

# Human Exploration Opportunities in Near-Venus Space

opportunity for  
opportunities

leveraging human  
spaceflight  
for Venus planetary  
science

A long time ago in a NASA  
far,  
far away....

**EPISODE MMXVI**

***EMPIRE STRIKES BACK***

EPISODE MMXV  
**EMPIRE STRIKES BACK**

*It is a dark time for the  
Venusians. Planetary Science  
thrives despite challenging  
budgetary environments, with  
missions in high competition for  
resources and opportunities. The  
second planet from the Sun  
remains a challenging and  
elusive goal.*

*A group of Intrepid Scientists  
seeks a new way forward,  
proposing two unlikely alliances;  
between humans and robots, and  
between Earth, Venus, AND  
Mars....*



# Dreams of EMPIRE

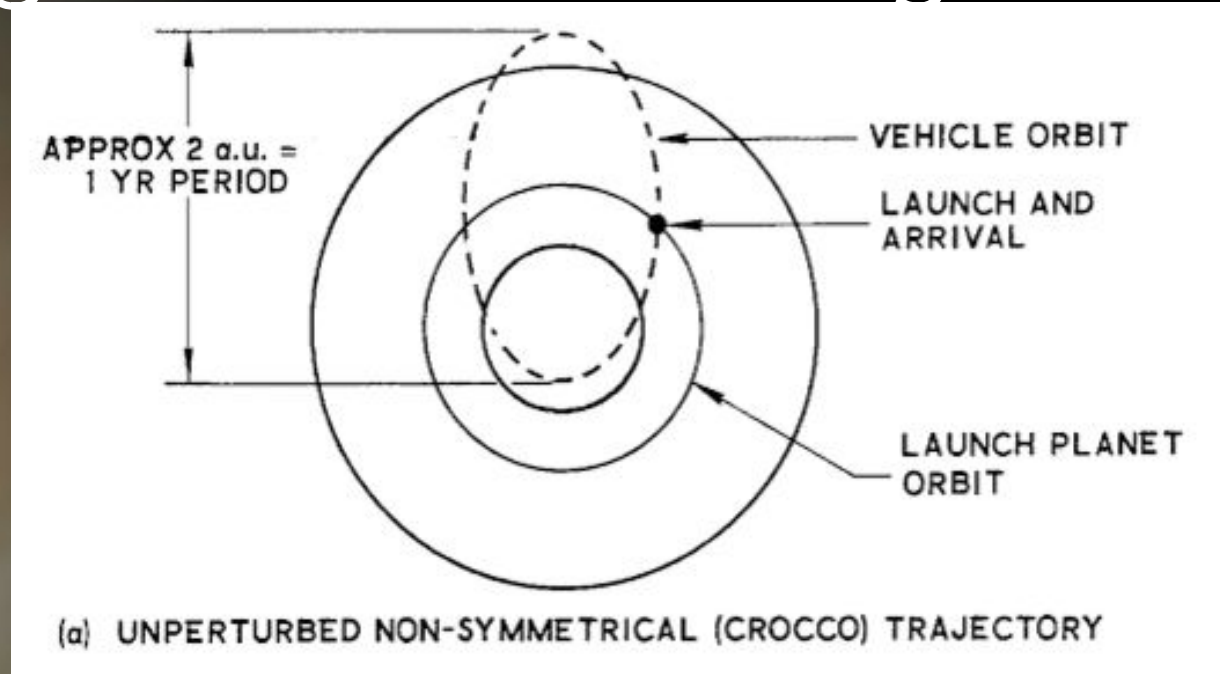
2016 – over 20 years since last US Venus mission ended

How else do we justify, enable, inspire Venus science?

2022 – Mandate in new Decadal Survey for Venus Strategy

How do you sustain Venus Science after V3NUS?

# Age of EMPIRE: Origins



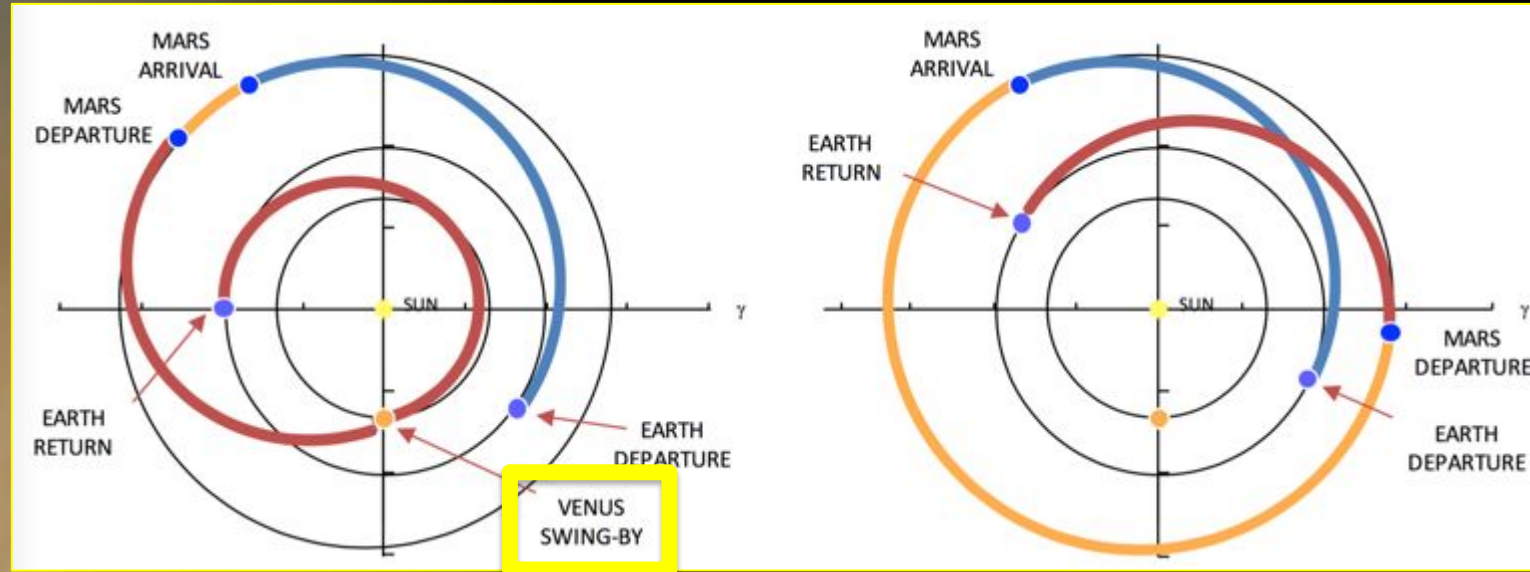
**1956** paper by Gaetano Crocco, 7<sup>th</sup> Int'; Astronautical Foundation Congress in Rome. Earth-Mars-Venus-Earth flyby mission to save fuel

