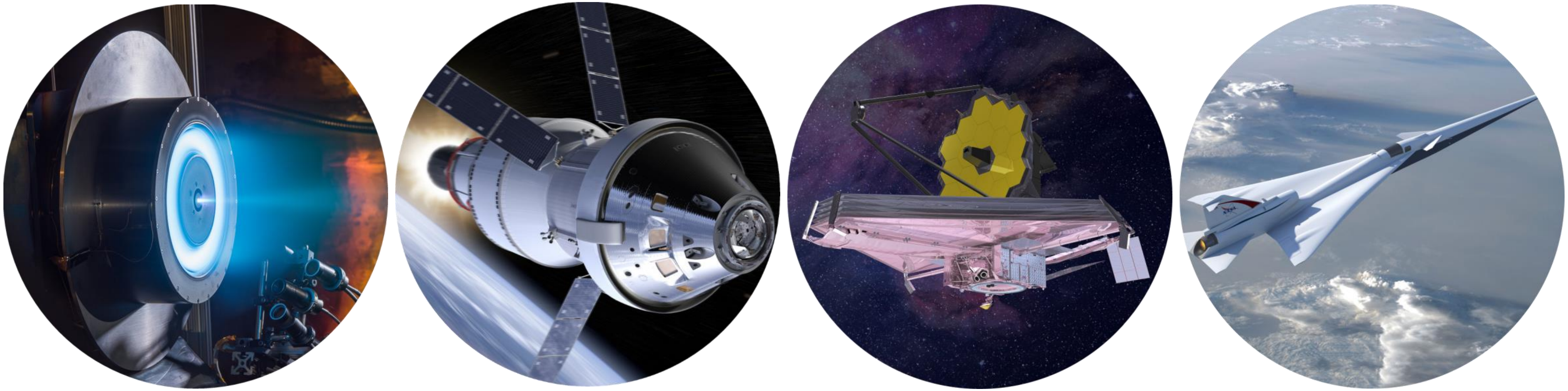
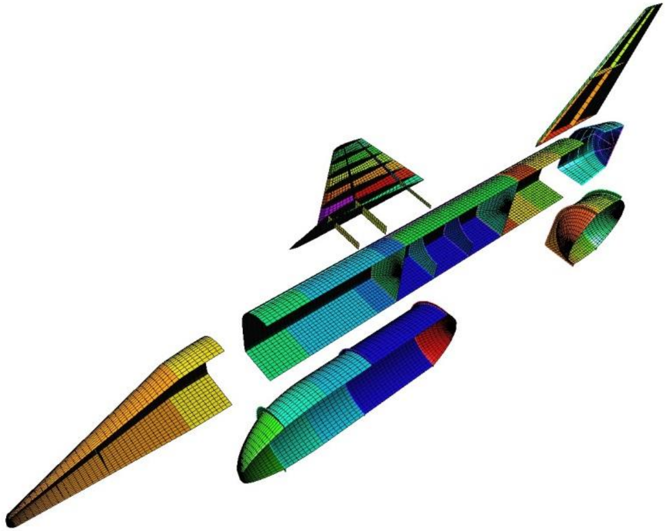
Using *Loft*

National Aeronautics and
Space Administration





An Automated Parametric Mesh Generator for Stiffened Shell Aerospace Vehicles

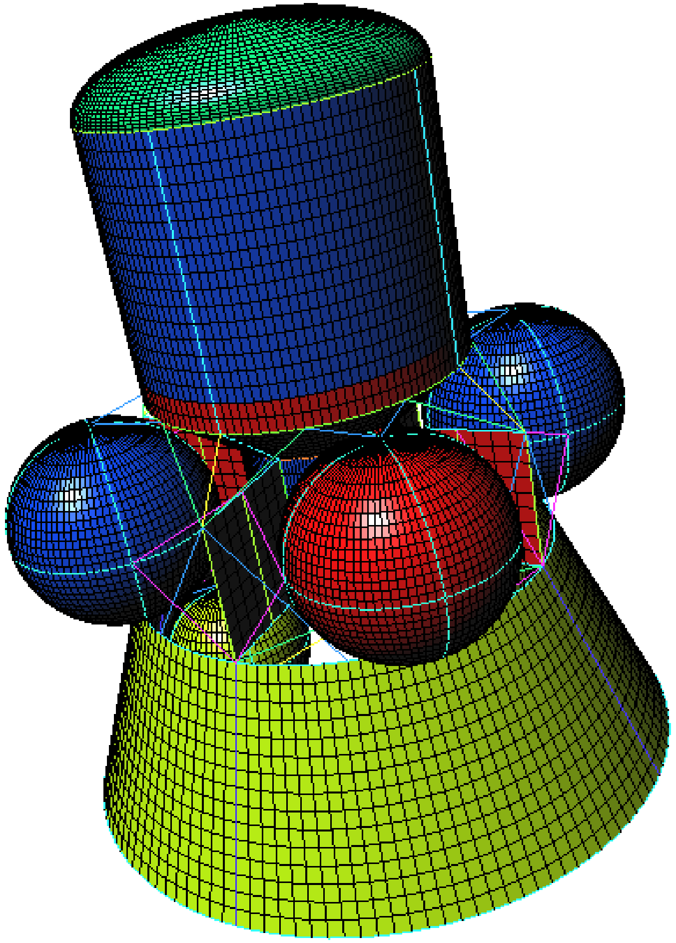
Lloyd B. Eldred

AIAA SciTech, January 2024

EXPLORE VAB

Outline

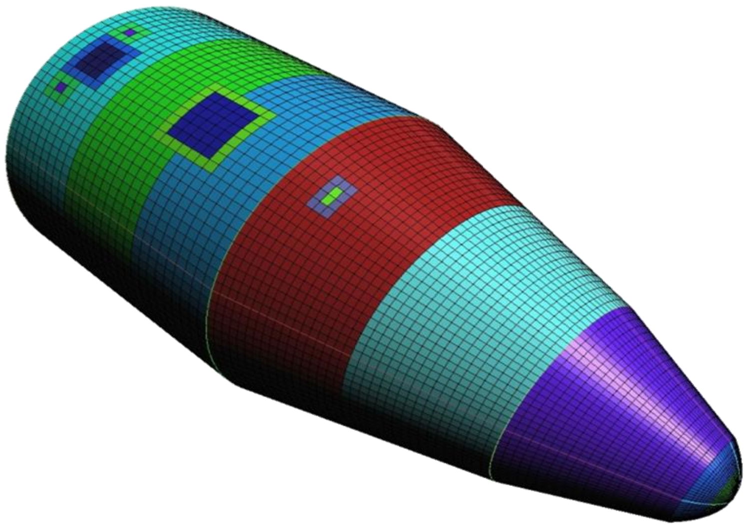
- *Loft* program overview
- *Loft* use scenarios
  - Rapid modeling
  - Parametrics for exploring design variations
  - Batch use with other tools
- Other features and limitations
- Conclusions
- Trying out *Loft*

