Venus Atmospheric Maneuverable Platform (VAMP)

A Concept for a Long-lived UAV at Venus

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Kristen Griffin, Daniel Sokol,
Greg Lee, Ronald Polidan

Northrop Grumman Aerospace Systems

Venus Atmospheric Maneuverable Platform (VAMP) Development

- Possible new approach to Venus upper atmosphere exploration found by combining
  - Recent Northrop Grumman (non-NASA) development programs
  - Awareness of the challenges associated with Venus upper atmosphere science missions
- A solution may exist in the form of a long-lived, maneuverable, semi-buoyant aircraft
- Northrop Grumman has an extensive corporate investment and history in
  - Aircraft and autonomous air vehicles
  - Science and other space missions
  - Large deployables
  - Reentry systems
- In 2012 we initiated a feasibility study for a semi-buoyant maneuverable vehicle that could operate in the upper atmosphere of Venus
  - Results presented here are the products of that small feasibility study
  - We have just begun a more in-depth engineering and science applicability effort that should run most of 2013
  - Effort is funded utilizing only Northrop Grumman internal funds

VAMP Integrates Diverse Capabilities into a Unique Planetary Exploration Vehicle

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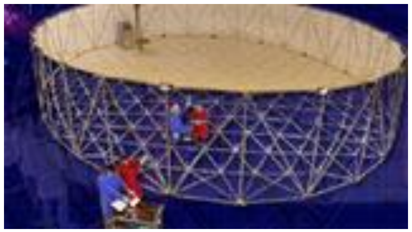
deployment and entry technology



- Exoatmospheric deployment of large structures
- Inflatable and low ballistic coefficient entry

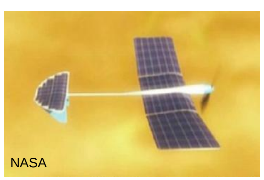
Northrop Grumman LEM-V
semi-buoyant vehicle
(First flight Aug 2012)

- Semi-buoyant flight
- Long on-station time
- Reduced aerodynamic requirements

Northrop Grumman Global Hawk
unmanned aircraft in production and use

- Long duration flight
- Automated science observation

JPL, Glenn & Others
Venus exploration technology development

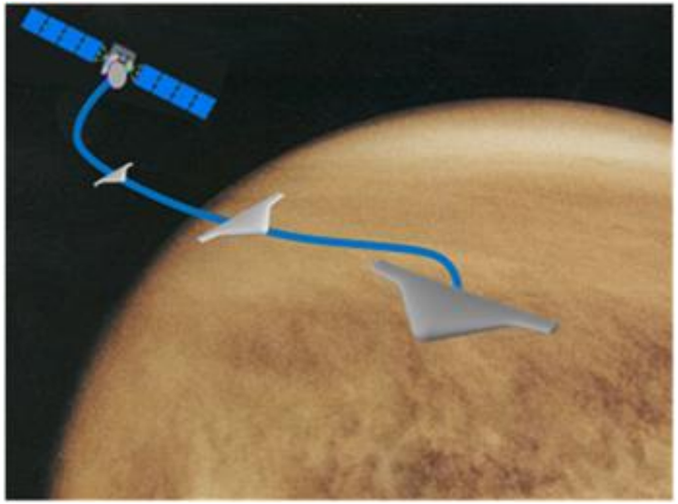


- Environmentally compatible materials/systems
- Variety of flight plans (ConOps), mission risk, science return

Introduction to the Concept

- Semi-buoyant unmanned propelled aerial vehicle
  - 5-15% buoyant at cruising altitudes
  - Sinks to altitude of 100% buoyancy and floats when propellers are off
- Entry into Venus atmosphere without an aeroshell
  - VAMP inflates in space
  - Large surface area produces benign heating loads during entry
  - Benign entry enables continuous data collection during descent
- Propellers provide altitude, latitude, and longitude mobility
  - Flight path is controllable (but not in real time)
  - Ability to survey large areas and/or focus on regions of interest
- Power source is some (TBD) combination of solar, ASRG, and batteries
- Supported by orbiting satellite
  - Orbiter delivers VAMP to Venus
  - Orbiter serves as data and communications relay with Earth

Notional VAMP air vehicle



VAMP released from Venus orbiting spacecraft and inflating exoatmospherically for benign entry

Summary of Key Advantages and Challenges

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Advantages

- Lifetime
  - Long life: months to a year
  - Limited only by gradual loss of buoyant gas through envelope and/or environmental effects
- Maneuverability
  - Directed flight with capabilities for atmospheric monitoring on small and large scales
  - Large range of accessible altitudes, latitudes, longitudes
- Benign entry
  - No aeroshell required
  - Maximizes mass available to science mission
  - Minimizes loading on science instruments
  - Data collection may be possible throughout entry from very high altitudes
- Low risk of mission failure
  - Simple flight plan and power cycling
  - Safe mode is easily recoverable from a passively floating state

Technical Challenges to be Explored in 2013

- Power
  - Sufficient to survive ~70 hr nights
  - Power source options: Solar, battery, ASRG
- Materials
  - Selection of envelope membrane and buoyant gas
  - Protection of exterior materials in Venus atmosphere
- Deployment
  - Packaging for transfer to Venus
  - On-orbit deployment sequence
- Navigation and communication architecture

Sample 1-Day Trajectory of Day-Night Vehicle

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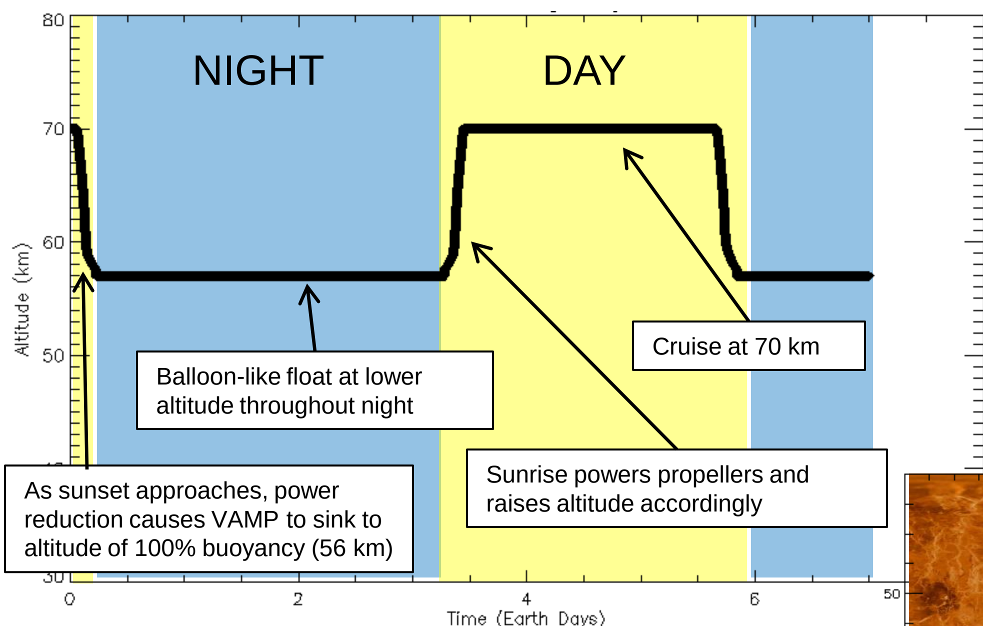


<u>Altitude</u>

Fully controllable during the day

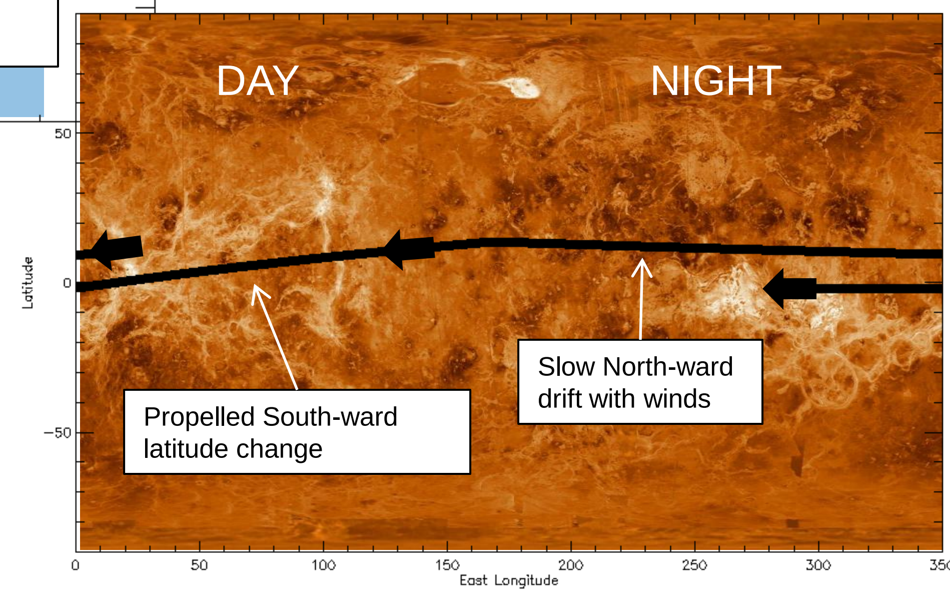
Altered via propelled speed at will in the 55-70 km range

