



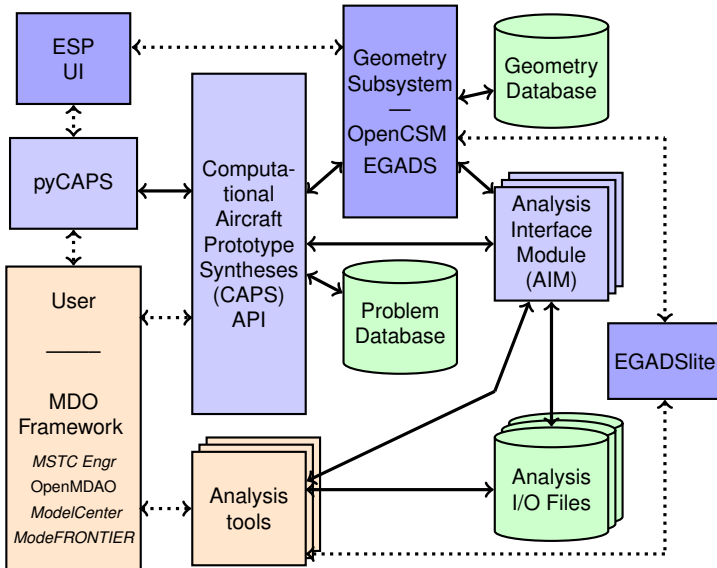
# Computational Aircraft Prototype Syntheses

## AIM Development

### For ESP Rev 1.24

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Note: Sections in **red** are changes in CAPS from Revision 1.21.



## Object-based Not *Object Orientated*

- Like *egos* in EGADS
- Pointer to a C structure – allows for a function-based API
- Treated as *blind pointers* (i.e., not meant to be dereferenced)  
Header info used to determine how to dereference the *pointer*
- API Functions
  - Returns an *int* error code or CAPS\_SUCCESS
  - Usually have one (or more) input Objects
  - Can have an output Object (usually at the end of the argument list)
- Can interface with multiple compiled languages

See \$ESP\_ROOT/doc/CAPSapi.pdf

## Problem Object

The Problem is the top-level *container* for a single mission. It maintains a single set of interrelated geometric models, analyses to be executed, connectivity and data associated with the run(s), which can be both multi-fidelity and multidisciplinary. There can be multiple Problems in a single execution of CAPS and each Problem is designed to be *thread safe* allowing for multi-threading of CAPS at the highest level.

## Value Object

A Value Object is the fundamental data container that is used within CAPS. It can represent *inputs* to the Analysis and Geometry subsystems and *outputs* from both. Also Value Objects can refer to *mission* parameters that are stored at the top-level of the CAPS database. The values contained in any *input* Value Object can be bypassed by the *linkage* connection to another Value (or *DataSet*) Object of the same *shape*. Attributes are also cast to temporary (*User*) Value Objects.

## Analysis Object

The Analysis Object refers to an instance of running an analysis code. It holds the *input* and *output* Value Objects for the instance and a directory path in which to execute the code (though no explicit execution is initiated). Multiple various analyses can be utilized and multiple instances of the same analysis can be handled under the same Problem.

## Bound Object

A Bound is a logical grouping of BRep Objects that all represent the same entity in an engineering sense (such as the “outer surface of the wing”). A Bound may include BRep entities from multiple Bodies; this enables the passing of information from one Body (for example, the aero OML) to another (the structures Body).

Dimensionally:

- 1D – Collection of Edges
- 2D – Collection of Faces

## VertexSet Object

A VertexSet is a *connected* or *unconnected* group of locations at which discrete information is defined. Each *connected* VertexSet is associated with one Bound and a single *Analysis*. A VertexSet can contain more than one DataSet. A *connected* VertexSet can refer to 2 differing sets of locations. This occurs when the solver stores it's data at different locations than the vertices that define the discrete geometry (i.e. cell centered or non-isoparametric FEM discretizations). In these cases the solution data is provided in a different manner than the geometric.

## DataSet Object

A DataSet is a set of engineering data associated with a VertexSet. The rank of a DataSet is the (user/pre)-defined number of dependent values associated with each vertex; for example, scalar data (such as *pressure*) will have rank of one and vector data (such as *displacement*) will have a rank of three. Values in the DataSet can either be deposited there by an application or can be computed (via evaluations, data transfers or sensitivity calculations).

Object	SubTypes	Parent Object
capsProblem	Parametric, Static	
capsValue	GeometryIn, GeometryOut, Parameter, User	capsProblem, capsValue
capsAnalysis		capsProblem
capsValue	AnalysisIn, AnalysisOut, AnalysisDynO	capsAnalysis
capsBound		capsProblem
capsVertexSet	Connected, Unconnected	capsBound
capsDataSet	FieldOut, FieldIn, User, GeomSens, TessSens, Builtin	capsVertexSet

Body Objects are EGADS Objects (egos)

See `$ESP_ROOT/include/capsTypes.h` for the correct capitalization

Filtering the active CSM Bodies occurs at two different stages, once in the CAPS framework, and once in the AIMs. The filtering in the CAPS framework creates sub-groups of Bodies from the CSM stack that are passed to the specified AIM. Each AIM instance is then responsible for selecting the appropriate Bodies from the list it has received.

The filtering is performed by using two Body attributes: “capsAIM” and “capsIntent”.

## Filtering within AIM Code

Each AIM can adopt it's own filtering scheme for down-selecting how to use each Body it receives. The “capsIntent” string is accessible to the AIM, but it is for information only.



## CSM AIM targeting: “capsAIM”

The CSM script generates Bodies which are designed to be used by specific AIMs. The AIMs that the Body is designed for is communicated to the CAPS framework via the “capsAIM” string attribute. This is a semicolon-separated string with the list of AIM names. Thus, the CSM author can give a clear indication to which AIMs should use the Body. For example, a body designed for a CFD calculation could have:

```
ATTRIBUTE capsAIM $su2AIM;fun3dAIM;cart3dAIM
```

## CAPS AIM Instantiation: “capsIntent”

The “capsIntent” Body attribute is used to disambiguate which AIM instance should receive a given Body targeted for the AIM. An argument to `caps_makeAnalysis` accepts a semicolon-separated list of keywords when an AIM is instantiated in CAPS/pyCAPS. Bodies from the “capsAIM” selection with a matching string attribute “capsIntent” are passed to the AIM instance. The attribute “capsIntent” is a semicolon-separated list of keywords. If the string to `caps_makeAnalysis` is **NUL**L, all Bodies with a “capsAIM” attribute that matches the AIM name are given to the AIM instance.

- Hides all of the individual Analysis details (and peculiarities)
  - Individual plugin functions *translate* from the Analysis' perspective back and forth to CAPS
  - Provides a direct connection to BRep geometry and attribution through EGADS
- Outside the CAPS Object infrastructure
  - Use of C structures
  - AIM Utility library (with the *context* embedded in `aimInfo`)

## Update Notes (from Rev 1.19):

- ➊ Changing directories within an AIM function is no longer needed. When an AIM function is invoked, you will be in the correct location. Therefore the path has been removed from the argument list of many AIM functions. This includes `aimPreAnalysis`, `aimExecute`, `aimPostAnalysis`, `aimCalcOutput` and `aimTransfer`.
- ➋ There is no longer an AIM parent/child relationship. This is now accomplished via linking AnalysisOut Values of the *parent* to AnalysisIn Values of the *child*.
- ➌ During restart only “Post” is executed at the last use of the AIM instance.
- ➍ AIM specific storage is no longer indexed by the instance and is held internally.

## Large Mesh IO

The meshing AIMs used to hold onto the grid information in memory and pass a pointer on to the CFD AIMs that write out a mesh file during solver preAnalysis. This is not the best use of resources and limits the ability for CAPS to perform its overall mission.

In order to have the meshing AIM know what kind of file the downstream solver AIM requires there needs to be information “passed” from the solver AIM to the meshing AIM. This is accomplished through the linkage itself. An AIM utility function has been added that returns the info for linked (solver) AIMs to aid in knowing what files to write in aimPostAnalysis. After the files have been written from PostAnalysis, the memory must be freed up.

