Chapter II

ROCKET SYSTEMS

2.1 Introduction

The purpose of this chapter is to provide the necessary background for the rocket system in general aspect. The basic concepts concerning with the flights of uncontrolled rockets, equations of the motion and its trajectory, and the dispersion of rockets have also been described for further knowledge reference.

2.2 Mathematical Representation of Rocket Systems

For an artillery rocket, the rocket system consists of the main body or the rocket motor with the propulsive charge as shown in Fig. (2.1). The rocket-head may be either a service rocket or a practical rocket type.

When the trajectory motion of the rocket lies in a plane. The equation of this motion can be written according to Newton's law as :

$$m.\frac{dv}{dt} = T + X \qquad (2.1)$$

where

$m(t)$ = mass of the rocket at the instant time t

T = constant thrust (see Appendix C)

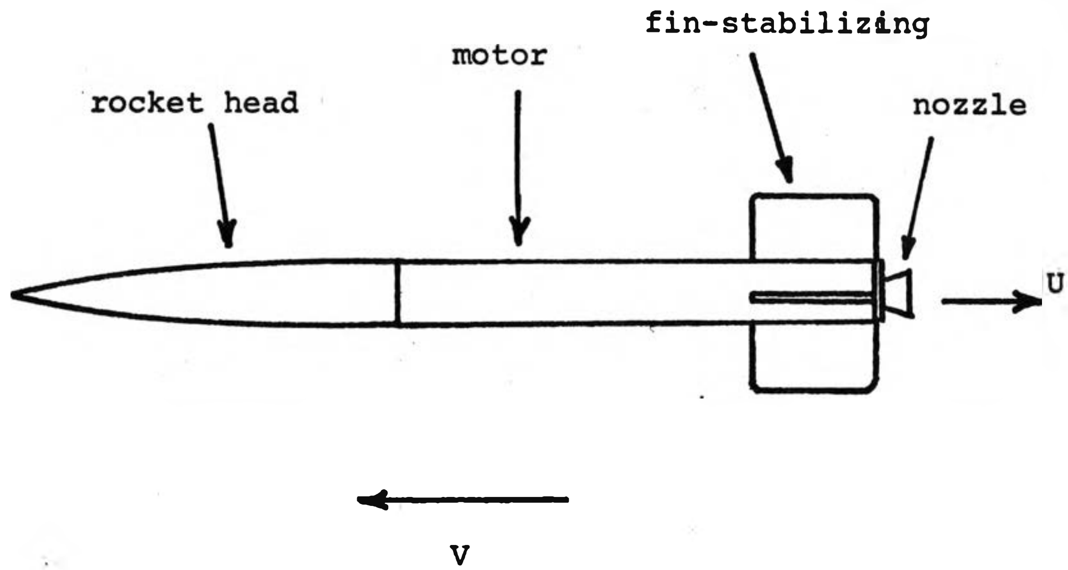

Figure 2.1

A Diagram of Fin-stabilized Artillery Rocket.

X = sum of all external forces

v(t) = velocity of the rocket at the instant time t

The motion of the mass-center of a rocket during powered flight under the gravity force mg and the drag D in the opposite direction to the velocity of the rocket is shown in Fig. (2.2). Consequently, the equations of the flight path are written as :

$$m.\frac{dv}{dt} = T - D - mg \sin\theta \qquad (2.2)$$

$$m\frac{v^2}{r} = mg \cos\theta \qquad (2.3)$$

where

θ = angle of the rocket with reference to horizontal line.

These equations are called the tangential and the normal forces to the rocket path respectively and may also define the trajectory of the rocket mass center.

2.3 Dispersion Configuration

For a fin-stabilized rocket, the interaction of the motion in the vertical plane and the horizontal plane is cancelled because the symmetry of the fin alignment.

In general, the longitudinal axis of the nozzle in the motor is differed from the axis of the rocket due to the improper construction.

From eqn. (2.2), the equation of the motion along the

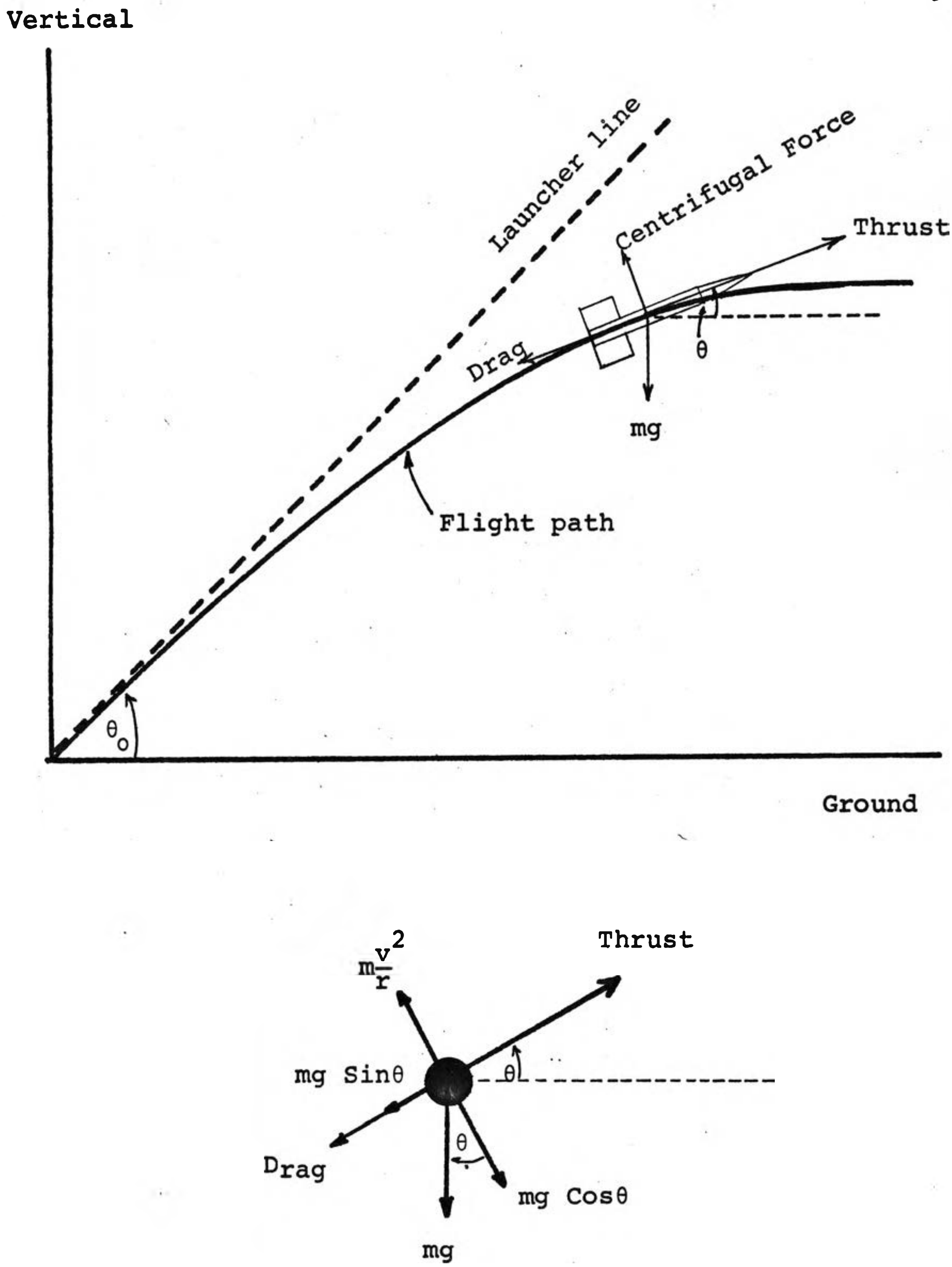

Figure 2.2

A Diagram of Forces Acting on a Rocket.

trajectory due to malalignment shown in Fig. (2.3) is :

$$m\frac{dv}{dt} = T \cos(\alpha - \beta) - mg \sin\theta - D \qquad (2.4)$$

in which the angle of attack α of the rocket is

$$\alpha = \phi - \theta \qquad (2.5)$$

and eqn. (2.3) becomes

$$mv.\frac{d\theta}{dt} = T\sin(\alpha - \beta) - mg \cos\theta + L \qquad (2.6)$$

This equation describes the angular deviation of the rocket, and this is the motion around the center of the mass. where

α = the attack angle

v = magnitude of the velocity of the rocket

θ = inclination of the velocity vector

ϕ = inclination of the axis of the rocket

m = mass of the rocket

g = gravitational constant

L = lift due to aerodynamic forces perpendicular to the direction of motion

D = drag paralleled to the direction of motion

T = constant thrust of the rocket motor

β = angular misalignment

δ = moment arm with respect to the center of gravity

It can be seen that the aerodynamic forces and the moment of the rocket are dependent upon the angle of attack α. If the fins on the rocket are not properly aligned, the

