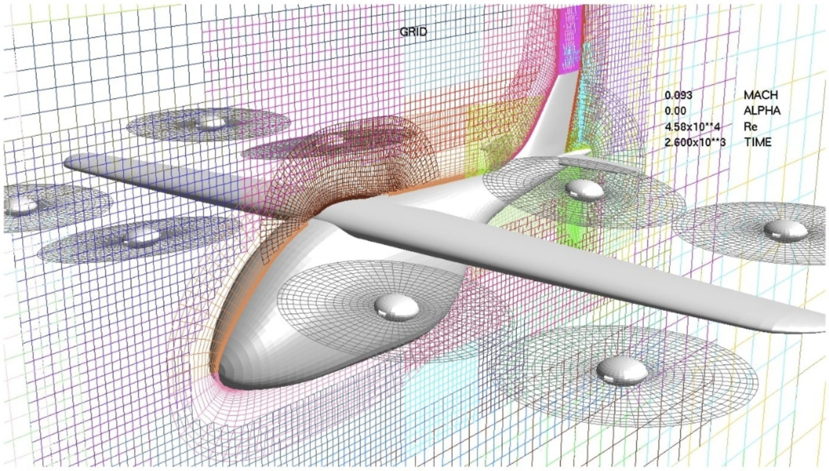

National Aeronautics and
Space Administration

TECHNOLOGY SOLUTION

Information Technology and Software

Rapid Aero Modeling for Computational Experiments

Powerful tool streamlines modeling and design of complex aircraft

Aerodynamic modeling plays a critical role in the development of new aircraft, particularly for innovative designs aimed at urban air mobility (UAM) applications. This includes electric vertical takeoff and landing (eVTOL) aircraft, which combine features of conventional aircraft and rotorcraft. Such advanced designs offer a host of new capabilities but also introduce significantly increased complexity relative to conventional aircraft, including intricate nonlinear aerodynamic responses as well as interactions between propulsion and aerodynamic control systems. For the flight dynamics and controls disciplines, this added complexity renders detailed computational fluid dynamics (CFD) models unable to produce results fast enough for flight simulations.

To address this challenge, NASA developed Rapid Aero Modeling for Computational Experiments (RAM-C), a software-implemented method capable of generating aerodynamic models that capture the important features of complex aircraft in a manner suitable for flight dynamics simulations. RAM-C can be thought of as a “wrapper” around computational (e.g., CFD) software, which it provides specific test inputs to, and receives aerodynamic measurements as outputs from. The input-output data are used to identify mathematical models and evaluate their statistical performance and fidelity. In essence, this NASA invention automates and streamlines the design phase for innovative aircraft while limiting computational requirements.

BENEFITS

- Suitable for highly complex aircraft: RAM-C is suitable for aerodynamic modeling of modern UAM aircraft designs (e.g., eVTOL) with significantly increased numbers of factors relative to conventional aircraft.
- Increased experimental efficiency: RAM-C offers increased efficiency of aerodynamic modeling for complex aircraft by limiting data collection requirements and automating the modeling process (while allowing for user supervision).
- Provides test guidance: RAM-C effectively guides computational code-based tests to obtain high-fidelity, statistically rigorous aircraft models – starting with experimental design, through test execution, and in final model analysis.
- Flexibility: RAM-C can be adapted for real-time, online, or batch processing approaches, depending on user needs and infrastructure.
- OVERFLOW availability: RAM-C has been implemented with NASA’s Overset Grid CFD Flow Solver (OVERFLOW) software. OVERFLOW is available to U.S. persons and companies via NASA’s software catalog.

