AE673A: Rocket and Missile Structures

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Assignment - 2

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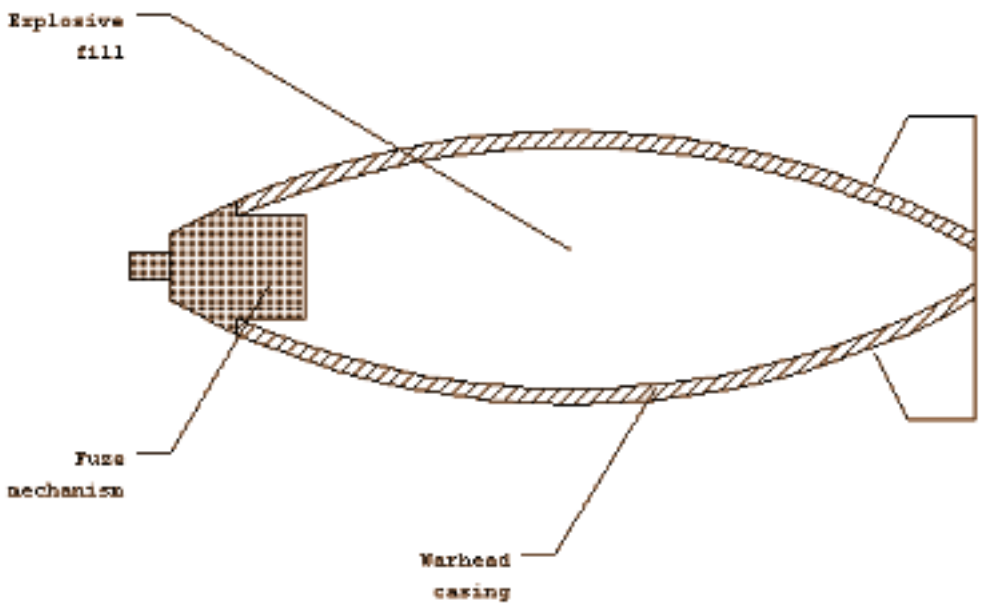
Topic: Warheads and Fuzes

Summary

The only purpose of the missile is to deliver a warhead and detonate at the correct moment by using fuzes.



- **Warheads**

  Its main function is to damage the target. They contain explosives like TNT, nuclear bombs, or metal fragmentation, volatile fuel. Each warhead is designed differently according to their specific roles or usage scenario.

  Here, we shall discuss the non-nuclear high explosive warheads and kinetic energy warheads. Some of them are given below:

- **Shaped Charge Warhead** - (Anti-tank, anti-armor; on impact or a signal the warhead is detonated, and a high-velocity fine jet of a molten metal like copper or aluminum emerges from the front end of the missile and due to its high velocity it penetrates the thick armor plates of tanks or armored personnel carriers)
- **Fragmentation Warhead** -(anti-aircraft, anti-personnel; warhead explodes and a large number of metallic fragments are dispersed at high velocities)
- **Blast-cum-Earth Shock** -(damaging radar, buildings, and humans by creating a high-pressure wave (due to blast) which spreads around from the point of the blast)
- **Runway Penetrators** -(creating huge craters and upheaval of the runway)
- **Incendiary Type** -(used to spread fire at the desired location)

➢ Fuzes

They are the device that senses the right time to detonate the warhead. So every warhead must be accompanied by a fuze. Different types of fuzes work on different principles so they can become suitable for different kinds of missiles, warheads, and environments of operation.

Some commonly used types of fuzes are:

- **Impact Fuzes** -(electric pulse develops when it hits the target due to high deceleration or inertia force of missile)
- **Altitude Fuze** -(Detonation initiated on sensing a preset altitude; uses barometric pressure measurement or radio-altimeter reading)
- **Proximity Fuze** -(Used when impact probability is less; uses inbuilt radar or laser system)

Missile Propulsion

Propulsion is the means of providing power to accelerate the missile body and sustain, if necessary, to reach the required target.

The propulsion of a missile is achieved with the help of a rocket engine. It produces thrust by ejecting very hot gaseous matter, called **propellant.** The hot gases are produced in the combustion chamber of the rocket engine by chemical reactions. The propellant is exhausted through a nozzle at a high speed. This exhaust causes the rocket to move in the opposite direction (Newton's third law). As per the second law, also called the law of momentum, the rate of change of momentum causes a force to be developed.

PARTS OF PROPULSION SYSTEM

All types of rocket propulsion engines contain a chamber, a nozzle, and an igniter. The chemical reaction of propellant chemicals (usually a fuel and an oxidiser) takes place in the chamber and produces gases. The energy due to this high-pressure reaction permits the heating of the product gases to a very high temperature (2000-3500 0C). These gases subsequently are expanded in the nozzle and accelerated to high velocities (2000-4500 m/s). The nozzle design, i.e., its shape and size are critical for the efficient function of the propulsion system.

The nozzle would be subsonic, sonic, or supersonic depending upon whether the exhaust velocity is below, equal to or greater than the speed of sound in air. Thus, the common shapes of nozzles are convergent type, divergent type, or of the converging-diverging type. There are also conical and bell-shaped nozzles.

The igniter, though a tiny element among the components of the rocket engine or rocket motor, has the function of initiating the propulsion system. The propellant ignition consists of a series of complex rapid events, commencing with the receipt of an electrical pulse and heat generation and heat transfer from the products (hot gases and particles) to the propellant grain surface.

PARAMETERS OF PROPULSION PERFORMANCE

The terms relevant for all types of rocket engines and some of which are used as standards for gauging the performance levels of different rocket motors are: thrust, specific impulse, exhaust

velocity, specific propellant consumption, mass ratio, factor of safety, etc

The merit of rocket propulsion design is governed by the impulse delivered per kilogram mass (I_{sp}). If' this figure is high, it means that we have obtained a better design, i.e., we are delivering the required thrust force to the missile with lesser weight of propulsion system). Since a major portion of the weight of most of the missiles is due to propulsion system and more so for longer range systems (For ICBMs it is >96% of total weight) this parameter is very important.)

