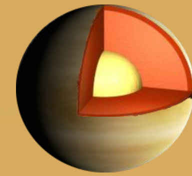

Venus Aerial Platforms Study

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Venus Aerial Platform Study Team

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Topics

- Motivation
- Venus Aerial Platforms Study Overview
- Types of Aerial Platforms Considered
- Trade Study
- Trajectory Models
- Venus Entry Option Space
- Venus Aerial Platforms – Design Sweet Spot
- Science Instruments Trade Study
- Aerial Platform Trajectories – Earth and Venus
- Technology Needs
- Summary

Motivation

- In situ exploration of Venus has been seriously hampered by the severe environment (T =460C and P=90 bars) of the Venus surface.

- Contemporary concepts for lander missions to Venus have more sophisticated instruments but do not survive on the surface of Venus for very much longer than Soviet- era Venera landers

- There are two plausible pathways to long-duration Venus *in-situ* missions
  - Aerial Platforms operating in the temperate regions of the upper atmosphere
  - Surface Platforms utilizing high temperature electronics

- NASA's Planetary Science Division (PSD) is currently studying both pathways for Venus exploration and is considering both concepts as U.S. provided contributions to a joint mission with Russia (Venera D)

Venus Aerial Platforms Study Overview

- NASA PSD formed a study team in April 2017 to assess the state of science and technology for aerial platforms and develop a technology plan
- Two face-to-face study meetings were held in June and December 2017 covering the science implementation concept and technical maturity
  - Scientific objectives and aerial platform options space (June 2017)
  - Technical feasibility and technology roadmap (Dec 2017)
- Since the second meeting the study team has been working on completing a report with the key findings of the study
- Today's presentation provides an overview of the principal accomplishments of the study
- The presentation by Jeff Hall that follows provides a detailed description of the principal trade study that will appear in our report

Types of Aerial Platform Considered

Superpressure Balloon (JPL Venus prototype)

Fixed Altitude

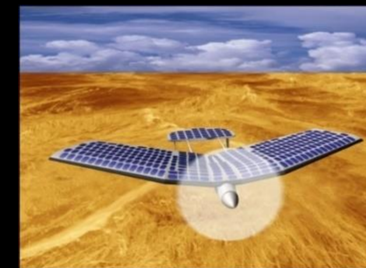
Mechanical Compression Balloon
(Thin Red Line Aerospace)

Pumped Helium Balloon
(Paul Voss CMET)

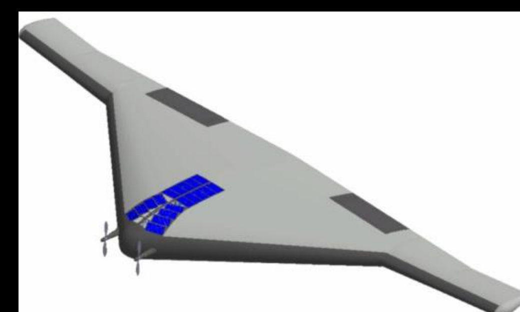
Air Ballast Balloon (Google Loon)

Phase Change Fluid Balloon (JPL)

