

MED 1.0

C Library API

The MED library is evolved and renamed from the Multiscale Electrophysiology Format (MEF), versions 1-3. The library is open source, and curated by Dark Horse Neuro, Inc. (DHN). Source code is available through the medformat.org website. The layout of the format is described in “MED 1.0 Records Specification”

The MED 1.0 C library is composed of four files:

- medlib_m10.c
- medlib_m10.h
- medrec_m10.c
- medrec_m10.h

The “_m10” suffix denotes “MED 1.0” and is found on all functions and defines in the library. Future library versions will change this suffix accordingly, allowing for easy concurrent use of two library versions, such as in version converters.

The medlib_m10 files contain library functions that are not intended for user manipulation except in collaboration with DHN to maintain library uniformity. In contrast, the medrec_m10 files are designed to allow user addition of custom record types. Generally useful record types that are shared with DHN will be permanently incorporated into this code. The functions required for adding new record types are described in “MED 1.0 Records Specification”

```

/*****
/***** Elemental Typedefs *****/
/*****/

typedef char          si1;
typedef unsigned char ui1;
typedef short         si2;
typedef unsigned short ui2;
typedef int           si4;
typedef unsigned int  ui4;
typedef long int      si8;
typedef long unsigned int ui8;
typedef float         sf4;
typedef double        sf8;
typedef long double   sf16; // NOTE: it may require an explicit compiler instruction
                           // to implement true long floating point math.
                           // In icc the instruction is:
                           // “-Qoption,cpp,-extended_float_types”

```

These typedefs are used throughout the library to facilitate compilation on systems with different word sizes.

The first character indicates signedness, “s” for signed, “u” for unsigned.

The second character indicates format: “i” for integer type, “f” for floating point type.

The final number indicates the number of bytes in the type, 1, 2, 4, 8, or 16

example: “si4” indicates a signed integer of 4 byte length

```

/*****
/***** MED “Boolean” Schema *****/
/*****/

typedef si1          TERN_m10;    // ternary “Boolean” type
#define TRUE_m10      1
#define UNKNOWN_m10   0
#define FALSE_m10     -1

```

A balanced ternary schema including true, unknown, & false states. This is used throughout the library, and is typically represented by an si1 type, typedef'd to TERN_m10.

```

/*****
/***** MED Globals *****/
/*****/

// Structures
typedef struct {
    // Common MED Structures
    PASSWORD_DATA_m10        password_data;
    // Time Constants
    si8                      recording_time_offset;
    si4                      standard_UTC_offset;
    si1                      standard_timezone_acronym[TIMEZONE_ACRONYM_BYTES_m10];
    si1                      standard_timezone_string[TIMEZONE_STRING_BYTES_m10];
    TERN_m10                 observe_DST;
    TERN_m10                 RTO_known;
    si1                      daylight_timezone_acronym[TIMEZONE_ACRONYM_BYTES_m10];
    si1                      daylight_timezone_string[TIMEZONE_STRING_BYTES_m10];
    DAYLIGHT_TIME_CHANGE_CODE_m10 daylight_time_start_code; // si1[8] / si8
    DAYLIGHT_TIME_CHANGE_CODE_m10 daylight_time_end_code;   // si1[8] / si8
    TIMEZONE_INFO_m10        *timezone_table;
    ui4                      recording_time_offset_mode;
    // Alignment Fields
    TERN_m10                 universal_header_aligned;
    TERN_m10                 metadata_section_1_aligned;
    TERN_m10                 time_series_metadata_section_2_aligned;
    TERN_m10                 video_metadata_section_2_aligned;
    TERN_m10                 metadata_section_3_aligned;
    TERN_m10                 all_metadata_structures_aligned;
    TERN_m10                 time_series_indices_aligned;
    TERN_m10                 video_indices_aligned;
    TERN_m10                 CMP_block_header_aligned;
    TERN_m10                 CMP_record_header_aligned;
    TERN_m10                 record_header_aligned;
    TERN_m10                 record_indices_aligned;
    TERN_m10                 all_record_structures_aligned;
    TERN_m10                 all_structures_aligned;
    // CMP
    sf8                      *CMP_normal_CDF_table;
    // CRC
    ui4                      **CRC_table;
    ui4                      CRC_mode;
    // AES tables
    si4                      *AES_sbox_table;
    si4                      *AES_rcon_table;
    si4                      *AES_rsbox_table;
    // SHA256 tables
    ui4                      *SHA_h0_table;
    ui4                      *SHA_k_table;
    // UTF8 tables
    ui4                      *UTF8_offsets_table;
    si1                      *UTF8_trailing_bytes_table;
    // Miscellaneous
    TERN_m10                 verbose;
    ui4                      behavior_on_fail;
} GLOBALS_m10;

// Global Defaults
#define GLOBALS_VERBOSE_DEFAULT_m10        FALSE_m10
#define GLOBALS_RECORDING_TIME_OFFSET_DEFAULT_m10    0
#define GLOBALS_RECORDING_TIME_OFFSET_NO_ENTRY_m10   0

```

```

#define GLOBALS_RECORDING_TIME_OFFSET_MODE_DEFAULT_m10 (RTO_APPLY_ON_OUTPUT_m10 | RTO_REMOVE_ON_INPUT_m10)
#define GLOBALS_STANDARD_UTC_OFFSET_DEFAULT_m10 0
#define GLOBALS_OBSERVE_DST_DEFAULT UNKNOWN_m10
#define GLOBALS_STANDARD_TIMEZONE_ACRONYM_DEFAULT_m10 "UTC"
#define GLOBALS_STANDARD_TIMEZONE_STRING_DEFAULT_m10 "Coordinated Universal Time"
#define GLOBALS_DAYLIGHT_TIMEZONE_ACRONYM_DEFAULT_m10 "UTC"
#define GLOBALS_DAYLIGHT_TIMEZONE_STRING_DEFAULT_m10 "Coordinated Universal Time"
#define GLOBALS_BEHAVIOR_ON_FAIL_DEFAULT_m10 EXIT_ON_FAIL_m10
#define GLOBALS_CRC_MODE_DEFAULT_m10 CRC_CALCULATE_ON_OUTPUT_m10
#define GLOBALS_ALLOC_TRACKING_DEFAULT_m10 FALSE_m10
#define GLOBALS_INIT_ALLOC_TRACKING_ARRAY_LEN_m10 100
#define GLOBALS_ALLOC_TRACKING_FUNCTION_STRING_LEN_m10 42

```

These values are used throughout the library in a thread-safe manner. They are initialized to the application heap via the function `initialize_MED_globals()`, which is in turn called by `initialize_medlib()`. These two functions are described below.

The `recording_time_offset` and `standard_UTC_offset` constants will be described with the recording time offset functions. The alignment fields will be discussed with the alignment checking functions. The `CRC_mode` constants and `CRC_table` will be described with the CRC functions. Likewise, the AES, UTF-8 and, SHA lookup tables will be discussed in their respective sections below.

```

/*****
/***** Error Checking Standard Functions *****/
/*****

// Error Handling Constants
#define USE_GLOBAL_BEHAVIOR_m10 0
#define RESTORE_BEHAVIOR_m10 1
#define EXIT_ON_FAIL_m10 2
#define RETURN_ON_FAIL_m10 4
#define SUPPRESS_ERROR_OUTPUT_m10 8
#define SUPPRESS_WARNING_OUTPUT_m10 16
#define SUPPRESS_ALL_OUTPUT_m10 (SUPPRESS_ERROR_OUTPUT_m10 | SUPPRESS_WARNING_OUTPUT_m10)
#define RETRY_ONCE_m10 32

// Function Prototypes
void *e_calloc_m10(ui8 n_members, ui8 el_size, const si1 *function, si4 line, ui4 behavior_on_fail);
void **e_calloc_2D_m10(ui8 dim1, ui8 dim2, ui8 el_size, const si1 *function, si4 line, ui4 behavior_on_fail);
FILE *e_fopen_m10(si1 *path, si1 *mode, const si1 *function, si4 line, ui4 behavior_on_fail);
size_t e_fread_m10(void *ptr, ui8 size, ui8 n_members, FILE *stream, si1 *path, const si1 *function, si4 line,
    ui4 behavior_on_fail);
void e_free_m10(void *ptr, const si1 *function, si4 line);
void e_free_2D_m10(void **ptr, si8 dim1, const si1 *function, si4 line);
si4 e_fseek_m10(FILE *stream, ui8 offset, si4 whence, si1 *path, const si1 *function, si4 line, ui4
    behavior_on_fail);
si8 e_ftell_m10(FILE *stream, const si1 *function, si4 line, ui4 behavior_on_fail);
ui8 e_fwrite_m10(void *ptr, ui8 size, ui8 n_members, FILE *stream, si1 *path, const si1 *function, si4 line,
    ui4 behavior_on_fail);
void *e_malloc_m10(ui8 n_bytes, const si1 *function, si4 line, ui4 behavior_on_fail);
void *e_realloc_m10(void *ptr, ui8 n_bytes, const si1 *function, si4 line, ui4 behavior_on_fail);

void **e_realloc_2D_m10(void **curr_ptr, size_t curr_dim1, size_t new_dim1, size_t curr_dim2, size_t
    new_dim2, size_t el_size, const si1 *function, si4 line, ui4 behavior_on_fail);
si4 e_system_m10(si1 *command, TERN_m10 null_std_streams, const si1 *function, si4 line, ui4
    behavior_on_fail);
void force_behavior_m10(ui4 behavior);

```

These functions are provided for convenience. They call their corresponding standard c functions (e.g. `e_calloc_m10()` calls `calloc()`), but have built in error messaging. The `behavior_on_fail` parameter defines what the function does on failure. They are written to maintain thread-safety.

force_behavior_m10() is described with the general functions, but essentially changes global behavior, and is one of the few library functions that **is not thread-safe**.

Example:

```
ui4    behavior;
si4    *data;

behavior = (RETURN_ON_FAIL | SUPPRESS_ERROR_OUTPUT);
data = (si4 *) e_malloc_m10((size_t) buffer_size, sizeof(si4), __FUNCTION__, __LINE__, behavior);
```

__FUNCTION__ and __LINE__ are compiler macros replaced with the function name and line of the function in which they occur; these can contain any string and number, however, for more complex failure tracking. Because of the way in which the behavior parameter is defined, on failure, this call to e_malloc_m10() will return NULL, as would calloc(), and no error messages will be displayed. If USE_GLOBAL_BEHAVIOR is passed into this parameter, the global value of behavior_on_fail will be used. This is the most common usage in the library. At the time of this writing the default global behavior_on_fail value is EXIT_ON_FAIL, which will produce error messages and then exit the program.

```
/******
/****** Alignment Checking Functions *****/
/******

// Alignment Function Prototypes
TERN_m10    check_all_alignments_m10(const si1 *function, si4 line);
TERN_m10    check_metadata_alignment_m10(ui1 *bytes);
TERN_m10    check_metadata_section_1_alignment_m10(ui1 *bytes);
TERN_m10    check_metadata_section_3_alignment_m10(ui1 *bytes);
TERN_m10    check_record_header_alignment_m10(ui1 *bytes);
TERN_m10    check_record_indices_alignment_m10(ui1 *bytes);
TERN_m10    check_CMP_block_header_alignment_m10(ui1 *bytes);
TERN_m10    check_CMP_record_header_alignment_m10(ui1 *bytes);
TERN_m10    check_time_series_indices_alignment_m10(ui1 *bytes);
TERN_m10    check_time_series_metadata_section_2_alignment_m10(ui1 *bytes);
TERN_m10    check_universal_header_alignment_m10(ui1 *bytes);
TERN_m10    check_video_indices_alignment_m10(ui1 *bytes);
TERN_m10    check_video_metadata_section_2_alignment_m10(ui1 *bytes);
```

The structures in the MED library are designed such that they can be read in directly from their sources (e.g. disk, network) to the structure without explicit assignment operations for each of the fields. Because compilers can rearrange fields within structures, this can fail in principle, but the fields are laid out such that this would be quite unlikely.

For example, on a 64 bit CPU structures are generally laid out on 8 byte boundaries. If they are not inherently 8 byte aligned, the compiler will often pad the structure. Explicitly padding the structure to create 8 byte alignment will alleviate this problem. Likewise an 8 byte data type should fall on a natural 8 byte boundary within the structure, if it does not the compiler may try to rearrange or pad the structure.

In practice designing a structure such that the compiler will leave it intact is usually quite easy. In the case of alignment failure, the library would need to be updated to perform explicit assignment.

The alignment checking functions simply compare compiler generated offsets to expected offsets from the layout on disk. If all the field offsets match, the functions return TRUE, if they do not they return FALSE. Prior to checking, the global alignment flags are each set to UNKNOWN. In addition to a return value, each of these functions also sets its corresponding GLOBAL field to TRUE or FALSE.

The function check_all_alignments_m10() calls all of the other alignment checking functions and returns TRUE if all of those functions return TRUE. This function also takes a function and line argument similar to the error checking functions. This function is called from initialize_medlib_m10(), and so need not be called explicitly if initialize_medlib_m10() is called.

If a buffer (the "bytes" field) is passed the function will not allocate any memory for the testing. If NULL is passed in the "bytes" field the function will allocate memory for the testing and then free it once the check is complete.

example 1 (exerpted from check_all_alignments_m10()):

```
...
bytes = (ui1 *) e_malloc_m10(METADATA_FILE_BYTES, __FUNCTION__, __LINE__, USE_GLOBAL_BEHAVIOR);

// METADATA is largest fixed file structure, so this will be enough memory to check all
// the library structures

// check all structures
return_value = MED_TRUE;
if ((check_universal_header_alignment_m10(bytes)) == MED_FALSE)
    return_value = MED_FALSE;
if ((check_metadata_alignment_m10(bytes)) == MED_FALSE)
    return_value = MED_FALSE;
if ((check_CMP_block_header_alignment_m10(bytes)) == MED_FALSE)
    return_value = MED_FALSE;
if ((check_time_series_indices_alignment_m10(bytes)) == MED_FALSE)
    return_value = MED_FALSE;
if ((check_video_indices_alignment_m10(bytes)) == MED_FALSE)
    return_value = MED_FALSE;
if ((check_record_indices_alignment_m10(bytes)) == MED_FALSE)
    return_value = MED_FALSE;
if ((check_record_header_alignment_m10(bytes)) == MED_FALSE)
    return_value = MED_FALSE;
if ((check_record_structure_alignments_m10(bytes)) == MED_FALSE)
    return_value = MED_FALSE;

free(bytes);

return(return_value);
```

example 2 (the most common use):

```
return_value = check_all_alignments(__FUNCTION__, __LINE__);
```

```

/*****
/***** MED String Functions *****/
/*****/

// Standard String Function Prototypes
si4    sprintf_m10(si1 *target, si1 *format, ...);
void   snprintf_m10(si1 *target, si4 target_field_bytes, si1 *format, ...);
si4    strcat_m10(si1 *target_string, si1 *source_string);
si4    strcpy_m10(si1 *target_string, si1 *source_string);
void   strncat_m10(si1 *target_string, si1 *source_string, si4 target_field_bytes);
void   strncpy_m10(si1 *target_string, si1 *source_string, si4 target_field_bytes);

// UTF8 Prototypes: these are described with the other UTF8 functions, but are mentioned here only because they
// are string functions with standard correlates.
si4    UTF8_fprintf_m10(FILE *stream, si1 *fmt, ...);
si4    UTF8_printf_m10(si1 *fmt, ...);
si4    UTF8_strlen_m10(si1 *s);
```

As a group, these functions facilitate working with MED strings. When there is a target string, unoccupied bytes are filled with zeros, per the MED specification.

```

/*****
/***** General Purpose MED Functions *****/
/*****/
```

As a group, these functions facilitate working with various aspects of the MED format. Each will be described separately below.

FUNCTION: absolute_index_to_time_m10()

```
// Prototype
si8 absolute_index_to_time_m10(si1 *seg_dir, si8 index, si8 absolute_start_sample_number, sf8
sampling_frequency, ui1 mode);
```

For a given segment, this function returns a μ UTC time for a given sample index. If `absolute_start_sample_number == SAMPLE_NUMBER_NO_ENTRY_m10` or `sampling_frequency == FREQUENCY_NO_ENTRY_m10`, the function will get these values from the segment metadata file. If they are known, passing them makes the function more efficient.

The returned value is an absolute index, numbered relative to the session, not the segment.

FUNCTION: all_zeros_m10()

```
// Prototype
TERN_m10 all_zeros_m10(ui1 *bytes, si4 field_length);
```

This function returns TRUE if field pointed to by “bytes” contains all zeros, and FALSE if not. The expected length of the field is passed in “field_length”. It is useful in checking fields whose “no entry” value is defined to be all zeros.

example (extracted from show_universal_header_m10()):

```
if (all_zeros(uh->level_1_password_validation_field, PASSWORD_VALIDATION_FIELD_BYTES) == TRUE_m10)
    printf("Level 1 Password Validation_Field: no entry\n");
```

FUNCTION: allocate_channel_m10()

```
// Prototype
CHANNEL_m10 *allocate_channel_m10(CHANNEL_m10 *chan, FILE_PROCESSING_STRUCT_m10 *proto_fps, si1
*enclosing_path, si1 *chan_name, ui4 type_code, si4 n_segs, TERN_m10 chan_recs, TERN_m10 seg_recs);
```

```
// Structures
typedef struct {
    FILE_PROCESSING_STRUCT_m10 *metadata_fps;
    FILE_PROCESSING_STRUCT_m10 *record_data_fps;
    FILE_PROCESSING_STRUCT_m10 *record_indices_fps;
    si4 number_of_segments;
    SEGMENT_m10 **segments;
    si1 path[FULL_FILE_NAME_BYTES_m10]; // full path to channel
    // directory (including channel directory itself)
    si1 name[BASE_FILE_NAME_BYTES_m10];
    TIME_SLICE_m10 time_slice;
} CHANNEL_m10;
```

This function allocates a CHANNEL_m10 structure and returns a pointer to it. If a channel structure pointer is passed, this structure is used; if NULL is passed, the channel structure is allocated.

If a prototype FPS is passed (NULL for no prototype), it is used to initialize the channel files.

Enclosing_path is the path to the directory enclosing the channel, not the channel directory itself.

Chan_name is the channel's base name, with no path or extension.

type_code is one of the defined channel types. Currently these are defined:

```

TIME_SERIES_CHANNEL_TYPE_m10 (== TIME_SERIES_CHANNEL_DIRECTORY_TYPE_CODE_m10)
VIDEO_CHANNEL_TYPE_m10 (== VIDEO_CHANNEL_DIRECTORY_TYPE_CODE_m10)
UNKNOWN_CHANNEL_TYPE_m10 (== NO_FILE_TYPE_CODE_m10)

```

But MED may include other channel types in the future.

n_segs is the number of segments to allocate for the channel. A segment structure is easily re-used, so allocation of just one segment is a common choice.

Chan_recs & seg_recs select whether to allocate channel-level & segment-level record file structures.

If records are requested, enough memory for one record of size LARGEST_RECORD_BYTES_m10 is allocated (call `reallocate_file_processing_struct_m10()` to change this). If records are requested, enough memory for one record index is also allocated (`reallocate_file_processing_struct_m10()` can also change this).

