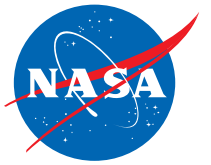
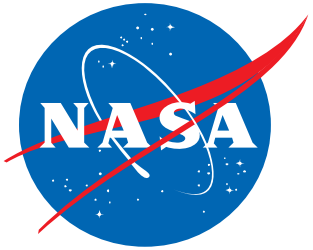


DAVE-ML: An XML Implementation of the AIAA Flight Dynamic Model Exchange Standard

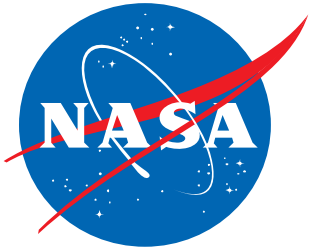
Bruce Jackson, NASA Langley
<bruce.jackson@nasa.gov>

December 2010



Outline

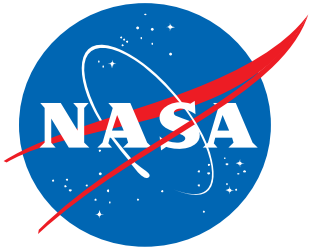
- Motivation
- Why XML?
- DAVE-ML workshop
  - –Features
  - –Limitations
  - –Examples
  - –Demos
  - –Resources
  - –Grammar



Motivation

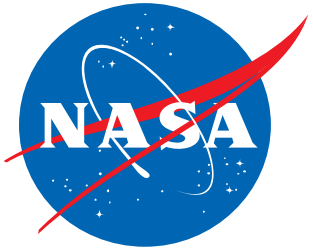
- Growth of teaming within aero industry
- Exponential increase in desktop compute power
- Increasing reliance on sim-based acquistion
- Emergence of web-based everything

- 1980’s simulation technology hasn't kept pace



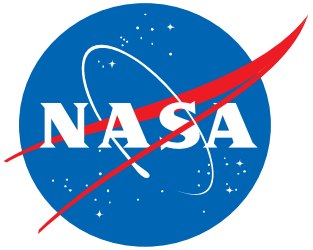
Why XML? Why not *[YAML, C++, FORTRAN…]*

- Open standard (W3C)
- Transportable
- Human- and machine-readable UNICODE
- Programming language agnostic
- Same source used for detail design & pilot training
- Good fit for databases and models
- Archive-able history of data with sources cited
- Transformable (->HTML, etc.)
- Lots of generic XML tools, editors, parsers, validators
- XSLT



DAVE-ML features

- Non-linear function descriptions
  - –Tabular (traditional aero models)
    - » Unlimited dimensionality
    - » Gridded or unstructured
  - –Polynomial or exponential expressions
- Model build-up equations
- Units of measure
- Both ‘standard’ and internal variable names for same variable
- Uncertainty metrics included
- Provenance (history/source of data)
- Checkcase/verification data included



Current DAVE-ML limitations

- Static models (dynamics not yet fully supported)
- No submodels (recursion not yet supported)
- No native DAVE-ML editor yet
  - Implies hand-editing with generic text or XML editor

DAVE-ML is at a sufficient stage of advancement to encode inertia, gear, and aero models, some of the more detailed subsystem models in flight simulation

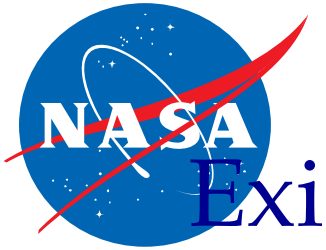
Existing DAVE-ML examples

F-16 subsonic aero model

- 51 variables, 18 tables, 744 points
- Switches & absolute-value nonlinear elements
- 17 verification check-cases included
- 154 KB file with 2,712 lines

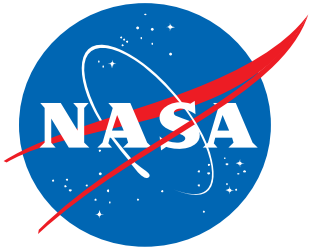
HL-20 lifting body aero model

- Supersonic and subsonic regimes
- 361 variables, 168 tables, 6,240 points
- 25 verification check-cases included
- 1.2 MB file with 22,299 lines



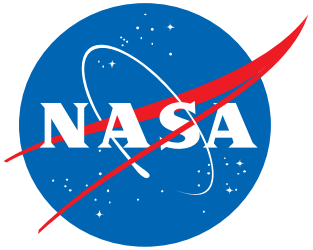
Existing (known) DAVE-ML resources

- DAVE-ML Reference manual (website)
- JANUS API (C++ library)
  - Australian DSTO/Ball Aerospace
- NASA Ames FTP tool (import/export Perl scripts)
- NASA Langley DaveMLTranslator API
- NAVAIR's CASTLE sim shell (latest release)
- XSLT conversion scripts
  - DAVE-ML => XHTML (LaRC)
  - DAVE-ML => C code (JSC)
- DAVEtools (Java packages):
  - DAVE-ML => Simulink
  - ModelSweeper => response surface plots



