ASCENT Project 050

Over-Wing Nacelle (OWN) Placement Evaluation

Georgia Institute of Technology

PI: Dimitri Mavris, Chung Lee

PM: Chris Dorbian

Cost Share Partner: Georgia Institute of Technology

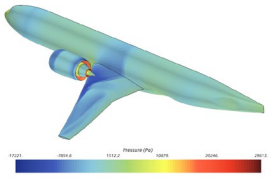
Objective:

- Use multidisciplinary design analysis and optimization (MDAO) methods to assess environmental impact of over-wing nacelle (OWN) placement
- Emphasis on high fidelity aerodynamics to capture drag penalty

Project Benefits:

- Enable accurate tradeoffs between noise benefits and fuel burn penalties
- Demonstrate computationally efficient methods for aircraft design studies

Research Approach:



- Computational efficiency is key challenge
- Numerical uncertainty is a major theme
- Fair comparison requires two optimization processes: OWN vs under-wing nacelle (UWN)

Major Accomplishments (to date):

- Developed coupled aero-propulsion analysis method
- First stage nacelle location study for OWN vs UWN

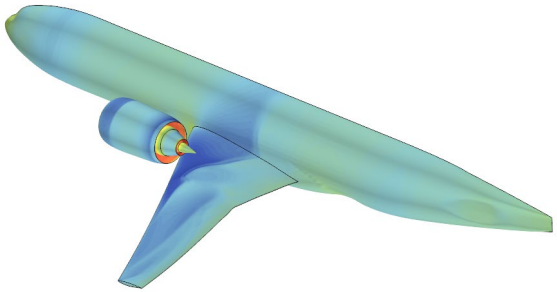
Future Work / Schedule:

- Larger scale, second-stage optimization on larger set of shape variables
- Final deliverable in June 2022

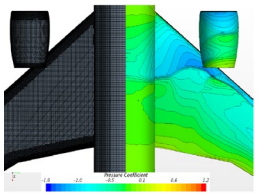
This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 050 through FAA Award Number 13-C-AJFE-GIT-057 under the supervision of Chris Dorbian. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

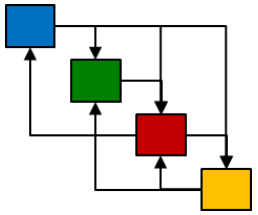
Do OWN Benefits Outweigh Disadvantages?

- Focus is **forward-mounted OWN** for single-aisle transports
  - Clearance for larger, efficient engines
  - Noise shielding
  - *Complex aero-propulsion coupling and interference* 🤔



- **Technical challenges**
  - CFD computational cost
  - Multi-disciplinary design analysis and optimization (MDAO)