The mesh writer is specified by using the Value structure member: `meshWriter`. This is filled in the link target (solver) AnalysisIn Value Object, which will allow for the upstream (meshing) AIM knowledge about how the mesh is to be written. The string contains the name of the so/DLL to be loaded for the writing. The meshing AIM accesses this information via the AIM utility function `aim_writeMeshes`.

## Analysis Dynamic Value Objects

- After successful AIM preAnalysis invocation, all existing Analysis Dynamic Output Objects that are stored in the instance are deleted (and those associated mirrored restart files)
- AIM postAnalysis is the only place where Analysis Dynamic Output Objects can be created (see `aim_makeDynamicOutput`)
- They should not be created (i.e., they will already exist) if the **restart** flag is set
- After successful postAnalysis (and not at restart), the created Dynamic Output Objects are given the serial number of postAnalysis (and are written for restart)
- If postAnalysis errors, any created Dynamic Output Objects are deleted

## Analysis Execution Calling Sequences

- `aimUpdateState` is always called before `aimDiscr`, `aimPreAnalysis` or `aimPostAnalysis`
- `aimDiscr` may be called before or after `aimPreAnalysis` or `aimPostAnalysis`
- `aimPreAnalysis` is always called before `aimExecute` or `aimPostAnalysis` (unless doing a restart/continuation)
- `aimPostAnalysis` is called right after `aimUpdateState` when CAPS is restarting (the *restart* argument is set), or if `aimPostAnalysis` is the first live function with continuation.

Only `aimPreAnalysis` and/or `aimPostAnalysis` (not a restart) should write to the Analysis directory.

- An AIM plugin is required for each Analysis code at:
  - a specific *intent*
  - a specific *mode* (i.e., where the inputs may be different)
- AIMs can “talk” to each other
  - AIM outputs of one AIM instance can be linked to inputs of another AIM instance
  - Communication is accomplished via pointers
- Dynamically loaded at runtime – extendibility and extensibility
  - Windows Dynamically Loaded Libraries (name .dll)
  - LINUX Shared Objects (name .so)
  - MAC Bundles, CAPS uses the so file extension
- Plugin names must be unique – loaded by the name
- † indicates memory handled by CAPS in the following functions  
i.e., CAPS will free these memory blocks when necessary

The **capsValue** Structure is simply the data found within a CAPS Value Object. `aimInputs` and `aimOutputs` must fill the structure with the *type*, *form* and optionally *units* of the data. `aimInputs` also sets the default value(s) in the *vals* member. The structure's members listed below must be filled (most have defaults).

## Value Type – no default

The value *type* can be one of:

```
enum capsValueType {Boolean, Integer, Double, String, Tuple, Pointer, DoubleDeriv, PointerMesh};
```

Notes:

- 1 The `Pointer/PointerMesh` types are only supported at the AIM level to communicate between AIMS. Linkages should be used from *AnalysisOut* to *AnalysisIn* to make the connection. The `units` member of the Value Structure must match for a successful link.
- 2 `DoubleDeriv` is a `Double` with optional derivatives (*AnalysisOut* & *GeometryOut* only)

## The tuple structure

```
typedef struct {  
    char *name;           /* the name */  
    char *value;          /* the value for the pair */  
} capsTuple;
```

## Shape of the Value – 0 is the default

*dim* can be one of:

- 0 scalar only
- 1 vector or scalar
- 2 scalar, vector or 2D array

## Value Dimensions – 1 is the default

*nrow* and *ncol* set the dimension of the Value. If both are 1 this has a `scalar` shape. If either *nrow* or *ncol* are one then the shape is `vector`. If both are greater than 1 then this represents a 2D array of values.

## Other enumerated constants

```
enum capsFixed      {Change, Fixed};  
enum capsNull       {NotAllowed, NotNull, IsNull, IsPartial};  
enum capstMethod    {Copy, Integrate, Average};
```



## Varying Length – the default is “Fixed”

The member *lfixed* indicates whether the length of the Value is allowed to change.

## Varying Shape – the default is “Fixed”

The member *sfixed* indicates whether the *shape* of the Value is allowed to change.

## Can Value be NULL? – the default is “NotAllowed”

The member *nullVal* indicates whether the Value is or can be **NULL**  
Options are found in `enum capsNULL`

## A Note on String Storage

Multiple Strings are not stored as a list of pointers, but as a contiguous block of memory where each individual string is zero terminated.

## capsValue Member Usage Notes

- *sfixed* & *dim*

If the shape is “Fixed” then *nrow* and *ncol* must fit that shape (or a lesser dimension). [Note that the length can change if *lfixed* is “Change”.] If *sfixed* is “Change” then you change *dim* before changing *nrow* and *ncol* to a higher dimension than the current setting.

- *lfixed* & *nrow/ncol*

If the length is “Fixed” then all updates of the Value(s) must match in both *nrow* and *ncol* (which presumes a “Fixed” shape).

- *nullVal* & *nrow/ncol*

*nrow* and *ncol* should remain at their values even if the Value is **NULL** to maintain the dimension (and possibly length) when “Fixed”. To indicate a **NULL** all that is necessary is to set *nullVal* to “IsNull”. The actual allocated storage can remain in the *vals* member or set to **NULL**.

- Use `EG_alloc` to allocate any memory required for the *vals* member.

```
/*
 * structure for derivative data w/ CAPS Value structure
 *   only used with "real" (double) data and
 *   only with GeometryOut, AnalysisOut or AnalysisDynO Value Objects
 */

typedef struct {
    char    *name;                /* the derivative with respect to */
                                   /* including optional [n] or [n,m] for vectors/arrays */
    int     rank;                 /* the number of members in the derivative */
    double *dot;                 /* the dot values -- rank*length in length */
} capsDot;

/*
 * structure for CAPS object -- VALUE
 */

typedef struct {
    int     type;                /* value type -- capsValueType */
    int     length;              /* number of values */
    int     dim;                 /* the dimension */
    int     nrow;                /* number of rows */
    int     ncol;                /* the number of columns */
}
```

# AIM Plugin Functions

- Registration & Declaring Inputs / Outputs
- Pre-Analysis, Analysis Execution & Retrieving Output  
Write and read files – or – use Analyses' APIs if available
- Discrete Support – Interpolation & Integration
- Data Transfers

## Initialization Information for the AIM

```
icode = aimInitialize(int qFlag, const char *uSys, void *aimInfo,
                    void **instStore, int *major, int *minor,
                    int *nIn, int *nOut, int *nFields,
                    char ***fnames, int **franks, int **fInOut)
```

**qFlag** -1 indicates a query and not a new analysis instance (0 or greater)

**uSys** a pointer to a character string declaring the unit system – can be **NULL**

**aimInfo** the AIM context – **NULL** if **qFlag == -1**

**instStore** a returned pointer to a block of memory to be associated with this AIM instance may be returned as **NULL** if no AIM state data is required

**major** the returned AIM major version number

**minor** the returned AIM minor version number

**nIn** the returned number of Inputs (minimum of 1)

**nOut** the returned number of possible Outputs

**nFields** the returned number of fields to responds to for DataSet filling

**fnames** a returned pointer to a list of character strings with the field/DataSet names †

**franks** a returned pointer to a list of ranks associated with each field †

**fInOut** a returned pointer to a list of field flags (FIELDIN - input, FIELDOUT - output) †

**icode** integer return code

## Return Analysis Inputs

```
icode = aimInputs(void *instStore, void *aimInfo, int index,  
                  char **ainame, capsValue *defval)
```

- instStore** the AIM *instance* storage – **NULL** if called from caps\_getInput
- aimInfo** the AIM context – **NULL** if called from caps\_getInput
- index** the Input index [1-nIn]
- ainame** a returned pointer to the returned Analysis Input variable name
- defval** a pointer to the filled default value(s) and units – any allocated memory will be freed
- icode** integer return code

## Return Analysis Outputs

```
icode = aimOutputs(void *instStore, void *aimInfo, int index,  
                   char **aoname, capsValue *form)
```

- instStore** the AIM *instance* storage – **NULL** if called from caps\_getOutput
- aimInfo** the AIM context – **NULL** if called from caps\_getOutput
- index** the Output index [1-nOut]
- aoname** a returned pointer to the returned Analysis Output variable name
- form** a pointer to the Value Shape & Units information – to be filled  
any actual values stored are ignored/freed
- icode** integer return code

## Set or Update the AIM's Internal State

```
icode = aimUpdateState(void *instStore, void *aimInfo,  
                        capsValue *inputs)
```

**instStore** the AIM *instance* storage

**aimInfo** the AIM context (used by the Utility Functions)

**inputs** the complete suite of Analysis inputs (nIn in length)

**icode** integer return code

Notes: This function is always called first in the execution sequence (before `aimDiscr`, `aimPreAnalysis` or `aimPostAnalysis`). It should not write into the Analysis directory.