Beginning of over 2 decades of human spaceflight studies looking beyond the moon

EMPIRE - Early Manned Planetary-Interplanetary Roundtrip Expeditions

Human space flight was assumed in an age before capable robotic craft

# Age of EMPIRE: 60's – 70's

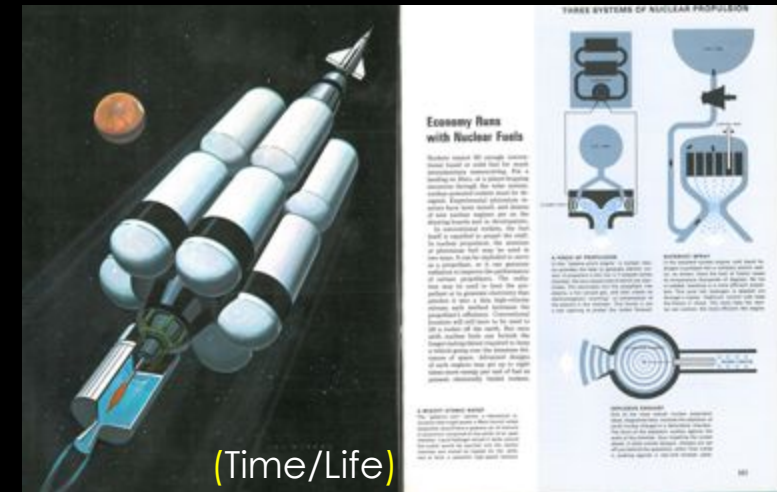


(Drake  
& Watts  
Eds DRA  
Appdx2  
2014, &  
others)

Opposition vs. Conjunction class missions: short vs. long stay

AEC-NASA nuclear rocket program,  
established in 1960; Nova rocket program

Explore advanced operational concepts  
necessary for flyby and orbiter missions  
Other studies leveraged Apollo instead



(Time/Life)



# Age of EMPIRE: 60's – 70's

- 'Feasible' Piloted Mars/Venus Flybys
  - Triple/Multiple planet flybys
  - Dispense automated probes based on Mariner and Voyager technology
- Piloted Mars Landing and piloted Venus Capture (orbiter) missions
  - Venus buoyant station (1969 concept for 1972-1973 launch)
- EMPIRE study mandate assumed nuclear propulsion was coming
  - “essential for a flexible Mars landing program”
  - Nuclear rocket programs didn't survive the '60s
  - Final NERVA cancelation 1972



# Fallen EMPIRE: 80's – 90's

- Nuclear rocket programs long gone
- End of Apollo was also the end of Apollo derivative human spaceflight
- Focus of Planetary missions on increasingly capable robotic craft
- Refocus of human spaceflight to LEO, Shuttle, ISS
  - Interplanetary Mission Design Handbook (George & Kos 1998): No DRM opportunities that include Venus
- Reduction, loss of US human rated heavy lift

# Ashes of EMPIRE: Early 21<sup>st</sup> Century

- Human spaceflight targets: Mars, Moon, Asteroids...Venus?
  - Venus competitive with MB Asteroids (Landis, 2003)
  - Competitive (or collaborative) with Moon
- Human spaceflight focus on pathway to Mars
- Heavy planetary payloads as part of revived heavy lift capability (SLS, Starship)
- Venus scenarios remain in Design Reference Architecture (DRA, 2009, through latest addendum (#2) 2014)
  - But not focused upon
  - Opportunity unexplored / unexploited



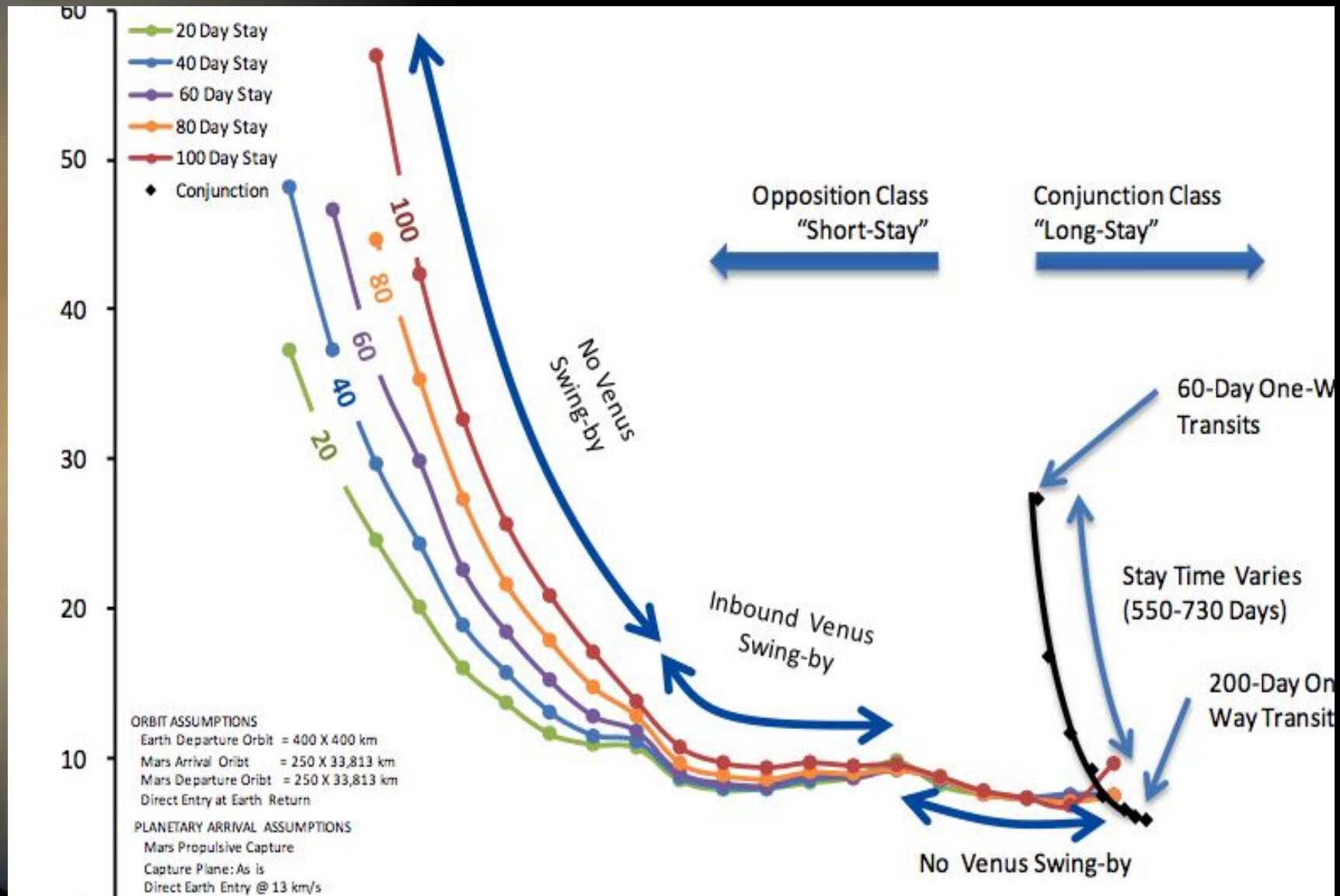
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MOON TO MARS