TYPES OF PROPULSION SYSTEMS

Missile propulsion will be mainly of the following two types:

- Air breathing,
- Non-air breathing

The air breathing rocket engines use the surrounding medium of air for the support of their oxidiser. Thus, they can be used only within the Earth 's atmosphere whereas in the case of non-air breathing engines the rocket engine itself carries its fuel and oxidiser on board and hence can be used in space above the Earth's atmosphere also and is thus independent of the air medium.

Airbreathing Propulsion

In this case the advantage is taken of the atmospheric oxygen for burning the fuel thereby reducing the quantity of propellants to be carried by a missile. This lowers the weight of the rocket greatly as 75 per cent of the total propellant's weight is due to the oxidiser. This can be used either by using small turbojet engines to power the missile or **ramjets**. Unlike turbojets which have extensive rotary machinery (and are therefore costly), there is no such system in ramjets. Here the speed of incoming air is utilised, i.e., when we slow it down using the geometry to intake passage, its pressure rises. Then we add fuel to this and through a nozzle obtain the thrust force, Here a conventional rocket motor (normally solid type) called booster is used to provide the velocity initially at which a ramjet engine can start operating in a steady way. Ramjets cannot operate without atmosphere and also at extremely high speeds. They also have constraints of producing high thrust for a given size. They are highly suited for long range, low manoeuvre, steady and level flying missiles. For such missions they result in a lighter missile.

However, advances in ramjets are being made to meet hypersonic propulsion requirements. Theoretical studies have shown promise in providing airbreathing propulsion even at near orbital speeds like twenty to twenty-five times the speed of sound.

These engines are called **scramjets.** In scramjet engines the very high airflow is slowed down and combustion is carried out when the speeds are supersonic say between Mach 2 and Mach 5. Liquid hydrogen fuel is the suitable fuel for such engines. These craft are winged and can take off from large conventional runways horizontally unlike rockets. They also land back and can be used many times.

State-of-art propulsion systems use chemical combustion as energy source though nuclear, solar radiation, electrical; anti-matter, anti-gravity and the like are under varying stages of feasibility studies and research.

Non-air breathing

Depending on the physical state of matter of the propellant used, the rocket propulsion system is designated as a solid rocket motor, a liquid propulsionsystem or a hybrid propulsion system.

Solid Rocket Motor (SRM)

In a solid propellant rocket, the propellant to be burnt is contained within the combustion chamber or case. The propellant charge or the grain contains the chemical elements for complete burning. Once ignited, it burns at a designed rate till the propellent is completely consumed. Solid rockets are relatively simple as compared to the other systems.

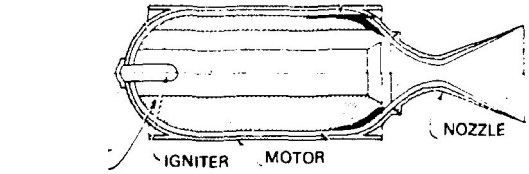


Fig. 3: Sketch of a solid rocket motor

Following are some of the main components of a solid rocket motor.

Casing In all solid rocket motors, the casing is a pressure vessel designed and fabricated to withstand up to certain internal pressures. The casings are subjected to a number of quality assurance tests for strength, toughness, soundness of weld and hydraulic pressure. The casings are provided with thermal insulation on their inner surface to protect them from hot gases.

Propellant grain Solid propellants have fuel and oxidiser mixed in a suitable proportion.

On composition basis there are two types of propellants.

Homogeneous: They are so called because in these oxidiser and fuel are at molecular level. Famous example being 'double base' type which is a mixture of nitrocellulose and nitro-glycerine in a certain proportion. They are gelled into a semi-rigid body and extruded. They have a fairly long shelf life of more than twelve years.

Heterogeneous: In this, as the name suggests, the oxidiser and fuel are mixed mechanically in a mixer. They are also called composite propellants. Oxidisers are inorganic crystalline salts like perchlorates or nitrates of sodium, potassium or ammonia, while the fuel, which also acts as binder, is an organic resin. HTPB has become the single most widely used resin.

Homogeneous propellants (double base) give specific impulse of about 220 seconds maximum, while composite propellants give 260 seconds and have higher densities but have smaller shelf life. In longer range missiles only composite propellants are used while in smaller tactical missiles, double base propellants are used.

Igniter Igniter is the device that helps to start the burning of the main propellant. grain of the rocket motor. The initiation is done using electrical power by heating a resistance wire and initiating a primary composition. Adequate safety provisions are made through electromechanical devices to prevent accidental initiation.

Nozzle. The nozzle is the component through which the hot gaseous mass in the motor case is expelled out. This has to be designed to withstand high temperatures and flow of gases at high velocities. The dimensions of the nozzle are critical for the performance and efficiency of the rocket motor. Nozzles are also used for producing control force for the missile. Such a technique is called **Thrust Vector Control**. It is done by deflecting the flow out of the nozzle or by gimballing of a portion of the nozzle. This nozzle gimballing requires flexible bearing nozzle.

Liquid Propulsion System

Most of the liquid propulsion rockets are used where long duration of operation is required. Here the oxidiser and fuel (both liquid) propellants are stored in separate tanks in the missile. There are basically two types of liquid propellants deployed: cryogenic (with boiling temperature below 120 K like liquid hydrogen, liquid oxygen, etc.) and noncryogenic or storable type (like kerosene, hydrazine, nitrogen tetroxide, hydrogen peroxide, etc.). In space missions usually both

propellants (oxidiser and fuel) used are cryogenic, whereas in missiles the propellants used are storable or non-cryogenic.

