



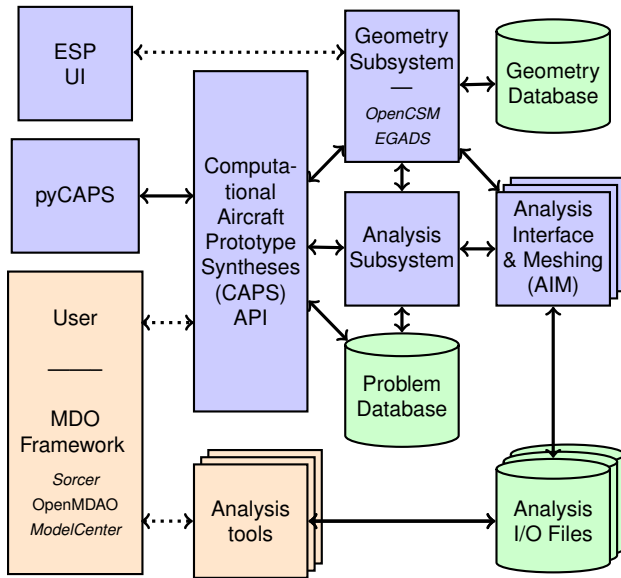
Computational Aircraft Prototype Syntheses: The CAPS API

Part of ESP Revision 1.17

Bob Haimes

haimes@mit.edu

Aerospace Computational Design Lab
Massachusetts Institute of Technology



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, Branch, Parameter, User	capsProblem, capsValue
capsAnalysis		capsProblem
capsValue	AnalysisIn, AnalysisOut	capsAnalysis, capsValue
capsBound		capsProblem
capsVertexSet	Connected, Unconnected	capsBound
capsDataSet	User, Analysis, Interpolate, Conserve, Builtin, Sensitivity	capsVertexSet

Body Objects are EGADS Objects (egos)

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_load` 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_load` is **NULL**, all Bodies with a “capsAIM” attribute that matches the AIM name are given to the AIM instance.

capsLength

This string Attribute must be applied to an EGADS Body to indicate the length units used in the geometric construction.

capsBound

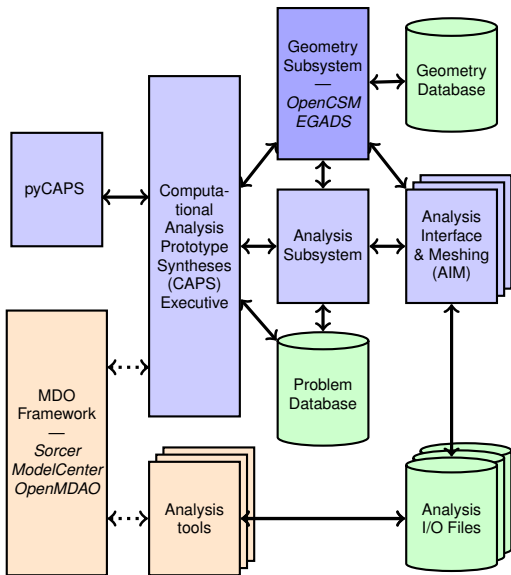
This string Attribute must be applied to EGADS BRep Objects to indicate which CAPS Bound(s) are associated with the geometry. A entity can be assigned to multiple Bounds by having the Bound names separated by a semicolon. Face examples could be “Wing”, “Wing;Flap”, “Fuselage”, and etc.

Note: Bound names should not cross dimensional lines.

capsGroup

This string Attribute can be applied to EGADS BRep Objects to assist in grouping geometry into logical sets. A geometric entity can be assigned to multiple groups in the same manner as the capsBound attribute.

Note: CAPS does not internally use this, but is suggested of classifying geometry.



