# Stability Analysis of Warhead satellite after Missile launch

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***Abstract:*** We know that a missile launch from a satellite can produce a huge amount of reaction force. In this paper we analyses the impact of such force on a satellite body in space orbiting around the earth. The satellite in orbit must be stabilized and unperturbed. Actuators and reaction thrusters are used to stabilize the satellite body according to the mission objectives. The concept of two body problems and orbital transfer applied over this problem to analyze the change in the attitude of the satellite and the concept of Kepler's third law can be used to find the time period for the satellite to return to its original orbital position. This paper identifies the final satellite attitude in terms of orbit distance & velocity after the missile launch impact and time period for return to the initial position.

**Keywords— Warhead Satellite, Stabilization, Kepler's third law, Newton's universal law of gravitation, specific angular momentum**

## I. INTRODUCTION

The recent trends show an increase in space technology. In these times a warhead satellite need not look an idea from a science fiction novel, many developments have taken place in recent past. In this paper we will study the stability of a Satellite equipped with a warhead missile. The effect of a missile leaving a satellite body can destabilize it out of its orbit. In the advanced and modern world, the hiding capabilities of weapons helps and plays an important and strategic role in attacking and defending the enemy. The space weapon or warhead satellite will help to do so. In space, the satellites play an important role in every possible way and can be used for many purposes like communication, espionage, and observation of space, planets, sun, moon and other planets. The type of satellite can differ according to their use, defined payload or orbital criteria. Similarly, satellites have capabilities of carrying missiles and warheads as its payload and the satellite carrying a warhead is called a warhead satellite. The target can be on land or in space such as another satellite.

The missile can be loaded as required and will have capabilities to fire on land from space, on a satellite (present in a space), on an incoming missile which is entering from the space (like ballistic missile, inter-continental ballistic missile and etc.), and even on asteroids approaching towards the earth. The threat posed by an asteroid impact is imminent and according to NASA nuclear missiles are our best bet and launching one within the space could be quite helpful. Rogue satellites and space debris is another danger lurking behind the horizon as the number of satellites are increasing in space.

The study intends to the impact of missile launching on the satellite stability. For this we will be considering *Vajrasat* a hypothetical satellite for analysis and stabilization study.

## II. SIMILAR CONCEPTS

A kinetic bombardment was a similar concept developed during the cold war era, the idea was to launch a projectile on a planetary surface. The kinetic energy stored in the projectile would create a large destructive force.
This idea of a weapons system involved a telephone size projectile launched from a satellite to earth's surface. Jerry Pournelle created the concept while working in operations research at Boeing in the 1950s before becoming a science-fiction writer.

An Orbital weapon is a weapon that is launched or executed from an orbit in space, as of now there are no orbital weapons in space although many countries have launched a series of renaissance satellites for defense and military purposes. Several orbital weaponry systems were designed by the United States and the Soviet Union during the Cold War. During the World War 2 the Nazi Germany planned to develop a large orbital mirror to laser beam, it was also known as sun gun.

Development of such weapons was stalled after the outer space treaties which prevented placement of any mass destruction weapon in space

The only true orbital weaponry to be executed for scientific purposes was the Japanese *Hayabusa2*(a robotic space probe), it released an explosive device named as 'impact or 'from space to an asteroid 162173 Ryugu, the plan was to collect the debris from the explosion.

## III. ASSUMPTIONS

The main focus of this analysis was on the stabilization of the satellite. There are few assumptions taken into consideration

1. The satellite is having all the essential and required components tested and are of space grade equipment.
2. The missile is capable of launching from space to space based objects (like satellites, asteroids or ballistic missiles etc.)

3. The targets are decided by using ground station and will work on the basis of algorithm coded in MCU (micro-controller Unit)
4. The center of gravity of the satellite is balanced.
5. The material considered for the satellite is of space grade (Aluminum T6061)
6. There are no external torques taken into consideration
7. For the purposes of calculating the specific angular momentum mass of the satellite is not considered
8. The orbital perturbations are not taken into account
9. The configuration of the missiles is not considered
10. the forces of other bodies in space are negligible.

**Symbols**

| | | |
|---|---|---|
| a | Semi major axis | $a = (r_1 + r_2)/2$ |
| T | Time period | $T = 2\pi a^{\frac{3}{2}}/\sqrt{\mu}$ |
| h | Angular Momentum | h= r X v |

## IV. Orbital Maneuvering.

At some point during the lifetime of almost all satellites, we need to change one or more of the orbital elements according to the mission objectives. The total maneuver need at least two propulsive burns. In general, the change in velocity vector to go from one orbit to another is

$$\Delta V = V_{NEED} - V_{CURRENT} \qquad (1)$$

We can determine the current and needed velocity vectors from the orbital elements, the position vector does not change much during impulsive burns.