Liquid propellants, especially with cryogenic propellants, give better specific impulse and better stage mass ratio for the same thrust force and duration of burn as compared to solid propellants

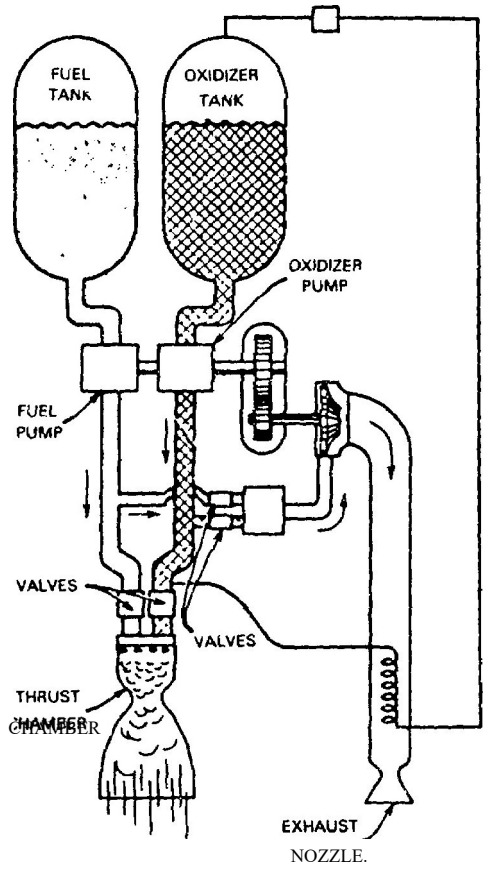


Fig. 4: Diagram of a liquid propellant rocket engine with turbopump feed system

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INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

AE673A: Rocket & Missile Structures

Assignment 2

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Chapter 2: Missile Propulsion

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1 INTRODUCTION

Propulsion refers to a process that accelerates a missile system to reach its intended target. Newton's three laws of motion provide the scientific basis behind the working of a missile propulsion system. A typical missile propulsion system consists of a rocket engine, which ejects propellant to produce thrust that propels the missile body.

2 PARTS OF PROPULSION SYSTEM

The three main parts of a propulsion system are:

1. Chamber: This is where the chemical reactions of the propellant take place to produce gases.
2. Nozzle: The gases are expanded in the nozzle and accelerated to high speeds.
3. Igniter: The igniter initiates the propulsion system. It is responsible for heat generation and transfer to the propellant grain surface.

3 PARAMETERS OF PROPULSION PERFORMANCE

Two important parameters for measuring the performance of propulsion systems are:

1. Burning rate: It is the rate of regression of the burning surface of a propellant as the combustion progresses.
2. Impulse delivered per kg mass: This parameter should be high, as it implies that we are imparting the required thrust force to the missile with a lesser weight of the propulsion system.

4 TYPES OF PROPULSION SYSTEMS

Propulsion systems can be broadly classified into the following two categories.

- Air-breathing Propulsion: Uses surrounding medium air as oxidiser.
- Non Air-breathing Propulsion: The fuel and the oxidiser are carried on board the engine.

In missiles, non air-breathing propulsion systems are widely used. Further classifications of non air-breathing rocket engines are:

1. Solid Rocket Motor (SRM): all the chemicals necessary for combustion are casted in a solid casing.
2. Liquid Propulsion System: the fuel and the oxidiser are stored in separate tanks in liquid state.
3. Hybrid Propulsion System: the fuel is in solid state while the oxidiser is in liquid state.

5 TESTING OF PROPULSION SYSTEMS

Before a rocket engine can be put to use, it has to be tested. Some of the tests performed are:

- Manufacturing, inspection and fabrication tests
- Component tests
- Static rocket systems tests
- Static vehicle tests
- Flight tests

6 Applications of Propulsion Systems

The modern-day applications of a propulsion system can be categorised as:

- Defense: Propulsion systems are used in guided lethal missiles for warfare.
- Civil: Propulsion systems are used to propel rockets which put satellites into the earth's orbit. These satellites are useful for scientific research, communication and weather forecasting.

Assignment 2

AE673

Missile Aerodynamics

Submitted by: Group ABS

Group Members

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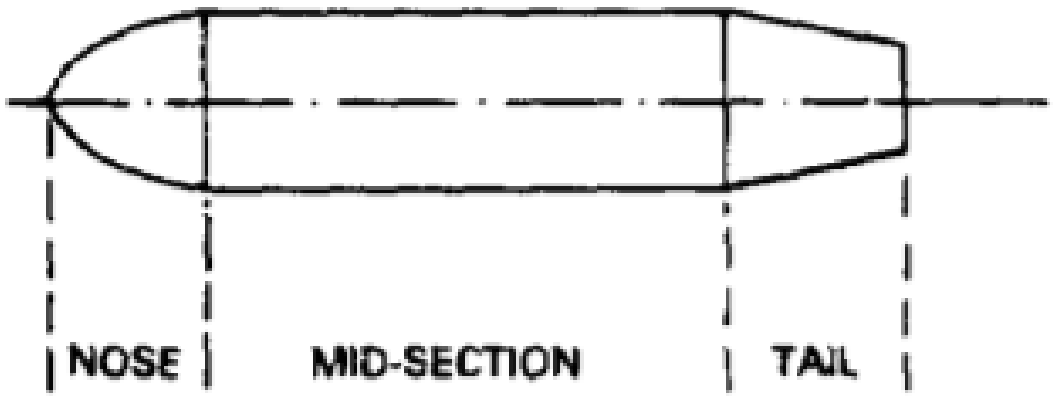
Aerodynamics:

Study of movement of a body in space in the presence of air is called aerodynamics. Study of Aerodynamics plays a vital role in the designing of rockets, aircrafts and missiles. Study of aerodynamics analyze different stability, performance and safeguard parameters.

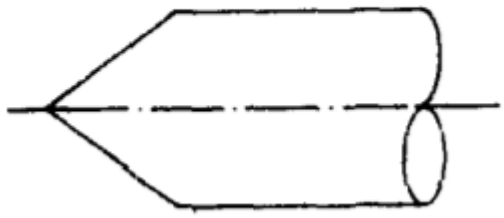
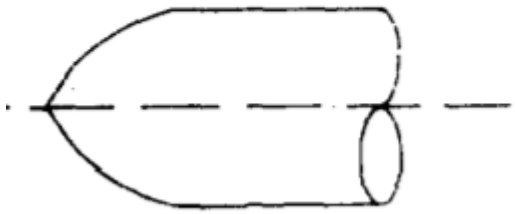
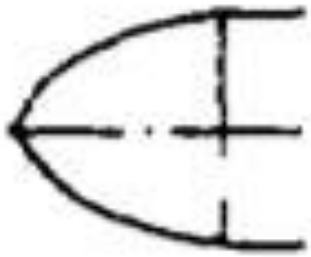
Aerodynamically advanced structures:

- Simple external configuration to reduce development time, cost, drag offered by air resulting optimizing the missile range, speed, stability and maneuverability.
- Less power consumption.

