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TOWARDS THE DEVELOPMENT OF A UNIFIED SYNTHESIS SYSTEM FRAMEWORK: ADVANCEMENT OF AVDS TOWARDS A GENERIC, MULTI-DISCIPLINARY, AND MULTI-FIDELITY AEROSPACE VEHICLE DESIGN ENVIRONMENT

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Abstract

At the start of any design program for the development of a novel aerospace vehicle, there can be millions of design, mission, and technology trades to be explored. A design software is needed that can modularly adapt itself such that it can be *generically* applied to a wide variety of aerospace applications. It needs to be *automated* such that it can 'stitch' together and generate synthesis codes using a wide variety of disciplinary methods including geometry, aerodynamics, propulsion, trajectory, weights, stability and control, cost, etc. It should also be able to modularly switch the multi-disciplinary synthesis execution process in the synthesis code such that it can accommodate for new disciplines in the sizing process, account for multi-stage vehicles, switch convergence criteria, etc. This enables a design team to rapidly compare both conventional and unconventional design configurations in a consistent manner.

Developing a *generic* and *multi-disciplinary* synthesis framework has been the primary focus of developing the AVD Laboratory's Aerospace Vehicle Design Synthesis (AVDS) software. However, having the automated capability to generically stitch together new disciplinary methods is only solving one part of the problem in addressing a wide-ranging design space. The other major challenge when considering the wider trade space is dealing with higher uncertainty in models of unconventional designs and new technologies, and how to accurately size so many different options in a reasonable amount of time. To ensure that the design with the most benefit and an acceptable risk is chosen, the desire would be to have a synthesis system that could assess as many trades as possible with the *highest speed* and *highest fidelity* (highest accuracy). Unfortunately, this combination of high speed and high accuracy is not possible for higher-fidelity tools because they require long lead times to setup and execute, require expert input, and they require a detailed knowledge of the vehicle's geometry, propulsion system, etc. in order to be able to execute. This detailed knowledge is not available at the beginning of a design project, particularly for a clean sheet design where major design, mission, and technology trades still need to be performed.

This requires a *multi-fidelity synthesis framework* software. If a synthesis framework software is to be able to screen the wider solution space but still have an accurately designed product to deliver to the customer, it needs to have the capability to switch between fidelity levels to trade between speed and accuracy. The ideal synthesis framework would combine both multi-disciplinary and multi-fidelity capabilities to first enable rapid lower-fidelity solution space screening of a wide range of concept/configuration combinations in the conceptual design phase, and then lead to a multi-disciplinary higher-fidelity point design evaluation in the preliminary design phase. This can be accomplished with a *unified multi-disciplinary multi-fidelity synthesis framework* that is able to generically swap synthesis processes and disciplinary methods to accommodate a wide range of disciplinary methods at varying fidelity levels.

Most aerospace organizations do have an integrated multi-disciplinary synthesis process for conceptual design, but this tightknit multi-disciplinary integration is lost in the higher-fidelity preliminary design phase. The disciplinary analysis results from the disciplines are not integrated into an iterating and converging synthesis process during the preliminary design phase. The solution hypothesis of this research is that an organization can be uniformly connected into an integrated multi-disciplinary design process via the use of a unified multi-disciplinary and multi-fidelity synthesis framework software. Such a software would be developed to progress with a design as it goes through conceptual and preliminary design.

In pursuit of a solution, 190 synthesis software systems have been reviewed for an assessment of their multi-fidelity capabilities, and a specification for a unified multi-disciplinary multi-fidelity synthesis framework for advancement of AVDS has been developed. Prototype processes for AVDS have also been executed at two fidelity levels and compared. A lower-fidelity parametric sizing process with level 0 methods is compared to a higher-fidelity configuration evaluation process with level 1 methods.