## V. Design and Analysis

The satellite is designed in CATIA V5 (CAD software). The satellite is of cylindrical shape from the top and at the bottom a closed latch (which contains missiles), is attached, which is placed towards the earth surface. The satellite is also attached with solar panels facing towards the sun and a parabolic antenna facing towards earth.

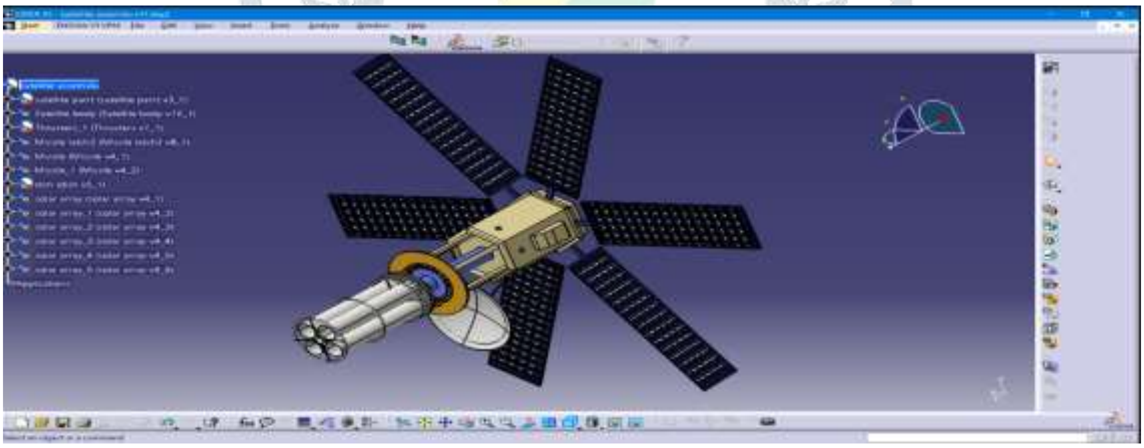


Fig.4 Design of Warhead satellite

**Satellite configuration:**

| | |
|---|---|
| Volume | 129.44 $m^3$ |
| Mass | 559053.737kg |
| Area | 914.55$m^2$ |
| Moment of Inertia | $I_{ox}G$ =6.77x$10^6$ kg.$m^2$<br>$I_{oy}G = 6.761\text{x}10^6$ kg. $m^2$,<br>$I_{oz}G = 1.798\text{x}10^6$kg. $m^2$<br>$I_{xy}G = 16562.73$kg. $m^2$,<br>$I_{xz}G = 10131.51$ kg. $m^2$<br>$I_{yz}G = -22002.576$kg. $m^2$ |

| | |
|---|---|
| Centre of Mass | $G_x$=-0.012m,<br>$G_y$=-0.019 m,<br>$G_z$=-1.847m. |
| Primary Material | Aluminum T6061, Titanium, Steel, plexiglass. |
| Span, Height | Span= 25.66 m,<br>Height= 18.056 m |