## Parse Input data & Generate Input File(s)

```
icode = aimPreAnalysis(const void *instStore, void *aimInfo,  
                       capsValue *inputs)
```

**instStore** the AIM *instance* storage

**aimInfo** the AIM context (used by the Utility Functions)

**inputs** the complete suite of Analysis inputs (nIn in length)

**icode** integer return code

## Execute Analysis – Optional

```
icode = aimExecute(const void *instStore, void *aimInfo, int *state)
```

**instStore** the AIM *instance* storage

**aimInfo** the AIM context (used by the Utility Functions)

**state** the returned status (0 - done, 1 - running) – currently unused

**icode** integer return code

Note: if this function exists it is an indication that the AIM can auto-execute.

## Processing after the Analysis is run

```
icode = aimPostAnalysis(void *instStore, void *aimInfo, int restart,  
                        capsValue *inputs)
```

**instStore** the AIM *instance* storage

**aimInfo** the AIM context (used by the Utility Functions)

**restart** restart state (0 - normal, 1 - restart invocation)

**inputs** the complete suite of Analysis inputs – for restart (nIn in length)

**icode** integer return code

Note: this function gets called by `caps_postAnalysis`, implicitly during `caps_execute`, during lazy execution (if auto-exec) and while restarting (only for the last invocation of an instance) to populate any internal state information (and should not write into the Analysis directory).



## Free up any memory the AIM has stored

```
void aimCleanup(void *instStore)
```

**instStore** the block of memory associated with a particular instance

Note:

- Called a number of times, once for each instance

## Calculate/Retrieve Output Information

```
icode = aimCalcOutput(void *instStore, void *aimInfo, int index,  
                      capsValue *val)
```

**instStore** the AIM *instance* storage

**aimInfo** the AIM context (used by the Utility Functions)

**index** the Output index [1-nOut] for this single result

**val** a pointer to the capsValue data to fill – CAPS will free any allocated memory

**icode** integer return code

Note:

- Called in a *lazy* manner, only when the output is needed (and after the Analysis is run)

## Discrete Structure – Used to define a VertexSet

The CAPS *Discrete* data structure holds the spatial discretization information for a Bound. It defines reference positions for the location of the vertices that support the geometry and optionally the positions for the data locations (if these differ). This structure can contain a homogeneous or heterogeneous collection of element types and optionally specifies match positions for conservative data transfers.

## EGADS Tessellation Object

- Used to specify the discretization of the entire Body
- Requires triangles
- Can be constructed from an external mesh generator
  - Look at `EG_initTessBody`, `EG_setTessEdge`,  
`EG_setTessFace` & `EG_statusTessBody`
  - Set in CAPS by invoking `aim_newTess`

```

/* defines the element discretization type by the number of reference positions
* (for geometry and optionally data) within the element.
* simple tri: nref = 3; ndata = 0; st = {0.0,0.0, 1.0,0.0, 0.0,1.0}
* simple quad: nref = 4; ndata = 0; st = {0.0,0.0, 1.0,0.0, 1.0,1.0, 0.0,1.0}
* internal triangles are used for the in/out predicates and represent linear
* triangles in [u,v] space.
* ndata is the number of data reference positions, which can be zero for simple
* nodal or isoparametric discretizations.
* match points are used for conservative transfers. Must be set when data
* and geometry positions differ, specifically for discontinuous mappings.
* For example:

```

```

*
*      2
*     /\
*    /\
*   /\
*  0-----1
*
*      neighbors
*      tri-side  vertices
*      0         1 2
*      1         2 0
*      2         0 1
*
*      4
*     /\
*    5  3
*   /\  /\
*  6
* /\  /\
0----1----2
*
*      neighbors
*      side  vertices
*      0     1 2
*      1     2 3
*      2     3 4
*      3     4 5
*      4     5 0
*      5     0 1
*
*      nref = 7
*
*      6
*     3---.---2
*    |       |
*   7.   8   .5
*    |       |
*   0---.---1
*      4
*
*      neighbors
*      quad-side  vertices
*      0         1 2
*      1         2 3
*      2         3 4
*      3         4 0
*      4         0 1
*
*      nref = 9
*
*      4-----3
*     |         |
*     |         2
*     |         |
*    0-----1
*
*      neighbors
*      side  vertices
*      0     1 2
*      1     2 3
*      2     3 4
*      3     4 0
*      4     0 1
*
*      nref = 5

```

```
*/

typedef struct {
    int    nref;           /* number of geometry reference points */
    int    ndata;          /* number of data ref points -- 0 data at ref */
    int    nmat;           /* number of match points (0 -- match at
                           geometry reference points) */

    int    ntri;           /* number of triangles to represent the elem */
    double *gst;           /* [s,t] geom reference coordinates in the
                           element -- 2*nref in length */

    double *dst;           /* [s,t] data reference coordinates in the
                           element -- 2*ndata in length */

    double *matst;         /* [s,t] positions for match points - NULL
                           when using reference points (2*nmat long) */

    int    *tris;          /* the triangles defined by geom reference indices
                           (bias 1) -- 3*ntri in length */

    int    nseg;           /* number of element segments (sides) */
    int    *segs;          /* the element segments by reference indices
                           (bias 1) -- 2*nsegs in length */
} capsEleType;
```

You will usually have only a small number of element types.

```
/*
 * defines the element discretization for geometric and optional data
 * positions.
 *
 */

typedef struct {
    int    tIndex;           /* the element type index (bias 1) */
    int    eIndex;           /* element owning index -- dim 1 Edge, 2 Face */
    int    *gIndices;        /* local indices (bias 1) geom ref positions,
                             tess index -- 2*nref in length */
    int    *dIndices;        /* the vertex indices (bias 1) for data ref
                             positions -- ndata in length or NULL */

    union {
        int tq[2];          /* tri or quad (bias 1) for ntri <= 2 */
        int *poly;          /* the multiple indices (bias 1) for ntri > 2 */
    } eTris;                /* triangle indices that make up the element */
} capsElement;
```

See AIAA paper 2014-0294 on the website in Publications for a complete write-up (AIAApaper2014-0294.pdf).

```
/*
 * defines a discretized collection of Elements for a body
 *
 * specifies the connectivity based on a collection of Element Types and the
 * elements referencing the types.
 */

typedef struct {
    ego            tess;                /* tessellation object associated with the
                                        discretization */
    int            nElems;              /* number of Elements */
    capsElement    *elems;              /* the Elements (nElems in length) */
    int            *gIndices;           /* memory storage for elemental gIndices */
    int            *dIndices;           /* memory storage for elemental dIndices */
    int            *poly;               /* memory storage for elemental poly */
    int            globalOffset;        /* tessellation global index offset across bodies */
} capsBodyDiscr;
```

```

/*
 * defines a discretized collection of Bodies
 *
 * nPoints refers to the number of indices referenced by the geometric positions
 * in the element which may be different from nVerts which is the number of
 * positions used for the data representation in the element. For simple nodal
 * or isoparametric discretizations, nVerts is zero and verts is set to NULL.
 */
typedef struct {
    int          dim;           /* dimensionality [1-3] */
    void         *instStore;    /* analysis instance storage */
    void         *aInfo;        /* AIM info */
                                /* below handled by the AIMS: */
    int          nVerts;        /* number data ref positions or unconnected */
    double       *verts;        /* data ref positions -- NULL if same as geom */
    int          *celem;        /* 2*nVerts (body, element) containing vert or NULL */
    int          nDtris;        /* number of triangles to plot data */
    int          *dtris;        /* NULL for NULL verts -- indices into verts */
    int          nDsegs;        /* number of segs (sides) to plot data mesh */
    int          *dsegs;        /* NULL for NULL verts -- indices into verts */
    int          nPoints;       /* number of entries in the geom positions */
    int          nTypes;        /* number of Element Types */
    capsEleType  *types;        /* the Element Types (nTypes in length) */
    int          nBodys;        /* number of Body discretizations */
    capsBodyDiscr *bodys;       /* the Body discretizations (nBodys in length) */
    int          *tessGlobal;   /* tessellation indices to this local space
                                2*nPoints in len (bodys index, global tess index) */
    void         *ptrm;         /* pointer for optional AIM use */
} capsDiscr;

```

See \$ESP\_ROOT/doc/capsDiscr.pdf for a more complete description.

