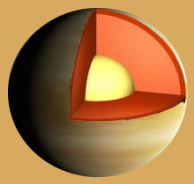
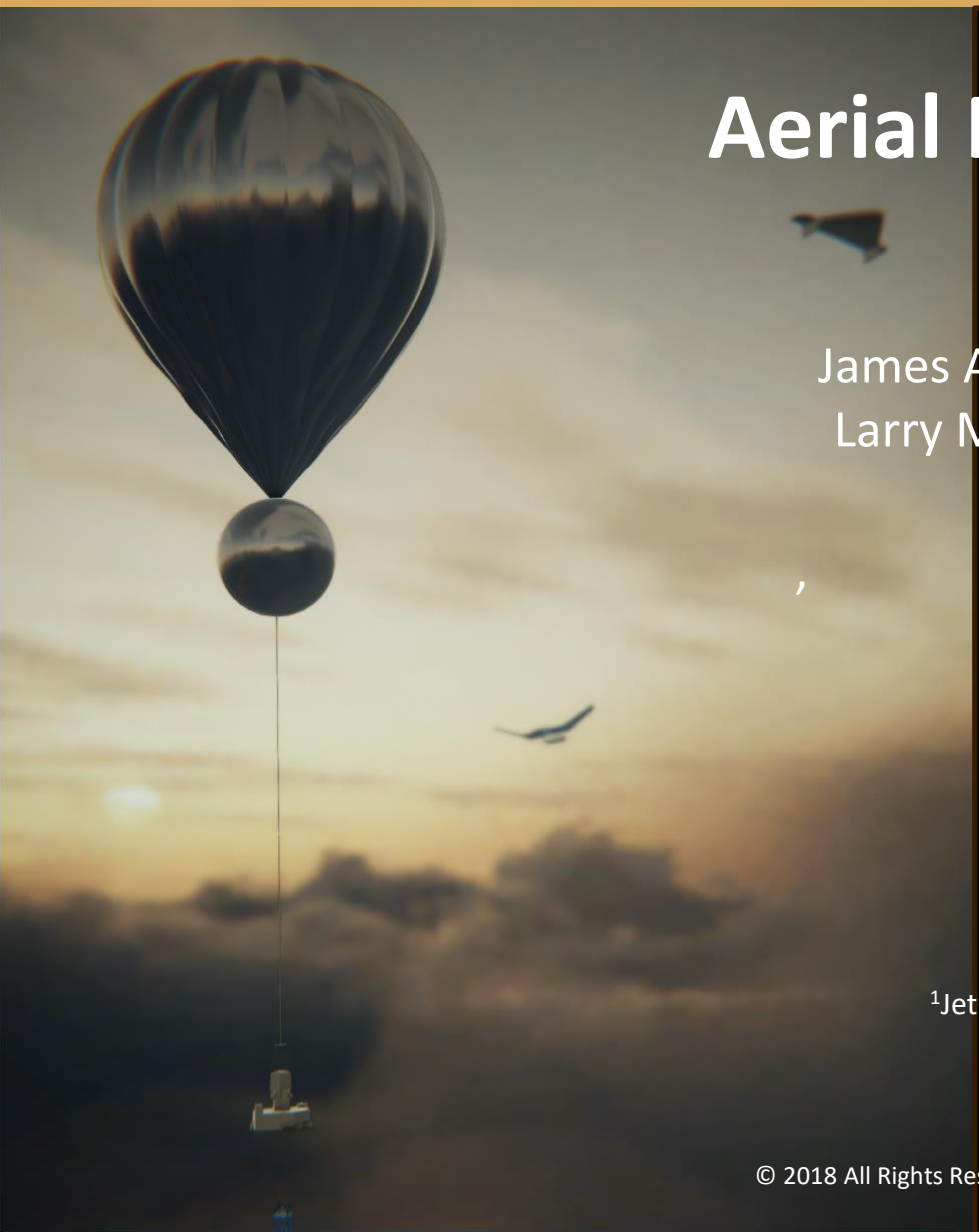




Aerial Platforms for Scientific Investigation of Venus

James A. Cutts[1], Kevin Baines[1,3], Robert Grimm[2], Larry Matthies[1], Jeffery L. Hall[1], Sanjay Limaye[3], and Thomas W. Thompson[1]

,

American Geophysical Union

Fall Meeting

Washington D.C.