Variable Altitude



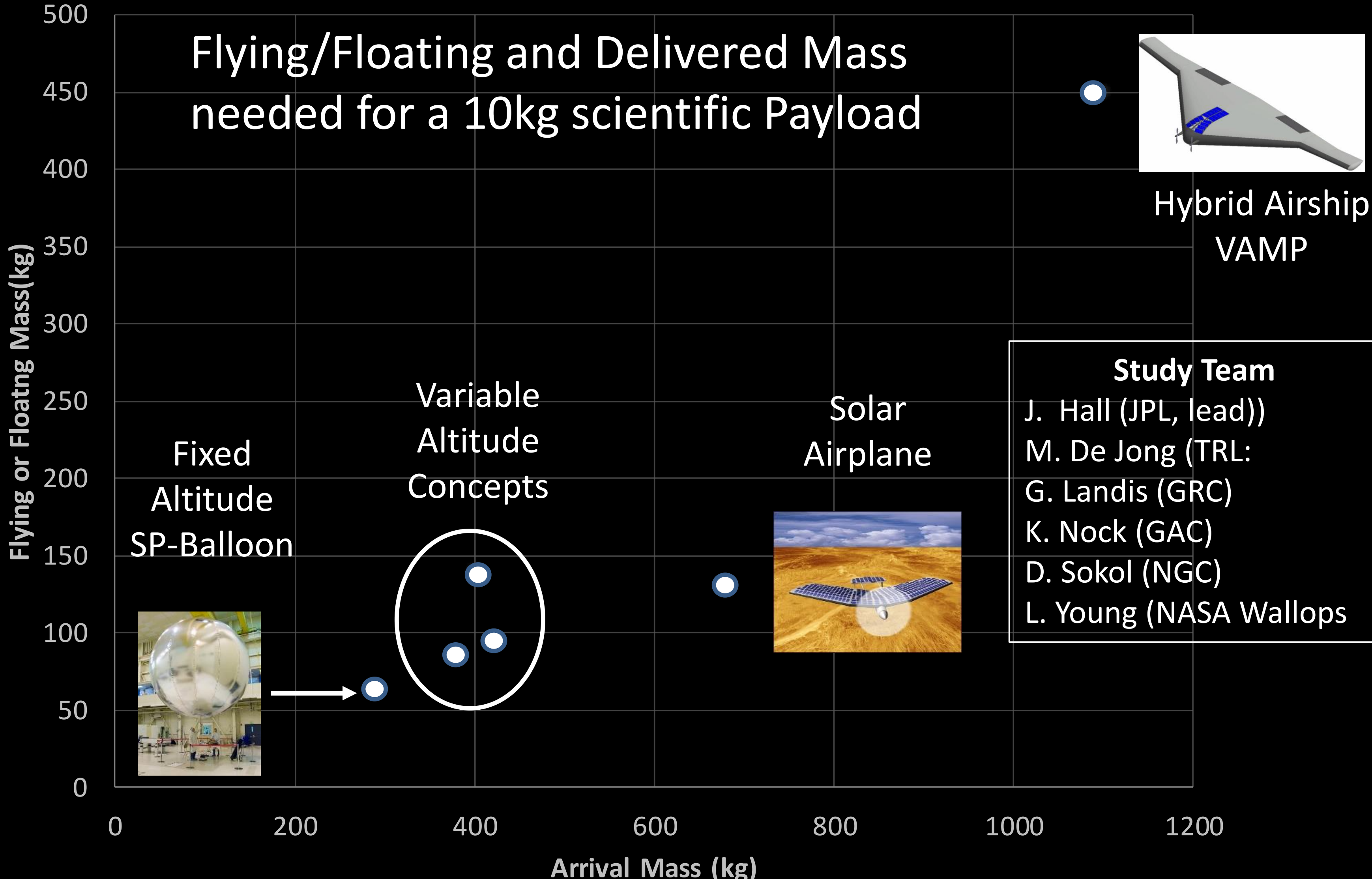
Solar Aircraft (Solar Impulse 2)
Geoff Landis (NASA-GRC)



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

Variable Altitude and Lateral Control

Venus Aerial Platform – Trade Study



Venus Entry System Trade Study

Mission Design
Direct Entry
Orbit from Entry

Entry State

Science Objectives
Measurement
Requirements

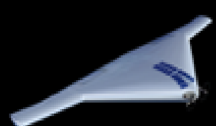
Payload and Measurement Details

Entry System Constraints

Entry Velocity
Entry Flight Path Angle Options

Payload Mass and Volume
Payload Environment Limits
Payload Deployment Conditions
Trajectory Timeline (Transitions)

Study Team
J. Corliss (LaRC, lead))
N. Cheatwood (LaRC)
R. Venkatapathy (ARC)
P. Wercinski (ARC)

