Multidisciplinary Optimization Branch* Experience Using iSIGHT Software

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*For more information: http://fmad-www.larc.nasa.gov/mdob/MDOB/

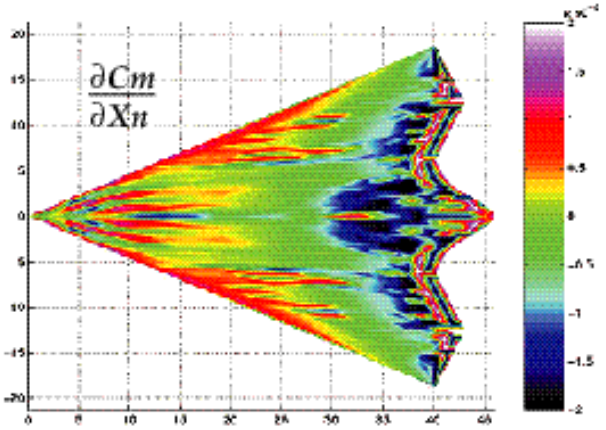
Outline

- Overview of MDO Branch research
- Experience gained using iSIGHT on three projects:
  - Reusable launch vehicle (RLV) sizing
  - Aerospike nozzle design
  - Low-noise rotorcraft trajectories
- Summary of iSIGHT contributions to research
- Wish list based on experience

MultiDisciplinary Optimization Branch

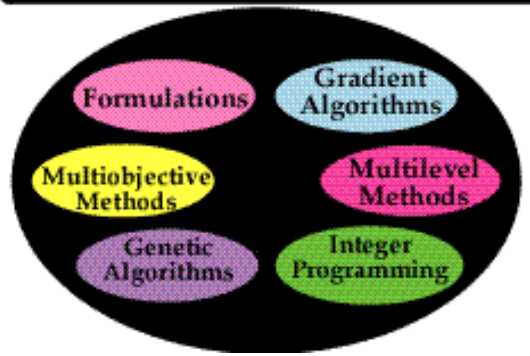
MD Integration
Geometry Models
Integration Methods

Design-Oriented Analysis
Approximations
Sensitivity



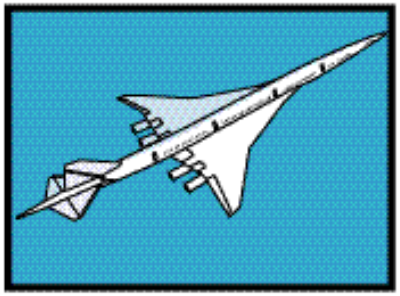
Charter
Develop MDO methods to increase design confidence and to cut development time

MD Optimization
Problem Decompositions
Solution Algorithms

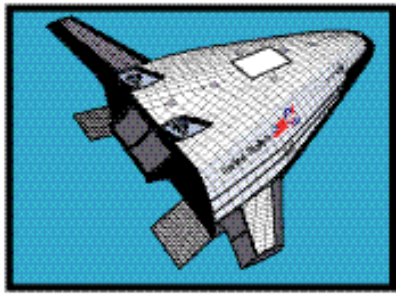


High-Fidelity Applications

Aeronautics



Space



Previous Experience with Optimization Frameworks including iSIGHT 3.1

Weston, R. P.; Townsend, J. C.; Eidson, T. M.; and Gates, R. L.: A Distributed Computing Environment for Multidisciplinary Design. *Proceedings of the 5th AIAA Symp on Multidisciplinary Analysis and Optimization*, 1994, vol 2, pp. 1091–1097.

Salas, A. O.; and Townsend, J. C.: Framework Requirements for MDO Application Development. *Proceedings of the 7th AIAA Symp on Multidisciplinary Analysis and Optimization*, 1998, vol 1, pp. 261–271.

Alexandrov, Natalia M.; and Kodiyalam, Srinivas: Initial Results of an MDO Method Evaluation Study. *Proceedings of the 7th AIAA Symp on Multidisciplinary Analysis and Optimization*, 1998, vol 2, pp. 1315–1327.