XSLT conversion script

- eXtensible Stylesheet Language Transformation
- XSLT scripts, themselves XML documents, specify how to convert XML-based files into other formats.
- 'DAVE_html.xsl' details a conversion from DAVE-ML XML file into an XHTML document
- Requires 'xerces' or similar XSLT tool
- Available for download =>
  http://www.daveml.org



DAVEtools 0.8

- Single Java DAVEtools.jar file
  - –Base package, "DAVE"
    - » Builds internal objects from DAVE-ML description
    - » Performs auto-verification of model
    - » Allows simple exercising of model
  - –Simulink® export tool, "DAVE2SL" (built on DAVE)
    - » Converts DAVE-ML models into Simulink blocks
  - –Response Surface viz tool, “ModelSweeper”
- Java 1.5 source code available
  - –Request public domain license via link from http://www.daveml.org/tools.html

Australian Government
Department of Defence
Defence Science and
Technology Organisation

Janus

Janus was the god of gates, doors, doorways, beginnings, and endings.
(*from Wikipedia*)

- C++ interface class for DAVE-ML datasets
- Enables DAVE-ML as native format – not just exchange
- Abstracts data from model code – component to total effect
- Common API for dissimilar data structures
- Centralises data handling functions
- Implements Gridded Data, Ungridded Data and MathML

Janus

- Validates dataset against DTD, then parses & loads into a Document Object Model (using Apache *Xerces* parser)
- Build numerical structures in memory for variables / tables
- Manages inputs, outputs and internal variables
- Performs specified interpolation / extrapolation
  - Discrete, Linear, Quadratic, Cubic
  - Add Spline and other basis functions in the future.

Janus

- Encryption/decryption capability using AES-256bit symmetric keys and RSA algorithm.
  - Impacts on instantiation but NO runtime penalty.
  - Used to ensure data integrity.
- Performance for >> real-time applications.

Janus - Since 2005

- Learning about DAVE-ML/Janus idiosyncrasies through dataset development.
- Increased robustness of data handling functions.
- Extended Math-ML support.
- Identified areas of deficiencies, including speed improvements.
- Developed a Matlab module to read and write DAVE-ML files.

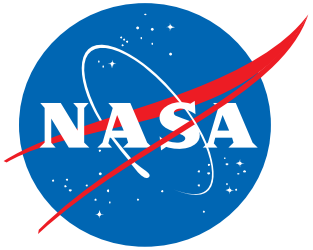
Janus Web Site

- Janus will be released as an open source application, covered by the DSTO Open Source Licence.

- A copy of Janus can be requested from:
  - Janus@dsto.defence.gov.au
  - http://www.dsto.defence.gov.au/ *(once finalised)*

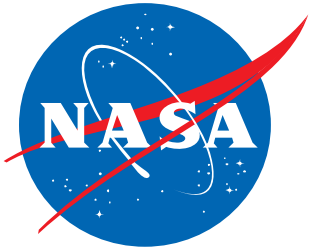
Further Work

- Maturity of DTD
  - Data uncertainty component.
    - Best approach for using this?
  - Data type definitions – Vectors, Matrices.
  - MathML definition.
    - Problems with validating XML files, appears to be associated with namespace definition.
  - Modification Record – Date attribute.
  - Test cases.



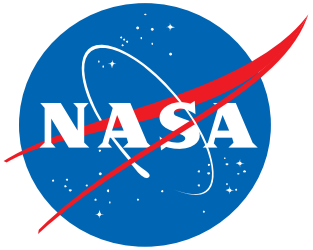
Quick demonstrations

- Generate HTML
- Generate Simulink® subsystem
- Exercise command line DAVEtool



DAVE-ML grammar

- Top-level syntax shown
- Specified by *DAVEfunc.dtd* Document Type Definition
- Examples taken from reference manual, available for download from http://www.daveml.org - see "DTDs"

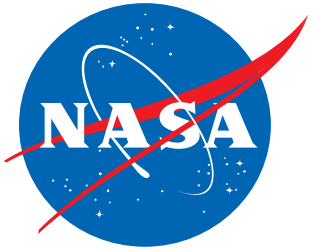


Top-level syntax

- Top level-element is <DAVEfunc>

```
DAVEfunc :
        fileHeader :
        variableDef+ :
        breakpointDef* :
        griddedTableDef* :
        ungriddedTableDef* :
        function* :
        checkData? :
```

Key: *element : attribute [optional attribute]*
subelement
'+' means 1 or more; '' means 0 or more; '?' means 0 or 1*

