Advancement of the General Aviation Synthesis Program Using Python to Enable Optimization-Based Hybrid-Propulsion Aircraft Design

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- NASA Transformative Tools and Technologies (TTT)
- Additional support from the Electrified Powertrain Flight Demonstrator (EPFD) project

- GASPy Development Team
  - Jennifer Gratz (GRC)
  - Sydney Schnulo (prev. GRC)
  - Eliot Aretskin-Harriton (GRC)
  - Benjamin Margolis (ARC)
- OpenMDAO Development Team (GRC)
- Advisors
  - Jeff Bowles (ARC)
  - Justin Gray (prev. GRC)
  - Rob Falck (GRC)

Background

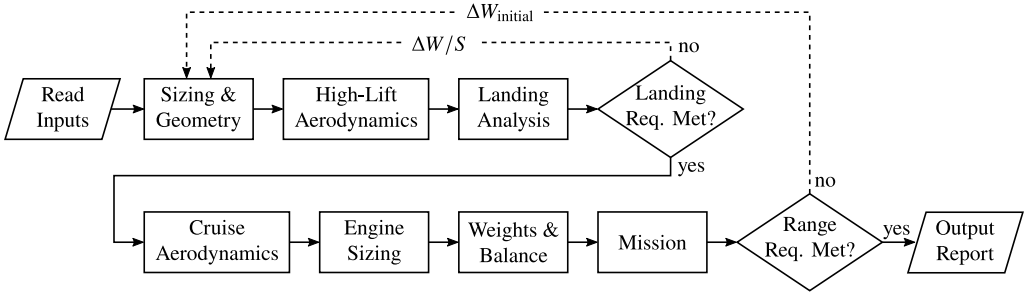
- Objective: Develop a modern tool to address challenges in assessing modern vehicles and concepts
- Balance trusted methods and models with new capabilities
- Generalize approach to vehicle analysis and design

GASP General Aviation Synthesis Program

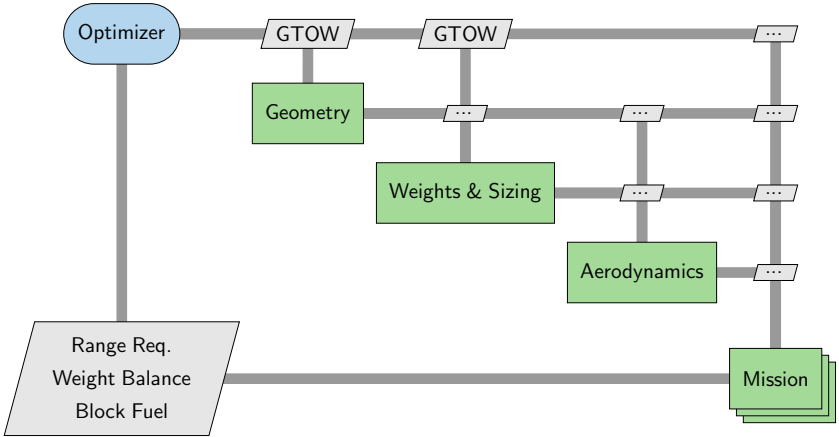
- FORTRAN IV originally written in the 70s
- Updates to improve subsystem models, accept electrified engine data
- Vehicle and technology assessments through sensitivity studies, Monte Carlo analyses