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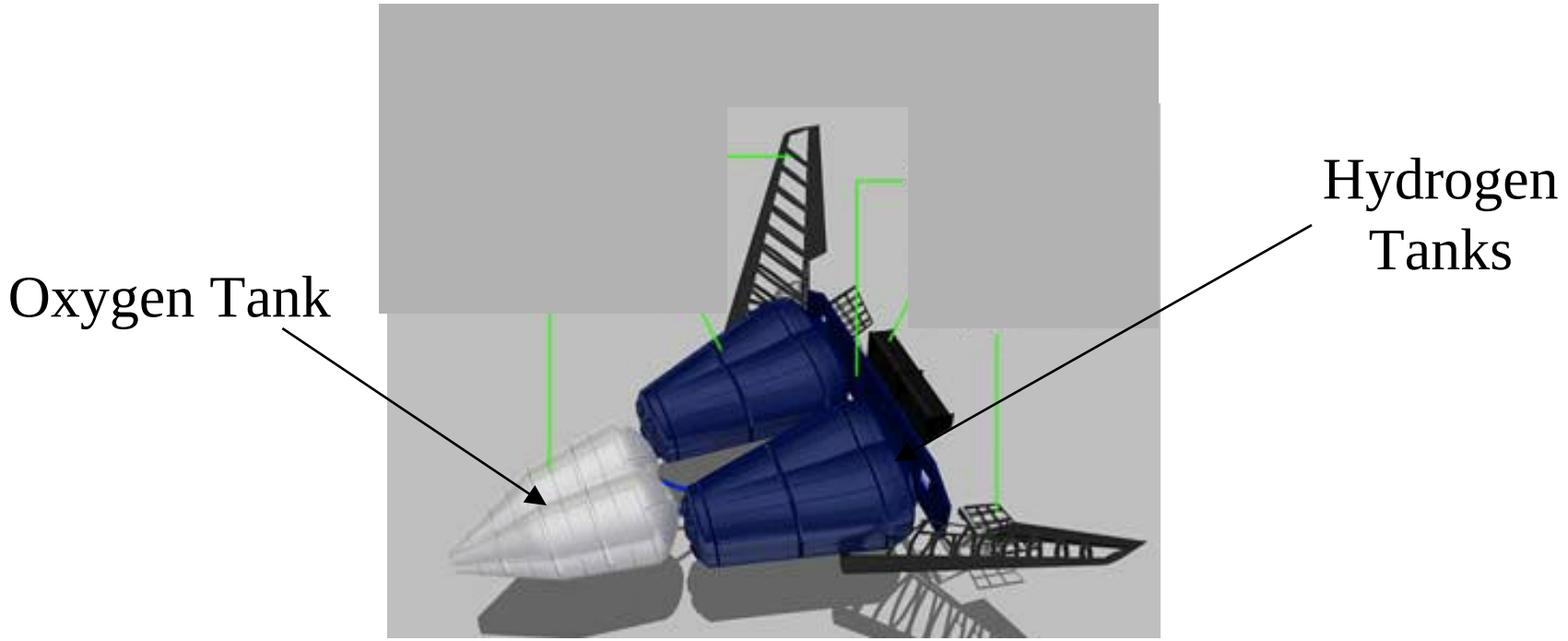
MDO Example #1 RLV Sizing Problem