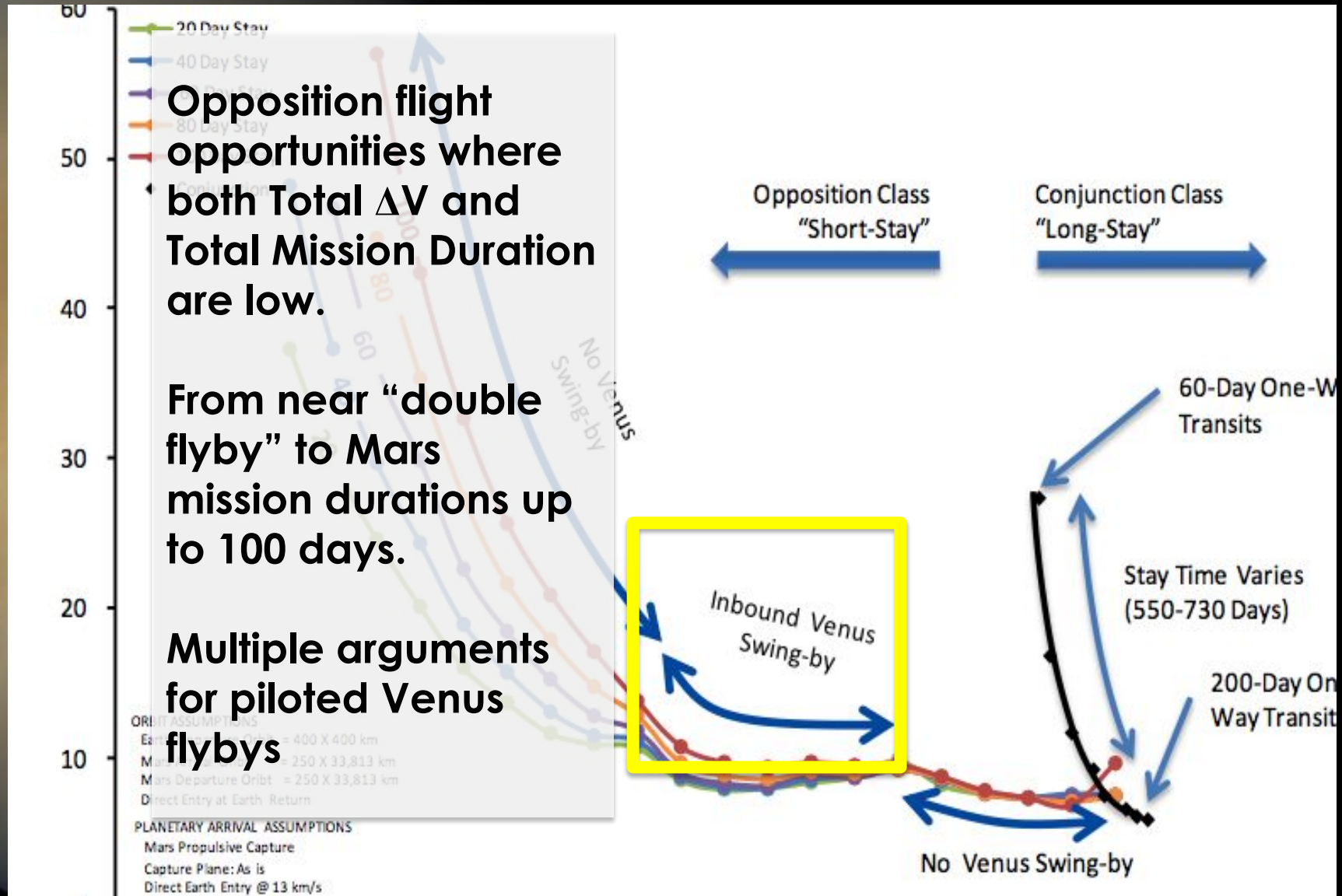
STRATEGY

# Echoes of EMPIRE: 21<sup>st</sup> Century



(Drake & Watts Eds, DRA Appdx2 2014)

# Echoes of EMPIRE: 21<sup>st</sup> Century



# A New EMPIRE?

## Putting the “Venus” in “Moon to Mars”

Opposition class piloted Mars missions with a Venus flyby offer a combination of the lowest delta V requirements and shortest mission durations for 20-100 days at Mars.

Venus flybys on the way to Mars create the opportunity for two-planet science missions with crews.

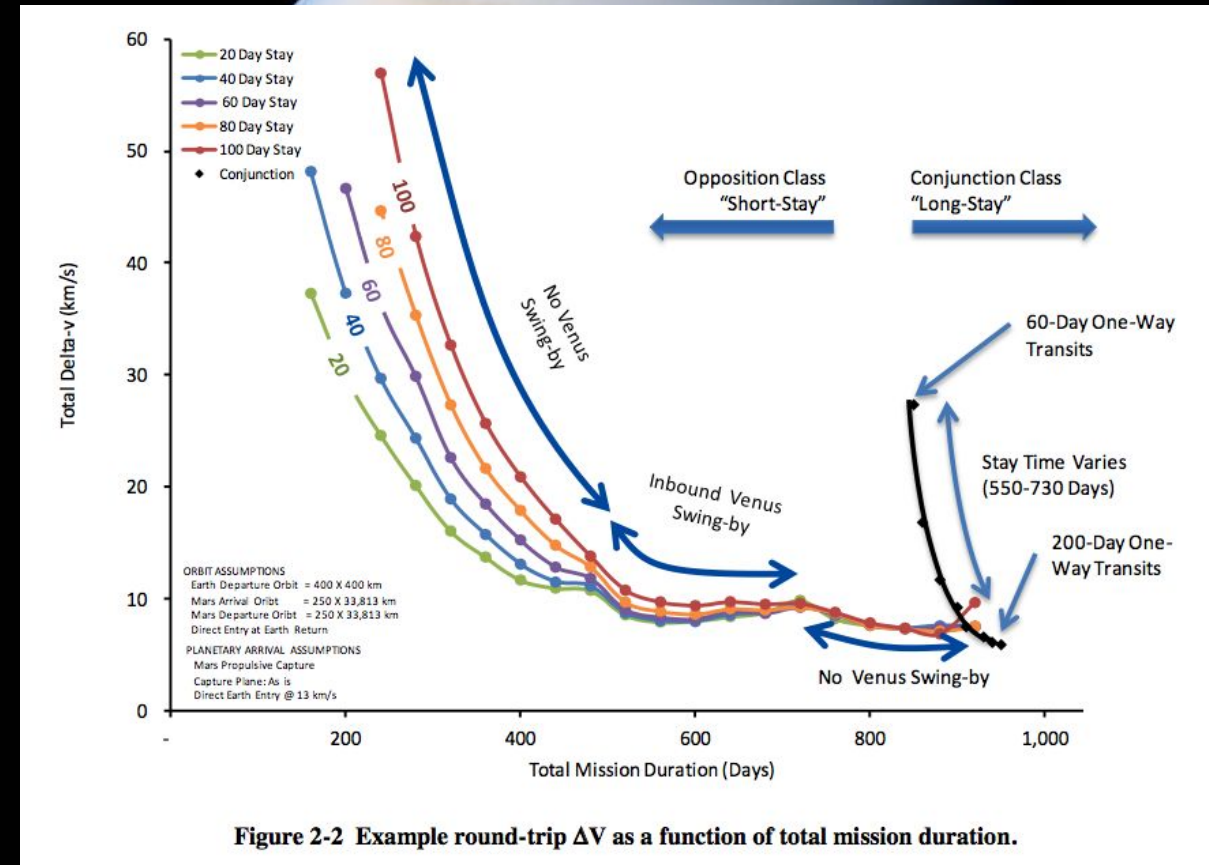
Advantages of Earth-Venus-Mars-Earth missions:

- Two-plus planetary science missions for the price of <2.

- E-V-E is both a training run and an abort scenario for E-V-M-E

- Psychological and health advantages for crew

- Real-time telemetry/operations at Venus



Mars Design Reference Mission, c.a. 2014



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Izenberg, McNutt, Runyon, Byrne +



# Putting the “Venus” in “Moon to Mars”

Logistics train between long stay vs. short stay mission in Moon to Mars Exploration Strategy briefing.

30 day stay currently more sustainable than a 500 day stay.

“Need to show work”

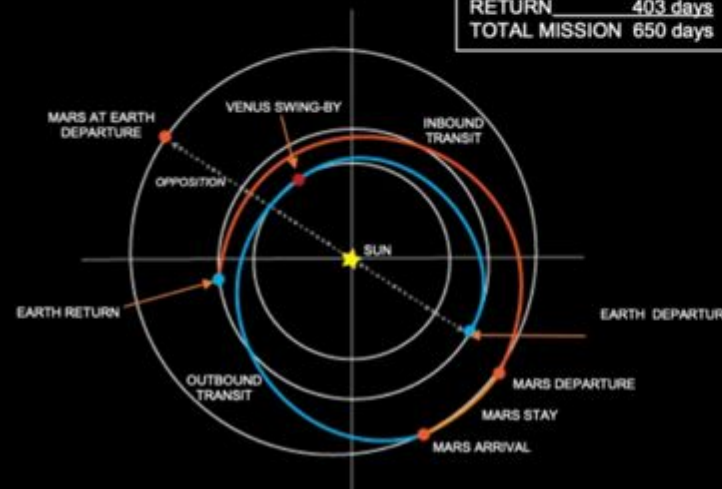
White Papers coming from M2M

## Mars Trajectory Design Reference Architecture



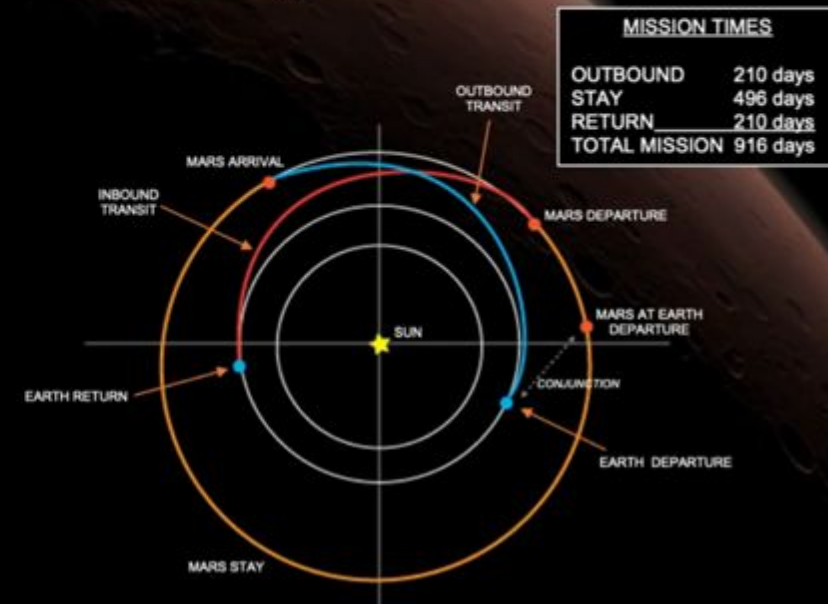
### Short-Stay Missions

Variations of missions with short Mars surface stays and may include Venus swing-by



### Long-Stay Missions

Variations about the minimum energy mission



# Putting the “Venus” in “Moon to Mars”

## VEXAG Response to M2M RFI

“The [Moon to Mars] reference mission that describes “EMVE” – an Earth-Mars-Venus-Earth mission for the short stay architecture provides all the benefits described. The alternative EVME (Earth-Venus-Mars-Earth), with the 400-day leg that includes the Venus flyby on the outbound part of the mission, accrues additional benefits, including an Earth-Venus-Earth (EVE) abort case.”