FUNCTION: allocate_file_processing_struct_m10()

```

// Prototype
FILE_PROCESSING_STRUCT_m10 *allocate_file_processing_struct_m10(FILE_PROCESSING_STRUCT_m10 *fps, si1
*full_file_name, ui4 type_code, si8 raw_data_bytes, FILE_PROCESSING_STRUCT_m10 *proto_fps, si8 bytes_to_copy);

```

This function allocates a `FILE_PROCESSING_STRUCT` and returns a pointer to it.

```

// Structures
typedef struct {
    TERN_m10                                mutex; // used by MED functions to ensure thread
                                                // safety
    si1                                     full_file_name[FULL_FILE_NAME_BYTES_m10]; // full
                                                // path including extension
    FILE                                    *fp; // file pointer
    si4                                    fd; // file descriptor
    si8                                    file_length;
    UNIVERSAL_HEADER_m10                  *universal_header;
    FILE_PROCESSING_DIRECTIVES_m10         directives;
    PASSWORD_DATA_m10                     *password_data; // this will typically be the same
                                                // for all files
    METADATA_m10                           metadata; // structure containing pointers to each
                                                // of the three metadata sections
    TIME_SERIES_INDEX_m10                  *time_series_indices;
    VIDEO_INDEX_m10                        *video_indices;
    ui1                                    *records;
    RECORD_INDEX_m10                       *record_indices;
    si8                                    raw_data_bytes;
    ui1                                    *raw_data;
    CMP_PROCESSING_STRUCT_m10              *cps; // associated with time series data FPS, NULL
                                                // in others
} FILE_PROCESSING_STRUCT_m10;

typedef struct {
    TERN_m10                                close_file;
    TERN_m10                                flush_after_write;
    TERN_m10                                update_universal_header; // when writing
    TERN_m10                                leave_decrypted; // if encrypted during write, return from write
                                                // function decrypted, also leave times unoffset
    TERN_m10                                free_password_data; // when freeing FPS
    TERN_m10                                free_CMP_processing_struct; // when freeing FPS

    ui4                                    lock_mode;
    ui4                                    open_mode;
} FILE_PROCESSING_DIRECTIVES_m10;

```



```

// Constants
#define FPS_FILE_LENGTH_UNKNOWN_m10 -1
#define FPS_FULL_FILE_m10 -1
#define FPS_NO_LOCK_TYPE_m10 (~(F_RDLCK | F_WRLCK | F_UNLCK)) // from <fcntl.h>
#define FPS_NO_LOCK_MODE_m10 0
#define FPS_READ_LOCK_ON_READ_OPEN_m10 1
#define FPS_WRITE_LOCK_ON_READ_OPEN_m10 2
#define FPS_WRITE_LOCK_ON_WRITE_OPEN_m10 4
#define FPS_WRITE_LOCK_ON_READ_WRITE_OPEN_m10 8
#define FPS_READ_LOCK_ON_READ_m10 16
#define FPS_WRITE_LOCK_ON_WRITE_m10 32
#define FPS_NO_OPEN_MODE_m10 0
#define FPS_R_OPEN_MODE_m10 1
#define FPS_R_PLUS_OPEN_MODE_m10 2
#define FPS_W_OPEN_MODE_m10 4
#define FPS_W_PLUS_OPEN_MODE_m10 8
#define FPS_A_OPEN_MODE_m10 16
#define FPS_A_PLUS_OPEN_MODE_m10 32
#define FPS_GENERIC_READ_OPEN_MODE_m10 (FPS_R_OPEN_MODE_m10 | FPS_R_PLUS_OPEN_MODE_m10 | \
FPS_W_PLUS_OPEN_MODE_m10 | FPS_A_PLUS_OPEN_MODE_m10)
#define FPS_GENERIC_WRITE_OPEN_MODE_m10 (FPS_R_PLUS_OPEN_MODE_m10 | FPS_W_OPEN_MODE_m10 | \
FPS_W_PLUS_OPEN_MODE_m10 | FPS_A_OPEN_MODE_m10 | \
FPS_A_PLUS_OPEN_MODE_m10)
#define FPS_PROTOTYPE_FILE_TYPE_CODE_m10 TIME_SERIES_METADATA_FILE_TYPE_CODE_m10 // any
// metadata type would do

#define FPS_FD_NO_ENTRY_m10 -2
#define FPS_FD_EPHEMERAL_m10 -3

// File Processing Directives Defaults
#define FPS_DIRECTIVE_CLOSE_FILE_DEFAULT_m10 TRUE_m10
#define FPS_DIRECTIVE_FLUSH_AFTER_WRITE_DEFAULT_m10 TRUE_m10
#define FPS_DIRECTIVE_FREE_PASSWORD_DATA_DEFAULT_m10 FALSE_m10
#define FPS_DIRECTIVE_FREE_CMP_PROCESSING_STRUCT_DEFAULT_m10 TRUE_m10
#define FPS_DIRECTIVE_UPDATE_UNIVERSAL_HEADER_DEFAULT_m10 FALSE_m10
#define FPS_DIRECTIVE_LEAVE_DECRYPTED_DEFAULT_m10 FALSE_m10
#define FPS_DIRECTIVE_LOCK_MODE_DEFAULT_m10 FPS_NO_LOCK_MODE_m10 // Unix
// file locking may cause
// problems with networked
// file systems

// #define FPS_DIRECTIVE_LOCK_MODE_DEFAULT_m10 (FPS_READ_LOCK_ON_READ_OPEN_m10 |
// FPS_WRITE_LOCK_ON_WRITE_OPEN_m10 |
// FPS_WRITE_LOCK_ON_READ_WRITE_OPEN_m10)

#define FPS_DIRECTIVE_OPEN_MODE_DEFAULT_m10 FPS_NO_OPEN_MODE_m10
#define FPS_DIRECTIVE_IO_BYTES_DEFAULT_m10 FPS_FULL_FILE_m10 // bytes
// to read or write

#define FPS_UNIVERSAL_HEADER_ONLY_m10 0

```

The FILE_PROCESSING_STRUCT (FPS) is the fundamental file handling unit of the MED library. The raw_data field contains the data as it is arranged in the MED structures, **and on disk**. The universal_header pointer within the FPS will be assigned the value of the start of the raw_data array. Depending on file type, one of the other pointers within the structure will be assigned to the raw_data array after the universal header region.

The passed parameter raw_data_bytes is the amount of memory to be allocated to the raw_data field minus the amount needed for a universal header, as all MED files have a universal header.

The FILE_PROCESSING_STRUCT's file_length field reflects the size of the file on disk (in bytes). This is set to zero on allocation, but is updated during read and write operations using MED library functions.

If a prototype `FILE_PROCESSING_STRUCT` is passed in `proto_fps`, its directives, password data, and raw data are copied to the new `FILE_PROCESSING_STRUCT` (unless `bytes_to_copy` plus universal header bytes is greater than `raw_data_bytes`). The amount of raw data copied is specified in the `bytes_to_copy` field. Bytes to copy does not include the bytes universal header bytes, as this is assumed. If copying is performed, the universal header's CRC will be not be recalculated, and may be inaccurate. This is updated in `write_file_m10()` before write out, and so is not usually an issue. It could be explicitly calculated with `calculate_CRC_m10()`.

If the prototype pointer is `NULL`, the file processing directives and universal header are set to their default values.

The `FILE_PROCESSING_DIRECTIVES` are used by the reading and writing functions. Specifically, **close_file** tells reading & writing functions to close the file when they are finished. **free_password_data** tells functions freeing a `FILE_PROCESSING_STRUCT` to free this also. This is often undesirable as the pointer to a single `PASSWORD_DATA` structure is often shared between many `FILE_PROCESSING_STRUCT`s. At this writing the default value of the **free_password_data** directive is `FALSE`. **lock_mode** specifies *advisory locking* on the file. All the MED library functions observe the advisory locking mechanism, to facilitate parallel processing of files. Note that, as this is *advisory* only, external functions may choose to ignore these locks. **open_mode** specifies how a file should be opened, and corresponds to standard Unix / Posix opening modes. This parameter interacts with the **lock_mode** parameter.

The `type_code` specifies which of the `FILE_PROCESSING_STRUCT` pointers will be assigned to the raw data after the universal header. The `type_string` field of the universal header is also set by the `type_code`. If the `type_code` is zero, these assignments are not made.

The `raw_data_bytes` parameter specifies how much memory to allocate to the raw data array. This value is copied into the corresponding member of the new FPS.

example 1: allocate an empty `FILE_PROCESSING_STRUCT` (just space for a universal header)

```
fps = allocate_file_processing_struct_m10(NULL, NULL, NO_TYPE_CODE_m10, 0, NULL, 0);
NO_TYPE_CODE_m10 == 0, so fps = allocate_file_processing_struct_m10(NULL, NULL, 0, 0, NULL, 0); would be the same
```

example 2: allocate a metadata `FILE_PROCESSING_STRUCT` and copy its universal header from the prototype FPS, "other_fps"

```
fps = allocate_file_processing_struct_m10(NULL, full_file_name, TIME_SERIES_METADATA_FILE_TYPE_CODE_m10,
METADATA_FILE_BYTES_m10, other_fps, FPS_UNIVERSAL_HEADER_ONLY_m10);
FPS_UNIVERSAL_HEADER_ONLY_m10 == 0, so fps = allocate_file_processing_struct_m10(NULL, full_file_name, TIME_SERIES_METADATA_FILE_TYPE_CODE_m10,
METADATA_FILE_BYTES_m10, other_fps, 0); would be the same
```

example 3: allocate a metadata `FILE_PROCESSING_STRUCT` and copy all of the data, including the universal header, from "other_metadata_fps".

```
fps = allocate_file_processing_struct_m10(NULL, full_file_name, TIME_SERIES_METADATA_FILE_TYPE_CODE_m10,
METADATA_FILE_BYTES_m10, other_metadata_fps, METADATA_FILE_BYTES_m10);
```

FUNCTION: allocate_metadata_m10()

```
// Prototype
METADATA_m10    *allocate_metadata_m10(METADATA_m10 *metadata, ui1 *data_ptr);

// Structures
typedef struct {
    ui1                                *metadata; // same as section_1 pointer (exists for
                                                // clarity in functions that operate on
                                                // whole metadata)

    METADATA_SECTION_1_m10             *section_1;
    TIME_SERIES_METADATA_SECTION_2_m10 *time_series_section_2;
    VIDEO_METADATA_SECTION_2_m10       *video_section_2;
    METADATA_SECTION_3_m10             *section_3;
} METADATA_m10;

typedef struct {
```

```

    si1    level_1_password_hint[PASSWORD_HINT_BYTES_m10];
    si1    level_2_password_hint[PASSWORD_HINT_BYTES_m10];
    si1    section_2_encryption_level;
    si1    section_3_encryption_level;
    ui1    protected_region[METADATA_SECTION_1_PROTECTED_REGION_BYTES_m10];
    ui1    discretionary_region[METADATA_SECTION_1_DISCRETIONARY_REGION_BYTES_m10];
} METADATA_SECTION_1_m10;

```

```

typedef struct {
    // channel type independent fields
    si1    session_description[METADATA_SESSION_DESCRIPTION_BYTES_m10]; // utf8[511]
    si1    channel_description[METADATA_CHANNEL_DESCRIPTION_BYTES_m10]; // utf8[255]
    si1    segment_description[METADATA_SEGMENT_DESCRIPTION_BYTES_m10]; // utf8[255]
    si1    equipment_description[METADATA_EQUIPMENT_DESCRIPTION_BYTES_m10]; // utf8[510]
    si4    acquisition_channel_number;
    // channel type specific fields
    si1    reference_description
            [TIME_SERIES_METADATA_REFERENCE_DESCRIPTION_BYTES_m10]; // utf8[255]
    sf8    sampling_frequency;
    sf8    low_frequency_filter_setting;
    sf8    high_frequency_filter_setting;
    sf8    notch_filter_frequency_setting;
    sf8    AC_line_frequency;
    sf8    amplitude_units_conversion_factor;
    si1    amplitude_units_description \
            [TIME_SERIES_METADATA_AMPLITUDE_UNITS_DESCRIPTION_BYTES_m10]; // utf8[31]
    sf8    time_base_units_conversion_factor;
    si1    time_base_units_description \
            [TIME_SERIES_METADATA_TIME_BASE_UNITS_DESCRIPTION_BYTES_m10]; // utf8[31]
    si8    absolute_start_sample_number;
    si8    number_of_samples;
    si8    number_of_blocks;
    si8    maximum_block_bytes;
    ui4    maximum_block_samples;
    ui4    maximum_block_difference_bytes;
    sf8    maximum_block_duration;
    si8    number_of_discontinuities;
    si8    maximum_contiguous_blocks;
    si8    maximum_contiguous_block_bytes;
    si8    maximum_contiguous_samples;
    ui1    protected_region[TIME_SERIES_METADATA_SECTION_2_PROTECTED_REGION_BYTES_m10];
    ui1    discretionary_region \
            [TIME_SERIES_METADATA_SECTION_2_DISCRETIONARY_REGION_BYTES_m10];
} TIME_SERIES_METADATA_SECTION_2_m10;

```

```

typedef struct {
    // type-independent fields
    si1    session_description[METADATA_SESSION_DESCRIPTION_BYTES_m10]; // utf8[511]
    si1    channel_description[METADATA_CHANNEL_DESCRIPTION_BYTES_m10]; // utf8[511]
    si1    segment_description[METADATA_SEGMENT_DESCRIPTION_BYTES_m10]; // utf8[511]
    si1    equipment_description[METADATA_EQUIPMENT_DESCRIPTION_BYTES_m10]; // utf8[510]
    si4    acquisition_channel_number;
    // type-specific fields
    si8    horizontal_resolution;
    si8    vertical_resolution;
    sf8    frame_rate;
    si8    number_of_clips;
    si8    maximum_clip_bytes;
    si1    video_format[VIDEO_METADATA_VIDEO_FORMAT_BYTES_m10]; // utf8[31]
    si4    number_of_video_files;
    ui1    protected_region[VIDEO_METADATA_SECTION_2_PROTECTED_REGION_BYTES_m10];
    ui1    discretionary_region[VIDEO_METADATA_SECTION_2_DISCRETIONARY_REGION_BYTES_m10];
} VIDEO_METADATA_SECTION_2_m10;

```

```

typedef struct {
    si8    recording_time_offset;
    DAYLIGHT_TIME_CHANGE_CODE_m10 daylight_time_start_code; // si1[8] / si8
    DAYLIGHT_TIME_CHANGE_CODE_m10 daylight_time_end_code; // si1[8] / si8
    si1    standard_timezone_acronym[TIMEZONE_ACRONYM_BYTES_m10]; // ascii[8]
    si1    standard_timezone_string[TIMEZONE_STRING_BYTES_m10]; // ascii[31]
    si1    daylight_timezone_acronym[TIMEZONE_ACRONYM_BYTES_m10]; // ascii[8]
    si1    daylight_timezone_string[TIMEZONE_STRING_BYTES_m10]; // ascii[31]
    si1    subject_name_1[METADATA_SUBJECT_NAME_BYTES_m10]; // utf8[31]
    si1    subject_name_2[METADATA_SUBJECT_NAME_BYTES_m10]; // utf8[31]
    si1    subject_name_3[METADATA_SUBJECT_NAME_BYTES_m10]; // utf8[31]
    si1    subject_ID[METADATA_SUBJECT_ID_BYTES_m10]; // utf8[31]
    si1    recording_country[METADATA_RECORDING_LOCATION_BYTES_m10]; // utf8[63]
    si1    recording_territory[METADATA_RECORDING_LOCATION_BYTES_m10]; // utf8[63]
    si1    recording_city[METADATA_RECORDING_LOCATION_BYTES_m10]; // utf8[63]
    si1    recording_institution[METADATA_RECORDING_LOCATION_BYTES_m10]; // utf8[63]
    si1    geotag_format[METADATA_GEOTAG_FORMAT_BYTES_m10]; // ascii[31]
    si1    geotag_data[METADATA_GEOTAG_DATA_BYTES_m10]; // ascii[1023]
    si4    standard_UTC_offset;
    ui1    protected_region[METADATA_SECTION_3_PROTECTED_REGION_BYTES_m10];
    ui1    discretionary_region[METADATA_SECTION_3_DISCRETIONARY_REGION_BYTES_m10];
} METADATA_SECTION_3_m10;

```

This function allocates a metadata structure (if NULL is passed), and the memory for the structures it contains (again, if NULL is passed). Internal memory is allocated to metadata->metadata, and caller must free that before freeing the metadata structure itself (you can also use free_metadata_m10() which does this for you). The function sets the internal pointers appropriately. Use of this functions is typically unnecessary as allocate_file_processing_struct_m10() for a metadata FPS perform this allocation and assignment.

FUNCTION: apply_recording_time_offset_m10()

```

// Prototype
void apply_recording_time_offset(si8 *time);

```

The global recording time offset is applied to the passed μ UTC time. The converse function is remove_recording_time_offset() described below.

FUNCTION: calculate_metadata_CRC_m10()

```

// Prototype
void calculate_metadata_CRC_m10(FILE_PROCESSING_STRUCT_m10 *fps);

```

Calculates the CRC for a metadata FPS, and enters that value in the universal header body_CRC.

FUNCTION: calculate_record_data_CRCs_m10()

```

// Prototype
void calculate_record_data_CRCs_m10(FILE_PROCESSING_STRUCT_m10 *fps, RECORD_HEADER_m10
*record_header, si8 number_of_items);

```

Calculates the CRCs for number_of_items record data entries, and enters their values in the record headers. It also updates the universal header body_CRC for each record. The record_header pointer is the beginning of an array of records.

FUNCTION: calculate_record_indices_CRCs_m10()

// Prototype

```
void calculate_record_indices_CRCs_m10(FILE_PROCESSING_STRUCT_m10 *fps, RECORD_INDEX_m10 *record_index, si8 number_of_items);
```

Calculates the CRCs for number_of_items record indices, and updates the universal header body_CRC for each index. The record_index pointer is the beginning of an array of record indices.

FUNCTION: calculate_time_series_data_CRCs_m10()

// Prototype

```
void calculate_time_series_data_CRCs_m10(FILE_PROCESSING_STRUCT_m10 *fps, CMP_BLOCK_FIXED_HEADER_m10 *block_header, si8 number_of_items);
```

Calculates the CRCs for number_of_items CMP blocks (time series data blocks entries), and enters their values in the CMP block headers. It also updates the universal header body_CRC for each record. The block_header pointer is the beginning of an array of CMP blocks.

FUNCTION: calculate_time_series_indices_CRCs_m10()

// Prototype

```
void calculate_time_series_indices_CRCs_m10(FILE_PROCESSING_STRUCT_m10 *fps, TIME_SERIES_INDEX_m10 *time_series_index, si8 number_of_items);
```

Calculates the CRCs for number_of_items time series indices, and updates the universal header body_CRC for each index. The time_series_index pointer is the beginning of an array of time series indices.

FUNCTION: channel_type_from_path_m10()

// Prototype

```
ui4 channel_type_from_path_m10(si1 *path);
```

Returns MED type code based on extension of the passed file name or path. UNKNOWN_CHANNEL_TYPE_m10 is returned for an unrecognized extension.

FUNCTION: check_password_m10()

// Prototype

```
si4 check_password(si1 *password, const si1 *function, si4 line);
```

Checks that the password pointer is not NULL, and that the password length is less than or equal to PASSWORD_BYTES. Returns 0 on success, 1 on failure. This function does not validate the password against the password validation fields. Process_password_data() does this. In fact, process_password_data() is the only library function to call check_password().

example (from process_password_data_m10()):

```
if (check_password(unspecified_password, __FUNCTION__, __LINE__) == 0)
    // password is not NULL, and is of valid length
```

FUNCTION: condition_time_slice_m10()

```
// Prototype
void condition_time_slice_m10(TIME_SLICE_m10 *slice)
```

Does the following to the passed time slice:

- 1) Offsets unoffset times (using global recording_time_offset)
- 2) Makes relative times (negative) absolute (using global session_start_time)
- 3) Sets start_time & end_time to BEGINNING_OF_TIME_m10 & END_OF_TIME_m10 if no index parameters are specified
- 4) Sets slice->conditioned to TRUE_m10

NOTE: globals session_start_time & recording_time_offset must be set before using this function.

FUNCTION: current_uutc_m10()

```
// Prototype
inline si8 current_uutc_m10(void);
```

Returns the current μ UCT based on the system clock.

FUNCTION: days_in_month_m10()

```
// Prototype
inline si4 days_in_month_m10(si4 month, si4 year);
```

Returns the days in a month based on the month and year. Note month is [0 - 11], where January == 0 (as in struct tm.tm_mon in <time.h>). This function expects the full value of the year (note struct tm.tm_year is (year - 1900) in <time.h>).