Setup (or read) the Problem:

- Initialize Problem with *csn* (or *static*) file
GeomIn and GeomOut parameters
- Specify *mission* parameters
- Make Analysis instances
AnalysisIn and AnalysisOut params
- Create *Bounds*, *VetrexSets* & *DataSets*
- Establish linkages between parameters

Run the Problem:

- Adjust the appropriate parameters
- Regenerate Geometry (if *dirty*)
- Call for Analysis Input file generation
- Framework/user runs each *solver*
- Inform CAPS that an Analysis has run
fills AnalysisOut params & *DataSets* (lazy)
- Generate *Objective Function*

Save the Problem DB (*checkpointing*)

Open CAPS Problem

```
icode = caps_open(char *name, char *pname, capsObj *problem)
```

name the input file name – action based on file extension:

***.caps** read the saved CAPS problem file

***.csm** initialize the project using the specified OpenCSM file

***.egads** initialize the project based on the static geometry

pname the input CAPS problem process name

problem the returned CAPS problem Object

Set Verbosity Level

```
icode = caps_outLevel(capsObj problem, int outLevel)
```

problem the CAPS problem object

outLevel 0 - minimal, 1 - standard (default), 2 - debug

icode the integer return code / old outLevel

Close CAPS Problem

```
icode = caps_close(capsObj problem)
```

problem the input CAPS problem to close and perform a memory cleanup

Save Problem file

```
icode = caps_save(capsObj problem, char *name)
```

problem the input CAPS problem Object to write

name the save file name – no extension (added by this function)

icode the integer return code

Information about an Object

```
icode = caps_info(capsObj object, char **name, enum *type, enum *stype,  
                 capsObj *link, capsObj *parent, capsOwn *last)
```

object the input CAPS Object

name the returned Object name pointer (if any)

type the returned data type: Problem, Value, Analysis, Bound, VertexSet, DataSet

stype the returned subtype (depending on type)

link the returned linkage Value Object (**NULL** – no link)

parent the returned parent Object (**NULL** for a Problem or an Attribute generated User Value)

last the returned last owner to *touch* the Object

icode integer return code

Children Sizing info from a Parent Object

```
icode = caps_size(capsObj object, enum type, enum stype, int *size)
```

object the input CAPS Object

type the data type to size: Bodies, Attributes, Value, Analysis, Bound, VertexSet, DataSet

stype the subtype to size (depending on type)

size the returned size

icode integer return code

Get Child by Index

```
icode = caps_childByIndex(capsObj object, enum type, enum stype,  
                          int index, capsObj *child)
```

object the input parent Object

type the Object type to return: Value, Analysis, Bound, VertexSet, DataSet

stype the subtype to find (depending on type)

index the index [1-size]

child the returned CAPS Object

icode integer return code

Get Child by Name

```
icode = caps_childByName(capsObj object, enum type, enum stype,  
                        char *name, capsObj *child)
```

object the input parent Object

type the Object type to return: Value, Analysis, Bound, VertexSet, DataSet

stype the subtype to find (depending on type)

name a pointer to the index character string

child the returned CAPS Object

icode integer return code

Delete an Object

```
icode = caps_delete(capsObj object)
```

object the Object to be deleted

Note: only Value Objects of subtype User and Bound Objects may be deleted!

icode integer return code

Get Body by index

```
icode = caps_bodyByIndex(capsObj obj, int ind, ego *body, char **unit)
```

obj the input CAPS Problem or Analysis Object

ind the index [1-size]

body the returned EGADS Body Object

units pointer to the string declaring the length units – **NULL** for unitless values

icode integer return code

Set Owner Data

```
icode = caps_setOwner(capsObj prob, char *pname, capsOwn *owner)
```

prob the input CAPS Problem Object

pname a pointer to the process name character string

owner a pointer to the CAPS Owner structure to fill

icode integer return code

- Notes: (1) This increases the Problem's sequence number
(2) This does not return the owner pointer, but uses the address to fill
(3) The internal strings can be freed up with `caps_freeOwner`

Free Owner Information

```
caps_freeOwner(capsOwn *owner)
```

owner a pointer to the CAPS Owner structure to free up the members pname, pID and user

