to encode all the samples in the block are encoded from the raw data.
- Blocks are required to be 8-byte boundary aligned, and are terminally padded to an 8-byte boundary with the value 0x7E (tilde, "~") as necessary. Pad bytes are included in the block bytes value, and in the block CRC.
- In compression, if the CMP_PROCESSING_DIRECTIVE detrend_data is set, each sample will be detrended prior to scaling and compressing. The gradient and intercept will be stored in the block header. This is a lossless operation, but has more utility in lossy compression.
- In compression, if the Amplitude Scale parameter flag bit is set, the (possibly offset) values will be divided by this value and rounded, prior to differencing. This is a lossy operation.
- In decompression, if the Amplitude Scale parameter flag bit is set, the values of the samples will be multiplied by this value and rounded after un-differencing.
- In compression, if the Frequency Scale parameter flag bit is set, the (possibly offset) values will be downsampled by this value, prior to differencing. This is a lossy operation.
- In decompression, if the Frequency Scale parameter flag bit is set, the values of the samples will be upsampled after un-differencing.
- In decompression, if the Gradient and Intercept parameter flag bits are set, data will be retrended after un-differencing and possibly scaling.

CMP Block Layout:

<table>
<tr><td colspan="2">CMP Block Header: Fixed Region</td></tr>
<tr><td rowspan="4">CMP Block Header: Variable Region</td><td>Records Region</td></tr>
<tr><td>Parameter Region</td></tr>
<tr><td>Protected Region</td></tr>
<tr><td>Discretionary Region</td></tr>
<tr><td colspan="2">CMP Block Header: Model Region</td></tr>
<tr><td colspan="2">CMP Block Compressed Data</td></tr>
</table>

CMP Block Format:

Field	Offset	Bytes	Type	Contents
CMP Block Header: Fixed Region Start				
Block Start UID	0	8	ui8	• Fixed value • Hexadecimal: 0x0123456789ABCDEF • Decimal: 81,985,529,216,486,895
Block CRC	8	4	ui4	• CRC of the remainder of block • If block encryption is used, it is performed before the CRC is calculated • 0 indicates no entry
Block Flags	12	4	ui4	• See CMP Block Flags table below • 0 indicates no entry
Start Time	16	8	si8	• μUTC time • If recording time offset is used for the session it is applied here also • 0x8000000000000000 indicates no entry
Acquisition Channel Number	24	4	si4	• Number of the channel in the original recording • -1 indicates no entry • Duplicated in Time Series Metadata

Field	Offset	Bytes	Type	Contents
Total Block Bytes	28	4	ui4	• Number of bytes in the compressed block including header and pad (boundary alignment) bytes • 0 indicates no entry
CMP Block Encryption Start • Block encryption is optional: specified in Block Flags • In RED/PRED encoding 16 byte blocks are encoded sequentially from here until a minimum of 16 bytes of compressed data have been encrypted (see below) • In rare cases there may be insufficient compressed data bytes to fulfill this requirement. In these cases encryption stops at the closest 16 byte to the end of the block (including pad bytes). • In MBE encoding the entire block is encrypted to the last 16 byte boundary to the end of the block (including pad bytes)				
Number of Samples	32	4	ui4	• Number of data samples encoded in the block • 0xFFFFFFFF indicates no entry
Number of Records	36	2	ui2	• Number of records stored in the records region • Equals bits set in Parameter Flags • 0xFFFF indicates no entry
Record Region Bytes	38	2	ui2	• Number of records region bytes in the block • Range 0-65532 • Must be a multiple of 8
Parameter Flags	40	4	ui4	• See CMP Parameter Flags table below • Each bit corresponds to a 4-byte entry in the parameters region
Parameter Region Bytes	44	2	ui2	• Number of parameter region bytes in the block • Range 0-65532 • Must be a multiple of 4
Protected Region Bytes	46	2	ui2	• Number of protected region bytes in the block • Range 0-65532 • Must be a multiple of 4

Field	Offset	Bytes	Type	Contents
Discretionary Region Bytes	48	2	ui2	• Number of discretionary region bytes in the block • Range 0-65532 • Must be a multiple of 4
Model Region Bytes	50	2	ui2	• Number of compression model bytes in the block • Range 0-65535 • The model region is guaranteed to start on a 4-byte memory boundary
Total Header Bytes	52	4	ui4	• Number of bytes in the block header including fixed header, record, parameters, protected, discretionary, and model region bytes • 0 indicates no entry
CMP Block Header: Variable Region Start				