FUNCTION: decrypt_metadata_m10()

```
// Prototype
TERN_m10 decrypt_metadata_m10(FILE_PROCESSING_STRUCT_m10 *fps);
```

Decrypts metadata in a metadata FPS in place. Returns TRUE_m10 on success, FALSE_m10 on failure.

FUNCTION: decrypt_records_m10()

```
// Prototype
TERN_m10 decrypt_records_m10(RECORD_HEADER_m10 *record_header, si8 number_of_items);
```

Decrypts the number_of_items records pointed to by record_header. Returns TRUE_m10 on success, FALSE_m10 on failure.

FUNCTION: decrypt_time_series_data_m10()

// Prototype

```
TERN_m10    decrypt_time_series_data_m10(CMP_BLOCK_FIXED_HEADER_m10 *block_header, si8
number_of_items);
```

Decrypts the number_of_items CMP blocks pointed to by block_header. Returns TRUE_m10 on success, FALSE_m10 on failure.

FUNCTION: DST_offset_m10()

// Prototype

```
si4    DST_offset_m10(si8 utc);
```

Returns seconds to add to standard time (as UUTC) to adjust for DST on that date, in the timezone specified in the MED globals.

FUNCTION: encrypt_metadata_m10()

// Prototype

```
TERN_m10    encrypt_metadata_m10(FILE_PROCESSING_STRUCT_m10 *fps);
```

Encrypts sections 2 and 3 of metadata file (passed in fps), if they are currently decrypted, to the encryption level specified in section 1 of the metadata. It marks encrypted sections as encrypted (positive of encryption level) in section 1 of the metadata. It returns TRUE_m10 on success, FALSE_m10 on failure.

FUNCTION: encrypt_records_m10()

// Prototype

```
TERN_m10    encrypt_records_m10(RECORD_HEADER_m10 *record_header, \
    si8 number_of_items);
```

Encrypts number_of_items records if currently decrypted to the level specified in the record headers. It marks the encrypted records as encrypted (positive of encryption level) in the record headers. It returns TRUE_m10 on success, FALSE_m10 on failure.

FUNCTION: encrypt_time_series_data_m10()

// Prototype

```
TERN_m10    encrypt_time_series_data_m10(CMP_PROCESSING_STRUCT_m10 *cps, \
    si8 number_of_items);
```

Encrypts number_of_items CMP blocks pointed to by cps->block_header. It marks the encrypted CMP block as encrypted in the CMP block header flags. It returns TRUE_m10 on success, FALSE_m10 on failure.

FUNCTION: error_message_m10()

// Prototype

```
void error_message_m10(si1 *fmt, ...);
```

Prints an error message to stderr in accordance with the parameters of the behavior_on_fail global variable. Used like fprintf(). Also see message_m10(), warning_message_m10() and force_behavior_m10().

Example:

```
error_message_m10("%s(): Cannot encrypt data (called from line %d)", __FUNCTION__, \
    __LINE__);
```

If you wish to ensure an exit(), regardless go the global behavior, do something like this:

```
if (x == 0) {
    error_message_m10("%s(): Divide by zero", __FUNCTION__);
    exit(1);
}
```

FUNCTION: escape_spaces_m10()

// Prototype

```
void escape_spaces_m10(si1 *string, si8 buffer_len);
```

Escapes all spaces (inserts a backslash ('\')) before all unescaped spaces in the string.

FUNCTION: extract_path_parts_m10()

// Prototype

```
void extract_path_parts_m10(si1 *full_file_name, si1 *path, si1 *name, si1 *extension);
```

Non-destructively copies the path (**full_file_name** string up to enclosing directory) into **path** (if not NULL), the name (last component in full_file_name) into **name** (if not NULL), and the extension (last component in full_file_name after a ".") into **extension** (if not NULL). Pass NULL for any components that are not needed. Terminal forward slashes ("/") are removed. the path is prepended with the current working directory if the **full_file_name** does not begin from root.
example:

```
si1 *passed_session_directory = "/Data/Session_1.medd";
```

```
extract_path_and_name(passed_session_directory, session_path, session_name,
    session_extension);
```

On return, session_path contains "/Data", session_name contains "Session_1", and extension contains "medd". If only the name was required the following call would suffice:

```
extract_path_and_name(passed_session_directory, NULL, session_name, NULL);
```


FUNCTION: extract_terminal_password_bytes_m10()

// Prototype

```
si4  extract_terminal_password_bytes_m10(si1 *password, si1 *password_bytes);
```

UTF-8 passwords can contain up to 4 bytes per character. In UTF-8 encoding, the most unique byte in each character is the terminal byte. This function extracts those bytes from the UTF-8 password (passed in **password**) to password_bytes, which is used to generate the encryption key for the AES algorithms. Unused bytes are zeroed. This function is called by process_password_data_m10().

FUNCTION: file_exists_m10()

// Prototype

```
ui4  file_exists_m10(si1 *path);
```

```
#define DOES_NOT_EXIST_m10      0
```

```
#define FILE_EXISTS_m10         1
```

```
#define DIR_EXISTS_m10          2
```

Returns FILE_EXISTS_m10 if path describes a file. Returns DIR_EXISTS_m10 if path describes a directory. Returns DOES_NOT_EXIST_m10 if path does not point to either a file or directory. If path does not begin from root, the current working directory is prepended.

FUNCTION: find_discontinuities_m10()

// Prototype

```
si8  *find_discontinuities_m10(TIME_SERIES_INDEX_m10 *tsi, si8 num_disconts, si8  
number_of_indices, TERN_m10 remove_offsets, TERN_m10 return_sample_numbers);
```

Allocates and returns an array of indices (into the tsi array) of blocks with discontinuities. If remove_offsets == TRUE_m10, the tsi start sample numbers will be "unflagged" to their true numbers. If return_sample_numbers == TRUE_m10, start sample numbers will be returned in the array, rather than indices.

FUNCTION: force_behavior_m10()

// Constants

```
#define RESTORE_BEHAVIOR        -1
```

// Prototype

```
void  force_behavior(si4 behavior);
```

Changes MED_globals value of behavior_on_fail and stores original value for restoration in a subsequent call.

THIS ROUTINE IS NOT THREAD SAFE: USE WITH CARE IN THREADED CODE.

example: force RETURN_ON_FAIL for a function call, and then restore its original value

```
force_behavior(RETURN_ON_FAIL);
```

```
function_whose_failure_can_be_handled();
force_behavior(RESTORE_BEHAVIOR);
```

```
//*****
//***** FILE PROCESSING STRUCT STANDARD FUNCTIONS *****
//*****
```

FUNCTION: fps_close_m10()

```
// Prototype
void fps_close(FILE_PROCESSING_STRUCT *fps);
```

Closes the file associated with the FPS's FILE pointer and sets it to NULL. It also sets the FPS's file descriptor to -1 (closed file).

FUNCTION: fps_lock_m10()

```
// Constants
#define FPS_NO_LOCK_TYPE          ~(F_RDLCK | F_WRLCK | F_UNLCK)  // <fcntl.h>
#define FPS_NO_LOCK_MODE          0
#define FPS_READ_LOCK_ON_READ_OPEN 1
#define FPS_WRITE_LOCK_ON_READ_OPEN 2
#define FPS_WRITE_LOCK_ON_WRITE_OPEN 4
#define FPS_WRITE_LOCK_ON_READ_WRITE_OPEN 8
#define FPS_READ_LOCK_ON_READ      16
#define FPS_WRITE_LOCK_ON_WRITE     32

// Prototype
si4 fps_lock_m10(FILE_PROCESSING_STRUCT_m10 *fps, si4 lock_type, const si1 *function, \
    si4 line, ui4 behavior_on_fail);
```

Sets an *advisory lock* on the file specified by the FPS directive's lock_mode. The lock is set in blocking mode (i.e. it waits until a lock can be obtained). **lock_type** specifies either a read or write lock. The function & line arguments are provided to know from whence the function was called in the case of failure.

NOTE: advisory locks often do not work on networked file systems.

FUNCTION: fps_mutex_off_m10()

```
// Prototype
inline void fps_mutex_off_m10(FILE_PROCESSING_STRUCT_m10 *fps);
```

Removes mutex lock on an FPS. The mutex is used by read_file_m10() & write_file_m10() to make sure fps is not in use while reading or writing. Other functions may also use this mechanism.

FUNCTION: fps_mutex_on_m10()

```
// Prototype
```

```
inline void fps_mutex_on_m10(FILE_PROCESSING_STRUCT_m10 *fps);
```

Activates mutex lock on an FPS. The mutex is used by read_file_m10() & write_file_m10() to make sure fps is not in use while reading or writing. Other functions may also use this mechanism.

FUNCTION: fps_open_m10()

```
// Constants
#define FPS_NO_OPEN_MODE          0
#define FPS_R_OPEN_MODE          1
#define FPS_R_PLUS_OPEN_MODE     2
#define FPS_W_OPEN_MODE          4
#define FPS_W_PLUS_OPEN_MODE     8
#define FPS_A_OPEN_MODE          16
#define FPS_A_PLUS_OPEN_MODE     32
#define FPS_GENERIC_READ_OPEN_MODE (FPS_R_OPEN_MODE |
                                     FPS_R_PLUS_OPEN_MODE |
                                     FPS_W_PLUS_OPEN_MODE |
                                     FPS_A_PLUS_OPEN_MODE)
#define FPS_GENERIC_WRITE_OPEN_MODE (FPS_R_PLUS_OPEN_MODE |
                                      FPS_W_OPEN_MODE |
                                      FPS_W_PLUS_OPEN_MODE |
                                      FPS_A_OPEN_MODE |
                                      FPS_A_PLUS_OPEN_MODE)

// Prototype
si4  fps_open_m10(FILE_PROCESSING_STRUCT_m10 *fps, const si1 *function, si4 line, ui4 \
                 behavior_on_fail);
```

Opens the file specified by the FPS according to the FPS directive open_mode. If the mode permits file creation, the file will be created. If higher level directories are needed to open the file in the specified location, they too are created. Once open, the file is optionally locked according to the FPS directive's lock_mode. The file descriptor and file length are also updated.

FUNCTION: fps_read_m10()

```
// Prototype
si4  fps_read_m10(FILE_PROCESSING_STRUCT_m10 *fps, si8 in_bytes, void *ptr, const si1 \
                 *function, si4 line, ui4 behavior_on_fail);
```

Locks the file, reads in_bytes bytes, and unlocks the file. Lock type is specified by the FPS directive's lock_mode.

FUNCTION: fps_unlock_m10()

```
// Prototype
si4  fps_unlock_m10(FILE_PROCESSING_STRUCT *fps, const si1 *function, si4 line, \
                   ui4 behavior_on_fail);
```

Releases the *advisory lock* on the file specified by the FPS. The function & line arguments are provided to know from whence the function was called in the case of failure.

NOTE: advisory locks often do not work on networked file systems.

FUNCTION: fps_write_m10()

// Prototype

```
si4  fps_write_m10(FILE_PROCESSING_STRUCT_m10 *fps, si8 out_bytes, void *ptr, const \
    si1 *function, si4 line, ui4 behavior_on_fail);
```

Writes out_bytes bytes. If write_lock_on_write is the specified in the FPS directive's lock_mode, the file will be locked prior to the write and unlocked after the write. The file descriptor and file length are also updated. If update_universal_header is set in the directives, the universal header CRCs will be updated, and the universal header rewritten. The file pointer is repositioned to the end of the file.

FUNCTION: free_channel_m10()

// Prototype

```
void  free_channel_m10(CHANNEL_m10 *channel, TERN_m10 channel_allocated_en_bloc);
```

Frees all the memory pointed to by a CHANNEL structure including all memory associated with SEGMENT structures within it. If channel_allocated_en_bloc == FALSE_m10, the passed CHANNEL structure will itself be freed also.

FUNCTION: free_file_processing_struct_m10()

// Prototype

```
void  free_file_processing_struct_m10(FILE_PROCESSING_STRUCT_m10 *fps, TERN_m10 \
    allocated_en_bloc);
```

Frees a FILE_PROCESSING_STRUCT's raw_data buffer if not NULL, and then frees the FILE_PROCESSING_STRUCT. It also closes the FILE pointer, if it is open and the close_file directive == TRUE_m10. If the FPS contains a CMP processing struct and the free_CMP_processing_struct directive == TRUE_m10, this will also be freed. If the free_password_data directive == TRUE_m10, the FILE_PROCESSING_STRUCT's password_data will be freed. If allocated_en_bloc == FALSE_m10, the FPS structure will itself be freed also.

FUNCTION: free_metadata_m10()

// Prototype

```
void  *free_metadata_m10(METADATA_m10 *metadata);
```

Frees passed metadata structure and associated memory.

FUNCTION: free_segment_m10()

// Prototype

```
void  free_segment_m10(SEGMENT_m10 *segment, TERN_m10 segment_allocated_en_bloc);
```

Frees all the memory pointed to by a SEGMENT structure. If segment_allocated_en_bloc == FALSE_m10, the passed SEGMENT structure will itself be freed also.

FUNCTION: free_session_m10()

// Prototype

```
void free_session_m10(SESSION *session);
```

Frees all the memory pointed to by a SESSION structure including all memory associated with CHANNEL structures within it, and the SEGMENT structures within them. The passed SESSION structure will itself be freed also.

FUNCTION: generate_file_list_m10()

// Prototype

```
si1 **generate_file_list_m10(si1 **file_list, si4 n_in_files, si4 *n_out_files, si1 \
    *enclosing_directory, si1 *name, si1 *extension, ui1 path_parts, TERN_m10 \
    free_input_file_list);
```

// Path Parts

```
#define PP_PATH_m10          1
#define PP_NAME_m10          2
#define PP_EXTENSION_m10     4
#define PP_FULL_PATH_m10     (PP_PATH_m10 | PP_NAME_m10 | PP_EXTENSION_m10)
```

This function may seem a bit arcane, but it is really quite useful. It returns a list of files given the inputs as follows:

1. If the passed file_list not NULL, a new file list is still returned; the passed list will be freed if free_input_file_list == TRUE_m10. The point of this is to allow passing of lists with regex that will be expanded. If enclosing_directory is not NULL, and the passed file list entries do not begin from root, the enclosing directory will be prepended to the file list entries prior to expansion.
2. If the passed file_list is NULL, the enclosing directory, name, or extension are not NULL, they will be incorporated into the a regex expansion. If name is NULL, it is replaced by "*" in the expansion; this is not true for enclosing_directory or extension.

The number of entries in the returned file_list is returned in n_out_files. Generate_file_list_m10() can be used to get a directory list also.

NOTE: If a file_list is passed should not be statically allocated, if free_input_file_list == TRUE_m10.

The path parts specify how the output file_list will be constructed.

Example 1:

```
file_list = generate_file_list_m10(NULL, 0, &n_out_files, "/Data/MED_Files/ \
    Session_1.meddd", NULL, "tcd", PP_FULL_PATH_m10, FALSE_m10);
```

Returns list of all time series channel directories (extension == "tcd") in /Data/MED_Files/Session_1, as full paths.

Example 2:

```
file_list = generate_file_list_m10(NULL, 0, &n_out_files, "/Data/MED_Files/ \
    Session_1.meddd", NULL, "tcd", PP_NAME_m10, FALSE_m10);
```

Returns list of all time series channel directories names in /Data/MED_Files/Session_1, as names only. Such a list could be used labels in a viewer, or to create a derivative MED session.

Example 3:

```
file_list[0] = "grid[1-3].tcd";
file_list[1] = "depth[2,4,6].tcd";
file_list[2] = "micro*";
file_list[3] = "*.vcd";
```

```
file_list = generate_file_list_m10(file_list, 4, &n_out_files, "/Data/MED_Files/ \
    Session_1.meddd", NULL, NULL, PP_NAME_m10 | PP_EXTENSION_m10, TRUE_m10);
```

Returns the following in file_list (you can imagine the full session directory contents):

```
grid1.tcd
grid2.tcd
grid3.tcd
depth2.tcd
depth4.tcd
depth6.tcd
micro_1.tcd
micro_2.tcd
camera_1.vcd
camera_2.vcd
```

On return, "n_out_files" will contain "10", and the input file_list will have been freed.

FUNCTION: generate_hex_string_m10()

// Prototype

```
si1  *generate_hex_string_m10(ui1 *bytes, si4 num_bytes, si1 *string);
```

```
#define HEX_STRING_BYTES_m10(x)      ( ((x) + 1) * 3 )
```

Creates a hexadecimal string from "num_bytes" of the bytes in "bytes" into the string pointed to by "string". If string is NULL, it will be allocated. The length of the string required is: (num_bytes + 1) * 3. This is conveniently generated by the macro HEX_STRING_BYTES().

example 1:

```
ui1  hex_str[HEX_STRING_BYTES(ENCRYPTION_KEY_BYTES)];
```

```
generate_hex_string_m10(pwd->level_1_encryption_key, ENCRYPTION_KEY_BYTES, hex_str);
printf("Level 1 Encryption Key: %s\n", hex_str);
```

example 2:

```
ui1  *hex_str;
```

```
hex_str = generate_hex_string_m10(pwd->level_1_encryption_key, ENCRYPTION_KEY_BYTES, \
    NULL);
printf("Level 1 Encryption Key: %s\n", hex_str);
free(hex_str);
```

FUNCTION: generate_MED_path_components_m10()

// Prototype

```
ui4 generate_MED_path_components_m10(si1 *path, si1 *MED_dir, si1 *MED_name);
```

Given a path to a MED directory or file, returns the full path to the enclosing directory in MED_dir, and the isolated name of the file (no path or extension) in MED_name, and the MED type code of the enclosing directory is the return value. If either MED_dir or MED_name are NULL, they will not be filled in.

The utility of this is to regularize a MED directory or file name into its path (including name and directory extension), and the isolated name. Thus:

```
generate_MED_path_components_m10(path_to_MED_file, MED_path, MED_name);
```

AND

```
generate_MED_path_components_m10(path_to_MED_directory, MED_path, MED_name);
```

... result in the same contents of MED_path and MED_name and the same returned type for the directory.

These components can be used to easily build other MED file names, given the naming conventions of the MED hierarchy.

FUNCTION: generate_numbered_names_m10()

// Prototype

```
si1 **generate_numbered_names_m10(si1 **names, si1 *prefix, si4 number_of_names);
```

Given a prefix and number of names, the function returns a file_list with these names constructed using FILE_NUMBERING_DIGITS_m10 to prefix necessary zeros. Numbering is from 1. If names is NULL, it will be allocated, otherwise it will be used, and is presumed to be large enough.

FUNCTION: generate_recording_time_offset_m10()

// Constants

```
#define USE_SYSTEM_TIME -1
```

// Prototype

```
si8 generate_recording_time_offset_m10(si8 recording_start_time_utc);
```

The function calculates the recording time offset from the passed recording_start_time_utc and local time zone information. The recording time offset is stored in the MED globals. If recording_start_time_utc equals USE_SYSTEM_TIME, the recording time offset will be based on the system time at the time of the function call.

The function returns the recording time offset (useful only if USE_SYSTEM_TIME was passed).

FUNCTION: generate_segment_name_m10()

// Prototype

```
si1 *generate_segment_name_m10(FILE_PROCESSING_STRUCT *fps, si1 *segment_name);
```

A simple convenience function to generate the segment name from the channel name and segment number in the FPS's universal header. The result is stored in **segment_name** if it is not NULL. The result is allocated and returned otherwise. If allocated, the calling function is responsible for freeing it.

FUNCTION: generate_UID_m10()

// Prototype

```
ui8 generate_UID_m10(ui8 *uid);
```

Generates an 8-byte random number that is not one of the MED reserved values. If NULL is passed for uid, this function will return a uid value, but is not thread-safe.