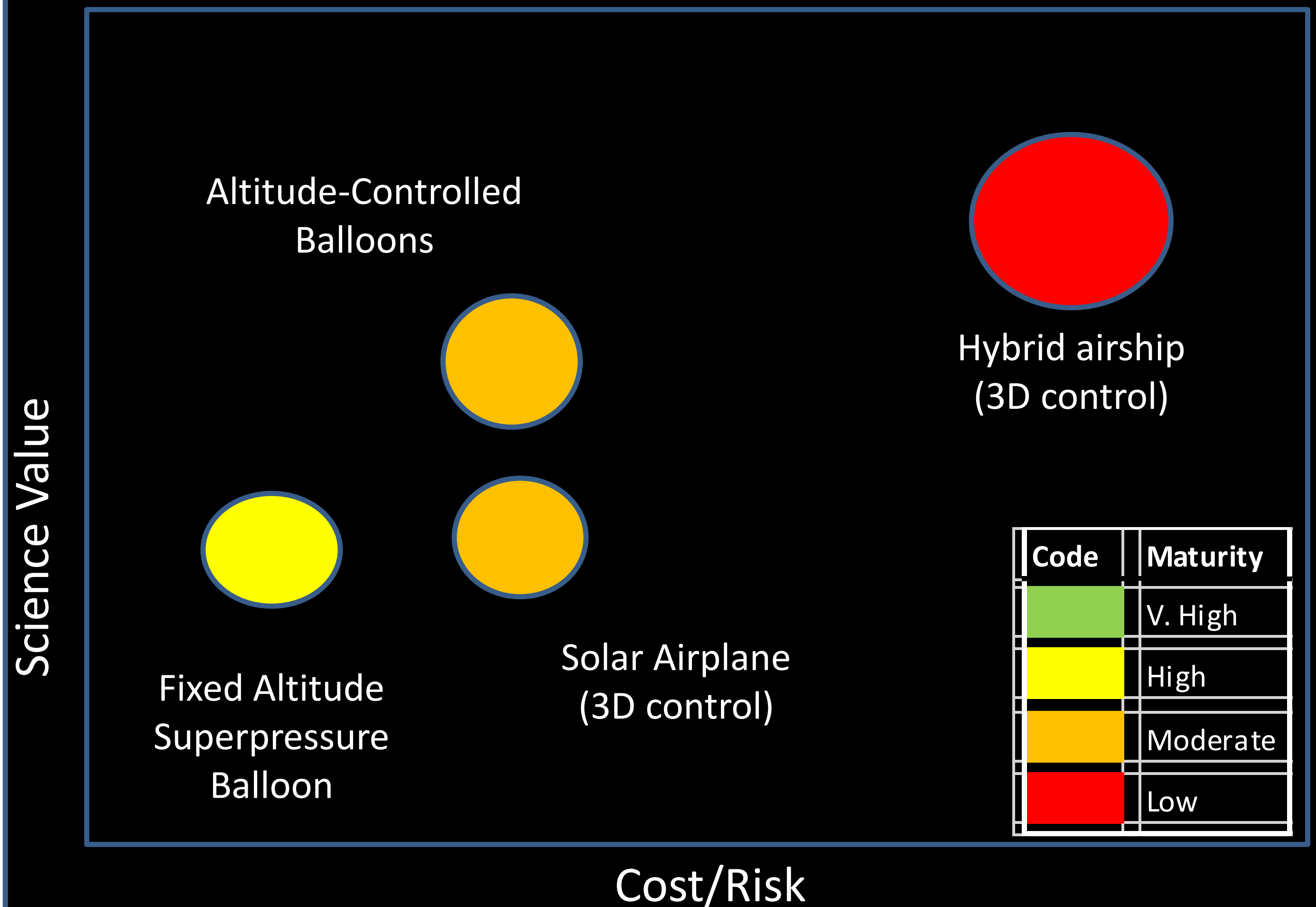


Ballistic Coefficient Trades
Controlled Entry
Ballistic Entry

Entry System Design Space

- Entry of most aerial platform concepts feasible with rigid body aeroshell technology
- Deployables (ADEPT and HIAD) may provide packaging and deployment advantages but they are still under development
- Dual-function VAMP requires a protracted multistage development/test program

Venus Aerial Platforms – Design Sweet Spot



Science Team

R. Grimm (SWRI co lead))
L. Glaze (GSFC, co lead)
K. Baines (JPL/UW)
K. Jessup (SWRI)
A. Komjathy (JPL)
S. Lebonnois (LMD)
S. Limaye (UWisc)
K. McGouldrick (UCol)
G. Schubert (UCLA)
D. Senske (JPL)