Body of missile:

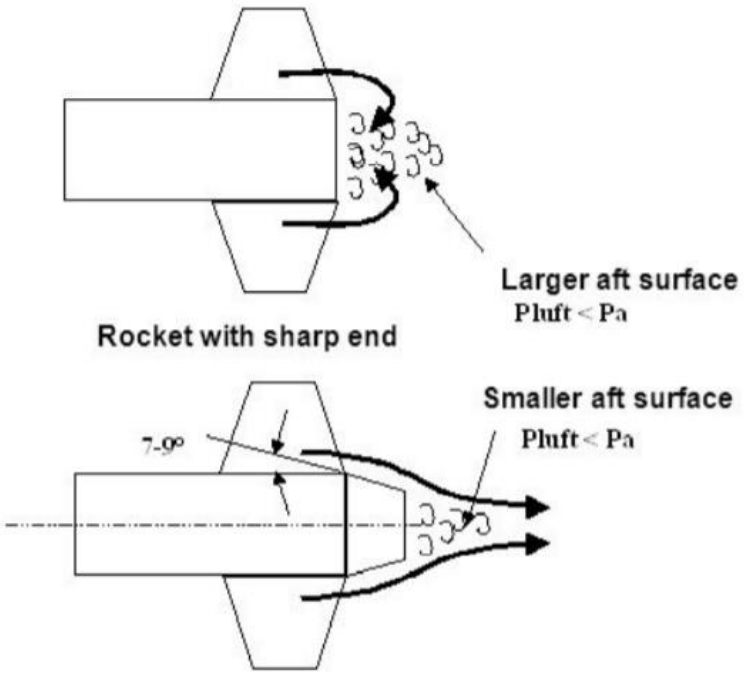


- <u>Nose:</u> (mostly at supersonic speeds)
  - Commonly used shapes:

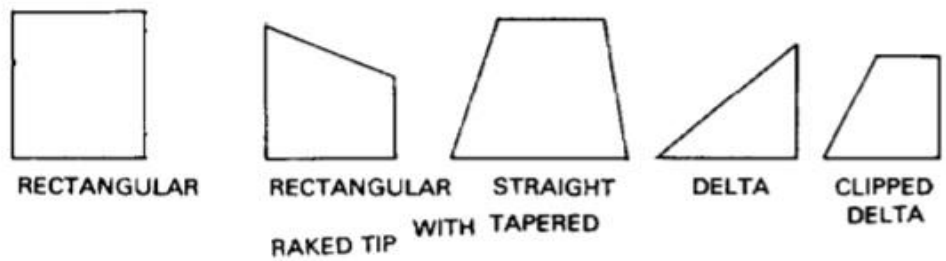
Shapes	Figure	Advantage	Disadvantage
Conical		Handles shock waves efficiently (Oblique instead of normal)	Lesser structural integrity compared to other two.
Ogive		Slightly lower drag compared to conical, Blunter nose provide better structural integrity.	Costly to manufacture
Hemispherical		Excellent structural integrity, High resistance to aerodynamic heating	Very High drag

- <u>Mid-section</u>: (Cylindrical in shape)
    - Easy to manufacture.
    - Objective of design– efficient Load carrying abilities.

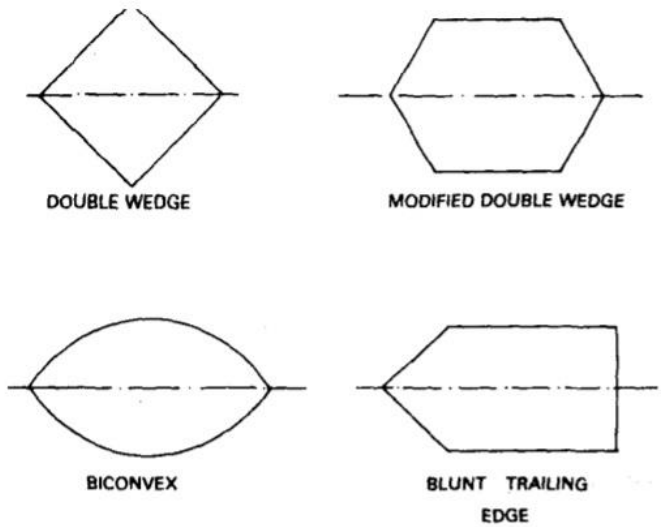
- <u>Boat tail section</u>: (Tapered)
    - Purpose- Reduce the drag of a body (base area reduced resulting decrease in drag)



<u>Wing design:</u>



Typical supersonic wing planforms



Typical supersonic airfoil sections

Each planform and airfoil have certain advantages and disadvantages over another. But usually we prefer one which offers minimum drag and maximum lift keeping the structural requirements in mind. In general, sharp nosed symmetrical airfoil sections of the double wedge, modified double-wedge, or biconvex variety result in the most efficient aerodynamic design.

Safeguards:

- A Designer should keep these in mind while designing missile structures:
    - The missile should not strike the parent aircraft during boost or jettison.

- The missile structure should not fail under any condition of flight in the immediate vicinity of the parent aircraft.
- The jet blast from the rocket of the missile should not adversely affect the parent aircraft structure and its operating components such as air inlets and control surfaces.

Fabrication material:

- Usually Al and its alloys, steel, magnesium and titanium are used
- A Designer should choose a material for missiles which have:
  - Material strength,
  - High temperature properties of the material,
  - Stiffness or deformation characteristics,
  - Corrosion resistance,
  - Ease of fabrication.

  And at last Adequate strength with minimum structural weight should be the aim of the designer.

AE 673 : Assignment 2

Summary of Chapter 6 :

Launchers & ground support systems

Submitted by group : Saturn IB

Launching in the case of missiles is different from take-off in the case of aircraft. Missiles are launched at very high speeds with the help of launchers. Launchers can be stationed in silos underground or on submarines or land vehicles. Small missiles can even be launched manually. The launchers can be complex to design as they may need a high rate of turning in elevation with a precise aim for a particular target.

The location of the target and tracking is done by a ground support system with the help of radars and detectors. The more the range of detectors the higher is its capability to intercept incoming threats. In certain surface to air missiles, the illumination of the target for the missile to home-in is done by ground support while command generation and transmission system are needed in command guided missiles for it to reach the intended targets. The intelligence and communication teams also form a part of ground support for getting accurate information on the target and its location.

