Remote sensing studies of our sister planet: Exploring Venus using planetary glider and CubeSat constellation

Adhithiyan Neduncharan[1], Sruthi Uppalapati[2] , Ugur Guven[1,3]
1 University of Petroleum and Energy Studies, India(adhithiyan.n@gmail.com) 2 University of Oslo, Norway
3 UN Center for Space Science and Technology Education in Asia and the Pacific

Introduction

This work proposes optimal interplanetary trajectory from Earth to Venus following the deployment of an unmanned robotic glider for exploring the atmosphere of Venus and a constellation of CubeSats deployed in different orbits of Venus to ensure global coverage for remote sensing application. Primary payload will be a glider that will study the atmospheric behavior of the Venus below the clouds of Venus at an altitude of ~40-50 Km. The glider provide a unique opportunity for high resolution surface observations and detection of gases in minor traces while it is airborne thereby providing more valuable data by transmitting it to the CubeSats orbiting the planet than a single lander or an orbiter mission. Trade studies regarding the scientific payload onboard the glider will be included. From the set of observations, the airfoil having high lift coefficient can be used for the design of the glider's wings thereby producing maximum lift force during the time of flight which is crucial for such exploratory missions. CubeSats constellation will be remotely tracking the clouds and can be used to study the plasma interactions. At the end of mission life of these CubeSats, it is proposed to deorbit all at once at different locations so as to gather global framework of the cloud movements across the planet. As these CubeSats enters the atmosphere, it will burn up during its Entry-Descant phase before which they'll transmit all the atmospheric entry data. This data can be accumulated and analyzed for the pattern in the cloud motions and other phenomenon taking place in the upper atmosphere. If this mission concept is implemented in future, it is expected to yield great results to study and model the atmosphere of our sister planet.

Methods

Investigations are conducted for atmospheric flight in the flight altitude below the cloud layers, some standard airfoils are modelled and Computational Fluid Dynamics analysis is done in COMSOL Multiphysics for Venusian atmospheric conditions.

Atmospheric flight below the cloud region

The airfoils mentioned in the below figures were analyzed in variation of coefficient of lift for various angle of attack in COMSOL Multiphysics, a Computational Fluid Dynamics software in which the Single phase turbulent flow was chosen and Spalart Alamaras module was used for the analysis for the airfoil under Venusian conditions at an altitude of 40Km from surface was chosen. This will enable us to escape the super-rotating cloud cover and help us observe the surface efficiently during it's flight time.

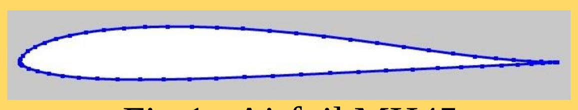


Fig 1 : Airfoil MH45

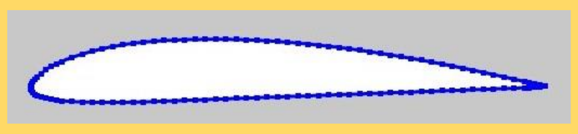


Fig 2 : Airfoil Clark Y

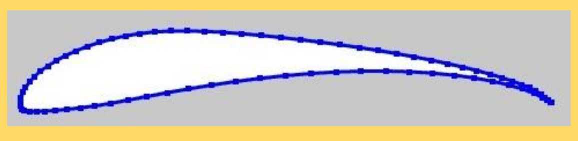
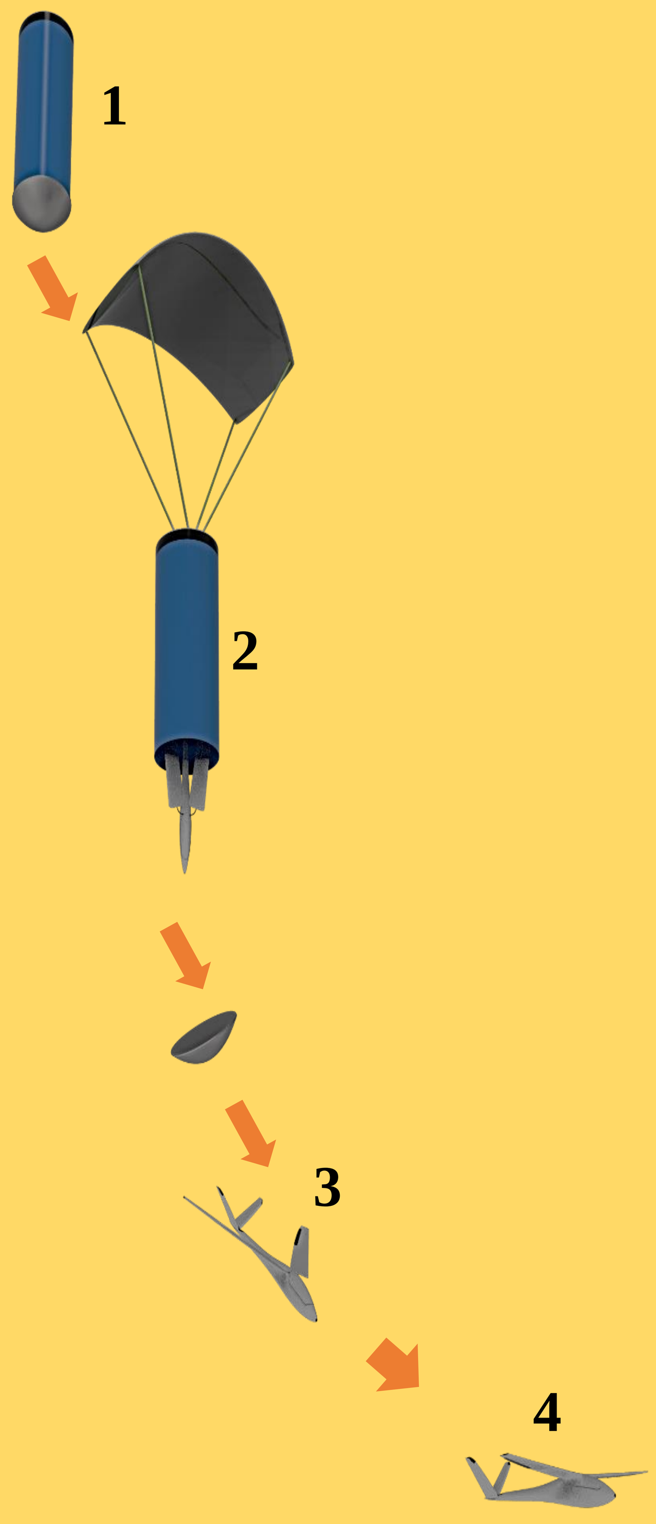
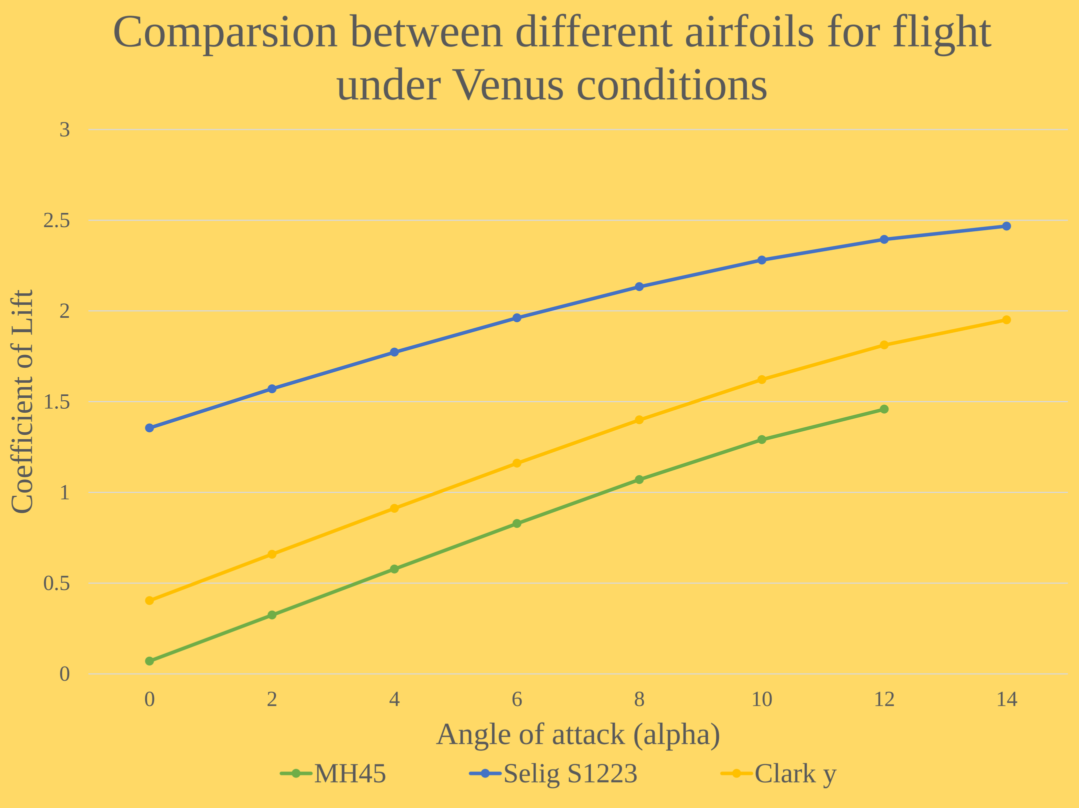


