Agenda

• M4 Structures Studio (M4SS): Overview and Updates
  – (Winter) History, capabilities, recent updates, and future work

• M4SS-SPL
  – (Nascenzi) Sketch Point Layout UI overview and capabilities

• M4SS-Sketch
  – (Nascenzi) Sketch Model UI overview and capabilities

• M4SS UAM Demonstration: Side-by-Side Helicopter
  – (Robinson) Example covering structural modeling and preliminary results
M4SS-Sketch

Thomas Nascenzi

OpenVSP Workshop 2020
• M4SS-SPL
  – Importing OpenVSP Models
  – Sketch Point Layouts
  – Automated Tools
  – Initializing a Sketch Model
• Intermission
• M4SS-Sketch
  – Sketch Model
  – Component Cards
  – Analysis Cards
Overview

• M4SS-SPL
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• M4SS-Sketch
  – Sketch Model
  – Component Cards
  – Analysis Cards
• Every part of the Sketch Model is defined with **Sketch Cards**
The Sketch Cards are used to automatically build bdf files ready for execution within NASTRAN.

Merge cards define how component meshes are merged together.

Analysis cards define various load cases and desired NASTRAN solutions.

Component cards define component level structural and aerodynamic information.
Easy to **add** cards

Easy to **delete** cards

Easy to **modify** cards
• The Model Tree also provides color and icon feedback

- Sketch Card
- Non-card Branch
  - Branch contains an INVALID card
  - Branch contains a NEW card
  - Branch contains only VALID cards

• Invalid card feedback allows for rapid model diagnostics
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Structural cards

- **SKIN4 and SKIN3 cards**
  - Defines outer surface plate elements
- **BEAM and FRAME cards**
  - Defines internal plate or bar elements
- **ATTACHMENT and LDGR cards**
  - Rigidly attached discrete mass
Materials and Properties

- **MTRL cards**
  - Defines an isotropic or orthotropic material

- **PROP cards**
  - Defines an isotropic shell, laminate shell, or isotropic bar property

- **PROPTAG**
  - Tags property regions for weight statement reporting

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**Composite Layup**

- Thickness (in):
  - 0.0101
  - 0.25

- Composition:
  - **PW Glass**
    - 0°/90° ±45°
  - **Aramid honeycomb core**
    - ±45°
  - **PW Glass**
    - 0°/90°
Aerodynamic cards

- **AERO4 and AEROPARAM**
  - Vortex lattice elements and splines
- **CONTROL**
  - Defines a control surface
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ANALYSIS and CASE card

• Defines NASTRAN analysis solution and subcases

• Solution types:
  – Linear Statics
  – Normal Modes
  – Static Aeroelasticity
  – Aeroelastic Flutter
  – Dynamic Aeroelasticity
  – Design Optimization

• Can add from 22 unique cards

Model with 5 ANALYSIS cards and several CASE cards
LOAD cards

- CASEs can have various loads added to them
- LOAD cards can define
  - Point Force
  - Point Moment
  - Surface Pressure
  - Acceleration
  - Flutter
  - Static Aeroelastic
  - Random Gust
Added masses

- **FUEL**
  - Creates a distributed mass, force, or pressure on an enclosed surface region
  - Acceleration and depth sensitive

- **SLUNG**
  - Defines a non-structural weight
• Initialized from M4SS-SPL model
• Provides a simple, card-based framework for creating NASTRAN ready FEM models
• Component cards define structural and aerodynamic properties
  – Surface and internal structural members
  – Lifting surfaces and control surfaces
• Analysis cards define Nastran solution types and load cases
  – 6 different solution types
  – 22 different analysis cards
  – Multiple solution types can be defined
    • Each solution type can contain multiple subcases
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• M4SS UAM Demonstration: Side-by-Side Helicopter
  – (Robinson) Example covering structural modeling and preliminary results
• **UAM Side-by-Side Concept Summary**
  - OpenVSP Model
  - Assumptions
  - Nonstructural Mass
  - Load Cases

• **UAM Side-by-Side Structural Model Development**
  - Component Layouts
  - Component Sketches
  - Detailed FEM Generation

• **UAM Side-by-Side Preliminary Results**

• **Future Work and Conclusions**
• Urban Air Mobility Side-by-Side Helicopter
• Vehicle Sizing Objective: Minimize structural weight subject to preliminary load cases
UAM-SBS: OpenVSP Model

Components Sized:
- Fuselage, Wing Strut

Components Not Sized:
- Horizontal Tail, Windshield

Components Modeled as NSM:
- Landing Gear, Rotor Group
### Material Layup

| Layer     | Plies | Thickness [in] | Ply Angle [deg] |
|-----------|-------|----------------|-----------------|
| UD carbon | 1     | 0.0055         | 0               |
| PW carbon | 3     | 0.0237         | +45             |
| PW carbon | 3     | 0.0237         | 0/90            |
| Core      | 1     | 0.375          | 0               |
| PW carbon | 3     | 0.0237         | 0/90            |
| PW carbon | 3     | 0.0237         | +45             |
| UD carbon | 1     | 0.0055         | 0               |
| Concept Paper          | Aircraft Component | Weight (lbs) [1] | Type            | Location   |
|-----------------------|--------------------|------------------|-----------------|------------|
| Passengers            | Passengers         | 1200             | ATTACHMENT      | Fuselage   |
| Rotor Group (Structure)| Rotor Group R      | 124              | ATTACHMENT      | Wing Strut |
|                       | Rotor Group L      | 124              | ATTACHMENT      | Wing Strut |
|                       | LDGR_F             | 53               | LDGR            | Fuselage   |
|                       | LDGR_B             | 161              | LDGR            | Fuselage   |
| Alighting Gear Group (Structure) | Fuel | 409 | ATTACHMENT | Fuselage |
|                       | Propulsion Misc.   | 283.5            | ATTACHMENT      | Fuselage   |
|                       | Engine L           | 93.5             | ATTACHMENT      | Wing Strut |
|                       | Engine R           | 93.5             | ATTACHMENT      | Wing Strut |
|                       | Engine M           | 93.5             | ATTACHMENT      | Wing Strut |
|                       | Battery            | 101              | ATTACHMENT      | Fuselage   |
| Systems               | Systems            | 508              | ATTACHMENT      | Fuselage   |
| Flight Controls       | Flight Controls    | 98               | ATTACHMENT      | Fuselage   |
| Not Described in Paper| Miscellaneous      | 20               | ATTACHMENT      | Fuselage   |

Total 3362

[1] W. Johnson, C. Silva, and E. Solis, “Concept Vehicles for VTOL Air Taxi Operations,” NASA 2018

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M4 Engineering Proprietary
### UAM-SBS: Load Cases

| Load Case | Loads [g] | Altitude [ft] | $V_x$ [KEAS] | Mass |
|-----------|-----------|---------------|--------------|------|
| Jump      | 2.0       | 0             | 0            | DGW  |
| Landing   | 1.33      | 0             | 0            | DGW  |

2.0g - Jump

1.33g - Landing
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  – Component Layouts
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• UAM Side-by-Side Preliminary Results

• Future Work and Conclusions
M4 Structures Studio Workflow

M4SS-SPL
• Sketch Points
• Automated layouts

M4SS-Sketch
• Structural model definition
• Analysis and load cases

M4SS-FEM
• Component FEM generation

M4SS-Merge
• FEM merging
• FEM trimming

NASTRAN
• Minimize weight subject to load cases

M4SS-Weight
• Comprehensive weight statement
• Component breakdown
UAM-SBS: FEM

9/17/2020

M4SS-SPL → M4SS-Sketch → M4SS-FEM → M4SS-Merge → NASTRAN → M4SS-Weight

M4 Engineering Proprietary
Overview

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UAM-SBS: Preliminary Results

2.0g - Jump

Max/Min Prn Strain
0.004

Max

Min

M4SS-SPL
M4SS-Sketch
M4SS-FEM
M4SS-Merge
NASTRAN
M4SS-Weight

M4 Engineering Proprietary
UAM-SBS: Preliminary Results

1.33g - Landing

Max/Min Prn Strain

0.004

0.00356

0.00311

0.00267

0.00222

0.00178

0.00133

0.00089

0.00044

0
| Published Data [lbs] [1] | M4SS [lbs] | Error (%) |
|-------------------------|------------|-----------|
| Fuselage Structure      | 374        | 400       | 7.0       |
| Fuselage NSM            | 2834       | 2834      | 0.0       |
| Wing Strut Structure    | 131        | 108       | 17.6      |
| Wing Strut NSM          | 529        | 529       | 0.0       |
| Horizontal Tail Structure | 83         | 23*       | 72.3      |
| Horizontal Tail NSM     | -          | -         | -         |
| Total Structure         | 588        | 531       | 9.7       |
| Design Gross Weight     | 3950       | 3893      | 1.4       |

*Horizontal Tail Structure not sized, min. gage assumed

M4SS shows reasonably good agreement with published data
Windshield not sized
Conservative composite layup assumed for fuselage (i.e. could remove some plies)
Wing Strut: Basic structure assumed (i.e. some items not modeled)

[1] W. Johnson, C. Silva, and E. Solis, “Concept Vehicles for VTOL Air Taxi Operations,” NASA 2018
Overview

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• Future Work and Conclusions
Future Work and Conclusions

• Future Work
  – Rotorcraft crashworthiness loads modeling capability
  – Integration with industry standard rotorcraft tools
    • IXGEN
    • RCAS
    • CAMRAD II

• Conclusions
  – Overview of M4 Structures Studio and workflow was given
  – Modeling approach and assumptions for a UAM Side-by-Side concept were reviewed
  – Preliminary results for a UAM Side-by-Side concept were presented
  – Initial results showed reasonably good agreement with published data
  – The UAM concept example will be revisited and refined once the improved loads modeling and integration with rotorcraft software developments are completed
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