S16.04 Unpiloted Aerial Platforms and Technologies for NASA Science Missions

Lead Center: ARC

Participating Center(s): AFRC, GSFC, JPL, LaRC

Scope Title:

Unpiloted Aerial Platforms for High-Altitude, Long-Endurance (HALE) Missions

Scope Description:

NASA is interested in increased utilization of innovative, cost-effective, unpiloted, aerial platforms, including ones that are heavier and lighter than air, to perform NASA missions in the stratosphere in order to supplement current piloted and satellite platforms. Unmanned aerial platforms are especially suited for HALE missions that occur at or above 50,000 to 90,000 ft and can support continuous flights of 30 days or more at altitude.

HALE missions enable new Earth and space science applications and an opportunity for testing spaceborne-like measurements in the stratosphere. High spatial and temporal resolution observations from HALE can improve measurements of Earth system processes or phenomena requiring sustained observations, including: air quality monitoring, coastal zone and ocean imaging and monitoring, mapping of geologically active regions, forest and agricultural monitoring, and imaging of polar regions. The NASA Surface Biology and Geology mission, for example, is anticipating the need for measurements of leaf canopy chemistry during the growing season, and significant changes can happen between overpasses of polar orbiting satellites. Similarly, the Surface Topography and Vegetation Incubation team recently released a report citing the need for more frequent observations of areas prone to landslides and other ephemeral or episodic events where time series observations can improve Earth system models.

HALE Platforms offer several key challenges, including solar/battery technologies, operation in regions of harsh radiation and temperatures, vehicle health monitoring, and mission deployment/support at remote locations. Methods for accurate stationkeeping in areas of interest would also have to be developed.

Proposals are solicited for both heavier- and lighter-than-air innovative stratospheric platforms that can operate at an altitude of 60,000 ft or above, for a mission of 30 or more days in duration. The proposed vehicle must be able to carry a scientific instrumentation payload of 22lbs or more on all science missions. The combined system must be able to maintain position within 100 nautical miles of a fixed point on the ground and be able to provide at least 100+ W of sustained power (28 Vdc) to payloads. The platform must also have high band width, line-of-sight payload telemetry, and SATCOM capability to enable beyond visual line of site command and control. Proposals can be based on new design platforms or extensively modified existing platforms to meet the above HALE mission requirements.

The primary focus of proposal should be on vehicle design towards a flight test prototype in Phase II. Other aspects such as concept of operations, vehicle maintenance, vehicle transport and deployment, ground station design, and
flight-test planning should also be addressed.

**Expected TRL or TRL Range at completion of the Project:** 2 to 6

**Primary Technology Taxonomy:**
Level 1: TX 04 Robotics Systems
Level 2: TX 04.2 Mobility

**Desired Deliverables of Phase I and Phase II:**

- Research
- Analysis
- Prototype
- Hardware

**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. Deliverable items for Phase I shall be a final report describing the results of the concept analysis and demonstration of any key component technology developed.

The Phase II effort will focus on the development of a concept prototype and feasibility testing. The Phase II deliverable should include a final report on design concept documentation, test reports, and photos of any prototypes that were built and tested.

**State of the Art and Critical Gaps:**

NASA Global Hawk unmanned aircraft system (UAS) previously provided HALE capability for NASA Earth Science missions but was retired from this mission in 2020. NASA presently has no UAS platforms serving in this role and is reliant on satellites and piloted aircraft to fly these missions. Currently, NASA Earth Science has needs but no platforms to meet this.

While NASA continues development of super-pressure balloons with extended duration, several lighter-than-air vehicles have recently been developed that can provide capabilities to meet NASA science needs.

Several prototype and proof-of-concept HALE vehicles are under development and flight testing. These next-generation HALE vehicles under development have had a focus on communications, and so payloads relevant to Earth Science have not been demonstrated. These existing platforms, which include both heavier- and lighter-than-air platforms could be modified to meet requirements of this solicitation, or new designs could meet them as well.

**Relevance / Science Traceability:**

As the impacts of climate change become more pronounced through long-term drought, more frequent and intense wildfires, and an increase in severe weather occurrences, there is increased emphasis on Earth Science missions by NASA, other Government Agencies, and private industry. This includes new technologies and capabilities to enhance our ability to observe and predict effects on the environment and the economy of these more frequently occurring events.

