SYSTEMS ENGINEERING RESEARCH CENTER

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Efficient Multidisciplinary System Design Optimization at the Mission Level

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By
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7th Annual SERC Doctoral Students Forum
November 18, 2019
FHI 360 CONFERENCE CENTER
1825 Connecticut Avenue NW, 8th Floor
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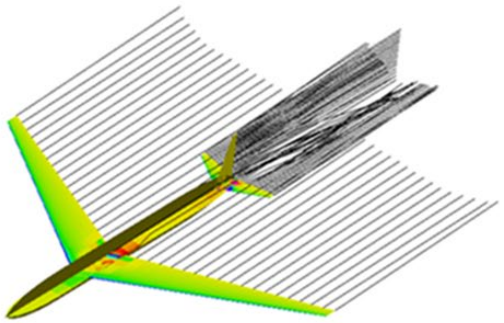
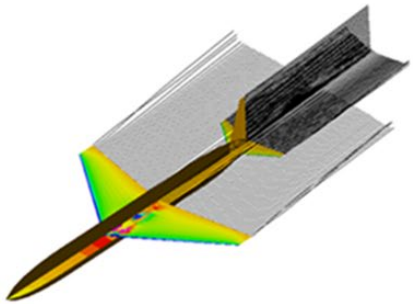
www.sercuarc.org

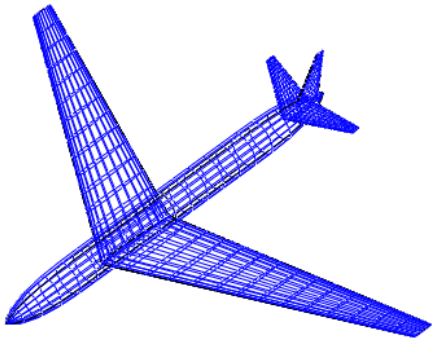
Presentation Overview

- Introduction
- Current projects
  - Multidisciplinary design optimization (MDO) architectures
  - Multifidelity optimization (MFO)
  - Mission-level optimization (MLO)
- Future research