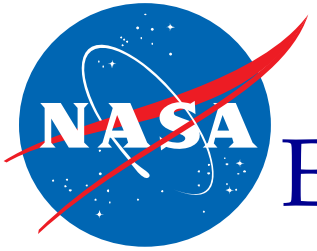


File header element

- Provides documentation trail for model

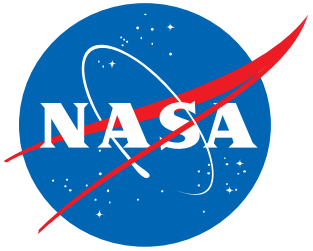
```
fileHeader : [name]
        author+ : name, org
        creationDate : date
        fileVersion? :
        description? :
        reference* :
        modificationRecord* :
        provenance* :
```

Key: element : attribute [optional attribute]
subelement
'+' means 1 or more; '' means 0 or more; '?' means 0 or 1*



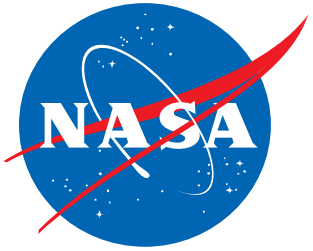
Example of `fileHeader` element

```
<!--                          =================                          -->
 <!-- ========================   FILE HEADER   ======================== -->
 <!--                           =================                          -->


 <fileHeader>
   <author name="Bruce Jackson" org="NASA Langley Research Center"
     email="bruce.jackson@nasa.gov">
     <address>MS 132 NASA, Hampton, VA 23681</address>
   </author>
   <creationDate date="2003-03-18"/>

   <fileVersion>$Revision: 233 $</fileVersion>

   <description>
     Version 2.0 aero model for HL-20 lifting body, as described in
     TM-107580. This aero model was used for HL-20 approach and
     landing studies at NASA Langley Research Center during 1989-1995
     and for a follow-on study at NASA Johnson Space Center in 1994
     and NASA Ames Research Center in 2001. This DAVE-ML version
     created 2003 by Bruce Jackson to demonstrate DAVE-ML.
   </description>

   <reference refID="REF01"
        author="Jackson, E. Bruce; Cruz, Christopher I. &amp;amp; and Ragsdale, W. A."
        title="Real-Time Simulation Model of the HL-20 Lifting Body"
        accession="NASA TM-107580"
        date="1992-07-01"
        />
```



`fileHeader` example, cont'd

```
    <reference refID="REF02"
      author="Cleveland, William B. <nospam@mail.arc.nasa.gov>"
      title="Possible Typo in HL20_aero.xml"
      accession="email"
      date="2003-08-19"
    />
  .
  .
  .

    <modificationRecord modID="A" refID="REF02" date="2002">
      <author name="Bruce Jackson" org="NASA Langley Research Center"
                  email="bruce.jackson@nasa.gov">
          <address>MS 132 NASA, Hampton, VA 23681</address>
      </author>
      <description>
          Revision 1.24: Fixed typo in CLRUD0 function description which
          gave dependent signal name as "CLRUD1." Bill Cleveland of NASA
          Ames caught this in his xml2ftp script. Also made use of 1.5b2
          fileHeader fields and changed date formats to comply with
          convention.
      </description>
  </modificationRecord>
  .
  .
  .

</fileHeader>
```

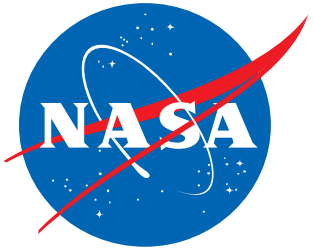


Variable Definition element (`variableDef`)

- Used to define each variable used in the model
  - Includes inputs, outputs, constants, parameters and local (temporary) variables

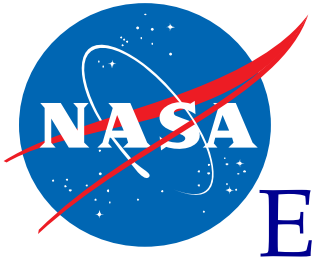
```
variableDef : name, varID, units,
          [axisSystem, sign, alias, symbol, initialValue]
     description? : (description character data)
     (provenance | provenanceRef)? : (historical information)
     calculation? : math (defined in MathML2.0 DTD)
     (isInput | isControl | isDisturbance)? :
     isOutput? :
     isState? :
     isStateDeriv? :
     isStdAIAA? :
     uncertainty? : effect (additive | multiplicative | percentage | absolute)
          (normalPDF : numSigmas | uniformPDF : symmetric )
```

Key: *element : attribute [optional attribute]*
subelement
'+' means 1 or more; '' means 0 or more; '?' means 0 or 1*



Example of `variableDef` for two input elements

```
    <!-- ================== -->
    <!--  Input variables   -->
    <!-- ================== -->

<variableDef name="mach" varID="XMACH" units="nd" symbol="M">
  <description>
       Mach number (dimensionless)
  </description>
  <isStdAIAA/>
</variableDef>

<variableDef name="lowerLeftBodyFlapDeflection"
             varID="DBFLL" units="deg" sign="ted" symbol="∂bfll">
  <description>
       Lower left body flap deflection, deg, +TED (so deflections are
       always zero or positive).
  </description>
</variableDef>
```