Examples:

```
generate_UUID(&universal_header->file_UID);
```

or

```
universal_header->file_UID = generate_UUID(NULL); // not thread safe
```

FUNCTION: get_channel_target_values_m10()

// Prototype

```
TERN_m10 get_channel_target_values_m10(CHANNEL_m10 *channel, si8 *target_uutc, si8 \
    *target_sample_number, si4 *target_segment_number, ui1 mode);
```

// Target Value Constants

```
#define FIND_START_m10 1
```

```
#define FIND_END_m10 2
```

Given a target_uutc or target_sample_number and a CHANNEL structure, finds target_uutc, target_sample_number, and target_segment_number. The mode parameter must be either FIND_START_m10, or FIND_END_m10. The unknown member of (target_uutc, target_sample_number) should contain (UUTC_NO_ENTRY_m10, SAMPLE_NUMBER_NO_ENTRY_m10). Returns TRUE_m10 on success, FALSE_m10 on failure.

FUNCTION: get_segment_range_m10()

// Prototype

```
si4 get_segment_range_m10(si1 **channel_list, si4 n_channels, TIME_SLICE_m10 *slice);
```

```
typedef struct {
```

```
    TERN_m10 conditioned;
```

```
    si8 start_time;
```

```
    si8 end_time;
```

```
    si8 start_index; // session-relative (global indexing)
```

```
    si8 end_index; // session-relative (global indexing)
```

```
    si8 local_start_index; // segment-relative (local indexing)
```

```
    si8 local_end_index; // segment-relative (local indexing)
```

```
    si8 number_of_samples;
```



```

    si4    start_segment_number;
    si4    end_segment_number;
    si8    session_start_time;
    si8    session_end_time;
    si1    *index_reference_channel_name; // channel base name or NULL, if unnecessary
    si4    index_reference_channel_index; // index of the index reference channel
                                              // in the session channel array
} TIME_SLICE_m10;

```

Finds the segment start and end number for the range described in the passed time slice. `idx_ref_chan` is needed if the channels in the channel list have different sampling frequencies, and the time slice specifies sample numbers. `idx_ref_chan` is the name of the channel that should be used to decide cutoffs. Other members of the time slice will be filled in. The function returns the number of segments that need to be read.

See heading "Time Slice Usage" below.

FUNCTION: `get_segment_target_values_m10()`

// Prototype

```

void get_segment_target_values_m10(SEGMENT_m10 *segment, si8 *target_uutc, si8 \
    *target_sample_number, ui1 mode);

```

// Target Value Constants

```

#define FIND_START_m10          1
#define FIND_END_m10            2

```

Given a `target_uutc` or `target_sample_number` and a `SEGMENT` structure, finds `target_uutc`, and `target_sample_number`. The mode parameter must be either `FIND_START_m10`, or `FIND_END_m10`. The unknown member of (`target_uutc`, `target_sample_number`) should contain (`UUTC_NO_ENTRY_m10`, `SAMPLE_NUMBER_NO_ENTRY_m10`).

If the passed `target_uutc` or `target_sample_number` do not fall within the segment, segment start or end parameters are returned as appropriate; hence the function returns void as it cannot fail.

FUNCTION: `get_session_target_values_m10()`

// Prototype

```

TERN_m10 get_session_target_values_m10(SESSION_m10 *session, si8 *target_uutc, si8 \
    *target_sample_number, si4 *target_segment_number, ui1 mode, si1 \
    *idx_ref_chan);

```

// Target Value Constants

```

#define FIND_START_m10          1
#define FIND_END_m10            2

```

Given a `target_uutc` or `target_sample_number` and a `SESSION` structure, finds `target_uutc`, `target_sample_number`, and `target_segment_number`. The mode parameter must be either `FIND_START_m10`, or `FIND_END_m10`. The unknown member of (`target_uutc`, `target_sample_number`) should contain (`UUTC_NO_ENTRY_m10`, `SAMPLE_NUMBER_NO_ENTRY_m10`). Returns `TRUE_m10` on success, `FALSE_m10` on failure.

`idx_ref_chan` is needed if the channels in the channel list have different sampling frequencies, and the target specifies a sample number. `idx_ref_chan` is the name of the channel that should be used to decide cutoffs.

See `get_segment_range_m10()` also.

FUNCTION: `initialize_file_processing_directives_m10()`

```
// Structures
typedef struct {
    TERN_m10    close_file;
    TERN_m10    flush_after_write;
    TERN_m10    update_universal_header; // when writing
    TERN_m10    leave_decrypted; // if encrypted during write, return from write
                                // function decrypted, also leave times unoffset
    TERN_m10    free_password_data; // when freeing FPS
    TERN_m10    free_CMP_processing_struct; // when freeing FPS
    ui4         lock_mode;
    ui4         open_mode;
} FILE_PROCESSING_DIRECTIVES_m10;

// File Processing Directives Defaults
#define FPS_DIRECTIVE_CLOSE_FILE_DEFAULT_m10    TRUE_m10
#define FPS_DIRECTIVE_FLUSH_AFTER_WRITE_DEFAULT_m10    TRUE_m10
#define FPS_DIRECTIVE_FREE_CMP_PROCESSING_STRUCT_DEFAULT_m10    TRUE_m10
#define FPS_DIRECTIVE_UPDATE_UNIVERSAL_HEADER_DEFAULT_m10    FALSE_m10
#define FPS_DIRECTIVE_LEAVE_DECRYPTED_DEFAULT_m10    FALSE_m10
#define FPS_DIRECTIVE_LOCK_MODE_DEFAULT_m10    FPS_NO_LOCK_MODE_m10
    // Unix file locking may cause problems with networked file systems
// #define FPS_DIRECTIVE_LOCK_MODE_DEFAULT_m10    (FPS_READ_LOCK_ON_READ_OPEN_m10 | \
    FPS_WRITE_LOCK_ON_WRITE_OPEN_m10 | FPS_WRITE_LOCK_ON_READ_WRITE_OPEN_m10)
#define FPS_DIRECTIVE_OPEN_MODE_DEFAULT_m10    FPS_NO_OPEN_MODE_m10

// Prototype
FILE_PROCESSING_DIRECTIVES_m10
*initialize_file_processing_directives_m10(FILE_PROCESSING_DIRECTIVES_m10 *directives);
```

If NULL is passed a FILE_PROCESSING_DIRECTIVES structure is allocated and it's pointer returned. In either case, the fields of the structure are set to their default values.

FUNCTION: `initialize_globals_m10()`

```
// Prototype
void initialize_globals_m10(void);
```

Allocates (if NULL) and initializes `globals_m10`, the MED globals structure on the global heap. Variables are initialized to their default values, and tables are assigned or constructed. The globals are used by many functions in the library. It includes boolean fields stating whether structure alignment has been confirmed, lookup tables for CRC calculation, UTF8 printing, AES encryption, and SHA hash functions, the session recording time offset and UTC offset, and a verbose flag which if set will cause many library functions to show the output of their processing.

This function is called by `initialize_medlib()`, but can be called before `initialize_medlib()` to change a default value.

Example (used to see verbose output of initialization functions):

```
initialize_globals_m10();
globals_m10->verbose = TRUE_m10;
initialize_medlib();
```

FUNCTION: initialize_medlib_m10()

```
// Prototype
si4 initialize_medlib_m10(void);
```

Initializes MED_globals to default values (if the MED_globals pointer is NULL, which it is at the launch of the library), checks CPU endianness, checks MED structure alignments, seeds the random number generator with the current time, sets the file creation umask, and loads the CRC, UTF8, AES, and SHA lookup tables into the global heap (not stack). Returns MED_TRUE if all structures are aligned, MED_FALSE if not. The function currently exits if the cpu endianness is not little endian. This can be changed if there is a demand for big endian processing going forward.

example 1:

```
if (initialize_medlib() == MED_FALSE) {
    fprintf(stderr, "error initializing medlib => exiting\n")
    exit(1);
}
MED_globals->verbose = MED_TRUE;    // globals initialized by initialize_medlib(),
                                   // default verbose setting is MED_FALSE
```

example 2:

```
initialize_MED_globals();           // globals will not be initialized by
initialize_medlib()
MED_globals->verbose = MED_TRUE;    // default verbose setting is MED_FALSE
initialize_medlib();
```

This example initializes MED_globals to their default values. It then sets verbose to MED_TRUE. Because MED_globals is not NULL, initialize_medlib() will not call initialize_MED_globals(), allowing verbose output of initialization routines, and preserving any other non-default global setting changes that were made.

FUNCTION: initialize_metadata_m10()

```
// Prototype
void initialize_metadata_m10(FILE_PROCESSING_STRUCT_m10 *fps, TERN_m10 \
    initialize_for_update);
```

The function sets all fields in a METADATA structure to their NO_ENTRY values. No encryption is performed. Section 2 fields are set according to the FPS/s channel type.

If initialize_for_update == TRUE_m10, the following section 2 fields are set to Zero rather than their No Entry values:

```
// time series, section 2
number_of_samples
number_of_blocks
maximum_block_byte
```

```
maximum_block_samples
maximum_block_difference_bytes
maximum_block_duration
number_of_discontinuities
maximum_contiguous_blocks
maximum_contiguous_block_bytes
maximum_contiguous_samples
```

```
// video, section 2
number_of_clips
maximum_clip_bytes
number_of_video_files
```

FUNCTION: initialize_time_slice_m10()

```
// Structure
typedef struct {
    TERN_m10    conditioned;
    si8    start_time;
    si8    end_time;
    si8    start_index; // session-relative (global indexing)
    si8    end_index; // session-relative (global indexing)
    si8    local_start_index; // segment-relative (local indexing)
    si8    local_end_index; // segment-relative (local indexing)
    si8    number_of_samples;
    si4    start_segment_number;
    si4    end_segment_number;
    si8    session_start_time;
    si8    session_end_time;
    si1    *index_reference_channel_name; // channel base name or NULL, if unnecessary
    si4    index_reference_channel_index; // index of the index reference channel
                                           // in the session channel array
} TIME_SLICE_m10;
```

```
// Prototype
TIME_SLICE_m10    *initialize_time_slice_m10(TIME_SLICE_m10 *slice);
```

The function allocates (if NULL is passed) and initializes the contents of a time slice structure.

See heading "Time Slice Usage" below.

FUNCTION: initialize_universal_header()

```
// Prototype
si4    initialize_universal_header_m10(FILE_PROCESSING_STRUCT_m10 *fps, ui4 type_code, \
    TERN_m10 generate_file_UID, TERN_m10 originating_file);
```

```
// Universal Header Structure
```

```

typedef struct {
    // start robust mode region
    ui4  header_CRC;      // CRC of the universal header after this field
    ui4  body_CRC;        // CRC of the entire file after the universal header
    si8  file_end_time;
    si8  number_of_entries;
    ui4  maximum_entry_size;
    // end robust mode region
    si4  segment_number;
    union { // anonymous union
        struct {
            si1  type_string[TYPE_BYTES_m10];
            ui1  MED_version_major;
            ui1  MED_version_minor;
            ui1  byte_order_code;
        };
        ui4  type_code;
    };
    si8  session_start_time;
    si8  file_start_time;
    si1  session_name[BASE_FILE_NAME_BYTES_m10];
    si1  channel_name[BASE_FILE_NAME_BYTES_m10];
    si1  anonymized_subject_ID[UNIVERSAL_HEADER_ANONYMIZED_SUBJECT_ID_BYTES_m10];
    ui8  session_UID;
    ui8  channel_UID;
    ui8  segment_UID;
    ui8  file_UID;
    ui8  provenance_UID;
    ui1  level_1_password_validation_field[PASSWORD_VALIDATION_FIELD_BYTES_m10];
    ui1  level_2_password_validation_field[PASSWORD_VALIDATION_FIELD_BYTES_m10];
    ui1  level_3_password_validation_field[PASSWORD_VALIDATION_FIELD_BYTES_m10];
    ui1  protected_region[UNIVERSAL_HEADER_PROTECTED_REGION_BYTES_m10];
    ui1  discretionary_region[UNIVERSAL_HEADER_DISCRETIONARY_REGION_BYTES_m10];
} UNIVERSAL_HEADER_m10;

```

The function sets universal header fields to default values. If generate_file_UID == TRUE_m10, it will be created. If originating_file == TRUE_m10, the provenance_UID will be set to the value of the file_UID. It fills in the current library's MED version and endianness.

example:

```

initialize_universal_header(fps, TIME_SERIES_METADATA_FILE_TYPE_CODE_m10, TRUE_m10,
TRUE_m10);

```

Initializes a time series metadata universal header with a new file UID, and the provenance UID set to the new file UID.

FUNCTION: CMP_normality_score_m10()

```

// Prototype
ui1  CMP_normality_score_m10(si4 *data, ui4 n_samps);

```

Returns the correlation of the distribution in the data to that expected from a normal distribution. Essentially a Kolmogorov-Smirnov test normalized to range [-1 to 0) = 0 & [0 to 1] = [0 to 254]. 255 is reserved for no entry. 0 is completely uncorrelated; 254 is “perfect” correlation. This is used as a noise score, and to decide whether lossy compression should be performed on a block if the CMP processing directive “require_normality” == TRUE_m10.

FUNCTION: MED_type_string_from_code_m10()

```
// Prototype
si1 *MED_type_string_from_code_m10(ui4 code);
```

Returns a pointer to a type string for all MED types, or NULL if the code does not exist.

FUNCTION: MED_type_code_from_string_m10()

```
// Prototype
ui4 MED_type_code_from_string_m10(si1 *string);
```

Returns a type code for all MED type strings, or NO_FILE_TYPE_CODE_m10 if no code exists for the passed string.

FUNCTION: merge_metadata_m10()

```
// Prototype
TERN_m10 merge_metadata_m10(FILE_PROCESSING_STRUCT_m10 *md_fps_1, \
                             FILE_PROCESSING_STRUCT_m10 *md_fps_2, FILE_PROCESSING_STRUCT_m10 \
                             *merged_md_fps);
```

If merged_md_fps == NULL, comparison results will be placed in md_fps_1->metadata.
Returns TRUE_m10 if md_fps_1->metadata == md_fps_2->metadata, FALSE_m10 otherwise.

FUNCTION: merge_universal_headers_m10()

```
// Prototype
TERN_m10 merge_universal_headers_m10(FILE_PROCESSING_STRUCT_m10 *fps_1, \
                                       FILE_PROCESSING_STRUCT_m10 *fps_2, FILE_PROCESSING_STRUCT_m10 *merged_fps);
```

If merged_fps == NULL, comparison results will be placed in fps_1->universal_header.
Returns TRUE_m10 if fps_1->universal_header == fps_2->universal_header, FALSE_m10 otherwise.

FUNCTION: message_m10()

```
// Prototype
void message_m10(si1 *fmt, ...);
```

Prints a warning message to stdout unless:
(globals_m10->behavior_on_fail & SUPPRESS_MESSAGE_OUTPUT_m10) != 0
and returns. Used like printf(). Also see error_message_m10(), warning_message_m10(), and force_behavior_m10().

Example:

```
message_m10("%s(): Test Message (called from line %d)", __FUNCTION__, \
__LINE__);
```

FUNCTION: numerical_fixed_width_string_m10()

// Prototype

```
si1 *numerical_fixed_width_string_m10(si1 *string, si4 string_bytes, si4 number);
```

Returns string, prepended with necessary number of zeros, to make a string of string_bytes characters containing the digits of number. If NULL is passed for string, it is allocated, and up to the caller to free. Useful in generating MED segment names, among other things.

FUNCTION: pad_m10()

// Prototype

```
si8 pad_m10(ui1 *buffer, si8 content_len, ui4 alignment);
```

Fills buffer beyond content_len (in bytes) with PAD_BYTE_VALUE, to next boundary determined by alignment. Returns (content_len + pad_bytes).

FUNCTION: process_password_data_m10()

// Prototype

```
TERN_m10 process_password_data_m10(si1 *unspecified_password, si1 \
    *L1_password, si1 *L2_password, si1 *L3_password, si1 *L1_hint, si1 *L2_hint, \
    FILE_PROCESSING_STRUCT_m10 *fps);
```

// Structures

```
typedef struct {
    ui1 level_1_encryption_key[ENCRYPTION_KEY_BYTES_m10];
    ui1 level_2_encryption_key[ENCRYPTION_KEY_BYTES_m10];
    si1 level_1_password_hint[PASSWORD_HINT_BYTES_m10];
    si1 level_2_password_hint[PASSWORD_HINT_BYTES_m10];
    ui1 access_level;
    ui1 processed; // 0 or 1 (not ternary)
} PASSWORD_DATA_m10;
```

Fills global PASSWORD_DATA structure and set it to processed.

If no passwords are passed (all are NULL), it simply sets the PASSWORD_DATA structure to an access_level of zero (access to unencrypted data only).

If an unspecified_password is passed, the function will determine whether the password is a level 1 or level 2 password and set the access_level of the PASSWORD_DATA structure accordingly via the password_validation_fields in the passed universal header. Appropriate decryption keys are generated and put into the PASSWORD_DATA structure. This is generally used for reading MED files.

If a level_1_password, level_2_password, or level_3_password is passed, the password validation fields will be generated into the passed universal_header structure. The access_level of the PASSWORD_DATA structure will be set according to whether a level_1 or level_2 password was passed. Appropriate encryption keys are generated and put into the PASSWORD_DATA structure. This is generally used for writing new MED files. *Note that for level 2 access, a level 1 password must be passed, even if level 1 encryption is never used in the new MED files.*

NOTE: If the FILE_PROCESSING_STRUCT corresponds to a metadata file, the password hints will be copied to the PASSWORD_DATA structure, otherwise they will be left empty. See set_time_and_password_data_m10() also.

The function also sets processed field to TRUE.

Example 1:

```
process_password_data(password, NULL, NULL, NULL, NULL, NULL, fps);
```

Processes an unspecified password for reading by validating against the password validation fields in the universal_header. Depending on the access level, a level 1 or both a level 1 and level 2 decryption keys are generated into their appropriate fields in the PASSWORD_DATA structure. A PASSWORD_DATA structure pointer is returned.

Example 2:

```
process_password_data(NULL, level_1_password, level_2_password, \
NULL, NULL, NULL, fps);
```

In writing a new MED file, a level 1 and level 2 password are passed, and their password validation fields are written into the universal header. Both level 1 and level 2 encryption keys are generated into their appropriate fields in the PASSWORD_DATA structure.

FUNCTION: read_channel_m10()

// Prototype

```
CHANNEL_m10 *read_channel_m10(CHANNEL_m10 *chan, si1 *chan_dir, TIME_SLICE_m10 *slice, \
    si1 *password, TERN_m10 read_time_series_data, TERN_m10 \
    read_record_data);
```

// Channel Types

```
UNKNOWN_CHANNEL_TYPE_m10    -1    // (NO_FILE_TYPE_CODE_m10)
TIME_SERIES_CHANNEL_TYPE_m10 1     // (TIME_SERIES_CHANNEL_DIRECTORY_TYPE_CODE_m10)
VIDEO_CHANNEL_TYPE_m10       2     // (VIDEO_CHANNEL_DIRECTORY_TYPE_CODE_m10)
```

// Structure

```
typedef struct {
    FILE_PROCESSING_STRUCT_m10 *metadata_fps; // ephemeral
    FILE_PROCESSING_STRUCT_m10 *record_data_fps;
    FILE_PROCESSING_STRUCT_m10 *record_indices_fps;
    si4 number_of_segments;
    SEGMENT_m10 **segments;
    si1 path[FULL_FILE_NAME_BYTES_m10];
    si1 name[BASE_FILE_NAME_BYTES_m10];
    TIME_SLICE_m10 time_slice;
} CHANNEL_m10;
```


This function will read the channel pointed to by `chan_dir` (full path to the channel directory) and fill in the the fields in the `CHANNEL` structure. If a channel structure is not passed (`NULL` passed), one will be allocated. A password should be passed to read encrypted fields if the global password structure has not already been set. In the case that no data is encrypted or only unencrypted data is needed, `NULL` can be passed for both fields.

If `read_time_series_data == TRUE_m10`, the time series segment data specified by `slice` will be read into its `SEGMENT` structures; otherwise only the segment data's universal header will be read into this field and the file pointer will be left at the beginning of the `CMP` block data for random or sequential reading. The same is true for the `read_record_data` parameter.