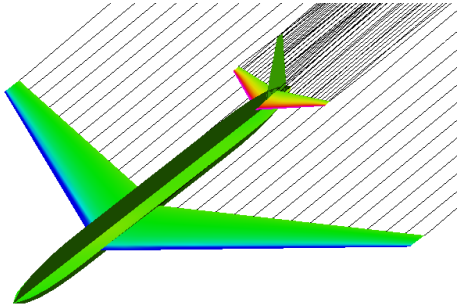




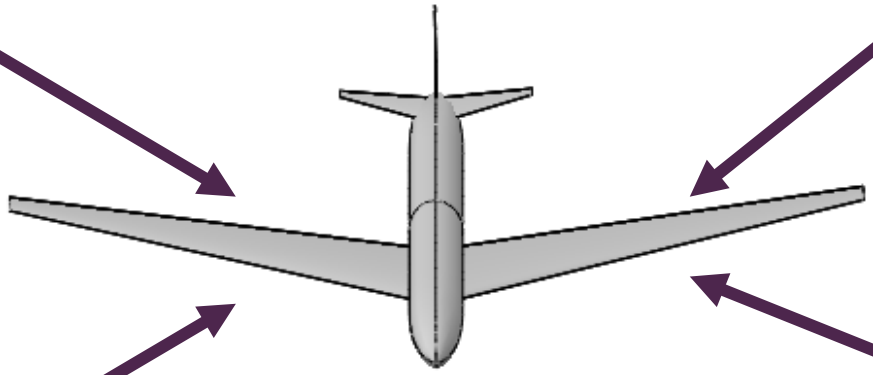
MDO Introduction



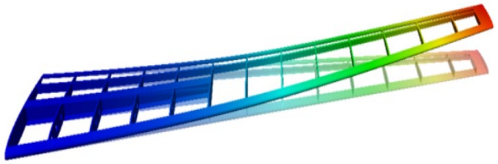
Geometry



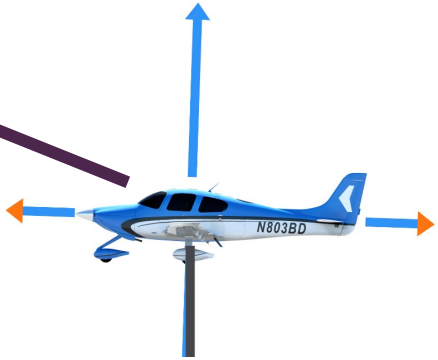
Aerodynamics



System Model



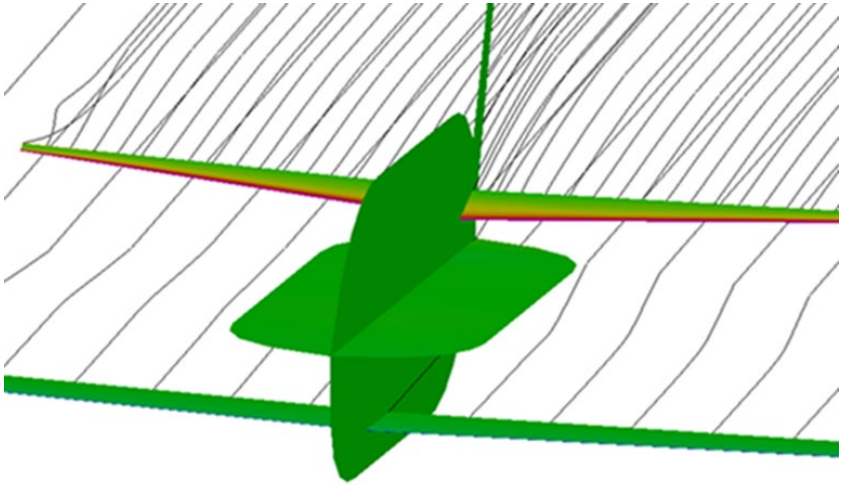
Structural Analysis



Performance

Research Introduction

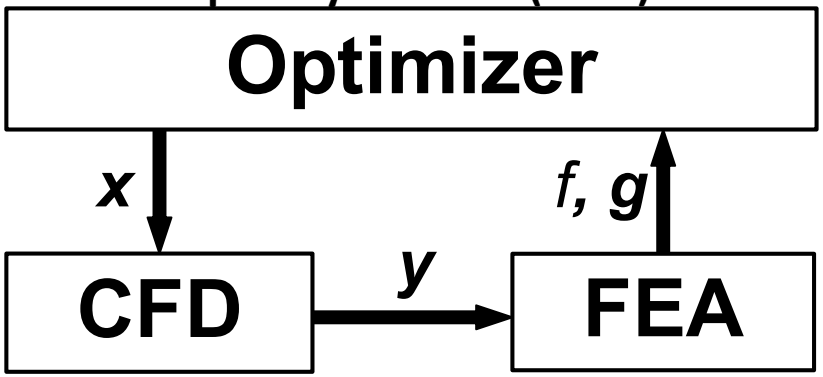
- Optimizing complex system models is computationally expensive
- Efficiency can be improved with the right MDO architecture and/or MFO method
- Optimizing for mission success, rather than system performance, may better align with stakeholder needs



MDO Architectures

MDO problems can be formulated in different ways;
this work compares two common architectures

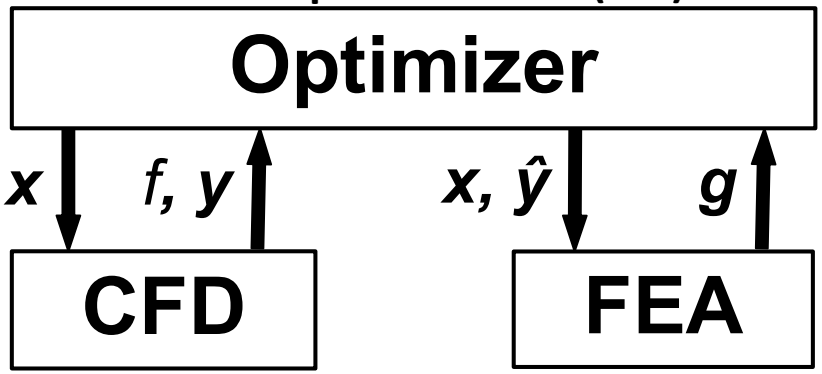
Multidisciplinary Feasible (MDF)



$$\min_{\mathbf{x}} \quad f$$

$$\text{s.t.} \quad \mathbf{g} \leq 0$$

Individual Discipline Feasible (IDF)



$$\min_{\mathbf{x}} \quad f$$

$$\text{s.t.} \quad \mathbf{g} \leq 0$$

$$\mathbf{y} - \hat{\mathbf{y}} = 0$$

MDO Architectures Results

- Architectures optimized 15 times using surrogate-based algorithm
- MDF finds better optima but takes more time – confirming predictions found in the literature
- MDF has a more straightforward set up
- IDF can take advantage of parallel processing and may be more suitable for siloed work structures
- IDF coupling constraints can hinder algorithm convergence

