

Engineering Sketch Pad (ESP)



Training Session 4 CSM Language (1)

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updated for v1.18

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

- 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

- 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** 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 open-bracket
@	as first character, introduces @-parameters
'	used to escape comma, plus, or open-bracket 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`

- 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 `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 CANNOT be computed for Configuration Parameters

- 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 `DIMENSIONED`
 - 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 <code>ocsmLoad</code> or <code>ocsmLoadDict</code>	Y	Y	Y	N	N
Can be set via <code>ocsmSetValu(D)</code>	Y	Y	N	N	N
Defined and set during <code>ocsmBuild</code>	N	N	N	Y	Y
Can be read via <code>ocsmGetValu(S)</code>	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

- Start with a letter, colon (:), or at-sign (@)
- Contains letters, digits, at-signs (@), underscores (_), and colons (:)
- Contains fewer than 32 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`

`x.ncol` number of columns in `x`

`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)

- 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
```

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

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

<code>sin(x)</code>	sine of x	(in radians)
<code>sind(x)</code>	sine of x	(in degrees)
<code>asin(x)</code>	arc-sine of x	(in radians)
<code>asind(x)</code>	arc-sine of x	(in degrees)
<code>cos(x)</code>	cosine of x	(in radians)
<code>cosd(x)</code>	cosine of x	(in degrees)
<code>acos(x)</code>	arc-cosine of x	(in radians)
<code>acosd(x)</code>	arc-cosine of x	(in degrees)

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

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

`val2str(num,digits)`

`str2val(string)`

`findstr(str1,str2)`

`slice(str,ibeg,iend)`

`path($pwd)`

`path($csm)`

`path($root)`

`path($file)`

convert `num` to a string

convert `string` to a number

finds location of `str2` in `str1`
(`bias-1`) or 0 if not found

substring of `str` from `ibeg`
to `iend` (`bias-1`)

returns present working directory

returns directory of current `.csm` file

returns `$ESP_ROOT`

returns name of `.csm` file

<code>ifzero(test,ifTrue,ifFalse)</code>	if <code>test = 0</code> , return <code>ifTrue</code> , else return <code>ifFalse</code>
<code>ifpos(test,ifTrue,ifFalse)</code>	if <code>test > 0</code> , return <code>ifTrue</code> , else return <code>ifFalse</code>
<code>ifneg(test,ifTrue,ifFalse)</code>	if <code>test < 0</code> , return <code>ifTrue</code> , else return <code>ifFalse</code>
<code>ifnan(test,ifTrue,ifFalse)</code>	if <code>test</code> is NaN, return <code>ifTrue</code> , else return <code>ifFalse</code>

```
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**:

The screenshot shows the ESP Engineering Sketch Pad interface with the CSM File Editor open. The editor displays the contents of a file named `../data/tutorial1.csm`. The code defines a cylinder with various parameters and features.

```
hint: CYLINDER xbeg ybeg zbeg xend yend zend radius
2 # written by John Dannenhoffer
3
4 # default design parameters
5 desgmt Lbar      6.00 # length of bar
6 desgmt Rbar      0.15 # radius of bar
7 desgmt T          0.50 # thickness of weights
8 desgmt D          2.00 # diameter of weights
9 desgmt Rout      1.20 # outer radius (for intersection)
10 desgmt Rfil      0.10 # fillet radius at end of bar
11
12 set L          Lbar/2
13
14 # shaft
15 cylinder -L    0.0  0.0  0.0  +L  0.0  0.0  Rbar
16 name shaft
17 attribute shaft 1
18
19 # left weight
20 box -L-2/2 -D/3 -D T D+2/3 2*D
21 name left_weight
22 attribute weight 1
23 union
24 fillet Rfil
25
26 # rite weight
27 box +L-2/2 -D/2 -D/2 T D D
28 name rite_weight
29 attribute weight 2
30 union
31 fillet Rfil
32
33 # clip weights with outer cylinder
34 cylinder -L-T 0.00 0.00 +L+T 0.00 0.00 Rout
35 attribute clipper 1
36 intersect
37
38 end
39
```

ESP has been initialized and is attached to 'serveCSM'
"../data/tutorial1.csm" has been loaded

- 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
 - ...

- 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