# Engineering Sketch Pad (ESP)



# Training Session 4
# CSM Language (1)

**John F. Dannenhoffer, III**
jfdannen@syr.edu
Syracuse University

**Bob Haimes**
haimes@mit.edu
Massachusetts Institute of Technology

updated for v1.19

# Overview

- Format of `.csm` file
- Special characters
- Numbers
- Parameters
    - Types
    - Names
    - Dimensions
    - Lower and Upper Bounds
- Expressions
    - Numeric
    - String
- Reading Help File
- CSM File Editor

# Opening Thoughts

- All configuration information is contained in `.csm` (or possibly `.udc`) files
    - `.csm` files are plain ASCII text that are readable by humans
    - because they are ASCII files, they can either be written directly by humans (using any text editor) or by other programs
- When you build a configuration using the ESP user interface, you are actually building a `.csm` file
- Using the interface can be effective for beginning users who are building small models
- Once a user gets experience with ESP, most of the models are created by "typing" a `.csm` directly

# Format of the `.csm` file (1)

- The `.csm` file contains a series of statements.
- If a line contains a hash (#), all characters starting at the hash are ignored.
- If a line contains a backslash (\), all characters starting at the backslash are ignored and the next line is appended; spaces at the beginning of the next line are treated normally.
- All statements begin with a keyword (described below) and must contain at least the indicated number of arguments.
- The keywords may either be all lowercase or all UPPERCASE.
- Any CSM statement can be used in a `.csm` file except the INTERFACE statement.

- Blocks of statements must be properly nested. The Blocks are bounded by
    - PATBEG/PATEND
    - IFTHEN/ELSEIF/ELSE/ENDIF
    - SKBEG/SKEND
    - SOLBEG/SOLEND
    - CATBEG/CATEND
- Extra arguments in a statement are discarded. If one wants to add a comment, it is recommended to begin it with a hash (#) in case optional arguments are added in future releases.
- Any statements after an END statement are ignored.
    - hint: if debugging, consider THROWing an error instead to avoid unclosed Blocks
- All arguments must not contain any spaces or must be enclosed in a pair of double quotes (for example, "a + b").

- Parameters are evaluated in the order that they appear in the file, using MATLAB-like syntax (see 'Expression rules' below).

- During the build process, OpenCSM maintains a last-in-first-out (LIFO) "Stack" that can contain Bodys, Marks, and Sketches.

- The `.csm` statements are executed in a stack-like way, taking their inputs from the Stack and depositing their results onto the Stack.

- The default name for each Branch is `Brch_xxxxxx`, where `xxxxxx` is a unique sequence number.

```
#              introduces comment
"              ignore spaces until following "
\              ignore this and following characters and
                  concatenate next line
<space>        separates arguments in .csm file (except
                  between " and ")
0-9            digits used in numbers and in names
A-Z a-z        letters used in names
_ : @          characters used in names (see rule for names)
.              decimal separator (used in numbers),
                  introduces dot-suffixes (in names)
,              separates function arguments and row/column
                  in subscripts
;              multi-value item separator
```

```
( )         groups expressions and function arguments
[ ]         specifies subscripts in form [row,column] or [index]
{ } < >     characters used in strings
+ - * / ^   arithmetic operators
$           as first character, introduces a string that is
               terminated by end-of-line or un-escaped plus,
               comma, or close-parenthesis
@           as first character, introduces @-parameters
'           used to escape comma, plus, or close-parenthesis
               within strings
!           if first character of implicit string, ignore
               $! and treat as an expression

|           cannot be used (reserved for OpenCSM internals)
~           cannot be used (reserved for OpenCSM internals)
&           cannot be used (reserved for OpenCSM internals)
```

- Start with a digit or decimal (.)
- Followed by zero or more digits and/or decimals (.)
- There can be at most one decimal in a number
- Optionally followed by an e, e+, e-, E, E+, or E-
- If there is an e or E, it must be followed by one or more digits
- If numbers are in a list, the elements are separated by a semicolon (;)