GASP

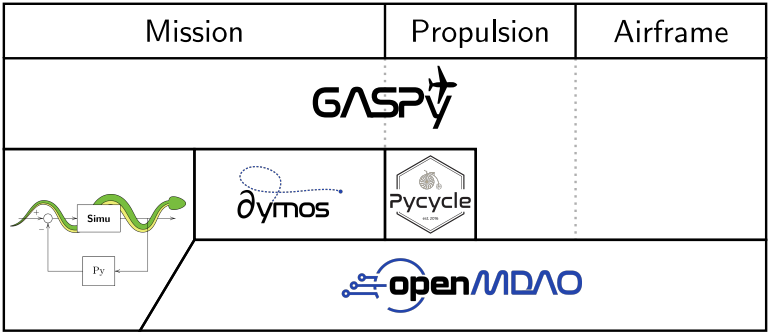
GASP Program Flow



GASPy: Optimization-Based Approach



Software Stack



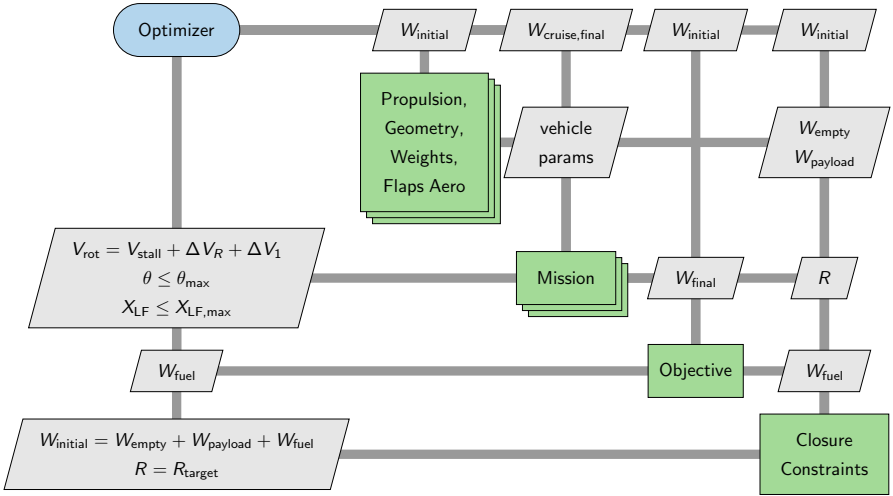
Gray et al., "OpenMDAO: an open-source framework for multidisciplinary design, analysis, and optimization," 2019.

Margolis, "SimuPy: A Python framework for modeling and simulating dynamical systems," 2017.

Falck et al., "dymos: A Python package for optimal control of multidisciplinary systems," 2021.

Hendricks and Gray, "pyCycle: A Tool for Efficient Optimization of Gas Turbine Engine Cycles," 2019.

Model Construction: Vehicle Closure Problem



Reference Vehicle

- GASP Boeing 737 MAX 8 model
- Basis of subsystem and integration testing

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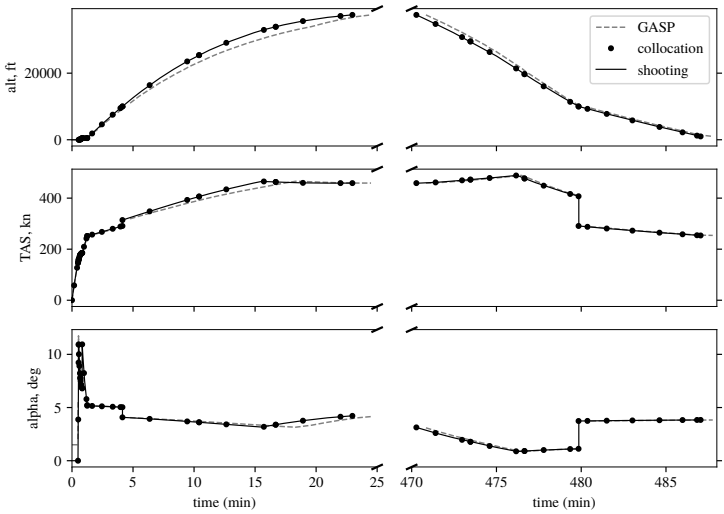
Payload	36,000 lb (180 PAX)
Range	3,675 NM
Cruise Mach	0.8
Cruise Altitude	37,500 ft
Reserve fuel	4,998 lb
SLS thrust	28,690 lbf

Vehicle Sizing Verification



	GASP	GASPy
GTOW (lb)	176,016	175,678
OEW (lb)	96,928	96,547
Block fuel (lb)	43,086	43,132
Cruise L/D	18.66	18.47
Cruise TSFC	0.5487	0.5484

Beyond Vehicle Sizing

Additional verification

- Support for additional mission types:
  - fallout range (fixed vehicle)
  - economic/short-range mission
- Additional vehicles verified against GASP: TTBW (154 PAX), E190-E2 (100 PAX)

Progress with pyCycle

- "N+3" high-bypass geared turbofan engine with electric augmentation
- Engine and simple battery models incorporated into 737 closure problem model
- Working toward automatic sizing, engine & airframe coupled optimization

Recine et al., "Analysis and Optimization of Baseline Single Aisle Aircraft for Future EPFD Comparisons," AVIATION 2023.

Conclusion

- NASA Ames and Glenn have migrated a FORTRAN aircraft synthesis tool to Python
- Flexible optimization-based architecture
- Progress in directly coupling engine cycle analysis tool with analytic gradients for engine & airframe optimization