The `CHANNEL` metadata structure is ephemeral, i.e is the same as those contained in a segment `FPS`, but is not associated with a real file, rather it is constructed via a merge of all the segment metadata structures. It contains summary information of the segment metadata files. Fields whose values vary across segments and whose value cannot be expressed as a maximum, etc. are filled with their `NO_ENTRY` values. Likewise the universal header of this `FPS` represents a merge of the metadata universal headers from the segments.

The function returns a pointer to a `CHANNEL` structure, which is allocated if `NULL` was passed for `chan`.

example:

```
(void) read_MED_channel(&session->channels[i], full_file_name, NULL, NULL, password,
MED_FALSE, MED_FALSE);
```

This call reads the channel specified by `full_file_name` into a preallocated `CHANNEL` structure. A password is passed. The `read_time_series_data` and `read_record_data` flags are set to `MED_FALSE`, so only the universal headers will be read in from the segment files. All segments will be read because `slice` was `NULL`.

See heading "Time Slice Usage" below.

FUNCTION: read_file_m10()

// Prototype

```
FILE_PROCESSING_STRUCT_m10 *read_file_m10(FILE_PROCESSING_STRUCT_m10 *fps, si1 \
    *full_file_name, si8 number_of_items, ui1 **data_ptr_ptr, si8 *items_read, si1 \
    *password, ui4 behavior_on_fail);
```

// Structures

```
typedef struct {
    TERN_m10                mutex;
    si1                     full_file_name[FULL_FILE_NAME_BYTES_m10];
    FILE                     *fp; // file pointer
    si4                      fd; // file descriptor
    si8                      file_length;
    UNIVERSAL_HEADER_m10    *universal_header;
    FILE_PROCESSING_DIRECTIVES_m10 directives;
    METADATA_m10             metadata;
    TIME_SERIES_INDEX_m10    *time_series_indices;
    VIDEO_INDEX_m10          *video_indices;
    ui1                      *records;
    RECORD_INDEX_m10         *record_indices;
    si8                      raw_data_bytes;
    ui1                      *raw_data;
    CMP_PROCESSING_STRUCT_m10 *cps;
} FILE_PROCESSING_STRUCT_m10;
```

```

typedef struct {
    TERN_m10    close_file;
    TERN_m10    flush_after_write;
    TERN_m10    update_universal_header;
    TERN_m10    leave_decrypted;
    TERN_m10    free_password_data; // when freeing FPS
    TERN_m10    free_CMP_processing_struct; // when freeing FPS
    ui4         lock_mode;
    ui4         open_mode;
} FILE_PROCESSING_DIRECTIVES_m10;

// Constants
#define FPS_FULL_FILE_m10            -1
#define FPS_UNIVERSAL_HEADER_ONLY_m10 0

```

The function reads any MED file type, identified by its full path in `full_file_name`, (or the same field in a passed FPS), into a `FILE_PROCESSING_STRUCT` (FPS). If NULL is passed for the FPS one will be allocated. If the FPS's `full_file_name` field is NULL the passed `file_name` will be copied into this field. The file will be opened if it is not already open. If the `close_file` directive is set to `FALSE_m10`, the file will be left open, otherwise it will be closed after reading. The `number_of_items` parameter specifies how much of the file to read, how this translates into bytes will depend upon the file type.

The data are read into the `raw_data` field of the FPS. The FPS's `universal_header` pointer is set to point to the beginning of the raw data. The appropriate file type's structure pointer in the FPS is set to point to the raw data after the universal header.

If `password_data` is NULL, the function will process the passed password as an unspecified password and generate `password_data`. Otherwise `password_data` will be assigned to that field in the FPS.

`read_MED_file()` validates file CRCs according to the global `CRC_mode`. It decrypts encrypted data to the access level allowed by the password data. It offsets times according to the global `recording_time_offset_mode`.

If `data_ptr_ptr` is NULL data is read into the FPS's `raw_data` array. If `*data_ptr_ptr` is within the `raw_data` array boundaries, the data will be read into `*data_ptr_ptr`, and the array will be enlarged as necessary (modifying `*data_ptr_ptr`). If `*data_ptr_ptr` is custom, data will be read to there, but `read_file_m10()` will have no way of knowing if the target array is large enough, so this is the caller's responsibility.

The function returns a pointer to a `FILE_PROCESSING_STRUCT` or NULL if unsuccessful.

Example:

```

segment->time_series_data_fps = read_file_m10(NULL, full_file_name, \
    UNIVERSAL_HEADER_ONLY_m10, NULL, NULL, NULL, password_data, USE_GLOBAL_BEHAVIOR);

```

Reads the time series data file pointed to by `full_file_name`. `read_MED_file()` allocates and returns a pointer to the FPS. A `PASSWORD_DATA` structure is supplied, so password is not processed, and need not be passed. Only the universal header read in as the `number_of_items` is 0 (== `UNIVERSAL_HEADER_ONLY_m10`). The file is closed after reading as the FPS directive's default for `close_file` is `TRUE_m10`.

FUNCTION: read_segment_m10()

// Prototype

```
SEGMENT_m10 *read_segment_m10(SEGMENT_m10 *seg, si1 *seg_dir, TIME_SLICE_m10 *slice, \
    si1 *password, TERN_m10 read_time_series_data, TERN_m10 \
    read_record_data);
```

// Structure

```
typedef struct {
    FILE_PROCESSING_STRUCT_m10 *metadata_fps; // also used as prototype
    FILE_PROCESSING_STRUCT_m10 *time_series_data_fps;
    FILE_PROCESSING_STRUCT_m10 *time_series_indices_fps;
    FILE_PROCESSING_STRUCT_m10 *video_indices_fps;
    FILE_PROCESSING_STRUCT_m10 *record_data_fps;
    FILE_PROCESSING_STRUCT_m10 *record_indices_fps;
    FILE_PROCESSING_STRUCT_m10 *segmented_session_record_data_fps;
    FILE_PROCESSING_STRUCT_m10 *segmented_session_record_indices_fps;
    si1 path[FULL_FILE_NAME_BYTES_m10];
    si1 name[SEGMENT_BASE_FILE_NAME_BYTES_m10];
    TIME_SLICE_m10 time_slice;
} SEGMENT_m10;
```

This function will read the segment pointed to by `seg_dir` (full path to the segment directory) and fill in the the fields in the SEGMENT structure. If a segment structure is not passed (NULL passed), one will be allocated. Either an unspecified password, or PASSWORD_DATA structure should be passed to read encrypted fields. In the case that no data is encrypted or only unencrypted data is needed, NULL can be passed for both fields.

If `read_time_series_data == TRUE_m10` (and it is a time series segment), the time series data will be read into the SEGMENT structure's `data_fps raw_data` according to the limits in `slice`, or the full file if `slice` is NULL; otherwise only the segment data's universal header will be read and the file will be left open with the file pointer pointing to the CMP blocks. If `read_record_data == TRUE_m10`, the same process is followed, but for segment records.

The function returns a pointer to the SEGMENT structure.

example:

```
SEGMENT *segment;
```

```
segment = read_MED_segment(NULL, full_file_name, NULL, NULL, MED_TRUE, MED_TRUE);
```

This call will read the all the files of the segment pointed to by `full_file_name` and allocate and populate a SEGMENT structure. The passed `password_data` is assigned in the FILE_PROCESSING_STRUCTs. The time series data file is opened, read in full, and closed. Likewise for the segment record files, if present. This is an uncommon use for large data files as reading all of the data into memory is frequently impractical.

See heading "Time Slice Usage" below.

FUNCTION: read_session_m10()

// Prototype

```
SESSION_m10 *read_session_m10(si1 *sess_dir, si1 **chan_list, si4 n_chans, \
    TIME_SLICE_m10 *slice, si1 *idx_ref_chan, si1 *password, \
    TERN_m10 read_time_series_data, TERN_m10 read_record_data);
```

```
typedef struct {
    FILE_PROCESSING_STRUCT_m10 *time_series_metadata_fps; // ephemeral
```

```

FILE_PROCESSING_STRUCT_m10    *video_metadata_fps; // ephemeral
si4                           number_of_segments;
si4                           number_of_time_series_channels;
CHANNEL_m10                   **time_series_channels;
si4                           number_of_video_channels;
CHANNEL_m10                   **video_channels;
FILE_PROCESSING_STRUCT_m10    *record_data_fps;
FILE_PROCESSING_STRUCT_m10    *record_indices_fps;
FILE_PROCESSING_STRUCT_m10    **segmented_record_data_fps;
FILE_PROCESSING_STRUCT_m10    **segmented_record_indices_fps;
si1                            path[FULL_FILE_NAME_BYTES_m10];
si1                            name[BASE_FILE_NAME_BYTES_m10];
TIME_SLICE_m10                time_slice;
} SESSION_m10;

```

This function will read all the files associated with the session pointed to by sess_dir (full path to the session directory) , or the channels listed in chan_list, and fill in the the fields in the SESSION structure. If a SESSION structure is not passed (NULL passed), one will be allocated. Either an unspecified password, or PASSWORD_DATA structure should be passed to read encrypted fields. In the case that no data is encrypted or only unencrypted data is needed, NULL can be passed for both fields.

If read_time_series_data == TRUE_m10 (for time series segments), the time series data will be read into the SEGMENT structure's data_fps raw_data according to the limits in slice, or the full file if slice is NULL; otherwise only the segment data's universal header will be read and the file will be left open with the file pointer pointing to the CMP blocks. If read_record_data == TRUE_m10, the same process is followed, but for segment records.

The function returns a pointer to the SEGMENT structure.

Example:

```

SESSION            *session;

session = read_session_m10(NULL, session_directory, NULL, 0, NULL, NULL, password, NULL,
MED_FALSE, MED_FALSE);
SESSION_m10 *read_session_m10(si1 *sess_dir, si1 **chan_list, si4 n_chans, \
    TIME_SLICE_m10 *slice, si1 *idx_ref_chan, si1 *password, \
    TERN_m10 read_time_series_data, TERN_m10 read_record_data);

```

This call will allocate a SESSION structure and read all files associated with the MED session specific by sess_dir and fill in the fields of at the SESSION structure and all of its substructures. It will not read the segment data, or record data, but the universal headers of those files will be read, and the files will be left open. Their file pointers will be left at the beginning of the data after the universal header. All other files will be read completely into their FILE_PROCESSING_STRUCTs and closed.

See heading "Time Slice Usage" below.

FUNCTION: read_time_series_data_m10()

```

// Prototype
si8  read_time_series_data_m10(SEGMENT_m10 *seg, si8 local_start_idx, \
    si8 local_end_idx, TERN_m10 alloc_cps);

```

This function reads a sample range from a segment. The parameters `local_start_idx` and `local_end_idx` are segment relative. The data are decompressed to `seg->time_series_data_fps->cps->decompressed_ptr`, and this pointer is updated.

It returns the number of samples read, which may be less than $(\text{local_end_idx} - \text{local_start_idx} + 1)$ if either exceeds the segment boundaries.

FUNCTION: `realloc_file_processing_struct_m10()`

// Prototype

```
si4  realloc_file_processing_struct_m10(FILE_PROCESSING_STRUCT_m10 *fps, si8 \
    new_raw_data_bytes);
```

This function reallocates the `raw_data` array to `new_raw_data_bytes` bytes. Existing data are preserved, extra bytes are zeroed. The `raw_data_bytes` field of the FPS is updated and appropriate pointers in the FPS are updated.

FUNCTION: `recover_passwords_m10()`

// Prototype

```
void  recover_passwords_m10(si1 *L3_password, UNIVERSAL_HEADER_m10 *universal_header);
```

This function will recover level 1 & level 2 passwords if they were created with a level 3 password, and it is passed.

FUNCTION: `remove_recording_time_offset_m10()`

// Prototype

```
inline void remove_recording_time_offset_m10(si8 *time);
```

The global recording time offset is removed from the passed μ UTC time.

FUNCTION: `reset_metadata_for_update_m10()`

// Prototype

```
void  reset_metadata_for_update_m10(FILE_PROCESSING_STRUCT_m10 *fps);
```

Resets a metadata structure section 2 fields for update. See `initialize_metadata_m10()` for details. Useful when acquiring new segment data and reusing the same segment metadata structures.

FUNCTION: `sample_number_for_uutc_m10()`

// Target Value Constants

```
#define DEFAULT_MODE_m10          0
#define FIND_START_m10            1
#define FIND_END_m10              2
#define FIND_CENTER_m10           3
#define FIND_CURRENT_m10          4
#define FIND_NEXT_m10             5
#define FIND_CLOSEST_m10          6
```

// Prototype

```
si8 sample_number_for_uutc_m10(si8 ref_sample_number, si8 ref_uutc, si8 target_uutc,  
sf8 sampling_frequency, FILE_PROCESSING_STRUCT_m10 *time_series_indices_fps, ui1 mode);
```

Return a sample number for a given uutc. Mode should be a member of { FIND_CURRENT_m10, FIND_CLOSEST_m10, FIND_NEXT_m10 }.

FIND_CURRENT_m10 (default): sample period within which the target_uutc falls

FIND_CLOSEST_m10: sample number closest to the target_uutc

FIND_NEXT_m10: sample number following the sample period within which the target_uutc falls

(FIND_NEXT_m10 == FIND_CURRENT_m10 + 1)

Examples:

- 1) Return sample number extrapolated from ref_sample_number
sample_number_for_uutc_m10(ref_sample_number, ref_uutc, target_uutc, sampling_frequency, NULL, 0, mode);
- 2) Return sample number extrapolated from closest time series index in local (segment-relative) sample numbering
sample_number_for_uutc_m10(SAMPLE_NUMBER_NO_ENTRY_m10, UUTC_NO_ENTRY_m10, \ target_uutc, sampling_frequency, tsi, number_of_indices, mode);
- 3) Return sample number extrapolated from closest time series index in absolute (channel-relative) sample numbering. In this case ref_sample_number is the segment absolute start sample number.
sample_number_for_uutc_m10(ref_sample_number, UUTC_NO_ENTRY_m10, \ target_uutc, sampling_frequency, tsi, number_of_indices, mode);

FUNCTION: search_segment_metadata_m10()

// Prototype

```
TERN_m10 search_segment_metadata_m10(si1 *MED_dir, TIME_SLICE_m10 *slice);
```

Used to find segment range encompassed by slice when Sgmt records do not exist (*plug: they are optional, but tiny, and make this process much more efficient*). Returns TRUE_m10 on success, FALSE_M10 on failure.

See heading "Time Slice Usage" below.

FUNCTION: search_Sgmt_records_m10()

// Prototype

```
TERN_m10 search_Sgmt_records_m10(si1 *MED_dir, TIME_SLICE_m10 *slice);
```

Used to find segment range encompassed by slice (*plug: Sgmt records are optional, but tiny, and make this process much more efficient*). Returns TRUE_m10 on success, FALSE_M10 on failure.

See heading "Time Slice Usage" below.

FUNCTION: set_global_time_constants_m10()

// Structure

```
typedef struct {
```

```

    si1    country[METADATA_RECORDING_LOCATION_BYTES_m10];
    si1    country_acronym_2_letter[3]; // two-letter acronym; (ISO 3166 ALPHA-2)
    si1    country_acronym_3_letter[4]; // three-letter acronym (ISO-3166 ALPHA-3)
    si1    territory[METADATA_RECORDING_LOCATION_BYTES_m10];
    si1    territory_acronym[TIMEZONE_STRING_BYTES_m10];
    si1    standard_timezone[TIMEZONE_STRING_BYTES_m10];
    si1    standard_timezone_acronym[TIMEZONE_ACRONYM_BYTES_m10];
    si4    standard_utc_offset; // seconds
    si4    observe_DST;
    si1    daylight_timezone[TIMEZONE_STRING_BYTES_m10];
    si1    daylight_timezone_acronym[TIMEZONE_ACRONYM_BYTES_m10];
    si1    daylight_time_start_description[METADATA_RECORDING_LOCATION_BYTES_m10];
    si8    daylight_time_start_code; // DAYLIGHT_TIME_CHANGE_CODE_m10
    si1    daylight_time_end_description[METADATA_RECORDING_LOCATION_BYTES_m10];
    si8    daylight_time_end_code; // DAYLIGHT_TIME_CHANGE_CODE_m10
} TIMEZONE_INFO_m10;

```

// Prototype

```

void set_global_time_constants_m10(TIMEZONE_INFO_m10 *timezone_info, si8
session_start_time);

```

Uses information in `timezone_info` to find the matching entry in the global timezone table, and then set time globals accordingly. Only enough information to make a solitary match is necessary. If there are multiple possible matches, a prompt dialog is initiated. If a value is passed for `session_start_time` (i.e. not zero), the global `recording_time_offset` is set also.

`session_start_time` parameter:

- pass zero to just match the timezone info (e.g. to get the `standard_utc_offset` based on locale)
 - global `recording_time_offset` is not set
 - set global `recording_time_offset` by calling `generate_recording_time_offset_m10()` separately after generating the `session_start_time` parameter
- pass `CURRENT_TIME_m10` to use the current time to generate the global `recording_time_offset`
- pass an unoffset `µUTC` to use that to generate the global `recording_time_offset`

FUNCTION: `set_time_and_password_data_m10()`

// Prototype

```

TERN_m10 set_time_and_password_data_m10(si1 *unspecified_password, si1 \
    *MED_directory, si1 *section_2_encryption_level, si1 *section_3_encryption_level);

```

Finds the closest metadata file given a MED directory, and reads it using the unspecified password. The metadata is used to fill in the global time data, and the unspecified password is used, in conjunction with the metadata file, to fill the global a password data structure. The metadata section 2 & 3 encryption levels are also returned. The metadata file is closed and freed. This function is useful when beginning to read a series of files in a MED session, as these functions need only be performed once. TRUE is returned on success, FALSE on failure.

NOTE: reading any metadata file with `read_file_m10()`, and then freeing it, will accomplish the same thing as this function.

FUNCTION: `show_file_processing_struct_m10()`

// Prototype

```

void show_file_processing_struct_m10(FILE_PROCESSING_STRUCT_m10 *fps);

```

```

// Structures
typedef struct {
    TERN_m10                mutex;
    si1                     full_file_name[FULL_FILE_NAME_BYTES_m10];
    FILE                    *fp;    // file pointer
    si4                     fd;     // file descriptor
    si8                     file_length;
    UNIVERSAL_HEADER_m10    *universal_header;
    FILE_PROCESSING_DIRECTIVES_m10 directives;
    PASSWORD_DATA_m10       *password_data;
    METADATA_m10            metadata;
    TIME_SERIES_INDEX_m10   *time_series_indices;
    VIDEO_INDEX_m10         *video_indices;
    ui1                     *records;
    RECORD_INDEX_m10        *record_indices;
    si8                     raw_data_bytes;
    ui1                     *raw_data;
    CMP_PROCESSING_STRUCT_m10 *cps;
} FILE_PROCESSING_STRUCT_m10;

```

Displays all the elements of a FILE_PROCESSING_STRUCT_m10 structure.

FUNCTION: show_globals_m10()

```

// Prototype
void show_globals_m10();

```

Displays MED globals.

FUNCTION: show_metadata_m10()

```

// Structure
typedef struct {
    ui1                     *metadata;
    METADATA_SECTION_1_m10  *section_1;
    TIME_SERIES_METADATA_SECTION_2_m10 *time_series_section_2;
    VIDEO_METADATA_SECTION_2_m10 *video_section_2;
    METADATA_SECTION_3_m10  *section_3;
} METADATA_m10;

```

```

// Prototype
void show_metadata_m10(FILE_PROCESSING_STRUCT_m10 *fps, METADATA_m10 *md);

```

Displays all the elements of a METADATA structure of the type specified by the passed FPS or METADATA structure pointer. Only one of the two parameters needs to be passed. The other can be NULL.