Get Owner Information

```
icode = caps_ownerInfo(capsOwn owner, char **pname, char **pID,  
                      char **userID, short datetime[6], long *sNum)
```

owner the input CAPS Owner structure

pname the returned pointer to the process name

pID the returned pointer to the process ID

userID the returned pointer to the user ID

datetime the filled date/time stamp info [year, month, day, hour, minute, second]

sNum the sequence number (always increasing)

icode integer return code

Get Error Information

```
icode = caps_errorInfo(capsErrs *errors, int eindex, capsObj *errObj,  
                      int *nLines, char ***lines)
```

errors the input CAPS Error structure

eindex the index into error (1 bias)

errObj the offending CAPS Object

nLines the returned number of comment lines to describe the error

lines a pointer to a list of character strings with the error description

icode integer return code

Free Error Structure

```
icode = caps_freeError(capsErrs *errors)
```

errors the CAPS Error structure to be freed

icode integer return code

Free memory in Value Structure

```
caps_freeValue(capsValue *value)
```

value a pointer to the Value structure to be cleaned up

Create A Value Object

```
icode = caps_makeValue(capsObj problem, char *vname, enum subtype,
                      enum vtype, int nrow, int ncol, void *data,
                      char *units, capsObj *val)
```

problem the input CAPS Problem Object where the Value to reside

vname the Value Object name to be created

subtype the Object subtype: Parameter or User

vtype the value data type:

0	Boolean	2	Double	4	String Tuple
1	Integer	3	Character String		

nrow number of rows (not needed for Character Strings)

ncol number of columns (not needed for strings) – `vlen = nrow * ncol`

data pointer to the appropriate block of memory
must be a pointer to a *capsTuple* structure(s) when **vtype** is a Tuple

units pointer to the string declaring the units – **NULL** for unitless values

val the returned CAPS Value Object

icode integer return code

Retrieve Values

```
icode = caps_getValue(capsObj val, enum *vtype, int *vlen, void **data,
                     char **units, int *nErr, capsErrs **errs)
```

val the input Value Object

vtype the returned data type:

0	Boolean	2	Double	4	String Tuple
1	Integer	3	Character String	5	Value Object

vlen the returned value length

data a filled pointer to the appropriate block of memory (**NULL** – don't fill)
Can use `childByIndex` to get Value Objects

units the returned pointer to the string declaring the units

nErr the returned number of errors generated – **0** means no errors

errs the returned CAPS error structure – **NULL** with no errors

icode integer return code

Use the structure *capsTuple* when casting data if a Tuple (4)

Reset A Value Object

```
icode = caps_setValue(capsObj val, int nrow, int ncol, void *data)
```

val the input CAPS Value Object (not for GeometryOut or AnalysisOut)
nrow number of rows (not needed for Character Strings)
ncol number of columns (not needed for strings) – $vlen = nrow * ncol$
data pointer to the appropriate block of memory used to reset the values

Get Valid Value Range

```
icode = caps_getLimits(capsObj val, void **limits)
```

val the input Value Object
limits an returned pointer to a block of memory containing the valid range [$2 * sizeof(vtype)$ in length] – or – **NULL** if not yet filled

Set Valid Value Range

```
icode = caps_setLimits(capsObj val, void *limits)
```

val the input Value Object (only for the User & Parameter subtypes)
limits a pointer to the appropriate block of memory which contains the minimum and maximum range allowed (2 in length)
icode integer return code

Get Value Shape/Dimension

```
icode = caps_getValueShape(capsObj val, int *dim, enum *lfixed,  
                           enum *sfixed, enum *ntype,  
                           int *nrow, int *ncol)
```

val the input Value Object

dim the returned dimensionality:

0 scalar only

1 vector or scalar

2 scalar, vector or 2D array

lfixed **0** – the length(s) can change, **1** – the length is fixed

sfixed **0** – the Shape can change, **1** – Shape is fixed

ntype **0** – NULL invalid, **1** – not NULL, **2** – is NULL

nrow number of rows – parent index for Value vtypes

ncol number of columns

Note: $vlen = nrow * ncol$

icode integer return code

Set Value Shape/Dimension

```
icode = caps_setValueShape(capsObj val, int dim, enum lfixed,  
                           enum sfixed, enum ntype)
```

val the input Value Object (only for the User & Parameter subtypes)

dim the dimensionality:

0 scalar only

1 vector or scalar

2 scalar, vector or 2D array

lfixed **0** – the length(s) can change, **1** – the length is fixed

sfixed **0** – the Shape can change, **1** – Shape is fixed

ntype **0** – NULL invalid, **1** – not NULL, **2** – is NULL

Units conversion

```
icode = caps_convert(capsObj val, char *units, double in, double *out)
```

val the reference Value Object

units the pointer to the string declaring the source units

in the source value to be converted

out the returned converted value in the Value Object's units

Transfer Values

```
icode = caps.transferValues(capsObj src, enum tmethod, capsObj dst,  
                           int *nErr, capsErrs **errs)
```

src the source input Value Object (not for Value or Tuple vtypes) – or –
DataSet Object

tmethod 0 – copy, 1 – integrate, 2 – weighted average – (1 & 2 only for DataSet src)

dst the destination Value Object to receive the data
Notes:

- Must not be GeometryOut or AnalysisOut
- Shapes must be compatible
- Overwrites any Linkage

nErr the returned number of errors generated – 0 means no errors

errs the returned CAPS error structure – NULL with no errors

icode integer return code

Establish Linkage

```
icode = caps_makeLinkage(capsObj link, enum tmethod, capsObj trgt)
```

link linking Value Object (not for Value or Tuple vtypes or Value subtype User) – or – DataSet Object

tmethod 0 – copy, 1 – integrate, 2 – weighted average – (1 & 2 only for DataSet link)

trgt the target Value Object which will get its data from link
Notes:

- Must not be GeometryOut or AnalysisOut
- Shapes must be compatible
- link = **NULL** removes any Linkage

icode integer return code

Note: circular linkages are not allowed!

Get Attribute by name

```
icode = caps_attrByName(capsObj object, char *name, capsObj *attr)
```

object any CAPS Object

name a string referring to the Attribute name

attr the returned User Value Object (must be deleted when no longer needed)

icode integer return code

Get Attribute by index

```
icode = caps_attrByIndex(capsObj object, int in, capsObj *attr)
```

object any CAPS Object

in the index (bias 1) to the list of Attributes

attr the returned User Value Object (must be deleted when no longer needed)
Attribute name is the Value Object name

icode integer return code

Note: The *shape* of the original Value Object is not maintained, but the length is correct.

Set an Attribute

```
icode = caps_setAttr(capsObj object, char *name, capsObj attr)
```

object any CAPS Object

name a string referring to the Attribute name – **NULL**: use name in **attr**
Note: an existing Attribute of this name is overwritten with the new value

attr the Value Object containing the attribute
The attribute will not maintain the Value Object's *shape*

icode integer return code

Delete an Attribute

```
icode = caps_deleteAttr(capsObj object, char *name)
```

object any CAPS Object

name a string referring to the Attribute to delete
NULL deletes all attributes attached to the Object

icode integer return code

Query Analysis – Does not ‘load’ or create an object

```
icode = caps_queryAnalysis(capsObj problem, char *aname,  
                           int *nIn, int *nOut, int *execution)
```

problem a CAPS Problem Object

aname the Analysis (and AIM plugin) name

Note: this causes the the DLL/Shared-Object to be loaded (if not already resident)

nIn the returned number of Inputs

nOut the returned number of Outputs

execution the returned execution flag: **0** – no execution, **1** – AIM performs analysis

icode integer return code

Get Bodies

```
icode = caps_getBodies(capsObj analysis, int *nBody, ego **bodies)
```

analysis the Analysis Object

nBody the returned number of EGADS Body Objects that match the Analysis’ intent

bodies the returned pointer to a list of EGADS Body/Node Objects,
Tessellation Objects (set by `aim_setTess`) follow (length – 2*nBody)

icode integer return code

Query Analysis Input Information

```
icode = caps_getInput(capsObj problem, char *aname, int index,  
                     char **ainame, capsValue *default)
```

problem a CAPS Problem Object

aname the Analysis (and AIM plugin) name

index the Input index [1-nIn]

ainame a pointer to the returned Analysis Input variable name (use EG_free to free memory)

default a pointer to the filled default value(s) and units – use caps_freeValue to cleanup

