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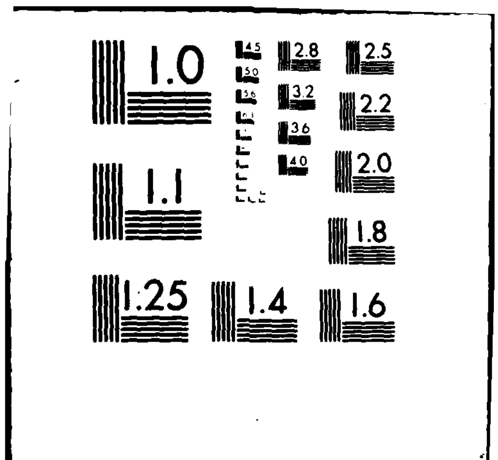

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TECHNICAL MEMORANDUM

WSRL-0236-TM

COMPUTATIONAL AERODYNAMICS AT WEAPONS SYSTEMS RESEARCH LABORATORY

L.M. SHEPPARD

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S U M M A R Y

A review is given of the computer-related aerodynamic research carried out at Weapons Systems Research Laboratory over the past twenty years or so. During this period, three main digital computers have been in use, namely WREDAC, IBM 7090 and IBM 370. A notable peak in research activity occurred during 1975 to 1978 when the task "Fluid Dynamics - Computing" was in existence and the IBM 370 computer was available. This task has since been terminated. Potential applications of computational aerodynamics at Weapons Systems Research Laboratory extend to unguided bombs, bomblets, bullets, mortars, rockets and shells, as well as terminally corrected precision-guided weapons, gliding munitions, guided missiles, release of external stores from aircraft and carriage of external stores on aircraft.

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1. INTRODUCTION

Aerodynamic computation on electronic, digital computers began at Weapons Systems Research Laboratory in 1960, following the formation of a Theoretical Supersonics Group in what is now the Aeroballistics Division. The first DRCS general purpose digital computer, which was known as WREDAC, was used by Chan(ref.1,2) to calculate pressure distributions on a wing-body combination at supersonic speeds using linearized small-perturbation theory. A range of Mach numbers was considered, with the leading edge being both "supersonic" and "subsonic". ie the Mach number component normal to the leading edge was supersonic and subsonic. Soon after the completion of this work, an IBM 7090 computer was installed and this was used extensively to support rocket development and rocket trials at Woomera. As part of this work, some of the aerodynamic estimation procedures were incorporated in computer programs while some other programs were obtained from overseas.

In 1975, an IBM 370 computer was installed at DRCS and a small research section began work on the application of finite element methods to aerodynamics. However, in 1978 this work was terminated, owing to a DSTO decision to reduce substantially the resources deployed on aerodynamics. Since 1978, a little work on aerodynamics estimation has continued in support of unguided weapons research.

Further comments are given below on rocket design, in Section 1.1, and on theoretical aerodynamics, in Section 1.2. In Section 2, the work on finite element methods is discussed. Recent work on missile aerodynamics prediction is outlined in Section 3. Finally, in Section 4, some comments are presented.

1.1 Rocket design 1958 to 1974

The broader issues of successful rocket design are covered by Shannon in reference 3, where the hypersonic research vehicles Jabiru Mk.I and Jabiru Mk.II are discussed. These vehicles enabled rocket experiments to be conducted at Woomera at speeds up to nearly Mach 10. Subsequent to reference 3, the Jabiru Mk.III vehicle with superior performance at lower altitudes was developed. In addition, the Aero-High sounding rocket mentioned in reference 4, and some other sounding rockets, have been developed. To support the hypersonic research rocket development and the higher altitude sounding rocket development, use was made of computer programs to predict rocket aerodynamics. Some programs were written locally(ref.4,5) and some were obtained from overseas(ref.6). In retrospect, it is interesting to note that effort was not available at the time to develop a fully integrated set of aerodynamic design programs.

1.2 Theoretical aerodynamics 1959 to 1969

Research on theoretical aerodynamics was conducted in Theoretical Supersonics Group over a period of 10 years. Much of the work was related closely to the hypersonic rocket developments mentioned earlier and is discussed by Sheppard in reference 3. The work covered satellite and exit aerodynamics, as well as aerodynamic heating(ref.7 to 10). The work by Bird on high speed aerodynamics is significant, as is the work by Jepps on aerodynamic heating. Jepps devised a novel and most effective method of analysing heat transfer through thermally thick walls. In addition, some work was carried out on supersonic aerodynamics(ref.11,12).

2. FINITE ELEMENT METHODS 1975 TO 1978

A DSTO research task "Fluid Dynamics - Computing" was set up in 1975. The aim was to apply numerical methods to problems in fluid dynamics and to develop computer software that would permit the rapid calculation of the exterior aerodynamics of missiles. Work on finite element methods ceased in 1978.