MDF

	Optimum (mi)	Time Elapsed (hr)	Run Time (min/run)
Avg.	9514.6	13.32	1.87
St. Dev	442.3	8.63	0.14

IDF

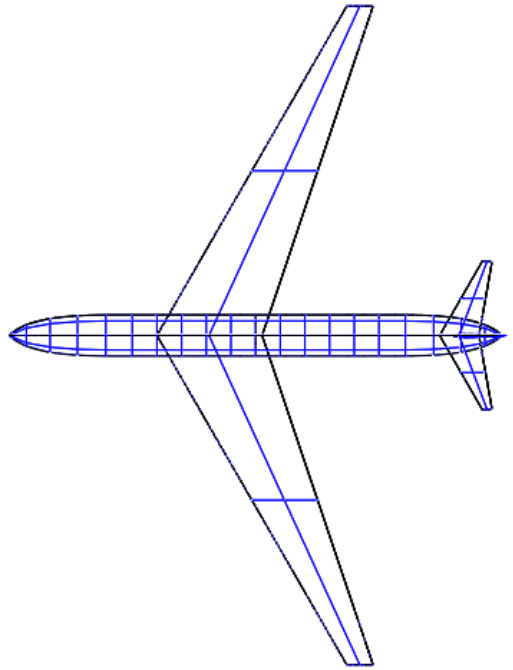
	Optimum (mi)	Time Elapsed (hr)	Run Time (min/run)
Avg.	9122.2	8.80	1.47
St. Dev	427.8	2.97	0.16

Chell, B., Hoffenson, S., and Blackburn, M.R. (2019) "A comparison of multidisciplinary design optimization architectures with an aircraft case study," *AIAA Scitech 2019 Forum,* San Diego, California, January 7-11.

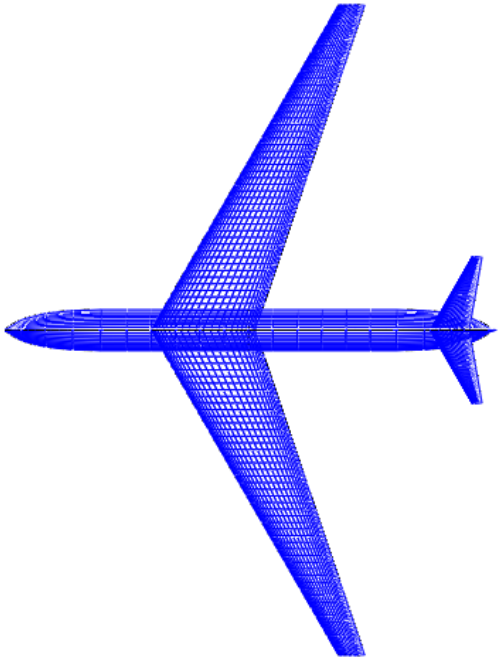
Multifidelity Optimization

Low-fidelity Model
Faster run time, less accurate results

High-fidelity Model
Slower run time, results accurate enough for application

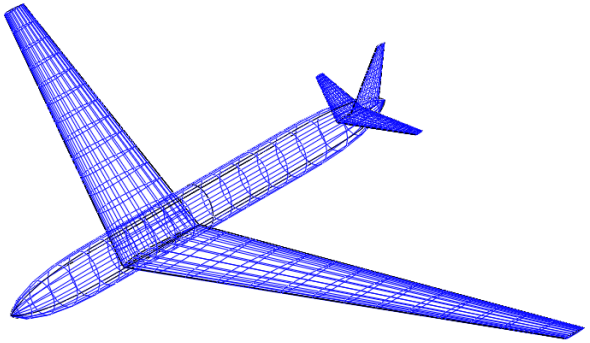


MFO:
Accurate enough results, significant time savings



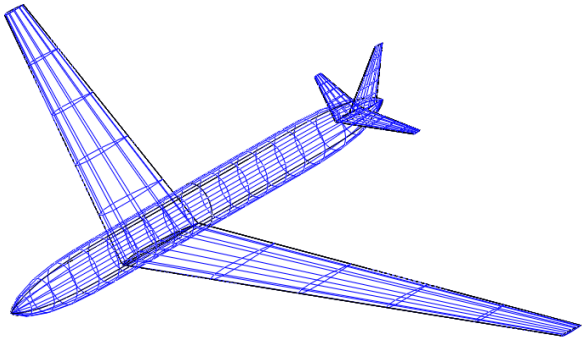
Models used in MFO Study

- Simplified models
- Projection-based models
- Surrogate models
- Experimental data