## Fill-in the Discrete data for a Bound Object – Optional

```
icode = aimDiscr(char *bname, capsDiscr *discr)
```

**bname** the Bound name

Note: all of the BRep entities are examined for the attribute **capsBound**. Any that match **bname** must be included when filling this **capsDiscr**.

**discr** the Discrete structure to fill

Note: the AIM *instance*, AIM *info* pointer and the dimensionality have been filled in before this function is invoked.

**icode** integer return code

## Frees up pointer in the Discrete Structure – Optional

```
void aimFreeDiscrPtr(void *ptrm)
```

**ptrm** the optional pointer in the Discrete Structure that needs to be freed  
will not be called if the pointer is already **NULL**



## Return Element in the *Mesh* – Optional

```
icode = aimLocateElement(capsDiscr *discr, double *params,  
                        double *param, int *bIndex, int *eIndex,  
                        double *bary)
```

- discr** the input Discrete Structure
- params** the input global *parametric* space (at all of the *geometry* support positions)  
rank is the dimensionality ( $t$  for 1D,  $[u, v]$  for 2D and  $[x, y, z]$  for 3D)
- param** the input requested parametric position in **params** (dimensionality in length)
- bIndex** the returned body index in **discr** where the position was found (1 bias)
- eIndex** the returned element index in **discr** where the position was found (1 bias)
- bary** the resultant Barycentric/reference position in the element **eIndex**
- icode** integer return code

## Data Associated with the Discrete Structure – Optional

```
icode = aimTransfer(capsDiscr *discr, const char *fname, int npts,  
                   int rank, double *data, char **units)
```

- discr** the input Discrete Structure
- fname** the field name to that corresponds to the fill
- npts** the number of points to be filled
- rank** the rank of the data
- data** a pointer associated with the data to be filled ( $\text{rank} \times \text{npts}$  in length)
- units** the returned pointer to the string declaring the units †  
return **NULL** to indicate unitless values
- icode** integer return code

### Fills in the DataSet Object

## Interpolation on the Bound – Optional

```
icode = aimInterpolation(capsDiscr *discr, const char *name,  
                        int bIndex, int eIndex, double *bary,  
                        int rank, double *data, double *result)  
icode = aimInterpolateBar(capsDiscr *discr, const char *name,  
                        int bIndex, int eIndex, double *bary,  
                        int rank, double *r_bar, double *d_bar)
```

**discr** the input Discrete Structure

**name** a pointer to the input DataSet name string

**bIndex** the input target body index (1 bias) in the Discrete Structure

**eIndex** the input target element index (1 bias) in the Discrete Structure

**bary** the input Barycentric/reference position in the element eIndex

**rank** the input rank of the data

**data** values at the data (or geometry) positions

**result** the filled in results (rank in length)

**r\_bar** input  $d(\text{objective})/d(\text{result})$

**d\_bar** returned  $d(\text{objective})/d(\text{data})$

**icode** integer return code

Forward and *reverse differentiated* functions

## Element Integration on the Bound – Optional

```
icode = aimIntegration(capsDiscr *discr, const char *name,  
                      int bIndex, int eIndex, int rank,  
                      double *data, double *result)  
icode = aimIntegrateBar(capsDiscr *discr, const char *name,  
                       int bIndex, int eIndex, int rank,  
                       double *r_bar, double *d_bar)
```

- discr** the input Discrete Structure
- name** a pointer to the input DataSet name string
- bIndex** the input target body index (1 bias) in **discr**
- eIndex** the input target element index (1 bias) in **discr**
- rank** the input rank of the data
- data** values at the data (or geometry) positions – **NULL** length/area/volume of element
- result** the filled in results (**rank** in length)
- r\_bar** input  $d(\text{objective})/d(\text{result})$
- d\_bar** returned  $d(\text{objective})/d(\text{data})$
- icode** integer return code

Forward and *reverse differentiated* functions

# AIM Helper Functions

- provides useful functions for the AIM programmer
- gives access to CAPS Object data
- provides a dynamically loadable writer interface for dealing with large meshes
- note that all function names begin with `aim_`
- if any of these functions are used, then the library must be included (`libaimUtil.a/aimUtil.lib`) in the AIM so/DLL build

## Get Problem root

```
icode = aim_getRootPath(void *aimInfo, const char **fullPath)
```

**aimInfo** the AIM context

**fullPath** the file path to find the root of the Problem/Phase directory structure  
if on Windows it will contain the drive

**icode** integer return code

Note: All other uses of *path* is relative to this point.

## Get absolute file name in Problem/Phase directory

```
icode = aim_file(void *aimInfo, const char *rPath, char *aPath)
```

**aimInfo** the AIM context

**rPath** a path filename relative to the Problem/Phase directory structure

**aPath** returned absolute path filename in the Problem/Phase directory structure (length  
PATH\_MAX)

**icode** integer return code

## Get CAPS revision

```
void aim_capsRev(int *major, int *minor)
```

**major** the returned major revision

**minor** the returned minor revision number

## Relative path file open

```
FILE *fp = aim_fopen(void *aimInfo, const char *rPath,  
                     const char *mode)
```

**aimInfo** the AIM context

**rPath** the relative path filename in the Problem/Phase directory structure

**mode** specifies the mode used for the file open

**fp** the returned FILE pointer

## Create relative path directory

```
icode = aim_mkdir(void *aimInfo, const char *rPath)
```

**aimInfo** the AIM context

**rPath** the relative path directory in the Problem/Phase directory structure

**icode** integer return code

## Execute a command in the AIMs path

```
icode = aim_system(void *aimInfo, const char *rpath, const char *cmd)
```

**aimInfo** the AIM context

**rpath** the relative path from the Analysis' directory or **NULL** (in the Analysis path)

**cmd** the command to execute in a shell

**icode** integer return code

## Check if relative path file exists

```
icode = aim_isFile(void *aimInfo, const char *rPath)
```

**aimInfo** the AIM context

**rPath** the relative path filename in the Problem/Phase directory structure

**icode** CAPS\_SUCCESS if the file exists, CAPS\_NOTFOUND otherwise

## Check if relative path directory exists

```
icode = aim_isDir(void *aimInfo, const char *rPath)
```

**aimInfo** the AIM context

**rPath** the relative path filename in the Problem/Phase directory structure

**icode** CAPS\_SUCCESS if the directory exists, CAPS\_NOTFOUND otherwise



## Copy a file

```
icode = aim_cpFile(void *aimInfo, const char *src, const char *dst)
```

**aimInfo** the AIM context

**src** the absolute path filename to copy

**dst** the path/filename (may be “”) in the Problem/Phase/AIM specific directory structure where the file is copied to

**icode** integer return code

## Make a relative symbolic Link

```
icode = aim_symlink(void *aimInfo, const char *src, const char *dst)
```

**aimInfo** the AIM context

**src** the absolute path filename to link to

**dst** the path/filename (may be “” or **NULL**) in the Problem/Phase/AIM specific directory structure where the relative link is made

**icode** integer return code

Notes:

- 1 On Windows this simply calls `aim_cpFile`
- 2 **dst** must not exist

## Relative path within a Problem/Phase directory

```
icode = aim_relPath(void *aimInfo, const char *src, const char *dst,  
                    char *relPath)
```