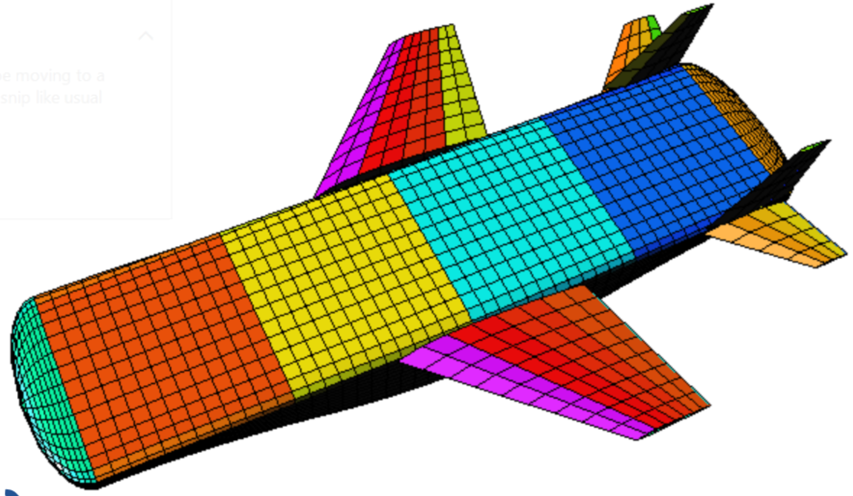


Loft Release

- *Loft* is an engineering tool not a professional software product
- *Loft* is available for free from **software.nasa.gov**
- 175 page manual available from **ntrs.nasa.gov**
- Release is a compiled Windows executable with examples

Links & QR code at end of presentation!





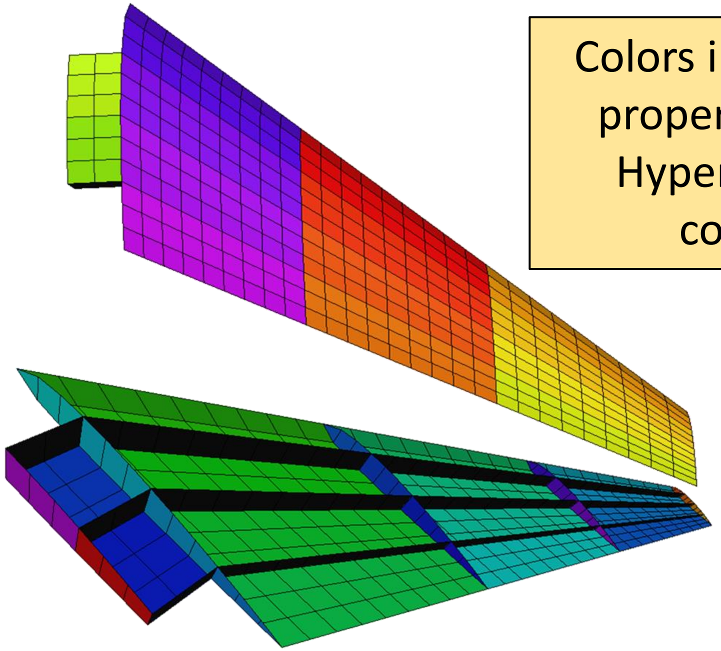
What is *Loft*?

Loft is a finite element model creation tool that takes a descriptive text file input and generates a structural mesh in NASTRAN, TecPlot, VRML, STL, etc. format.

```
object wing Main Wing
    chord 30
    span 60
    taper 0.25
    sweep 40
    wingbox 6
    nribs 4
    nspars 3
    mesh 0.5
    naca 2412
write vrml mywing.wrl
```

11-line text input file

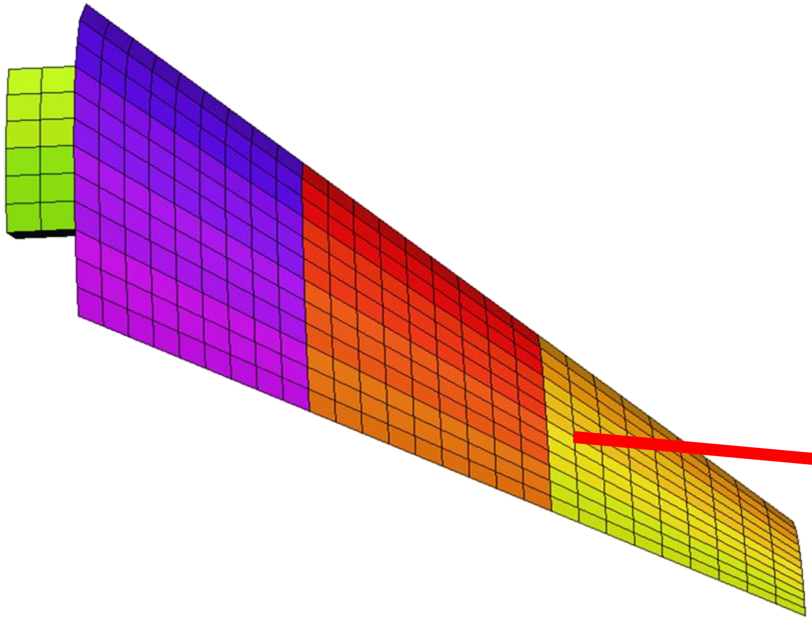
Loft



Colors indicate physical property changes for HyperSizer/HyperX components

Top skin removed to show ribs and spars

Loft Automatic Group Labeling



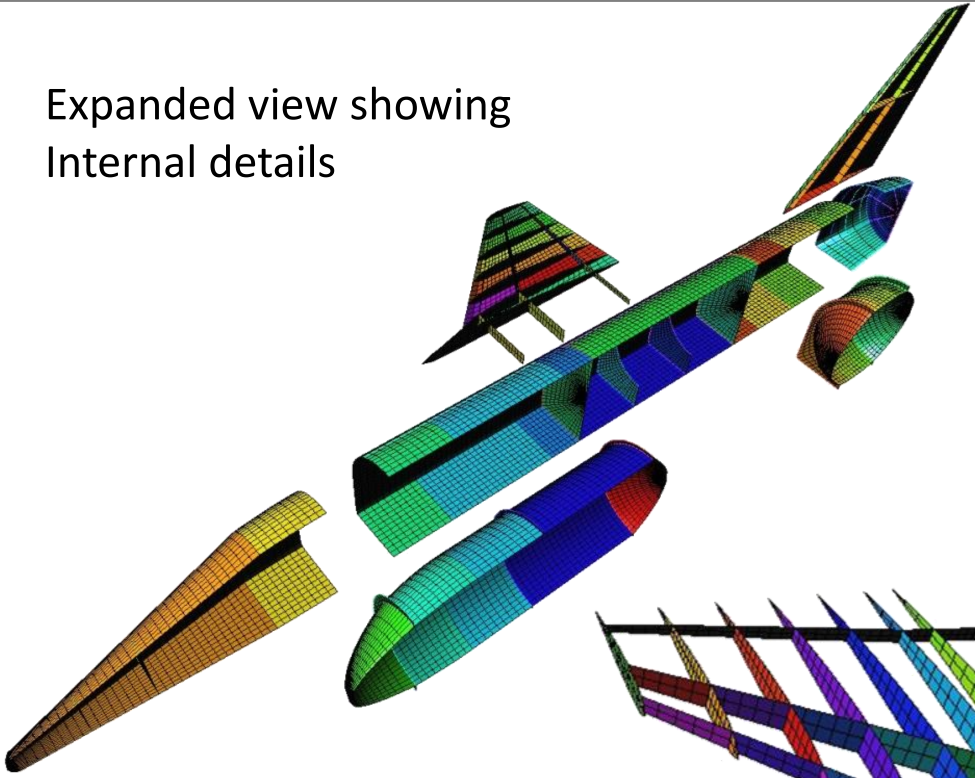
```
Read line: list groups

 Group list for mesh Main Wing:

        0: Main Wing ROOT NODES
        1: Main Wing TIP NODES
        2: Main Wing ROOT SPAR NODES
        3: Main Wing ROOT RIB NODES
        4: Main Wing CARRYTHR NODES
        5: Main Wing SKIN UP ELEMS
        6: Main Wing SKIN LOW ELEMS
        7: Main Wing SPAR ELEMS
        8: Main Wing RIB ELEMS
        9: Main Wing QUARTER CHORD VECT
       10: Main Wing CT SKIN UP ELEMS
       11: Main Wing CT SKIN LOW ELEMS
       12: Main Wing CT SPAR ELEMS
       13: Main Wing ALL NODES
       14: Main Wing ALL PANELS
```

```
Region Element Listing
   i    node1  node2  node3  node4  matprop  physprop
 100000 100000 100007 100009 100002    100000    100003
 100001 100002 100009 100011 100004    100000    100003
 100002 100004 100011 100013 100006    100000    100003
 100003 100007 100014 100016 100009    100000    100003
 100004 100009 100016 100018 100011    100000    100003
 100005 100011 100018 100020 100013    100000    100003
```

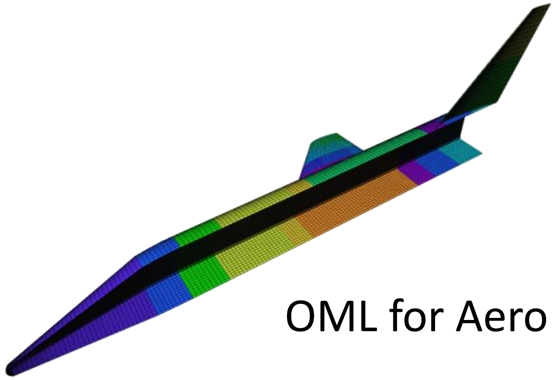
Lists of nodes/elements to apply loads/bc to are easy to create.

Loft Manual Group Labeling

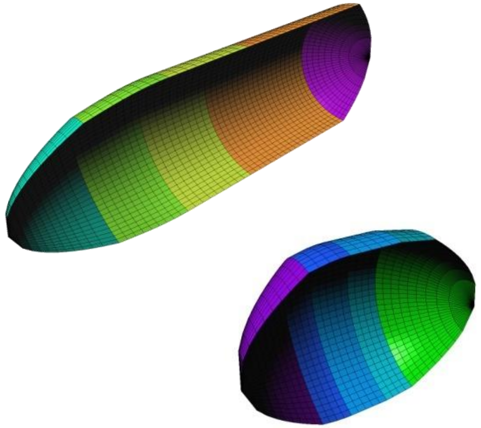
Expanded view showing
Internal details

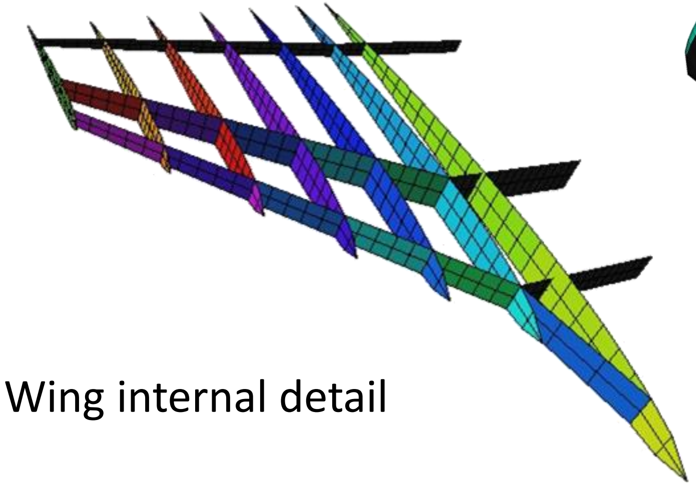


OML for Aero mapping



LH2 and LOX tanks for
hydrostatic fuel load
application



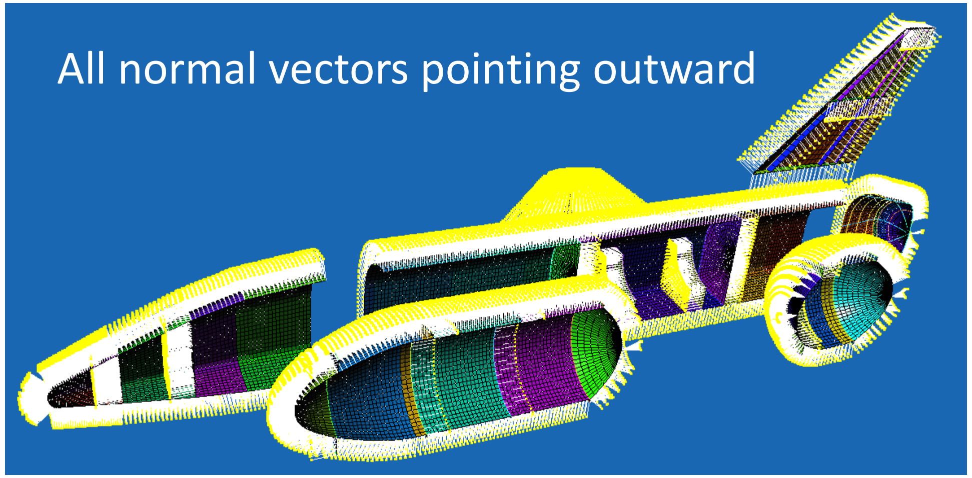


Wing internal detail

Partial models with element and node indexing intact are easily saved along with the full model

Loft meshing overview

- Clean, smooth meshes
- Automatic and manual labeling of mesh components
  - HyperSizer/HyperX component, Patran properties.
  - Postprocessing ease.
  - Batch use (load, boundary condition application.)
- Input-file variable & math support for parametric changes and ease of reading
- Consistent element normal vector & material directions with user overrides
- 99% four-node Quad elements
- Tri elements at dome nose & wing leading edge
- Beam and bar stiffeners for rib/spar caps, ring frames, longerons, struts, etc.



