# Flight Performance of Planetary Atmospheric Flight Airship (PLAS)

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**Abstract—*This paper studies flight performance of airship employed to observe scientifically the atmosphere of planet including Mars and Venus with little effort or fuel expenditure (Planetary Atmospheric Flight Airship: PLAS). The flight region of the planetary airship is determined taking into consideration the temperature and pressure on Mars and Venus, as well as basic limitations of airships. The performance of the atmospheric flight airship is studied on its longitudinal dynamical feature. Result of the study shows some interesting features of the airship flying on Mars and Venus.***

**Index Terms—** ***Airship, Planet, observation***

## 1. INTRODUCTION

VENUS has been observed scientifically using balloons in 1985 as a result of cooperation between the Soviet Union and France (VEGA 1 & 2)[1]. These balloons had a diameter of 3.4 m and flew over one third of Venus in 46.5 hours at an altitude of 53.6 km. Future plans of ISAS/JAXA and NASA include a Mars airplane[2,3] and other planetary balloons[4,5], however, balloon is an only platform that has been successfully used.

The present study employs remotely piloted airships as a platform in the atmosphere for planetary observation[6-8]. The planet's surface topography, gravitational field, magnetic field, and atmospheric layer can be observed over an extended period of time with little effort or fuel expenditure. An observational platform can be located in a target planet's atmospheric layer from 50 m for a ground probe to as high as the altitude used for satellites. Data obtained from such platforms can be used to examine the general characteristics of the planet and its atmospheric layer and also to validate and to complement the data obtained from satellites or ground probes.

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Figure 1: Planetary Atmospheric Flight Airship (PLAS)

Planetary observations can be classified into 6 categories depending on the location of the observational platform. These six categories include the remote sensing of the target planet: (1) using telescopes; (2) using a space telescope that is located in another planet's orbit; (3) a spacecraft that is in an interplanetary orbit, such as Mariner 2 and 5; (4) from spacecraft[2] that are in the target planet's orbit, like Venera 15-16 and Pioneer Venus 1; (5) or direct observation at the time of descent under the target planet's gravitational field, such as an observation by Venera 1-7, or by flying a probe such as VEGA 1-2; and (6) or direct observation from a fixed point probe on the surface of the target planet, such as that performed by Venera 8-14 or the Rover Mars Pathfinder[3]. Study of a planet using planetary airships in its atmosphere is now being studied by ISAS[4,5], while NASA[9-12] is under study of the use of planetary balloons located in the atmosphere of the target planet. A team of Georgia Institute of Technology is studying the use of a Mars helicopter, "GTMARS[13]", while the University of Maryland the use of a Martian Autonomous Rotary-wing Vehicle (MARV)[14].

Information obtained using the methods described above is usually available either for a microscopic area over a short period of time or for a macroscopic area with low resolution. In the present study, an airship platform is presented of a subcategory of category (5) that include probes with "remote sensing or direct observation at the time of descent under the target planet's gravitational field or by flying a probe." One of the advantages of such an airship is that energy is not needed to produce the dynamic lift that would support the weight of the spacecraft. Instead, this lift results from the buoyancy of gas inside the airship. The airship is never in danger of falling, and its flight control permits a large observational area. Moreover, the speed of the spacecraft is slow enough so that the communication delay from Earth is covered.

The flyable region is already studied by the authors[6] based on the pressure and temperature in the atmospheres of Venus and Mars, and the required size and mass of the spacecraft.

## 2. FLYING CHARACTERISTICS OF PLAS

### 2.1 Review Stage

Papers can be submitted only electronically, as indicated on the web site. The longitudinal characteristics of PLAS is studied for flying characteristics under the change of flight atmosphere as the planet. The shape and dimensions of PLAS are fixed in the comparison between the flight atmosphere of Mars and Venus with Earth as a reference. The PLAS is modeled as shown in Fig. 2 and Table 1 with reference to the manned airship of type WDL-1. The dynamics of the model is numerically analyzed by the linear analysis employed with the small perturbation theory and a software MATLAB is employed in the dynamic analysis. The gravitational acceleration and atmospheric density are changed as the environment of the planet. Mass of PLAS is assumed to change in accordance with the change of atmospheric density. The changed mass is assumed to concentrate in the center of mass and the moments of inertia of the PLAS is assumed not to depend on atmospheric density.