Dec 14, 2018

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA
[2] South West Research Institute Boulder, Colorado
[3] University of Wisconsin, Madison, Wisconsin

© 2018 All Rights Reserved. California Institute of Technology. Government sponsorship acknowledged.

Aerial Platform Study Participants

- Michael Amato, GSFC, michael.amato@nasa.gov
- Giada Arney, NASA Goddard, giada.arney@gmail.com
- Dave Atkinson, JPL, David.H.Atkinson@jpl.nasa.gov
- Josette Bellan, JPL, Josette.Bellan@jpl.nasa.gov
- Kevin Baines, JPL/U. Wisc.-Madison, blueskies4321@yahoo.com
- Kumar Bugga, JPL, Ratnakumar.V.Bugga@jpl.nasa.gov
- Neil Cheatwood, NASA LaRC, f.m.cheatwood@nasa.gov
- Jim Corliss, NASA LaRC, james.m.corliss@nasa.gov
- Dave Crisp, JPL, David.Crisp@jpl.nasa.gov
- James Cutts, JPL, james.a.cutts@jpl.nasa.gov
- Maxim de Jong, Thin Red Line, maxim@thin-red-line.com
- Mona Delitsky, CSE, cal_specialty@yahoo.com
- Debbie Fairbrother, NASA Langley, debora.a.fairbrother@nasa.gov
- Lori Glaze, GSFC, lori.s.glaze@nasa.gov
- Ben Goldman, Global Aerospace.com, benjamin.d.goldman@gaerospace.com
- Jonathan Grandidier, JPL, Jonathan.Grandidier@jpl.nasa.gov
- Bob Grimm, SwRI, grimm@boulder.swri.edu
- Jeffery Hall, JPL, jlhall@jpl.nasa.gov
- Matt Heun, Global Aerospace Corp., matthew.k.heun.1@gaerospace.com
- Jacob Izraelevitz, JPL, jacob.izraelevitz@jpl.nasa.gov
- Kandis-Lea Jessup, SwRI, jessup@boulder.swri.edu
- Attila Komjathy, JPL, komjathy@jpl.nasa.gov
- Tibor Kremic, NASA Glenn, tibor.kremic@nasa.gov
- Siddharth Krishnamoorthy, JPL, siddharth.krishnamoorthy@jpl.nasa.gov
- Tim Lachenmeier, Near Space Corp., Tim.Lachenmeier@nsc.aero
- Damon Landau, JPL, Damon.Landau@jpl.nasa.gov
- Geoffrey A. Landis, NASA Glenn Res. Center, geoffrey.landis@nasa.gov
- Sebastien Lebonnois, LMD/CNRS, sebastien.lebonnois@lmd.jussion.fr
- Sanjay Limaye, U. Wisconsin, SanjayL@ssec.wisc.edu
- **Larry Matthies, JPL, lhm@jpl.nasa.gov**
- Kevin McGouldrick, U. Colorado-Boulder, kevin.mcgoudrick@lasp.colorado.edu
- David Mimoun, ISAE, France, david.mimoun@isae.fr
- Peter Ngo, Global Aerospace Corp., peter.ngo@gaerospace.com
- Kerry Nock, Global Aerospace Corp., kerry.t.nock@gaerospace.com
- Julian Nott, Consultant, nott@nott.com
- Mike Pauken, JPL, mpauken@jpl.nasa.gov
- Mina Rais-Zadeh, JPL, Mina.Rais-Zadeh@jpl.nasa.gov
- Tom Randolph, JPL, Thomas.M.Randolph@jpl.nasa.gov
- Kim Reh, JPL, Kim.R.Reh@jpl.nasa.gov
- Gerald Schubert, UCLA, schubert@ucla.edu
- Dave Senske, JPL, david.senske@jpl.nasa.gov
- Daniel Sokol, Northrop Grumman, daniel.sokol@northropgrumman.com
- Tom Spilker, Consultant, planetaryflightarchitect@yahoo.com
- Paul Steffes, Georgia Tech, stefffes@gatech.edu
- **Tommy Thompson, JPL, twthompson@jpl.nasa.gov**
- Allan Treiman, LPI, Houston, TX, treiman@lpi.usra.edu
- Eugene Ustinov, JPL, eugene.a.ustinov@jpl.nasa.gov
- Raj Venkatapathy, NASA, Ames, ethiraj.venkatapathy-1@nasa.go
- William Warner, JPL, william.n.warner@jpl.nasa.gov
- Steve Warwick, Northrop Grumman, steven.warwick@ngc.com
- Paul Wercinski, NASA Ames, paul.wercinski@nasa.gov
- Leyland Young, NASA/WFF/GSFC, leyland.g.young@nasa.gov