Query Analysis Output Information

```
icode = caps_getOutput(capsObj problem, char *aname, int index,  
                     char **aaname, capsValue *form)
```

problem a CAPS Problem Object

aname the Analysis (and AIM plugin) name

index the Output index [1-nOut]

aaaname a pointer to the returned Analysis Output variable name (use EG_free)

form a pointer to the Value Shape & Units information – returned
use caps_freeValue to cleanup

Load Analysis into a Problem

```
icode = caps_load(capsObj problem, char *aname, char *apath,  
                 char *unitSys, char *intent, int naobj,  
                 capsObj *aobjs, capsObj *analysis)
```

problem a CAPS Problem Object

aname the Analysis (and AIM plugin) name

Note: this causes the the DLL/Shared-Object to be loaded (if not already resident)

apath the absolute filesystem path to both read and write files

this is required even if the AIM does not use the the filesystem, so that the combination of aname and apath is unique

unitSys pointer to string describing the unit system to be used by the AIM (can be **NULL**)
see specific AIM documentation for a list of strings for which the AIM will respond

intent the *intent* character string used to pass Bodies to the AIM, **NULL** – no filtering

naobj the number of *parent* Analysis Object(s)

aobjs a list of the *parent* Analysis Object(s) – may be **NULL** if `naobj == 0`

analysis the resultant Analysis Object

icode integer return code

Initialize Analysis from another Analysis Object

```
icode = caps_dupAnalysis(capsObj from, char *apath, int naobj,  
                        capsObj *aobjs, capsObj *analysis)
```

- from** an existing CAPS Analysis Object
- apath** the absolute filesystem path to both read and write files
required so that the combination of **aname** and **apath** is unique
- naobj** the number of *parent* Analysis Object(s)
- aobjs** a list of the *parent* Analysis Object(s) – may be **NULL** if **naobj** == 0
- analysis** the resultant Analysis Object
- icode** integer return code

Get Dirty Analysis Object(s)

```
icode = caps_dirtyAnalysis(capsObj object, int *nAobj, capsObj **aobjs)
```

- problem** a CAPS Problem, Bound or Analysis Object
- nAobjs** the returned number of *dirty* Analysis Objects
- aobjs** a returned pointer to the list of *dirty* Analysis Objects (*freeable*)
- icode** integer return code

Get Info about an Analysis Object

```
icode = caps_analysisInfo(capsObj analysis, char **apath,  
                           char **unitSys, char **intent, int *naobj,  
                           capsObj *aobjs, int *nfields, char ***fnames,  
                           int **ranks, int *exec, int *status)
```

analysis the input Analysis Object

apath a returned pointer to the string specifying the filesystem path for file I/O

unitSys returned pointer to string describing the unit system used by the AIM (can be **NULL**)

intent the returned pointer to the *intent* character string used to pass Bodies to the AIM

naobj the returned number of *parent* Analysis Object(s)

aobjs a returned pointer to a list of the *parent* Analysis Object(s)

nfields the returned number of fields for DataSet filling

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

ranks a returned pointer to a list of ranks associated with each field

exec the returned execution flag: **0** – no execution, **1** – AIM performs analysis

status **0** – up to date, **1** – *dirty* Analysis inputs, **2** – *dirty* Geometry inputs

3 – both Geometry & Analysis inputs are *dirty*, **4** – new geometry,

5 – *post Analysis* required, **6** – Execution & *post Analysis* required

Generate Analysis Inputs

```
icode = caps_preAnalysis(capsObj analysis, int *nErr, capsErrs **errs)
```

- analysis** the Analysis (or Problem) Object
a *Geometry*-only regen is forced when this is a Problem Object
- nErr** the returned number of errors generated – 0 means no errors
- errs** the returned CAPS error structure – NULL with no errors
- icode** integer return code

Mark Analysis as Run

```
icode = caps_postAnalysis(capsObj analysis, capsOwn current, int *nErr,  
                          capsErrs **errors)
```

- analysis** the Analysis Object
Note: this clears all Analysis Output Objects to force reloads/recomputes
- current** the CAPS owner structure information for the run
- nErr** the returned number of errors generated – 0 means no errors
- errors** the returned CAPS error structure – NULL with no errors
- icode** integer return code

Create a Bound – Open until `completeBound`

```
icode = caps_makeBound(capsObj problem, int dim, char *bname,  
                      capsObj *bound)
```

problem a CAPS Problem Object

dim the dimensionality of the Bound (1 – 3)

bname the Bound name (matching the *capsBound* Attribute)

bound the resultant *open* Bound Object

icode integer return code

Complete a Bound

```
icode = caps_completeBound(capsObj bound)
```

bound the CAPS Bound Object to close after creating all of the VertexSets & DataSets
make calls to `makeVertexSet` and `makeDataSet` in between these 2 functions

icode integer return code

Get Information about a Bound

```
icode = caps_boundInfo(capsObj bound, enum *state, int *dim,  
                      double *plims)
```

bound the CAPS Bound Object

state the returned Bound state:

- 1 Open
- 0 Empty & Closed
- 1 single BRep entity
- 2 multiple BRep entities
- 2 multiple BRep entities – Error in reparameterization!

dim the returned dimensionality of the Bound (1 – 3)

plims the filled parameterization limits (2 values when dim is 1, 4 when dim is 2)

icode integer return code

Make a VertexSet

```
icode = caps_makeVertexSet(capsObj bound, capsObj analysis,  
                           char *vname, capsObj *vset)
```

- bound** an input *open* CAPS Bound Object
- analysis** the Analysis Object (**NULL** – Unconnected)
- vname** a character string naming the VertexSet (can be **NULL** for a Connected VertexSet)
- vset** the returned VertexSet Object
- icode** integer return code

Get Info about a VertexSet

```
icode = caps_vertexSetInfo(capsObj vset, int *nGpts, int *nDpts,  
                           capsObj *bound, capsObj *analysis)
```

- vset** the VertexSet Object
- nGpts** the returned number of *Geometry* points in the VertexSet
- nDpts** the returned number of point *Data* positions in the VertexSet
- bound** the returned associated Bound Object
- analysis** the returned associated Analysis Object (**NULL** – Unconnected)
- icode** integer return code

Fill VertexSets for cyclic/incremental transfers

```
icode = caps_fillVertexSets(capsObj bound, int *nErr, capsErrs **errs)
```

bound an input *closed* CAPS Bound Object

nErr the returned number of errors generated – **0** means no errors

errs the returned CAPS error structure – **NULL** with no errors

icode integer return code

Note: Causes the filling of the VertexSets owned by the Bound by forcing the invocation of the appropriate `aimDiscr` functions in the AIM. Under normal circumstances this is deferred to the last `postAnalysis` call of the collected VertexSets.

Fill an Unconnected VertexSet

```
icode = caps_fillUnVertexSet(capsObj vset, int npts, double *xyzs)
```

vset the input Unconnected VertexSet Object

npts the number of points in the VertexSet

xyzs the point positions (3*npts in length)

icode integer return code

Output a VertexSet for Plotting/Debugging

```
icode = caps_outputVertexSet(capsObj vset, char *filename)
```

vset the VertexSet Object

filename the VertexSet filename (should have the extension “.vs”)

icode integer return code

The CAPS application **vVS** can be used to interactively view the file generated by this function.

DataSet Naming Conventions

- Multiple DataSets in a Bound can have the same Name
- Allows for automatic data transfers
- One *source* (from either *Analysis* or *User Methods*)
- Reserved Names:

DSet Name	rank	Meaning	Comments
xyz	3	<i>Geometry</i> Positions	
xyzd	3	<i>Data</i> Positions	Not for vertex-based discretizations
param*	1/2	t or [u,v] data for <i>Geometry</i> Positions	
paramd*	1/2	t or [u,v] for <i>Data</i> Positions	Not for vertex-based discretizations
<i>GeomIn</i> *	3	Sensitivity for the <i>Geometry</i> Input <i>GeomIn</i>	can have [<i>irow</i> , <i>icol</i>] in name