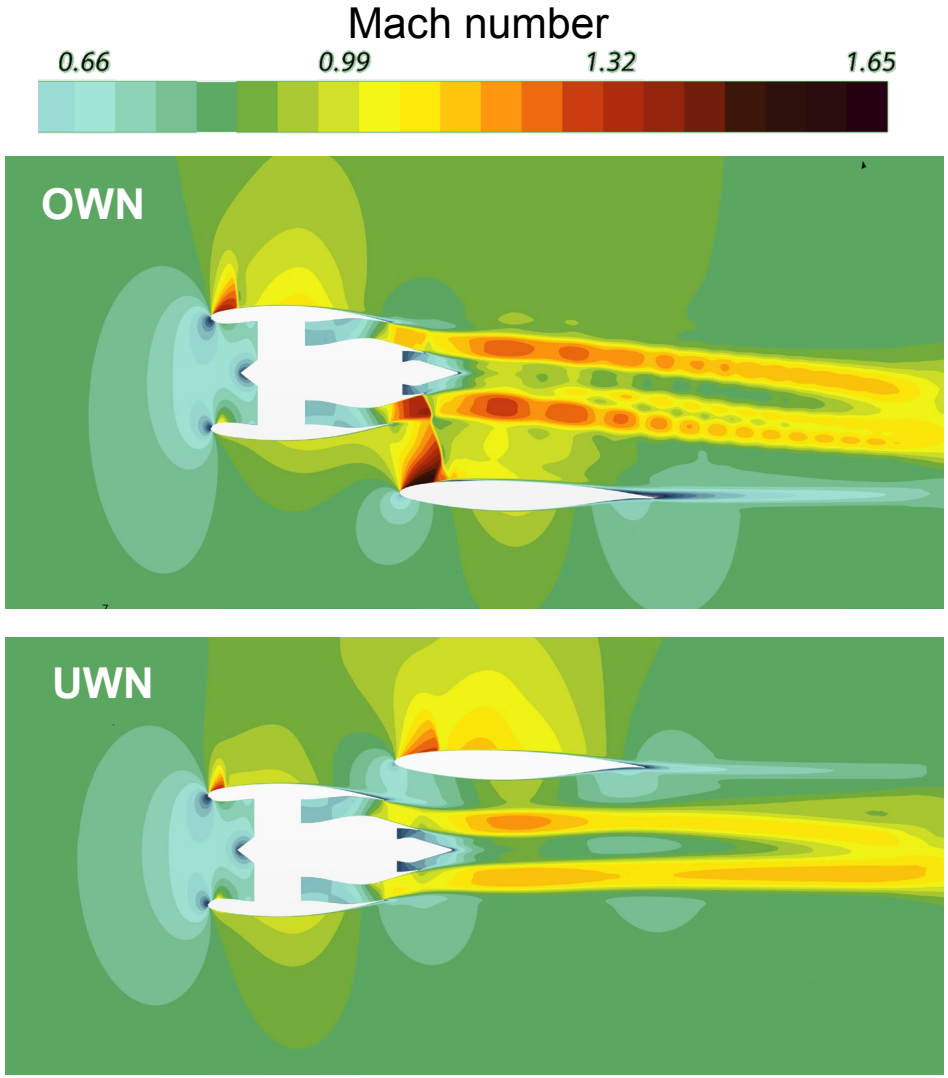


Methodology: Optimize OWN **and UWN** Under Same Rules

- More physics constraints already enforced in mature UWN

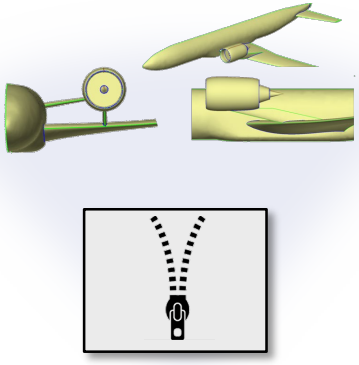
- Challenge of posing a *controlled experiment*

