"HENRI COANDA"
AIR FORCE ACADEMY
ROMANIA

"GENERAL M.R. STEFANIK"
ARMED FORCES ACADEMY
SLOVAK REPUBLIC

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SATELLITES MOVEMENTS DECAY

MIHALACHE Radu-Catalin

Military Technical Academy, Bucharest, Romania

Abstract: *Drag, by definition, will be opposite to the velocity of the satellite relative to the atmosphere. The calculation of the drag force on satellites will be made by two methods: one, based on experimental observations, similar to the calculations of the incompressible flows, the second based on the Newtonian Theory of movement of the molecules. The importance of these calculations is given by the fact that the atmospheric drag is involved in the length of the life of satellites and is implicated, like other perturbations, in the movement of those. We show how this implication works, alone or in combination with other factors.*

Keywords: *drag, satellites, high altitude*

1. INTRODUCTION

The problematic of movement of satellites is one with a great importance, given the constant support of our day by day life. Communications, transportations and more depends of the utilization on a large scale of satellites and theirs support. So knowing better how long a satellite will stay in orbit and how we can prolong its life is a big necessity.

2. ATMOSPHERIC DRAG

2.1 Drag, by definition, will be the opposite to the velocity of the satellite relative to the atmosphere. The perturbing force F is given by:

$$F = \frac{1}{2m} C_D A_e \rho v^2 \qquad (2.1)$$

Where:

C_D=aerodynamic drag coefficient

A_e=average cross-sectional area of the satellite

ρ=air density

m=satellite mass

v=satellite velocity relative to the rotating atmosphere.

The aerodynamic drag coefficient C_D is approximately 1 when the mean free path of the atmospheric molecules is small compared to the satellite size, although the exact value depends upon the satellite shape, the nature of its surfaces, and its attitude.

C_D takes value between 2 and 3 – dependent on the shape of the satellite – when the mean free path is large compared with the dimensions of the satellite. Exact values are best determined by actual flight test, but a value of about 2.2 will give a good, slightly conservative result.

2.2 Atmospheric density

The complicating factor in the calculation of drag, is the variable nature of the atmospheric density.

For heights between 0 and 100 km, the U.S. Standard Atmosphere of 1962 can be used.

A good approximation is the following simple exponential law:

$$\rho = \rho_0 \exp\left[-h / H\right] \qquad (2.2)$$

Where:

h=altitude above sea level in km

ρ_0=sea level density at 288.15K = =1.225kg/m^3

H="scale height"=6966 km

However, for greater heights, the atmospheric density exhibits variations with respect to altitude and latitude. There are large day-to-night variations, a 27-day cycle due to ultraviolet radiation, and an 11 year cycle due to the solar flux. The table below gives average values for the atmospheric density for three representative values of solar activity (based on the Jacchia 1964 model).

Tables of Atmospheric Density (kg/m^3) as a Function of Altitude.

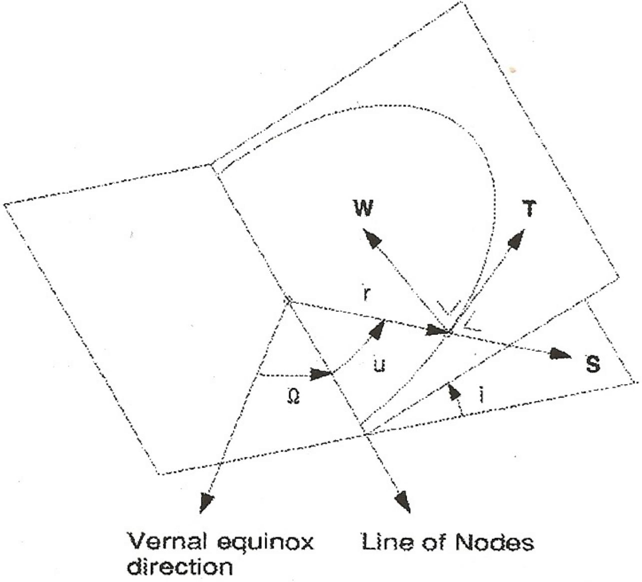
Altitude(km)	Quiet Sun
150	7.4 E-10
200	1.7 E-10
250	5.5 E-11
300	1.7 E-11
350	5.9 E-12
400	2.3 E-12
450	7.4 E-13
500	3.0 E-13
550	1.2 E-13
600	5.7 E-14
650	2.5 E-14
700	1.2 E-14

Altitude(km)	Average Sun
150	7.4 E-10
200	2.4 E-10
250	1.0 E-10
300	3.8 E-11
350	1.7 E-11
400	7.4 E-12
450	3.3 E-12
500	1.7 E-12
550	8.0 E-13
600	4.1 E-13
650	2.3 E-13
700	1.3 E-13

Altitude(km)	Active Sun
150	7.4 E-10
200	3.0 E-10
250	1.3 E-10
300	5.5 E-11
350	2.6 E-11
400	1.3 E-11
450	6.9 E-12
500	3.8 E-12
550	2.1 E-12
600	1.2 E-13
650	7.4 E-13
700	4.8 E-13

2.3 Computations.

The drag is calculated like in the next figure:



Where:

S is the component along the radius vector

T is the component perpendicular to S in the orbital plane

W is the component perpendicular to the orbital plane

Before the acceleration F in expression can be used in the Variation of Parameters Method, it is necessary to resolve F into two orthogonal components S and T:

$$S = -F\sin B = -F\frac{e\sin v}{\sqrt{1+2e\cos v+e^2}}$$

$$T = -F\cos B = -F\frac{1+e\cos v}{\sqrt{1+2e\cos v+e^2}}$$

Where v is the flight path angle, i.e. the complement of the angle between velocity v and r.