Izenberg, McNutt, Runyon, Byrne +

# Putting the “Venus” in “Moon to Mars”

Mission opportunity cadence

Venus: 19 mo / <8 years

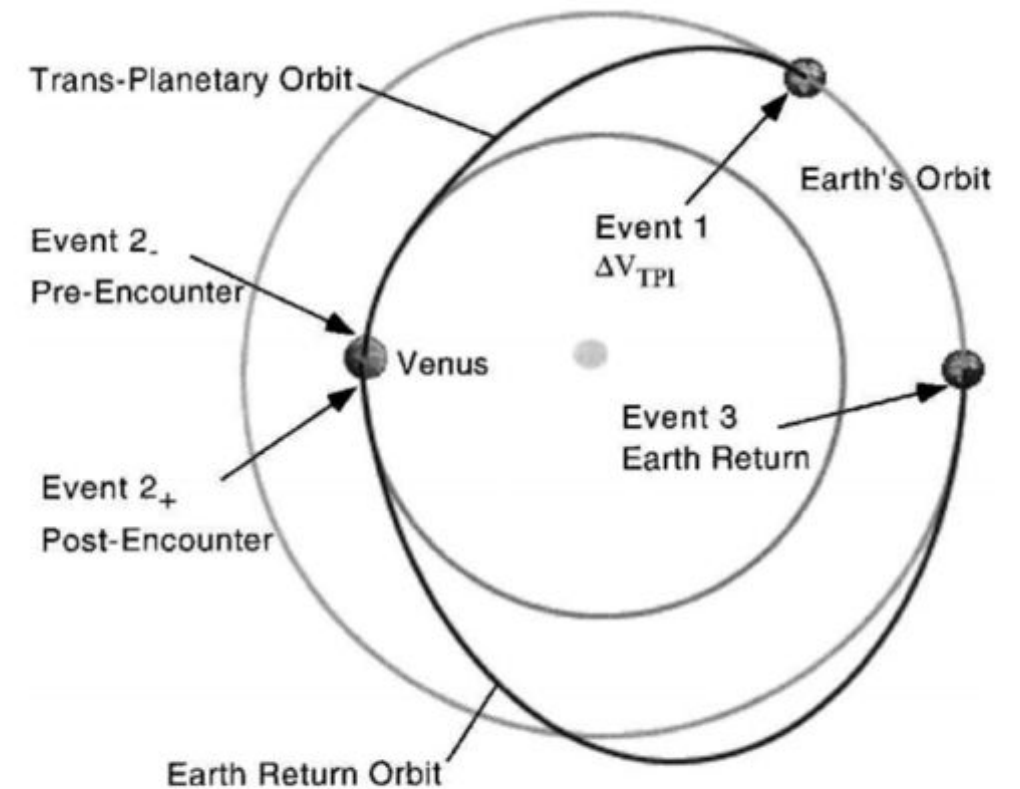
Mars: 26 mo / 15-18 years

Architecture repeatability

Mission Time: Missions ~ 1 year.

Delta V Lower still

Earth-Venus-Earth (EVE) mission



**Fig. 2 Mission profile illustration (EVE).**

(Crain et al., 2000)

Putting the “Venus” in “Moon to Mars”

Venus science during human flybys en route to or from Mars is obvious. “That’s just a matter of fact.”

How do we realize this fact in M2M?





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How do we realize this fact in M2M? M2V2M





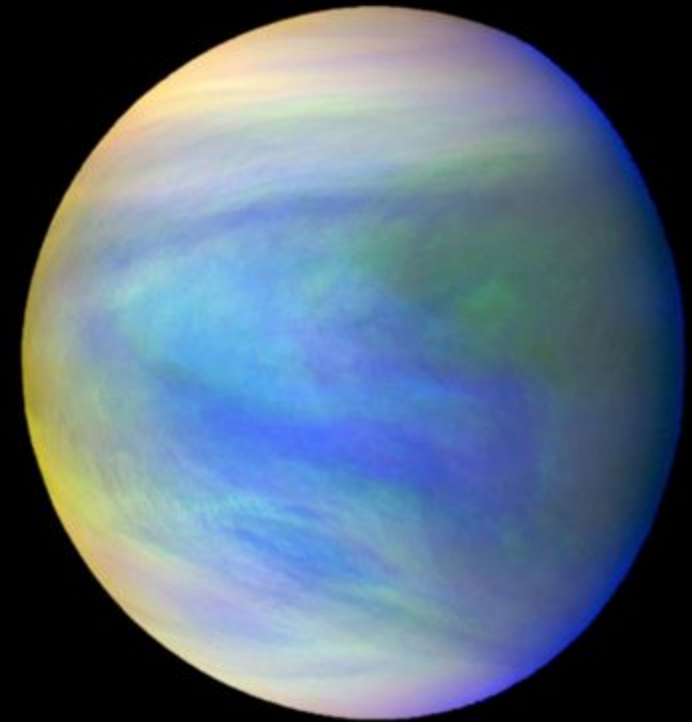
# The Case for, and Opportunity of Venus

Venus as flyby destination alone  
and/or on way to Mars.

Significant opportunity for Venus  
planetary community (science)

Significant opportunity for diverse  
NASA communities (e.g. HEOMD,  
SMD) to advocate for common  
goal

Extension of the Human Adventure



Is there Life on Venus?  
Do you want there to be?  
(JAXA/Akatsuke) (Limaye et al, 2018)

# A New EMPIRE

Large Probes Enabled by  
new launcher carrying  
capacity

Power, Data volume,  
Capability

Real-Time Telemetry

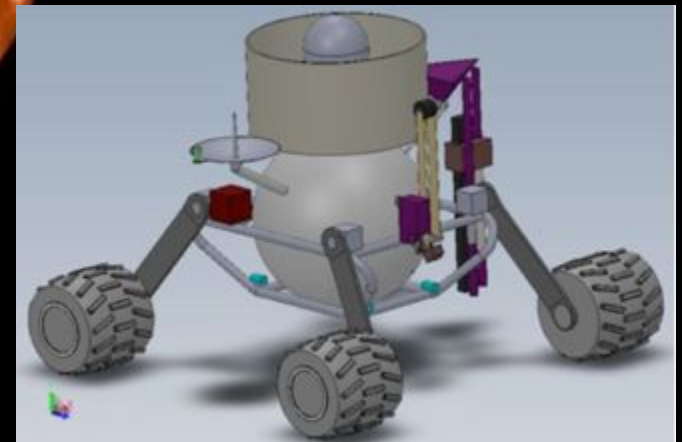
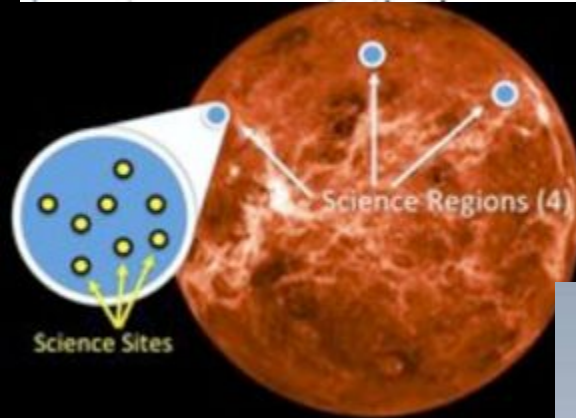
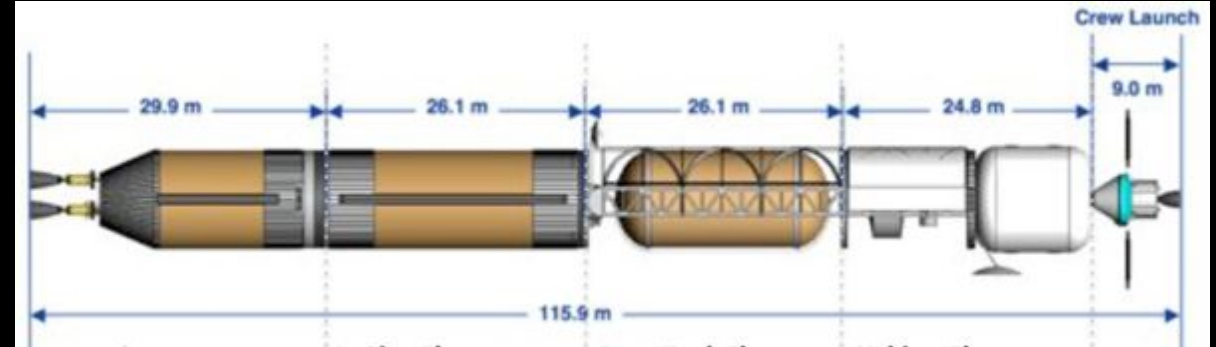
No light speed delay