* Note: not valid for 3D Bounds

Create a DataSet

```
icode = caps_makeDataSet(capsObj vset, char *dname, enum method,  
                        int rank, capsObj *dset)
```

vset the VertexSet Object – associated Bound must be *open*

dname a pointer to a string containing the name of the DataSet (i.e., *pressure*)

method the method used for data transfers: (Sensitivity, Analysis, Interpolate, Conserve, User)

rank the rank of the data (e.g., 1 – scalar, 3 – vector)

dset the returned DataSet Object

Initialize DataSet for cyclic/incremental startup

```
icode = caps_initDataSet(capsObj dset, int rank, double *startup)
```

dset the DataSet Object (Method must be Interpolate or Conserve)

rank the rank of the data (e.g., 1 – scalar, 3 – vector)

startup the pointer to the constant *startup* data (rank in length)

Note: invocations of `caps_getData` and `aim_getDataSet` will return this data (and a length of 1) until properly filled.

Get Data from a DataSet

```
icode = caps_getData(capsObj dset, int *npts, int *rank,  
                    double **data, char **units)
```

dset the DataSet Object

npts the returned number of points in the DataSet

rank the returned rank of the data (e.g., 1 – scalar, 3 – vector)

data the returned pointer to the data (rank*npts in length)

units the returned pointer to the string declaring the units

icode integer return code

Get History of a DataSet

```
icode = caps_getHistory(capsObj dset, capsObj *vset, int *nhist,  
                      capsOwn **hist)
```

dset the DataSet Object

vset the returned associated VertexSet Object

nhist the returned length of the history list

hist the returned pointer to the list (nhist in length)

icode integer return code

Put *User* Data into a DataSet

```
icode = caps_setData(capsObj dset, int nverts, int rank, double *data,  
                    char *units)
```

dset the DataSet Object

nverts the number of points in data – must match declared npts

rank the rank of the data – must match declared rank (e.g., 1 – scalar, 3 – vector)

data a pointer to the data (rank*nverts in length)

units the pointer to the string declaring the units

icode integer return code

Get DataSet Objects by Name

```
icode = caps_getDataSets(capsObj bound, char *dname, int *nobj,  
                        capsObj **dsets)
```

bound an input CAPS Bound Object

dname a pointer to a string containing the name of the DataSet

nobj the returned number of Objects with the name

dsets a returned pointer to the list of DataSet Objects (*freeable*)

icode integer return code

Get Triangulations for a 2D VertexSet

```
icode = caps.triangulate(capsObj vset, int *nGtris, int **Gtris,  
                        int *nDtris, int **Dtris)
```

- vset** the input CAPS Connected VertexSet Object
- nGtris** the returned number of *Geometry*-based Triangles
- Gtris** the returned pointer to a list of indices (bias 1) referencing *Geometry*-based points (3*nGtris in length) – *freeable*
- nDtris** the returned number of *Data*-based Triangles (0 if discretization is vertex based)
- Dtris** the returned pointer to a list of indices (bias 1) referencing *Data*-based points (3*nDtris in length) – *freeable*
- icode** integer return code

Backdoor AIM Specific Communication

```
icode = caps_AIMbackdoor(capsObj analysis, char *JSONin,  
                        char **JSONout)
```

analysis the Analysis Object

JSONin a pointer to a character string that AIM function `aimBackdoor` will respond to.

JSONout a returned pointer to a character string that AIM function `aimBackdoor` creates and passes back as the result to the request (may be *freeable* – depending on the AIM).

icode integer return code

Note: Look at the specific AIM documentation to determine if it will respond and to what **JSONin** commands.

CAPS_SUCCESS	0	CAPS_CIRCULARLINK	-319
CAPS_BADRANK	-301	CAPS_UNITERR	-320
CAPS_BADDSETNAME	-302	CAPS_NULLBLIND	-321
CAPS_NOTFOUND	-303	CAPS_SHAPEERR	-322
CAPS_BADINDEX	-304	CAPS_LINKERR	-323
CAPS_NOTCHANGED	-305	CAPS_MISMATCH	-324
CAPS_BADTYPE	-306	CAPS_NOTPROBLEM	-325
CAPS_NULLVALUE	-307	CAPS_RANGEERR	-326
CAPS_NULLNAME	-308	CAPS_DIRTY	-327
CAPS_NULLOBJ	-309	CAPS_HIERARCHERR	-328
CAPS_BADOBJECT	-310	CAPS_STATEERR	-329
CAPS_BADVALUE	-311	CAPS_SOURCEERR	-330
CAPS_PARAMBNDERR	-312	CAPS_EXISTS	-331
CAPS_NOTCONNECT	-313	CAPS_JOERR	-332
CAPS_NOTPARMTRIC	-314	CAPS_DIRERR	-333
CAPS_READONLYERR	-315	CAPS_NOTIMPLEMENT	-334
CAPS_FIXEDLEN	-316	CAPS_EXECERR	-335
CAPS_BADNAME	-317	CAPS_CLEAN	-336
CAPS_BADMETHOD	-318	CAPS_BADINTENT	-337