- Design Parameter
    - values are declared in a DESPMTR statement
        - in .csm file or
        - in top-level include-type .udc file
    - must contain one or more numbers (no strings)
    - if multi-valued, must be first DIMENSIONed
    - can contain lower- and upper-bounds, specified in LBOUND and UBOUND statements
    - values are only visible at the top-level
    - values can be changed by a call to ocsmSetValu or ocsmSetValuD (after ocsmLoad and before ocsmBuild)
    - values can be read by call to ocsmGetValu
    - sensitivities can be computed by a call to ocsmSetVel or ocsmSetVelD

# Types of Parameters (2)

- Configuration Parameter
    - values are declared in a `CFGPMTR` statement
        - in `.csm` file or
        - in top-level include-type `.udc` file
    - must contain one or more numbers (no strings)
    - if multi-valued, must be first `DIMENSION`ed
    - can contain lower- and upper-bounds, specified in `LBOUND` and `UBOUND` statements
    - values are only visible at the top-level
    - values can be changed by a call to `ocsmSetValu` or `ocsmSetValuD` (after `ocsmLoad` and before `ocsmBuild`)
    - values can be read by call to `ocsmGetValu`
    - sensitivities CANNOT be computed for Configuration Parameters

# Types of Parameters (3)

- Constant Parameter
    - values are declared in a CONPMTR statement
        - in .csm file
        - in top-level include-type .udc file
    - must contain only one number (no strings)
    - values are visible from any .csm or .udc file
    - values CANNOT be changed by a call to ocsmSetValu or ocsmSetValuD
    - sensitivities CANNOT be computed for Constant Parameters

- Local Variables
  - is created by a `SET`, `PATBEG` or `GETATTR` statement
  - can contain one or more numbers or a character string
  - if multi-valued, must first be `DIMENSION`ed
  - can be an @-parameter (described below)
  - are only usable in `.csm` or `.udc` file in which it was defined
    (unless the `.udc` file has `INTERFACE . ALL` in its preamble)
- Output Parameters
  - declared in a `OUTPMTR` statement
  - refers to any local variable whose value is available outside
    ESP (such as to CAPS)

|  | DESPMTR. | CFGPMTR. | CONPMTR. | OUTPMTR. | LOCALVAR. |
|---|---|---|---|---|---|
| Can be vector or array of numbers | Y | Y | N | Y | Y |
| Can have a string value | N | N | N | Y | Y |
| Can be restricted by LBOUND or UBOUND | Y | Y | N | N | N |
| Scope | T | T | G | L | L |
| Defined during ocsmLoad or ocsmLoadDict | Y | Y | Y | N | N |
| Can be set via ocsmSetValu(D) | Y | Y | N | N | N |
| Defined and set during ocsmBuild | N | N | N | Y | Y |
| Can be read via ocsmGetValu(S) | Y | Y | Y | Y | Y* |
| Can find associated sensitivity | Y | N | N | N | N |

Y*=Parameter index may be different for different builds

scopes: T=top-level, G=global, L=local

- General form is: DIMENSION $pmtrName nrow ncol
- Can only be applied once to a DESPMTR or CFGPMTR
- Cannot be applied to a CONPMTR
- When applied to an OUTPMTR or LOCALVAR
    - if the new size has fewer elements than the old size
        - the old values are copied to fill the new size
        - extra old elements are lost
    - if the new size has more elements than the old size
        - the old values are all copied
        - the last old value is copied into all the remaining new locations

# Valid Parameter Names

- Start with a letter, colon (:), or at-sign (@)
- Contains letters, digits, at-signs (@), underscores (_), and colons (:)
- Contains fewer than 64 characters
- Names that start with an at-sign cannot be set by a `CONPMTR`, `DESPMTR`, `CFGPMTR`, `SET`, or `PATBEG` statement
- When listed in `ESP`, are sub-grouped based upon the colons (:)