The figures 1 and 2 illustrate the influence of atmospheric drag on life time of a satellite in low orbit. In both examples, a satellite of 450 kg and A$_e$ of 25 m^2 is in 400 km circular orbit. The first case relates to average solar conditions; the second case is for an active sun.

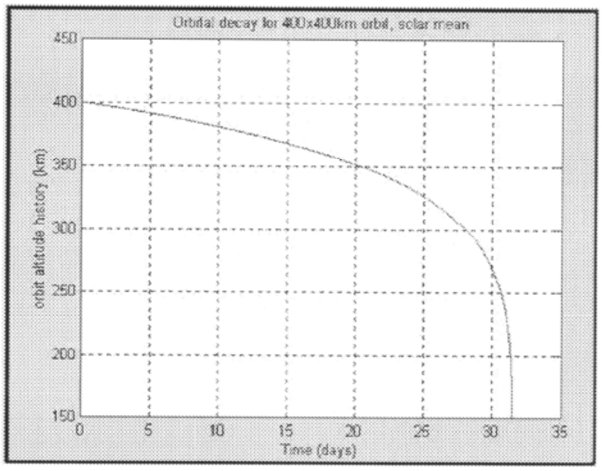


Figure 1. Orbit decay for a 450kg satellite, Mean Sun

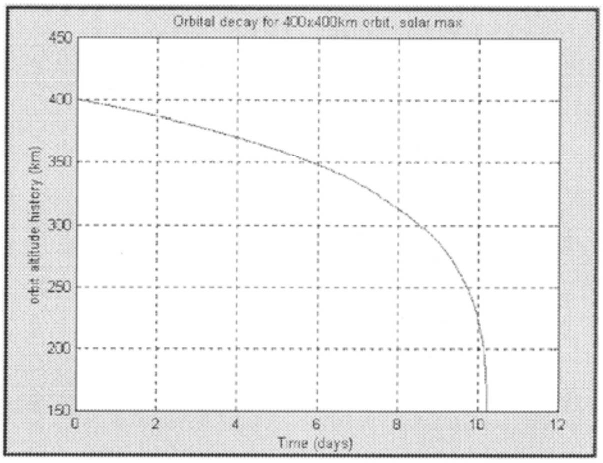


Figure 2. Orbit decay for a 450kg satellite, Active Sun.

We can see the life span decreased from about 32 days at about 10 days, only taken in consideration the sun activity.

3. OTHER MOVEMENTS ANOMALUES

3.1 Electrical Charging.

One of the most common anomalies caused by radiations hazards is satellite electrical charging. Charging can be produced three ways:

- by an object’s motions through a medium containing charged particles (called “wake charging”), which is a significant problem for large objects;
- directed particle bombardment, as occurs during geomagnetic storms and proton events;
- solar illumination, which causes electrons to escape from an object’s surface (called the “photoelectric effect”).

The impact of each phenomenon is strongly influenced by variations in an object’s shape and materials used in its construction.

An electrical charge can be deposited either on the surface or deep within an object, resulting in two types of charging:

- Surface charging-low energy electrons attach to the satellites causing different charges on parts of it, leading to an electrical arc discharge on the surface. Solar illumination and wake charging are surface charging phenomena;
- Deep electric charging-high energy electrons penetrate through the shielding of the satellites and build up inside.

3.2 Single event upsets.

Single Event Upsets are caused by very high energy particles which penetrate he shielding. The high energy particles have two sources: cosmic rays, which are a slow steady flux of high energy, sometimes of heavy particles and solar proton emissions of very large fluxes from solar flares.

In fact, a single proton or cosmic ray, can (by itself) deposit enough charge to cause an electrical upset.

3.2 Radiations hazards.

Total dose effects-radiation from galactic cosmic rays and solar proton events can cause cumulative radiations disruptions. Both low and high-orbiting satellites are subject of radiations hazards.

3.3 Disorienting magnetic fluctuations and discharges.

Some satellites that use the Earth’s magnetic field to help orient themselves can lose orientation during a magnetic storm. Many satellites rely on electro-optical sensors to maintain their orientation in space. They can cause disorientation in the star tracking devices or misreading in sensors, causing the satellite to lose altitude lock with respect to Earth.

3.4 Radio interference.

A satellite’s telemetry may be masked by a solar radio frequency burst when the Sun is aligned with satellite and the ground antenna. Radio propagation problems through and within the ionosphere are caused by space weather, and affect nearly all satellites to a greater or lesser extent.

4. CONCLUSIONS

The natural trade-off between the needing to build a big, robust satellite capable of resisted space weather caprices and the drag force makes a difficult choice. Increased mass and surface conduct to an increased drag and shortened the life span of the satellite.