**aimInfo** the AIM context

**src** a filename in a Problem/Phase/AIM specific directory

**dst** the path/filename (may be “”) in the Problem/Phase/AIM specific directory structure

**relPath** the relative path from **dst** to **src**

**icode** integer return code

## Is this Analysis Directory a Link?

```
icode = aim_fileLink(void *aimInfo, char *srcPath)
```

**aimInfo** the AIM context

**srcPath** the returned full filename of the source directory (length PATH\_MAX)  
can be **NULL** if this information is not required

**icode** integer return code

CAPS\_NOTFOUND indicates the analysis directory is not a CAPS link

## Remove a relative path directory

```
icode = aim_rmDir(void *aimInfo, const char *rPath)
```

**aimInfo** the AIM context

**rPath** the relative path directory in the Problem/Phase/AIM directory structure

**icode** integer return code

Note: Wildcards \* and/or ? may be used in **rPath**

## Remove a relative path file

```
icode = aim_rmFile(void *aimInfo, const char *rPath)
```

**aimInfo** the AIM context

**rPath** the relative path file in the Problem/Phase/AIM directory structure

**icode** integer return code

Note: Returns success even if the **rPath** file does not exist

## Get Bodies

```
icode = aim_getBodies(void *aimInfo, const char **intent, int *nBody,  
                     ego **bodies)
```

**aimInfo** the AIM context

**intent** the returned pointer to the capsIntent string used to filter the Bodies

**nBody** the returned number of EGADS Body Objects that match the **intent**

**bodies** the returned pointer to a list of EGADS Body/Node Objects

**icode** integer return code

## Is Node Body

```
icode = aim_isNodeBody(ego body, double *xyz)
```

**body** the EGADS Body Objects to query

**xyz** the returned XYZ of the Node (if a Node Body)

**icode** integer return code

## Unit conversion

```
icode = aim_convert(void *aimInfo, const int count  
                  const char *inUnits, double *inValue,  
                  const char *outUnits, double *outValue)
```

**aimInfo** the AIM context

**count** length of *inValue* and *outValue*

**inUnits** the pointer to the string declaring the source units

**inValue** array of values to be converted

**outUnits** the pointer to the string declaring the desired units

**outValue** array of returned converted value (may be same pointer as *inValue*)

**icode** integer return code

## Unit inversion

```
icode = aim_unitInvert(void *aimInfo, const char *inUnits,  
                      char **outUnits)
```

**aimInfo** the AIM context

**inUnits** the pointer to the string declaring units

**outUnits** the returned string units = 1/*inUnits* (freeable)

**icode** integer return code

## Unit multiplication

```
icode = aim_unitMultiply(void *aimInfo, const char *inUnits1,  
                        const char *inUnits2, char **outUnits)
```

**aimInfo** the AIM context

**inUnits1** the pointer to the string declaring left units

**inUnits2** the pointer to the string declaring right units

**outUnits** the returned string units = inUnits1\*inUnits2 (freeable)

**icode** integer return code

## Unit division

```
icode = aim_unitDivision(void *aimInfo, const char *inUnits1,  
                        const char *inUnits2, char **outUnits)
```

**aimInfo** the AIM context

**inUnits1** the pointer to the string declaring numerator units

**inUnits2** the pointer to the string declaring denominator units

**outUnits** the returned string units = inUnits1/inUnits2 (freeable)

**icode** integer return code

## Unit raise to a power

```
icode = aim_unitRaise(void *aimInfo, const char *inUnits,  
                      const int power, char **outUnits)
```

**aimInfo** the AIM context

**inUnits** the pointer to the string declaring units

**outUnits** the returned string units = inUnits ^ power (freeable)

**icode** integer return code

## Unit Offset

```
icode = aim_unitOffset(void *aimInfo, const char *inUnits,  
                       const double offset, char **outUnits)
```

**aimInfo** the AIM context

**inUnits** the pointer to the string declaring units

**offset** offset to add to inUnits

**outUnits** the returned string units = inUnits @ offset (freeable)

**icode** integer return code

## Name to Index lookup

```
icode = aim_getIndex(void *aimInfo, const char *name,  
                     enum capssType stype)
```

**aimInfo** the AIM context

**name** the pointer to the string specifying the name to look-up  
**NULL** returns the total number of members in the subtype

**stype** GEOMETRYIN, GEOMETRYOUT, ANALYSISIN, ANALYSISOUT or  
ANALYSISDYN0

**icode** index (1 bias) or negative integer return code

## Index to Name lookup

```
icode = aim_getName(void *aimInfo, int index, enum capssType stype,  
                   const char **name)
```

**aimInfo** the AIM context

**index** the index to use (1 bias)

**stype** GEOMETRYIN, GEOMETRYOUT, ANALYSISIN, ANALYSISOUT or  
ANALYSISDYN0

**name** the returned pointer to the string specifying the name

**icode** integer return code



## Get GeometryIn Type

```
icode = aim_getGeomInType(void *aimInfo, int index)
```

**aimInfo** the AIM context  
**index** the index of GEOMETRYIN (1 bias)  
**icode** integer return code – 0 is Design, 1 is Configuration, 2 is Constant

## Get Discretization State

```
icode = aim_getDiscrState(void *aimInfo, const char *bname)
```

**aimInfo** the AIM context  
**bname** the Bound name  
**icode** integer return code – CAPS\_SUCCESS is clean

## Get Value Structure

```
icode = aim_getValue(void *aimInfo, int index, enum capsType type, capsValue **value)
```

**aimInfo** the AIM context  
**index** the index to use (1 bias)  
**type** GEOMETRYIN, GEOMETRYOUT, ANALYSISIN, ANALYSISOUT or ANALYSISDYN  
**value** the returned pointer to the capsValue structure

## Initialize Value Structure

```
icode = aim_initValue(capsValue *value)
```

**value** a pointer to the capsValue structure  
sets the initial state of the structure as if aimOutput has been invoked

**icode** integer return code

## Free Value Structure

```
icode = aim_freeValue(capsValue *value)
```

**value** a pointer to the capsValue structure  
frees pointers in value and calls aim\_initValue to rest

**icode** integer return code

## Create Dynamic Output Value Object

```
icode = aim_makeDynamicOutput(void *aimInfo, const char *dynObjName,  
                              capsValue *value)
```

**aimInfo** the AIM context

**dynObjName** the Name to give the Dynamic Output Object  
must be unique for Dynamic Objects in this AIM instance

**value** the value structure used to create the Dynamic Value Object  
the contents are copied into the capsAnalysis structure therefore any pointers in value  
become “owned” by CAPS

**icode** integer return code

These functions are used to manage Dynamic Output Value Objects and can only be used from within `aimPostAnalysis`

## Get AnalysisIn State WRT the Analysis

```
icode = aim_newAnalysisIn(void *aimInfo, int index)
```

**aimInfo** the AIM context

**index** the index to use (1 bias)

**icode** integer return code

## Register a New Tessellation

```
icode = aim_newTess(void *aimInfo, ego tess)
```

**aimInfo** the AIM context

**tess** the EGADS Tessellation Object to register

**icode** integer return code

### Notes:

- 1 If the Body associated with **tess** already has a registered Tessellation Object, the previous tessellation **ego** will be deleted
- 2 Any Tessellation Object registered will be deleted by CAPS before a Geometry regeneration
- 3 If the Body associated with **tess** is not on the OpenCSM stack, the Body Object will be deleted when the Tessellation Object is cleaned up (i.e., CAPS takes ownership of the Body from the AIM)

## Get Geometry State WRT the Analysis

```
icode = aim_newGeometry(void *aimInfo)
```

**aimInfo** the AIM context

**icode** CAPS\_SUCCESS for new, CAPS\_CLEAN if not regenerated since last here

## Get the number of instances in the Analysis

```
icode = aim_numInstance(void *aimInfo)
```

**aimInfo** the AIM context

**icode** Error code (negative) or the number of instances

## Get the instance index for the Analysis

```
icode = aim_getInstance(void *aimInfo)
```

**aimInfo** the AIM context

**icode** Error code (negative) or the Instance index (Bias 0)

## Get Discretization Structure

```
icode = aim_getDiscr(void *aimInfo, const char *bname, capsDiscr **discr)
```

**aimInfo** the AIM context

**bname** the Bound name

**discr** pointer to the returned Discrete structure

**icode** integer return code

## Get Data from Existing DataSet

```
icode = aim_getDataSet(capsDiscr *discr, const char *dname,  
                      enum capsdMethod *method, int *npts,  
                      int *rank, double **data, char **units)
```

