LECTURE 1

A BRIEF REVIEW OF AIR-FLIGHT WEAPONS

1 INTRODUCTION

The history of air-flight weapons probably began with the sling-shot, the spear, the arrow and perhaps the boomerang. The invention of gunpowder brought about a huge increase in range, but prior to the 20th century gun-fired projectiles were purely ballistic in their flight - they had no built-in propulsion, no built-in guidance, no built-in control. The science of ballistics pre-dated the science of aerodynamics and the first studies of supersonic flight were prompted by the behaviour of artillery projectiles. During the 20th century, however, and particularly since the second world war, there has been a great increase in the number of weapons which are self-propelled or guided or both, and the science of aerodynamics, which has been so extensively developed in the study of aircraft flight, now contributes more than ballistics to the design of modern air-flight weapons.

Let us start by considering why the title of this course is "Missile Aerodynamics"? Are we to infer from this that the science of aerodynamics and its laws are different when applied to the design of weapons than they are when applied to the design of aircraft? The answer, of course, is "No". The scientific laws are the same, but it is sensible to differentiate between weapon aerodynamics and aircraft aerodynamics on three grounds:

1 The objectives of the design of the flying vehicles are usually quite different.

2 The range of attitudes and flight conditions are usually quite different.

3 The shapes which are appropriate to achieve the design objectives in the required flight conditions can be very different, and since applied aerodynamics usually requires a number of assumptions and approximations to be made in order to obtain practically useful results, the assumptions

and approximations appropriate for typical weapons may not be appropriate for aircraft shapes.

The difference in design objectives between civil aircraft and weapons can be seen from Figure 1. The aircraft is designed for efficient and economical cruising flight, which implies a high volume of lift/drag ratio: by the use of variable geometry devices it adapts its flying characteristics to make it suitable for landing and take-off: its manoeuvres and acceleration must be tolerable by ordinary people wearing ordinary clothes who comprise the payload. A typical weapon, on the other hand does not have the same emphasis on economical operations, it is required to deliver a payload to a prescribed point in space as effectively as possible. The lateral and longitudinal accelerations necessary to do this may well be beyond the range acceptable to human beings. The weapon is controlled, if at all, by an autopilot which does not have the same flexibility of response as a human being but which will be much faster. On grounds of cost and reliability, control systems including aerodynamic controls must be as simple as possible so that variable geometry such as variable-sweep wings and complicated flap systems are not usually a practical proposition.

Military aircraft lie between civil aircraft and weapons in this comparison since the aircrew can be asked to tolerate an environment that would be unacceptable to civilian passengers, and because there is not the same emphasis on the economics of the flight. In the last year or two, remote piloted vehicles (RPV), hitherto used primarily as target aircraft, have been considered for operational roles in order to avoid the expenditure of the lives of human aircrew, so the distinction between military aircraft and weapons is becoming less clearly defined. However, at present one would expect an RPV to look and fly more like an aircraft than like a typical weapon, though here again there have been guided weapon designs (for example, Mace, Styx) which looked like aircraft because that was a suitable shape for their particular purpose.

How then, do we define the field of interest of the weapon aerodynamicist. In my opinion, our field is the aerodynamics of narrow, low-aspect-ratio, slender wing-body-control combinations. Not all these descriptions necessarily apply to a given shape, and not all weapons have these three component parts. If you were to ask an aerodynamicist what branch of the subject he worked in, and if he replied "Aircraft aerodynamics" you probably would not consider that to be a very narrow specialisation. And yet the corresponding field of "Weapon aerodynamics" is regarded as a specialised activity. In fact, the weapon aerodynamicist has to have a wide knowledge of the various branches of aerodynamics: the flow around inclined bodies; the characteristics of wings (usually very different in geometry from aircraft wings) and the interference effects between wings and bodies; the behaviour of several types of controls; the effect of the complete range of roll angle on monoplanes and cruciform configurations; boundary layers; base pressure and base drag with a very hot jet efflux present; the effects of vortices on downstream components; the effect of nose shape on drag and the drag due to excrescences and protuberances; kinetic heating effects; an incidence range from 0° to 180°; a Mach number range from moderate subsonic to high supersonic; static and dynamic aerodynamic derivatives. All this has to be applied to shapes which may be by no means ideal for aerodynamic efficiency such as bodies with square cut noses (Figure 2), or wings which look like those in Figure 3, or the bomblet shown in Figure 4. It must be conceded that the weapon aerodynamicist does not usually have to concern himself with the fine details of the flow around a configuration, such as the effect of the threedimensional boundary layer on a swept wing, but this is at least partly offset by the need to consider a wide range of incidence angle and roll angle.