<u>Latitude</u>

Fully controllable during the day

Altered via propelled direction

Maneuvered at will between > ±20º



Trade Studies on Vehicle Design

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- Initial assessment completed during feasibility study
  - Day-only vs day/night vehicle
    - Driving parameters: power requirements
  - Altitude range of flight
    - Driving parameters: vehicle volume and mass, atmospheric temperature
  - Buoyancy
    - Driving parameters: atmospheric density, time spent in day vs night, latitude range accessible, vehicle mass

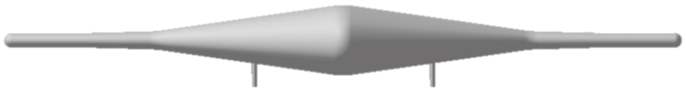
- Next steps (2013)
  - Detailed vehicle shape
  - Entry loading vs buoyancy
  - Flight speed vs buoyancy and vehicle mass
  - Materials
    - Envelope membrane
    - Buoyant gas
  - Use of ASRG instead of batteries for power at night
  - Etc!

Side

Top

Current Design

Max Altitude: 70 km
Buoyancy: 6%
Wing Span: 41 m
Volume: 370 m^3



Front

Trade Study: Altitude Range Accessible

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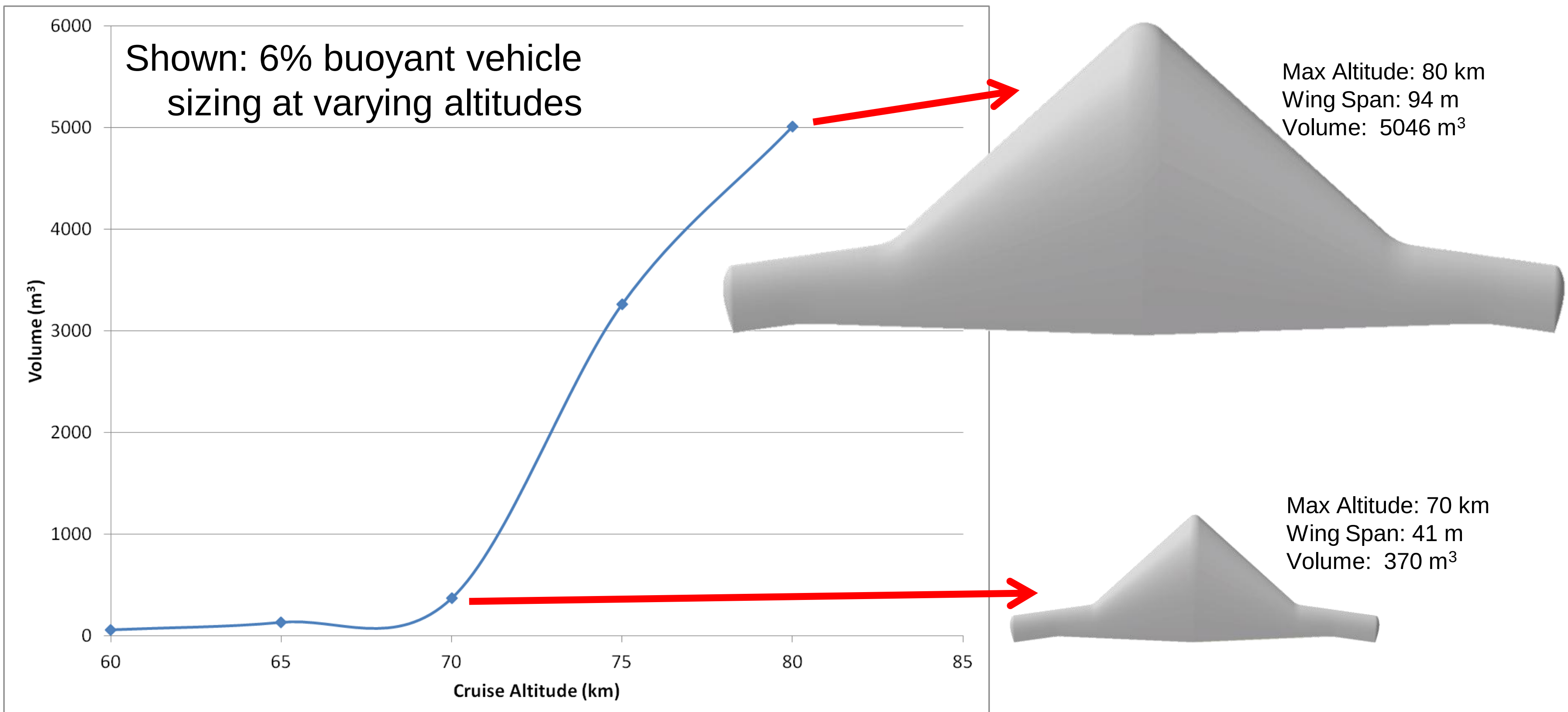
- Study of day-time (maximum) cruise altitude attainable
- At all buoyancies, mass and volume of vehicle rise steeply above 70 km due to the fall off of atmospheric density
  - Vehicle volume increase is order of magnitude to increase flight altitude from 70 km and 80 km