The difference between enemy aircraft and friendly aircraft is essential to avoid friendly fire. This is done with the help of IFF or Identification Friend or Foe. In this system, an audio signal of known frequency is beamed at target and if the signal is returned then it's a friendly aircraft.

Several periodic checks and monitoring of vitals are done to maintain the workability of missiles which are carried out by automatic and computerised methods. Several simulators are also provided for training the personnel to effectively operate the missile.

Test ranges are made for real-life testing of missiles in safe areas. These tests are carried out in 2 phases – deployment testing and user evaluation testing, with the help of suitable instruments. The location of the test range depends on the range and size of the missiles.Thus the launchers and ground support systems play a very crucial role in eliminating threats.

AE-673

ROCKET AND MISSILE STRUCTURES

PROF KAMLE

ASSIGNMENT 2

CHAPTER - 5 WARHEADS AND FUZES

GROUP - VALIANT

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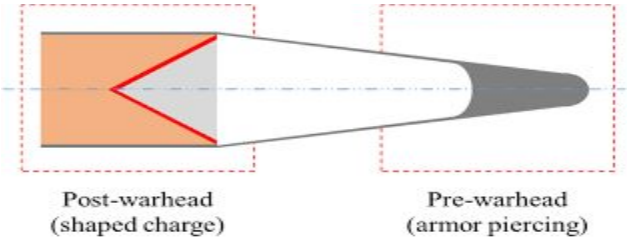
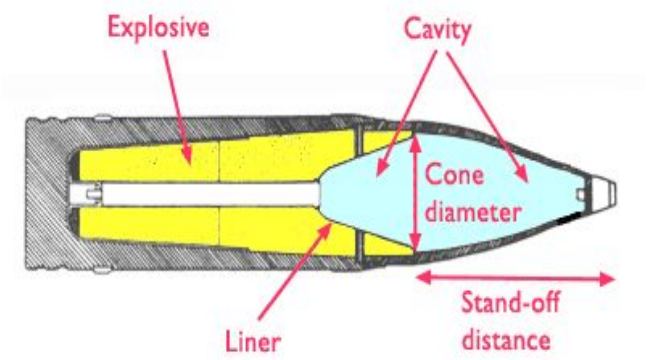
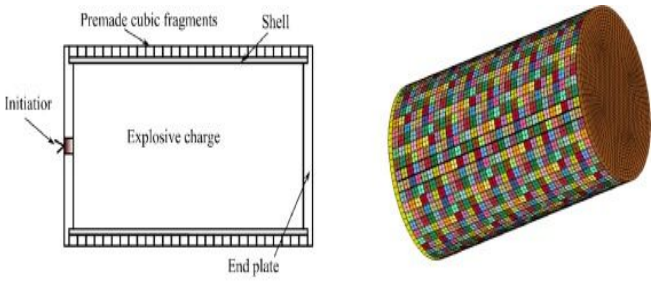
WARHEADS

A warhead is the explosive or toxic material that is delivered by a missile, rocket, or torpedo. The main purpose of a warhead is to damage the target. A typical warhead is based on chemical explosives and is called **"High explosives"**.

In non-nuclear high explosive warheads and kinetic energy warheads. These are specifically designed for different roles:

Name: **Shaped charge warhead**	
Target: **Tanks or armoured personnel carriers**	
Explosive Shape: **Hollow cone of pure Copper**	
Draw-backs: **Loses lethality when deflected**	
Counter-measures: **1- Upper layer of armour filled with explosive which explodes on being hit.** **2- Having composite (multilayered) armour on the tanks.**	
Modifications: **1- Twin warheads in the missile which detonate sequentially within milliseconds.** **2- Composite armours are penetrated using kinetic energy warheads.**	

Name: **Fragmentation Warhead**	 (a) Warhead structure (b) 3D Element model
Target: **Aircraft or missiles, light vehicles or persons.**	
Explosive Shape: **Metallic casing around with groovings or a large number of small metallic cubes or spheres.**	
Impact: **The damage is measured by the number of fragments hitting the target and the energy content of these fragments (which is a function of mass and velocity of these fragments).**	
Advantage: **Used when direct hit is difficult because of high velocity of target aircraft and limitations of guidance**	

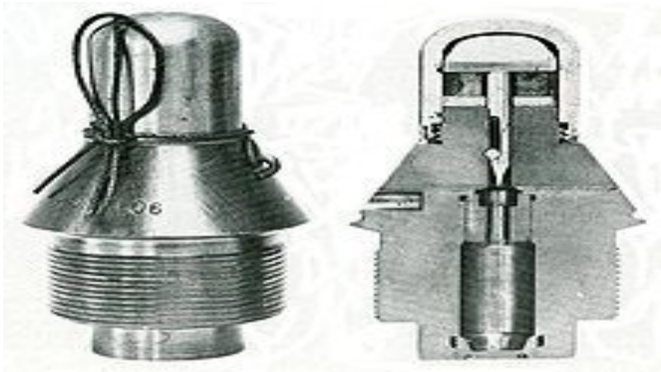
Name: **Blast-cum-Earth Shock**	
Target: **Damaging radars, buildings and even human beings**	
Impact: **Creation of a high pressure wave (blast) which spreads around from the point of blast. In other types shock waves are generated and propagated through the ground.**	
Advantage: **Can damage the foundations of buildings and destroy them; effective against inflammable targets, PF (Pre fragmented) for soft targets.**	

Name: **Runway Penetrators**	
Target: **Penetrate the runway concrete surface**	
Impact: **Create huge craters and upheaval of the runway.**	
Advantage: **Difficult to repair the runways once damaged, preventing takeoff of other missiles of the enemy**	

Name: **Incendiary Type Fuze**	
Target: **Fuel dumps and ammunition depots.**	
Impact: **Cause large-scale Fire**	

FUZES

Fuzes are the devices which sense the right moment to detonate the warhead. In addition, a fuze will have safety and arming mechanisms that protect users from premature or accidental detonation. The most common types of fuzes are impact fuze, altitude fuze, and proximity fuze:

Name: **Impact Fuzes**	
Used in: **Anti-tank missiles, anti-aircraft and anti-ship missiles.**	
Mechanism: **An electric pulse develops when it hits another solid object with a certain relative velocity which leads to high deceleration or inertia force. This electric pulse is used to trigger the warhead.**	

Name: **Proximity Fuze**	
Used in: **Missiles designed for targets such as planes, missiles, ships at sea, and ground forces.**	
Mechanism: **A very low power and low range radar system transmits radiation only when the target is a small distance away and then when it receives a certain strength of reflected signal it detonates.(active)** **In a passive system it is generally infrared based proximity fuze.**	
Use: **Used when the impact possibility is less due to unavoidable errors in guidance and control**	

Altitude Fuze - Warhead detonation is initiated on sensing a preset altitude. This altitude sensing could be based on barometric pressure measurement or radio-altimeter reading.