Fig 3 : Airfoil Selig S1223

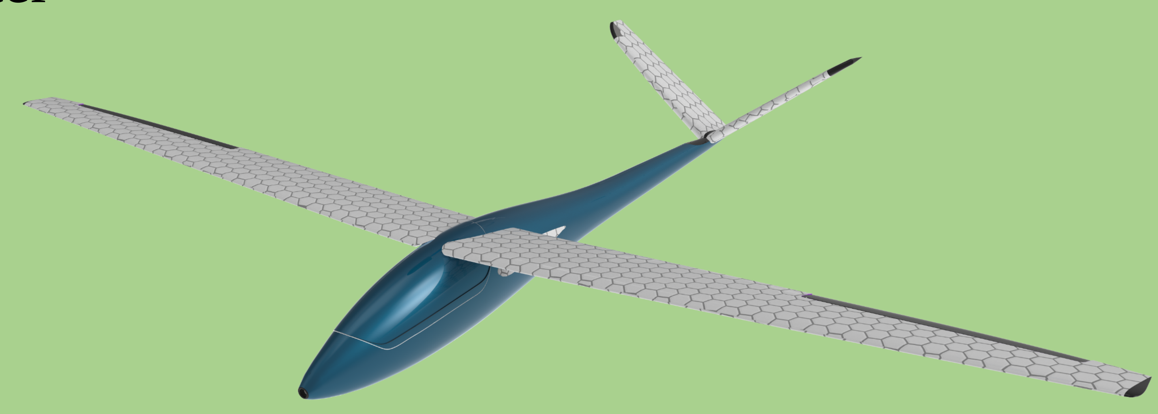
Altitude	**40Km**
Density	**4.404 kg/m3**
Temperature	**417.6 K**
Pressure	**3.501 bar**
Velocity	**40.7 m/s**
Reynolds Number	**796634.6667**





Payload in the glider

Imaging multispectral spectrometer (Vis-IR)
Noble gas mass spectrometer
Solar wind spectrometer
Electric field sensor
Optical microscope
Trace gas analyzer
UV Spectrometer



Altitude	Temperature	Voc Intensity Factor	Voltage Efficiency	Current Factor	Effective efficiency	Power
40Km	175 C	0.98	14.80%	29.01%	4.29%	112 W/m2

Table 1: Power availability for triple junction solar cell parameters at an altitude of 40Km *(extracted from [1])*

Launch window

It was obtained using the trajectory design tool by Ames Research Center Trajectory browser[2] considering the technological development and mission readiness the year 2032 was selected.