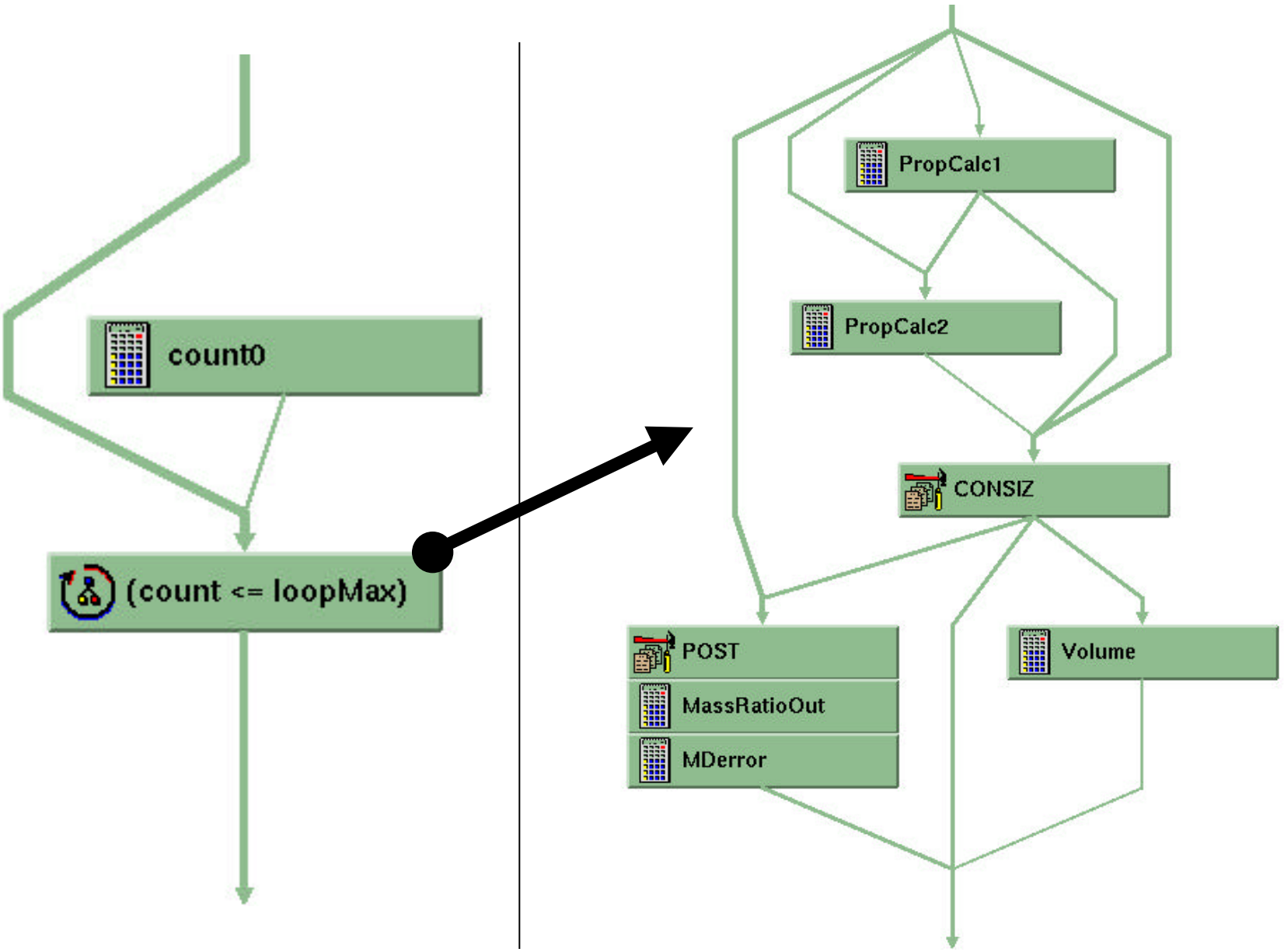
- 1st Design Variable: Propellant Mass Fraction
  - Determines volume of Liquid Oxygen tank
  - Determines volume of Liquid Hydrogen tank
- 2nd Design Variable: Engine Thrust-to-Vehicle Weight Ratio
  - Determines engine size



RLV Sizing Problem in iSIGHT

- Use CONMIN optimization method in iSIGHT
  - Minimize Gross Lift-off Weight
    - 2 design variables
    - 1 constraint on payload weight
- Use two disciplinary codes
  - CONSIZ - Given payload weight, calculate vehicle weight
  - POST - Find trajectory to maximize payload weight into orbit
  - Iterate to find consistent payload weight

Iterative Task in farSIGHT



Lessons Learned

- Integrating CONSIZ and POST into iSIGHT was easy.
- Completing multidisciplinary optimization was not easy:
  - Conditional “WHILE” loops not available.
  - Adequate number of iterations must be determined.
  - A “warm start” for POST provided by UNIX scripts for now.
- Using farSIGHT and overSIGHT displays improved communication with our launch vehicle design experts.
- Optimizing the RLV for a full payload was successful.
- The iSIGHT design had essentially the same vehicle size as designs found by manual “cut and try” methods.