High fidelity model

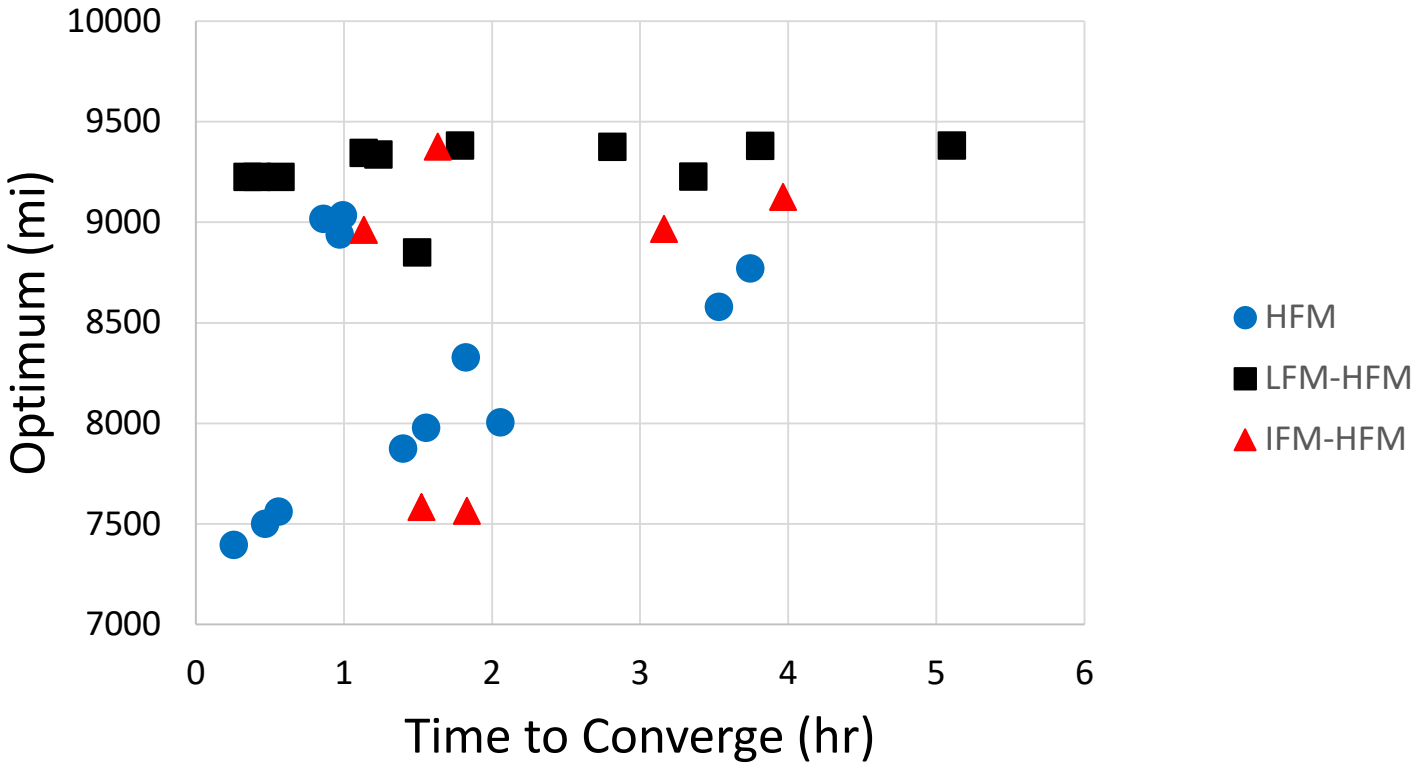
This project uses a coarsened mesh and a surrogate model for the two lower-fidelity models



Intermediate fidelity model

Multifidelity Optimization Results

- Multifidelity model management strategy did not save time
- Time and effort to create MFO routines needs to be considered



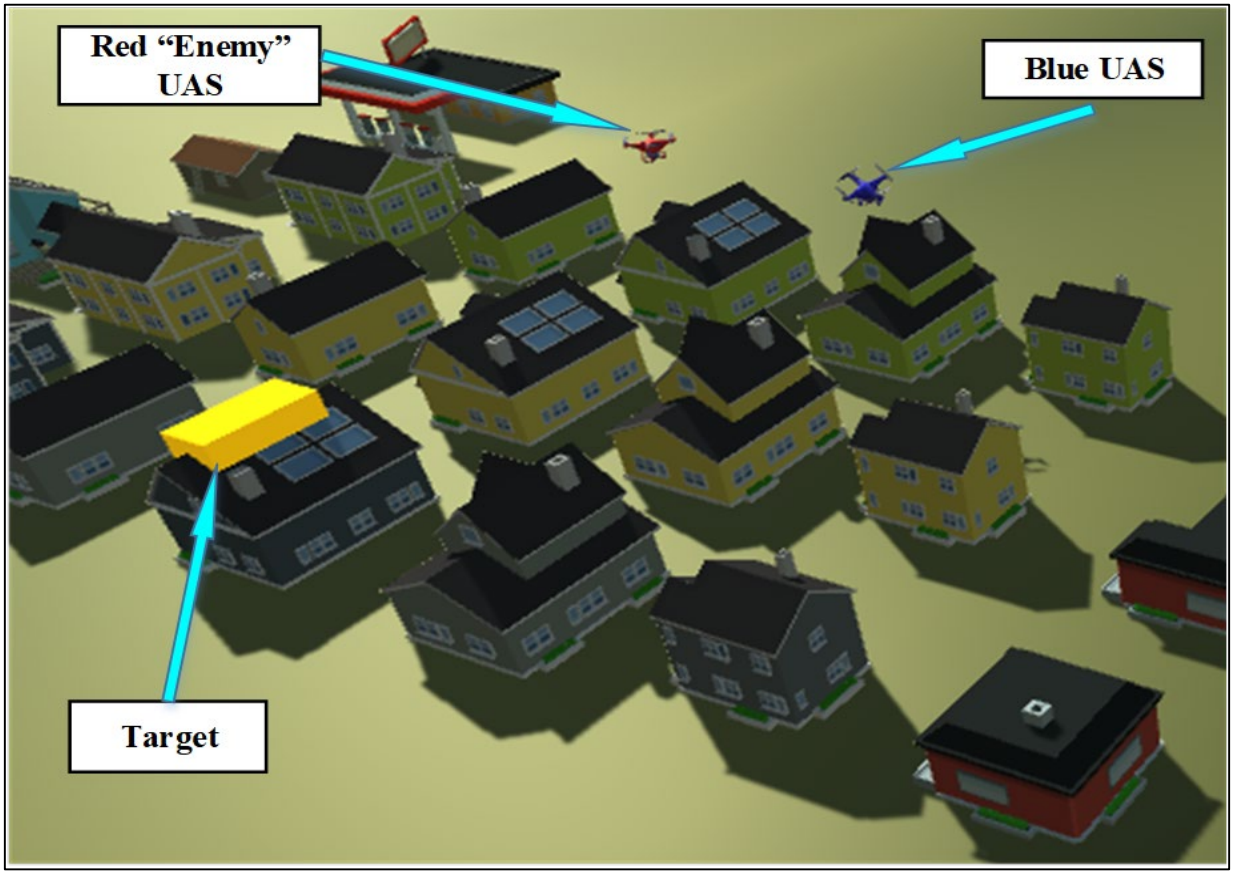
Chell, B., Hoffenson, S., and Blackburn, M.R. (2019) "Comparing multifidelity model management strategies for multidisciplinary design optimization," *ASME 2019 International Design Engineering Technical Conferences,* Anaheim, California, August 18-21.