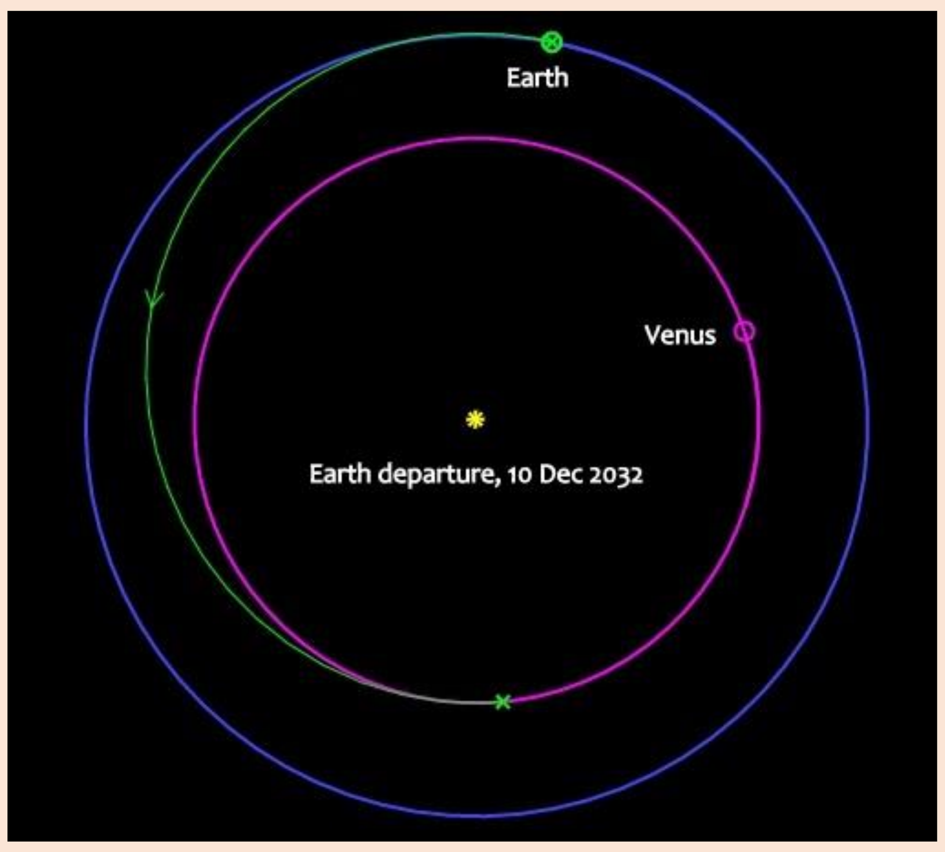


Fig 4 : Earth departure

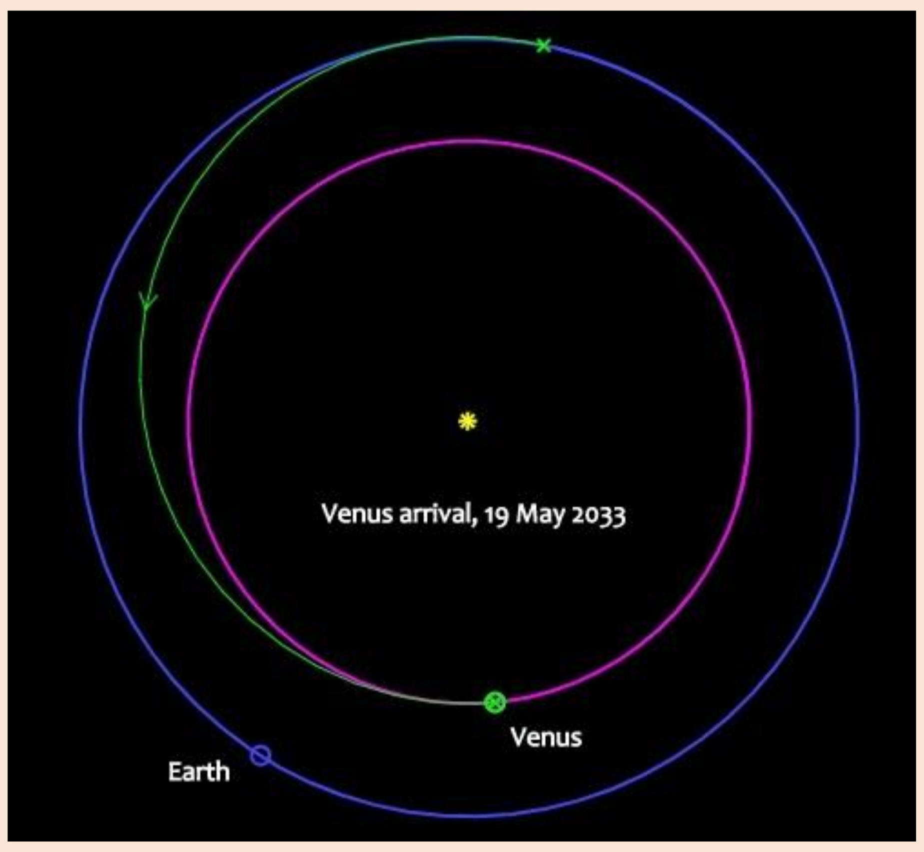


Fig 5 : Venus arrival

Discussions

The equatorial regions is the best place to deploy the glider so that it doesn't drift with eddy formation in the atmosphere. The V-Tail of the glider will be advantageous in maneuvering in the super-rotating atmosphere. The yawing and rolling of the glider will provide assistance in the helical path. The designed V-Tail can be made deployable during the flight conditions thereby reducing some significant drag forces. The use of airfoil Selig S1223 for flight under the cloud region can be considered as it has better lift coefficient at various angle of attack and not just at the stall region. The satellite constellation shall be placed in equatorial orbits.

Future scope

Venusian glider is aimed to help us better understand the atmospheric conditions of Venus and detection of gases using enhance remote sensing techniques on board. Development of high end electronics is to be done to protect them from extreme temperatures of the planet. If missions using gliders are successful, we can then work towards exploring other planets and their moons using such gliders especially designed for them.

Reference

[1] Landis, Geoffrey A., and Emily Haag. "Analysis of solar cell efficiency for Venus atmosphere and surface missions." *11th International Energy Conversion Engineering Conference*. 2013.
[2] https://trajbrowser.arc.nasa.gov/

Acknowledgement

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