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

Instrument Systems Trade Study – In progress

Atmospheric Gas Composition

Cloud Haze Composition

Atmospheric Structure Investigations

Geophysical Investigations

Surface Imaging

Aerial Platform Instruments

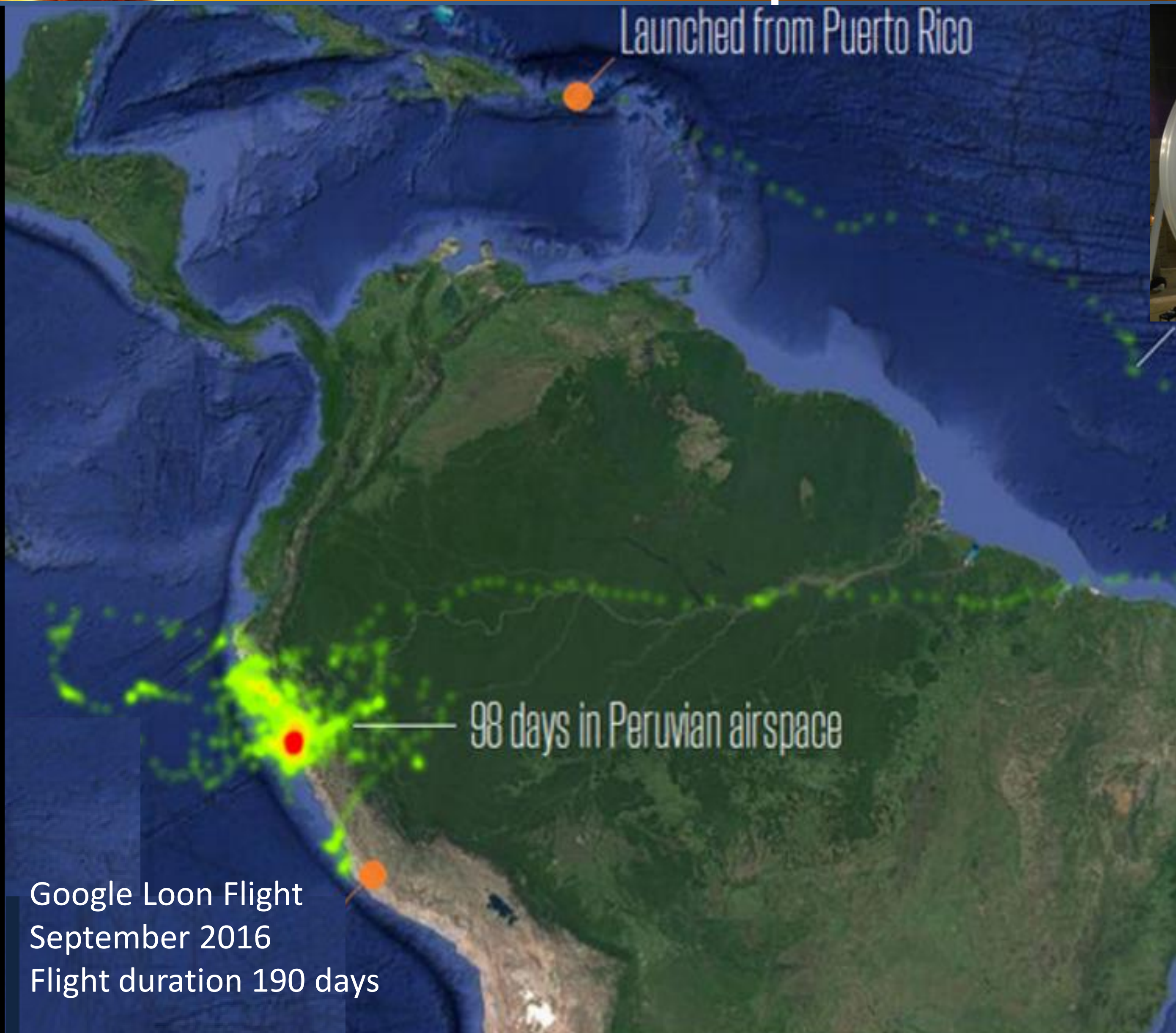
Drop Sondes

Study Team

K. Baines (JPL,)
D. Atkinson (JPL)
S. Krishnamurthy(JPL)
L. Matthies (JPL)
M. Rais-Zadeh (JPL)

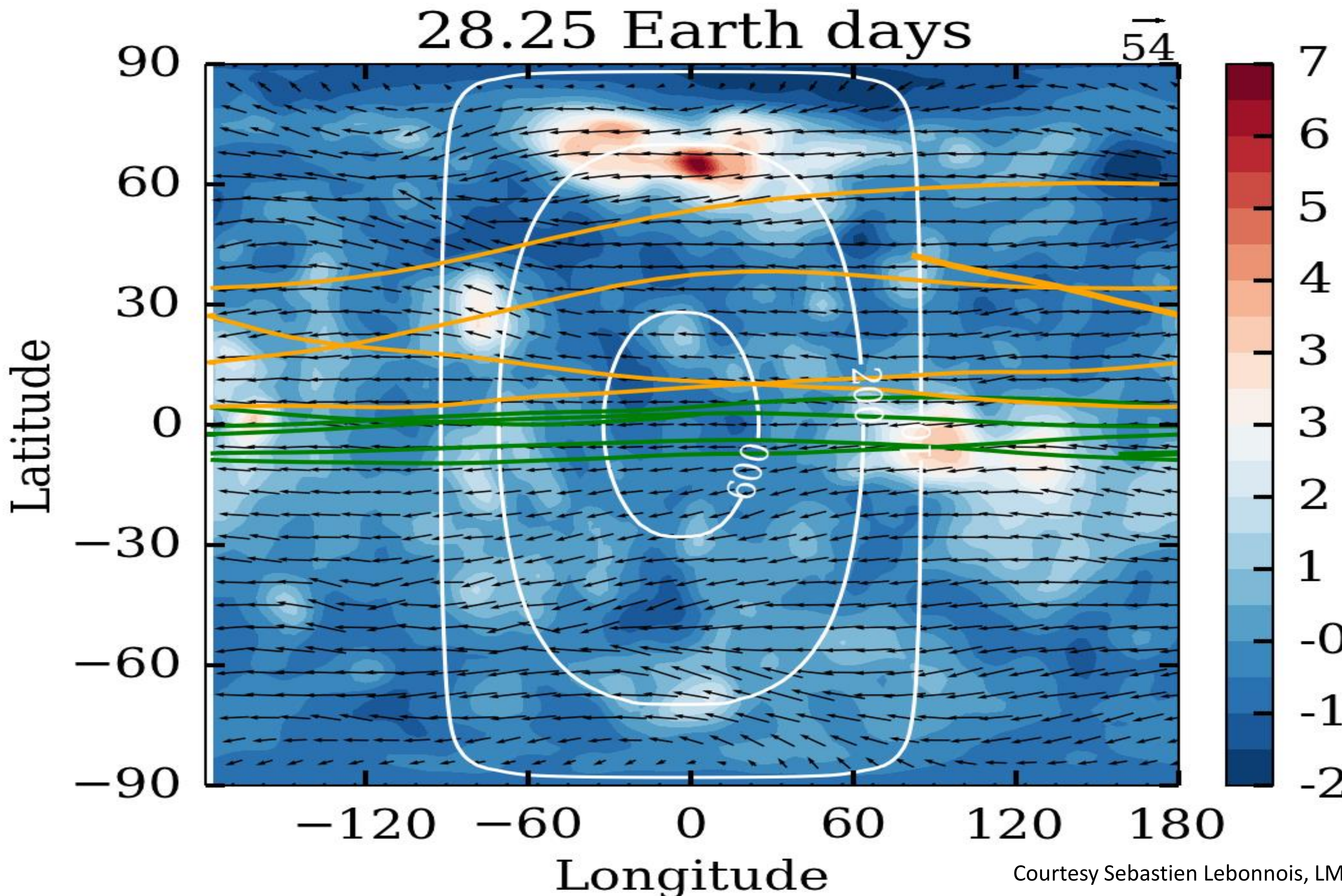
- Experimental techniques identified and evaluated
- Instruments with multiple science functions e.g. magnetometers identified
- Prospects of miniaturization assessed

Altitude Controlled Balloons
Current Capabilties at Earth



Variable altitude
air ballast balloon

Venus Aerial Platform – Constant Altitude Trajectory Models



Courtesy Sebastien Lebonnois, LMD

Venus Aerial Platform Technology Needs

- Altitude Control Systems Development
  - Design and build subscale models of options.
  - Perform laboratory and atmospheric flight tests
  - Compare performance of options
  - Build full scale model of selected option

- Aerobot Science Module (Gondola) Development
  - Demonstrate GN&C and telecommunications systems
  - Integrate science instruments
  - Incorporate miniaturization (SmallSat and CubeSat technologies)
  - Flight test with full scale model

- Modeling and Simulation Tools
  - Venus environment– atmospheric circulation and solar and thermal fluxes
  - Altitude control systems within the Venus environment
  - Power guidance and telecommunications modesl

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