FUNCTION: show_password_data_m10()


```
// Structures
typedef struct {
    ui1    level_1_encryption_key[ENCRYPTION_KEY_BYTES_m10];
    ui1    level_2_encryption_key[ENCRYPTION_KEY_BYTES_m10];
    si1    level_1_password_hint[PASSWORD_HINT_BYTES_m10];
    si1    level_2_password_hint[PASSWORD_HINT_BYTES_m10];
    ui1    access_level;
    ui1    processed; // 0 or 1 (not ternary)
} PASSWORD_DATA_m10;
```

```
// Prototype
void show_password_data_m10(FILE_PROCESSING_STRUCT_m10 *fps);
```

Displays all the elements of a PASSWORD_DATA structure. Only one of the two parameters needs to be passed; the other can be NULL.

FUNCTION: show_records_m10()

```
// Constants
#define UNKNOWN_NUMBER_OF_ENTRIES_m10    -1
#define ALL_TYPES_CODE_m10                (ui4) 0xFFFFFFFF
```

```
// Prototype
void show_records_m10(FILE_PROCESSING_STRUCT_m10 *fps, ui4 type_code);
```

This function displays the contents of the records data file of type type_code, or all records if type_code == ALL_TYPES_CODE_m10. If the record needs to be decrypted and the access level is sufficient, the record will be decrypted. show_records_m10() calls show_record_m10() for each record to be displayed. show_record_m10() resides in the medrec_m10.c file. The number of records is read from the universal header's number_of_entries field. If that field contains UNKNOWN_NUMBER_OF_ENTRIES_m10, the function will still work (but could fail in the case of an incomplete terminal record).

FUNCTION: show_time_slice_m10()

```
// Prototype
void show_time_slice_m10(TIME_SLICE_m10 *slice);
```

This function displays the contents of a time slice.

FUNCTION: show_timezone_info_m10()

```
// Structure
typedef struct {
    si1    country[METADATA_RECORDING_LOCATION_BYTES_m10];
    si1    country_acronym_2_letter[3]; // (ISO 3166 ALPHA-2)
    si1    country_acronym_3_letter[4]; // (ISO-3166 ALPHA-3)
    si1    territory[METADATA_RECORDING_LOCATION_BYTES_m10];
```

```

    si1    territory_acronym[TIMEZONE_STRING_BYTES_m10];
    si1    standard_timezone[TIMEZONE_STRING_BYTES_m10];
    si1    standard_timezone_acronym[TIMEZONE_ACRONYM_BYTES_m10];
    si4    standard_UTC_offset; // seconds
    si4    observe_DST;
    si1    daylight_timezone[TIMEZONE_STRING_BYTES_m10];
    si1    daylight_timezone_acronym[TIMEZONE_ACRONYM_BYTES_m10];
    si1    daylight_time_start_description[METADATA_RECORDING_LOCATION_BYTES_m10];
    si8    daylight_time_start_code; // DAYLIGHT_TIME_CHANGE_CODE_m10 as si8
    si1    daylight_time_end_description[METADATA_RECORDING_LOCATION_BYTES_m10];
    si8    daylight_time_end_code; // DAYLIGHT_TIME_CHANGE_CODE_m10 as si8
} TIMEZONE_INFO_m10;

```

// Prototype

```
void show_timezone_info_m10(TIMEZONE_INFO_m10 *timezone_entry);
```

This function displays the contents of a TIMEZONE_INFO_m10 structure.

FUNCTION: show_universal_header_m10()

// Structure

```

typedef struct {
    // start robust mode region
    ui4    header_CRC;      // CRC of the universal header after this field
    ui4    body_CRC;        // CRC of the entire file after the universal header
    si8    file_end_time;
    si8    number_of_entries;
    ui4    maximum_entry_size;
    // end robust mode region
    si4    segment_number;
    union { // anonymous union
        struct {
            si1    type_string[TYPE_BYTES_m10];
            ui1    MED_version_major;
            ui1    MED_version_minor;
            ui1    byte_order_code;
        };
        ui4    type_code;
    };
    si8    session_start_time;
    si8    file_start_time;
    si1    session_name[BASE_FILE_NAME_BYTES_m10];
    si1    channel_name[BASE_FILE_NAME_BYTES_m10];
    si1    anonymized_subject_ID[UNIVERSAL_HEADER_ANONYMIZED_SUBJECT_ID_BYTES_m10];
    ui8    session_UID;
    ui8    channel_UID;
    ui8    segment_UID;
    ui8    file_UID;
    ui8    provenance_UID;
}

```

```

    ui1    level_1_password_validation_field[PASSWORD_VALIDATION_FIELD_BYTES_m10];
    ui1    level_2_password_validation_field[PASSWORD_VALIDATION_FIELD_BYTES_m10];
    ui1    level_3_password_validation_field[PASSWORD_VALIDATION_FIELD_BYTES_m10];
    ui1    protected_region[UNIVERSAL_HEADER_PROTECTED_REGION_BYTES_m10];
    ui1    discretionary_region[UNIVERSAL_HEADER_DISCRETIONARY_REGION_BYTES_m10];
} UNIVERSAL_HEADER_m10;

```

// Prototype

```

void show_universal_header_m10(FILE_PROCESSING_STRUCT_m10 *fps, UNIVERSAL_HEADER_m10
*uh);

```

This function displays the contents of a UNIVERSAL_HEADER_m10 structure. Only one of the two parameters needs to be passed; the other can be NULL.

FUNCTION: size_string_m10()

// Prototype

```

si1    *size_string_m10(si1 *size_str, si8 n_bytes);

```

// size_str buffer should be of length SIZE_STRING_BYTES_m10;

Returns a pointer to a string describing the number of bytes (n_bytes) in the largest size units covered by the size. If size_str is not NULL it will be used for the return string; if not a pointer to a static string is returned, which is not thread safe.

SECTION: Time Slice Usage

// Structure

```

typedef struct {
    TERN_m10    conditioned;
    si8    start_time;
    si8    end_time;
    si8    start_index; // session-relative (global indexing)
    si8    end_index; // session-relative (global indexing)
    si8    local_start_index; // segment-relative (local indexing)
    si8    local_end_index; // segment-relative (local indexing)
    si8    number_of_samples;
    si4    start_segment_number;
    si4    end_segment_number;
    si8    session_start_time;
    si8    session_end_time;
    si1    *index_reference_channel_name; // channel base name or NULL, if unnecessary
    si4    index_reference_channel_index; // index of the index reference channel
                                           // in the session channel array
} TIME_SLICE_m10;

```

// Constants

```

#define BEGINNING_OF_INDICES_m10    ((si8) 0x0000000000000000)
#define END_OF_INDICES_m10          ((si8) 0x7FFFFFFFFFFFFFFF)

```

```

#define SAMPLE_NUMBER_NO_ENTRY_m10 ((si8) 0x8000000000000000)
#define UUTC_NO_ENTRY_m10           ((si8) 0x8000000000000000)
#define UUTC_EARLIEST_TIME_m10      ((si8) 0x0000000000000000)
                                     // 00:00:00.000000 Thursday, 1 Jan 1970, UTC
#define UUTC_LATEST_TIME_m10        ((si8) 0x7FFFFFFF00000000)
                                     // 04:00:54.775808 Sunday, 10 Jan 29424, UTC
#define BEGINNING_OF_TIME_m10       UUTC_EARLIEST_TIME_m10
#define END_OF_TIME_m10             UUTC_LATEST_TIME_m10

```

The time slice is used throughout the library to pass a set of parameters that describe a portion of time that occurred within a MED session. The slice will accept either times or indices as boundaries. The search functions fill in the unfilled values, i.e. if times are passed, samples will be returned. The boundary values themselves might also be modified, if for instance the session end time occurs before the requested time.

To begin with the first sample in a session:

```

slice->start_time = BEGINNING_OF_TIME_m10; ...AND... slice->start_index = SAMPLE_NUMBER_NO_ENTRY_m10;
...OR...
slice->start_index = BEGINNING_OF_INDICES_m10; ...AND... slice->start_time = UUTC_NO_ENTRY_m10;

```

To finish with the last sample in a session:

```

slice->end_time = END_OF_TIME_m10; ...AND... slice->end_index = SAMPLE_NUMBER_NO_ENTRY_m10;
...OR...
slice->end_index = END_OF_INDICES_m10; ...AND... slice->end_time = UUTC_NO_ENTRY_m10;

```

NOTE: If indices are passed as the search medium, and the sampling frequency varies between channels in the selected channel set, an **index_reference_channel_name** must be supplied. This is the channel to which the passed indices refer. The other channels will be returned based on the points in time that the passed indices refer to in the index reference channel. If no index reference channel is passed when one is required, a warning is displayed and the first channel in the channel set will be used as the index reference channel.

The functions handle offset and un-offset times without modification. If the times are < 0, they are considered to be microseconds **relative to the session start time**. E.g. to get the first second of data: slice->start_time = 0; slice->end_time = 999999. These times are considered relative. On return, the times will be replaced by absolute times (offset applied).

FUNCTION: time_string_m10()

// Text Color String Constants

```

#define TC_BLACK_m10           "\033[30m"
#define TC_RED_m10             "\033[31m"
#define TC_GREEN_m10           "\033[32m"
#define TC_YELLOW_m10          "\033[33m"
#define TC_BLUE_m10            "\033[34m"
#define TC_MAGENTA_m10         "\033[35m"
#define TC_CYAN_m10            "\033[36m"
#define TC_WHITE_m10           "\033[37m"
#define TC_BRIGHT_BLACK_m10    "\033[30;1m"
#define TC_BRIGHT_RED_m10      "\033[31;1m"
#define TC_BRIGHT_GREEN_m10     "\033[32;1m"
#define TC_BRIGHT_YELLOW_m10    "\033[33;1m"
#define TC_BRIGHT_BLUE_m10      "\033[34;1m"
#define TC_BRIGHT_MAGENTA_m10  "\033[35;1m"

```

```
#define TC_BRIGHT_CYAN_m10      "\033[36;1m"
#define TC_BRIGHT_WHITE_m10     "\033[37;1m"
#define TC_RESET_m10            "\033[0m"
```

```
// Prototype
```

```
si1  *time_string_m10(si8 utc, si1 *time_str, TERN_m10 fixed_width, si4 /
    colored_text, ...);
```

```
// time_str buffer should be of length TIME_STRING_BYTES_m10;
```

Returns a string with local date and time from a μ UTC time. If time_str is not NULL it will be used for the return string; if not a pointer to a static string is returned, which is not thread safe.

If utc == 0, the current time will be returned.

If fixed_width == TRUE_m10, the string will be formatted so that all times have the same width.

If colored_text == TRUE_m10, two more arguments are expected: date_color & time_color. The arguments should be one of the defined text color strings (above).

If a recording time offset is applied the standard timezone acronym is set to "oUTC", and the standard timezone string is set to "offset Coordinated Universal Time".

If Daylight Saving Time (DST) was in effect at the passed time, in the recording locale, it will be applied and reflected in the timezone acronym and string.

FUNCTION: ts_sort_m10()

```
// Prototype
```

```
si8  ts_sort_m10(si4 *x, si8 len, NODE_m10 *nodes, NODE_m10 *head, NODE_m10 *tail, si4 \
    return_sorted_ts, ...);
```

This is an efficient sorting algorithm for *time series data*. If nodes are NULL they will be allocated and freed, but head and tail nodes should still be passed. If return_sorted_ts == TRUE_m10, an extra argument should be passed which is the array into which to place the sorted data. This can be the input array if desired. The node array (linked list) is often the target form of the data; expanding back to a sorted array may be unnecessary and inefficient.

FUNCTION: unescape_spaces_m10()

```
// Prototype
```

```
void  unescape_spaces_m10(si1 *string);
```

This function removes backslashes occurring before spaces in the passed string.

FUNCTION: utc_for_sample_number_m10()

```
// Prototype
```

```
si8  utc_for_sample_number_m10(si8 ref_sample_number, si8 ref_utc, si8 \
    target_sample_number, sf8 sampling_frequency, FILE_PROCESSING_STRUCT_m10 \
    *time_series_indices_fps, ui1 mode);
```

```
// Target Value Constants
```

```
#define DEFAULT_MODE_m10      0
#define FIND_START_m10        1
#define FIND_END_m10          2
#define FIND_CENTER_m10       3
#define FIND_CURRENT_m10      4
#define FIND_NEXT_m10         5
#define FIND_CLOSEST_m10      6
```

Return a μ UTC for a given sample number. Mode should be a member of { FIND_START_m10, FIND_END_m10, FIND_CENTER_m10 }.

Sample time is defined as the period from sample onset until the next sample.

FIND_START_m10 (default): first uutc \geq start of target_sample_number period

FIND_END_m10: last uutc $<$ start of next sample period

FIND_CENTER_m10: uutc closest to the center of the sample period

Examples:

- 1) Return uutc extrapolated from ref_uutc with sample numbering in context of ref_sample_number & target_sample_number
uutc = uutc_for_sample_number_m10(ref_sample_number, ref_uutc, target_sample_number, \ sampling_frequency, NULL, mode);
- 2) Return uutc extrapolated from ref_uutc, assumed to occur at sample number 0, with local (segment-relative) sample numbering
uutc = uutc_for_sample_number_m10(SAMPLE_NUMBER_NO_ENTRY_m10, ref_uutc, \ target_sample_number, sampling_frequency, NULL, mode);
- 3) Return uutc extrapolated from ref_uutc with local (segment-relative) sample numbering
uutc = uutc_for_sample_number_m10(SAMPLE_NUMBER_NO_ENTRY_m10, UUTC_NO_ENTRY_m10, \ target_sample_number, sampling_frequency, time_series_indices_fps, mode);
- 4) Return uutc extrapolated from closest time series index using absolute sample numbering
uutc = uutc_for_sample_number_m10(ref_sample_number, UUTC_NO_ENTRY_m10, \ target_sample_number, sampling_frequency, time_series_indices_fps, mode);

FUNCTION: validate_record_data_CRCs_m10()

```
// Prototype
```

```
TERN_m10 validate_record_data_CRCs_m10(RECORD_HEADER_m10 *record_header, si8 \ number_of_items);
```

The function validates the record header CRCs for number_of_items records pointed to by record_header. Returns TRUE_m10 if all CRCs are valid, FALSE_M10 otherwise.

FUNCTION: validate_time_series_data_CRCs_m10()

```
// Prototype
```

```
TERN_m10 validate_time_series_data_CRCs_m10(CMP_BLOCK_FIXED_HEADER_m10 \ *block_header, si8 number_of_items);
```

The function validates the CMP block header CRCs for number_of_items CMP blocks pointed to by block_header. Returns TRUE_m10 if all CRCs are valid, FALSE_M10 otherwise.

FUNCTION: warning_message_m10()

// Prototype

```
void warning_message_m10(si1 *fmt, ...);
```

Prints a warning message to stderr unless:

(globals_m10->behavior_on_fail & SUPPRESS_WARNING_OUTPUT_m10) != 0

and returns. Used like fprintf(). Also see error_message_m10(), message_m10(), and force_behavior_m10().

Example:

```
warning_message_m10("%s(): No samples in block (called from line %d)", __FUNCTION__, \
__LINE__);
```

FUNCTION: write_file_m10()

// Constants

```
#define FPS_FULL_FILE_m10 -1
```

```
#define FPS_UNIVERSAL_HEADER_ONLY_m10 0
```

// Prototype

```
si8 write_file_m10(FILE_PROCESSING_STRUCT_m10 *fps, ui8 number_of_items, void \
*data_ptr, ui4 behavior_on_fail);
```

The function will write out the file contained in the FILE_PROCESSING_STRUCT. If the file is not yet open, it will be opened. If the file requires encryption it will be encrypted. Times will be offset according to the global recording_time_offset_mode. The file CRCs will be calculated according to the global CRC_mode and the entered into the universal header. It returns the number of bytes written. If the close_file directive is set to TRUE_m10, the file will be closed after writing, otherwise it will be left open.

Specifics of function behavior:

- 1) If (fps->fp == NULL)
 - a) Opens file for writing and creates directory tree to the file if it doesn't exist
 - b) Writes out universal header to set file pointer to end of universal header
 - c) Clobbers file if it exists
- 2) If (number_of_items == FPS_FULL_FILE_m10)
number_of_items set to universal_header->number_of_entries
- 3) If (number_of_items == 0) // for clarity in code, the constant FPS_UNIVERSAL_HEADER_ONLY_m10 is defined as 0
 - a) the universal header will be written out
 - b) universal header is not updated unless fps->directives.update_universal_header == TRUE_m10
 - c) the file pointer will be left at the end of the universal header
- 4) Data is written from data_ptr to the current file pointer
if (data_ptr == NULL), data_ptr is set to end of universal_header
- 5) All times are offset
- 6) All encryptable file types are encrypted

7) All CRCs are calculated or updated

8) The universal header field `number_of_entries` is increased by the calling argument `number_of_items`. If overwriting existing data, or truncating a file, this field should be set explicitly.

9) The universal header field `maximum_entry_size` is updated if the size of any of the items written exceeds its current value. If overwriting existing data, or truncating a file, this field should be set explicitly.

10) Output is written to files according to `number_of_items`:

- a) time series data files: an item is a compressed data block
- b) time series indices files: an item is a time series index
- c) record data files: an item is a record
- d) record index files: an item is a record index
- e) metadata files: an item is a metadata structure

11) If `(fps->directives.update_universal_header == TRUE_m10)`

- a) the universal header CRC will be updated and the universal header will be written out
- b) the file pointer is repositioned to the end of the file

12) If `(fps->directives.close_file == TRUE_m10)`
the universal header is updated before closure: `fps->directives.update_universal_header` does not need to be set

13) If `(behavior_on_fail == USE_GLOBAL_BEHAVIOR_m10)`
`behavior_on_fail` is set to `globals_m10->behavior_on_fail`

```
/*
/*****
/***** CMP Functions *****/
/*****/
```

```
// Structures
typedef struct {
    // CMP block header fixed region start
    ui8    block_start_UID;
    ui4    block_CRC;
    ui4    block_flags;
    si8    start_time;
    si4    acquisition_channel_number;
    ui4    total_block_bytes;
    // CMP block encryption start
    ui4    number_of_samples;
    ui2    number_of_records;
    ui2    record_region_bytes;
    ui4    parameter_flags;
    ui2    parameter_region_bytes;
    ui2    protected_region_bytes;
    ui2    discretionary_region_bytes;
    ui2    model_region_bytes;
    ui4    total_header_bytes;
    // CMP block header variable region start
} CMP_BLOCK_FIXED_HEADER_m10;
```

```
typedef struct {
```



```

ui4      mode; // CMP_COMPRESSION_MODE_m10, CMP_DECOMPRESSION_MODE_m10
ui4      algorithm; // RED, PRED, or MBE
si1      encryption_level; // encryption level for data blocks:
                        // passed in compression
TERN_m10 fall_through_to_MBE; // if MBE would be smaller than RED/PRED,
                        // use MBE for that block
TERN_m10 reset_discontinuity; // if discontinuity directive == TRUE_m10,
                        // reset to FALSE_m10 after compressing the
                        // block
TERN_m10 include_noise_scores;
TERN_m10 no_zero_counts; // in RED & PRED codecs (when blocks must be
                        // encoded with non-block statistics. This is a
                        // special case.)
TERN_m10 free_password_data; // when freeing CPS
TERN_m10 set_derivative_level; // value passed in "derivative_level"
                        // parameter
TERN_m10 find_derivative_level; // mutually exclusive with
                        // "set_derivative_level"
// lossy compression directives
TERN_m10 detrend_data; // Lossless operation, but most useful for lossy
                        // compression.
TERN_m10 require_normality; // For lossy compression - use lossless if data
                        // amplitudes are too oddly distributed. Pairs
                        // with "minimum_normality" parameter.
TERN_m10 use_compression_ratio; // Used in "find" directives. Mutually
                        // exclusive with
                        // "use_mean_residual_ratio".
TERN_m10 use_mean_residual_ratio; // Used in "find" directives. Mutually
                        // exclusive with
                        // "use_compression_ratio".
TERN_m10 use_relative_ratio; // divide goal ratio by the block coefficient
                        // of variation in lossy compression routines
                        // (more precision in blocks with higher
                        // variance)
TERN_m10 set_amplitude_scale; // value passed in "amplitude_scale"
                        // parameter
TERN_m10 find_amplitude_scale; // mutually exclusive with
                        // "set_amplitude_scale"
TERN_m10 set_frequency_scale; // value passed in "frequency_scale"
                        // parameter
TERN_m10 find_frequency_scale; // mutually exclusive with
                        // "set_frequency_scale"
} CMP_DIRECTIVES_m10;

typedef struct {
    si4      number_of_block_parameters;
    ui4      *block_parameters; // pointer beginning of parameter region of block
                        // header
    ui4      block_parameter_map[ CMP_PF_PARAMETER_FLAG_BITS_m10 ];
    si4      minimum_sample_value; // found on compression, stored for use in

