Ascent Mission Description

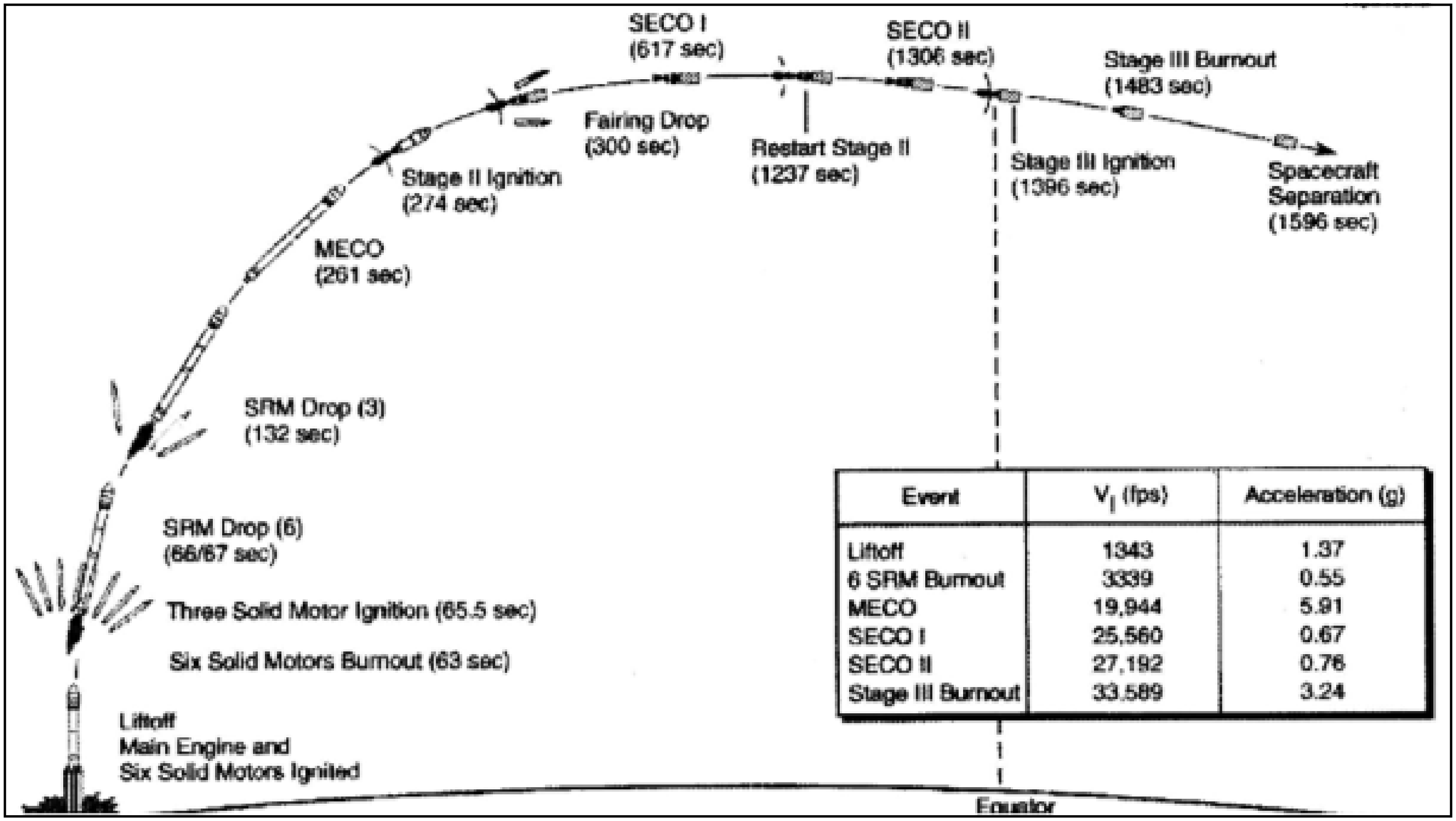
Ascent Mission Analysis

In general, **ascent** mission is characterized by **events** that occur at specific time **intervals**.

These are usually **related** to operation of various **stages** as well as other **considerations** that impact the **performance**.