Example of local variable definition

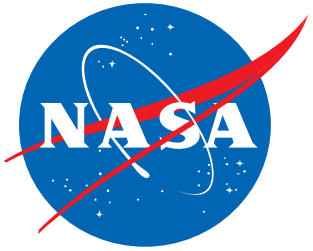
```
<!-- PRELIMINARY BUILDUP EQUATIONS -->

<!--  LOWER LEFT BODY FLAP CONTRIBUTIONS -->

<!--    table output signal   -->
  <variableDef name="Cldbfll_0" varID="CRBFLL0" units=”nd">
    <description>
        Output of CRBFLL0 function; rolling moment contribution of
        lower left body flap deflection due to alpha^0 (constant
        term).
    </description>
  </variableDef>
```

A more complex variable definition

```
<!--     lower left body flap lift buildup -->
  <variableDef name="CLdbfll" varID="CLBFLL" units="nd">
    <description>
         Lift contribution of lower left body flap deflection
         CLdbfll = CLdbfll_0 + alpha*(CLdbfll_1 + alpha*(CLdbfll_2 + alpha*CLdbfll_3))
    </description>
    <calculation>
      <math>
        <apply>
          <plus/>
          <ci>CLBFLL0</ci>
          <apply>
            <times/>
            <ci>ALP</ci>
            <apply>
              <plus/>
             <ci>CLBFLL1</ci>
             <apply>
                <times/>
                <ci>ALP</ci>
                <apply>
                  <plus/>
                  <ci>CLBFLL2</ci>
                  <apply>
                    <times/>
                    <ci>ALP</ci>
                    <ci>CLBFLL3</ci>
                  </apply> <!--             a*c3   -->
                </apply> <!--         (c2 + a*c3)  -->
              </apply> <!--         a*(c2 + a*c3)  -->
            </apply> <!--     (c1 + a*(c2 + a*c3)) -->
          </apply> <!--     a*(c1 + a*(c2 + a*c3)) -->
        </apply> <!-- c0 + a*(c1 + a*(c2 + a*c3)) -->
      </math>
    </calculation>
  </variableDef>
```

This MathML2 encodes:

$$C_{L\partial BF\,LL} = C_{L\partial BF\,LL0} + \alpha C_{L\partial BF\,LL1} + \alpha^2 C_{L\partial BF\,LL2} + \alpha^3 C_{L\partial BF\,LL3}$$



An output variable definition

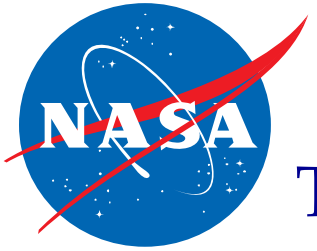
```
      <!-- ================== -->
      <!--  Output variables  -->
      <!-- ================== -->

<variableDef name="totalCoefficientOfLift" varID="CL" units="nd" sign="up" symbol="CL">
  <description>
   Coefficient of lift
   CL = CL0 + CLBFUL + CLBFUR + CLBFLL + CLBFLR +
                     CLWFL + CLWFR + CLRUD + CLGE + CLLG
  </description>
  <calculation>
    <math>
      <apply>
        <plus/>
        <ci>CL0</ci>
        <ci>CLBFUL</ci>
        <ci>CLBFUR</ci>
        <ci>CLBFLL</ci>
        <ci>CLBFLR</ci>
        <ci>CLWFL</ci>
        <ci>CLWFR</ci>
        <ci>CLRUD</ci>
        <ci>CLGE</ci>
        <ci>CLLG</ci>
      </apply>
    </math>
  </calculation>
  <isOutput/>
</variableDef>
```

Breakpoint set definition element (`breakpointDef`)

- Used to define a common set of independent variable values associated with one or more tables of function data

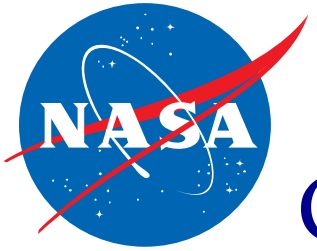
```
breakpointDef : bpID, [name, units]
        description? : (description character data)
        bpVals : (list of comma-separated set of breakpoint values)
```

Key: *element : attribute [optional attribute]*
subelement
'+' means 1 or more; '' means 0 or more; '?' means 0 or 1*



Two examples of `breakpointDef` elements

```
<!--                          ====================                          -->
<!-- ========================   BREAKPOINT SETS   ======================== -->
<!--                          ====================                          -->


  <breakpointDef name="Mach" bpID="XMACH1_PTS" units="nd">
    <description>
      Mach number breakpoints for all aero data tables
    </description>
    <bpVals>
       0.3, 0.6, 0.8, 0.9, 0.95, 1.1, 1.2, 1.6, 2.0, 2.5, 3.0, 3.5, 4.0
    </bpVals>
  </breakpointDef>

  <breakpointDef name="Lower body flap" bpID="DBFL_PTS" units="deg">
    <description>Lower body flap deflections breakpoints for tables</description>
    <bpVals>0., 15., 30., 45., 60.</bpVals>
  </breakpointDef>
```