James Cutts, Larry Matthies and Tommy Thompson are study co-leads

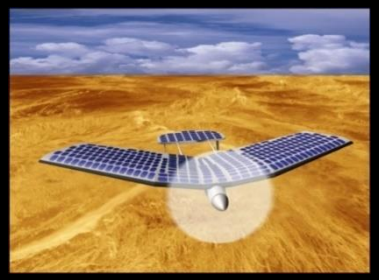
Pre-Decisional Information -- For Planning and Discussion Purposes Only

Aerial Platform Concepts Considered

Superpressure Balloon (JPL Venus prototype)

Mechanical Compression Balloon (Thin Red Line Aerospace)

Pumped Helium Balloon (Paul Voss CMET)



Solar Aircraft
Geoff Landis (NASA-GRC)

Air Ballast Balloon (Google Loon)

Phase Change Fluid Balloon (JPL)

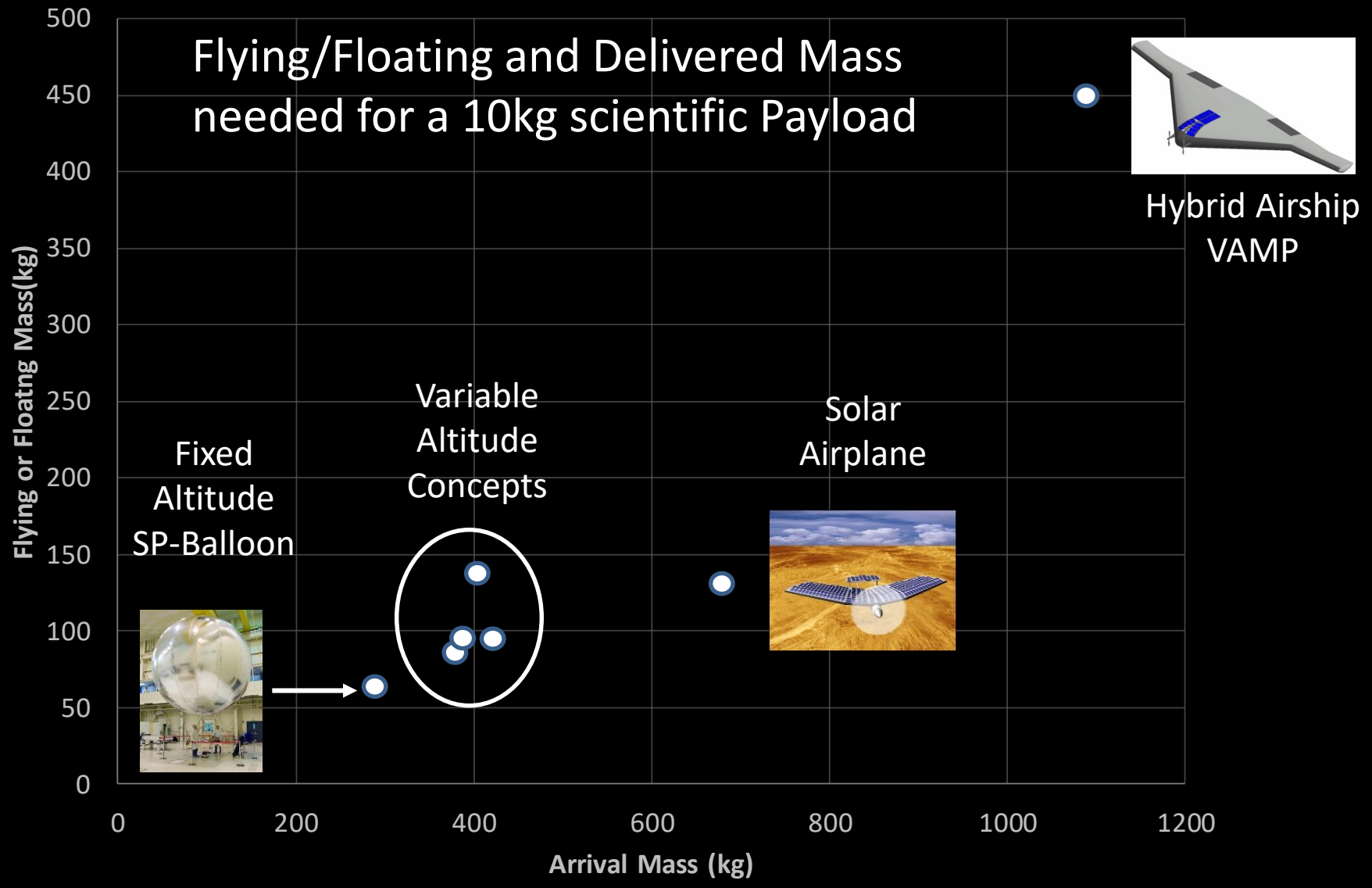
Hybrid Airship (Northrup Venus Atmospheric Maneuverable Platform (VAMP)
Northrop Grumman

