“Multidisciplinary Analysis & Optimization Generation 1 and Next Steps”

Presented at the NASA Fundamental Aeronautics Program 2nd Annual Meeting
Atlanta, GA, October 2008

The Multidisciplinary Analysis & Optimization Working Group (MDAO WG) of the Systems Analysis Design & Optimization (SAD&O) discipline in the Fundamental Aeronautics Program’s Subsonic Fixed Wing (SFW) project completed three major milestones during Fiscal Year (FY)08: “Requirements Definition” Milestone (1/31/08); “GEN 1 Integrated Multi-disciplinary Toolset” (Annual Performance Goal) (6/30/08); and “Define Architecture & Interfaces for Next Generation Open Source MDAO Framework” Milestone (9/30/08). Details of all three milestones are explained including documentation available, potential partner collaborations, and next steps in FY09.
Multidisciplinary Analysis & Optimization Generation 1 and Next Steps

Cynthia Gutierrez Naiman
Subsonic Fixed Wing Project
Fundamental Aeronautics Program
2nd Annual Meeting
Atlanta, GA
October 7-9, 2008
### SFW System Level Metrics

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<tr>
<td>Noise</td>
<td>- 32 dB (cum below Stage 4)</td>
<td>- 42 dB (cum below Stage 4)</td>
<td>55 LDN (dB) at average airport boundary</td>
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<tr>
<td>LTO NOx Emissions (below CAEP 6)</td>
<td>-60%</td>
<td>-75%</td>
<td>better than -75%</td>
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<tr>
<td>Performance: Aircraft Fuel Burn</td>
<td>-33%**</td>
<td>-40%**</td>
<td>better than -70%</td>
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<tr>
<td>Performance: Field Length</td>
<td>-33%</td>
<td>-50%</td>
<td>exploit metro-plex* concepts</td>
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** An additional reduction of 10 percent may be possible through improved operational capability

* Concepts that enable optimal use of runways at multiple airports within the metropolitan areas

EIS = Entry Into Service; IOC = Initial Operating Capability

**N+1 Conventional**

**N+2 Hybrid Wing/Body**

**N+3 Generation**
Topic Outline

• Background
• Organization
• Milestones
• Major Accomplishments
• Status & Plans
• Conclusion
Physics Based MDAO

• **National Need: Environment & Economy**
  – Unconventional configurations are essential to further reduce noise and emissions, while increasing performance.
  – PB MDAO is critical in designing & optimizing unconventional vehicles.
  – Industry needs advances in PB MDAO tools to design revolutionary vehicles in a cost-effective way.

• **Benefits include**
  – Enabling of unconventional design
  – Increased confidence in designs
  – Reduced technical risk, time to market, & cost

• **Gaps include**
  – Highly customized (and proprietary) to specific configurations and analysis processes
  – Configuration change necessitates rework
  – Lack of integrated variable fidelity capability
MDAO Working Group Organization

**Fundamental Aeronautics Program Office**
Director: Juan Alonso

**Subsonic Fixed Wing Project**
Principal Investigator: Fay Collier

- **Project Scientist:** Richard Wahls, **Project Manager:** Ruben Del Rosario, **Tech Integrator:** Anna McGowan
- **Acoustics API:** Russell Thomas
- **Aerodynamics API:** Mike Rogers
- **Aeroelasticity API:** Jennifer Heeg
- **Aerothermodynamics API:** Jim Heidmann

**Level 3 Lead**
Steve Smith

**Level 4 Lead**
Craig Nickol

**GEN1 Validation**
Subteam Lead: Haller

**GEN2 HWB**
Subteam Lead: Nickol

**OpenMDAO**
Subteam Lead: Naiman

**Discipline, Systems, & MAO Experts**

**Computer Scientists**

**Support**

**Acoustics**

**Aerodynamics**

**Aeroelasticity**

**Combustion**

**Materials & Structures**

**Aerothermodynamics**

**Controls & Dynamics**

**SAD&O**

**MDAO Integrated Discipline Group Lead:** Dean Kontinos

**Supersonic Project API:** Lori Ozoroski

**SAD&O TWG**
### MDAO Milestones

<table>
<thead>
<tr>
<th>Title</th>
<th>End Date</th>
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<tbody>
<tr>
<td>Define Requirements for Integrated Design/Analysis Environment</td>
<td>1/2008</td>
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</table>

- Requirements defined applicable to all milestones
## MDAO Milestones

<table>
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<tr>
<th>Title</th>
<th>End Date</th>
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</thead>
<tbody>
<tr>
<td>Define Requirements for Integrated Design/Analysis Environment</td>
<td>1/2008</td>
</tr>
<tr>
<td>Complete GEN 1 Integrated Multi-disciplinary Toolset</td>
<td>6/2008</td>
</tr>
<tr>
<td>GEN 1 Validation of Integrated Tool Set w/Experimental Data</td>
<td>12/2008</td>
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</table>

- **Requirements defined applicable to all milestones**
- **GEN1 milestones**
### MDAO Milestones

<table>
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<tr>
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<tr>
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<td>6/2008</td>
</tr>
<tr>
<td>GEN 1 Validation of Integrated Tool Set w/Experimental Data</td>
<td>12/2008</td>
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<tr>
<td>Complete GEN 2 Integrated Multi-disciplinary Toolset</td>
<td>6/2010</td>
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<tr>
<td>GEN 2 Validation of Integrated Tool Set w/Experimental Data</td>
<td>12/2010</td>
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</table>