- If a name has a dot-suffix, a property of the parameter (and not its value) is returned

  x.nrow    number of rows in x (0 for string)

  x.ncol    number of columns in x (0 for string)

  x.size    number of elements or characters in x

  x.sum    sum of elements in x

  x.norm    RMS norm of elements in x

  x.min    minimum value in x

  x.max    maximum value in x

- Example:

```
DIMENSION   myvar   2 3 1
DESPMTR     myvar   "1; 2; 3;\
                     4; 5; 6"
```

  - myvar.nrow returns 2
  - myvar.sum returns 21

- Basic format is: `name[irow,icol]` or `name[ielem]`
- Name must follow rules above
- `irow`, `icol`, and `ielem` must be valid expressions
- `irow`, `icol`, and `ielem` start counting at 1
- For 2D arrays, either `name[irow,icol]` or `name[ielem]` be used
- Values are stored across rows ([1,1], [1,2], ..., [2,1], ...)

- Every time a Body gets created, or after a SELECT statement, readable local variables are set

```
          body face edge node  <- last SELECT
@seltype  -1    2    1    0    selection type (0=node,1=edge,2=face)
@selbody   x    -    -    -    current Body
@sellist  -1    x    x    x    list of Nodes/Edges/Faces

@nbody     x    x    x    x    number of Bodys
@ibody     x    x    x    x    current  Body
@nface     x    x    x    x    number of Faces in @ibody
@iface    -1    x   -1   -1    current  Face  in @ibody
@nedge     x    x    x    x    number of Edges in @ibody
@iedge    -1   -1    x   -1    current  Edge  in @ibody
@nnode     x    x    x    x    number of Nodes in @ibody
@inode    -1   -1   -1    x    current  Node  in @ibody
@igroup    x    x    x    x    group of current Body
@itype     x    x    x    x    0=NodeBody, 1=WireBody,
                                       2=SheetBody, 3=SolidBody
@nbors    -1    x    -    x    number of incident Edges
@nbors    -1    -    x    -    number of incident Faces
```

```
@ibody1 -1   x    x   -1   first  element of 'Body' Attribute in @ibody
@ibody2 -1   x    x   -1   second element of 'Body' Attribute in @ibody

@xmin   x    x    *   x    x-min of bounding box or x at beg of edge
@ymin   x    x    *   x    y-min of bounding box or y at beg of edge
@zmin   x    x    *   x    z-min of bounding box or z at beg of edge
@xmax   x    x    *   x    x-max of bounding box or x at end of edge
@ymax   x    x    *   x    y-max of bounding box or y at end of edge
@zmax   x    x    *   x    z-max of bounding box or z at end of edge

@length 0    0    x   0    length of edge
@area   x    x    0   0    area of face or surface area of body
@volume x    0    0   0    volume of body (if a solid)

@xcg    x    x    x   x    location of center of gravity
@ycg    x    x    x   x
@zcg    x    x    x   x
```

```
@Ixx     x    x    x    0    centroidal moment of inertia
@Ixy     x    x    x    0
@Ixz     x    x    x    0
@Iyx     x    x    x    0
@Iyy     x    x    x    0
@Iyz     x    x    x    0
@Izx     x    x    x    0
@Izy     x    x    x    0
@Izz     x    x    x    0

@signal  x    x    x    x    current signal code
@nwarn   x    x    x    x    number of warnings

@edata                       only set up by EVALUATE statement
@stack                       Bodys in stack: 0=mark, -1=none
@version                     version number

in above table:
   x -> value is set
   - -> value is unchanged
   * -> special value is set (if edge)
   0 -> value is set to  0
  -1 -> value is set to -1
```

- Valid operators (in order of precedence):

  | | |
  |---|---|
  | ( ) | parentheses, inner-most evaluated first |
  | func(a,b) | function arguments, then function itself |
  | $\wedge$ | exponentiation (evaluated left to right) |
  | * / | multiply and divide (evaluated left to right) |
  | + - | add and subtract (evaluated left to right) |