Record Region	56	Multiple of 8 bytes		• Must be a multiple of 8 bytes long
				• CMP Record Region Header:
				  • Bytes 0 - 3: record type code
				  • Byte 4 (ui1): record version major
				  • Byte 5 (ui1): record version minor
				  • Bytes 6-7 (ui2): record size

Parameter Region	*varies*	Multiple of 4 bytes		• 4-bytes for each parameter bit set • Accessed via parameter map in CPS • Contains reserved discretionary parameters
Protected Region	*varies*	Multiple of 4 bytes		• Reserved for future use • Must be a multiple of 4 bytes long • No required format
Discretionary Region	*varies*	Multiple of 4 bytes		• Discretionary end-user use • Must be a multiple of 4 bytes long • No required format
CMP Block Header: Model Region Start				

Field	Offset	Bytes	Type	Contents
Model Region	*varies*	*varies*		• See CMP Block Models Table • Model Region is considered part of the header, but not part of the variable region
Compressed Data				
Compressed Data	*varies*	*varies*	ui1	• Compressed data • A minimum of 16 bytes of compressed data will be encrypted if block encryption is performed (unless not available: see note with **Block Encryption Start** above
Alignment Bytes				
Pad Bytes	*varies*	*varies*	ui1	• 0-7 bytes as needed for 8-byte alignment • Value: 0xFE (ascii tilde, “~”)

CMP Block Flags:

Field	Name	Contents
General CMP Flags		
Bit 0	Discontinuity Bit	• 0 indicates no discontinuity • 1 indicates that this block began after a discontinuity in recording. • The first block in a file is always considered a discontinuity.
Bits 1 to 3	Protected Bits	• Reserved for potential future use
Bit 4	Level 1 Encryption Bit	• 0 indicates the block is not currently level 1 encrypted. • 1 indicates the block is currently level 1 encrypted. • The desired encryption level is set by the “encryption” field in the CMP_PROCESSING_DIRECTIVES. • This bit is mutually exclusive with “Level 2 Encrypted Block Bit” (bit 5)

Field	Name	Contents
Bit 5	Level 2 Encryption Bit	• 0 indicates the block is not currently level 2 encrypted. • 1 indicates the block is currently level 2 encrypted. • The encryption level desired is set by the “encryption” field in the RED_PROCESSING_DIRECTIVES. • This bit is mutually exclusive with “Level 1 Encrypted Block Bit” (bit 1)
Bits 6 to 7	Protected Bits	• Reserved for potential future use
Bit 8	RED Encoding Bit	• 0 indicates the block is not RED encoded • 1 indicates the block is RED encoded • This bit is mutually exclusive with “Predictive RED Encoding Bit” (bit 4) and “MBE Encoding Bit” (bit 5)
Bit 9	PRED Encoding Bit	• 0 indicates the block is not PRED encoded • 1 indicates the block is PRED encoded • This bit is mutually exclusive with “RED Encoding Bit” (bit 3) and “MBE Encoding Bit” (bit 5)
Bit 10	MBE Encoding Bit	• 0 indicates the block is not MBE encoded • 1 indicates the block is MBE encoded • This bit is mutually exclusive with “RED Encoding Bit” (bit 3) and “Predictive RED Encoding Bit” (bit 4)
Bits 11 to 23	Protected Bits	• Reserved for potential future use
Bits 24 to 31	Discretionary Bits	• Reserved for end-user use

CMP Parameter Flags:

Field	Name	Contents
Bit 0	Intercept Bit	• 0 indicates the block data was not offset prior to compression • 1 indicates the block data was offset prior to compression and the intercept value is stored in the Block Parameters Region • If this bit is set, this value will be subtracted from the data before compression and added back during decompression • This is used in conjunction with the Gradient bit • Ordinate intercept of the block's first order trend line (fit using least absolute deviations) • Units Conversion Factor is not applied to this number • This operation is **not** inherently lossy
Bit 1	Gradient Bit	• 0 indicates the block data was not offset prior to compression • 1 indicates the block data was offset prior to compression and the gradient value is stored in the Block Parameters Region • If this bit is set, this gradient will be subtracted from the data before compression and added back during decompression • This is used in conjunction with the Intercept bit • Slope of the block's first order trend line (fit using least absolute deviations) • Units Conversion Factor is not applied to this number • This operation is **not** inherently lossy
Bit 2	Amplitude Scale Bit	• 0 indicates the block amplitude was not scaled prior to compression • 1 indicates the block data was amplitude scaled prior to compression and the scale value is stored in the Block Parameters Region • If this bit is set, data is divided by the scale factor during compression and multiplied by it during decompression • This operation is inherently lossy