**discr** the input Discrete Structure

**dname** the requested DataSet name

**method** the returned method used for data transfers

**npts** the returned number of points in the DataSet

**rank** the returned rank of the DataSet

**data** a returned pointer to the data within the DataSet

**units** the unit string associated with the data within the DataSet

**icode** integer return code

Note: may only be called from aimPreAnalysis

## Get Bound Names

```
icode = aim_getBounds(void *aimInfo, int *nBname, char ***bnames)
```

**aimInfo** the AIM context

**nBname** returned number of Bound names

**bnames** returned pointer to list of Bound names (freeable)

**icode** integer return code

## Get Unit System

```
icode = aim_unitSys(void *aimInfo, char **unitSys)
```

**aimInfo** the AIM context

**unitSys** a returned pointer to a character string declaring the unit system – can be **NULL**

**icode** integer return code

## Clear AIM's directory

```
icode = aim_clear(void *aimInfo)
```

**aimInfo** the AIM context

**icode** integer return code

## Get Value Attributes

```
icode = aim_valueAttrs(void *aimInfo, int index, enum capsType type,  
                      int *nValue, char ***names, capsValue **values)
```

**aimInfo** the AIM context

**index** the index to use (1 bias)

**stype** GEOMETRYIN, GEOMETRYOUT, ANALYSISIN, ANALYSISOUT or  
ANALYSISDYNO

**nValue** returned number of attributes

**names** the returned names – nValue in length (freeable)

**values** the returned pointer to the capsValue structures – nValue in length (freeable)

**icode** integer return code

Note: use `EG_freeAttrs` to free up the memory.



## Get Analysis (our) Attributes

```
icode = aim_analysisAttrs(void *aimInfo, int *nValue, char ***names,  
                           capsValue **values)
```

**aimInfo** the AIM context

**nValue** returned number of attributes

**names** the returned names – nValue in length (freeable)

**values** the returned pointer to the capsValue structures – nValue in length (freeable)

**icode** integer return code

Note: use `EG_freeAttrs` to free up the memory.

## Free Attribute storage

```
void aim_freeAttrs(int nValue, char **names, capsValue *values)
```

**aimInfo** the AIM context

**nValue** the number of attributes

**names** the names to be freed – nValue in length

**values** the pointer to the capsValue structures – nValue in length

## Setup for Sensitivities

```
icode = aim_setSensitivity(void *aimInfo, const char *GIname,  
                          int *irow, int *icol)
```

**aimInfo** the AIM context

**GIname** the pointer to the string that matches the *Geometry Input* Parameter name

**irow** the parameter row to use – 1 bias

**icol** the parameter column to use – 1 bias

**icode** integer return code

### Notes:

- 1 **aim\_newTess** must have been invoked sometime before calling this function to set the tessellations for the Bodies of interest
- 2 Call **aim\_setSensitivity** before call(s) to **aim\_getSensitivity**.

## Get Sensitivities based on Tessellation Components

```
icode = aim_getSensitivity(void *aimInfo, ego tess, int ttype,  
                           int index, int *npts, double **dxyz)
```

**aimInfo** the AIM context

**tess** the EGADS Tessellation Object

**ttype** topological type – 0 - NODE, *Tessellation Sensitivities*: 1 - EDGE, 2 - FACE  
*Geometric Sensitivities*: -1 - EDGE, -2 - FACE

**index** the index in the Body (associated with the tessellation) based on the *type*

**npts** the returned number of sensitivities (number of tessellation points)

**dxyz** a pointer to the returned sensitivities – 3\*npts in length (*freeable*)

**icode** integer return code

Note:

- Call `aim_setSensitivity` before call(s) to `aim_getSensitivity`

## Get Global Tessellation Sensitivities

```
icode = aim_tessSensitivity(void *aimInfo, const char *name,  
                           int irow, int icol, ego tess, int *npts,  
                           double **dxyz)
```

- aimInfo** the AIM context
- name** the pointer to the string that matches the *Geometry Input* Parameter name
- irow** the parameter row to use – 1 bias
- icol** the parameter column to use – 1 bias
- tess** the EGADS Tessellation Object
- npts** the returned number of sensitivities (number of global vertices)
- dxyz** a pointer to the returned sensitivities – 3\*npts in length (*freeable*)
- icode** integer return code

### Notes:

- 1 Used to get the tessellation sensitivities for the entire Tessellation Object
- 2 The number of points is the global number of vertices in the tessellation

## Set Step Size for Sensitivities

```
icode = aim_setStepSize(void *aimInfo, double step)
```

**aimInfo** the AIM context

**step** the step size used for subsequent AIM-based sensitivity calculations  
minus indicates defaulting to CAPS, 0.0 is for analytic, positive sets the finite difference step size

**icode** integer return code

## Get Step Size for Sensitivities

```
icode = aim_getStepSize(void *aimInfo, double *step)
```

**aimInfo** the AIM context

**step** the step size used for subsequent AIM-based sensitivity calculations  
minus indicates defaulting to CAPS, 0.0 is for analytic, positive sets the finite difference step size

**icode** integer return code

These functions should only be used for debugging

## Function Status MACRO

`AIM_STATUS(void *aimInfo, int status, ...)`

`aimInfo` the AIM context

`status` return status from a function

`...` printf type format string and data

### Notes:

- 1 Tracks file, line, and function name backtrace information – if `status != CAPS_SUCCESS`
- 2 Includes “goto cleanup” if `status != CAPS_SUCCESS`

### Pseudo Code Examples

```
status = myfunc1(aimInfo, arg1, arg2);  
AIM_STATUS(aimInfo, status, cleanup)
```

```
status = myfunc2(aimInfo, arg1, arg2);  
AIM_STATUS(aimInfo, status, cleanup, "myfunc2 args %d, %d", arg1, arg2)
```

## ANALYSISIN Error Message MACRO

```
AIM_ANALYSISIN_ERROR(void *aimInfo, enum index, const char *format,  
                    ...)
```

**aimInfo** the AIM context

**index** index of ANALYSISIN

**format** printf format string

**...** printf data

Note: Tracks file, line, and function name backtrace information

### Pseudo Code Examples

```
mach = inputs[Mach-1].vals.real;  
if (mach < 0) {  
    AIM_ANALYSISIN_ERROR(aimInfo, Mach,  
                        "Mach = %f must be >= 0\n", mach);  
    status = CAPS_BADVALUE;  
    goto cleanup;  
}
```

## Error Message MACRO

```
AIM_ERROR(void *aimInfo, const char *format, ...)
```

**aimInfo** the AIM context  
**format** printf format string  
**...** printf data

Note: Tracks file, line, and function name backtrace information

## Message Add Line MACRO

```
AIM_ADDLINE(void *aimInfo, const char *format, ...)
```

**aimInfo** the AIM context  
**format** printf format string  
**...** printf data

## Pseudo Code Examples

```
status = aim_getBodies(aimInfo, &nBody, &bodies);
AIM_STATUS(aimInfo, status)

If (nBody != 1) {
    AIM_ERROR(aimInfo, "Only one body expected, but nBody = %d", nBody);
    AIM_ADDLINE(aimInfo, "This aim can only work with one body");
    status = CAPS_BADVALUE;
    goto cleanup;
}
```



## Warning Message MACRO

```
AIM_WARNING(void *aimInfo, const char *format, ...)
```

**aimInfo** the AIM context

**format** printf type format string

**...** printf data

### Notes:

- 1 Tracks file, line, and function name backtrace information
- 2 Use AIM\_ADDLINE to add additional lines

## Pseudo Code Examples

```
status = aim_getBodies(aimInfo, &nBody, &bodies);  
AIM_STATUS(aimInfo, status)
```

```
If (nBody > 1) {  
    AIM_WARNING(aimInfo, "Only one body will be used, but nBody = %d", nBody);  
    AIM_ADDLINE(aimInfo, "This aim only uses one body");  
}
```