Application: Rapid FEA Models

- Ease of model definition allows creation of usable FEA models in minutes to hours
- *Loft* has been used by multiple summer intern design teams
- There is interest to use it for undergraduate design classes
- STL (STereo Lithography) file support allows models to be 3D printed

Microsoft Office also supports STL files which can be rotated while in edit mode.

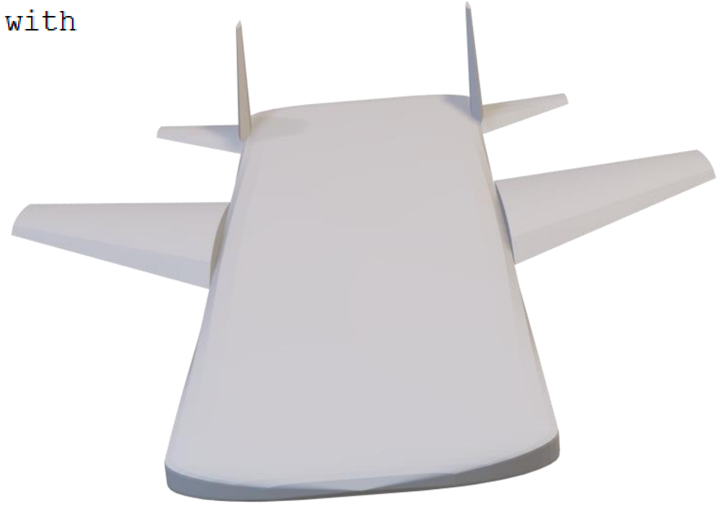
Rapid Hypersonic *Loft* Model

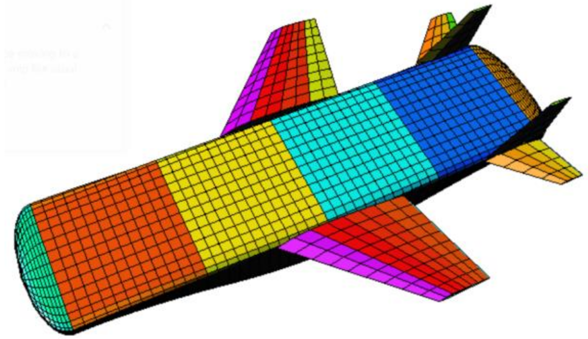
National Aeronautics and
Space Administration

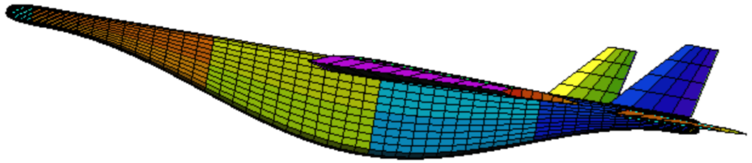
- 72 lines of text input commands plus comments and named variables for ease of reading

```
# Demo rapid model of a hypersonic vehicle with
# a spatulated nosed fuselage
#
# Global dimensions in feet
define fuselength 200
define fusewidth 25
define wingrootchord 50
define wingtipchord 20
define wingspan 40
define wingsweep 45
define wingletiplocation 70
define tailrootchord 25
define tailtipchord 10
define tailspan 20
define tailsweep 45
```

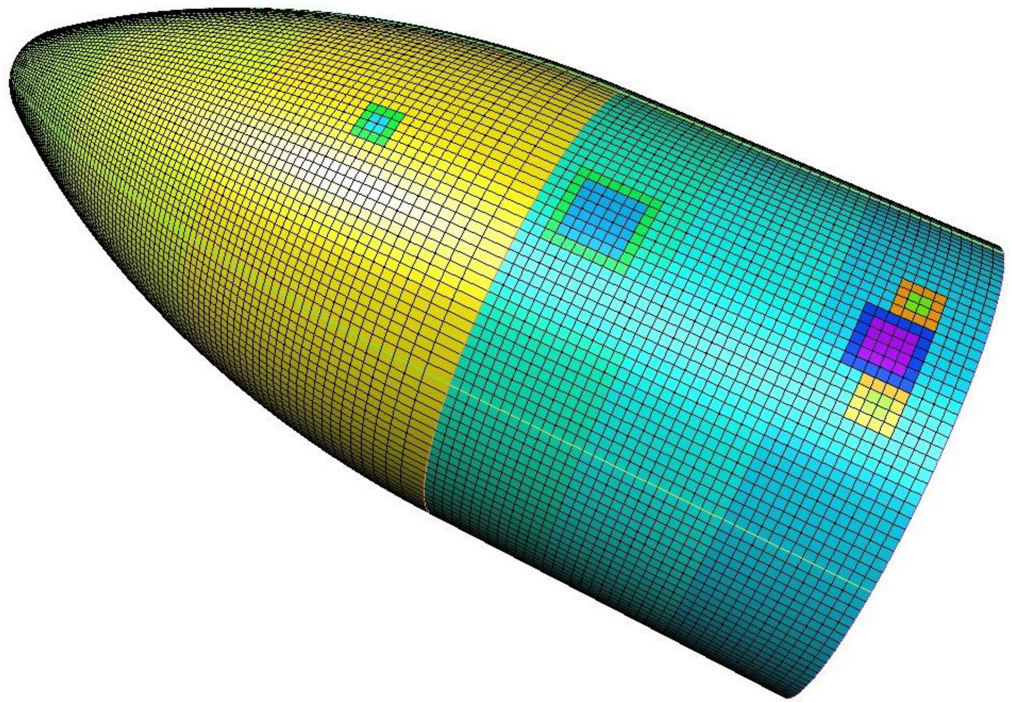
Beginning of input file for cartoon vehicle model