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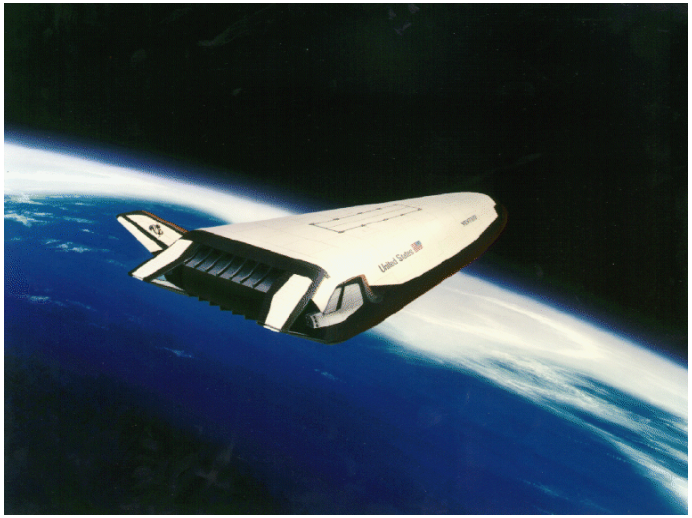
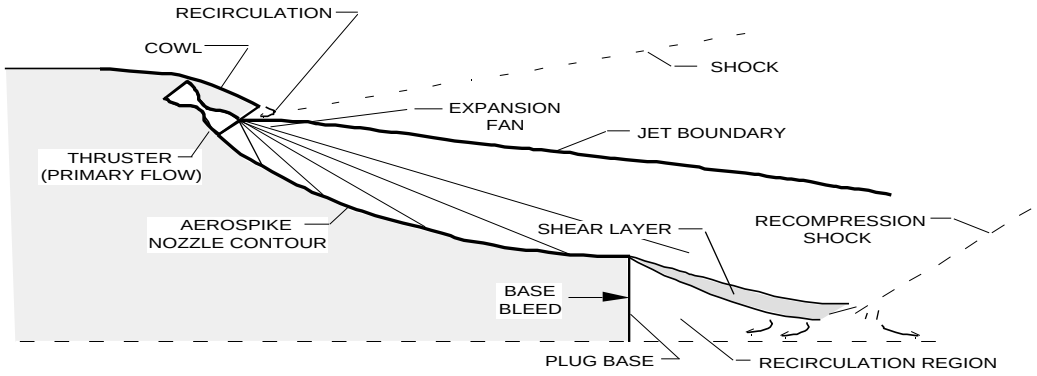
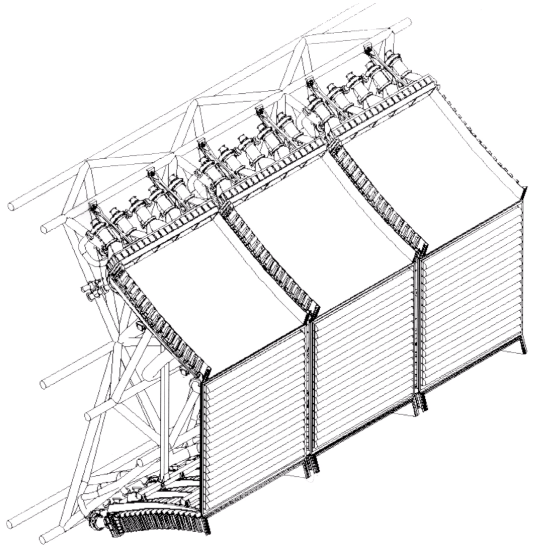
RLV Concept