In most cases, **events** are time **referenced** in order to **ensure** that each segment performs as **designed.**

Ascent Mission Sequence –Delta II



Event	V_I (fps)	Acceleration (g)
Liftoff	1343	1.37
6 SRM Burnout	3339	0.55
MECO	19,944	5.91
SECO I	25,560	0.67
SECO II	27,192	0.76
Stage III Burnout	33,589	3.24

Figure Courtesy Space Vehicle Encyclopaedia

Ascent Mission Characteristics

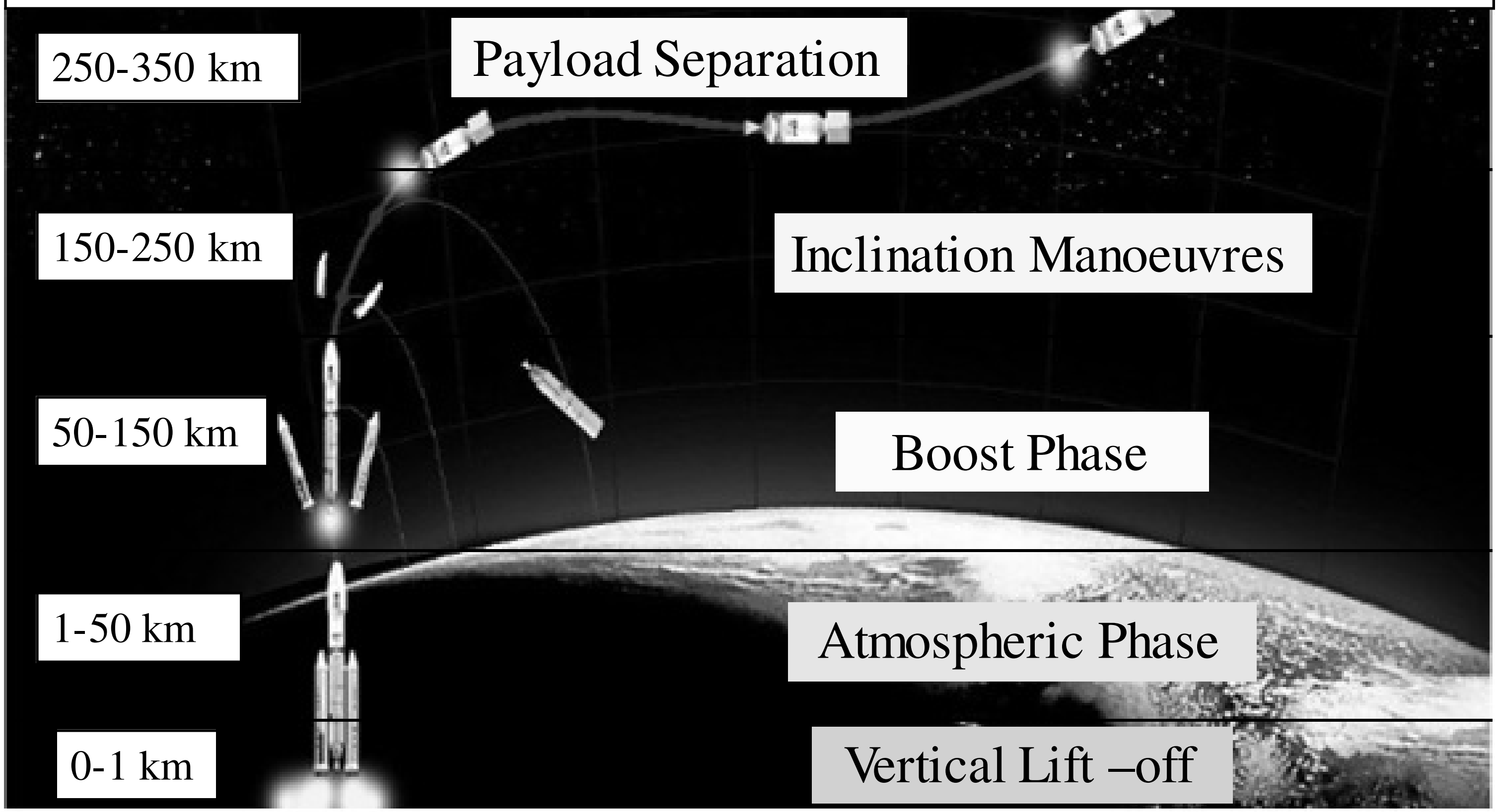
We note that **events** are not only time **stamped** but also have **trajectory** information e.g. velocity, altitude, inclination etc., **connected** to it.