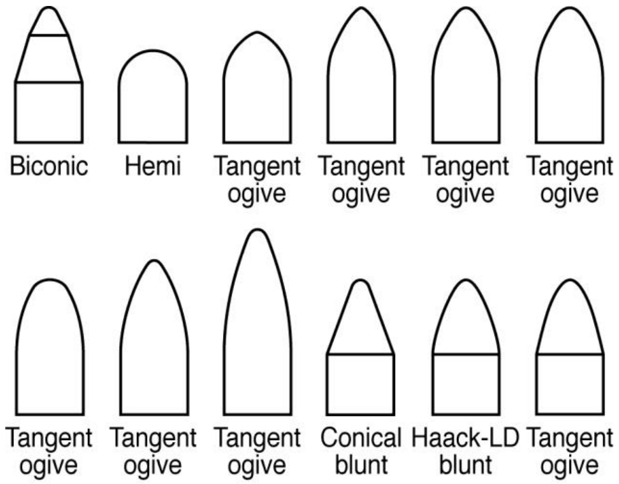


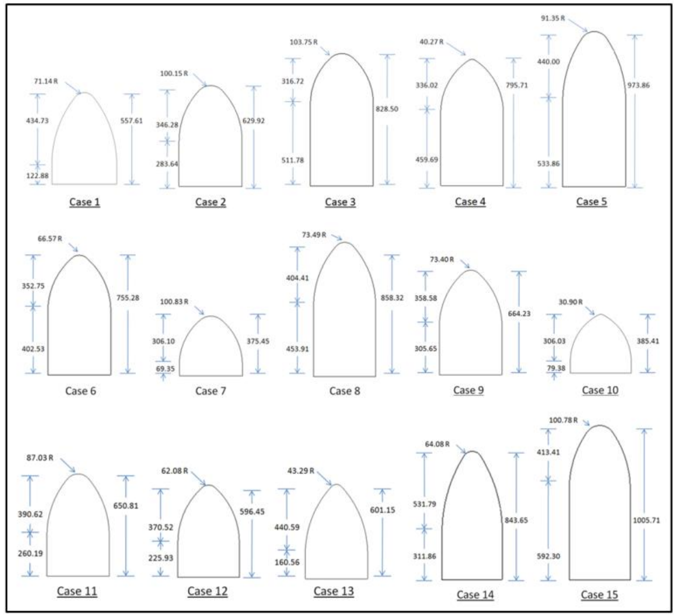




Rapid Space Launch System Payload Fairing





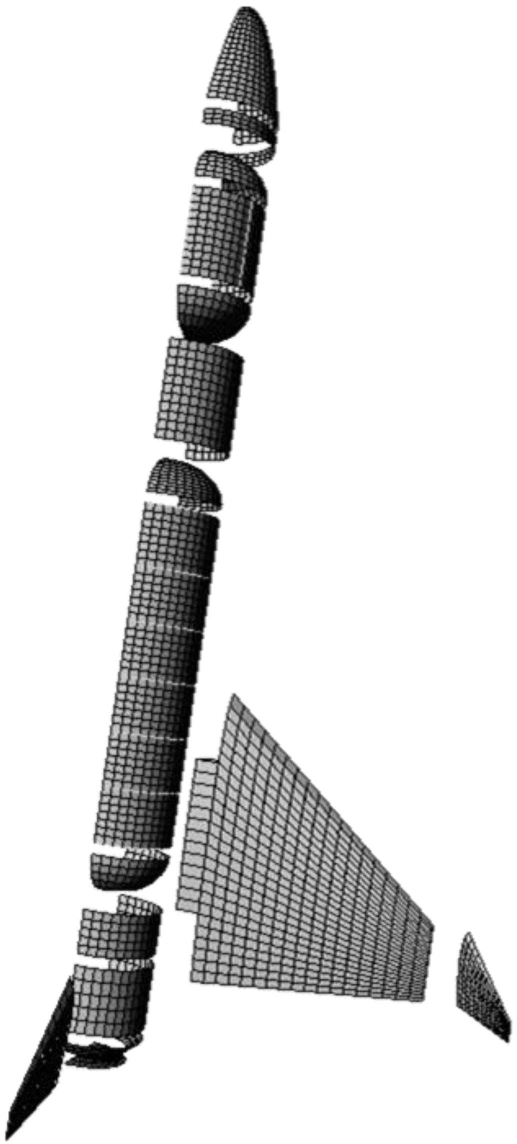


- Created dozens of different shaped shroud FEA models for the shroud team over 5.5 years
- All shroud FEA models used by SLS, Constellation, and ACT are either directly created by or based on the Loft models

EXPLORE VAB

Application: Parametric Modeling

- Loft is inherently semi-parametric
  - Change a cross section shape, dimension, or mesh count and later objects will use those settings
  - Change a length and later objects will reposition behind the shorter/longer section
- Input file variables and math add optional explicit parameterization
  - Variables and math can be used anywhere in an input file that a number is used
  - Changing a single variable value will update every dimension that uses that value



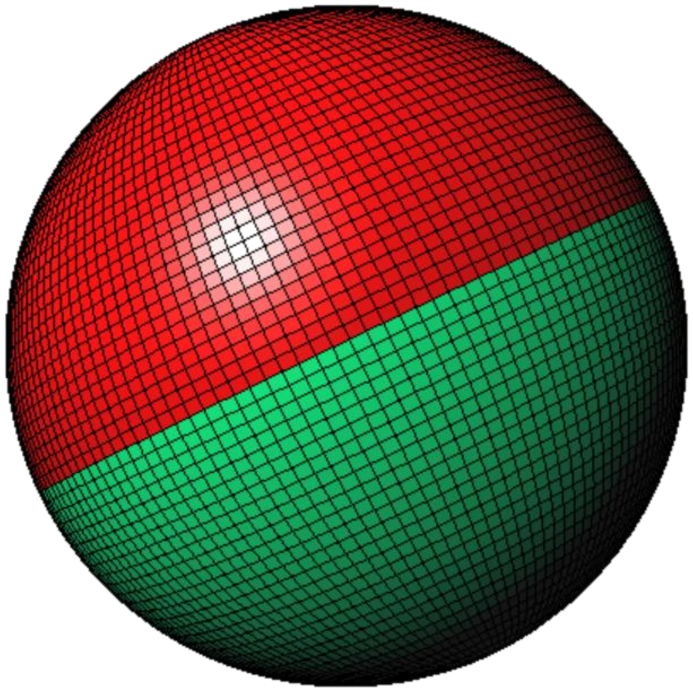
Parametric modeling: Variables & Math

This example uses $\cos^{-1}$ to calculate π and a cube root to build a model of a sphere with a desired volume

```
# Example use of variables & math to create a
# FEA model of a sphere with a specified volume
define volume 10.0
define piover2 0.0 %acos
define pi $piover2 * 2.0
define radius $volume * 3.0 / 4.0 / $pi %cbrt
list variables
#
object dome sphere top
   curve1 cir
   c1_xscale $radius
   c1_yscale $radius
   length -1.0 * $radius
   nodes_axial 30
   nodes_circ 150
object dome sphere bottom
   length $radius
   nodes_axial 30
write vrml sphere.wrl
end
```

___ Variable List ___

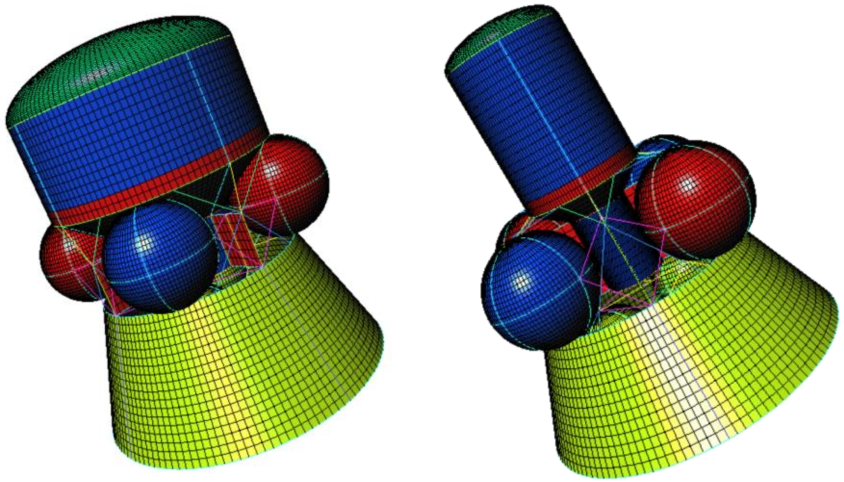
Value	Name
10.000000	volume
1.570796	piover2
3.141592	pi
1.336505	radius