Fixed Altitude

Variable Altitude

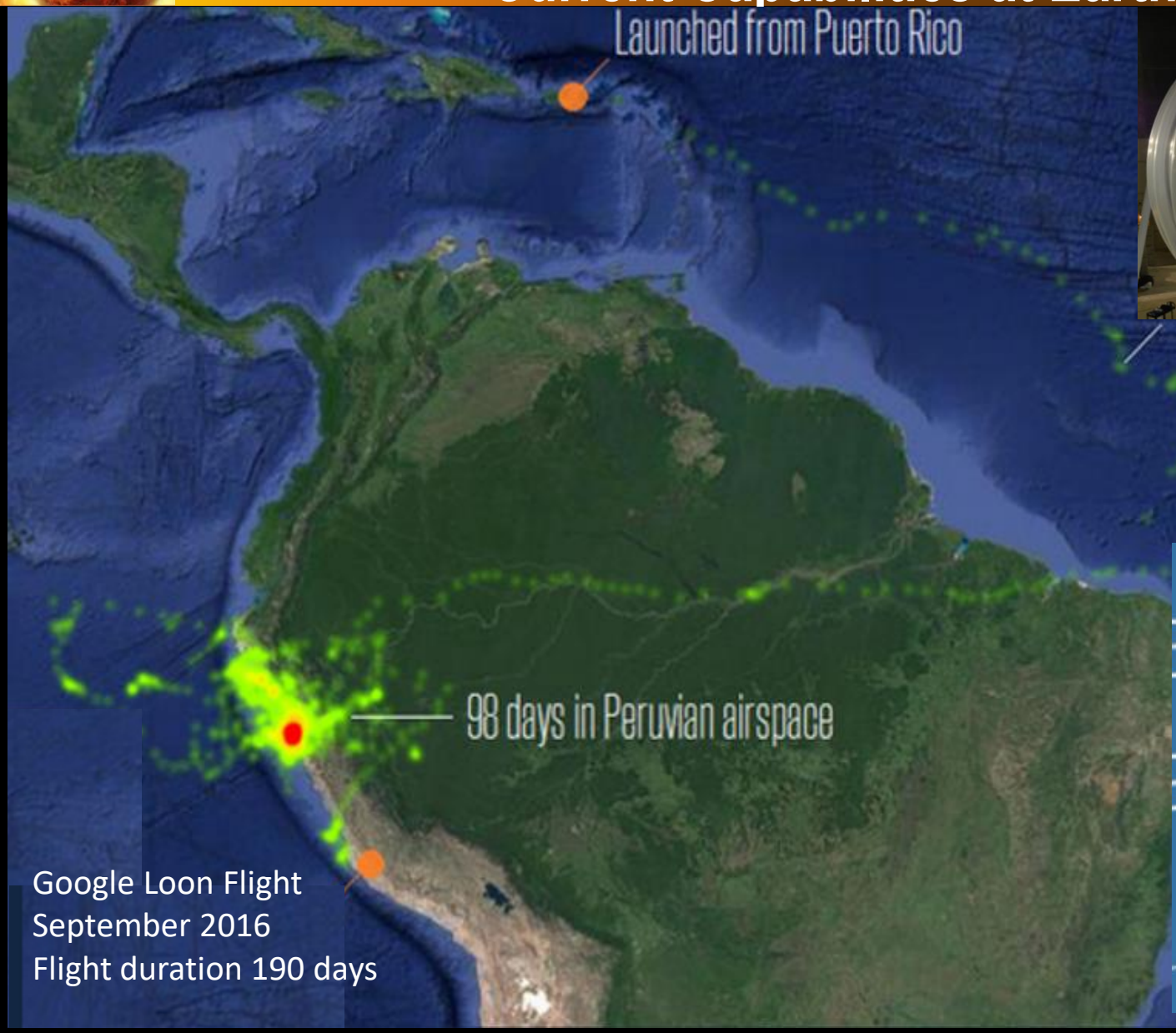
Variable Altitude and Lateral Control

Venus Aerial Platform Trade Study



Pre-Decisional Information -- For Planning and Discussion Purposes Only

Altitude Controlled Balloons
Current Capabilities at Earth



Google Loon Flight
September 2016
Flight duration 190 days

Variable altitude
air ballast balloon

Using air currents to navigate

Aerial Platforms Technology Maturity Assessment (1 of 2)

