NASA SBIR 2020 Phase I Solicitation

S3.05 Terrestrial Balloons and Planetary Aerial Vehicles

Lead Center: GSFC

Participating Center(s): AFRC, JPL

Technology Area: TA4 Robotics, Telerobotics and Autonomous Systems

Scope Title
Planetary Aerial Vehicles for Venus

Scope Description

NASA is interested in scientific investigation of the Venus atmosphere and planetary surface using aerial vehicles. Aerial vehicles are expected to carry scientific payloads at Venus that will perform in-situ investigations of its atmosphere, surface and interior structure. The 2018 Venus Aerial Platforms Study report identified several key science investigations that are ideally suited to aerial platforms. The areas of scientific interest include: Atmospheric Gas Composition, Cloud and Haze Particle Characterization, Atmospheric Structure, Surface Imaging and Geophysical Investigations. Venus features a challenging atmospheric environment that significantly impacts the design of aerial vehicles. Proposals are sought in the following areas:

Aerial Vehicle Platforms for Venus - Concepts for Lighter-than-Air (e.g., balloons, airships) and Heavier-than-Air (e.g., fixed wing, rotary wing) vehicles are encouraged. The current state of the art in Venus aerial vehicles has been designed to operate within the altitude range of 50 to 60 km above the surface where the atmosphere is similar to the lower Earth atmosphere. The science objectives described in the Venus Aerial Platform study indicate that a wider range of altitudes is strongly desirable.

There are 3 areas of interest in this call:

1. Aerial systems that can maneuver throughout the range 40 to 70 km altitude for a long duration. The aerial platform should be able to operate on the sunlit side of Venus and be able to transit the night side and survive several circumnavigations around the planet. The proposal should describe how the vehicle concept would be deployed into the atmosphere and operated for its mission. The proposal does not have to address thermal design of the payload (if it is suspended under a balloon), but should include concepts for addressing the thermal requirements for the aerial platform. The atmospheric temperature ranges from 145C at 40 km to -10C at 60 km altitude. The aerial platform is not expected to operate extensively at the lower altitudes but should be capable of operating for short durations at high temperatures. Concepts for any of the following capabilities of aerial vehicle are encouraged:

- Technology demonstration with science payload less than 5 kg.
- Pathfinder mission with science payload less than 30 kg.
- Flagship mission with science payload up to 60 kg.

Other areas of interest include low cost approaches to:

1. Solar heated balloon systems to carry small science payloads (i.e. less than 10 kg payload) from 60 to 70 km altitude which would operate only on the sunlit side. These should be relatively simple systems that could operate collectively as a swarm system.
2. Deep atmospheric probes, deployed from aerial vehicles, to measure diurnal variations in the deep atmosphere of Venus. These could be deployed at different locations around Venus to capture atmospheric differences between day and night. Concepts for vehicles or neutrally buoyant probes that perform vertical descents, or guided/gliding descents to the surface are desired.

References

The Venus Aerial Platforms Study report can be found here: https://solarsystem.nasa.gov/resources/2197/aerial-platforms-for-the-scientific-exploration-of-venus/

Information about Venus can be found here: https://solarsystem.nasa.gov/planets/venus/in-depth/

Hall, J., Kerzhanovich, V., Fredrikson, T., Sandy, C., Pauken, M., Kulczycki, E....Day, S. (2017). Technology development for a Long Duration Mid-Cloud level Venus Balloon. Advances in Space Research Vol. 48 No. 7, 1238-1247.

Khatuntsev, I. V. (2017). Winds in the Middle Cloud Deck from the Near-IR. Journal of Geophysical Research: Planets. https://doi.org/10.1002/2017JE005355

Expected TRL or TRL range at completion of the project: 2 to 3

Desired Deliverables of Phase II

Prototype, Analysis, Research

Desired Deliverables Description

It is expected that a Phase I effort will consist of a system-level design and a proof-of-concept experiment on one or more key components.

Deliverables shall be a final report describing the results of the concept analysis, demonstration of any key technology developed and photos of any prototypes that were built and tested.

State of the Art and Critical Gaps

Terrestrial based aerial vehicles, including lighter-than-air and heavier-than-air are mature technologies and continue making advancements in capability, reliability and autonomy. But these need adaptation for operation in the Venus environment.

A gap exists in aerial vehicle technology that allows for variable altitude investigation in the Venus atmospheric environment. Floating at a fixed altitude means the vehicle is basically collecting samples of the same atmosphere each time it performs a collection since it floats with the wind. Having variable altitude capability allows significantly better investigation into the atmospheric structure. Variable altitude balloon concepts have been developed to operate over the altitude range of 50 to 60 km. New science goals defined in the Venus Aerial Platforms Study have indicated that stretching this operating range over 40 to 60 km is needed. This is a significant challenge because of the high atmospheric temperature at the 40 km altitude.

Relevance / Science Traceability

Relevance: Applied Physics Laboratory's (APL) Dragonfly mission selection by New Frontiers shows there is significant interest in aerial vehicles for science investigations. It is in NASA's interests through the SBIR program to continue fostering innovative ideas to develop mission concepts to explore Venus using aerial vehicles.

JPL's Solar System Mission Formulation Office and the NASA Science Mission Directorate's Planetary Science Division advocate Venus aerial vehicle platform development. Furthermore, there are many enthusiastic supporters of exploring other worlds with aerial platforms throughout NASA.

Science Traceability: The 2018 Venus Aerial Platforms Study report identified several key science investigations that are ideally suited to aerial platforms. The areas of scientific interest include: Atmospheric Gas Composition, Cloud and Haze Particle Characterization, Atmospheric Structure, Surface Imaging and Geophysical Investigations. The variable altitude aerial vehicle platform is ideal for investigating these science goals and objectives.

Scope Title
Satellite Communications for Balloons

Scope Description

Improved downlink bitrates and innovative solutions using satellite relay communications from balloon payloads are needed. Long duration balloon flights currently utilize satellite communication systems to relay science and operations data from the balloon to ground based control centers. The current maximum downlink bit rate is 150 kilobits per second operating continuously during the balloon flight. Future requirements are for bit rates of 1 megabits per second or more. Improvements in bit rate performance, reduction in size and mass of existing systems, or reductions in cost of high bit rate systems are needed. Tracking and Data Relay Satellite (TDRSS) and Iridium satellite communications are currently used for balloon payload applications. A commercial S-band TDRSS transceiver and a mechanically steered 18 dBi gain antenna provide 150 kbps continuous downlink. TDRSS K-band transceivers are available but are currently cost prohibitive. Open port Iridium service is also in use, but the operational cost is high per byte transferred.

References

NASA's SuperTIGER Balloon Flies Again to Study Heavy Cosmic Particles:https://sites.wff.nasa.gov/code820/

Expected TRL or TRL range at completion of the project: 1 to 3

Desired Deliverables of Phase II

Prototype, Analysis, Hardware, Software, Research

Desired Deliverables Description

Desired deliverables include results of analysis or simulation, or test results of actual prototype hardware and/or software. Phase II deliverables could include a prototype that could be test flown on a balloon mission.

State of the Art and Critical Gaps

Current commercially available satellite relays systems that could be used for balloon flight are either too costly, or do not provide the needed downlink data rates.

Relevance / Science Traceability

Science Mission Directorate (SMD) - NASA HQ (Astrophysics Division). Enables multiple Research Opportunities in Space and Earth Science (ROSES) opportunities, Small Explorer (SMEX) Announcement of Opportunity (AO) (Astrophysics), Astrophysics Mission of Opportunity, Hands-On Project Experience (HOPE) (annually). Improvements to satellite communications for research balloons would enable greater and better data collection, possibly extended flight duration, and other such potential benefits.

Scope Title
Helium Replenishment System

Scope Description

NASA long duration Super Pressure Balloons (SPB) are large and complex structures that contain seams and fittings. Since these balloons are hand constructed, there is potential for gas loss due to leaks through the seams or fittings, or permeation through the balloon envelope that is made of linear low-density polyethylene. In the event of a gas loss, a helium replenishment system is needed to augment the lifting gas in order to increase the likelihood of payload recovery overland, and to extend the flight duration. The desired system shall not significantly affect the overall mass of the payload and shall require limited power for efficient operation.

References

NASA's SuperTIGER Balloon Flies Again to Study Heavy Cosmic Particles:https://sites.wff.nasa.gov/code820/

Expected TRL or TRL range at completion of the project: 1 to 3

Desired Deliverables of Phase II

Prototype, Analysis, Hardware, Software, Research

Desired Deliverables Description

Desired deliverables include results of analysis or simulation, or test results of actual prototype hardware and/or software. Phase II deliverables could include a prototype that could be test flown on a balloon mission.

State of the Art and Critical Gaps

No such system currently exists.

Relevance / Science Traceability

SMD - NASA HQ (Astrophysics Division). Enables multiple ROSES opportunities, Small Explorer (SMEX) Announcement of Opportunity (AO) (Astrophysics), Astrophysics Mission of Opportunity, Hands-On Project Experience (HOPE) (annually). A replenishment system can potentially prove very beneficial for avoiding payload termination over water by extending flight duration and enabling payload recovery overland in case of limited gas loss. This in turn can result in salvaging high value science data and payload recovery. Such a system can also possibly extend flight duration enabling more science data collection as well as other such potential benefits.