# String Variables

- Contains the sequence of characters starting after a dollar-sign($) and ending with a space, plus-sign (+), comma (,), or closed-parenthesis ())
- If escaped with an apostrophe ('), can contain a plus-sign ('+), comma (',) or closed-parenthesis (')))
    - for example:

        ```
        $thisStringContainsAComma(',')
        ```

      returns `thisStringContainsAComma(,)`
- Can never contain a space
- Are parsed left-to-right, as is any expression
    - for example:

        ```
        SET    one 1
        SET    mystr $thereIsA+one+$inThisString
        ```

      returns (in `mystr`) `thereIsA1inThisString`

# Functions (1)

| | |
|---|---|
| `pi(x)` | $3.14159...*x$ |
| `min(x,y)` | minimum of $x$ and y |
| `max(x,y)` | maximum of $x$ and y |
| `sqrt(x)` | square root of $x$ |
| `abs(x)` | absolute value of $x$ |
| `int(x)` | integer part of $x$ ($3.5 \rightarrow 3$, $-3.5 \rightarrow -3$) |
| | produces derivative=0 |
| `nint(x)` | nearest integer to $x$ |
| | produces derivative=0 |
| `ceil(x)` | smallest integer not less than $x$ |
| | produces derivative=0 |
| `floor(x)` | largest integer not greater than $x$ |
| | produces derivative=0 |

| `mod(a,b)` | modulus(a/b), with same sign as a and b$\geq$0 |
| `sign(test)` | returns -1, 0, or +1 |
| | produces derivative=0 |
| `exp(x)` | exponential of $x$ |
| `log(x)` | natural logarithm of $x$ |
| `log10(x)` | common logarithm of $x$ |

| | | |
|---|---|---|
| $\sin(x)$ | sine of $x$ | (in radians) |
| $\text{sind}(x)$ | sine of $x$ | (in degrees) |
| $\text{asin}(x)$ | arc-sine of $x$ | (in radians) |
| $\text{asind}(x)$ | arc-sine of $x$ | (in degrees) |
| $\cos(x)$ | cosine of $x$ | (in radians) |
| $\text{cosd}(x)$ | cosine of $x$ | (in degrees) |
| $\text{acos}(x)$ | arc-cosine of $x$ | (in radians) |
| $\text{acosd}(x)$ | arc-cosine of $x$ | (in degrees) |

| | | |
|---|---|---|
| `tan(x)` | tangent of $x$ | (in radians) |
| `tand(x)` | tangent of $x$ | (in degrees) |
| `atan(x)` | arc-tangent of $x$ | (in radians) |
| `atand(x)` | arc-tangent of $x$ | (in degrees) |
| `atan2(y,x)` | arc-tangent of $y/x$ | (in radians) |
| `atan2d(y,x)` | arc-tangent of $y/x$ | (in degrees) |
| `hypot(x,y)` | hypotenuse: $\sqrt{x^2 + y^2}$ | |
| `hypot3(x,y,z)` | hypotenuse: $\sqrt{x^2 + y^2 + z^2}$ | |

| | |
|---|---|
| `Xcent(xa,ya,dab,xb,yb)` | *X*-center of circular arc |
| | produces derivative=0 |
| `Ycent(xa,ya,dab,xb,yb)` | *Y*-center of circular arc |
| | produces derivative=0 |
| `Xmidl(xa,ya,dab,xb,yb)` | *X*-point at midpoint of circular arc |
| | produces derivative=0 |
| `Ymidl(xa,ya,dab,xb,yb)` | *Y*-point at midpoint of circular arc |
| | produces derivative=0 |
| `seglen(xa,ya,dab,xb,yb)` | length of segment |
| | produces derivative=0 |