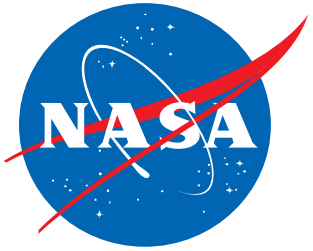


Gridded function table definition

- Defines nonlinear function dependent values

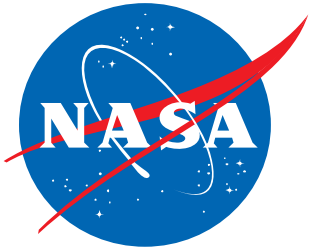
```
griddedTableDef : [gtID, name, units]
     description? : (description character data)
     provenance? : [provID] (or provenanceRef if duplicating previous provenanace)
          author+ : name, org
               (address* | contactInfo*) : (contact information)
          creationDate
          documentRef* : refID
          modificationRef* : modID
        description?
     breakpointRefs :
          bpRef+ : bpID
     uncertainty? : effect (additive | multiplicative | percentage | absolute)
          (normalPDF : numSigmas | uniformPDF : symmetric )
     dataTable : (list of comma-separated set of table values)
```

Key: element : attribute [optional attribute]
subelement
'+' means 1 or more; '' means 0 or more; '?' means 0 or 1*



Example of griddedTableDef

```
<griddedTableDef name="CLBFL0" gtID="CLBFL0_table">
  <description>
    Lower body flap contribution to lift coefficient, polynomial constant term
  </description>
  <provenance>
    <author name="Bruce Jackson" org="NASA Langley Research Center"/>
    <creationDate date="2003-01-31"/>
    <documentRef refID="REF01"/>
  </provenance>
  <breakpointRefs>
    <bpRef bpID="DBFL_PTS"/>
    <bpRef bpID="XMACH1_PTS"/>
  </breakpointRefs>
  <dataTable> <!-- last breakpoint changes most rapidly -->
    <!--   CLBFL0    POINTS    -->
    <!-- DBFL =        0.0     -->
 0.00000E+00 , 0.00000E+00 , 0.00000E+00 , 0.00000E+00 , 0.00000E+00 ,
 0.00000E+00 , 0.00000E+00 , 0.00000E+00 , 0.00000E+00 , 0.00000E+00 ,
 0.00000E+00 , 0.00000E+00 , 0.00000E+00 ,
    <!-- DBFL =       15.0     -->
-0.86429E-02 ,-0.10256E-01 ,-0.11189E-01 ,-0.12121E-01 ,-0.13520E-01 ,
-0.86299E-02 ,-0.53679E-02 , 0.76757E-02 , 0.11300E-01 , 0.62992E-02 ,
 0.51902E-02 , 0.38813E-02 , 0.37366E-02 ,
   .
   .
   .
  </dataTable>
</griddedTableDef>
```



An aside about table ordering…

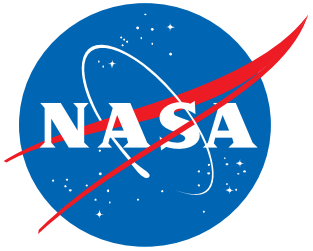
- The appearance of tables in DAVE-ML files can be confusing, in that they appear to be 2-dimensional
- In actuality, the values are a vector of the 'unraveled' n-dimensional tables with last index changing fastest
- Example: given $C_L = C_L(\alpha, M, \delta f)$, value sequence is

  `<datatable>`

  $C_L(\alpha_1, M_1, \delta f_1)$, $C_L(\alpha_1, M_1, \delta f_2)$, … $C_L(\alpha_1, M_1, \delta f_n)$,
  $C_L(\alpha_1, M_2, \delta f_1)$, $C_L(\alpha_1, M_2, \delta f_2)$, … $C_L(\alpha_1, M_2, \delta f_n)$,
  $C_L(\alpha_1, M_m, \delta f_1)$, $C_L(\alpha_1, M_m, \delta f_2)$, … $C_L(\alpha_1, M_m, \delta f_n)$,
  $C_L(\alpha_2, M_1, \delta f_1)$, …

  `</datatable>`

- Line breaks can occur anywhere - they are ignored



Aside - table ordering (cont'd)

- Previous example could also be encoded

<datatable>

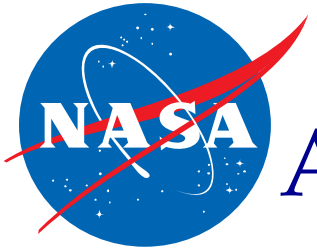
$C_L(\alpha_1, M_1, \delta f_1)$, $C_L(\alpha_1, M_1, \delta f_2)$, …