***NOTE**: For the analysis purpose and due to time and design constraints we have used a small model.*

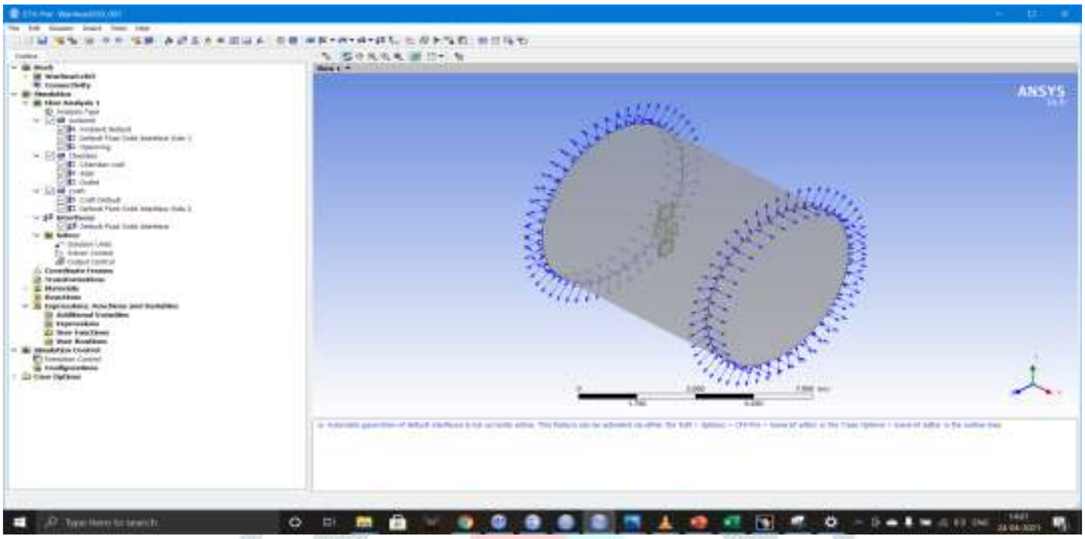



Fig.5 Analysis

In the analysis phase the values of force acting upon the satellite after the missile launched was computed. The analytical software used for this purpose was the ANSYS 16.1
From the physical values of force and mass flow rate the value of change in velocity was calculated using the below equation:

$$T = \dot{M} \times \Delta V \qquad (2)$$

Here,
T= thrust of the missile at launch
$\dot{M}$= change in mass of the satellite or mass flow rate
$\Delta V$= the change in velocity of the satellite

Change on velocity is given by

$$\Delta V = V_2 - V_1 \qquad (3)$$

Here
$V_1$= the velocity of satellite in the initial orbit
$V_2$= the velocity of satellite in final orbit

## I. Theory

### 1.1 Specific Angular Momentum:

The two body problem in orbital mechanics deals with two point particles interacting in space under gravitational influence, any third body in this case is neglected.

The specific angular momentum h is initially fixed, so the position and rate of change of position i.e. the velocity gives the specific angular momentum of the body which further helps in finding the final velocity after the change in the position of satellite i.e. the change in its orbital radius r. We can find it from the cross product of the position and velocity vectors.

$$h = r \times v \qquad (4)$$

We find that from Kepler's second law, the angular momentum is constant in magnitude and direction for the two-body problem. Therefore, the orbital plane defined by the position and velocity vectors must remain fixed in inertial space.

The velocity if Initial velocity can be calculated using the below equation

$$h = r \times v = r \times m \times v/m \qquad (5)$$

Here
h= specific angular momentum
r= radius of the orbit
v= velocity of satellite body

### 1.2 Time Period:(Kepler's Third law)

To calculate the Time period of the satellite in orbit using Kepler's third law the below equation is given:

$$T = 2\pi\,(a^3/\mu)^{1/2} \qquad (6)$$

Here,
T= time period of the satellite
r= radius of the orbit from the center of earth
$\mu$= the product of gravitational constant and mass of the earth.

## II. Boundary Conditions and analysis

**Mesh Information for Warhead Satellite**

| Domain | Nodes | Elements |
|---|---|---|
| Ambient | 34286 | 182628 |
| Chamber | 10302 | 50028 |
| Craft | 25842 | 128142 |
| All Domain | 70430 | 360798 |

**Physics Report**

| | |
|---|---|
| **Domain Ambient** | |
| Type | Fluid |
| Reference pressure | 0.00 [atm] |
| Heat transfer | Total Energy |
| **Domain Craft** | |
| Type | Fluid |
| Morphology | Continuous fluid |
| Turbulence Model | k epsilon |
| **Domain Craft** | |
| Type | Solid |
| Domain Motion | Stationary |
| Domain Interface- Default Fluid Solid Interface | |
| Boundary list 1 | Default Fluid Solid Interface Side 1 |
| Boundary list 2 | Default Fluid Solid Interface Side 2 |
| Interface Type | Fluid Solid |

**Boundary Physics for Warhead Satellite**

| Domain | Boundary Opening | |
|---|---|---|
| Ambient | Flow Regime | Subsonic |
| | Opening temperature | 200 [K] |
| | Relative Pressure | 1.20e-12 |
| Chamber | Boundary Inlet | |
| | Heat transfer | Static Temperature |
| | Static Temperature | 400 [K] |
| | Normal Speed | 250, 500, 750, 1000, 1250, 1500 [m/s] |
| | Boundary Outlet | |
| | Pressure Profile Blend | 5.00e-02 {Pa] |
| | Relative Pressure | 0.00 [Pa] |

## VI. CALCULATION

| Parameters | Values |
|---|---|
| Orbital velocity ($V_1$) | $V = 3.0754\ X10^3\ \ m/s$ |
| Orbital Radius | Earth's radius + height of satellite above earth surface i.e. 6378+35786 = 42,164 km = 4.21 X $10^7\ m$ |
| Mass of Earth ($M_e$) | 5.9742 x$10^{24}$ kg |
| Gravitational Constant (G) | 6.6742 x 10-11 N m2 kg-2 = 6.6742 x $10^{-11}$ $m^3$ $s^{-2}$ $kg^{-1}$ |
| Missile Velocity | 250, 500, 750, 1000, 1250, 1500 [m/s] |