Further, as events **denote** changes in **force** system, these have a **mechanics** related implication, as well.

Therefore, it is **possible** to define appropriate **segments** of ascent **mission** that are based on **corresponding** models.

Ascent Mission Phases

A typical **ascent** trajectory is **broken** into broad **phases,** based on **nature** of forces / manoeuvres, as shown **below.**



Lift off & Atmospheric Phase

Lift –off is a critical phase, as **toppling** due to gravity is the **major** issue and is modelled simply as **T > W**, while ensuring vertical **attitude.**

Once **clear** of launch tower, **boosters** and/or first stage **engines** propel the **vehicle** through dense **atmosphere.**

In this phase, while **gravity** & thrust are the **dominant** forces, aerodynamic **drag** is also quite significant.

Boost Phase & Inclination Manoeuvres

In **boost** phase, as the **rocket** is out of **atmosphere**, larger velocity **increments** are possible.

Towards the end of **boost** phase, manoeuvres are carried out to **rotate** the velocity **vector** in order to **achieve** the desired terminal **inclination.**

In these phases, **motion** is assumed to be in **vacuum**, though altitude correction to **gravity** may be needed.

Ascent Mission – Terminal

Terminal phase is considered the **most** crucial as spacecraft **separates** after acquiring required **velocity /** inclination.

In this **phase**, thrust is very **small** so that the motion is **governed** mainly by the gravitational **force**.

However, **distance** travelled over Earth can be very **large**, needing a suitable **Earth** surface geometric model.

Ascent Mission Modelling

Ascent Mission Modelling

Modelling of the ascent mission involves, (1) identifying the applicable **forces**, (2) desired motion **parameters** and (3) the physical **laws**, governing the motion.

As we have seen, **launch** vehicle experiences **forces** due to **propellant** burning, gravity and **atmosphere**.

Similarly, **motion** variables of interest are **position** and velocit**y** vectors of the **centre of mass** (or velocity, altitude and flight path angle).

Basic Governing Equation

In **inertial** frame, equation of **motion** for the centre of **mass** can be written using **Newton's** 2nd law as,

$$\boxed{\frac{d}{dt}\{m\vec{V}\} = \vec{F}; \quad \vec{x} = \int \vec{V} dt}$$

Basic Governing Equation

Here, the inertial **velocity** vector is expressed as,

$$\vec{V} = \vec{V}_0 + \vec{V}_b + \vec{\Omega}_0 \times \vec{R}_b; \quad \vec{V}_0 \rightarrow \text{ Velocity of Origin}$$

$$\vec{\Omega}_0 \rightarrow \text{ Frame Rotational Velocity}$$

$$\vec{R}_b, \vec{V}_b \rightarrow \text{ Relative Position, Velocity}$$

In the context of **ascent** missions, launch point is commonly **taken** as origin of a suitable reference **frame.**

Choice of Coordinate Axes

Further, generally **Cartesian** (i.e. X, Y & Z) coordinate **axes** are used to represent forces and motion variables.

However, in cases where **motion** is confined to a **plane**, either polar **(R, θ)** coordinates or **curvilinear** (s, n) coordinates are also **employed.**

Ascent Mission Force Models

Ascent mission starts from **earth's** surface and ends at a **pre-fixed** point where **payload** is released.

Further, **motion** profile is generally highly **curvilinear**.

Ascent Mission Force Models

In addition, launch vehicle **accelerates** through propulsive **forces**, in the presence of **gravity** & aerodynamic **forces**.

Thus, we need **models** for gravity, propulsive and **aerodynamic** forces, to setup the governing **equations.**

It should be **noted** here that, while there are **other** forces e.g. due to magnetic field, solar radiation, **these** are much smaller in **magnitude** and, hence, are generally **ignored** for the ascent mission **modelling**.

Summary

Ascent mission, while **composed** of time-sequenced **events**, can be defined in terms of **trajectory** segments based on the **nature** of forces and motion.

Newton's law is employed to **formulate** equations in the **coordinate** system that is **located** on the launch **site.**

Forces that influence the **ascent** trajectory are propulsive, gravitational and **aerodynamic**.