There were significant advances overseas in the application of numerical methods to fluid dynamic problems in the decade ending 1975. These advances stemmed not only from greater understanding of the nature of fluid flow about three-dimensional bodies, but also from the availability of high speed digital computers with sufficiently large memories; indeed, without the latter, the field of computational fluid dynamics would have remained almost static.

For many years the customary sources of aerodynamic design data for weapons and aircraft have been data sheets, charts and text books. Much applied research in wind tunnels and in flight has been directed towards improving the data in these sources. The modern digital computer enables two significant improvements to this situation. Firstly, it is now possible to develop programs which calculate flow fields using general computer codes capable of handling three-dimensional attached flow over even such complex shapes as aircraft or missiles, in engine intakes and through ducts. It is now standard practice at NASA and at many major US aircraft companies to use the numerical techniques as design tools to evaluate the effects of configuration changes at subsonic and supersonic speeds, and then to restrict the wind tunnel testing to the most promising configuration. Because of the complex nature of transonic flow fields, less use is able to be made of computer methods at transonic speeds. Thus a new technique is becoming available to assist in providing the hard data which designers need; and the cost of obtaining data by numerical solution is decreasing due to the rapid development of computer hardware and more efficient numerical methods, while the cost of wind tunnel experiments can only increase. Consequently, computer simulation will complement wind tunnel testing.

The second major advance which the computer allows in the field of applied aerodynamics is that all the aerodynamic data which the designer uses can be stored in the computer's memory. Appropriate programs can then be devised to allow estimation of the forces and moments on complete missiles or aircraft.

The work at WSRL on computational fluid dynamics was planned to use finite element methods, rather than finite difference methods. Since a typical finite element is much larger than the mesh sizes for finite differences, finite element methods are readily able to handle complex body shapes, such as guided missiles and aircraft; in addition, they require less setting-up time to solve a subsequent problem once a general computer code has been written.

The achievements of the finite element research over the years 1975 to 1978 are described in references 13 to 19. The Galerkin method of approach was coupled to finite elements in investigations of two-dimensional and axisymmetric fluid flows. This led to a most successful method for handling incompressible two-dimensional flow and a promising start was made on the extension of this work to compressible subsonic speeds. An improved integration technique of international significance was developed by Fletcher(ref.17). The investigation of axisymmetric flow was not successful, and no effective method had been developed for incompressible flow when work ceased.

3. AERODYNAMICS PREDICTION 1978 TO 1981

An outcome of the DSTO task "Fluid Dynamics - Computing", mentioned in Section 2, was work on aerodynamics prediction methods(ref.20 to 22). The research centred on a program of US origin obtained through TTCP/WTP-2. The program had been devised by the Naval Surface Weapons Center (NSWC). The aim was to predict missile static forces to within 10% and centres of pressure to within 0.5 calibre (or maximum body diameter) at both supersonic and subsonic speeds; larger errors were expected at transonic speeds. Errors in dynamic derivatives were larger than for the static derivatives. However, the maximum Mach number was limited to 3 and the angle of attack to about 15°.

Use of the program over the past 3 years has shown how demanding the task of maintaining such a program can be. Staff with different interests have sought advice on the program and used its results, sometimes with modifications where deemed necessary by the user. The basic program has been extended to handle bombs, a task for which the original computer program was ill equipped. Currently, a graphical plot output is being devised for the program. In addition, many small changes have been incorporated in the program.

Program predictions are made using three main methods, namely data tables, empirical estimation procedures and simple computational procedures. The program has been used to provide aerodynamic data for bombs, bullets, mortars, rockets, shells and surface-to-air missiles. In an application to glide bomb configurations, the lift-dependent drag results at subsonic speeds were modified using handbook data available on subsonic wing characteristics. The wide range of applications at DRCS to date is noteworthy. The applications ranged over preliminary design, modification and assessment.

Accuracy of the program's predictions has been assessed when possible. The claimed accuracy has generally been found to be a good guide. When defects have been found, as in the case of bombs, improvements have been incorporated in the program.

4. COMMENTS

Potential applications of computational fluid dynamics at DRCS are many and varied. Most applications are likely to occur in WSRL and cover unguided weapons, both spin-stabilized and fin-stabilized, terminally corrected precision-guided munitions, gliding munitions and guided missiles. Store separation from aircraft is another vital field of work at WSRL; this field of work covers external stores when carried on aircraft and external stores after release from, but still within the influence of, the aircraft. In design of new weapons, computer simulation will complement wind tunnel tests by substantially reducing the amount of testing required, and produce better designs. Looking to the future, preliminary design will be able to be carried out on the computer. In other cases where modification of an existing weapon is required or assessment of the performance of an existing weapon is being made, satisfactory results should often be possible without recourse to wind tunnel testing.

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