The Population of the VertexSets

Bounds needed to be fully populated (i.e., the VertexSets need to be filled for all analyses) before they can be used. This is due to the requirement to have all points available to ensure that there is a single UV space (either by construction or by re-parameterization).

By default this is done in the “post” phase of the last analysis in the Bound to be updated, which makes it basically impossible to have an intermediate result for the first iteration (such as in Fluid/Structure Interaction). This issue is mitigated by using the function `caps_fillVertexSets` before the first analysis is invoked. What this does is call the AIM to fill the `aimDiscr` structure (basically the VertexSet) before the “pre” phase but requires the mesh (or performs the meshing) at that time.

NOTE: An analysis AIM that supports `aimDiscr` and also generates meshes “on the fly” must be able to generate meshes and call `aim_setTess` from both `aimDiscr` and `aimPreAnalysis` (whenever and wherever the mesh gets generated).

Fluid/Structure Interaction Pseudocode

```
caps_load TetGen aim -> mobj
caps_load fluids aim -> fobj
caps_load structures -> sobj
caps_makeBound "srf" -> bobj
caps_makeVertexSet(bobj, fobj) -> vfobj
caps_makeVertexSet(bobj, sobj) -> vsobj
caps_makeDataSet(vfobj, "Pressure", Analysis, 1) -> dpfobj
caps_makeDataSet(vfobj, "Pressure", Conserve, 1) -> dpsobj
caps_makeDataSet(vsobj, "Displace", Analysis, 3) -> ddsobj
caps_makeDataSet(vfobj, "Displace", Conserve, 3) -> ddfobj
caps_completeBound(bobj)

caps_preAnalysis(mobj)
caps_postAnalysis(mobj)                                /* generate fluids mesh */
caps_fillVertexSets(bobj)                              /* Note #1 */
caps_initDataSet(ddfobj, 3, zeros)                     /* Note #2 */

for (iter = 0; iter < nIter; iter++) {
    caps_getData(ddfobj, ...)                          /* Note #3 */
    caps_preAnalysis(fobj)
    /* execute fluids analysis */
    caps_postAnalysis(fobj)

    caps_getData(dpsobj, ...)                          /* Note #3 */
    caps_preAnalysis(sobj)
    /* execute structures analysis */
    caps_postAnalysis(sobj)
}
```

Pseudocode Notes

The fluids AIM requires the “Displace” values during its “pre” phase, just as the structural analysis AIM requires “Pressure” (i.e., loads) during its “pre” phase to fill in all the inputs.

- ❶ `caps_fillVertexSets` calls `aimDiscr` in the fluids AIM, so that AIM must transfer the data from the TetGen AIM to populate the `aimDiscr` structure. The structures AIM can still do the tessellation in its `aimDiscr` function, but it will be invoked before any “pre” phase. Care must be taken so that any tessellation input data can be taken from the AIM inputs.
- ❷ `caps_initDataSet` gets called to set the first displacement data to zeros, in that no structural analysis will have been run at start, but is needed by the fluids.
- ❸ `caps_getData` is currently required to actually do the interpolation/conservative data transfer (i.e., it cannot be done in the AIM by the invocation of `aim_getDataSet`). This will be changed in the future, so these calls will not be required, but current scripts and code will still function.
- ❹ The lines in red cause `aimUsesDataSet` to be invoked to determine if the DataSet is required by the Analysis (and will make it *dirty*).