- **Requirements defined applicable to all milestones**
- **GEN1 milestones**
- **GEN2 milestones**
### MDAO Milestones

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<thead>
<tr>
<th>Title</th>
<th>End Date</th>
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<tr>
<td>Define Requirements for Integrated Design/Analysis Environment</td>
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<tr>
<td>Complete GEN 1 Integrated Multi-disciplinary Toolset</td>
<td>6/2008</td>
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<tr>
<td>Define Architecture &amp; Interfaces for Next Generation Open Source MDAO Framework</td>
<td>9/2008</td>
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<tr>
<td>GEN 1 Validation of Integrated Tool Set w/Experimental Data</td>
<td>12/2008</td>
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<tr>
<td>Complete GEN 2 Integrated Multi-disciplinary Toolset</td>
<td>6/2010</td>
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<tr>
<td>Complete Alpha Release of Next Generation Open Source MDAO Framework</td>
<td>9/2010</td>
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<td>GEN 2 Validation of Integrated Tool Set w/Experimental Data</td>
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<tr>
<td>Demonstrate Next Generation Open Source MDAO Framework</td>
<td>9/2012</td>
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- **Requirements defined applicable to all milestones**: Red
- **GEN1 milestones**: Magenta
- **GEN2 milestones**: Blue
- **Open Source milestones**: Cyan
FY08 Major Accomplishments

• Met “Requirements Definition” Milestone (1/31/08)
  – Completed:
    • Vision & Scope Document
    • Use Case Document
    • Software Requirements Specification (424 functional & 23 non-functional)
    • Glossary
    • Requirements Prioritization

• GEN1
  – Met “GEN 1 Integrated Multi-disciplinary Toolset” (Annual Performance Goal) (6/30/08)
    • Completed Improvements to Codes & Integration Techniques: stability and control, noise, medium-fidelity aero prediction, high-lift aero prediction, and aircraft synthesis
    • Verified Improvements Using Demonstration Cases: Ultra High Bypass Engine, DC9 Drag Polar, Supersonic Business Jet/Mixed Flow Turbofan
  – Completed GEN 1 Integrated Multi-disciplinary Toolset SFW.01.01.009 Milestone Report (6/30/08)
  – Hosted GEN1 Review Day (7/29/08)
  – Defined validation plan (conventional configuration)

• GEN2
  – Defined validation plan (conventional & unconventional configurations)

• OpenMDAO
  – Met “Define Architecture & Interfaces for Next Generation Open Source MDAO Framework” Milestone (9/30/08)
  – Completed Next Generation Open Source MDAO Framework Architecture Document (9/30/08)
Decision Point: Parallel Path Approach

2008 Near Term Solutions 2010 Far Term Solutions 2012 & beyond

GEN 1 Toolset Development

Near Term Path: Continue to use & improve currently available frameworks to meet near-term milestones (GEN2)

MDAO Requirements Definition

Far Term Path: Develop open source framework as start of long-term solution (Alpha)

Far Term Path: Next Generation Open Source MDAO Framework (OpenMDAO)
A framework is only as good as its components

- Open source $\rightarrow$ more users
- More users $\rightarrow$ more component developers
- More component developers $\rightarrow$ more components
- More components $\rightarrow$ more functionality for users

- We can maximize the number of available components by making it easy to package a component and publish it on the web

- Easier collaboration
  - No need to pay a price per seat to purchase the framework
  - Minimal red tape; just download it, install it, and go

- Transparency -- Source code can be viewed by users
  - Researchers can see the algorithms
  - Many eyes find many bugs
Government Interest In Open Source Distribution

• NASA *(Outreach, Tech Transfer, Contributions back to NASA)*
  – NASA’s Motivation for Open Source software distribution:
    • To increase NASA software quality via community peer review
    • To accelerate software development via community contributions
    • To maximize the awareness and impact of NASA research
    • To increase dissemination of NASA software in support of NASA's education mission
  – “Developing An Open Source Option for NASA Software” by Moran, TR NAS-03-009
  – NASA Open Source Agreement (NOSA)

• DoD
• **GEN1**
  – Prepare model to validate GEN1 (due 12/08)

• **GEN2**
  – Identify specific codes & integration improvements needed for HWB configuration

• **OpenMDAO:** OS framework does not require that components be OS
  – Pursue potential collaboration in OS MDAO community
  – Identify & define verification/validation test cases
  – Continue prototyping using python
  – Set up development environment & begin implementation
  – Follow process to classify framework as open source & publicly available
  – Follow up with industry, academia, & other government agencies

• **Leverage NRA & SBIR MDAO efforts**
Conclusion

• Completed 3 major milestones in FY08

• On schedule to meet future milestones

• 2-Path approach benefits near- and long-term needs

• Partnering with industry, academia, and other government agencies is essential to realize MDAO vision
# Data on Requirements Development

### Requirements Inspections

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Fundamental Aeronautics Program
Subsonic Fixed Wing Project
### MDAO Framework Requirements

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GEN 1 MDAO Framework Schematic

- Dark blue boxes indicate new capabilities over the GEN 0 Framework
- Red outline boxes identify tools discussed in further detail in GEN1 Milestone Report
- Solid arrows – integrated    Dashed arrows – not integrated yet
Top level context diagram
Class diagram of most important classes, followed by descriptions of each class
Sequence diagrams covering important areas, such as component execution and component creation
A list of interfaces for system plug-ins (IComponent, IDriver, ICaselIterator, IResourceAllocator,...)
Important design decisions and reasoning behind them
Deployment diagram for component publishing/downloading via egg servers
Deployment diagram for a distributed model execution