$C_L(\alpha_1, M_1, \delta f_n)$, $C_L(\alpha_1, M_2, \delta f_1)$,

$C_L(\alpha_1, M_2, \delta f_2)$, … $C_L(\alpha_1, M_2, \delta f_n)$,
$C_L(\alpha_1, M_m, \delta f_1)$,

$C_L(\alpha_1, M_m, \delta f_2)$, … $C_L(\alpha_1, M_m, \delta f_n)$,
$C_L(\alpha_2, M_1, \delta f_1)$, …

</datatable>



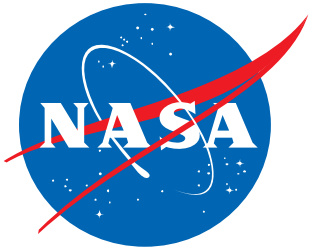
Aside - table ordering (concluded)

- Order of `<bpRefs>` in `<breakpointRefs>` element is important!
- In previous example, order would have to be

```
<breakpointRefs>
    <bpRef bpID="ALPHA_PTS"/>
    <bpRef bpID="MACH_PTS"/>
    <bpRef bpID="DELTA_FLAP_PTS"/>
</breakpointRefs>
```

…so interpreter will know which breakpoint set to associate with which dimension of this function table.

- This is one of the few places in DAVE-ML where order is important.



Function definition element

- This element ties breakpoint sets to tables
- Several different syntaxes; below is most common

```
function : name
    description? : (description character data)
    (provenance | provenanceRef)?
    independentVarRef+ : varID, [min, max, extrapolate,
       interpolate=(discrete|floor|ceiling|linear|
                    quadraticSpline|cubicSpline)]
    dependentVarRef : varID
    functionDefn : [name]
        griddedTableRef : gtID
```

Key: element : attribute [optional attribute]
subelement
'+' means 1 or more; '' means 0 or more; '?' means 0 or 1*

Interpolation / extrapolation options

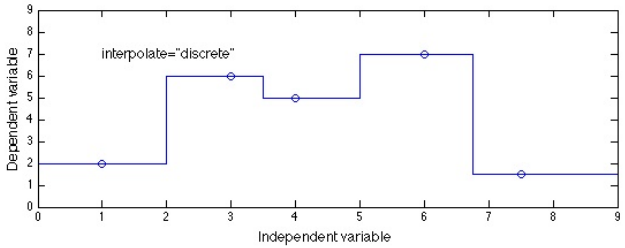
extrapolate="none"

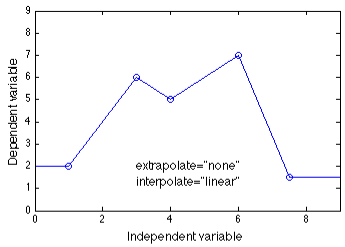
extrapolate="both"

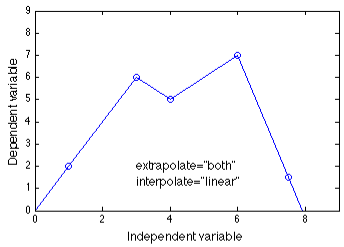
interpolate= "discrete"

interpolate= "ceiling"

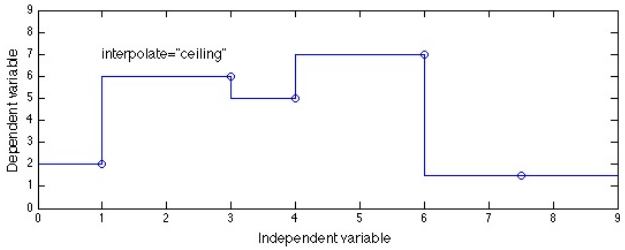
interpolate= "floor"

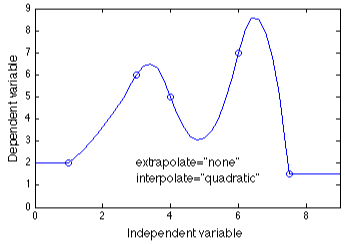


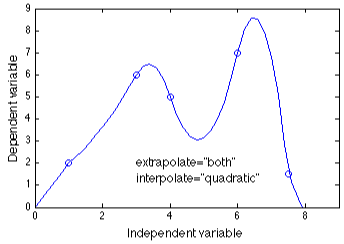




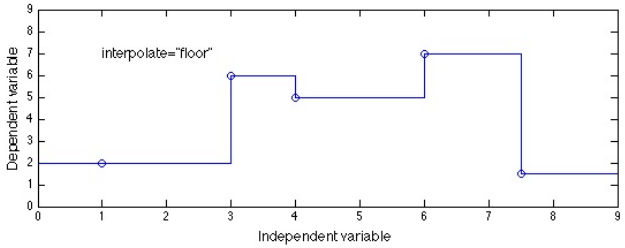
interpolate= "linear"