Trade Study: Vehicle Buoyancy

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Buoyancy at 70 km	4%	6%	8%	10%	12%	14%	16%
ALTITUDE							
Max flight altitude (day)	~ 71 km	71 km	~ 70 km	70 km	~ 70 km	< 70 km	< 70 km
Buoyant altitude (night)	47 km	51 km	54 km	56 km	57 km	58 km	59 km
Temperature at night altitude	373 K	342 K	313 K	292 K	283 K	275 K	269 K
CONOPS							
Max overnight time (equator)	90 hr	83 hr	79 hr	76 hr	75 hr	73 hr	72 hr
Min overnight time (critical latitude)	82 hr	78 hr	74 hr	72 hr	70 hr	69 hr	68 hr
Latitude range accessible for v=10 m/s	-25° to +25°	-21° to +21°	-19° to +19°	-19° to +19°	-18° to +18°	-18° to +18°	-18° to +18°
SIZING (at z=70 km)							
Mass	444 kg	443 kg	446 kg	452 kg	459 kg	467 kg	475 kg
Max flight speed at mass~450 kg	~60 m/s	in progress	in progress	11 m/s	in progress	in progress	~ 7 m/s
Max stagnation heating rate on entry	higher	higher	higher	<60 W/cm^2	lower	lower	lower

< 1.5% of that of Pioneer Venus (~4 kW/cm^2)

Summary & Plans for 2013

- Our initial feasibility study identified a promising approach for a maneuverable Venus air vehicle that could explore the upper Venus atmosphere with the following characteristics
  - It is a semi-buoyant (6-12%) powered aircraft capable of a mission lifetime of months
  - The vehicle deploys/inflates in orbit and has a benign entry into Venus, requiring no aeroshell
  - It has the ability to fly at altitudes between 55 and 70 km and cover a wide range of latitude, and in the event of a safe mode entry, will float at a safe altitude until recovered
- Technology development plans for 2013
  - Complete trade studies and select initial “point design” for detailed development
  - Detailed architecture of VAMP, companion spacecraft, and their interaction (e.g. data relay to Earth, navigation of VAMP)
  - Extensive stowing and deployment study, including envelope, propellers, etc
  - Refine flight plan for “point design,” including most accurate Venus atmospheric model possible
  - Study of envelope and solar panel materials, followed by lab testing
  - If possible, fabricate and test behavior of small scale model in wind tunnels / relevant environments

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