NASA, other Government Agencies, and private companies have also shown increased interest in utilizing UAS platforms, both heavier and lighter than air, for Earth Science data collection, supplementing satellite and piloted Earth Science aircraft. This is largely because of the ability of UAS to perform dull, dirty, difficult, and dangerous missions more easily than other platforms.
There is interest from the highest levels of Government to invest in the domestic UAS manufacturing base to reduce reliance on foreign manufacturers as well as security concerns with foreign UAS platforms and technologies.

References:


Scope Title:

Unpiloted Aerial Platforms for Extreme Environment Missions on Earth

Scope Description:

NASA is interested in increased utilization of unpiloted aerial platforms, both lighter and heavier than air, for Earth Science missions to supplement current piloted and satellite platforms, taking advantage of unpiloted aerial platforms to perform dull, dirty, difficult, and dangerous missions. These platforms are especially suited for extreme environment missions such as volcano, storm, and wildfire penetration as there would be no risk to humans compared to piloted aircraft.

Numerous Earth Science missions require aircraft to operate in situ or in close proximity to extreme environments. This includes flights into volcano plumes to compare sulfur dioxide concentration measurements with those measured by satellites. Another application is storm penetration where unmanned aircraft system (UAS) platforms are flown into thunderstorms and hurricanes to obtain measures of air pressure, wind conditions, temperatures, and other data used for storm forecasting and weather model development. A third example is operation in wildfires where unmanned aerial vehicles (UAVs) can gather information on emissions and fire behavior.

UAS Platforms designed for operation in extreme environments offer several key challenges to developers. Strong winds in the area of these missions usually ground smaller UAS platforms. Turbulence could cause vehicle upset and loss of control in addition to structural damage. Many UAS platforms are not weather resistant and so cannot operate in visible precipitation. For operation in extremely cold conditions, icing could cause loss of the aircraft.

Proposals are solicited for both heavier- and light-than- air aerial platforms that can operate in the extreme environments described above. Proposed platforms should address the operational challenges described to enable missions to be accomplished with minimal vehicle loss. The proposed vehicle must be able to carry a scientific instrumentation payload on all science missions. The proposal can be based on new design platforms or extensively modified existing platforms to meet the above mission requirements.

The primary focus of the proposal should be on vehicle design. However, other aspects such as concept of operations, vehicle maintenance, vehicle transport and deployment, ground station design, and flight test planning should also be addressed.

Expected TRL or TRL Range at completion of the Project: 2 to 6
Primary Technology Taxonomy:
Level 1: TX 04 Robotics Systems
Level 2: TX 04.2 Mobility

Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Hardware

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 or enabling technologies. Deliverable items for Phase I shall be a final report describing the results of the concept analysis and demonstration of any key component technology developed.

The Phase II effort will focus on the development of a concept prototype and feasibility testing. Phase II deliverables should include a final report on design concept documentation, test reports, and photos of any prototypes that were built and tested.

State of the Art and Critical Gaps:

Currently, most UAS platforms can operate only in the proximity of extreme environments but do not have capability for actual penetration other than with a high probability of vehicle loss. The strong winds and turbulence associated with these environments usually grounds smaller UAS platforms or could cause vehicle upset and loss of control as well as structural damage.

Many UAS platforms are not weather resistant and so cannot operate in precipitation. For operation in extremely cold conditions such as polar regions, icing could cause loss of the vehicle.

Because of the capability and operational limits of current UAS platforms, it may not be possible to capture important Earth Science data in hazardous environments.

NASA ARMD (Aeronautics Research Mission Directorate) and NASA ARMD SBIR technologies as well as technologies developed by universities could be utilized by the proposed to address some of these challenges such as icing detection and removal; gust load alleviation; upset prevention, detection, and recovery; see-and-avoid systems; technologies for beyond visual line of sight operation; and others.

Relevance / Science Traceability:

Because of global warming and associated effects such as long-term drought, more frequent and intense wildfires, and an increase in severe weather occurrences, there is an increased priority of Earth Science missions by NASA, other Government Agencies, and private industry. This includes prediction of, detection of, response to, and measurement of effects on the environment and the economy of these more frequently occurring events.