https://www.flickr.com/photos/26176646@N04/2492945625
Creative Commons 2.0

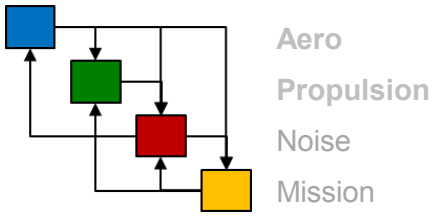


MDAO Strategy Focus On Efficient Use of Supercomputing Resources

Mathematical techniques for reducing design dimensions



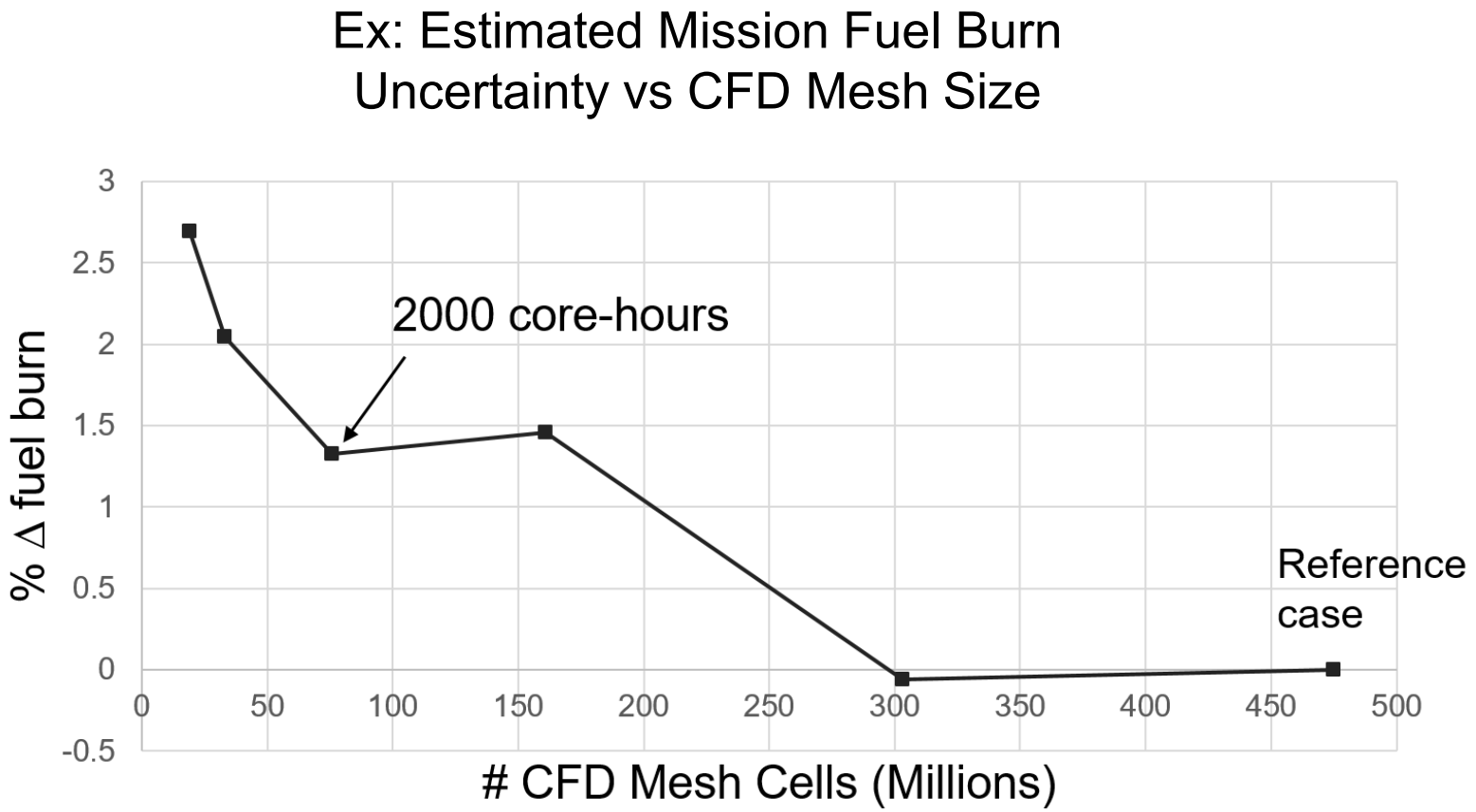
Architecting of multidisciplinary analysis



Adaptive sampling methods on supercomputing clusters

https://en.wikipedia.org/wiki/Pleiades_(supercomputer)