Tele-operated probes

Human decision making in the  
loop

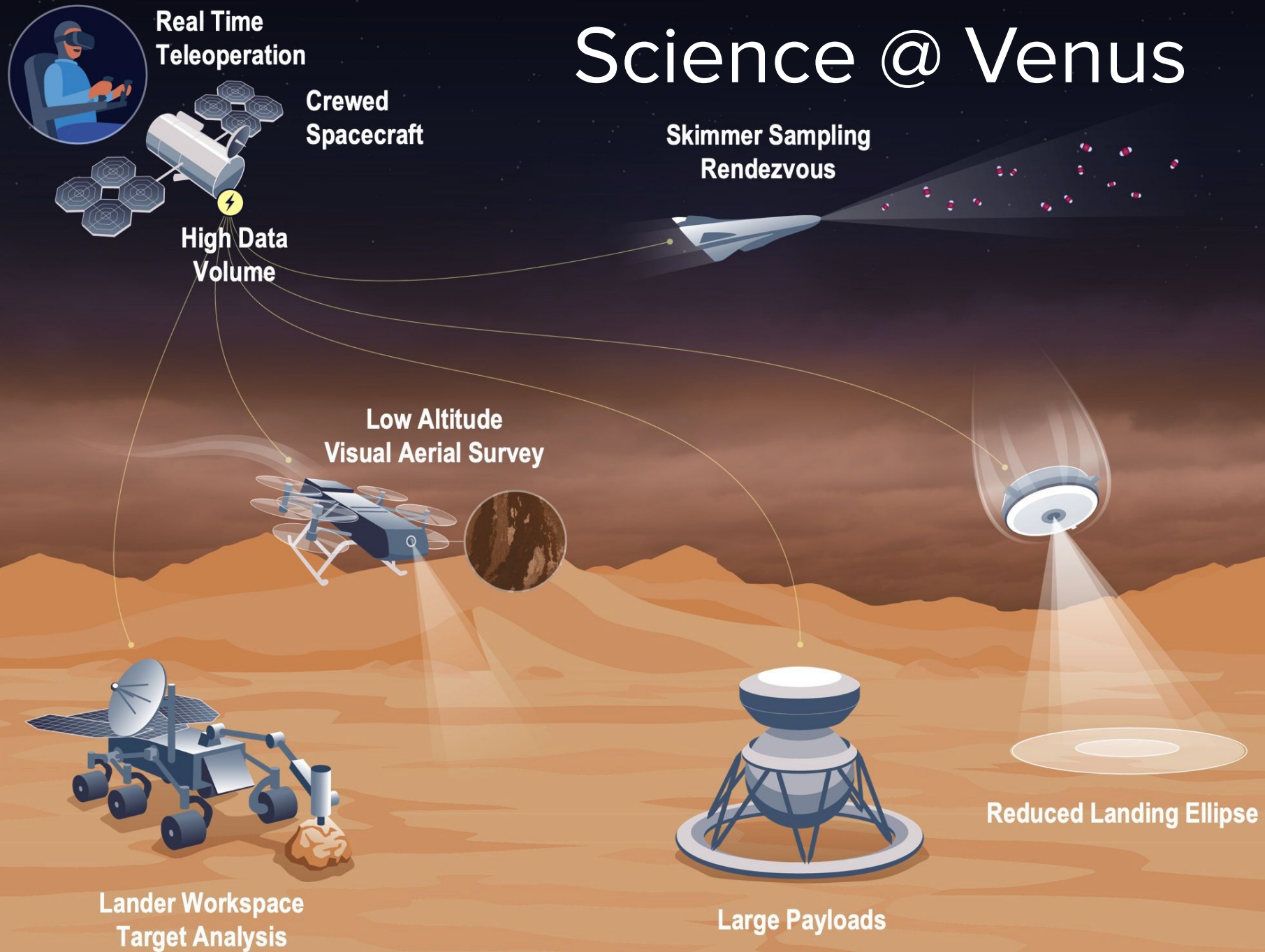
Guided aerial and landers  
(flight/descent control)

Optimized sampling



Human Exploration using Real-time Robotic  
Operations (HERRO) (Schmidt et al., 2011)

# Science @ Venus



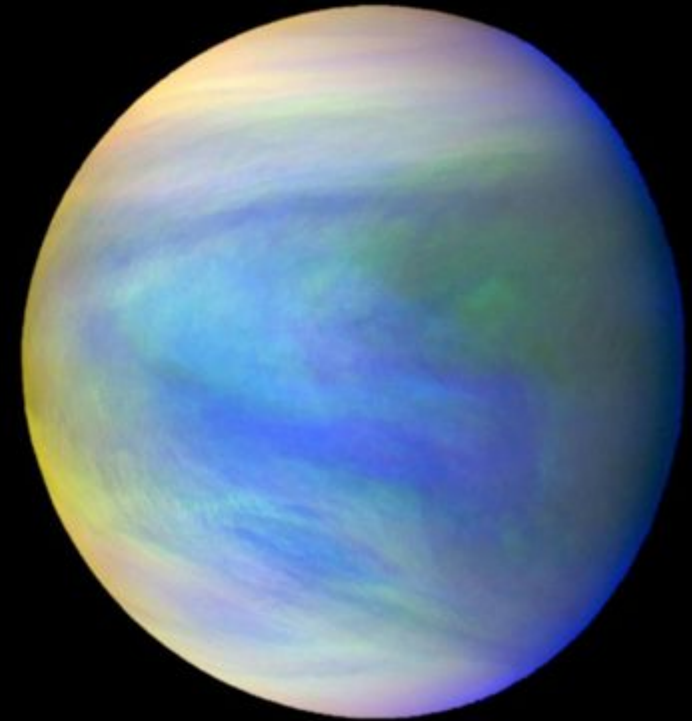


# Science @ Venus

Astrobiology

Time on Target companions  
Independent launches

Science Infrastructure  
Assembly



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Do you want there to be?  
(JAXA/Akatsuke) (Limaye et al, 2018)