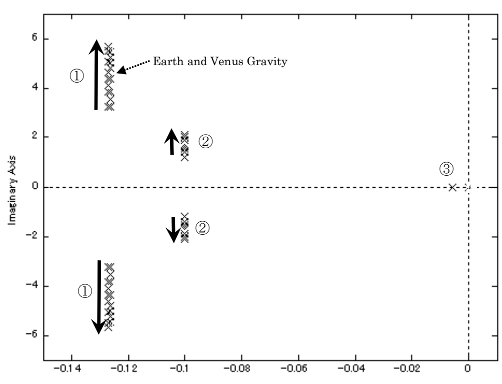


Figure 2: A model of PLAS

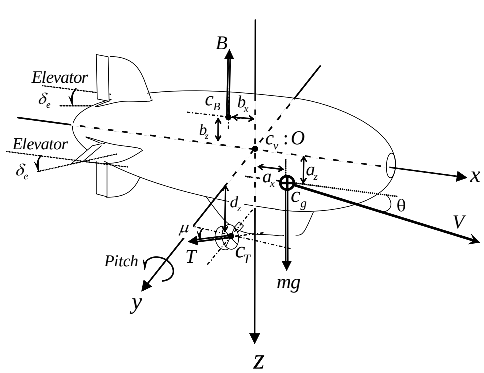


Figure 3: Root locus for the atmospheric density from 0.01kg/m$^3$ to 7.0kg/m$^3$ (gravity 1G, and flight velocity 0.5m/s)

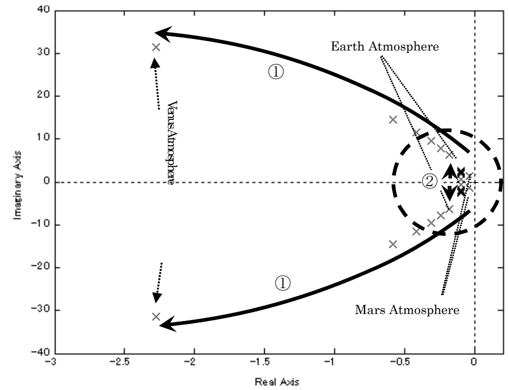


Figure 4: Root locus for the atmospheric density from 0.01kg/m$^3$ to 1.0kg/m$^3$ (gravity 1G, and flight velocity 0.5m/s)

Figure 3 shows the time response of the pitching motion for the PLAS in the atmospheric density from 0.01kg/m$^3$ to 1.0kg/m$^3$ with flight velocity, 0.5m/s, and a step input of 0.2N in thrust is applied for the motion. The atmospheric environment is earth and the period of motion is 4.8 sec. The short period mode is shown in the figure by (1), and the long period mode by (2), and the linear motion in flight by (3). It is seen the locus moves to bold arrow as atmospheric density increases. The short period mode is seen to be more stabilized and the frequency increases as the atmospheric density increases. The stability is seen insensitive for the atmospheric density but the frequency increases for the long period mode. The dotted circle is shown in Fig.4 enlarged. The atmospheric density is 7.0, 1.2, and 0.02 kg/m$^3$ for Venus in the altitude 35km, earth on the surface, and Mars on the surface, respectively.