Platform Concepts	Altitude Range Studied
• Fixed Altitude –SP Balloon	Nominal Range • Design Altitude(53km, 30C) • Excursions of (2km, 15C)
• Variable Altitude – Air ballast – Pumped Helium – Mech. Compression – Phase Change	Nominal Range • Upper limit (60km, -35C) • Lower limit (50 km, 65C) Extended Altitude Range (Note 1) • Upper limit (60km, -35C) • Lower limit (40km, 115C)
• Variable Altitude and Lateral Control – Solar Airplane – Hybrid Airship	Nominal Range (Note 2) • Upper limit (66km, -45C) • Lower limit (62 km, -35C) Nominal Range • Upper limit (60km, -35C) • Lower limit (50 km, 65C)

Note 1 : For brief excursions into the high temperature region, temperature sensitive components(electronics, sensors, batteries can be maintained below 30C)

Note 2 : Solar airplane can only fly on the day side of Venus above the clouds

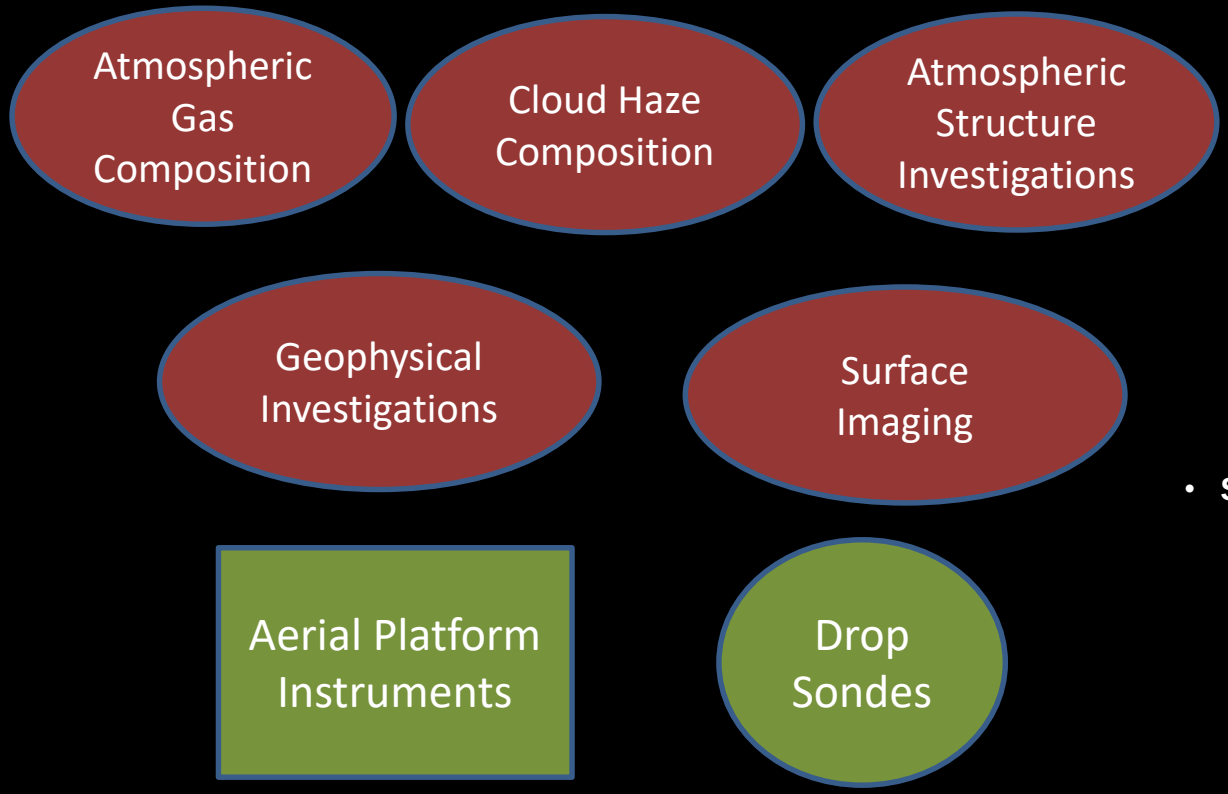
Aerial Platforms Technology Maturity Assessment (2 of 2)