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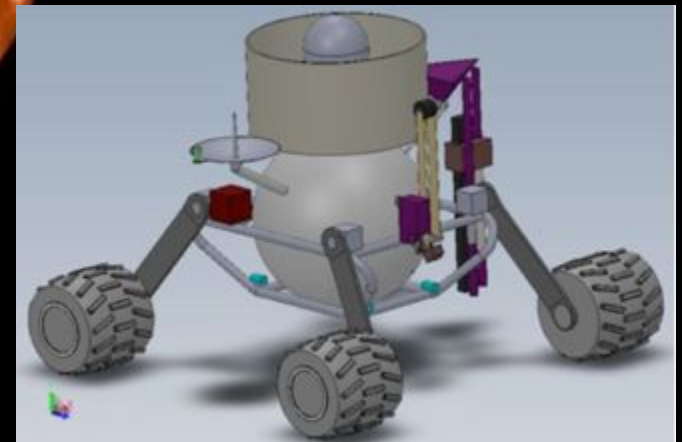
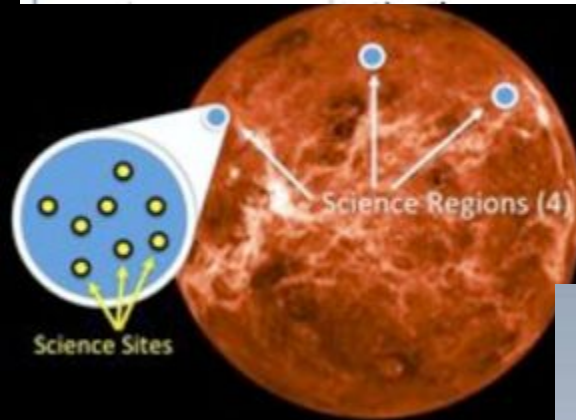
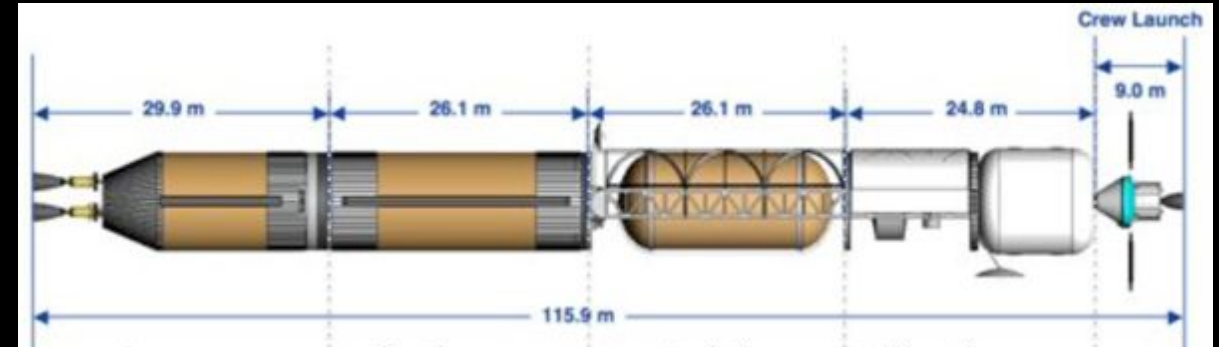
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# A New EMPIRE

Sample Return (Upper atmosphere)

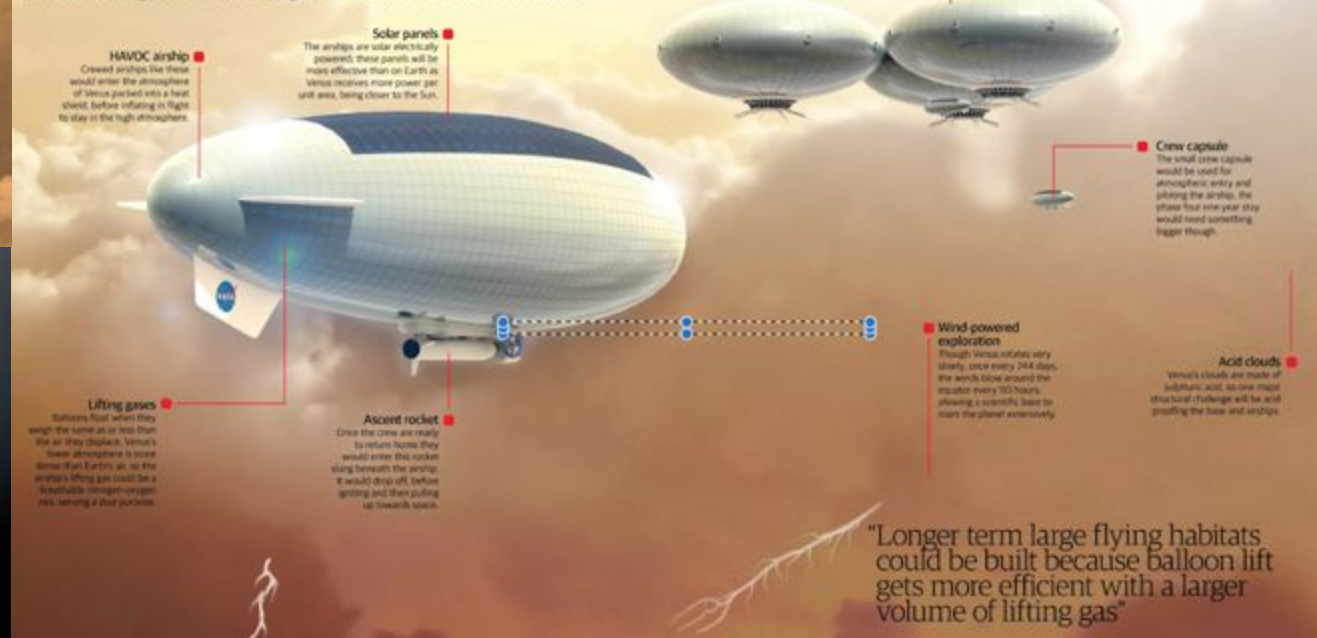
Beyond (HAVOC)

Wildcards (Commercial Space)



## Piloted mission to venus

Once believed to be off limits for human exploration, NASA is considering how Venus might be better to visit than Mars