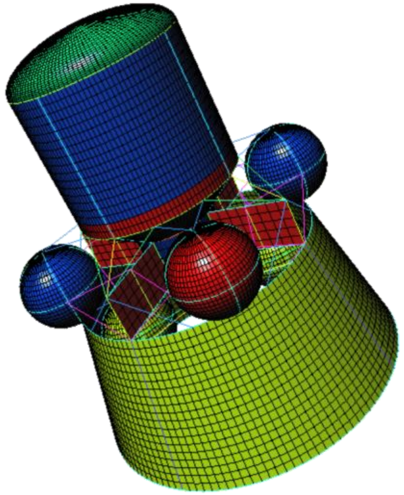
Note that the curve name, radii, and circumferential node count did not have to be given

Parametric modeling: Lander Concept

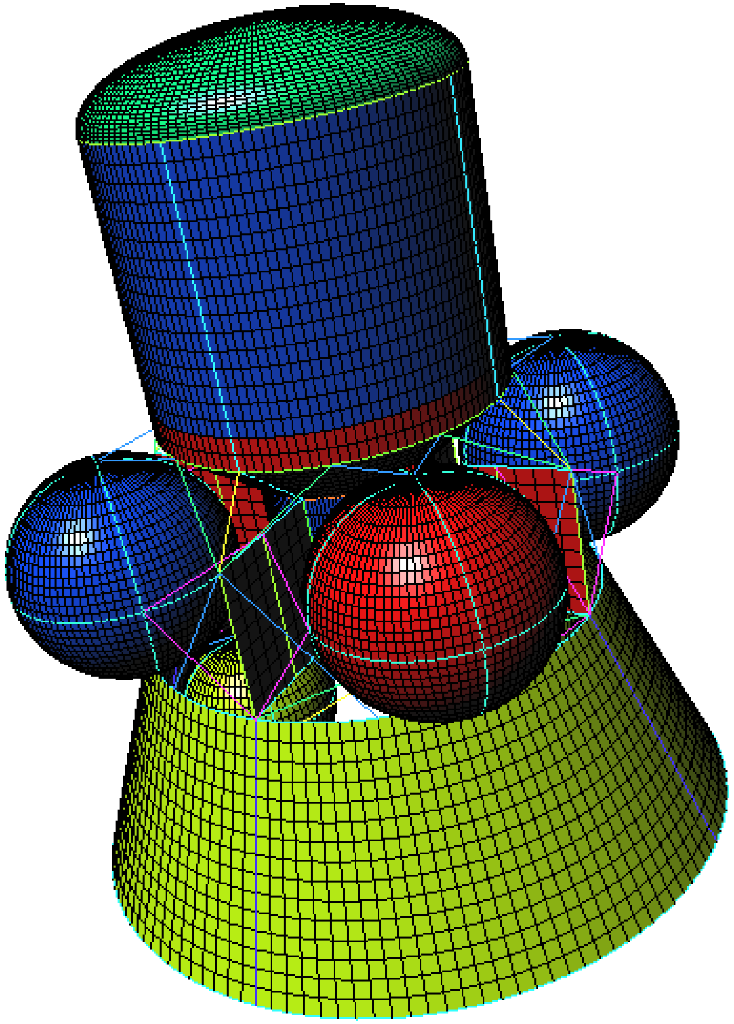
Parametric model using *Loft's* variables and math capabilities automatically regenerates complete, stitched model based on changes to input vehicle dimensions. (650 lines)



1.5 or 0.75 scale cabin diameters



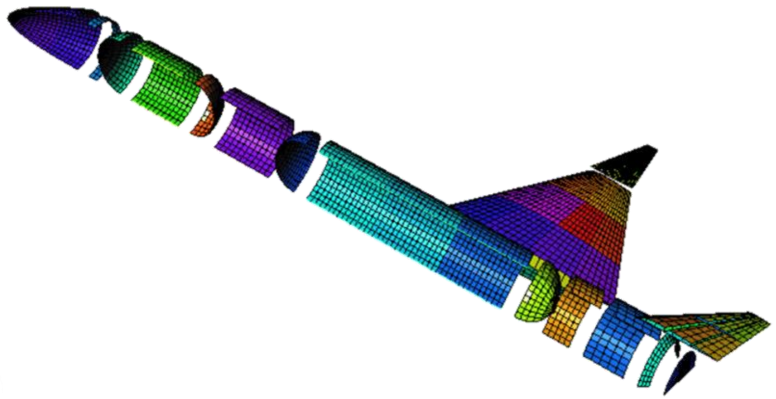
0.75 scale fuel tanks



Baseline model

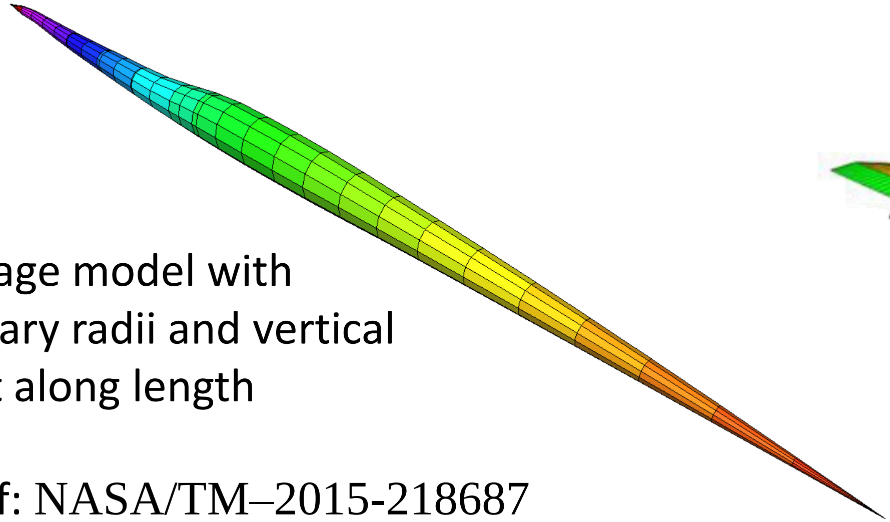
Application: Batch Integration

- *Loft* is easy to integrate into a batch environment
  - Runs from a command line
  - Has no graphical user interface (GUI)
- Written in portable C; should run on most operating systems
- Text input and multiple text output options including partial models and lists of nodes or elements that meet desired criteria
  - Examples: list of centerline nodes, OML elements, wing upper skin elements, etc.