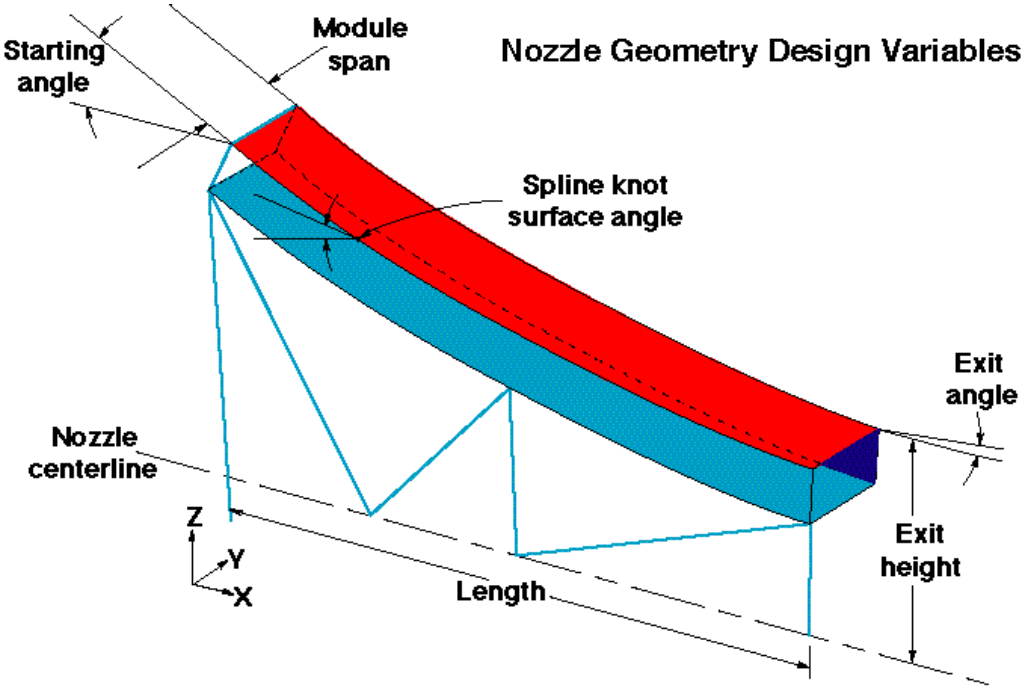
CFD & Structural Analysis



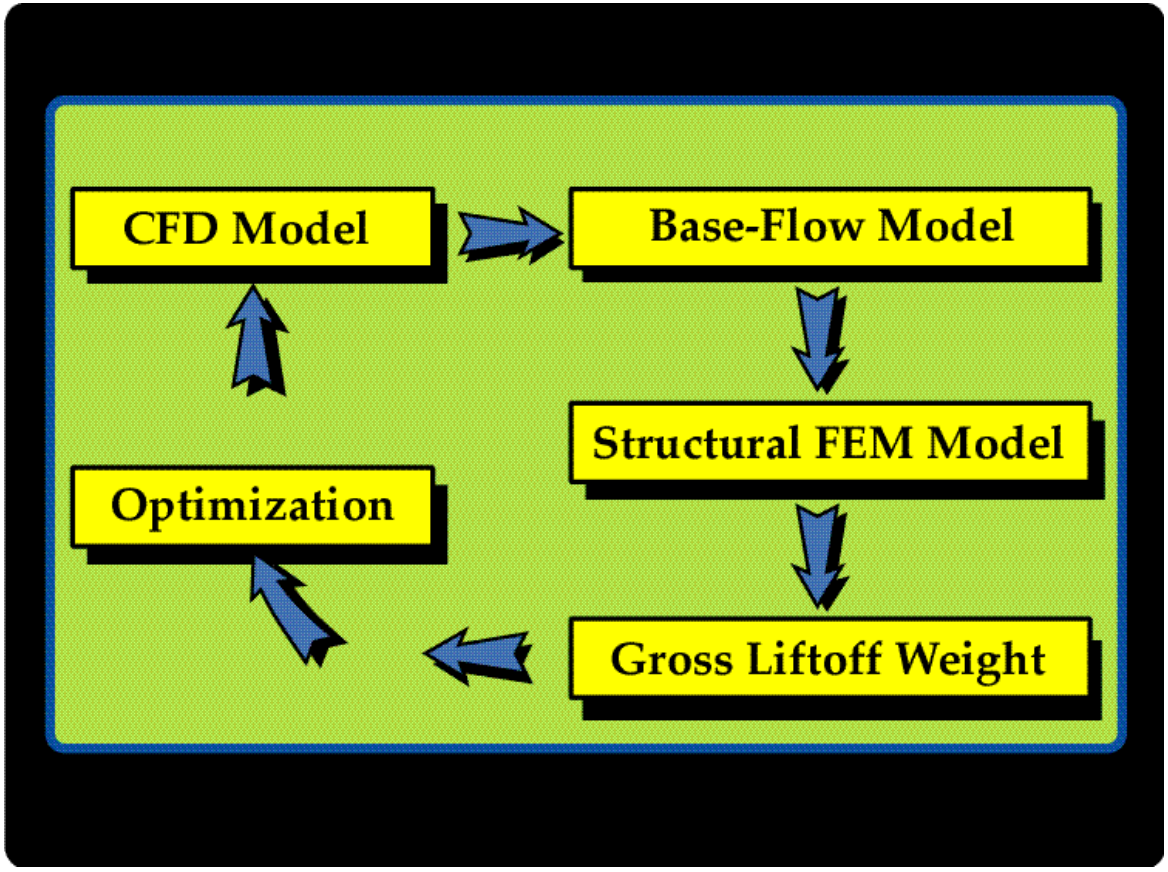
Aerospike Nozzle



Multidisciplinary Design Variables

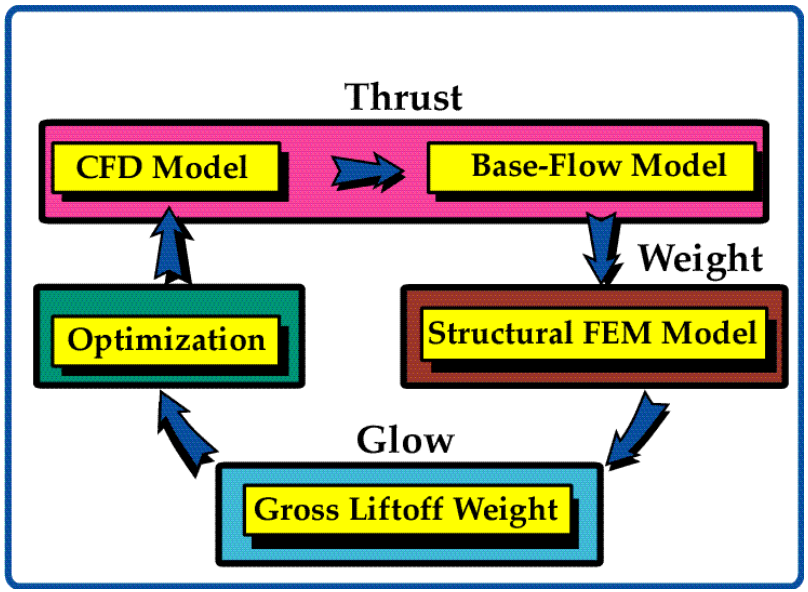


Aerospike Nozzle Optimization for Minimum Gross Lift-off Weight



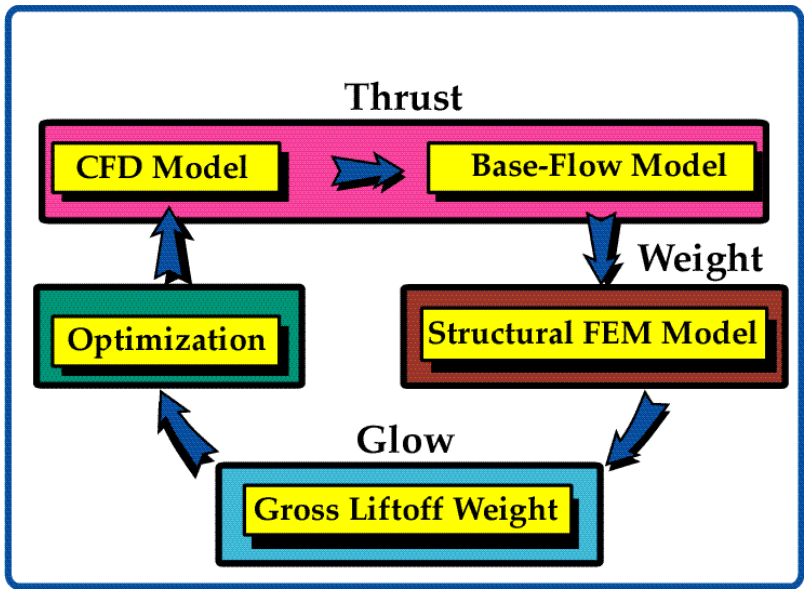
Aerospike Optimization in iSIGHT

- iSIGHT tasks *Thrust*, *Weight* and *Glow* are created and saved as components
- A top level task, *Aerospike*, assembles *Thrust*, *Weight*, *Glow* components
