A3.06  Physics-Based Conceptual Design Tools

Lead Center: GRC

Participating Center(s): LaRC

Conceptual design and analysis of unconventional vehicle concepts and technologies is needed for technology portfolio investment planning, development of advanced concepts to provide technology pull and independent technical assessment of new concepts. The aerospace flight vehicle conceptual design phase is the most important step in the product development sequence, because of its predefining function. However, the conceptual design phase is the least well understood part of the entire flight vehicle design process, owing to its high level of abstraction and associated risk, its multidisciplinary design complexity, its permanent shortage of available design information and its chronic time pressure to find solutions. Often, the important primary aerospace vehicle design decisions at the conceptual design level (e.g., overall configuration selection) are still made using simple analyses and heuristics. Progress has been made recently in incorporating more physic-based analysis tools in the conceptual design process, especially in the aerodynamics area, and NASA has developed a capability that integrates several analysis tools and models in engineering architectures, such as ModelCenter and OpenMDAO. However, gaps still remain in many disciplines.

Developing higher order, high fidelity tools suitable for conceptual design is a difficult challenge. The first issue is analysis turnaround time. To perform the configuration trades and optimization typical of conceptual design, runtimes measured in seconds or minutes, instead of hours or days, are required. However, rapid analysis turn around time alone is insufficient. To be suitable for conceptual design, tools and methods are needed which accurately predict the "as-built" characteristics. Because it is not possible to model every detail of the design and account for all the underlying physics in the problem formulation, it is difficult to predict the "as-built" characteristics with physics-based methods alone. What is usually required is a combination of these methods with some semi-empirical corrections. Ignoring this aspect can lead to higher order tools which are lower fidelity (less accurate) than the lower order tools they are intended to replace. Another challenge in conceptual design is a lack of detailed design information. Lower order, empirical-based methods typically used in the past for conceptual design often require only gross design parameters as inputs. It is, therefore, not necessary to know design details to obtain a reasonable estimate of the design's performance. High-order, physics-based methods currently require detailed design knowledge to be useful. For example, whereas semi-empirical drag prediction tools provide estimates for wing drag without needing full 3-D geometry including an airfoil design, such detail is necessary to successfully utilize CFD tools. This gap in the analysis capability and the maturity of the design being analyzed limits the usefulness of the high order analysis in conceptual design. Physics-based tools for conceptual design must be developed which are consistent with the amount of design knowledge that is available at the conceptual design stage.

NASA continues to investigate the potential of advanced, innovative propulsion and aircraft to improve fuel
efficiency (i.e., reduce CO₂ emissions) and to reduce the environmental footprint (noise and NOx) of future
generations of commercial transports across the flight speed regime. As such, the agency’s systems analysts need
to have the best design/analysis tools possible. The intention of this sub-topic is to solicit proposals for robust,
physics-based tools enabling unconventional configurations to be addressed in the conceptual design process.
Specifically for 2012, the solicitation will center on new tools and methods that pertain to the propulsion system.
Modeling areas where enhanced capabilities are desired include the following:

- Electric/Turbo-electric performance & weight estimation methodologies. Some examples:
  - Electric component performance/weight estimation.
  - Electric grid performance and analysis.
  - Thermal management analysis.
- Enhanced propulsion system performance & weight methodologies. Some examples:
  - Turbomachinery loss modeling.
  - "Rapid" boundary layer ingestion performance.
  - Physics-based component weight estimation.
  - Engine controls & accessories weight/volume.
- High order environmental tools. Some examples:
  - Sonic boom modeling.
  - Combustion emission indices generation.
  - Advanced (beyond ANOPP) acoustics models.
  - Reduced order atmospheric chemistry/global mixing.