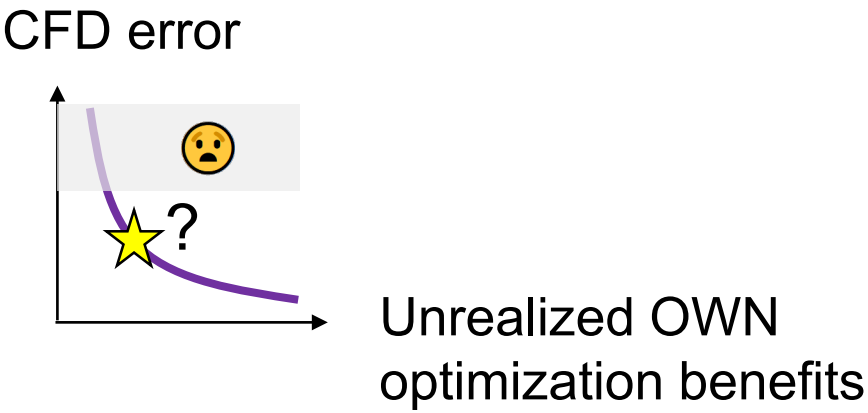
CFD Uncertainty Affects Entire Strategy



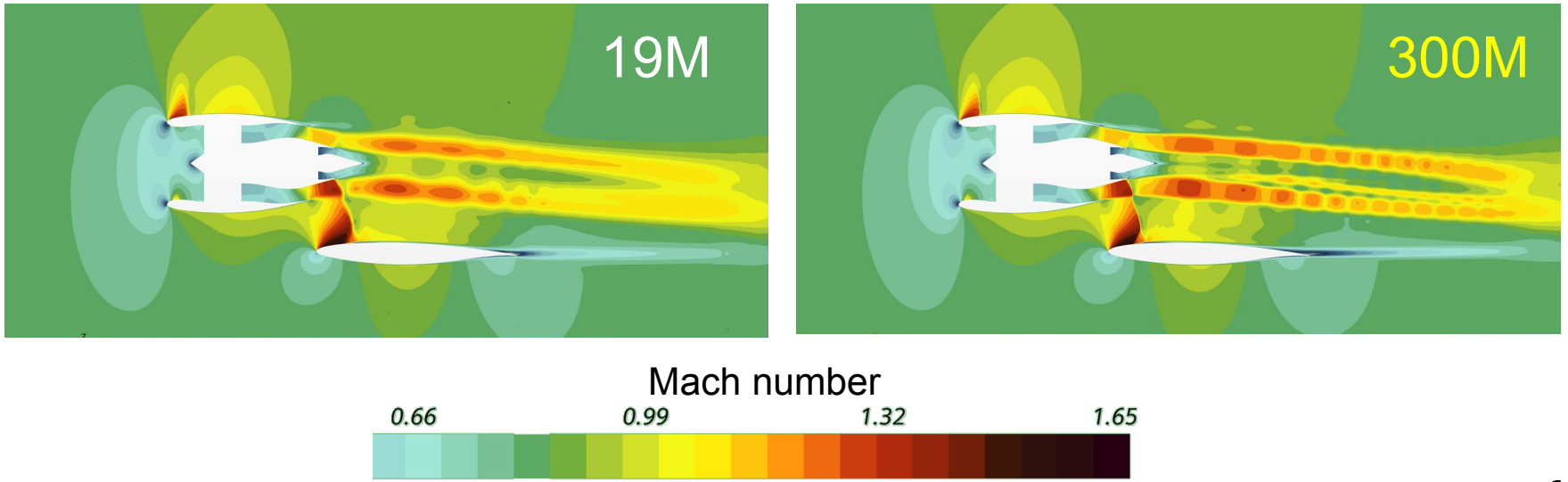
- Published OWN literature uses **0.8 to 30M** cells or grid points
- **Present research requires *much* higher accuracy and cost**
- (Caveat: grids above are relatively inefficient in favor of robustness over design space)

