“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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<td>LTO NOx Emissions (below CAEP 6)</td>
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<td>better than -75%</td>
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<tr>
<td>Performance: Aircraft Fuel Burn</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+1 Conventional](image1.png)

### N+2 Hybrid Wing/Body
![N+2 Hybrid Wing/Body](image2.png)

### N+3 Generation
![N+3 Generation](image3.png)
• 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, Combustion API: Dan Bulzan
Aerodynamics API: Mike Rogers, Controls & Dynamics API: Diana Acosta
Aeroelasticity API: Jennifer Heeg, Materials & Structures API: Karen Taminger
Aerothermodynamics API: Jim Heidmann, SAD&O API: Bill Haller

MDAO Working Group

Level 3 Lead
Steve Smith

Software Development Lead
Cynthia Naiman

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
Aerothermodynamics
Aerodynamics
Combustion
Aeroelasticity
Materials & Structures

Software Testing
Software Configuration Management
Technical Writing
System Administration

MDAO Integrated Discipline Group
Lead: Dean Kontinos

SAD&O TWG
### MDAO Milestones

<table>
<thead>
<tr>
<th>Title</th>
<th>End Date</th>
</tr>
</thead>
<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>
<thead>
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<th>End Date</th>
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<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>
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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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</table>

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

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<th>Title</th>
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<tr>
<td>Define Requirements for Integrated Design/Analysis Environment</td>
<td>1/2008</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>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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<td>GEN 2 Validation of Integrated Tool Set w/Experimental Data</td>
<td>12/2010</td>
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- **Requirements defined applicable to all milestones**
- **GEN1 milestones**
- **GEN2 milestones**
## MDAO Milestones

<table>
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<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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<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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<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>
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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>
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- **Red**: Requirements defined applicable to all milestones
- **GEN1 milestones**: GEN1 milestones
- **GEN2 milestones**: GEN2 milestones
- **Open Source milestones**: Open Source milestones
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
  - 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)**
**Near Term Path:**
Continue to use & improve currently available frameworks to meet near-term milestones (GEN2)

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

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**GEN 1 Toolset Development**

**MDAO Requirements Definition**

**Far Term Path:**
Next Generation Open Source MDAO Framework (OpenMDAO)
Why Open Source? Components & Collaboration

A framework is only as good as its components

- Open source → more users
- More users → more component developers
- More component developers → more components
- More components → 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
## Priorities for Functional Requirements

### 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
OpenMDAO Architecture Document

- 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, ICaselteerator, IResourceAllocator,...)
- Important design decisions and reasoning behind them
- Deployment diagram for component publishing/downloading via egg servers
- Deployment diagram for a distributed model execution