Mission-Level Optmization

- MLO is an alternative to system-level optimization
- Can leverage mission scenario simulations to improve communication with key stakeholders
- MLO combines several challenging aspects of optimization

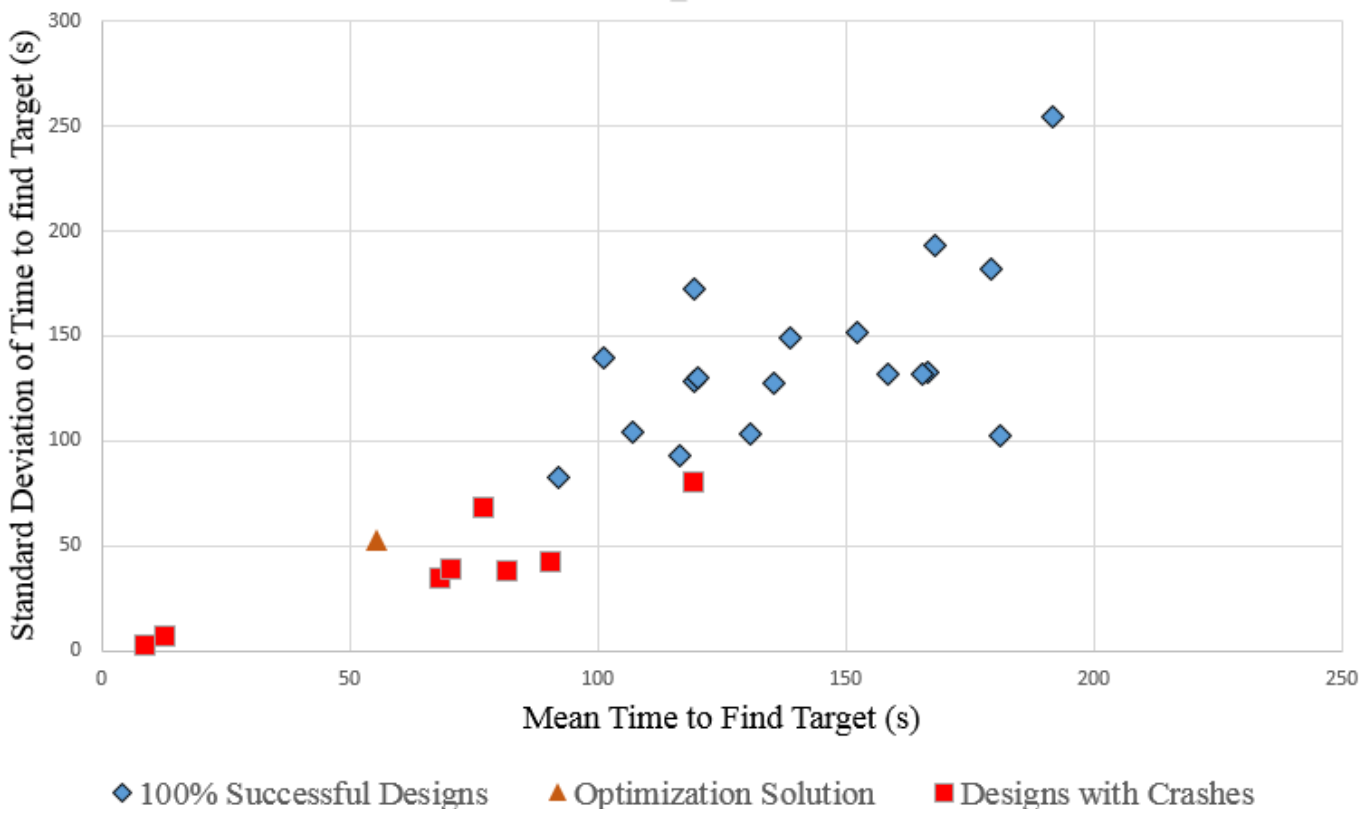
Mission-Level Optimization Research Methodology

- Highly stochastic UAS/counter-UAS search mission
- Sampled using definitive screening design and created surrogate models for mission success and two “intermediate” variables



Mission-level Optimization Results

- Solution improved over other designs with no crashes
- Intermediate variables provide opportunities and difficulties
- Capability to run simulation faster than real time is important



Chell, B., Hoffenson, S., Ray, D., Jones,. R.D., and Blackburn, M.R. (*in press*) "Optimizing for mission success using a stochastic gaming simulation," *The Journal of Cyber Security and Information Systems: Modeling and Simulation Special Edition.*

Future Research

- Extend and validate MDO architecture and MFO work with new models currently under development
- Conduct an in-depth literature review of mission-level modeling and define and test a new strategy for MLO
- Combine MDO architectures, MFO methods, and MLO strategy to efficiently optimize a more complex mission scenario

Questions

Thank you for your time!

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