## Informational Message MACRO

```
AIM_INFO(void *aimInfo, const char *format, ...)
```

**aimInfo** the AIM context

**format** printf type format string

**...** printf data

Notes:

- 1 Tracks file, line, and function name backtrace information
- 2 Use AIM\_ADDLINE to add additional lines

## Remove Error Message

```
aim_removeError(void *aimInfo)
```

**aimInfo** the AIM context

## Pseudo Code Example

```
status = myfunc3(aimInfo, arg1, arg2);  
if (status == CAPS_BADVALUE) {  
    aim_removeError(aimInfo);  
    /* Resolve CAPS_BADVALUE error */  
} else {  
    AIM_STATUS(aimInfo, status);  
}
```

## Memory Allocation MACROs

AIM\_ALLOC(**void** \*ptr, **size\_t** size, **type**, **void** \*aimInfo, **int** status)

AIM\_REALL(**void** \*ptr, **size\_t** size, **type**, **void** \*aimInfo, **int** status)

**ptr** pointer assigned allocation (must be **NULL** for AIM\_ALLOC)

**size** number of **type** allocations

**type** data type for the allocation

**aimInfo** the AIM context

**status** function return status

Notes:

- 1 Tracks file, line, and function name backtrace information
- 2 Includes “goto cleanup” on error and sets **status** = EGADS\_MALLOC

## Free Memory

AIM\_FREE(**void** \*ptr)

**ptr** frees pointer memory and sets **ptr** = **NULL**

## String Duplication MACRO

```
AIM_STRDUP(char *ptr, const char *str, void *aimInfo, int status)
```

**ptr** pointer assigned allocation (must be **NULL**)

**str** string for duplication

**aimInfo** the AIM context

**status** function return status

Notes:

- 1 Tracks file, line, and function name backtrace information
- 2 Includes “goto cleanup” on error and sets **status** = EGADS\_MALLOC

## Enum Name Creation MACRO

```
char *AIM_NAME (enum Name)
```

**Name** enumeration

Notes: Converts enumeration Index “Name” to a string and returns a duplicate string

## NULL Check MACRO

```
AIM_NOTNULL(char *ptr, void *aimInfo, int status)
```

**ptr** pointer checked

**aimInfo** the AIM context

**status** function return status

Notes: If **ptr == NULL**, sets **status = CAPS\_NULLVALUE** and then “goto cleanup”

## Pseudo Code Example

```
enum aimInputs {  
    Mach = 1,          /* index is 1-based */  
    NUMINPUT = Mach    /* Total number of inputs */  
};  
...  
if (index == Mach) {  
    *ainame = AIM_NAME(Mach);  
    ...  
}  
AIM_NOTNULL(*ainame, aimInfo, status);
```

## Initialize capsBodyDiscr Pointer

```
void aim_initBodyDiscr(capsBodyDiscr *discBody)
```

**discBody** pointer to initialize

## Linear Triangle/Quad Element Type with Nodal Data

```
icode = aim_nodalTriangleType(capsEleType *eletype)  
icode = aim_nodalQuadType(capsEleType *eletype)
```

**eletype** element type pointer to fill  
**icode** integer return code

## Linear Triangle/Quad Element Type with Cell Data

```
icode = aim_cellTriangleType(capsEleType *eletype)  
icode = aim_cellQuadType(capsEleType *eletype)
```

**eletype** element type pointer to fill  
**icode** integer return code

## Return Element in a Linear *Mesh*

```
icode = aim_locateElement(capsDiscr *discr, double *params,  
                        double *param, int *eIndex, int *bIndex,  
                        double *bary)
```

- discr** the input Discrete Structure
- params** the input global *parametric* space (at all of the *geometry* support positions)  
rank is the dimensionality ( $t$  for 1D,  $[u, v]$  for 2D and  $[x, y, z]$  for 3D)
- param** the input requested parametric position in **params** (dimensionality in length)
- bIndex** the returned body index in **discr** where the position was found (1 bias)
- eIndex** the returned element index in **discr** where the position was found (1 bias)
- bary** the resultant Barycentric/reference position in the element **eIndex**
- icode** integer return code

## Interpolation on the Bound in a Linear *Mesh*

```
icode = aim_interpolation(capsDiscr *discr, const char *name,  
                          int bIndex, int eIndex, double *bary,  
                          int rank, double *data, double *result)  
icode = aim_interpolateBar(capsDiscr *discr, const char *name,  
                           int bIndex, int eIndex, double *bary,  
                           int rank, double *r_bar, double *d_bar)
```

**discr** the input Discrete Structure for a Linear *Mesh*

**name** a pointer to the input DataSet name string

**bIndex** the input target body index (1 bias) in the Discrete Structure

**eIndex** the input target element index (1 bias) in the Discrete Structure

**bary** the input Barycentric/reference position in the element eIndex

**rank** the input rank of the data

**data** values at the data (or geometry) positions

**result** the filled in results (rank in length)

**r\_bar** input d(objective)/d(result)

**d\_bar** returned d(objective)/d(data)

**icode** integer return code

Forward and *reverse differentiated* functions



## Element Integration on the Bound in a Linear *Mesh*

```
icode = aim_integration(capsDiscr *discr, const char *name,  
                       int bIndex, int eIndex, int rank,  
                       double *data, double *result)  
icode = aim_integrateBar(capsDiscr *discr, const char *name,  
                        int bIndex, int eIndex, int rank,  
                        double *r_bar, double *d_bar)
```

- discr** the input Discrete Structure for a Linear *Mesh*  
**name** a pointer to the input DataSet name string  
**bIndex** the input target body index (1 bias) in **discr**  
**eIndex** the input target element index (1 bias) in **discr**  
**rank** the input rank of the data  
**data** values at the data (or geometry) positions – **NULL** length/area/volume of element  
**result** the filled in results (**rank** in length)  
**r\_bar** input  $d(\text{objective})/d(\text{result})$   
**d\_bar** returned  $d(\text{objective})/d(\text{data})$   
**icode** integer return code

Forward and *reverse differentiated* functions

# AIM meshWriter Structures and Functions

- Structures filled by an AIM mesh generation
- Functions for initializeing and filling the structures
- The library (libaimMesh.a/aimMesh.lib) must be included in the AIM so/DLL build

## Dynamically loading the mesh writer

The meshing AIM dynamically loads the appropriate so/DLL to output the mesh file in its default location. If the mesh data is memory resident during postAnalysis, it needs be written to disk and freed. The mesh writer shared object/DLL needs to contain only the entry points: `meshExtension` & `meshWrite` (see below).

## aimMesh Structure

The complete representation of a mesh

```
typedef struct {  
    aimMeshData *meshData;  
    aimMeshRef *meshRef;  
} aimMesh;
```

**meshData** represents the mesh coordinates and connectivity

**meshRef** mapping of the boundary mesh vertexes to the interior vertexes

A mesh generation AIM is responsible for filling the complete [aimMesh](#) Structure, which is passed to a `meshWriter` shared library, which is responsible for writing the data to disk. Only the `meshRef` pointer is passed via a link to an analysis AIM.

## aimMeshData Structure

Represents the Cartesian coordinates and element connectivity of the mesh

```
typedef double aimMeshCoords[3];
typedef int    aimMeshIndices[2];
typedef struct {
    int          dim;           /* Physical dimension: 2D or 3D */
    int          nVertex;      /* total number of vertices in the mesh */
    aimMeshCoords *verts;      /* the xyz coordinates of the vertices
                               nVertex in length */
    int          nElemGroup;    /* number of element groups */
    aimMeshElemGroup *elemGroups; /* element groups -- nElemGroup in length */
    int          nTotalElems;   /* total number of elements */
    aimMeshIndices *elemMap;    /* group,elem map in original element ordering
                               nTotalElems in length -- can be NULL */
} aimMeshData;
```

**dim** must be 2 or 3 to represent the number Physical dimensions used in verts.  
**nVertex** number of coordinates

**verts** Coordinates stored as  $verts[iv][d]$  for  $iv \in [0, nVertex)$  and  $d \in [0, dim)$ .

**nElemGroup** number of element groups

**elemGroups** group of elements with all the same type (nElemGroups in length)

**nTotalElems** total number of elements in the mesh

**elemMap** The original element ordering (*nTotalElems* in length).  $elemMap[ie][0]$  is the 0-based element group index into *elemGroups*, and  $elemMap[ie][1]$  is 0-based index of the element in the group.