- *Thrust* task uses CONMIN to maximize thrust. Results are checked against previous non-iSIGHT optimization results.
- *Weight* task is currently being tested



Assessment of iSIGHT Interface to NASTRAN

- Input limitations
  - 80-char NASTRAN records
  - Single precision input only
- Output limitations
  - One eigenvalue problem only
  - No calculated responses (e.g., no DEQATN allowed)
  - Ten responses per region
- Other concerns
  - Interfacing NASTRAN with other simulation codes
  - Using NASTRAN sensitivities



Alternative iSIGHT Implementation including NASTRAN

- Execute NASTRAN as any other iSIGHT simcode
- Use finite difference approximations for all sensitivities
- Concerns
  - NASTRAN text output files are very large
  - Parsing NASTRAN output may be inefficient
  - Number of structural responses and constraints may be too large for overSIGHT and foreSIGHT

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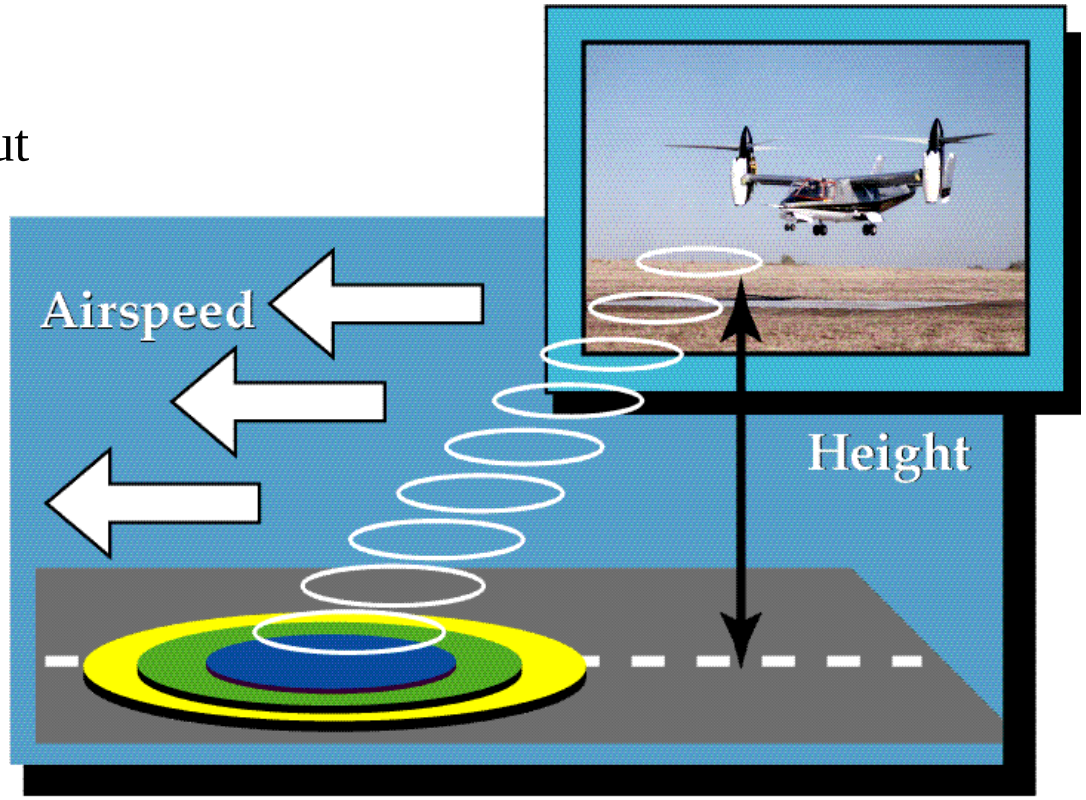
MDO Example #3
Low-Noise Trajectories