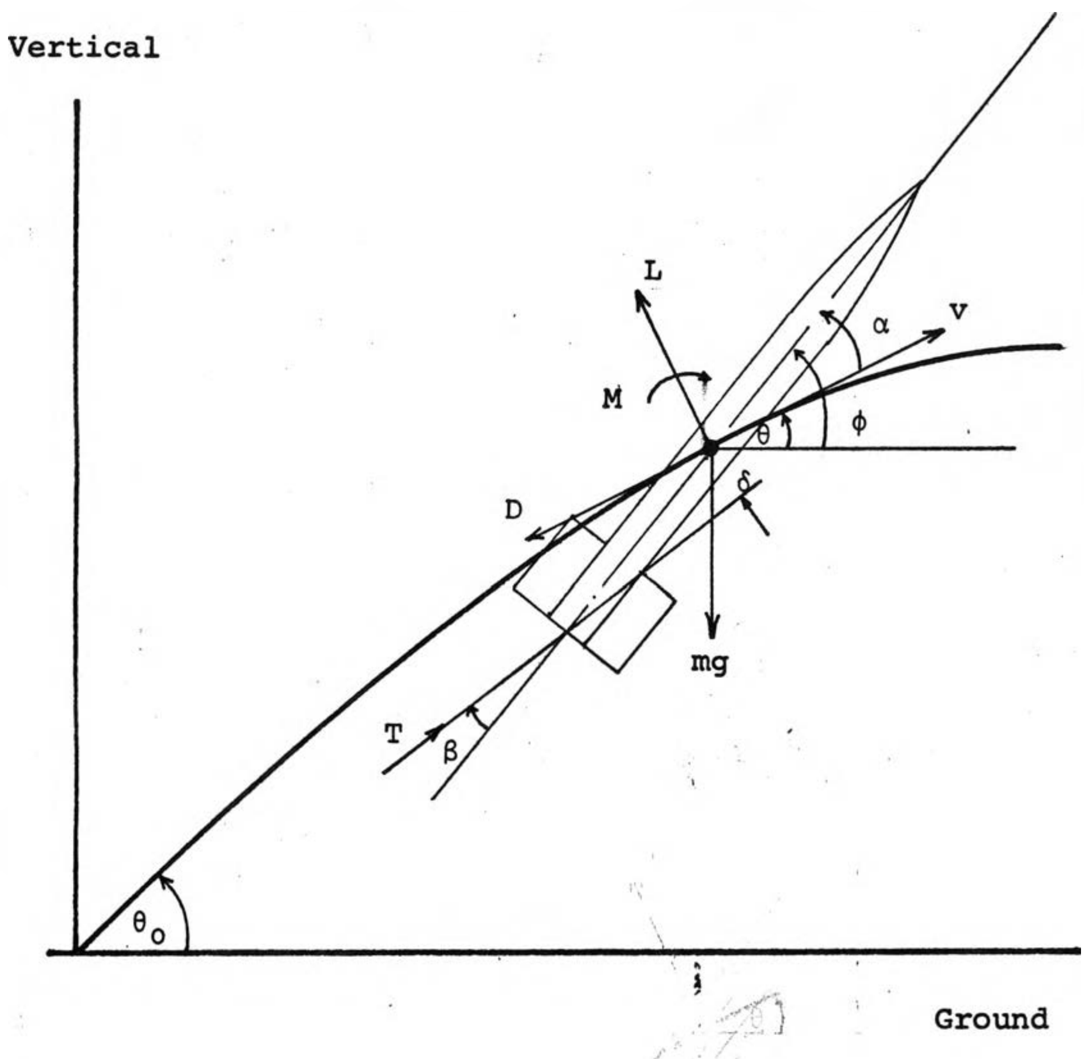

Figure 2.3

A Diagram Showing the Angular Deviation

of Fin-stabilized Rocket

lift and this moment will not vanish even if α is zero. The relations of the lift, the drag and the moment of the rocket can be expressed in term of the density of air, ρ ; the diameter of the rocket body, d ; the lift coefficient, C_L ; the drag coefficient, C_D ; and the moment coefficient, C_M ; as follows [5]:

$$L = C_L \rho v^2 d^2 \tag{2.7}$$

$$D = C_D \rho v^2 d^2 \tag{2.8}$$

$$M = C_M \rho v^2 d^2 \tag{2.9}$$

For short-range rockets, the summit of the trajectory is not high, therefore the air density ρ can be treated as a constant. Furthermore, the maximum velocity is small so that all the coefficients C_L, C_D and C_M can be considered as constants. These coefficients are not influenced by the Mach number on the trajectory. Moreover, the propellant fraction of the total mass is also small, thus the mass of the rocket can be approximated a constant. The identification of the coefficients C_D and C_L will be presented in Chapter 4.

The mathematical modeling of the short-range rocket systems has been described in more details in the next chapter.