Platform Type	Concept	Altitude Range	Temperature Range	Technology Maturity			
				Entry	Descent Deployment	Aerial Mobility	System
Fixed Altitude	Superpressure balloon	53 +/-2Km	30 +/-8C	Very High	High	High	High
Variable Altitude	All four concepts	50 to 60 km	-30C to 60C	Very High	High	Moderate	Moderate
Variable Altitude	All four concepts	40 to 60 km	-30C to 115C	Very High	High	Low to Moderate	Low to Moderate
Full 3D Control	Solar Airplane	60 to 67 km	-30C to -45C	Very High	High	Moderate	Moderate
Full 3D control	Hybrid Airship (VAMP)	50 to 60 km	-30C to 60C	Low	Moderate	Moderate	Low

Low | Low to Moderate | Moderate | High | Very High

Pre-Decisional Information -- For Planning and Discussion Purposes Only

Scientific Assessment of Aerial Platforms



- **Atmospheric Science**
  - **Kevin Baines, JPL/University of Wisconsin**
  - **Kevin McGouldrick, University of Colorado**
  - Giada Arney, GSFC
  - Dave Atkinson, JPL
  - Dave Crisp, JPL
  - Mona Delitsky, CSE
  - Sebastien Lebonnois, LMD, Paris, France
  - Sanjay Limaye, University of Wisconsin
  - Kandis-Lea Jessup, SWRI
  - Paul Steffes, Geogia Tech

- **Surface and Interior Science**
  - **Bob Grimm, SWRI, Boulder**
  - **Lori Glaze, GSFC**
  - Attila Komjathy, JPL
  - Siddharth Krishnamoorthy, JPL
  - Alan Treiman, LPI
  - Gerald Schubert, UCLA
  - Tommy Thompson, JPL

- Experimental techniques identified and evaluated
- Instruments with multiple science functions e.g. magnetometers identified
- Contributions to VEXAG Goals Objectives and Investigations (GOI) assessed

Pre-Decisional Information -- For Planning and Discussion Purposes Only

Scientific Assessment of Aerial Platforms

VEXAG Goals, Objectives and Investigations				Venus Aerial Platform and Sonde Types with Altitude Range (km)							
				Constant Altitude	Variable Altitude Aerobot		3D control		Probes/Sondes		
Goals	Objectives	Investigations	GOI Code	SP Balloon	Nominal Range	Enhanced Range	Solar Airplane	Airship VAMP	Large Probe	Targeted Sonde	Shallow Sond (mult)
				55	50 to 60	40 to 60	66 to 75	50 to 60	65 to 0	55 to 0	60 to 40
Atmosphere	Atmospheric Evolution	Solar Nebula/noble gases	I.A.1								
		Atmospheric Escape	I.A.2								
	Radiative balance, climate and superotation	Global circulation	I.B.1								
		Radiative Balance	I.B.2								
		Vertical motions	I.B.3								
	Clouds and Haze characterization	Cloud chemistry	I.C.1								
		Greenhouse /Cloud physics	I.C.2								
		Role of lightning	I.C.3								
		Biologically relevant chemistry	I.C.4								
Surface and Interior	Geodynamics	Stratigraphy/deformation	II.A.1								
		Radiogenic He_4 Ar_{40} in atmos	II.A.2								
		Geophysical studies	II.A.3								
		Active volcanism and tectonism	II.A.4								
		Absolute rock ages	II.A.5								
	Differentiation	Elemental composition	II.B.1.								
		Large scale composition variations	II.B.2								
		Structure of crust	II.B.3								
		Core and mantle structure	II.B.4								
		Radiogenic crustal elements	II.B.5								
		Subsurface layering	II.B.6								
Interior Surface Atmosphere	Liquid water and the greenhouse effect	History of water from Isotopes	III.A.1								
		Role of water in tessera	III.A.2								
		Hydrous minerals and sediments	III.A.3								
	Interactions of interior-surface and atmosphere over time	Elemental composition-noble gas	III.B.1								
		Rock weathering investigations	III.B.2								
		Altitude profiles of reactive species	III.B.3								
		Sulfur outgassing from surface	III.B.4								
	Other	Solid Body Atmosphere Ang Mom	NA								