```

```

// METADATA (and MBE, if used)
si4      maximum_sample_value; // stored for use in METADATA (and MBE, if used)
TERN_m10 discontinuity; // set if block is first after a discontinuity, passed
// in compression, returned in decompression
ui1      no_zero_counts_flag;
ui1      derivative_level; // used by with set_derivative_level directive, also
// returned in decode
// lossy compression parameters
sf8      goal_ratio; // either compression ratio or mean residual ratio
sf8      actual_ratio; // either compression ratio or mean residual ratio
sf8      goal_tolerance; // tolerance for lossy compression mode goal, value of
// <= 0.0 uses default values, which are returned
si4      maximum_goal_attempts; // maximum loops to attain goal compression
ui1      minimum_normality;
sf4      amplitude_scale; // used with set_amplitude_scale directive
sf4      frequency_scale; // used with set_frequency_scale directive
ui2      user_number_of_records;
ui2      user_record_region_bytes; // set by user to reserve bytes for records
// in header
ui4      user_parameter_flags; // user bits to be set in parameter flags of
// block header (library flags will be set
// automatically)
ui2      protected_region_bytes; // not currently used
ui2      user_discretionary_region_bytes; // set by user to reserve bytes for
// discretionary region in header
} CMP_COMPRESSION_PARAMETERS_m10;

```

```

typedef struct {
TERN_m10  mutex;
ui4      **count; // used by RED/PRED encode & decode
CMP_STATISTICS_BIN_m10 **sorted_count; // used by RED/PRED encode & decode
ui8      **cumulative_count; // used by RED/PRED encode & decode
ui8      **minimum_range; // used by RED/PRED encode & decode
ui1      **symbol_map; // used by RED/PRED encode & decode
si4      *input_buffer;
ui1      *compressed_data; // passed in decompression, returned in compression,
// should not be updated
CMP_BLOCK_FIXED_HEADER_m10 *block_header; // points to beginning of current
// block within compressed_data array,
// updatable
si4      *decompressed_data; // returned in decompression or if lossy data
// requested, used in some compression modes,
// should not be updated
si4      *decompressed_ptr; // points to beginning of current block within
// decompressed_data array, updatable
si4      *original_data; // passed in compression, should not be updated
si4      *original_ptr; // points to beginning of current block within
// original_data array, updatable
si1      *difference_buffer; // passed in both compression & decompression

```

```

    si1      *derivative_buffer; // used if needed in compression & decompression,
                                // size of maximum block differences
    si4      *detrended_buffer; // used if needed in compression, size of
                                // decompressed block
    si4      *scaled_amplitude_buffer; // used if needed in compression, size of
                                // decompressed block
    si4      *scaled_frequency_buffer; // used if needed in compression, size of
                                // decompressed block

    CMP_DIRECTIVES_m10    directives;
    ui1      *records;
    CMP_PARAMETERS_m10    parameters;
    ui1      *protected_region;
    ui1      *discretionary_region;
    ui1      *model_region;
    PASSWORD_DATA_m10 *password_data;
} CMP_PROCESSING_STRUCT_m10;

// Macros
#define CMP_MAX_DIFFERENCE_BYTES_m10(block_samps) // full si4 plus 1 keysample flag
                                                // byte per sample
#define CMP_MAX_COMPRESSED_BYTES_m10(block_samps, n_blocks) // (no compression + header +
                                                // maximum pad bytes) for
                                                // n_blocks blocks

// NOTE: does not take variable region bytes into account and assumes fall through to MBE
#define CMP_IS_DETRENDED_m10(block_header_ptr)
#define CMP_VARIABLE_REGION_BYTES_v1_m10(block_header_ptr) // does not require
                                                // total_header_bytes
#define CMP_VARIABLE_REGION_BYTES_v2_m10(block_header_ptr) // requires total_header_bytes

// Compression Modes
#define CMP_COMPRESSION_MODE_NO_ENTRY_m10      ((ui1) 0)
#define CMP_DECOMPRESSION_MODE_m10             ((ui1) 1)
#define CMP_COMPRESSION_MODE_m10               ((ui1) 2)

// Lossy Compression Modes
#define CMP_AMPLITUDE_SCALE_MODE_m10           ((ui1) 1)
#define CMP_FREQUENCY_SCALE_MODE_m10           ((ui1) 2)

```

FUNCTION: CMP_allocate_processing_struct_m10()

```

// Prototype
CMP_PROCESSING_STRUCT_m10
*CMP_allocate_processing_struct_m10(CMP_PROCESSING_STRUCT_m10 *cps, ui4 mode, si8
data_samples, si8 compressed_data_bytes, si8 difference_bytes, ui4 block_samples,
CMP_PROCESSING_DIRECTIVES_m10 *directives, CMP_COMPRESSION_PARAMETERS_m10 *parameters,
TERN_m10 global_flag);

```

Allocates a CMP_PROCESSING_STRUCT (CPS). Within the CPS, various buffers are allocated. The PASSWORD_DATA structure is assigned. The directives are set to their defaults. The compression parameters are set to their defaults. If the cps parameter is not NULL, it will not be allocated. This is most common when an array of CPS's has been pre-allocated, and this function is being used to perform initialization, and allocation it's contents.

If directives or parameters are NULL, they are set to their defaults, if not, their contents are copied into the CPS.

data_samples: the size of the input or output data arrays, may be large enough to hold many blocks

block_samples: number of samples in a single block (typically maximum number)

global_flag: assign the allocated CPS to the global CPS pointer.

example:

```
cps = CMP_allocate_processing_struct_m10(NULL, CMP_DECOMPRESSION_MODE_m10, max_samps,
CMP_MAX_COMPRESSED_BYTES_m10(max_samps, 1), 0,
CMP_MAX_DIFFERENCE_BYTES_m10(max_samps), max_samps, NULL, NULL, FALSE_m10);
```

Create an CPS large enough to compress one block of size max_samps. Lossless compression is the default, so no decompressed, offset, or scaled data buffers are requested.

FUNCTION: CMP_calculate_mean_residual_ratio_m10()

// Prototype

```
inline sf8 CMP_calculate_mean_residual_ratio_m10(si4 *original_data, si4 *lossy_data,
ui4 n_samps);
```

Calculates and returns the mean residual ratio between the original_data and lossy_data buffers. Used in the mean residual ratio lossy compression mode.

FUNCTION: CMP_calculate_statistics_m10()

// Prototype

```
void CMP_calculate_statistics_m10(CMP_STATISTICS_m10 *stats, si4 *input_buffer, si8 len,
, NODE_m10 *nodes);
```

Calculates CMP block statistics, if requested. Called by CMP_encode_m10(), not typically called directly.

FUNCTION: CMP_check_CPS_allocation_m10()

// Prototype

```
TERN_m10 CMP_check_CPS_allocation_m10(CMP_PROCESSING_STRUCT_m10 *cps);
```

Checks that the appropriate buffers are allocated in a CPS for the type of operation being performed. The operation is determined by the values of the members of the CPS's compression and directives structures. It returns TRUE_m10 if the appropriate buffers are allocated and FALSE_m10 if not unless the behavior_on_fail global is set to exit. Deficient allocations are printed to stderr, as are unnecessarily allocated buffers. This function may be used if the programmer is uncertain which buffers to allocate for specific compression & decompression requirements. It is not called by any of the other functions in the library and must be called independently.

example:

```
cps = CMP_allocate_processing_struct_m10(NULL, CMP_DECOMPRESSION_MODE_m10, max_samps,
CMP_MAX_COMPRESSED_BYTES_m10(max_samps, 1), 0,
```

```
CMP_MAX_DIFFERENCE_BYTES_m10(max_samps), max_samps, NULL, NULL, FALSE_m10);
```

```
cps->compression.mode = RED_FIXED_COMPRESSION_RATIO;
```

```
force_behavior(RETURN_ON_FAIL);  
CMP_check_CPS_allocation_m10(cps);  
force_behavior(RESTORE_BEHAVIOR);
```

FUNCTION: CMP_decode_m10()

// Prototype

```
void CMP_decode_m10(CMP_PROCESSING_STRUCT_m10 *cps);
```

Decompress data passed in the CPS from block_header pointer to the CPS decompressed_ptr field. If CRC validation is requested in the directives, the block CRC will be checked, if the block does not have a valid CRC, it will not be decompressed and the function will return zero. If the block is encrypted and the access level is sufficient, the block will be decrypted before decompression. Encryption status is returned in the encryption directive. Scaling and retrending are performed as necessary. The block discontinuity status is returned in the discontinuity directive.

FUNCTION: CMP_decrypt_m10()

// Prototype

```
si4 CMP_decrypt_m10(CMP_BLOCK_FIXED_HEADER_m10 *block_header);
```

Decrypts data in the block pointed to by the block_header pointer in place.

FUNCTION: CMP_detrend_m10()

// Prototype

```
void CMP_detrend_m10(si4 *input_buffer, si4 *output_buffer, si8 len,  
CMP_PROCESSING_STRUCT_m10 *cps);
```

Detrends data from input_buffer to output_buffer. The detrended slope and intercept values entered into CPS's block_header. If the input_buffer == output_buffer detrending is done in place.

FUNCTION: CMP_encode_m10()

// Prototype

```
void CMP_encode_m10(CMP_PROCESSING_STRUCT_m10 *cps, si8 start_time, si4  
acquisition_channel_number, ui4 number_of_samples);
```

Compress data from original_ptr to block_header pointer (compressed data array). This is the main entry point into the library's compression routines. It detrends the data if set in the directives, and uses lossless or lossy compression as specified in the directives. It also sets the discontinuity flag in the block header.

FUNCTION: CMP_encrypt_m10()

// Prototype

```
si4 CMP_encrypt_m10(CMP_BLOCK_FIXED_HEADER_m10 *block_header, si1 encryption_level);
```

Encrypts data in the block pointed to by the block_header pointer in place.

FUNCTION: CMP_find_amplitude_scale_m10()

// Prototype

```
void CMP_find_amplitude_scale_m10(CMP_PROCESSING_STRUCT_m10 *cps, void (*compression_f)(CMP_PROCESSING_STRUCT_m10 *cps));
```

This is used in lossy compression in amplitude scaling mode.

FUNCTION: CMP_find_extrema_m10()

// Prototype

```
void CMP_find_extrema_m10(si4 *input_buffer, si8 len, si4 *minimum, si4 *maximum, CMP_PROCESSING_STRUCT_m10 *cps);
```

This function will find the minimum & maximum in input_buffer, and return those values in the minimum & maximum pointer arguments. If CPS is not NULL, all the other parameters can be, and the results in the CPS parameters, minimum_sample_value & maximum_sample_value will also be filled in.

Example 1: Find min & max of input_buffer

```
CMP_find_extrema_m10(input_buffer, buffer_len, &minimum, &maximum, NULL);
```

Example 2: Find min & max of cps->input_buffer & place results in minimum, maximum, and CPS

```
CMP_find_extrema_m10(NULL, 0, &minimum, &maximum, cps);
```

Example 3: Find min & max of cps->input_buffer & place results in CPS

```
CMP_find_extrema_m10(NULL, 0, NULL, NULL, cps);
```

FUNCTION: CMP_find_frequency_scale_m10()

// Prototype

```
void CMP_find_frequency_scale_m10(CMP_PROCESSING_STRUCT_m10 *cps, void (*compression_f)(CMP_PROCESSING_STRUCT_m10 *cps));
```

This is used in lossy compression in frequency scaling mode.

FUNCTION: CMP_free_processing_struct_m10()

// Prototype

```
void CMP_free_processing_struct_m10(CMP_PROCESSING_STRUCT_m10 *cps);
```

Frees any arrays allocated within the CPS, and the CPS itself.

FUNCTION: CMP_generate_lossy_data_m10()

// Prototype

```
void CMP_generate_lossy_data_m10(CMP_PROCESSING_STRUCT_m10 *cps, si4 *input_buffer, si4 *output_buffer);
```

Used by lossy compression algorithms to measure mean residual ratio.

FUNCTION: CMP_get_variable_region_m10()

// Prototype

```
void CMP_get_variable_region_m10(CMP_PROCESSING_STRUCT_m10 *cps);
```

Used by CMP_decode() to calculate the size of the variable region of a CMP block header, based on the header flags.

FUNCTION: CMP_initialize_normal_CDF_table_m10()

// Prototype

```
sf8 *CMP_initialize_normal_CDF_table_m10(TERN_m10 global_flag);
```

Initializes the global Normal Cumulative Distribution Function table, used to determine if block data is normally distributed for lossy compression functions.

FUNCTION: CMP_lad_reg_m10()

// Prototype

```
void CMP_lad_reg_m10(si4 *input_buffer, si8 len, sf8 *m, sf8 *b);
```

Returns least absolute deviation regression (LAD) slope (m) and intercept (b) of the input buffer. The abscissa is presumed to be [1:len].

FUNCTION: CMP_lin_reg_m10()

// Prototype

```
void CMP_lin_reg_m10(si4 *input_buffer, si8 len, sf8 *m, sf8 *b);
```

Returns least squares deviation (LAD) slope (m) and intercept (b) of the input buffer. The abscissa is presumed to be [1:len].

FUNCTION: CMP_MBE_decode_m10()

// Prototype

```
void CMP_MBE_decode_m10(CMP_PROCESSING_STRUCT_m10 *cps);
```

Decompress data from block_header pointer to decompressed_ptr in CPS if compressed with Minimal Bit Encoding (MBE). This is called by CMP_decode_m10() for MBE encoded blocks.

FUNCTION: CMP_MBE_encode_m10()

```
// Prototype
```

```
void CMP_MBE_encode_m10(CMP_PROCESSING_STRUCT_m10 *cps);
```

Compress data using Minimal Bit Encoding (MBE) from cps->input_buffer to block_header. This is called by CMP_encode_m10(), or as fall through from CMP_RED_encode_m10() and CMP_PRED_encode_m10().

FUNCTION: CMP_offset_time_m10()

```
// Prototype
```

```
void CMP_offset_time_m10(CMP_BLOCK_FIXED_HEADER_m10 *block_header, si4 action);
```

Apply or remove recording time offset from CMP block header according to global recording_time_offset_mode. Action is either of the defined values RTO_INPUT_ACTION_m10 or RTO_OUTPUT_ACTION_m10, depending on calling scenario.

FUNCTION: CMP_PRED_decode_m10()

```
// Prototype
```

```
void CMP_PRED_decode_m10(CMP_PROCESSING_STRUCT_m10 *cps);
```

Decompress data from block_header pointer to decompressed_ptr in CPS if compressed with the Predictive RED (PRED) algorithm. This is called by CMP_decode_m10() for PRED encoded blocks.

FUNCTION: CMP_PRED_encode_m10()

```
// Prototype
```

```
void CMP_PRED_encode_m10(CMP_PROCESSING_STRUCT_m10 *cps);
```

Compress data from cps->input_buffer to cps->block_header with the Predictive RED (PRED) algorithm. This is called by CMP_encode_m10().

FUNCTION: CMP_quantile_value_m10()

```
// Prototype
```

```
sf8 CMP_quantile_value_m10(sf8 *x, si8 len, sf8 quantile, TERN_m10 preserve_input, sf8 *buff);
```

Returns the requested quantile value i.e 0.0 == minimum, 1.0 == maximum, 0.5 == median, etc. If the input array can be destroyed, set preserve_input to TRUE_m10, as this is most efficient, if it cannot, set preserve_input to FALSE_m10.

Under these circumstances a buffer is required, if one is passed it will be used, if not it will be allocated and freed with each call.

FUNCTION: CMP_RED_decode_m10()

// Prototype

```
void CMP_RED_decode_m10(CMP_PROCESSING_STRUCT_m10 *cps);
```

Decompress data from block_header pointer to decompressed_ptr in CPS if compressed with the Range Encoded Derivatives (RED) algorithm. This is called by CMP_decode_m10() for RED encoded blocks.

FUNCTION: CMP_RED_encode_m10()

// Prototype

```
void CMP_RED_encode_m10(CMP_PROCESSING_STRUCT_m10 *cps);
```

Compress data from cps->input_buffer to cps->block_header with the Range Encoded Derivatives (RED) algorithm. This is called by CMP_encode_m10().

FUNCTION: CMP_retrend_m10()

// Prototype

```
void CMP_retrend_m10(si4 *input_buffer, si4 *output_buffer, si8 len, sf8 m, sf8 b);
```

Retrend data from input_buffer to output_buffer. If input_buffer == output_buffer retrending data will be done in place. "m" & "b" are slope & intercept of trendline.

FUNCTION: CMP_round_m10()

// Prototype

```
inline si4 CMP_round_m10(sf8 val);
```

Return rounded si4 from sf8, taking into account the MED reserved values: NAN_m10, POSITIVE_INFINITY_m10, & NEGATIVE_INFINITY_m10.

FUNCTION: CMP_scale_amplitude_m10()

// Prototype

```
void CMP_scale_amplitude_m10(si4 *input_buffer, si4 *output_buffer, si8 len, sf8 scale_factor);
```

Scale amplitude from input_buffer to output_buffer. If input_buffer == output_buffer scaling will be done in place.

FUNCTION: CMP_scale_frequency_m10()

// Prototype

```
void CMP_scale_frequency_m10(si4 *input_buffer, si4 *output_buffer, si8 len, sf8 scale_factor);
```

Scale frequency from input_buffer to output_buffer. If input_buffer == output_buffer scaling will be done in place.

FUNCTION: CMP_set_variable_region_m10()

// Prototype

```
void CMP_set_variable_region_m10(CMP_PROCESSING_STRUCT_m10 *cps);
```

Performs all requested data conditioning (detrending, scaling, rectifying) & metrics calculations prior to compression, based on CPS directives. This is called by CMP_encode_m10();

FUNCTION: CMP_show_block_header_m10()

// Prototype

```
void CMP_show_block_header_m10(CMP_BLOCK_FIXED_HEADER_m10 *bh);
```

Displays contents of a CMP block header. Useful in debugging.

FUNCTION: CMP_show_block_model_m10()

// Prototype

```
void CMP_show_block_model_m10(CMP_BLOCK_FIXED_HEADER_m10 *block_header);
```

Displays the compression model vales and parameters in CMP block header. Useful in debugging.

FUNCTION: CMP_unscale_amplitude_m10()

// Prototype

```
void CMP_unscale_amplitude_m10(si4 *input_buffer, si4 *output_buffer, si8 len, sf8 scale_factor);
```

Unscale amplitude from input_buffer to output_buffer. If input_buffer == output_buffer scaling will be done in place.

FUNCTION: CMP_unscale_frequency_m10()

// Prototype

```
void CMP_unscale_frequency_m10(si4 *input_buffer, si4 *output_buffer, si8 len, sf8 scale_factor);
```

Unscale frequency from input_buffer to output_buffer. If input_buffer == output_buffer scaling will be done in place.

FUNCTION: CMP_update_CPS_pointers_m10()

```
// Prototype
inline CMP_BLOCK_FIXED_HEADER_m10
*CMP_update_CPS_pointers_m10(CMP_PROCESSING_STRUCT_m10 *cps, ui1 flags);

// Update CPS Pointer Flags
#define CMP_UPDATE_ORIGINAL_PTR_m10      ((ui1) 1)
#define CMP_UPDATE_BLOCK_HEADER_PTR_m10  ((ui1) 2)
#define CMP_UPDATE_DECOMPRESSED_PTR_m10  ((ui1) 4)
```

A function to update pointers in the CPS during rounds of compression or decompression. The examples below will make its utility more clear.