Request from Rotorcraft Manager

- One week time limit
- Executable with sample input and output files provided
- Code is “black box”
- MDOB should recommend:
  - Problem formulation
  - Optimization method
  - Approximation needed
  - Testing methods



MDO Branch Approach to Tiltrotor Trajectory Optimization

- Use iSIGHT framework
- Select five design variables for initial testing
- Minimize noise at three locations due to XV-15 landing
- Use off-the-shelf Rotorcraft Noise Model (RNM) code
- Potential design variables are airspeed, nacelle angle and initial height for each segment of landing trajectory
- Predict noise contours for initial and final designs

Lessons Learned

- Approximation tools can overcome non-smooth and nonexistent RNM analysis results
- iSIGHT allows optimization experts to develop tools for disciplinary experts to use
- Prototypes are ready in days rather than weeks
- Rapid availability of results using the iSIGHT tools generates interest in MDO and provides a path from simplified applications to new research areas

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Overview of Examples

Example # and name	# of simulation codes	# of design variables	# of constraints	estimated analysis time
1. Reusable Launch Vehicle	2	2	1	90 min.
2. Aerospike Nozzle	4	18	564	1.5 min
3. Low-Noise Trajectory	1	5	7	1 sec.

Initial Assessment of iSIGHT

- Pro
  - Provides method for connecting analysis components
  - Visually monitors progress and builds historical database
  - Tests possible choices of design variable/optimizer/approximation
  - Documents optimization process using MDOL description file
- Con
  - Requires significant investment for training and software licenses
  - Incurs computational overhead due to parsing large I/O files
  - Fails to process large number of design variables and constraints with current GUI
- Undetermined
  - Facilitates structural analysis using NASTRAN

Suggested Improvements to iSIGHT

- Reconsider implementation of NASTRAN interface
- Provide better tools for integrating several disciplinary analysis codes:
  - Provide advanced flow control (e.g. conditional WHILE)
  - Allow codes with input and output files but no iSIGHT parameters
  - Implement branching based on error messages or status codes
- Improve overSIGHT tools so that a subset of parameters can be collected during optimization process
- Include diagnostic messages for inexperienced users as well experienced developers.

Summary

- MDO Branch is using iSIGHT for
  - Developing and testing new MDO methods
  - Applying MDO methods to aerospace vehicles
  - Consulting with other NASA organizations and contractors
- iSIGHT increases customer satisfaction
  - Prototype is ready quickly
  - GUI and data visualization aid in team communication
  - Complex analysis tasks are enabled and documented
- iSIGHT version 4.0 is much better than previous versions but still may be inadequate for large MDO applications