SHOGUN

ASSIGNMENT - II

Guided Missiles – Chapter II Summary

Sanjay Dumpeti
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9/16/2020

Chapter 2

Summary

Propulsion is the means of providing power to accelerate the missile body or sustain it. The main basis of the propulsion system is based on Newton's Laws of motion. Propulsion of the missile is like that of the rocket system; propellent is used to burn in the combustion chamber to accelerate by releasing the hot gases through the nozzle.

The propulsion system mainly consists of the igniter, combustion chamber and the nozzle. The igniter starts the reaction between the propellant chemicals, the combustion chamber provides the space to burn the chemicals to full potential, and the nozzle acts as the exit for the hot gases such that it gives the power to propel the missile.

The parameters of the propulsion performance are thrust, specific impulse, exhaust velocity, specific propellant consumption, mass ratio, the factor of safety. The success of the rocket design is determined by burning rate (The burning surface of a propellant recedes as combustion proceeds, the rate of this regression is called burning rate) and impulse delivered per kilogram mass, more the impulse better the design.

Missile propulsion is of two types: -

- Air-breathing System
  This type of system uses the atmospheric oxygen as the oxidizer thus reducing the load carried by the missile. These can be used only in the earth atmosphere.

- Non-Air breathing system
  Non-breathing engines carry their own fuel and the oxidizer and can be used in the outer space. Based on the state of the propellant used, there are three types of system.
    1. Solid Rocket Motor
    2. Liquid Propulsion System
    3. Hybrid Propulsion

AE673A: Rocket and Missile Structures (2020-21)

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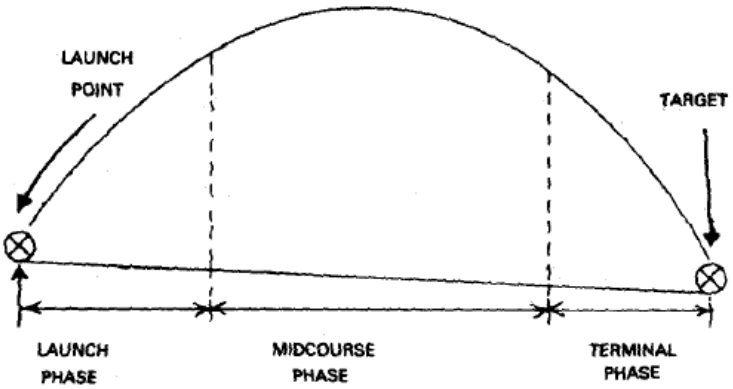
Agni-5 (Intercontinental Ballistic Missile) | *src: google images*

CH3: MISSILE GUIDANCE & CONTROL

MISSILE GUIDANCE

In order to ensure that a launched missile hits the target, a guidance system is essential.
Based on the mission profile, various types of guidance systems are used.

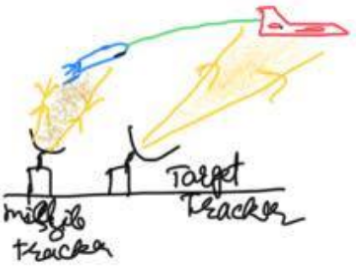


Stages of typical missile mission | *src: DRDO guided missiles*

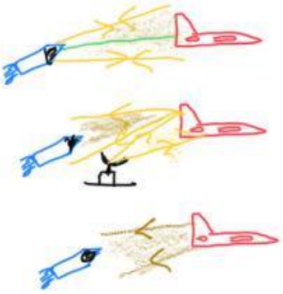
The following are the types of guidance systems used in general:

- <u>Command Guidance</u>
  The guidance signal to stay on the trajectory(aka LOS) is computed and transmitted from the launch site to the missile. And thus the missile after receiving the signal actuates via its control systems.
  Communication links:
  - Wired link (up to 4km range and v<1Mach)
  - Fibre-optic wire link (beyond line of sight and v<1Mach)
  - Wireless radio link

  Pros: Little guidance equipment onboard
  Cons: cannot be used for multiple targets

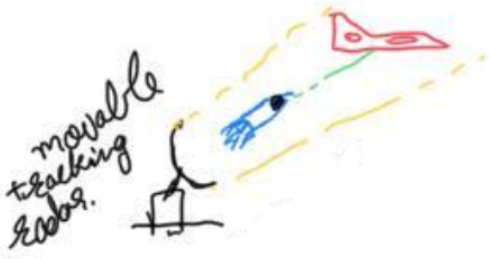


- <u>Homing Guidance</u>
  The missile receives signals reflected/emanated from the target and corrects itself thus aka “fire & forget”. Instruments: homing head and seeker head. Types:



  - Active: Missile illuminates the target and receives its location. Range<4km. Accuracy>>command guidance
  - Semi-Active: Base station illuminates the target which is reflected towards the missile. Range~50/60km
  - Passive: No illumination, just receiving the EM/infrared signals from the target. Aka “Heatseeker”. Range~7/8km

- <u>Beam Rider Guidance</u>
  The missile is fired into a cone of radiation formed by base station radar pointing towards the target. The sensitivity decreases at the start and end of flight. Missile equipment tracks the center axis of the radar beam. Missile needs to be launched nearly parallel to the beam axis.



  Pros: Simple, low cost, high reliability
  Cons: Not at operating speed thus less efficient controls and high lateral acceleration in the terminal phase.

- <u>Inertial Navigation System</u>
  Accelerometers are used to measure translation acceleration, velocity and distance traveled. Systems can have accelerometers kept on reference axis (using gyroscope) or fixed with body axes.
  Pros: It does not rely on external reference and guidance, and therefore cannot be easily detected.
  Cons: It demands high accuracy from individual components. Small errors can combine to produce substantial errors. Therefore, this system is used for a large and fixed target like a city.
- <u>Stellar Guidance</u>
  Uses star constellation as a reference point for guidance.