Example 1: Increment original_ptr & block_header in CPS during sequential compression

```
for (i = start_block; i < end_block; ++i) {
    CMP_encode_m10(cps);
    cps->block_header = CMP_update_CPS_pointers_m10(cps, \
        CMP_UPDATE_ORIGINAL_PTR_m10 | CMP_UPDATE_BLOCK_HEADER_PTR_m10);
}
```

Example 2: Increment block_header & decompressed_ptr pointers in CPS during sequential decompression

```
for (i = start_block; i < end_block; ++i) {
    CMP_decode_m10(cps);
    cps->block_header = CMP_update_CPS_pointers_m10(cps, \
        CMP_UPDATE_BLOCK_HEADER_PTR_m10 | CMP_UPDATE_DECOMPRESSED_PTR_m10);
}
```

```
/*****
/***** CRC Utilities *****/
/*****/
```

FUNCTION: CRC_calculate_m10()

```
// Prototype
inline ui4  CRC_calculate_m10(const ui1 *block_ptr, si8 block_bytes);

// Constant
#define CRC_POLYNOMIAL_m10      ((ui4) 0xEDB88320)
#define CRC_START_VALUE_m10     ((ui4) 0x00000000)
```

Returns the 32-bit CRC for a block of length block_bytes, pointed to by block_ptr.

Note library CRC routines are customized to the polynomial defined above; it cannot be changed arbitrarily.

```
crc = CRC_calculate_m10(block_ptr, block_bytes);
```

is equivalent to:

```
crc = CRC_update_m10(CRC_calculate_m10, block_bytes, CRC_START_VALUE);
```

FUNCTION: CRC_combine_m10()

```
// Prototype
```

```
ui4  CRC_combine_m10(ui4 block_1_crc, ui4 block_2_crc, si8 block_2_bytes);
```

Returns the 32-bit CRC for two blocks with known CRCs as if they were joined and calculated as one. This allows efficient incremental addition of blocks with known CRCs as occurs in CMP blocks and MED records.

Example: update universal header body CRC from with record CRC (from calculate_record_data_CRCs_m10()):

```
// calculate record CRC
```

```
record_header->record_CRC = CRC_calculate_m10((ui1 *) record_header + \  
    RECORD_HEADER_CRC_START_OFFSET_m10, record_header->total_bytes - \  
    RECORD_HEADER_CRC_START_OFFSET_m10);
```

```
// calculate record header CRC
```

```
header_CRC = CRC_calculate_m10((ui1 *) record_header, \  
    RECORD_HEADER_CRC_START_OFFSET_m10);
```

```
// combine record header & record body CRCs
```

```
full_record_CRC = CRC_combine_m10(header_CRC, record_header->record_CRC, \  
    record_header->total_bytes - RECORD_HEADER_CRC_START_OFFSET_m10);
```

```
// combine universal_header->body_CRC & full_record_CRC
```

```
fps->universal_header->body_CRC = CRC_combine_m10(fps->universal_header->body_CRC, \  
    full_record_CRC, record_header->total_bytes);
```

FUNCTION: CRC_initialize_table_m10()

```
// Prototype
```

```
ui4  **CRC_initialize_table_m10(TERN_m10 global_flag);
```

Allocates and initializes the CRC table generated from the CRC polynomial into heap space. If global_flag is set, the MED_globals pointer CRC_table is also set to this value. This function is called by initialize_medlib_m10().

FUNCTION: CRC_update_m10()

```
// Prototype
```

```
inline ui4 CRC_update_m10(const ui1 *block_ptr, si8 block_bytes, ui4 current_crc);
```

Returns the CRC of a block based on the current CRC of the bytes preceding that block.

FUNCTION: CRC_validate()

```
// Prototype
```

```
inline TERN_m10 CRC_validate_m10(const ui1 *block_ptr, si8 block_bytes, ui4  
crc_to_validate);
```

Returns TRUE_m10 if the calculated CRC of the block pointed to by block_ptr matches the value passed in crc_to_validate. If they do not match, FALSE_m10 is returned.

```
/*  
***** UTF-8 Utilities *****  
*/
```

```
// Prototypes
```

```
si4 UTF8_charnum(si1 *s, si4 offset); // byte offset to character number
```

```
void UTF8_dec(si1 *s, si4 *i); // move to previous character
```

```
si4 UTF8_escape(si1 *buf, si4 sz, si1 *src, si4 escape_quotes); // convert UTF-8 "src"  
to
```

```
// ASCII with escape sequences.
```

```
si4 UTF8_escape_wchar(si1 *buf, si4 sz, ui4 ch); // given a wide character, convert it  
to an ASCII escape sequence stored in buf, where buf is "sz" bytes. returns the number of  
characters output
```

```
si4 UTF8_f
```

```
uments may be in UTF-8. You can avoid this function and just use ordinary printf()  
// if the current locale is UTF-8.
```

```
si4 UTF8_hex_digit(si1 c); // utility predicates used by the above
```

```
void UTF8_inc(si1 *s, si4 *i); // move to next character
```

```
ui4 *UTF8_initialize_offsets_from_UTF8_table(si4 global_flag);
```

```
si1 *UTF8_initialize_trailing_bytes_for_UTF8_table(si4 global_flag);
```

```
si4 UTF8_is_locale_utf8(si1 *locale); // boolean function returns if locale is UTF-8,  
0
```

```
// otherwise
```

```
si1 *UTF8_memchr(si1 *s, ui4 ch, size_t sz, si4 *charn); // same as the above, but  
searches
```

```

    // a buffer of a given size instead of a NUL-terminated string.
ui4  UTF8_nextchar(si1 *s, si4 *i); // return next character, updating an index
variable
si4  UTF8_octal_digit(si1 c); // utility predicates used by the above
si4  UTF8_offset(si1 *str, si4 charnum); // character number to byte offset
si4  UTF8_printf(si1 *fmt, ...); // printf() where the format string and arguments may
be in
    // UTF-8. You can avoid this function and just use ordinary printf() if the current
    // locale is UTF-8.
si4  UTF8_read_escape_sequence(si1 *str, ui4 *dest); // assuming src points to the
character
    // after a backslash, read an escape sequence, storing the result in dest and
returning
    // the number of input characters processed
si4  UTF8_seqlen(si1 *s); // returns length of next UTF-8 sequence
si1  *UTF8_strchr(si1 *s, ui4 ch, si4 *charn); // return a pointer to the first
occurrence of
    // ch in s, or NULL if not found. character index of found character returned in
*charn.
si4  UTF8_strlen(si1 *s); // count the number of characters in a UTF-8 string
si4  UTF8_toucs(ui4 *dest, si4 sz, si1 *src, si4 srcsz); // convert UTF-8 data to wide
// character
si4  UTF8_toutf8(si1 *dest, si4 sz, ui4 *src, si4 srcsz); // convert wide character to
UTF-8 data
si4  UTF8_unescape(si1 *buf, si4 sz, si1 *src); // convert a string "src" containing
escape
    // sequences to UTF-8 if escape_quotes is nonzero, quote characters will be
preceded by
    // backslashes as well.
si4  UTF8_vfprintf(FILE *stream, si1 *fmt, va_list ap); // called by UTF8_fprintf()
si4  UTF8_vprintf(si1 *fmt, va_list ap); // called by UTF8_printf()
si4  UTF8_wc_toutf8(si1 *dest, ui4 ch); // single character to UTF-8

```

Not all of the UTF-8 functions are used in the library, but they are included in the library for end-user and potential future use. Some of the included functions are used by other UTF-8 functions, and thus require inclusion. Only those functions that are currently used in other (non-UTF-8) medlib functions are described in this section.

FUNCTION: UTF8_initialize_offsets_from_UTF8_table()

```
// Prototype
```

```
ui4    *UTF8_initialize_offsets_from_UTF8_table(si4 global_flag);
```

Allocates and initializes the offsets_from_UTF8 table into heap space. If global_flag is set, the MED_globals pointer UTF8_offsets_from_UTF8_table is also set to this value. This function is called by initialize_medlib().

FUNCTION: UTF8_initialize_trailing_bytes_for_UTF8_table()

```
// Prototype
```

```
si1    *UTF8_initialize_trailing_bytes_for_UTF8_table(si4 global_flag);
```

Allocates and initializes the trailing_bytes_for_UTF8 table into heap space. If global_flag is set, the MED_globals pointer UTF8_trailing_bytes_for_UTF8_table is also set to this value. This function is called by initialize_medlib().

FUNCTION: UTF8_fprintf()

```
// Prototype
```

```
si4    UTF8_fprintf(FILE *stream, si1 *fmt, ...);
```

Used like fprintf(), but accommodates UTF-8 as well as conventional strings.

FUNCTION: UTF8_nextchar()

```
// Prototype
```

```
ui4    UTF8_nextchar(si1 *s, si4 *i);
```

Returns the next character in the UTF-8 string s, updating the index variable i. Used by extract_terminal_password_bytes().

FUNCTION: UTF8_printf()

```
// Prototype si4    UTF8_printf(si1 *fmt, ...);
```

Used like printf(), but accommodates UTF-8 as well as conventional strings.

FUNCTION: UTF8_strlen()

```
// Prototype
```

```
si4    UTF8_strlen(si1 *s);
```

Returns the number of UTF-8 characters in the UTF-8 string s. Used by check_password().

```

/*****
/***** AES Utilities *****/
/*****/

```

```

// Function Prototypes

```

```

void AES_add_round_key(si4 round, ui1 state[][4], ui1 *RoundKey);
void AES_decrypt(ui1 *in, ui1 *out, si1 *password, ui1 *expanded_key);
void AES_encrypt(ui1 *in, ui1 *out, si1 *password, ui1 *expanded_key);
void AES_key_expansion(si4 Nk, si4 Nr, ui1 *RoundKey, si1 *Key);
void AES_cipher(si4 Nr, ui1 *in, ui1 *out, ui1 state[][4], ui1 *RoundKey);
si4 AES_get_sbox_invert(si4 num);
si4 AES_get_sbox_value(si4 num);
si4 *AES_initialize_rcon_table(si4 global_flag);
si4 *AES_initialize_rsbox_table(si4 global_flag);
si4 *AES_initialize_sbox_table(si4 global_flag);
void AES_inv_cipher(si4 Nr, ui1 *in, ui1 *out, ui1 state[][4], ui1 *RoundKey);
void AES_inv_mix_columns(ui1 state[][4]);
void AES_inv_shift_rows(ui1 state[][4]);
void AES_inv_sub_bytes(ui1 state[][4]);
void AES_mix_columns(ui1 state[][4]);
void AES_shift_rows(ui1 state[][4]);
void AES_sub_bytes(ui1 state[][4]);

```

Not all of the AES functions are used by the other functions in the library, but are used by other AES functions, and thus require inclusion. Only those functions that are currently used in other (non-AES) medlib functions are described in this section.

FUNCTION: AES_initialize_rcon_table()

```

// Prototype

```

```

si4 *AES_initialize_rcon_table(si4 global_flag);

```

Allocates and initializes the AES rcon table into heap space. If `global_flag` is set, the `MED_globals` pointer `AES_rcon_table` is also set to this value. This function is called by `initialize_medlib()`.

FUNCTION: AES_initialize_rsbox_table()

```
// Prototype  
si4  *AES_initialize_rsbox_table(si4 global_flag);
```

Allocates and initializes the AES rsbox table into heap space. If `global_flag` is set, the `MED_globals` pointer `AES_rsbox_table` is also set to this value. This function is called by `initialize_medlib()`.

FUNCTION: AES_initialize_sbox_table()

```
// Prototype  
si4  *AES_initialize_sbox_table(si4 global_flag);
```

Allocates and initializes the AES sbox table into heap space. If `global_flag` is set, the `MED_globals` pointer `AES_sbox_table` is also set to this value. This function is called by `initialize_medlib()`.

FUNCTION: AES_decrypt()

```
// Prototype  
void AES_decrypt(ui1 *in, ui1 *out, si1 *password, ui1 *expanded_key);
```

Decrypts a 16 byte (128 bit) block of AES-128 encrypted data in the “in” buffer to the “out” buffer. The decryption can be done in place (“in” equals “out”), and is most often done this way within the library functions. Either `expanded_key` or `password` must be non-NULL. If both are non-NULL, the expanded key will be used, as it is more efficient. An expanded key can be obtained from the function `AES_key_expansion()`. If a password is to be used, an expanded key is generated from it, used, and discarded. A password is a 16 byte sequence. If, as is usually the case, this is a string, unused bytes should be zeroed, as these bytes, while meaningless to the string, cannot vary for reproducible decryption. If a UTF-8 string is used for a password, the medlib routines extract the terminal (most unique) bytes from each character to be used as the password bytes. This can be done with the function `extract_terminal_password_bytes()`; it is not done in this function.

FUNCTION: AES_encrypt()

```
// Prototype  
void AES_encrypt(ui1 *in, ui1 *out, si1 *password, ui1 *expanded_key);
```

Encrypts a 16 byte (128 bit) block of data in the “in” buffer to the “out” buffer using the AES-128 algorithm. The encryption can be done in place (“in” equals “out”), and is most often done this way within the library functions. Either `expanded_key` or `password` must be non-NULL. If both are non-NULL, the expanded key will be used, as it is more efficient. An expanded key can be obtained from the function `AES_key_expansion()`. If a password is to be used, an expanded key is generated from it, used, and discarded. A password is a 16 byte sequence. If, as is usually the case, this is a string, unused bytes should be zeroed, as these bytes, while meaningless to the string, cannot vary for reproducible encryption. If a UTF-8 string is used for a password, the medlib routines extract the terminal (most unique) bytes from each character to be used as the password bytes. This can be done with the function `extract_terminal_password_bytes()`; it is not done in this function.

FUNCTION: AES_key_expansion()

```
// Prototype
void AES_key_expansion(ui1 *expanded_key, si1 *key);
```

Generates an expanded key from a key. A key is a 16 byte sequence. If, as is usually the case, the key is a password, unused bytes should be zeroed, as these bytes, while meaningless to the string, cannot vary for reproducible encryption / decryption. If a UTF-8 string is used for a password, the medlib routines extract the terminal (most unique) bytes from each character to be used as the password bytes. This can be done with the function `extract_terminal_password_bytes()`; it is not done in this function.

```

/*****
/***** SHA Utilities *****/
/*****/

```

// Function Prototypes

```
ui4  *SHA_initialize_h0_table(si4 global_flag);
ui4  *SHA_initialize_k_table(si4 global_flag);
void  SHA_sha(const ui1 *message, ui4 len, ui1 *digest);
void  SHA_final(SHA256_ctx *ctx, ui1 *digest);
void  SHA_init(SHA256_ctx *ctx);
void  SHA_transf(SHA256_ctx *ctx, const ui1 *message, ui4 block_nb);
void  SHA_update(SHA256_ctx *ctx, const ui1 *message, ui4 len);
```

SHA-256 is the 256-bit version of the SHA-2 cryptographic hash function. Only the 256-bit version is included in the library. Not all of the SHA functions are used by other functions in the library, but are used by other SHA functions, and thus require inclusion. Only those functions that are currently used in other (non-SHA) medlib functions are described in this section.

FUNCTION: SHA_initialize_h0_table()

```
// Prototype
ui4  *SHA_initialize_h0_table(si4 global_flag);
```

Allocates and initializes SHA AES h0 table into heap space. If `global_flag` is set, the `MED_globals` pointer `SHA_h0_table` is also set to this value. This function is called by `initialize_medlib()`.

FUNCTION: SHA_initialize_k_table()

```
// Prototype
ui4  *SHA_initialize_k_table(si4 global_flag);
```

Allocates and initializes SHA AES k table into heap space. If global_flag is set, the MED_globals pointer SHA_k_table is also set to this value. This function is called by initialize_medlib().

FUNCTION: SHA_sha()

// Prototype

```
void SHA_sha(const ui1 *message, ui4 len, ui1 *digest);
```

// Constant

```
#define SHA_OUTPUT_SIZE 256
```

Returns a 256 byte SHA-2 hash of the message (of length len) in digest. This function is used by process_password_data().

MED Records API

User defined records are defined and coded in “medrec_m10.c” and “medrec_m10.h”. The functions required for adding a new record type are described here. Record types themselves are described in the file “MED 1.0 Records Specification”.

All records have an identically structured record header, followed by a customizable body. The body length must be padded out to a multiple of 16 bytes in length to facilitate individual record encryption with AES-128.

Structures within records should have all members aligned to their type and the total size evenly divisible by 8 (for 64-bit CPUs).

Records are named with 4 ascii characters and have a major and minor version associated with them so that they can evolve, as needed, with time. These 4 characters also define a type code as the bytes of a 4 byte unsigned integer. **Note that translation of ascii to hexadecimal on little endian machines requires reversing the byte ordering in the hexadecimal representation.**

Each new record type should have two or three associated functions:

- 1) a “show” function)
- 2) an “alignment” function

“Show” functions display the contents of the records and have the following form:

Name: show_rec_xxxx_type_m10()
(where “xxx” is the record type name)

// Prototype

```
void show_medrec_xxxx_type_m10(RECORD_HEADER_m10 *record_header);  
(where a RECORD_HEADER_m10 is a structure defined in “medlib_m10.h”)
```

The “show” function should handle all versions of the record type. An example “show function is shown below for the “Note” record type.

```
void show_rec_Note_type_m10(RECORD_HEADER_m10 *record_header)  
{  
    si1    *Note;  
  
    // Version 1.0  
    if (record_header->version_major == 1 && record_header->version_minor == 0) {  
        Note = (si1 *) record_header + REC_Note_v10_TEXT_OFFSET_m10;  
        UTF8_printf("Note text: %s\n", Note);  
    }  
    // Unrecognized record version  
    else {  
        warning_message_m10("Unrecognized Note version (%hhd.%hhd)\n", \  
            record_header->version_major, record_header->version_minor);  
    }  
  
    return;  
}
```

All show function constants are defined in “medrec_m10.h”. The function show_record_m10() defined in medrec_m10.c must be modified in the switch statement, copied below, to add new record types.

```

switch (type_code) {
    case REC_Sgmt_TYPE_CODE_m10:
        show_rec_Sgmt_type_m10(record_header);
        break;
    case REC_Stat_TYPE_CODE_m10:
        show_rec_Stat_type_m10(record_header);
        break;
    case REC_Note_TYPE_CODE_m10:
        show_rec_Note_type_m10(record_header);
        break;
    case REC_Seiz_TYPE_CODE_m10:
        show_rec_Seiz_type_m10(record_header);
        break;
    case REC_SyLg_TYPE_CODE_m10:
        show_rec_SyLg_type_m10(record_header);
        break;
    default:
        warning_message_m10("%s(): 0x%x is an unrecognized record type code", \
            __FUNCTION__, type_code);
        break;
}

```

“Alignment” functions have the following form:

Name: `check_rec_xxxx_type_alignment_m10()`
 (where “xxxx” is the record type name)

// Prototype

`TERN_m10 check_rec_xxxx_type_alignment_m10(ui1 *bytes);`
 (where “bytes” is an optional buffer to check alignment with)

New record “alignment” functions check the alignment of any structures represented in the record body. Those structures are defined in “medrec_m10.h”. The function `check_record_structure_alignments_m10()` defined in `medrec_m10.c` must be modified in the serial if statements, copied below, to add a new record type.

```

if ((check_rec_Sgmt_type_alignment_m10(bytes)) == FALSE_m10)
    return_value = FALSE_m10;
if ((check_rec_Stat_type_alignment_m10(bytes)) == FALSE_m10)
    return_value = FALSE_m10;
if ((check_rec_Note_type_alignment_m10(bytes)) == FALSE_m10)
    return_value = FALSE_m10;
if ((check_rec_Seiz_type_alignment_m10(bytes)) == FALSE_m10)
    return_value = FALSE_m10;
if ((check_rec_SyLg_type_alignment_m10(bytes)) == FALSE_m10)
    return_value = FALSE_m10;

```