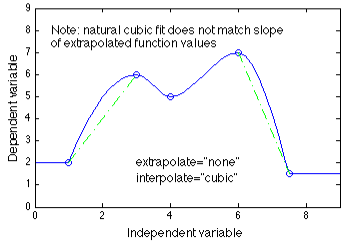


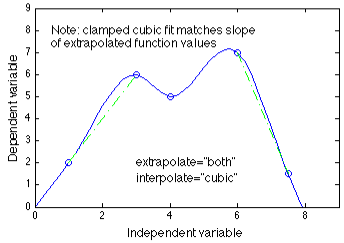




interpolate= "quadratic"

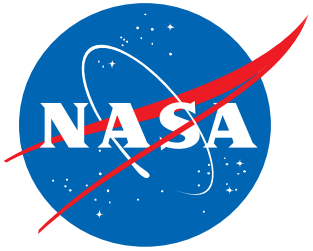






interpolate= "cubic"

Defaults are "linear" interpolation and "none" for extrapolation



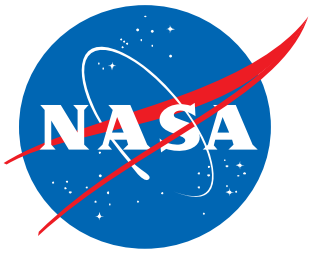
Example of `function` element

```
    <!-- ============================== -->
    <!-- Lower left body flap functions -->
    <!-- ============================== -->

<function name="CLBFLL0">
  <description>
    Lower left body flap lookup function for lift, polynomial constant term.
  </description>
  <independentVarRef varID="DBFLL"  min="0.0" max="60." extrapolate="neither"/>
  <independentVarRef varID="XMACH" min="0.3" max="4.0" extrapolate="neither"/>
  <dependentVarRef varID="CLBFLL0"/>
  <functionDefn name="CLBFL0_fn">
    <griddedTableRef gtID="CLBFL0_table"/>
  </functionDefn>
</function>
```

This defines a function `CLBFLO_fn` to be

```
CLBFLO_fn = CLBFLO_fn(DBFLL, XMACH)
```

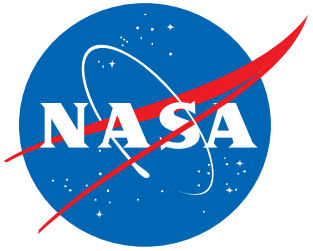
with limits on input values and no extrapolation



Verification data (`checkData`) element

```
checkData :
    staticShot* : name, [refID]
        checkInputs :
            signal+ :
               signalName :
               signalUnits :
               signalValue :
        internalValues? :
            signal+ :
               varID :
               signalValue :
        checkOutputs :
            signal+ :
               signalName :
               signalUnits :
               signalValue :
               tol :
```

Key: element : attribute [optional attribute]
subelement
'+' means 1 or more; '' means 0 or more; '?' means 0 or 1*

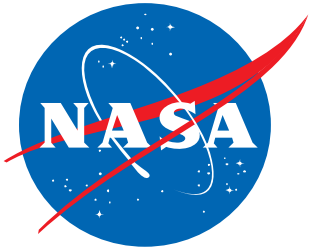


Example `checkData` element

```
<checkData>
  <staticShot name="Nominal" refID="NOTE1">
    <checkInputs>
     <signal>
        <signalName>true_Airspeed</signalName>
        <signalUnits>f_s</signalUnits>
        <signalValue> 300.000</signalValue>
      </signal>
      <signal>
        <signalName>angleOfAttack</signalName>
        <signalUnits>deg</signalUnits>
        <signalValue>   5.000</signalValue>
      </signal>
      <signal>
        <signalName>bodyAngularRate_Pitch</signalName>
        <signalUnits>rad_s</signalUnits>
        <signalValue>   0.000</signalValue>
      </signal>
      <signal>
        <signalName>elevatorDeflection</signalName>
        <signalUnits>deg</signalUnits>
        <signalValue>   0.000</signalValue>
      </signal>
          .
          .      (other input values)
          .
    </checkInputs>
      .
      .
      .
```

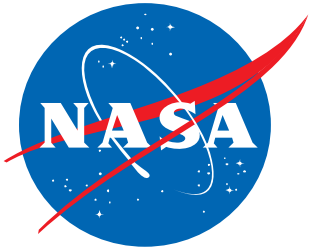
Example `checkData` element (cont'd)

```
        .
        .
        .
      <checkOutputs>
        <signal>
          <signalName>aeroBodyCoefficient_X</signalName>
          <signalValue>-0.00400000000000</signalValue>
          <tol>0.000001</tol>
        </signal>
        <signal>
          <signalName>aeroBodyCoefficient_Z</signalName>
          <signalValue>-0.41600000000000</signalValue>
          <tol>0.000001</tol>
        </signal>
        <signal>
          <signalName>aeroBodyMomentCoefficient_Pitch</signalName>
          <signalValue>-0.04660000000000</signalValue>
          <tol>0.000001</tol>
        </signal>
          .
          .      (other output values & tolerances)
          .
      </checkOutputs>
    </staticShot>
        .
        .    (other input/output vector pairs)
        .
</checkData>
```