MISSILE CONTROL

The Control system actuates the control surfaces and thrust vector surfaces to maintain zero deviations from the critical path. Various turn generation methods are used such as,

- Aerodynamic Control generates a differential force. It results in the rotation about a particular axis by computing the turning moment as a function of control force, altitude, velocity, location of NP, CG, and CP during a mission.
- Thrust Vector Control generates force and moment by deflecting thrust force. Either by gimballing the engine, rotation of nozzle, or by vane/blade insertion at the jet's exit.
- Reaction Control System governs on the propulsion. Extra small thrusters provide controls along with the various axes.

Major control system elements, Autopilot, and Actuation systems use feedback from the inertial sensors & aerodynamic deflection respectively, throughout the mission to develop counter moments that keep the missile on its desired path.

MISSILE PROPULSION

Submitted by: Group 14

Propulsion is one of the main conceptual parts of a rocket or missile. A theory of propulsion is needed to get the rocket off and get it where it needs to be arrived. Propulsion makes use of Newton's Laws of motion, just like any other physical substance. So, a force is needed to propel the missile/rocket. By making use of Newton's third law, where we eject matter out of the rocket at high velocity, the ejected matter inturn gives off an equal and opposite reaction to the rocket/missile, and there we have the force needed to propel.

Propulsion is a high energy process. It needs special structures to facilitate the process. Every propulsion system basically contains a chamber, a nozzle, and an ignitor. Since the initial stage of propulsion is combustion, which in itself means increased temperatures and pressure, we will need a shell that can withstand both high temperature and pressure, which in itself is a challenge from a structural perspective. The nozzle converts the potential of the pressure built up on the combustion into kinetic energy. The shape of the nozzle is mostly a converging diverging type, but can vary according to the requirements. The ignitor is responsible for the start of the whole process. The ignitor part is made of heat releasing things, which is often ignited by an electric pulse.

Types of Propulsion systems

They are basically of 2 types-

1. Air breathing(used only inside earth's atmosphere)
2. Non-Air breathing(can also be used in empty space).

Depending on the physical state of matter of the propellant used, it can be divided as a solid, liquid or a hybrid propulsion system.

In a solid propulsion system, the propellant grains are burnt inside a pressure chamber to produce thrust. The grains can be homogeneous or heterogeneous. In longer range missiles only heterogeneous propellants are used while in smaller tactical missiles, homogeneous propellants are used. The grains can vary from a few kgs to 125 tonnes. An igniter is used to start the combustion.

In the liquid propulsion system, the oxidiser and fuel (both liquid) propellants are stored in separate tanks. In space missions generally both propellants (oxidiser and fuel) are cryogenic (boiling point below 120 kelvin), whereas in missiles the propellants used are non-cryogenic. The engine has an injector through which propellants are injected at high speeds. They react in the thrust chamber and produce hot gaseous products. Cryogenic propellants give better specific impulse and better stage mass ratio for the same thrust force and duration of burn as compared to solid propellants.

In the Hybrid Propulsion system, one of the propellants is solid while the other is liquid. Usually the oxidizer is in liquid state. This system is very rarely used though it has certain advantages. It has not found much favour with missile designers the world over

Airbreathing Propulsion

In this system the advantage is taken of the atmospheric oxygen for burning the fuel thereby &&g the quantity of propellants to be carried by *unissile. This lowers the weight of the rocket greatly. 75 percent of the total propellant's weight is due to the oxidizer. This can be used either by using small turbojet engines to power the missile or ramjets.

Ramjets cannot operate without atmosphere and also at extremely high speeds. They also have constraints of producing high thrust for a given size. They are highly suited for long range, low manoeuvre, steady and level flying missiles. For such missions they result in a lighter missile.

However, advances in ramjets are being made to meet hypersonic propulsion requirements. Theoretical studies have shown promise in providing airbreathing propulsion even at near orbital speeds like twenty to twenty five times the speed of sound.

In scramjet engines the very high airflow is slowed down and combustion is carried out when the speeds are supersonic between Mach 2 and Mach 5. Liquid hydrogen fuel is the suitable fuel for such engines. These craft are winged and can take off from large conventional runways horizontally unlike rockets. They also land back and can be used many times. However a large effort has to go in to make this realisable.

Testing of Propulsion system

Before a rocket engine can be put to use, it has to be tested. Some of the tests are as follows.

1.Manufacturing, inspection and fabrication tests
2. Component tests
3.Static rocket systems tests
4.Static vehicle tests
5.Flight tests:
    (a) on a specially instrumented flight test range with special flight test vehicle

(b) with a production vehicle.

Uses of Propulsion System

As stated earlier, the rocket engines are used in all kinds of missiles, satellite launch vehicles, etc. The technology of warhead gtridance accuracy determines the lethal capacity of a missile They are particularly used in meteorology, weather forecasting data, survey for minerals, satellite communication, mapping, etc.

Missile Propulsion

The process or act of providing power to rockets/missiles is called Propulsion, whose core is based on Newton's laws of motions. The rocket engine, responsible for *Thrust* production, does so by ejecting propellants produced in the combustion chamber, leading to the act of propulsion.

Three main parts of propulsion engine are :

- ***Chamber*** :- The place where the chemical reaction of propellants takes place, causing the temperature to reach (2000-3500 C).
- ***Nozzle*** :- A device with varying cross-section of area, used to expand and accelerate the gases produced in the chamber.
- ***Igniter*** :- The component of rockets responsible for initiating the propulsion system. Although small in size, they are no less important to the above parts.

There are certain propellant combinations which do not need an igniter and they are called hypergolic.

The parameter of performance of rockets can be measured using thrust, specific impulse, exhaust velocity, burning rate, etc.

Missile Propulsion are mainly of the following categories

- ***Air breathing*** :- The engines of this kind use the surrounding air as oxidizer limiting them to Earth's atmosphere.
- ***Non-air breathing*** :- Carry both oxidizer and fuel, allowing for use even in outer space.

Depending on the physical state of propellant we have *Solid Rocket Motor*, *Liquid Propulsion System*, *Hybrid Propulsion*.