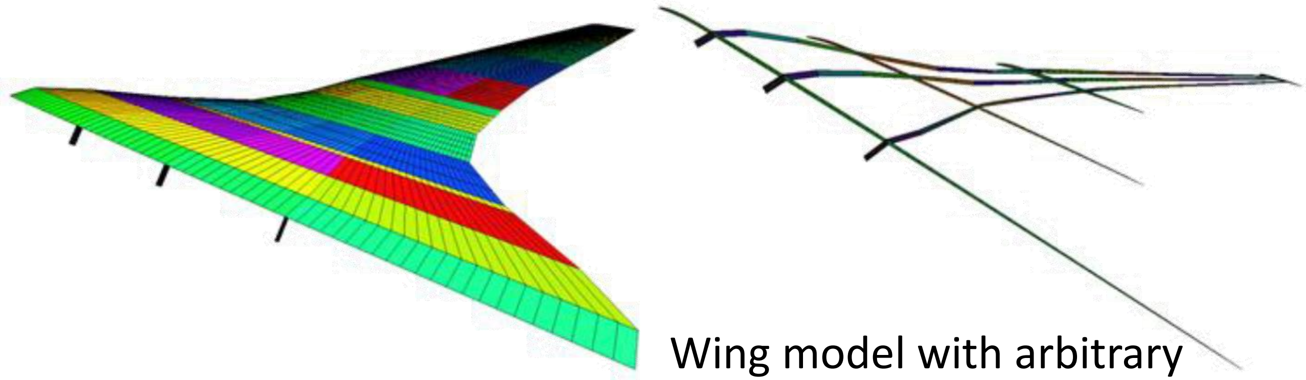


Batch Applications: Supersonics

- *Loft* integrated into design-of-experiments based tool for low boom designs
- Simple fuselage and piecewise trapezoidal wings glued in NASTRAN and sized in HyperSizer
- Wing spar carry-throughs aligned with fuselage bulkheads



Fuselage model with arbitrary radii and vertical offset along length



Wing model with arbitrary thickness, sweep, chord, and dihedral at each station

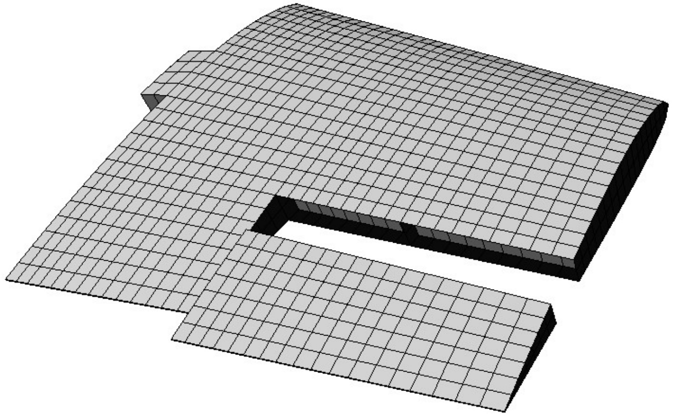
Ref: NASA/TM–2015-218687

Batch Applications: *SPARC*

Structural Preliminary Analysis for aeRospaCe vehicles

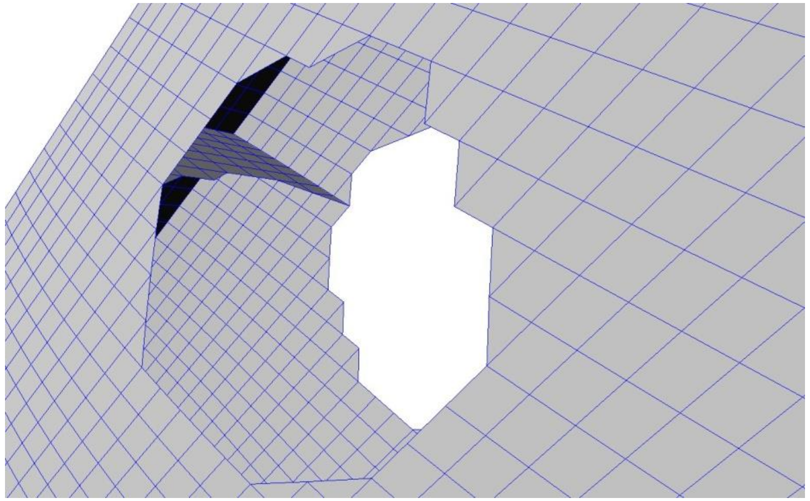
- Current effort to build a low-maturity design environment where non-structural inputs are approximated and mapped to a *Loft* generated FEA model
- Uses our high-fidelity analysis tools: NASTRAN and HyperSizer/HyperX and existing utilities with simpler models and loads
- Application to aircraft, rockets, and components like wings and tanks
- Allows for structural design insight and input in a system before detailed aero, thermal, propulsion, and trajectory analyses are available

Some other *Loft* Features

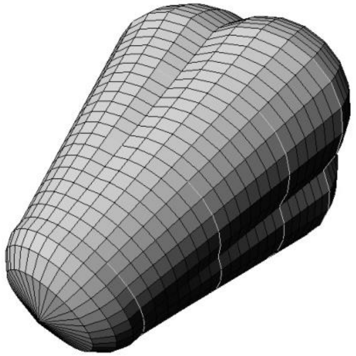


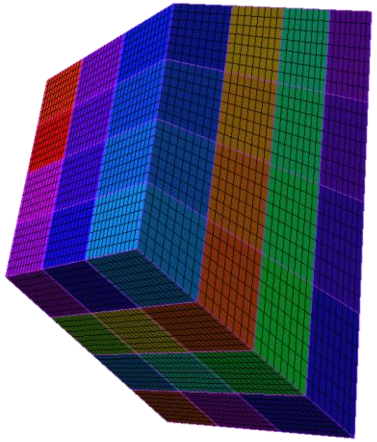
Partial wings to make control surface models