Tradeoff: Physics Inaccuracy vs. Unrealized Optimization Benefit

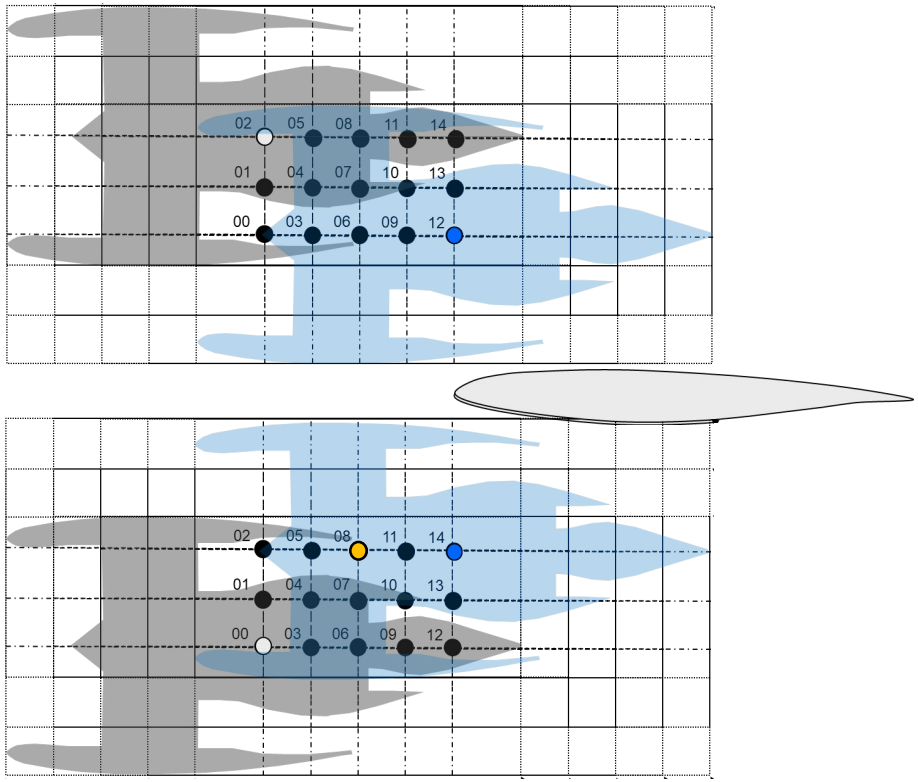
Notional tradeoff under constant cost:



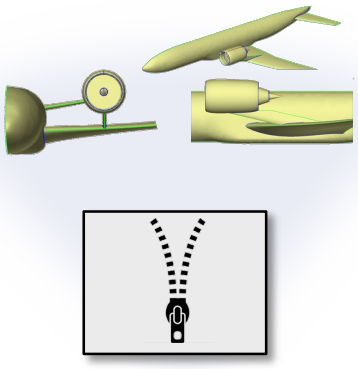
Subtle differences yield Δ fuel burn > 2%