Before being put to use, the rocket engines have to be tested. Some of the tests are manufacturing, inspection, fabrication, component, static rocket systems, static vehicle and flight tests. Among which the flight test of the integrated system is the ultimate test.

The rocket engines have vast areas of military applications like warheads, various missiles, etc., and civil applications like satellite launch vehicles, meteorology, weather forecasting, mineral survey, satellite communication, mapping, etc.

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GROUP – 6

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6. Launchers and Ground Support Systems

Ground system is needed for the missile system to launch at a specific target. The launchers can be vary based on the types of missile. The large ballistic missiles are launched from silos under the ground or submarines or mobile vehicle based launchers. The small missiles are launched from a launch-cum-container tube resting on a human shoulder. Radar, optical sights or infrared detectors are required for target search and tracking.

Along with this a communication and intelligence systems are also needed on the ground to coordinate the functions of various missile launching units and have adequate information on targets. The system **IFF**(Identification Friend or Foe) is used to differentiate between friendly and enemy aircraft. It works on the audio signals by sending the audio signals at known frequencies at pre-defined targets. If the signal is returned by the aircraft it is classified as friendly aircraft.

CHECKOUT AND SIMULATORS

An automatic and computerized check procedure is done on the ground to test if the deployment and other operations are working properly. Similarly, simulators simulate all the electrical and microwave components of the missile.

TEST RANGES

Extensive testing takes place in two phases:

a) Development testing.
b) User evaluation testing.

These safe ranges have instrumentation facilities to collect data. The size and range of the missile and the flight path decides the safety zones. The instrumentation facilities provide for tracking radars, electro-optic instruments and telemetry receiving stations and meteorological facilities. In the range, flight tests are carried out from the Block House. Real-time data processing facilities and other facilities exist to ensure the range safety for carrying oat flight vehicles in case of using telemetry command system.

GROUP – VOYAGERS

TOPIC – MISSILE AERODYNAMICS

ASSIGNMENT -2

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ASSIGNMENT - 2 , DRDO-Summary

Introduction – Basic Structure of Missiles

The missile is launched generally vertically or at angle from vertical, the thrust it produces has to counter gravity and aerodynamic forces (drag) acting on it

A missile has three sections:

1**. Nose section -** They can be conical, ogival, hemispherical. The shape is chosen on basis on required characteristics such as - conical for hypersonic speed, hemispherical - though it increases drag but is better in structural integrity and infrared sensing, thus there's always a trade off

2. **Mid - section** - in most cases its cylindrical due to advantage of drag, ease in manufacturing and load carrying capacity. The midsection increases lift coefficient and move Centre of pressure towards the end

3**. Tail section** - in a boat tail section the base area is reduced due to tapering thus there's a decrease in base drag

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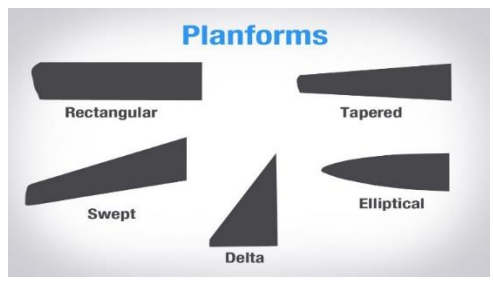
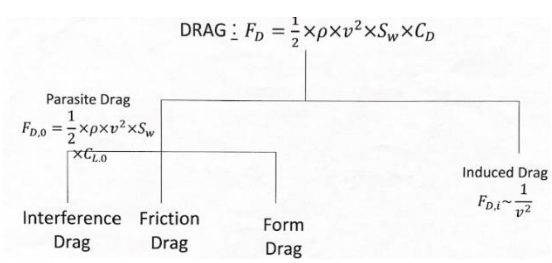
WING DESIGN

Important factors such as Reynold's number, fluid viscosity and some other dimensional properties compare the aerodynamic characteristics for planform



For selecting particular configuration of airfoil for a particular mission, there is a tradeoff between **aerodynamic efficiency, structural weight and cost of manufacturing**.

The various forms of drag are given in figure –



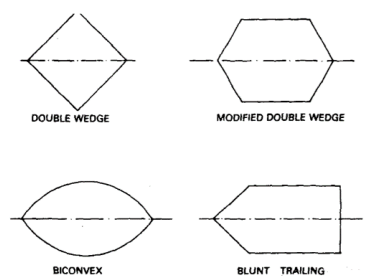


Fig. 17: Typical supersonic airfoil sections

Aerodynamic Launching Problems

Undesirable **launching dispersion,** danger to parent are some risks that designers have to overcome. **Ground Launching problems** can be resolved by ensuring range safety and installing destruct system. In **shipboard and underwater launchers** space limitation, motions of the ship and people in ship requires care before launching a missile.

FABRICATION MATERIAL

The major concern during fabrication is the strength-to-weight ratio of the material used. Higher this ratio the better it is. Newer and lighter materials like carbon-carbon variety, graphite compounds etc. are used instead of metals.

Some important criteria during material selection are as follows:

1. Material strength,
2. High temperature properties of the material,
3. Stiffness or deformation characteristics,
4. Corrosion resistance, and
5. Ease of fabrication.

- Adequate strength with minimum structural weight should be the aim of the designer.

Roll No. 20101049 Assignment - 2 15/09/20

Summary - Chapter 7

The growth in knowledge of guided missiles has been spurred by an international race for supermacy and commercial aspects. The development ~~is~~ or failure hits headlines and acquires political proportions both nationally and internationally. MTCR, a union of seven countries have decided to stop export of knowledge and such items to third world countries, with successful launch of missiles in India, China being advanced in this field is not affected but a lot of heat, light have been developed by ~~politicians~~ political observers of ~~&~~ Pakistan. Nationwide, few ~~more~~ side effects are surfacing like private ventures in missile projects. One is 'Strategic Defence Initiative' which provides protective shield against missiles using laser beam technology called as 'Star Wars'. Such strategic thought has developed 'Mutally Assured Destruction - MAD Theory'. India has come out with a proposal HYPERPLANE for nuclear waste disposal into sun. In this, a single-stage fully reusable vehicle would be used. It is safe, reliable and low cost means of transportation. It demands ~~three phase~~ highest possible specific impulse for which various options of propulsion are available. With advancement of Indian technology, poorer Third World countries would turn to India for weapons at low price which India can gladly afford.