Damaged structure:
wing and rib example

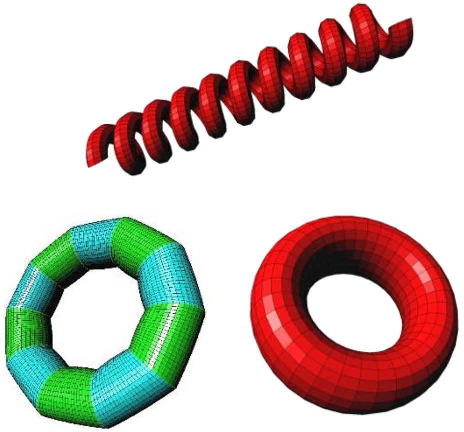


Multi-lobe tanks

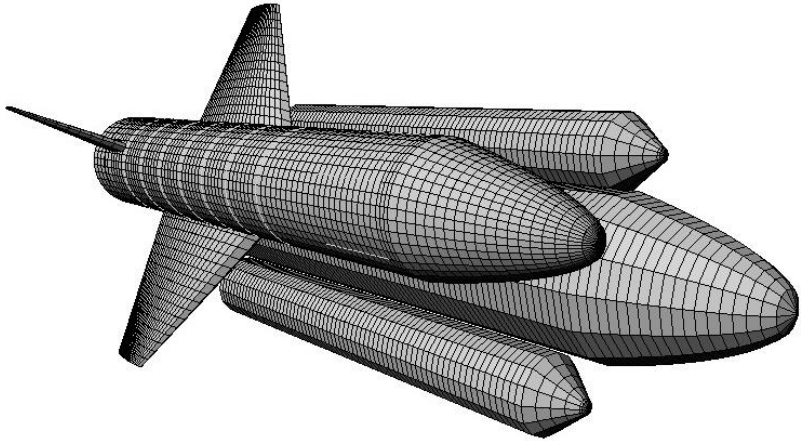




Stiffened Mattress tanks



Bodies of revolution

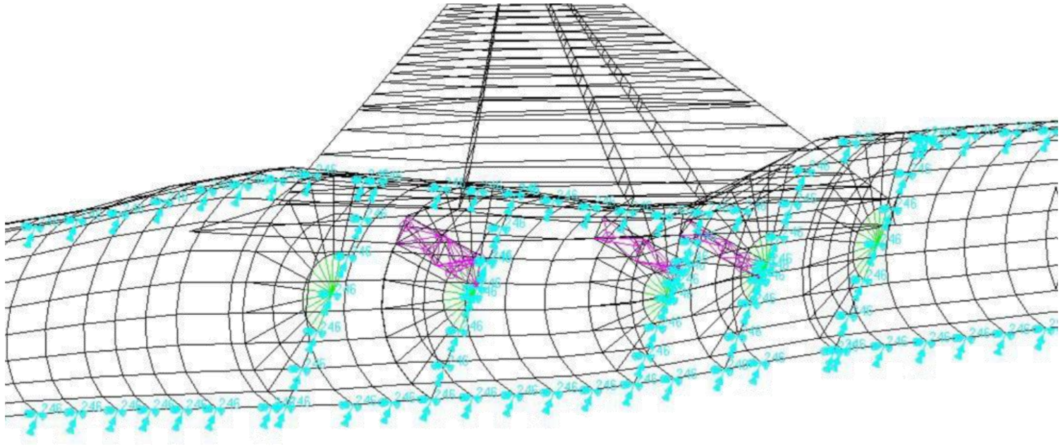


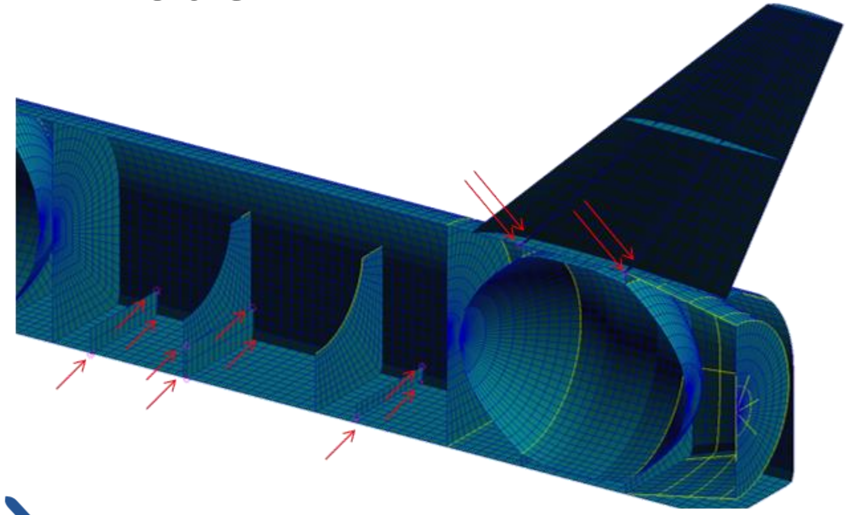
Copy, paste, flip, scale, and position to make different versions of complex vehicles easily

EXPLORE VAB

Loft Limitations

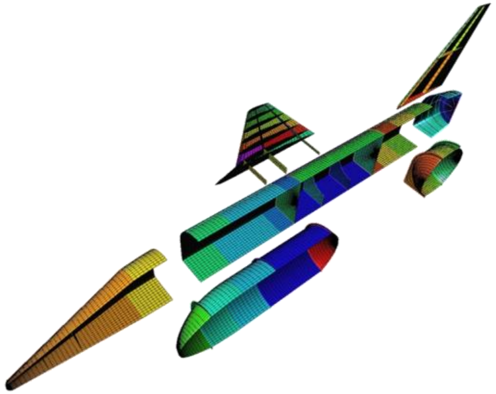
- Best suited for conceptual level models
- Not suited for fine details
- No CAD/geometry (STEP/IGES) interface (in or out)
- Wings/tails/fins generally require manual stitching or careful gluing (automatable) to connect to fuselage FEA model





Conclusions

- Loft is a general purpose conceptual finite element mesh generator for stiffened shell aerospace vehicles
- Model creation is quick and easy
- Models are parametric allowing for fast changes and rapid trade studies
- Loft can be easily integrated as part of a design environment
- Its unique combination of other features may fit a need for a rapid model creation
- Could be useful for college design classes



Trying Out *Loft*

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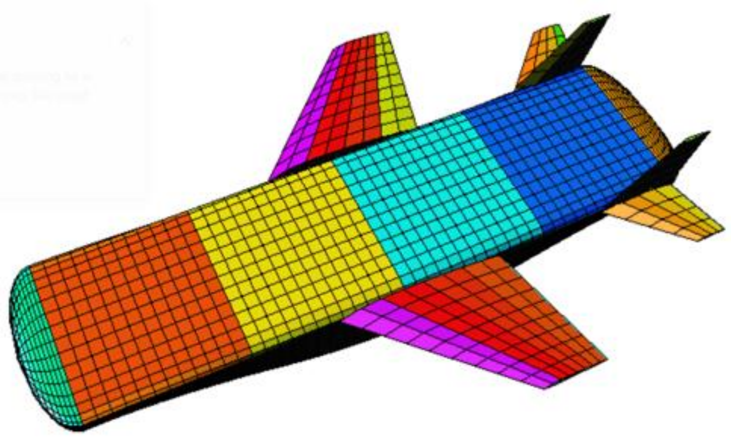
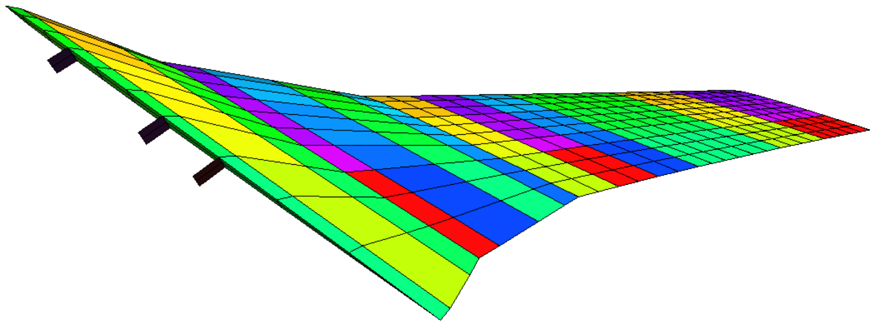
Download the manual:
https://ntrs.nasa.gov/citations/20230001772

Request the software:
https://software.nasa.gov/software/LAR-18704-1





EXPLORE VAB