checkData elements can have intermediate values to assist debugging

```
<checkData>
  <staticShot name="Skewed inputs">
    <checkInputs>
      .
      .    (checkcase input values)
      .
    </checkInputs>
    <internalValues>
      <signal>
        <signalID>vt</signalID>
        <signalValue>300.0</signalValue>
      </signal>
      <signal>
        <signalID>alpha</signalID>
        <signalValue>16.2</signalValue>
      </signal>
      <signal>
        <signalID>q</signalID>
        <signalValue>-0.76</signalValue>
      </signal>
          .
          .    (additional internal values; normally one for every internal variable)
          .
    </internalValues>
    <checkOutputs>
      .
      .    (checkcase output values)
      .
    </checkOutputs>
  </staticShot>
</checkData>
```



uncertainty Element

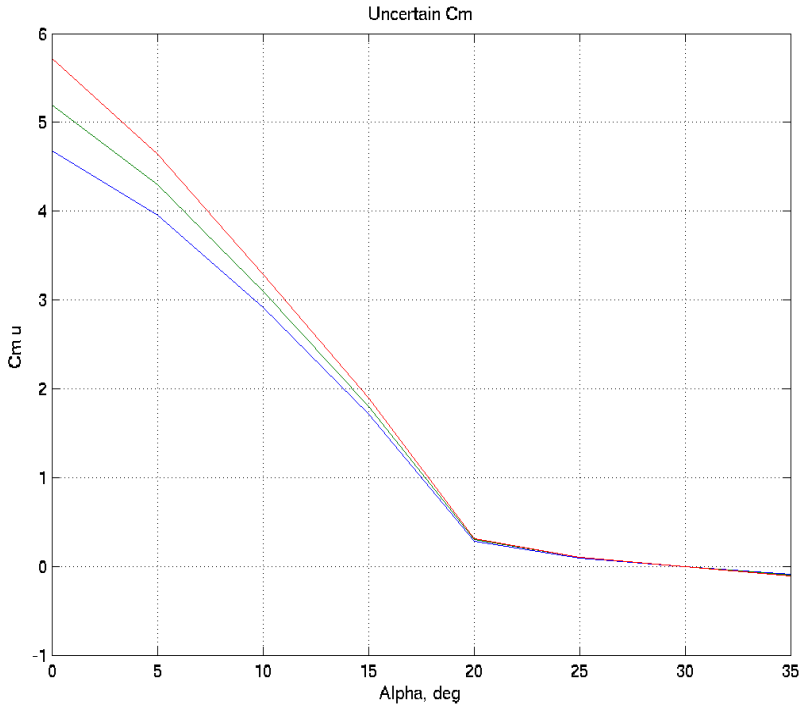
```
uncertainty : effect=['additive'|'multiplicative'|'percentage'|'absolute']
   EITHER
    normalPDF : numSigmas=['1','2','3',…]
        bounds : (value corresponding to 1, 2, 3,… σ)
        correlatesWith* : varID
        correlation : varID, corrCoef
   OR
    uniformPDF :
        bounds : (symmetric or lower bound value)
            (dataTable | variableDef | variableRef | PCDATA)
        [bounds : (upper bound value)]
```

Key: *element : attribute [optional attribute]*
subelement
'+' means 1 or more; '' means 0 or more; '?' means 0 or 1*

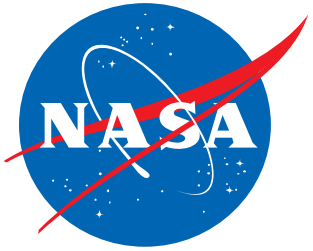
Application of `uncertainty` element

Example: add 5-12% uncertainty bound around C_m

```
<function name="Uncertain Cm">
  <independentVarRef varID="Alpha_deg"/>
  <dependentVarRef varID="Cm_u"/>
  <functionDefn>
    <griddedTableDef>
      <breakpointRefs>
        <bpRef bpID="ALP"/>
      </breakpointRefs>
      <uncertainty effect="percentage">
        <normalPDF numSigmas="3">
          <bounds>
            <dataTable>
  0.10, 0.08, 0.06, 0.05, 0.05,
  0.06, 0.07, 0.12
            </dataTable></bounds>
        </normalPDF>
      </uncertainty>
      <dataTable>
  5.2, 4.3, 3.1, 1.8, 0.3, 0.1, 0.0, -0.1
      </dataTable>
    </griddedTableDef>
  </functionDefn>
</function>
```



(assuming ALP = [0:5:35])



Summary

- DAVE-ML 'ready-for-use' on production models
  - –static models only, such as aero, mass properties
- Limited tools available, but slowly growing
  - –Chicken or egg problem right now
  - –Hand-coding not recommended - write export script
- Syntax will evolve in backwards-compatible way
- Still to tackle: dynamics & subsystems
- Help wanted! Join the mailing list - see website

http://www.daveml.org