| | |
|---|---|
| `incline(xa,ya,dab,xb,yb)` | inclination of chord (in degrees) |
| | produces derivative=0 |
| `radius(xa,ya,dab,xb,yb)` | radius of curvature (or 0 for linseg) |
| | produces derivative=0 |
| `sweep(xa,ya,dab,xb,yb)` | sweep angle of circular arc (in degs) |
| | produces derivative=0 |
| `turnang(xa,ya,dab,...` | |
| `xb,yb,dbc,xc,yc)` | turning angle at b (in degrees) |
| | produces derivative=0 |
| `dip(xa,ya,xb,yb,rad)` | acute dip between arc and chord |
| | produces derivative=0 |
| `smallang(x)` | ensures $-180 \leq x \leq 180$ |

| | |
|---|---|
| `val2str(num,digits)` | convert `num` to a string |
| `str2val(string)` | convert `string` to a number |
| `findstr(str1,str2)` | finds location of `str2` in `str1` (bias-1) or 0 if not found |
| `slice(str,ibeg,iend)` | substring of `str` from `ibeg` to `iend` (bias-1) |
| `path($pwd)` | returns present working directory |
| `path($csm)` | returns directory of current `.csm` file |
| `path($root)` | returns $ESP_ROOT |
| `path($file)` | returns name of `.csm` file |

| | |
|---|---|
| `ifzero(test,ifTrue,ifFalse)` | if $test = 0$, return `ifTrue`, else return `ifFalse` |
| `ifpos(test,ifTrue,ifFalse)` | if $test > 0$, return `ifTrue`, else return `ifFalse` |
| `ifneg(test,ifTrue,ifFalse)` | if $test < 0$, return `ifTrue`, else return `ifFalse` |
| `ifnan(test,ifTrue,ifFalse)` | if `test` is NaN, return `ifTrue`, else return `ifFalse` |

```
STORE      $name index=0 keep=0
           use:    stores Group on top of Stack
           pops:   any
           pushes: -
           notes:  Sketch may not be open
                   Solver may not be open
                   $name is used directly (without evaluation)
                   previous Group in name/index is overwritten
                   if $name=.   then Body is popped off stack
                                      but not actually stored
                   if $name=..  then pop Bodys off stack back
                                      to the Mark
                   if $name=... then the stack is cleared
                   if keep==1, the Group is not popped off stack
                   cannot be followed by ATTRIBUTE or CSYSTEM
                   signals that may be thrown/caught:
                      $insufficient_bodys_on_stack
```

# Reading Help File (2)

- If argument starts with dollar-sign ($), then the argument is assumed to be string, and the user does not need to prepend the argument with a dollar-sign ($)

  - if an expression is given that should be evaluated (to a string value), prepend the argument with an exclamation point (!), as in:

    ```
    SET    i 10
    STORE  !$ThisIsBody+i+$.
    ```

    stores the Body in a location named `ThisIsBody10`.

- For arguments that are listed with an equal-sign (=), the value after the equal sign is the default value

# CSM File Editor (1)

- Started via the button **File→Edit:**

# CSM File Editor (2)

- Options (on top row) include:
  - **Copy** — copy highlighted text into paste-buffer
  - **Cut** — copy highlighted text into paste-buffer and remove it from the file
  - **Paste** — copy paste-buffer into `.csm` file at the cursor
  - **Search** — search for text (input is on top line)
  - **Next** — search for next occurrence
  - **Prev** — search for previous occurrence
  - **Replace** — replace one text string with another
  - . . .

# CSM File Editor (3)

- Options on top row include:
    - . . .
    - **Comment** — if first statement in highlighted region is not a comment, block comment the whole region. Otherwise, block un-comment the whole region
    - **Indent** — indent the highlighted region
    - **Hint** — provide a hint (on the top line) for the statement at the cursor
    - **Undo** — un-do the previous edit
    - **Cancel** — leave the editor (and lose your changes)
    - **Save** — save the file to disk. If there is only one file in the session, the configuration is also automatically re-built