## ...Or the rise of VAMPIRE

**V**enus **A**nd **M**ars **P**iloted Interplanetary  
**R**oundtrip **E**xpeditions

Revive ambition and philosophy, with  
application of current tech

Build new generation on the work  
already done

Advocate in Path to Mars and  
planetary community

**“Moon to Venus to Mars”**

**Unique & unprecedented opportunity  
for Venus science and Human  
exploration of the Solar System**



# Putting the “Venus” in “Moon to Mars”

Internal feedback in NASA

Federated board

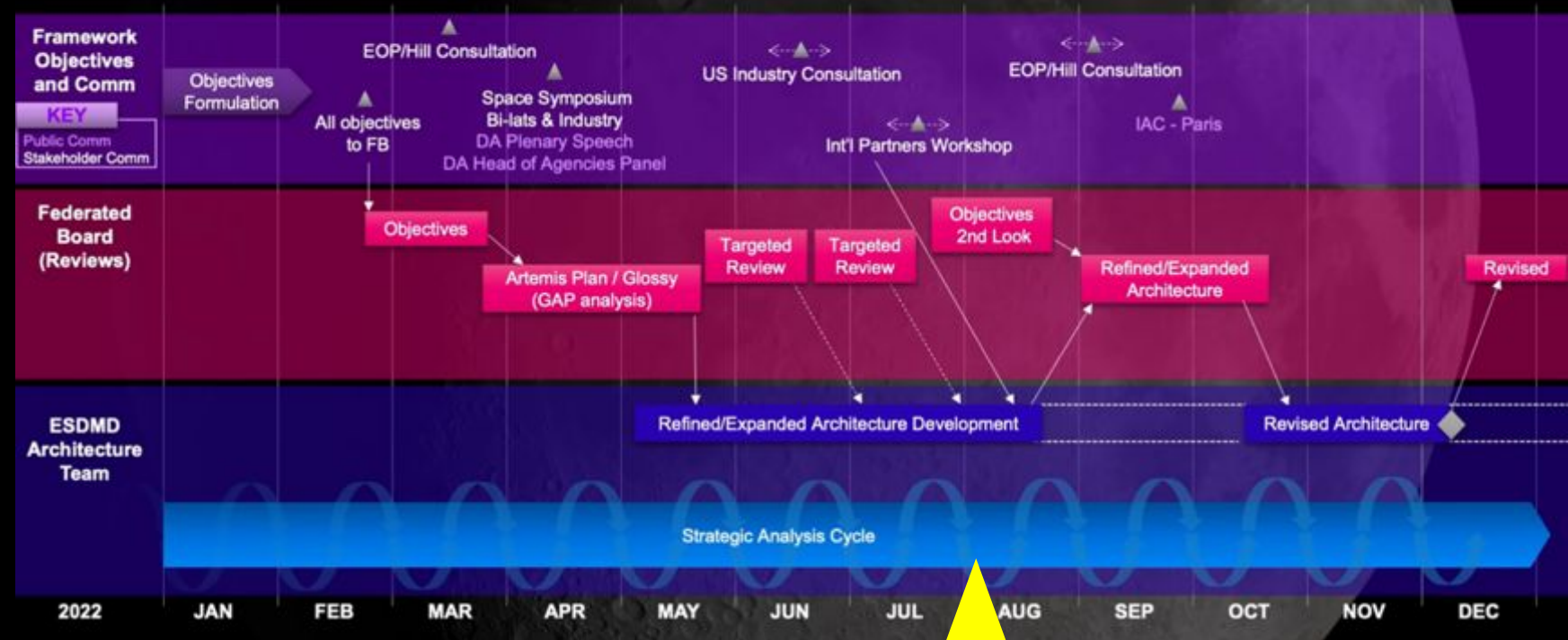
International partners

Industry partners

Community feedback

“Cauldron of inputs” for next gap analysis in fall with refined architecture.

## Framework Objectives and Moon to Mars Architecture Timeline





Putting the “Venus” in “Moon to Mars”

The iron is hot.

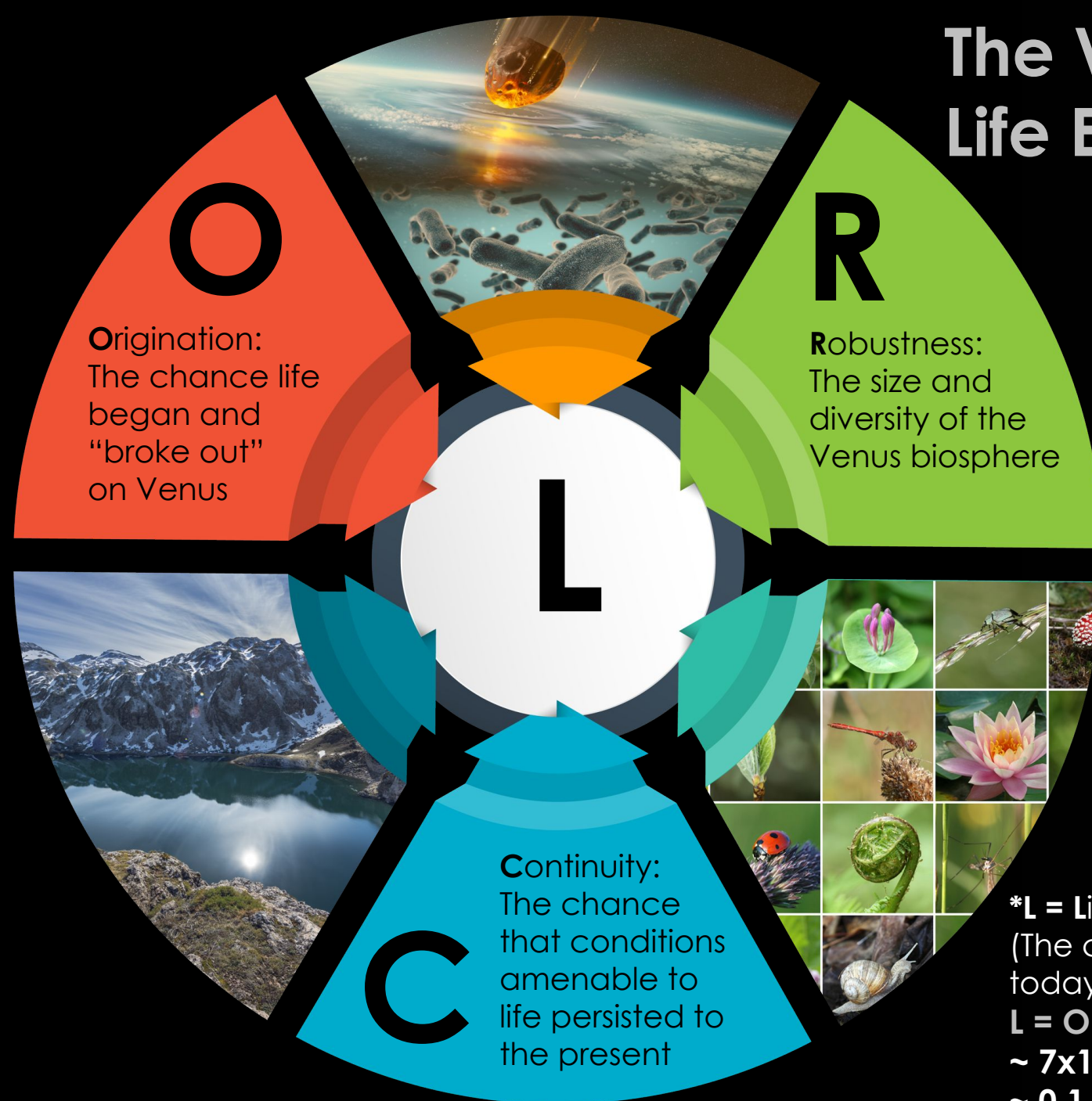
Venus flyby is an integral part of the architecture.

Venus flyby science is a no-brainer.

*Venus flyby activities, benefits, science should be an integral and talked-about part of the architecture.*



# The Venus Life Equation



MOON TO VENUS TO MARS  
STRATEGY

\***L** = Life  
(The chance life exists  
today on Venus)  
**L** = **O** • **R** • **C**  
~  $7 \times 10^{-9}$  (low)  
~ 0.1 (high)