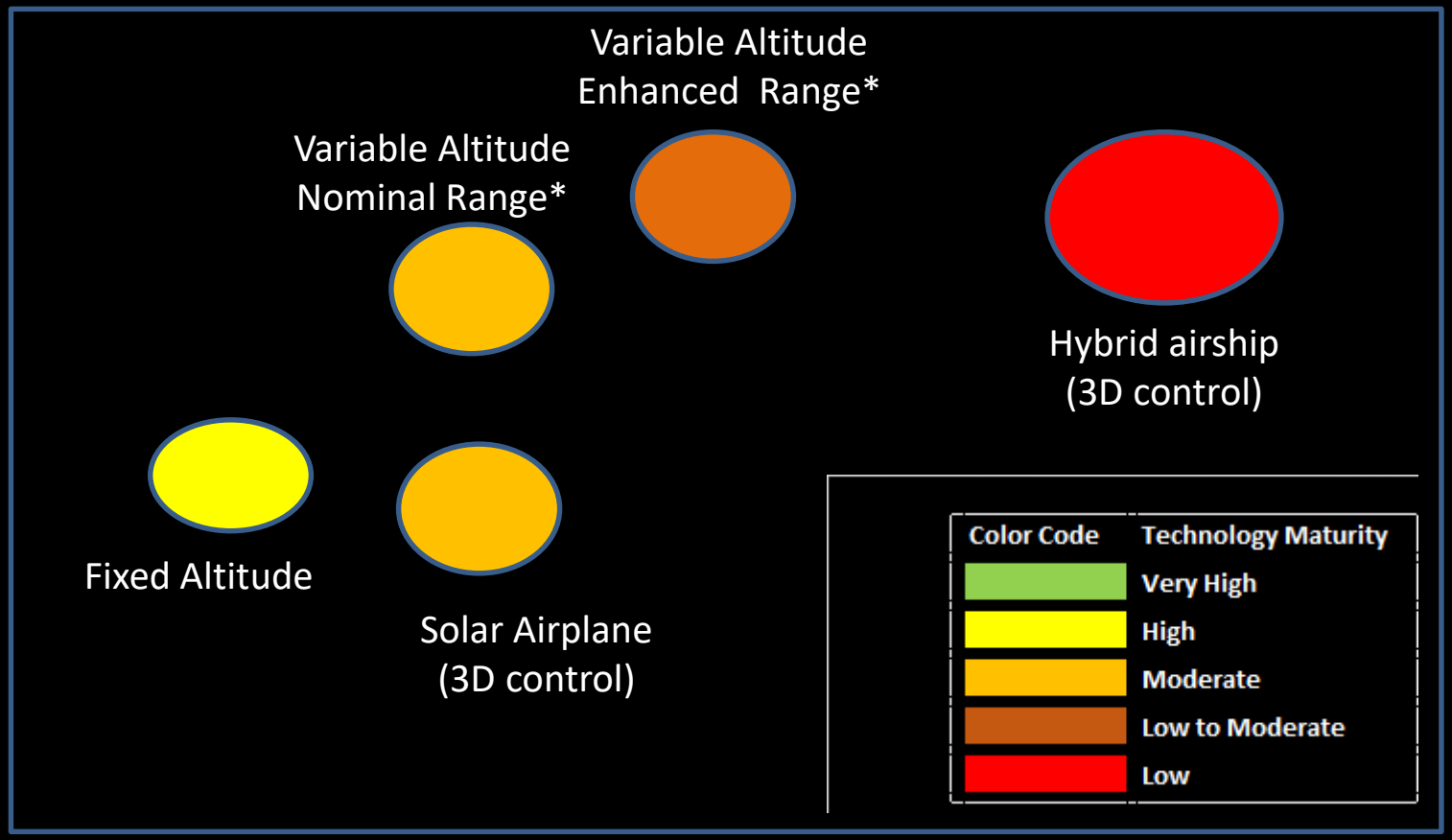
Necessary and sufficient to address the investigation in the GOI