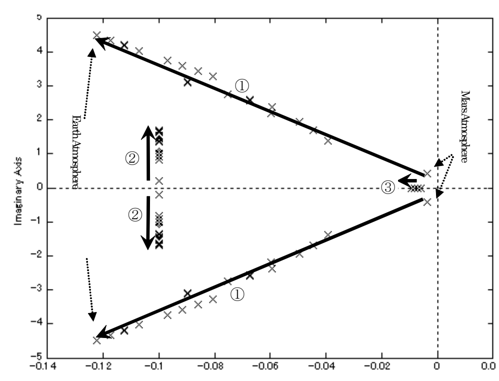


Figure 5: Root locus for the gravity acceleration from 0.5G to 1.5G (The air density 1.2g/m$^3$ and flight velocity 0.5m/s)

Table 1: Data for the atmosphere[15]

| | Venus | Earth | Mars |
|---|---|---|---|
| Mean distance from Sun | 1.082 x $10^8$ [km] | 1.496 x $10^8$ [km] | 2.279 x $10^8$ [km] |
| Solar day | 117 [days] | 1 [days] | 1.0287 [days] |
| Surface gravity | 8.87 [m/$s^2$] | 9.81 [m/$s^2$] | 3.72 [m/$s^2$] |
| Mean atmospheric temperature(surface) | 735 [K] | 288 [K] | 215 [K] |
| Mean atmospheric pressure(surface) | 92x$10^5$ [N/$m^2$] | 1x$10^5$ [N/$m^2$] | 0.007x$10^5$ [N/$m^2$] |
| Composition of the terrestrial planet atmospheres | $CO_2$ : 96.5 %, $N_2$ : 3.5 % | $N_2$ : 77 %, $O_2$ : 21 % | $CO_2$ : 95 %, $N_2$ : 2.7 % , Ar : 1.6% |
| Mean molecular weight of atmosphere | 43.4 | 28.96 | 43.5 |
| Lapse rate of lower atmosphere | 7.8 [K/km] (AGL 0 to60km)<br>8.6 [K/km] (AGL 60) | 6.5 [K/km](AGL 0 to11km)<br>0.0 [K/km](AGL 11 to 20km)<br>-1.0 [K/km](AGL 20 to 32km)<br>[ under ISA] | 2.5 [K/km]<br>(AGL 0 to40km) |
| Wind Speed | Surface : 1 to 1.5 [m/s]<br>cloud deck : 100[m/s] | 7 to10 [m/s] | Max.: 90 to100 [m/s] |
| Round trip of radio transport time from Earth | 4.6 to 28 [min] | 0 [min] | 8.7 to 41.9 [min] |

Figure 5 shows the time response of the pitching motion for the PLAS in change of the gravity acceleration from 0.5G to 1.5G with flight velocity, 0.5m/s, and a step input of 0.2N in thrust is applied for the motion. The atmospheric environment is earth and the period of motion is 4.8 sec. Dotted arrows point the short period modes for the earth with 9.81m/$s^2$ and Venus with 8.87m/$s^2$.

It is seen from the figure that the frequencies of motion increase but stability stays same for the change of the gravity acceleration. It is understood that the effect of gravity is not serious since the gravity balances with buoyancy and stability is not affected by the gravity.

It is concluded that the PLAS at the altitude 43km of Venus has the short period mode with increased stability and frequency of motion and the long period mode with identical stability and increased frequency of motion. It is also concluded that stability and frequency of motion decreases for both of the short and long period modes of the PLAS on the surface of Mars due to the effect of atmospheric density and gravity acceleration.

It may be recommended to apply similar analysis for unknown planets to obtain information of flight environment through the motion of PLAS.

## 3. *Conclusion*

This part can be broken in a as many sections and subsections as needed. The airship flying on the atmosphere of planet (PLAS) is studied in its flight performance with parameters of such atmospheric environment as atmospheric density and gravity acceleration. The analysis is applied to PLAS on Venus and Mars with Earth as a reference in which the atmospheric parameters are relatively known. Results of the study on the longitudinal performance have shown that the implementation is possible for the PLAS for the flight under the cloud of Venus.

It is recommended that the similar analysis can be applied for unknown planets to obtain information of flight environment through the motion of PLAS.

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