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APPROACHES TO NON-LINEAR AERODYNAMIC ANALYSIS AND DESIGN

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Within the last two decades, there has been increasing emphasis on developing more sophisticated computational fluid dynamics (CFD) methods to handle a wide range of problems of interest to the aerospace community. The reasons for this are well-covered in the references which also provide a fairly comprehensive picture of the status of CFD development and capability as well as an assessment of requirements and future directions. An independent review and assessment was also carried out by the author as part of the current assignment and the results are outlined herein.

As the problems faced by vehicle and systems designers become more complex and critical, particularly at very high speeds and altitudes, the need to predict flow characteristics about intricate body shapes under conditions involving complex physical phenomena becomes more acute. Problems which previously were handled (however inadequately) by solving the linearized equations governing fluid flow must now take account of the essential non-linear character of these relationships. Since no known mathematical techniques exist to accomplish this, the focus has shifted to methods based on finite difference techniques using timewise integration to determine the flow variables throughout the fluid. This includes the creation of a three-dimensional (3-D) mesh or grid within the zone of interest which provides the framework for systematic calculations leading to a (usually) steady state or stationary solution. In order to achieve the desired definition and accuracy, a grid comprising large numbers of very small elements is usually necessary. Typically, billions of calculations are required to establish dynamic compatibility at matching faces of the grid elements for each increment in time. The computer capability required is of gigantic proportions such that only very special facilities supported at the national level are sufficient to approach the quality of simulation needed. As computer capabilities increase, the objectives become more demanding and the focus changes to problems of ever increasing complexity. Ultimately, this will include such micro-scale phenomena as turbulence and combustion dynamics or the mega-scale of planetary atmospherics. Such goals now appear visionary and would require orders of magnitude improvement in computer speed and capacity.

Consideration of the current status of computer development and the need for more realistic and affordable analysis and design capability has inspired the current study to identify alternative approaches to cope with the wide spectrum of physical phenomena involved with the design and operation of aerospace vehicles and systems. The continued reliance on grid methods appears to present some fundamental limitations in terms of simulation quality, time and cost. Thus, the present effort has focused on a hierarchy of methods based on fundamental solutions of the linearized system equations. To handle the non-linear aspects several schemes have been identified for efficient algorithms applicable to both analysis and design in 4-D.

An architecture for a CFD system utilizing these or similar concepts has been proposed which would include the following characteristics:

- Essential physics and mathematics
- Realistic configurations in 4-D
- Avoids basic limitations of grid methods
- Small to large-scale phenomena
- Affordable computing time and cost
- Verifiable accuracy
- Logical progression to complex problems
- Methods matched to needs and resources

Figure 1 shows the elements of such a system arranged in a logical sequence for development.

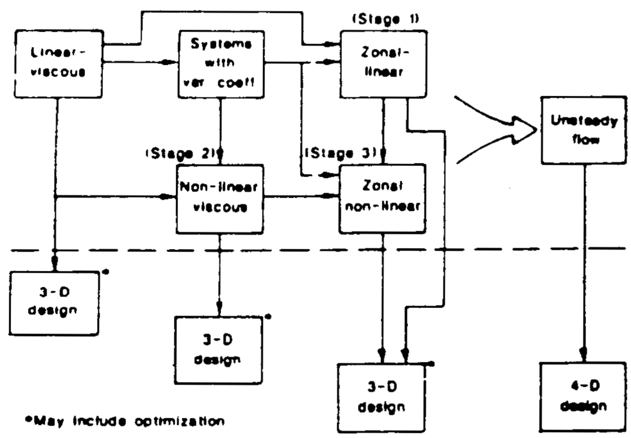

Figure 1. - Architecture for CFD System

To support this initiative, an exploratory approach is recommended as an extension to the present study. The initial steps would involve, 1) development of fundamental solutions to the linearized Navier-Stokes equations for compressible, heat conducting fluids and 2) identification and evaluation of promising algorithms for non-linear CFD codes needed to implement the proposed systems.

It is concluded that this approach could lead to a more-effective CFD systems complex to support advanced aerospace vehicle design and the creation of new leading edge technologies. Properly implemented, such a system would find wide application within the private sector as well and help to reestablish U.S. preeminence in industry.

References

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