Necessary but not sufficient

Complementary to a primary measurement

Pre-Decisional Information -- For Planning and Discussion Purposes Only

Venus Aerial Platforms – Design Sweet Spot



Science Value

Mass/Complexity

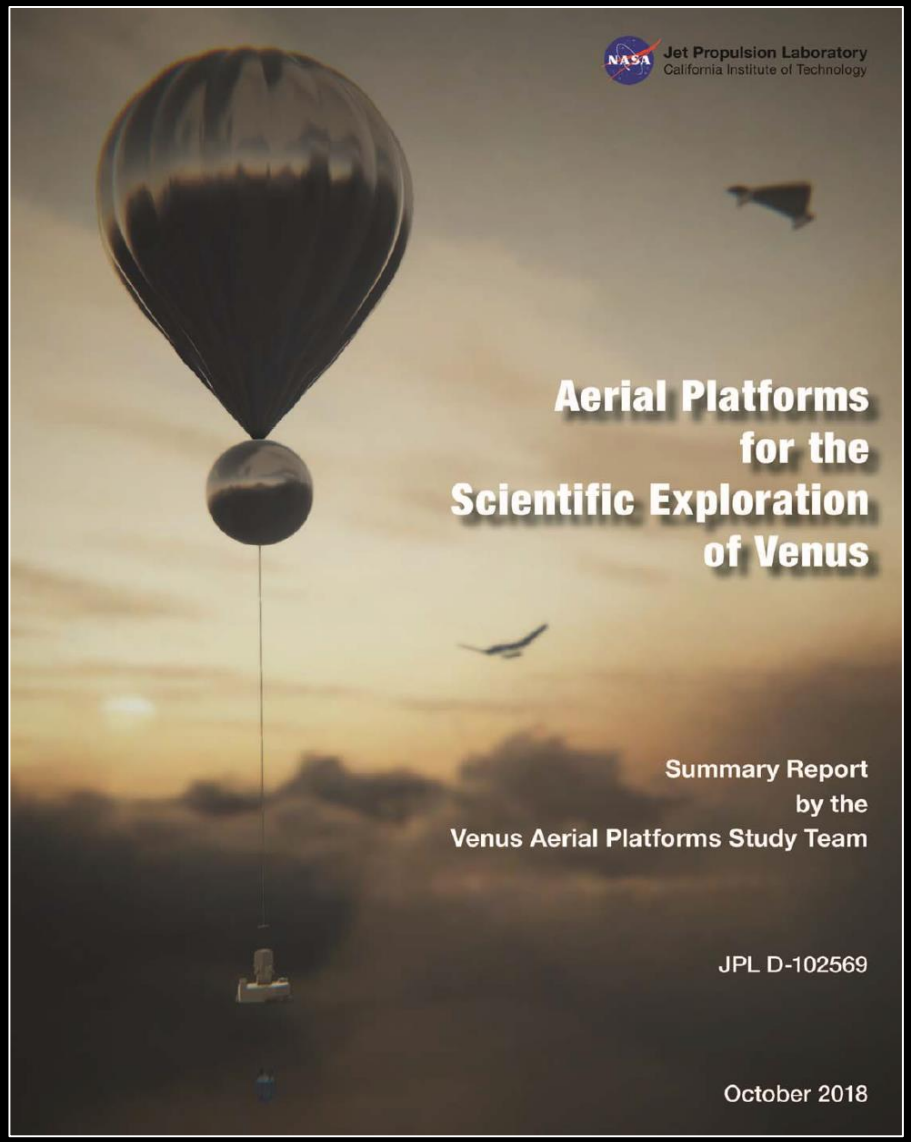
Altitude controlled balloons represent a "sweet spot" in the aerial platform option space.

* Nominal Range
Altitude 50 to 60 km

* Enhanced Range
Altitude 40 to 60 km

Pre-Decisional Information -- For Planning and Discussion Purposes Only

Venus Aerial Platform Summary Report



https://www.lpi.usra.edu/vexag/reports/Venus_Aerial_Platforms_Final_Report_Summary_Report_10_25_2018.pdf

Summary

- Venus Aerial Platforms (VAPs) could offer a credible pathway to long duration in situ missions at Venus. Missions which explore the temperate zone in the Venus clouds are the place to start

- Focusing on the temperate zone enable us to capitalize on the rich heritage of conventional sensors and electronic systems.

- Although the VAP technology for the SP platform is almost ready now, a multi-year investment program focusing on variable altitude capability would enhance the science capability of these platforms

- Among the opportunities for the application of VAP technology are:
  - Joint NASA Russian Venera D Mission Concept– NASA contribution
  - Venus Flagship Mission – currently being studied by NASA
  - Venus Bridge – atmospheric elements
  - Future competitive opportunities – New Frontiers and Discovery

Pre-Decisional Information -- For Planning and Discussion Purposes Only