NASA, other Government Agencies, and private companies have also shown increased interest in utilizing unmanned aircraft system (UAS) platforms, both heavier and lighter than air, for Earth Science data collection, supplementing satellite and piloted Earth Science aircraft. This is largely due to the ability of UAS to perform dull, dirty, difficult, and dangerous missions more easily than other platforms. In addition, simpler UAS platforms could be more easily deployed to quickly respond to events of interest.

In addition, there is interest from the highest levels of government to invest in the domestic UAS manufacturing
base to reduce reliance on foreign manufacturers such as DJI as well as security concerns with foreign UAS platforms and technologies.

Historically it has been difficult to operate UAS platforms in the National Airspace, primarily because of safety concerns. A large amount of planning, coordination, and approvals were required, making a quick response nearly impossible. Less restrictive operational requirements as developed by the NASA UAS in the NAS program and advances in UAS Air Traffic Technologies developed under the NASA UAS Traffic Management (UTM) Project have enabled simpler, safer, and more efficient UAS flight operations both for private companies and for NASA Earth Science missions.

Advances in UAS technologies, developed under the NASA Aeronautics Research Mission Directorate (ARMD), have enables more capable, less expensive, and higher performing platforms, resulting in an increase of small, innovative, domestic UAS manufacturers. This pool of UAS companies have the expertise and capabilities to develop UAS platforms for future NASA Earth Science missions as well as to commercialize these platforms for non-NASA users.

References:


Scope Title:

Lighter-than-air platform subsystems for Earth and Venus

Scope Description:

1. Venus lighter-than-air platform:

NASA is interested in scientific exploration of Venus using aerial vehicles to perform in situ investigations of its atmosphere and is currently developing concepts for variable-altitude balloons operating at an altitude range between 52 and 62 km.

One concept for a variable-altitude balloon features a super-pressure (SP) balloon located within a zero-pressure (ZP) balloon. The configuration can be described as one small balloon inside a large balloon that are co-located at the bottom. Altitude changes are made by transfer of helium between the two balloons. Pumping helium from the ZP balloon into the SP balloon reduces buoyancy to descend in altitude. Venting helium from the SP balloon into the ZP balloon increases buoyancy to ascend in altitude. Isolating the ZP and SP balloons when neither the pump or vent is operated enables the balloon to float at constant altitude. Details on the variable-altitude balloon system concept can be found in [Hall 2021].

Proposals for an innovative balloon altitude modulation system featuring a lightweight, high-efficiency pump, isolation valves, and venting orifices are desired. The performance requirements of the balloon altitude modulation system will vary depending on the size of the balloon system and payload. For the purposes of adequately scaling this effort, the following specifications represent the requirements for a current Venus balloon concept (the fluid medium is helium gas):

- The pump shall have a nominal flow rate of 250 liters per minute at a pressure rise of 30 kPa.
- The vent shall have a nominal flow rate of 1,000 liters per minute at a pressure drop of 5 kPa.
For reliability purposes, the mission operating lifetime is about 100 days of continuous operations.

Typical commercial pumps with this pressure rise and flow rate have a mass around 15 kg and require 250 W of power. Ground-breaking solutions to reduce pump mass to <7 kg and reduce power to <120 W are goals for the specified flow rate and operating pressure.

The specified pressure and flow requirements are current best estimates and will not change during the Phase I proposal development period but may be updated for Phase II.

Venus features a challenging atmospheric environment that significantly impacts the design and operation of devices on aerial vehicles. Proposers should be familiar with the properties of the Venus atmosphere as described in this call. Additional information on the Venus atmospheric environment can be found in the References section.

2. Earth Lighter-than-air platform:

NASA is also looking for an innovative way to reduce the termination dispersions from a few miles to within 1/2 to 1/4 mile of the predicted termination point by the use of a steerable parachute recovery system (SPRS). The SPRS will need to be able to maneuver around infrastructure (e.g., oil wells, power lines, wind mills), protected areas (e.g., national parks, special habitats), natural resources (e.g., rivers, mountains, lakes), and other areas of interest (e.g., farm land). The SPRS will need to provide real-time maneuverability for a science gondola from a remote operations control room using the communications and telemetry systems provided by the Columbia Scientific Balloon Facility (CSBF). The system should be lightweight—no more than 75 lb—including power.