### I. Speed of Satellite in geosynchronous orbit

Newton's second law

F = ma

$$m_s\,.a_g = m_s\,.a_c$$

Where:

$m_s$ – Mass of satellite

$a_g$ – Gravitational acceleration

$a_c$ – Centrifugal acceleration

The centripetal acceleration provided by Earth's gravity:

$$a_g = \frac{M_e\,.\,G}{r^2} = m_s\,.\frac{v^2}{r}$$

Magnitudes of the centrifugal acceleration derived from orbital motion:

$$a_c = \omega^2\,.r$$

Where;

ω - Angular velocity in radians per second.

r - Orbital radius in meters as measured from the Earth's center of mass.

$$a_c = (\frac{v}{r})^2\,.r\ a_c = \frac{v^2}{r}$$

From the relationship

$$m_s\,.\frac{M_e.G}{r^2} = m_s.\frac{v^2}{r}$$

$$F_{centripetal} = F_{centrifugal}$$

We note that the mass of the satellite, **$m_s$**, appears on both sides, geostationary orbit is independent of the mass of the satellite.

$$\frac{M_e.G}{r^2} = \frac{v^2}{r} V = \sqrt{\frac{M_{e\,.G}}{r}}$$

**r**= orbital radius

After calculation using the Velocity formulae we get $V_1 = 3.0754\ X10^3\ \ m/s$

### II. Change in velocity

$$T = \dot{M} \times \Delta V$$

$\Delta V$=T/Ṁ

=629.805/2.51685

=250.235413 m/s (same for other values)

$\Delta V = V_2 - V_1$

$V_2 = \Delta V + V_1$

=250.2+3075.4 (in meters)

=3325.6 m/s

### III. Specific angular momentum

h= $r_1 \times V_1$

= 42164 x 3.0754 (In kilometers)

=129671.1656 $m^2$/s

$r_2 = \frac{h}{V_2}$

$= \frac{129671.1656}{3.3256}$

=38991.39547 km

### IV. Time period

$$T = 2\pi(a^3/\mu)^{½}$$

$$= \frac{2\ X\ 3.14\ X(\frac{40842.52^3}{398600})^{1/2}}{3600}$$

= 22.80 hours

Same for other values

## VII. Result and Discussion

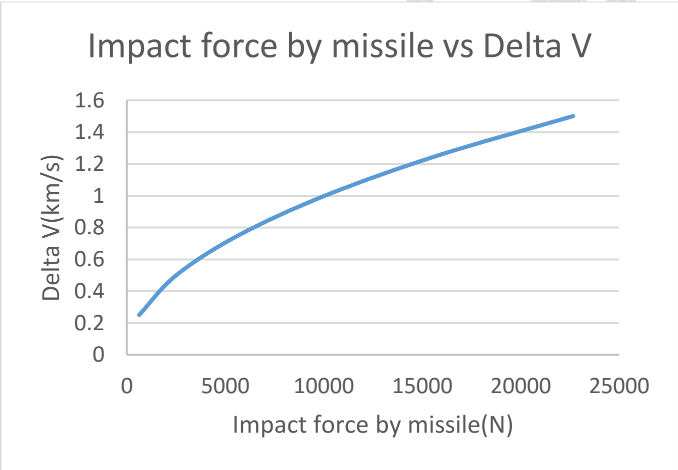
From Graph (1 and 2) we found that:

1. With the increasing force the mass flow rate also increases.
2. As the force increases the velocity also increases.

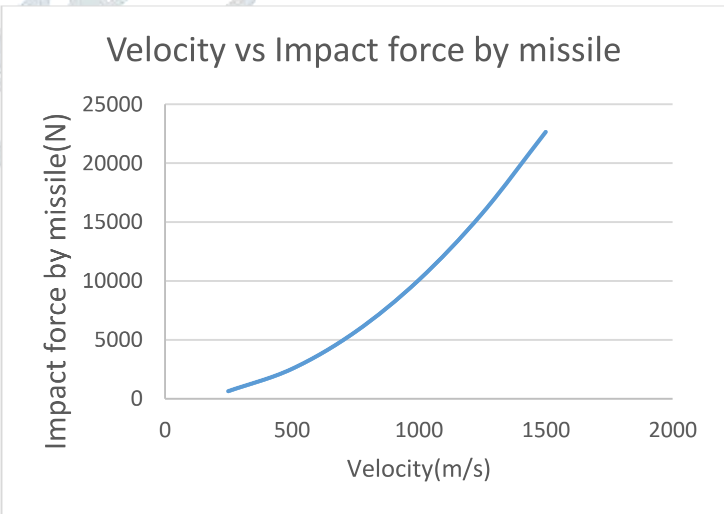
After analyzing the design, we found the value of $V_2$ (velocity of satellite after shifting to new orbit), forces, angular momentum, time period and etc.
The angular momentum is constant for all the velocities i.e. 129671.1656