## aimMeshElemGroup Structure

Represents a group of elements of the same type

```
typedef struct {
    char          *groupName; /* name of group or NULL */
    int           ID;         /* Group ID */
    enum aimMeshElem elementTopo; /* Element topology */
    int           order;      /* order of the element (1 - Linear) */
    int           nPoint;     /* number of points defining an element */
    int           nElems;     /* number of elements in the group */
    int           *elements;  /* Element-to-vertex connectivity (1-based)
                               nElem*nPoint in length */
} aimMeshElemGroup;
```

**groupName** group identifier that may be non-unique

**ID** group identifier that may be non-unique

**elementTopo** is one of:

```
enum aimMeshElem {aimUnknownElem, aimLine, aimTri, aimQuad, aimTet,
                  aimPyramid, aimPrism, aimHex};
```

**order** polynomial degree of element

**nPoint** number of points in an element

**nElems** number of elements the group

**elements** Element-to-vertex (1-based) connectivity nElem\*nPoint in length

## aimMeshRef Structure

Represents the boundary of a mesh and a reference to the full mesh

```
typedef struct {  
    enum aimMeshType type;      /* type of mesh referenced */  
    int nmap;                   /* number of EGADS Tessellation Objects */  
    aimMeshTessMap *maps;       /* the EGADS Tess Object and map to mesh verts */  
    int nbnd;                   /* number of boundary groups */  
    aimMeshBnd *bnds;           /* boundary group info */  
    char *fileName;             /* full path name (no extension) for grids */  
    int _delTess;               /* internal use only, whether tess/body ego are deleted */  
} aimMeshRef;
```

**type** is one of:

```
enum aimMeshType {aimUnknownMeshType, aimAreaMesh,  
                  aimSurfaceMesh, aimVolumeMesh};
```

**nmap** number of mappings from the boundary to the interior

**maps** boundary to the interior mapping

**nbnd** number of boundary groups

**bnds** boundary group information

**fileName** absolute path to the full mesh file name without the extension

**\_delTess** Internal usage that should not be modified

## aimMeshTessMap Structure

Represents the a boundary mesh and it's mapping to the interior

```
typedef struct {  
    ego tess;          /* the EGADS Tessellation Objects (contains Body) */  
    int *map;          /* the mapping between Tessellation vertices and  
                      mesh vertices -- tess verts in length */  
} aimMeshTessMap;
```

- tess** an EGADS tessellation of the boundary
- map** mapping from global tessellation vertices to the interior mesh verticies. Use EG\_statusTessBody to get the length.

## aimMeshBnd Structure

Represents the a boundary group information

```
typedef struct {  
    char *groupName;  /* name of group or NULL */  
    int ID;           /* Group ID */  
} aimMeshBnd;
```

- groupName** a name associated with a boundary group
- ID** an identifier associated with the group

## Mesh writer entry points

The following two functions are required for each dynamically loaded mesh writer. They allow the AIM mesh writer interface the ability to complete the filenames and to output the meshes. This is dynamically loadable so that new (or custom) mesh writer can be easily attached to a CAPS session.

```
const char *extension = meshExtension()
```

**extension** the file extension used for this writer

```
icode = meshWrite(void *aimInfo, aimMesh *mesh)
```

**aimInfo** the AIM context

**mesh** the mesh data structure that will be written

**icode** integer return code



## Delete previous meshes

```
icode = aim_deleteMeshes(void *aimInfo, aimMeshRef *meshRef)
```

**aimInfo** the AIM context

**meshRef** the pointer to the Mesh Reference Structure

**icode** integer return code

This should be called during the mesh writing preAnalysis to cleanup mesh files from previous invocations of the AIM instance. This is required because if the mesh file already exists, it is not (re)written in `aim_writeMeshes`.

## Query mesh existence

```
icode = aim_queryMeshes(void *aimInfo, int index, aimMeshRef *meshRef)
```

**aimInfo** the AIM context

**index** the AnalysisOut Value index to query

**meshRef** the pointer to the Mesh Reference Structure

**icode** integer return code

This call returns `CAPS_SUCCESS` if the mesh file already exists and no others are needed, if positive then this is the number of file types that need to be written via calling `aim_writeMeshes`.

## Write meshes

```
icode = aim_writeMeshes(void *aimInfo, int index, aimMesh *mesh)
```

**aimInfo** the AIM context

**index** the AnalysisOut Value index to write

**mesh** the pointer to the Mesh Structure

**icode** integer return code

If meshes need to be output (see `aim_queryMeshes`), the mesh data must be populated and then written out by calling this function (all within `calcOutput`).

This calls `writeMesh` for each linked solver Analysis Input (as specified in the linkage) unless the file already exists. After this call the memory allocated to fill **mesh** should be freed.

## Initialize aimMeshRef

```
icode = aim_initMeshRef( aimMeshRef *meshRef)
```

**meshRef** the aimMeshRef instance for member data initialization

**icode** integer return code

## Free aimMeshRef

```
icode = aim_freeMeshData( aimMeshRef *meshRef)
```

**meshRef** the aimMeshRef instance to free member data

**icode** integer return code

## Initialize aimMeshBnd

```
icode = aim_initMeshBnd( aimMeshBnd *meshBnd)
```

**meshBnd** the aimMeshBnd instance for member data initialization

**icode** integer return code

## Initialize aimMeshData

```
icode = aim_initMeshData( aimMeshData *meshData)
```

**meshData** the aimMeshData instance for member data initialization

**icode** integer return code

## Free aimMeshData

```
icode = aim_freeMeshData( aimMeshData *meshData)
```

**meshData** the aimMeshData instance to free member data

**icode** integer return code

## Add element group to aimMeshData

```
icode = aim_addMeshElemGroup( void *aimInfo, const char *groupName,  
                               int ID, enum aimMeshElem elementTopo,  
                               int order, int nPoint,  
                               aimMeshData *meshData)
```

**aimInfo** the AIM context  
**groupName** the name of the group (may be **NULL**)  
**ID** an integer group ID  
**order** the degree of the polynomial for the elements  
**nPoint** number of points in the element  
**meshData** the aimMeshData where the element group is added  
**icode** integer return code

## Add element group to aimMeshData

```
icode = aim_addMeshElem( void *aimInfo, int nElems,  
                         aimMeshElemGroup *elemGroup)
```

**aimInfo** the AIM context  
**nElems** number of elements to add to the element group  
**elemGroup** the aimMeshElemGroup where the elements are added  
**icode** integer return code

## Write meshRef to disk

```
icode = aim_storeMeshRef( void *aimInfo, const aimMeshRef *meshRef,  
                          const char *mesheextension)
```

**aimInfo** the AIM context

**meshRef** the aimMeshRef instance written to disk

**mesheextension** the mesh extension used by the analysis AIM

**icode** integer return code

Note: This function should be called by an analysis AIM during preAnalysis to store a meshRef instance for mesh morphing.

## Load aimMeshRef from disk

```
icode = aim_loadMeshRef( void *aimInfo, aimMeshRef *meshRef )
```

**aimInfo** the AIM context

**meshRef** the aimMeshRef instance fill from disk

**icode** integer return code

Note: This function should be called by an analysis AIM during preAnalysis to load a meshRef instance for mesh morphing.

## Morph a meshRef

```
icode = aim_morphMeshUpdate( void *aimInfo, aimMeshRef *meshRef,  
                             , int numBody, ego *bodies)
```

**aimInfo** the AIM context

**meshRef** the aimMeshRef instance to be updated

**numBody** number of bodies

**bodies** ego list of new bodies (*numBody* in length)

**icode** integer return code

Note: The tessellation objects in *meshRef* are mapped to *bodies* and the boundary to interior mapping is updated.