Field	Name	Contents
Bit 3	Frequency Scale Bit	• 0 indicates the block amplitude was not scaled prior to compression • 1 indicates the block data was amplitude scaled prior to compression and the scale value is stored in the Block Parameters Region • If this bit is set, data is divided by the scale factor during compression and multiplied by it during decompression • This operation is inherently lossy

Bit 4	Noise Scores	• Scores range 0-255:
		  • ui1s (1 byte each)
		  • 0 - 245 lowest to highest noise
		  • 255 denotes no entry
		• Four scores:
		  • Byte 0: Line Noise score
		  • Byte 1: Entropy score
		  • Byte 2: Normality score (Kolmogorov Smirnov)
		  • Byte 3: Local Linear Prediction score
		• Noise scores are calculated on the data that will be decoded, so if lossy encoding is used, the scores are calculated on the lossy data.

Bits 5 to 15	Protected Bits	• Reserved for potential future parameters
Bits 16 to 31	Discretionary Bits	• Reserved for end-user parameters

CMP Parameter Flags Usage:

The existence of a block parameter is indicated by a bit being set in the block parameter flags. If a bit is set, 4 bytes of space will be allocated in the parameter region for that value. If any parameters exist, a parameter map will be created in the CMP_processing_struct.

Access a block parameter as in the following examples:

```
//  get block parameters pointer
CMP_BLOCK_FIXED_HEADER_m10       *bh;
ui4                              *params;
```

```
ui1                             *param_map;

bh = cps->block_header;
params = cps->parameters.block_parameters;
param_map = cps->parameters.block_parameter_map;

// get value (values are considered ui4s, so cast may be required)
intercept_value = *((si4 *) params + param_map[CMP_PM_INTERCEPT_INDEX_m10]);


Where:
// Note: “CMP_PM_” prefix denotes CMP “parameter map”
CMP_PM_INTERCEPT_IDX_m10 = 0;
param_map[CMP_PM_INTERCEPT_IDX_m10] = 0

If, for example, the data is not detrended, but is amplitude scaled, the amplitude
scale bit will be the first bit set. The map will function as follows:

sf4    amplitude_scale;

amplitude_scale = *((sf4 *) params + param_map[CMP_PM_AMPLITUDE_SCALE_IDX_m10]);

Where:

CMP_PM_AMPLITUDE_SCALE_IDX_m10 = 2;
param_map[CMP_PM_AMPLITUDE_SCALE_IDX_m10] = 0
```

To write a custom parameter (bits 16-31):

```
si4    PM_CUSTOM_PARAM_IDX = 16;
sf4    custom_value = 1.61803;

// set the parameter bit (before calling CMP_encode_m10())
cps->parameters.discretionary_parameter_flags |= (1 << PM_CUSTOM_PARAM_INDEX);

// generate parameter map (encode)
CMP_encode_m10();   // CMP_encode_m10(); automatically creates parameter map if any
                    // parameter bit is set by calling
                    // CMP_generate_parameter_map_m10(). If you call this yourself,
                    // realize that no further bits can be set, and the built-in bits
                    // are set by CMP_encode, depending on directives.

// set the value (parameters are considered ui4s, so we cast)
params[param_map[PM_CUSTOM_PARAM_INDEX]] = *((ui4 *) &custom_value);
```

To read a custom parameter (bits 16-31):

```
// generate parameter map (decode)
CMP_decode_m10();   // CMP_decode_m10(); automatically creates parameter map if any
                    // parameter bit is set in the block by calling
                    // CMP_generate_parameter_map_m10(). You can also call this
```

```
                    // yourself

// get the value (parameters are considered ui4s, we have to cast to sf4)
custom_value = *((sf4 *) params + param_map[PM_CUSTOM_PARAM_INDEX]);
```

CMP Records Region Usage:

The records region exists to store record structures in the CMP block header. Typically these structures will contain information about the block data, but can contain anything. Block records are very similar to MED records with the following differences:

- The record header is defined by CMP_RECORD_HEADER_m10 instead of RECORD_HEADER_m10. It is 8 bytes vs. 24 bytes (because the CMP_FIXED_BLOCK_HEADER_m10 contains the other relevant information)
- The CMP_RECORD_HEADER_m10 and RECORD_HEADER_m10 structures are very similar, *but not identical*:
  - Bytes 0 - 3 (ui4): record type code *(not null-terminated string)*
  - Byte 4 (ui1): record version major
  - Byte 5 (ui1): record version minor
  - Byte 6-7 (ui2): record size: *Maximum of 65535 bytes.*
  - Bytes 8 to end: content of entry plus pad bytes, if needed
- The body alignment requirement is 8 byte instead of 16 byte (because if encryption is desired, block encryption can be selected)
- Any standard MED record body can be used as a block record, but not vice-versa (i.e. if the body is 8-byte aligned, but not 16-byte aligned)
- Example: a MED “Stat” record could be included to store statistics for every block
- CMP record structures are define in medrec.c & medrec.h with the standard MED records

CMP Block Models:

Range Encoded Differences (RED)				
Initial Sample Value	*0*	4	si4	• Value of the first sample in the block
Difference Bytes	*4*	4	ui4	• The number of difference bytes in the encoded block • 0 indicates no entry

Derivative Level	*8*	1	ui1	• The number of derivatives employed in encoding the data • If greater than 1, the first byte of the compressed data is the initial value of the next lower derivative, recursively • 1 is default • 0 indicates no entry
No Zero Counts Flag	*9*	1	ui1	• 1 indicates encoding using No Zero Counts directive • 0 indicates **not** encoded using No Zero Counts directive
Number of Statistics Bins	*10*	2	ui2	• Number of statistics entries • Range 0-256 • Zero-count bins are not encoded
End RED Model Fixed Region (12 bytes)				
Statistics Bin Counts	*varies*	*varies*	ui2[*bins*]	• Statistical model of difference values for the block • There are no entries for zero count bins
Statistics Bin Values	*varies*	*varies*	ui1[*bins*]	• The difference values corresponding to the counts bins • There are no entries for zero count bins
Predictive RED (PRED)				
Initial Sample Value	*0*	4	si4	• Value of the first sample in the block
Difference Bytes	*4*	4	ui4	• The number of difference bytes in the encoded block • 0 indicates no entry
Derivative Level	*8*	1	ui1	• The number of derivatives employed in encoding the data • If greater than 1, the first byte of the compressed data is the initial value of the next lower derivative, recursively • 1 is default • 0 indicates no entry

No Zero Counts Flag	*9*	1	ui1	• 1 indicates encoding using No Zero Counts directive • 0 indicates **not** encoded using No Zero Counts directive
Number of NIL Statistics Bins	*10*	2	ui2	• Number of statistics entries • Range 0-256 • Zero-count bins are not encoded
Number of POS Statistics Bins	*12*	2	ui2	• Number of statistics entries • Range 0-256 • Zero-count bins are not encoded
Number of NEG Statistics Bins	*14*	2	ui2	• Number of statistics entries • Range 0-256 • Zero-count bins are not encoded
End PRED Model Fixed Region (16 bytes)				
NIL Statistics Bin Counts	*varies*	*varies*	ui2 [NIL *bins*]	• NIL statistical model of difference values for the block • There are no entries for zero count bins
POS Statistics Bin Counts	*varies*	*varies*	ui2 [POS *bins*]	• POS statistical model of difference values for the block • There are no entries for zero count bins
NEG Statistics Bin Counts	*varies*	*varies*	ui2 [NEG *bins*]	• NEG statistical model of difference values for the block • There are no entries for zero count bins
NIL Statistics Bin Values	*varies*	*varies*	ui1 [NIL *bins*]	• The difference values corresponding to the NIL counts bins • There are no entries for zero count bins
POS Statistics Bin Values	*varies*	*varies*	ui1 [POS *bins*]	• The difference values corresponding to the POS counts bins • There are no entries for zero count bins
NEG Statistics Bin Values	*varies*	*varies*	ui1 [NEG *bins*]	• The difference values corresponding to the NEG counts bins • There are no entries for zero count bins

Minimal Bit Encoding (MBE)				
Minimum Sample Value	*0*	4	si4	• Minimum value of the samples in the block
Bits per Sample	*4*	1	ui1	• The number of bits employed in encoding each sample of the data • 0 indicates no entry
End MBE Model Fixed Region (5 bytes)				