| Velocity (m/s) | Force (N) | Mass Flow (Kg/s) | Delta V(km/s) | GEO Height | GEO Velocity (km/s) | $V_2$ (km/s) | $r_2$ (km) | Time Period (hrs) |
|---|---|---|---|---|---|---|---|---|
| 250 | 629.805 | 2.51685 | 0.2502 | 42164 | 3.0754 | 3.3256 | 38986.24 | 22.58 |
| 500 | 2518.67 | 5.03369 | 0.500 | 42164 | 3.0154 | 3.57576 | 36255 | 21.45 |
| 750 | 5666.51 | 7.55054 | 0.7504 | 42164 | 3.0154 | 3.825877 | 33881.49 | 20.49 |
| 1000 | 10073.2 | 10.0674 | 1.00057 | 42164 | 3.0154 | 4.075996 | 31799.79 | 19.65 |
| 1250 | 15738.70 | 12.5842 | 1.250671 | 42164 | 3.0154 | 4.326071 | 29959.11 | 18.92 |
| 1500 | 22662.8 | 15.1011 | 1.50073 | 42164 | 3.0154 | 4.576138 | 28320.04 | 18.28 |

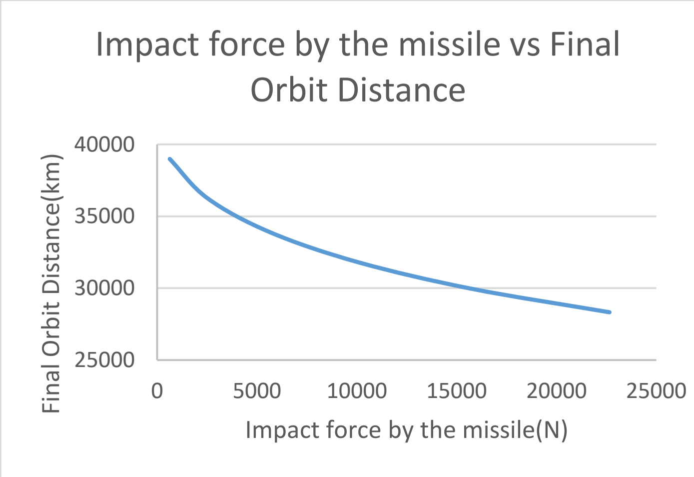
## Graphs



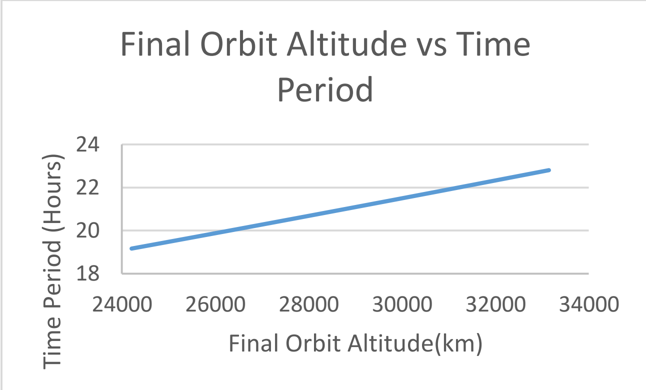

Graph.1: Impact force by missile vs Delta V




Graph. 2: Velocity vs Impact force by missile




Graph. 3: Impact force by the missile vs Final Orbit Distance




Graph.4: Final Orbit Altitude vs Time Period

We have observed the change in properties such as orbital velocity, orbit radius and orbit time period of satellite orbit due to different missile impact forces on the body.

## VIII. Conclusion

After doing the research and analysis work we found that after the launch of a missile from the satellite, the force induced will change the satellite's orbital velocity, orbit radius and orbit time period. The Displaced satellite will return to the initial orbit by using the orbit transfer method i.e. Hohmann Transfer method or principal.

Graph 1 shows changes in the orbital velocity due to different impact forces of missile on satellite body

Graph 2 shows variation in the missile velocity due to different impact forces of missile on satellite body

Graph 3 shows variation in the final orbit distance due to different impact forces of missile on satellite body

Graph 4 shows variation in the time period with respect to final orbit distance for different impact forces of missile on satellite body

## IX. Acknowledgments

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