

U.S. AIR FORCE





Project Gemini

Towards Gradient-Based Optimization Using Measures of Effectiveness

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Towards Gradient-Based EBD

- What is Effectiveness-Based Design (EBD)?
- Past/Current Contracted Research efforts
- Gemini (AFRL)
 - Methods
 - OpenMDAO application
 - Challenges
 - Lessons



Notional EXPEDITE vehicle (Lockheed Martin)



What is Effectiveness-Based Design (EBD)?





Definitions

Measures of Performance (MoP): metric quantifying vehicle performance

e.g., speed, MTOW, range

Measures of Effectiveness (MoE): metric quantifying the effectiveness of a vehicle/system to fulfill a mission

e.g., seat-mile-cost, ID/\$



NASA CRM









EBD Research Efforts



EBD Research Efforts







OPTIMUS (concluded) EXPEDITE (active, until Dec 2022)

EQUATE (active)

• Subsystems

- Mission effectiveness
- Subsystem modeling
- Manufacturing

- Mission effectiveness
- Uncertainty Quantification





EXPanded MDO for Effectiveness-based DesIgn Technologies

Demonstrated

- Subsystem modeling
- Mission analysis (determining MoE)
- Business-to-Business (B2B) MDO integration
- Manufacturing constraints in conceptual design

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Gemini

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Top Speed	-
Cornering Speed	
Downforce	++

Top Speed	++
Cornering Speed	+
Downforce	

Top Speed	++
Cornering Speed	++
Downforce	-



Mission Analysis Frameworks



AFRL

AGI/Ansys

NASA



- Mission simulation framework
- Multi-domain
- Varying levels of mover fidelity
- Modeling of sensors (and subsystems)
- Gov. controlled source code
- Modular
- Used widely by gov. and industry





ROAM mover plugin

- Reduced Order Air Mover
- 2.5 DOF mover model
- AFSIM plugin developed from ROAVS (RQVC/PCKA)
- Includes GNC for waypoint charting

Mover model

- weights
- 5-column engine deck
- Aerodynamic polar information
 - $C_{L\propto}, C_{L0}$
 - C_{D0} , k_{drag} , $C_{L0,d}$







AFSIM/ROAM OpenMDAO wrapper (Castor)



Finite differencing will result in a large number of function evaluations.



Mission description

- Notional mission over continental U.S.
- Only search pattern modeled
 - Ingress, egress calculated through Breguet range
- Search pattern for points of interest
 - Count number found
 - Discrete metric not suited to gradient-based optimization
 - Need a continuous metric







Optimization statement

 $max(t_{target})$

w.r.t.:

 $x = [span \ \lambda \ c_{root}]^T$

subject to:

$$m_{fuel,startloiter} - m_{fuel,return} > 0$$

 $m_{fuel,end} > 0$ Ensure AFSIM completion

Genetic Algorithm: population size 10, 20 generations

Runtime between 4:30 and 6:00 hours



AFSIM execution required hardening for use in optimization problems.



Optimization results



wing planform



Concluding Remarks

- Optimizing effectiveness (EBD) is a necessity
- EBD requires mission/operational analysis tools that were not designed for gradient-based optimization
- AFRL/RQVC has been able to
 - automate AFSIM execution
 - conduct gradient-free optimization
- Ongoing research into gradient-based optimizations
- OpenMDAO has enabled quick prototyping
- Additional work required for industrial scale applications







Questions

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