Recent Progress: First Stage Study Focused on Nacelle Location

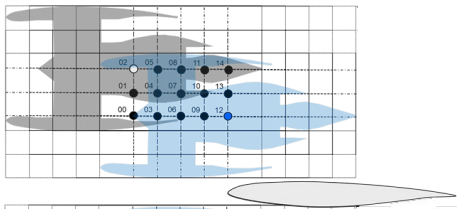


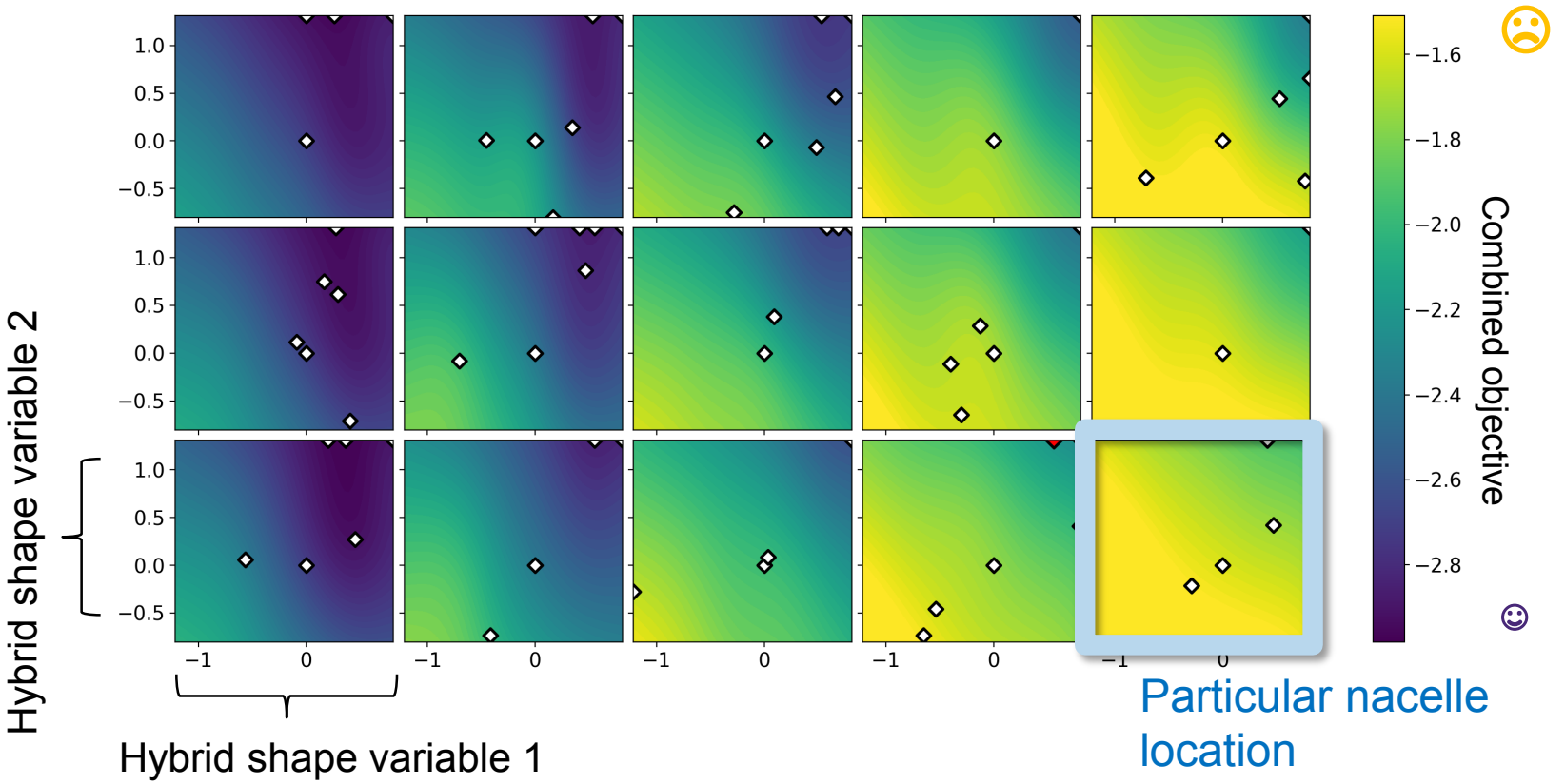
- First stage is to select baseline nacelle location
- For each location:
  - Hybrid ("active surface" wing and nacelle variables) optimized within uncertainty



Adaptive Sampling Example

- Each color-map "pane" corresponds to an engine location
- Shape variables sequentially sampled within each pane
- Objective function is sum of normalized L/D and -excess thrust

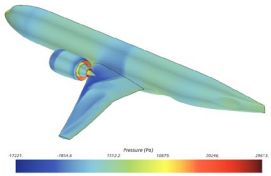




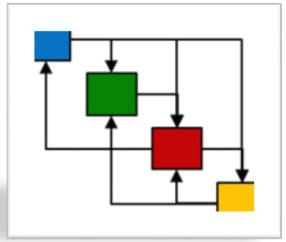
Next Steps Emphasize on Tight MDAO Integration and Uncertainty Tracking

By June 2022:

- **Larger scale optimization (stage 2)**
  - At fixed nacelle locations, OWN and UWN
  - Tightly coupled CFD and propulsion cycle analysis



- **MDAO integration** with mission analysis
  - Legacy methods incur physics uncertainties that must be tracked!



- **Supporting design sensitivity studies**