THE TECHNOLOGY

RAM-C interfaces with computational software to provide test logic and manage a unique process that implements three main bodies of theory: (a) aircraft system identification (SID), (b) design of experiment (DOE), and (c) CFD. SID defines any number of alternative estimation methods that can be used effectively under the RAM-C process (e.g., machine learning techniques, regression, neural nets, fuzzy modeling, etc.). DOE provides a statistically rigorous, sequential approach that defines the test points required for a given model complexity. Typical DOE test points are optimized to reduce either estimation error or prediction error. CFD provides a large range of fidelity for estimating aircraft aerodynamic responses. In initial implementations, NASA researchers “wrapped” RAM-C around OVERFLOW, a NASA-developed high-fidelity CFD flow solver. Alternative computational software requiring less time and computational resources could be also utilized.

RAM-C generates reduced-order aerodynamic models of aircraft. The software process begins with the user entering a desired level of fidelity and a test configuration defined in terms appropriate for the computational code in use. One can think of the computational code (e.g., high-fidelity CFD flow solver) as the “test facility” with which RAM-C communicates with to guide the modeling process. RAM-C logic determines where data needs to be collected, when the mathematical model structure needs to increase in order, and when the models satisfy the desired level of fidelity.

RAM-C is an efficient, statistically rigorous, automated testing process that only collects data required to identify models that achieve user-defined levels of fidelity – streamlining the modeling process and saving computational resources and time. At NASA, the same Rapid Aero Modeling (RAM) concept has also been applied to other “test facilities” (e.g., wind tunnel test facilities in lieu of CFD software).

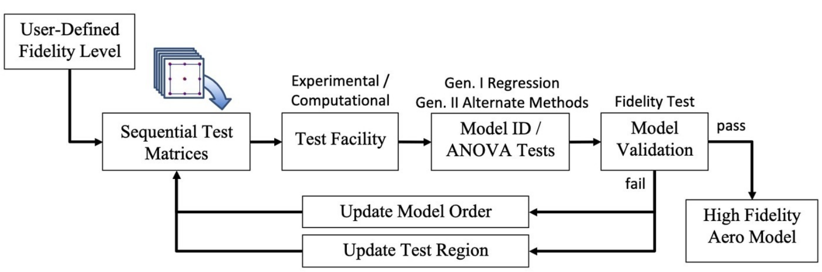

Figure 1: An overview of NASA's Rapid Aero Modeling (RAM) process. For RAM-C, the "test facility" is a computational software program, such as NASA's OVERFLOW CFD flow solver.

APPLICATIONS

The technology has several potential applications:

- Aircraft design & simulation: RAM-C was developed as a tool to efficiently obtain aerodynamic models of complex aircraft during computational investigations in an automated or guided manner. These aerodynamic models can then be used for flight dynamics studies and simulations (i.e., aircraft design). RAM-C may be particularly useful in the design of UAM aircraft (e.g., eVTOL) or other aircraft with significant complexity and aerodynamic nonlinearities.

PUBLICATIONS

Patent Pending

"Rapid Aero Modeling for Urban Air Mobility Aircraft in Computational Experiments." Murphy, Patrick et al., 2021, https://ntrs.nasa.gov/citations/20205010446

"Rapid Aero Modeling of a Lift+Cruise UAM Configuration for Stability & Control Using Overset Grid CFD." Buning, Pieter et al., 2022, https://ntrs.nasa.gov/citations/20220015534

"Preliminary Steps in Developing Rapid Aero Modeling Technology." Murphy, Patrick et al., 2020, https://ntrs.nasa.gov/citations/20200003103

"Rapid Aero Modeling for Urban Air Mobility Aircraft in Wind-Tunnel Tests." Murphy, Patrick et al., 2021, https://ntrs.nasa.gov/citations/20205010453

Full-Envelope Aero-Propulsive Model Identification for Lift+Cruise Aircraft Using Computational Experiments." Simmons, Benjamin et al., 2021, https://ntrs.nasa.gov/citations/20210017459

More Information

National Aeronautics and Space Administration

Agency Licensing Concierge

Langley Research Center

Mail Stop 020
Hampton, VA 23681
202-358-7432
Agency-Patent-Licensing@mail.nasa.gov

www.nasa.gov

NP-2023-11-3200-HQ

technology.nasa.gov

LAR-19724-1, LAR-TOPS-382