**Expected TRL or TRL Range at completion of the Project:** 2 to 6

**Primary Technology Taxonomy:**
Level 1: TX 15 Flight Vehicle Systems
Level 2: TX 15.6 Vehicle Concepts

**Desired Deliverables of Phase I and Phase II:**

- Prototype
- Hardware

**Desired Deliverables Description:**

The deliverables for Phase I include a trade study of the potential systems, a simulation of how each system should work, and a report on the recommendation of one to two systems to be further developed in Phase II. It is anticipated that these products are achievable given the SBIR time and funding constraints.

The deliverables for Phase II include an engineering development unit and flight testing with a report of the results.

**State of the Art and Critical Gaps:**

1. Venus lighter-than-air platform state of the art:

There are few commercially available pumps in the market today that have the pressure rise and flow rate capabilities needed for a Venus balloon. Most pumps are not built to be lightweight or efficient, which are of critical importance on a balloon mission. Commercial pumps with the targeted flow rate and pressure capability typically have a mass around 15 kg and require 250 W of power. Isentropic pumping power analysis shows that only 80 W of power are required to achieve the desired flow rate and pressure rise. Therefore, the thermodynamic efficiency of commercial pumps is only about 33%. The Venus balloon system desires a system that is at least 65% efficient
(2x over commercial products) and half the mass of commercial pump systems to maximize resource availability on the balloon system.

2. Earth lighter-than-air platform state of the art:

A scientific balloon floats at an average altitude of 110,000 ft or more and carries science payloads up to 8,000 lb. At the end of a scientific balloon mission, the science payload on the gondola ("science gondola" from this point on) is separated from the balloon and falls to Earth on a parachute, following the wind currents at the time of release, and then lands on cardboard crush pads. In most cases this allows recovery of the science gondola, although the payload and gondola may be in areas that are hard to reach using conventional recovery trucks. However, there are rare cases where the science gondola falls either into water or in areas that require special equipment or are difficult for recovery (i.e., inaccessible area). Currently, trajectory predictions for termination are within a few miles and are dependent on models, map overlays (showing restricted air space, national/state parks), and observations from a plane on areas along the trajectory to determine the best area to terminate the balloon and bring the science gondola safely to the ground. Some items that are considered during the termination discussions are science mission minimums, trajectory predications (e.g., national or state parks, lakes, mountains, rivers, infrastructure, crop lands), weather conditions, and risk to the public.

Current state of the art does not include steerable systems in balloon parachutes. Success in this endeavor will primarily entail steerability, and will also frequently result in a safety analysis, which will allow more “green lights” for launch than would otherwise be the case.

**Relevance / Science Traceability:**

1. Venus Lighter-than-air platform relevance:

The Mars Helicopter, Ingenuity, and the Titan Dragonfly mission show there is significant interest in planetary aerial vehicles for science investigations. It is in NASA's interest through the SBIR program to continue fostering innovative ideas to extend our exploration capabilities by developing technologies for Venus aerial mission concepts.

The NASA Jet Propulsion Laboratory's (JPL's) Solar System Mission Formulation Office and Science Mission Directorate's (SMD's) Planetary Science Division advocate Venus aerial vehicle platform development. NASA recently completed the Venus Flagship Mission concept study, which included a balloon system for the Planetary Decadal Survey [Gilmore, 2020].

Science traceability: The 2019 VEXAG Venus Strategic Plan 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. Building the variable-altitude balloon requires the development of several key components such as the helium transfer system identified in this call.

2. Earth Lighter-than-air platform relevance:

This subtopic will be relevant to any mission directorate, commercial entity, or other government agency that drops payloads from an altitude, including the Balloon Program. Other potentially interested projects include NASA sounding rockets, unmanned aerial vehicles (UAVs), and aircraft programs.

**References:**

Venus Lighter-than-air platform:


Earth Lighter-than-air platform: