



**Human Flight to Mars:  
Studying Planets Beyond Earth**

**Prof. G. Scott Hubbard,  
Department of Aeronautics and Astronautics  
Stanford University**

**November 6, 2015**

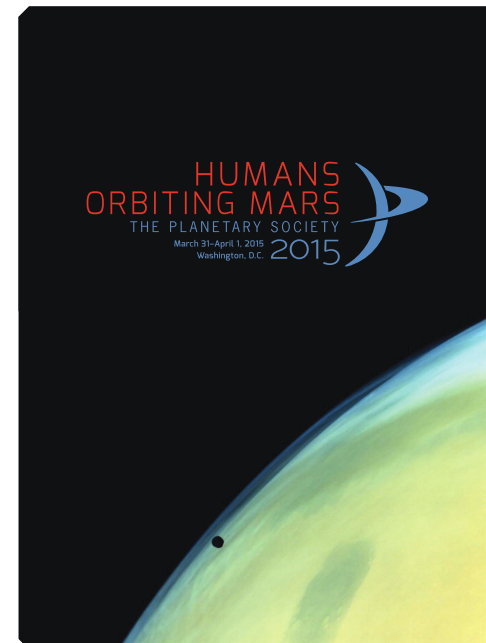
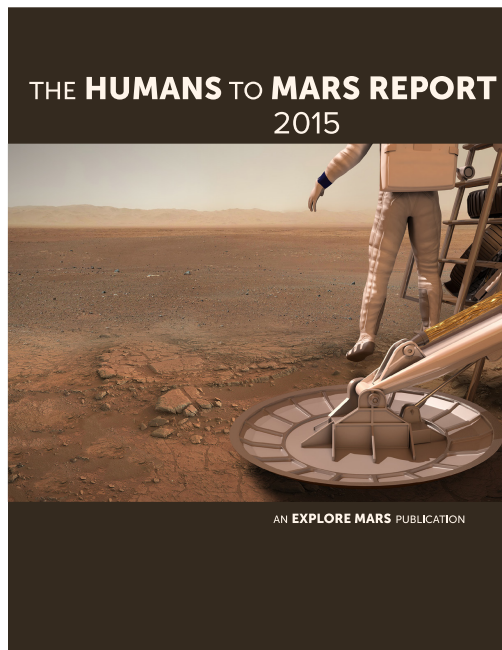


- Major scientific discoveries: “Where did we come from?”; “Are we alone?”
- National Interest: (e.g., US, or ESA or Russian or Chinese, etc. Leadership)
  - Nations that don’t explore become stagnant
- New technology or business enterprise: Return on Investment
- International cooperation for peaceful purposes: International Space Station
- Stimulate student interest in science, technology, engineering and mathematics
- A hedge against future catastrophe? A second home for humanity?
- Which of these pieces are necessary to Afford and Sustain the Exploration of Mars?

**All of Them**



- **Similar to Strategic Planning or Scenario Planning**
  - What's the landscape for Humans to Mars in the 2030's?
  - Strengths, weaknesses, threats and opportunities (SWOT)
  - Future strategic and policy directions
- **Material based on the Affording Mars workshops/Explore Mars Report, The Planetary Society Humans Orbiting Mars workshop April, 2015, the 2015 Finding of the NASA Advisory Council and the National Academy Planetary Science Decadal Survey.**



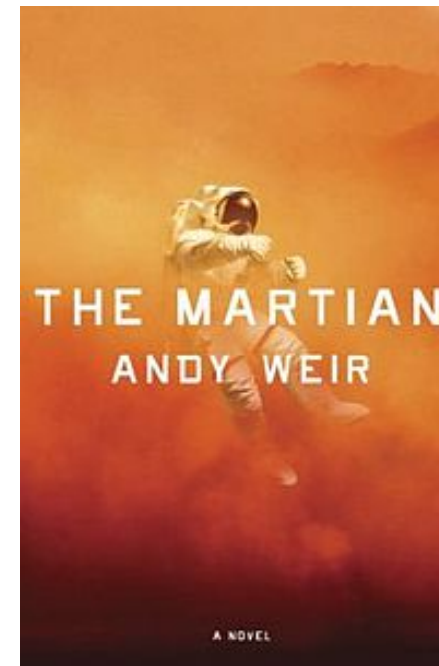


- Many initiatives conducted or underway
- Legacy Organizations > 10 years old:
  - The Planetary Society: Founded 1980 with ~50,000 members. Recently (re) endorsed Humans to Mars and conducted Humans Orbiting Mars workshop
  - Mars Society: Founded 1998 with ≈5,000 members. Conducts conferences, Mars analog studies
  - General interest: National Space Society, Space Frontier Foundation, etc.
- New Organizations < 10 years old:
  - Explore Mars, Inc.: Founded 2011, Conducts events including the 2013 and 2014 Affording Mars workshops.
  - Inspiration Mars: Founded 2013, Aims to (partially) fund a 2021 two-person humans to Mars journey using NASA capabilities.
  - Mars One: Founded 2011, Plans for humans to Mars by 2027 using a for-profit media based business plan; ~200,000 expressions of interest

Significant evidence of a new public interest in humans to Mars



- **The Martian Book and Movie**
  - *The Martian* is science fiction film directed by Ridley Scott from a screenplay written by Drew Goddard, which is in turn based on the novel by Andy Weir.
  - The film was released October 2 to critical acclaim, and stars Matt Damon

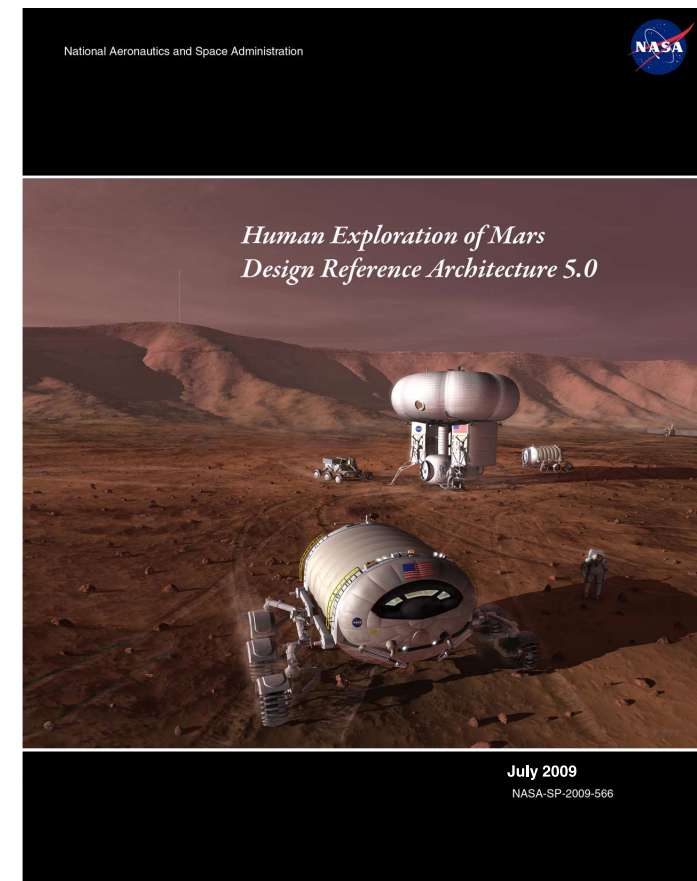
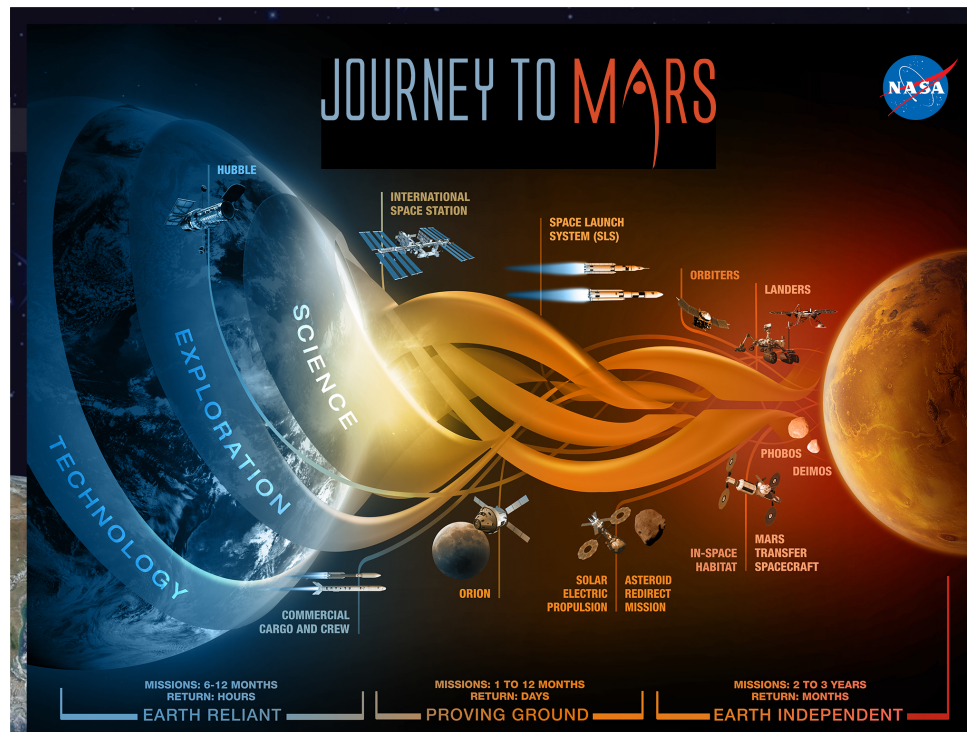


- **The Space Between Us**
  - Asa Butterfield, who starred in *Ender's Game*, and Gary Oldman, *Harry Potter*, a sci-fi adventure on Mars that Peter Chelsom is directing and Richard Lewis producing for STX Entertainment





- NASA's stated position (per response to the NASA Advisory Council recommendation) is:
  - Current program is “Evolvable Mars” a series of “capabilities-based” efforts that “hold open architecture decisions” for the Journey to Mars
  - The last Architecture is Design Reference Architecture (DRA) #5, 2009
  - No other H2M architectures are available, but new details emerging



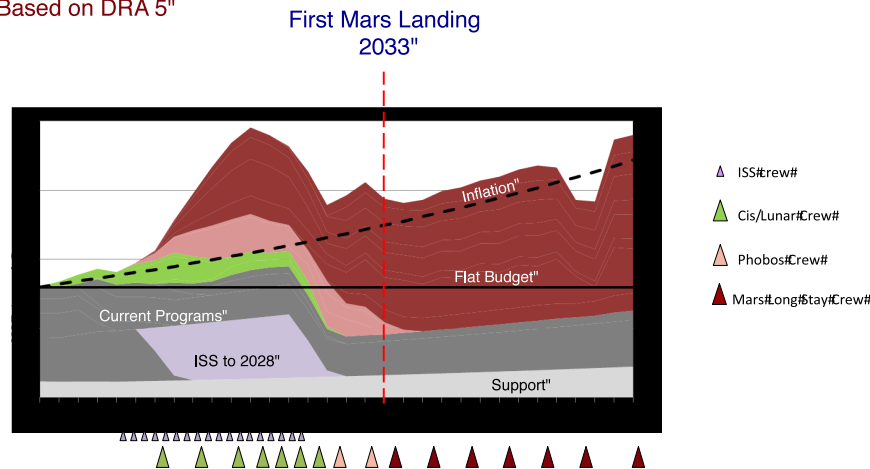
## NASA's Plans for Humans to Mars (2)



- Evolvable Mars has been criticized as having no strategy or implementation plan. "By 20 years from now NASA will have spent \$160B and be no closer to Humans on Mars than we are today.." Tom Young
- DRA #5 was used by the National Research Council 2014 study on human spaceflight (*Pathways to Exploration*), "Mars is the Horizon Goal" but yielding untenable outcomes.

### NRC Schedule Driven Pathway: First Mars Landing by 2033!

Based on DRA 5"

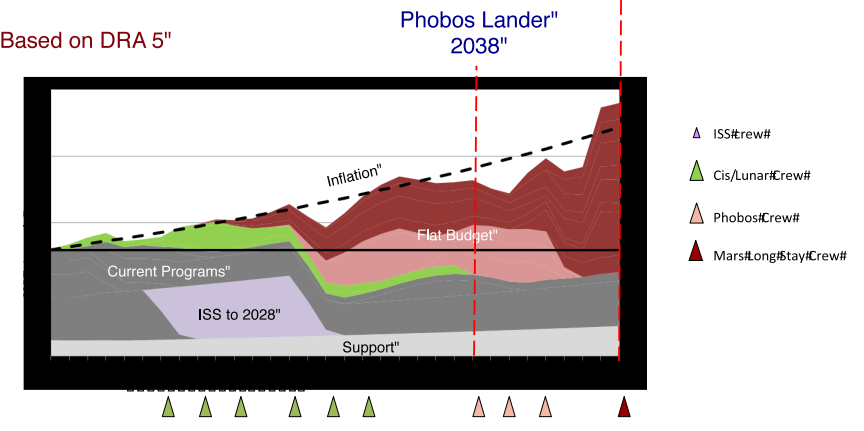


### NRC Budget Driven Pathway !

Constrained by Current NASA Human  
Space Flight Budget Adjusted for Inflation!

Mars Lander  
2046"

Based on DRA 5"



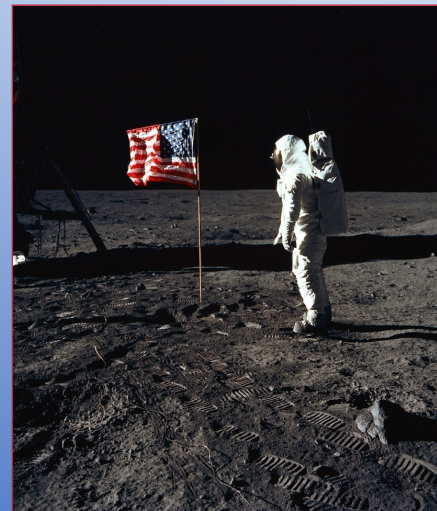
While I understand NASA's predicament  
none of these outcomes are desirable

## WHAT MADE THE KENNEDY MOMENT SUCCESSFUL?

- There must be an easily understandable goal.
- Goal to be achieved must be technically feasible
- Goal must have been debated long enough so that political support and opposition identified, and likely support perceived to outweigh opposition
- There must be a dramatic “occasion for decision” to catalyze action
- There must be a government leader willing to propose a large-scale activity with long-term payoffs and having the political skill to identify opportunities for proposing and sustaining such a commitment.

Prof. John Logsdon's analysis includes the decision by Richard Nixon to remove NASA from special program status to compete with all other Agencies

THE KENNEDY MOMENT  
WILL IT COME AGAIN?



THE ANSWER IS "NO."



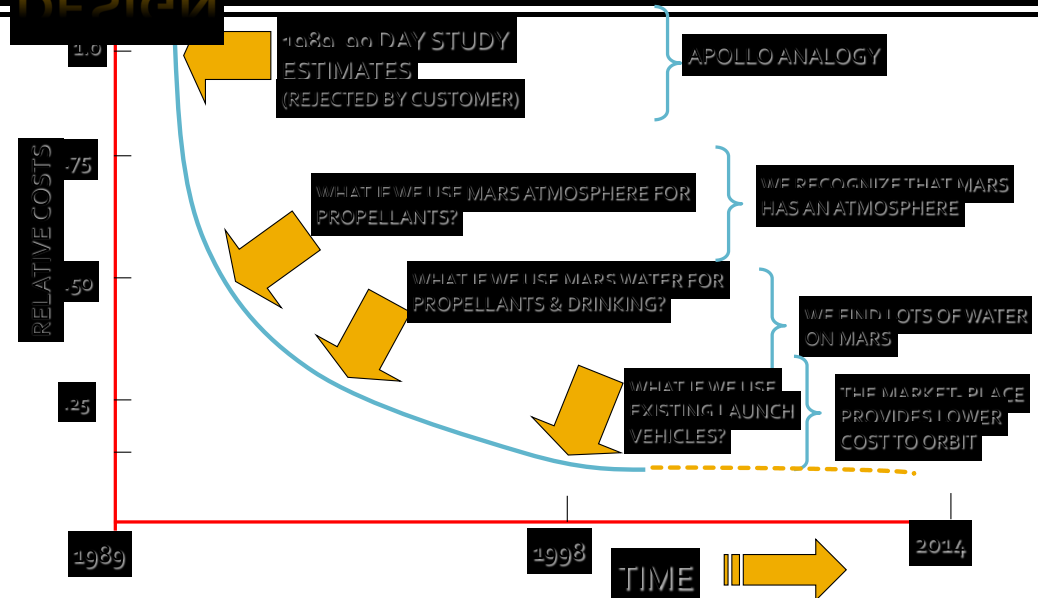
HUMBOLDT C. MANDELL, JR., Ph.D.  
THE UNIVERSITY OF TEXAS CENTER FOR SPACE RESEARCH  
THE MARS SOCIETY (2014)

## HUMAN MARS MISSIONS ARE AFFORDABLE (AND WE CAN PROVE IT)

Presented March 31, 2015  
at the Planetary Society's  
Human Orbiting Mars Workshop hosted by the SPI at GWU  
by Joseph Hamaker, PhD  
Galorath Federal Inc.

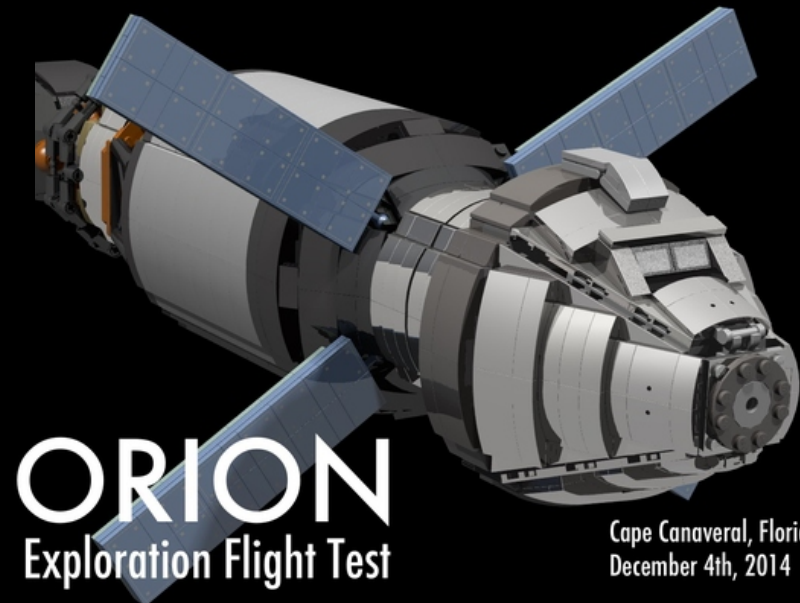
Mandell's review also outlines the "budget busting" assumptions by previous cost estimates: decades of operations, adding full Moon and Mars programs to existing plans and so on.

## ENORMOUS HELP FROM MISSION DESIGN

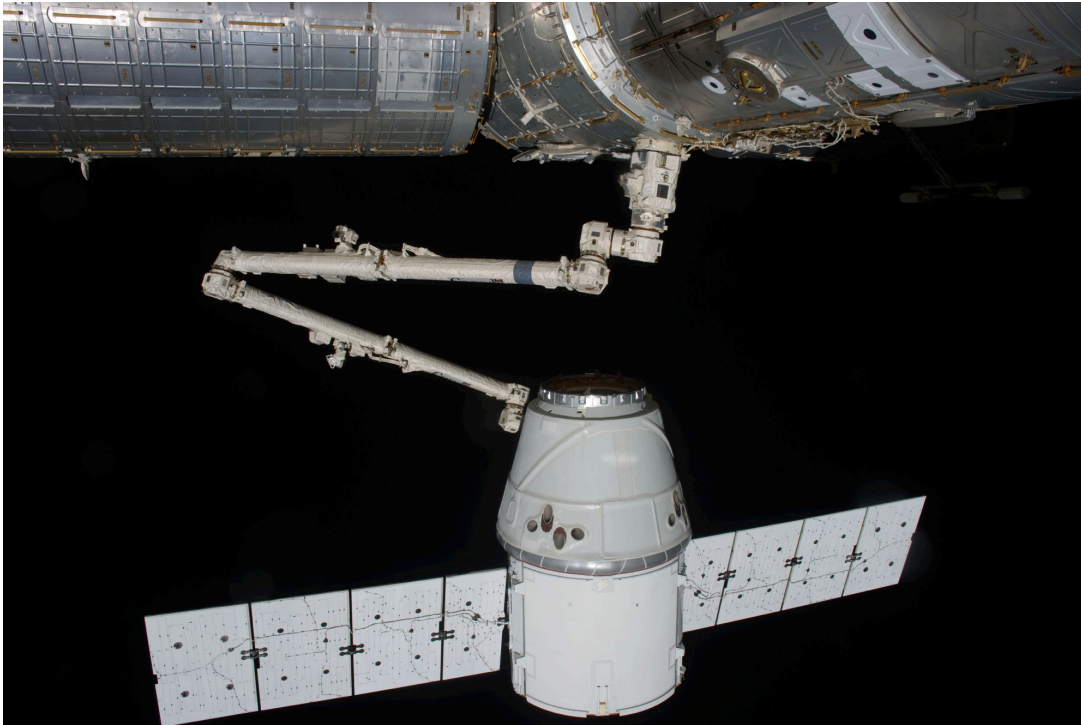




## SLS and Orion developments well underway



Cape Canaveral, Florida  
December 4th, 2014



Orbital Sciences  
Cygnus berths with ISS  
Returning to flight  
despite 2014 mishap

SpaceX Dragon  
berths with ISS  
Returning to flight  
despite 2015 mishap





Commercial Crew selection:  
Boeing, SpaceX flight in 2017



# *Radiation and Human Exploration of Mars*

## *Briefing to NAC*

**Rich Williams**  
Chief Health and Medical Officer  
January 14, 2015

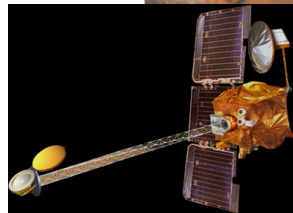
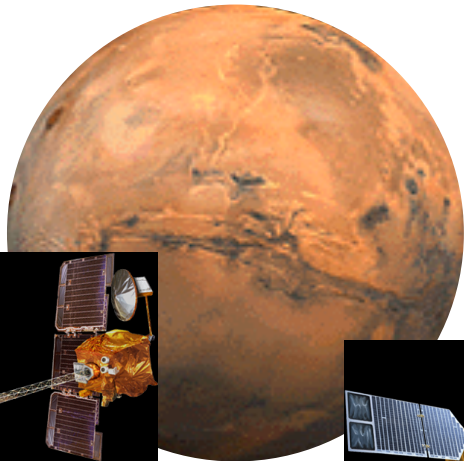


**Good news on  
Radiation effects!**

### **Overview of Mars Mission Crew Health Risks**



- **Mission And Crew Health Risks Are Associated With Any Human Space Mission**
  - Briefing is focused on space exploration crew health risks associated with space radiation
- **Exploration Health Risks Have Been Identified, And Medical Standards Are In Place To Protect Crew Health And Safety**
  - Further investigation and development is required for some areas, but this work will likely be completed well before a Mars mission launches
- **There Are No Crew Health Risks At This Time That Are Considered “mission-stoppers” for a Human Mission to Mars**
  - The Agency will accept some level of crew health risk for a Mars mission, but that risk will continue to be reduced through research and testing
- **The Most Challenging Medical Standard To Meet For A Mars Mission Is That Associated With The Risk Of Radiation-induced Cancer**
  - Research and technology development as part of NASA’s integrated radiation protection portfolio will help to minimize this long-term crew health risk



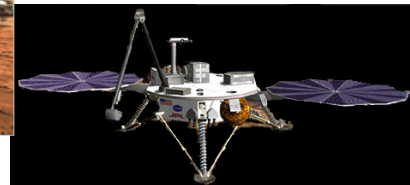
**Mars  
Odyssey**



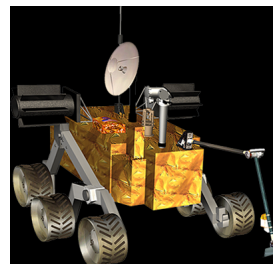
**Mars  
Reconnaissance  
Orbiter**



**Mars  
Exploration  
Rovers**



**Phoenix**



**Mars  
Science  
Laboratory/  
Curiosity**

Since 1960, 46 attempts to reach the Red Planet – only 15 fully successful (13 US and 2 Int'l)

Successfully restructured in October 2000 after twin failures in 1999

Central among the questions to be asked is...

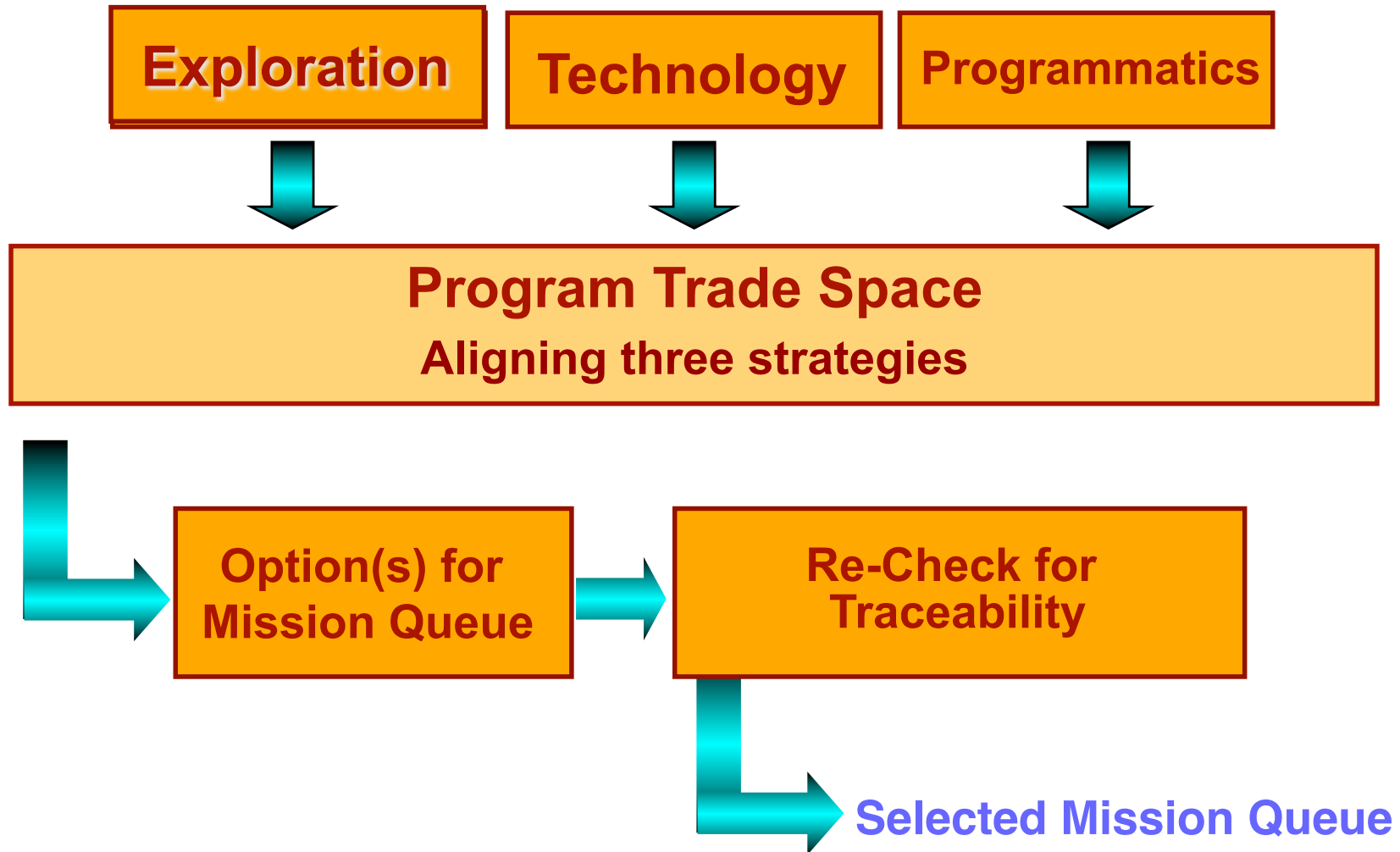
“Did life ever arise on Mars?”

The science strategy has been “Follow the Water.”

Budget 2001 -2012 ~\$400 – 500M/yr

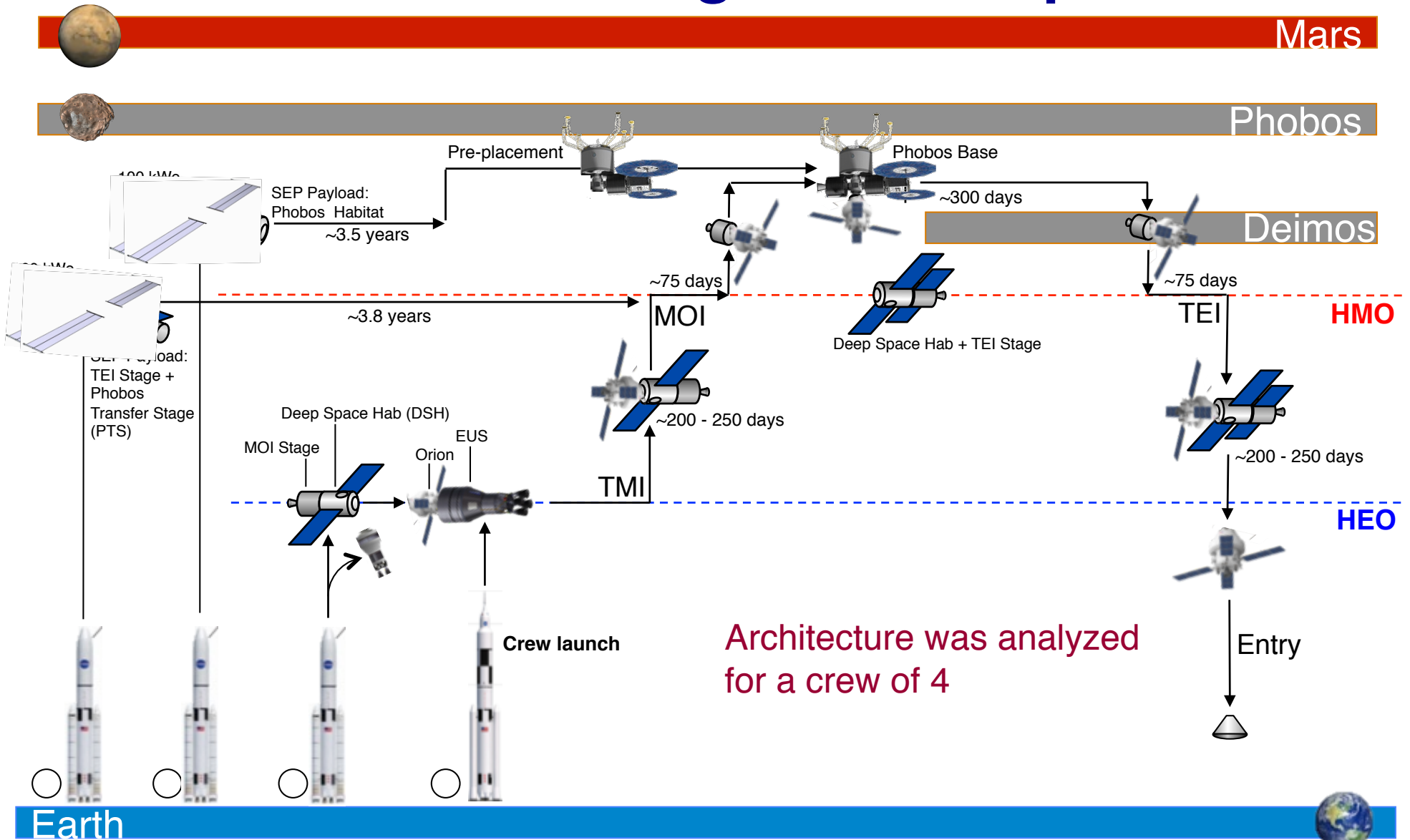
Single Mars Program Director at NASA HQs

Mars Program Manager at JPL



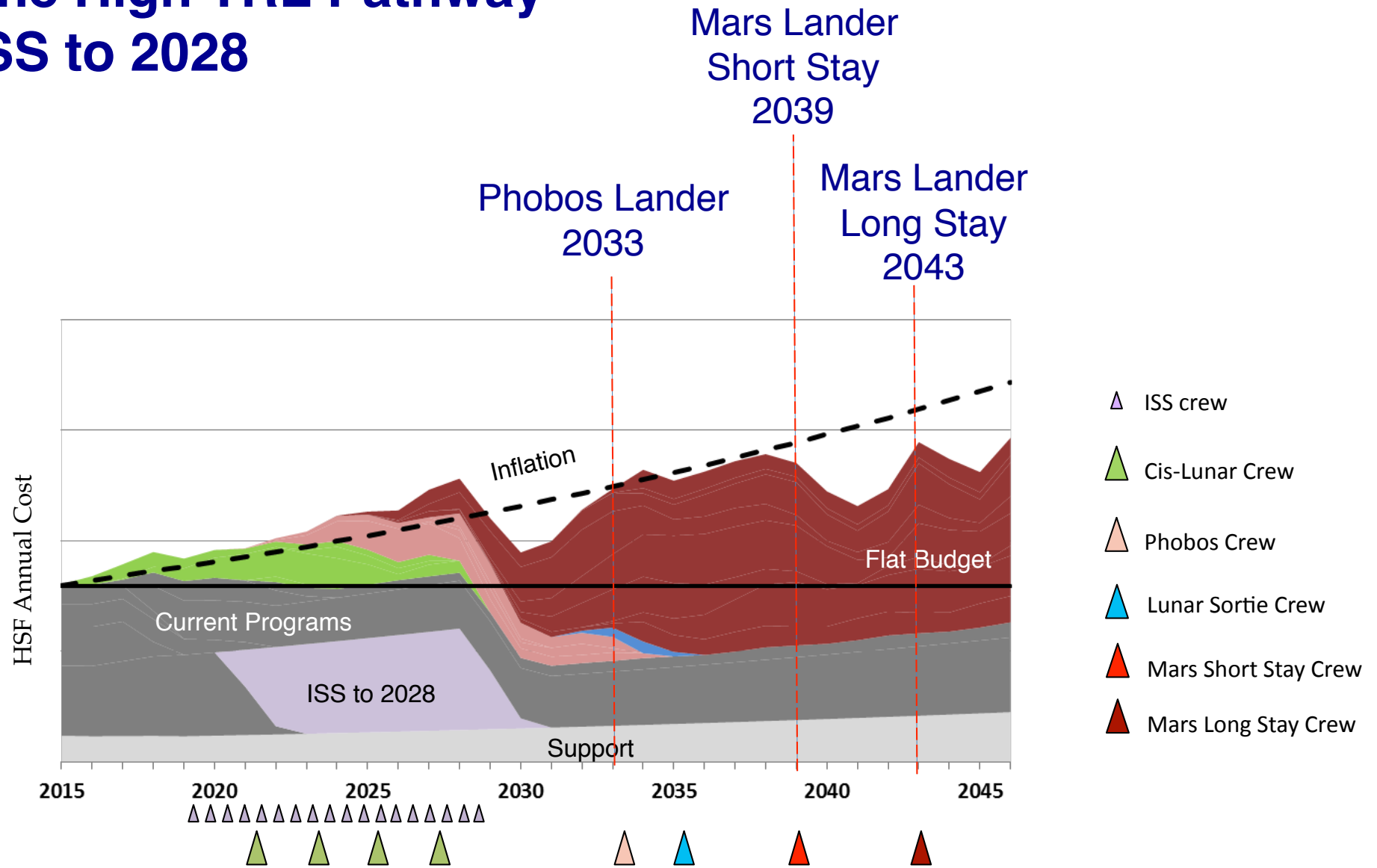
JPL team study of minimal architecture for Humans to Mars is one example

# Overall Architecture Based on Robotic Program Principles

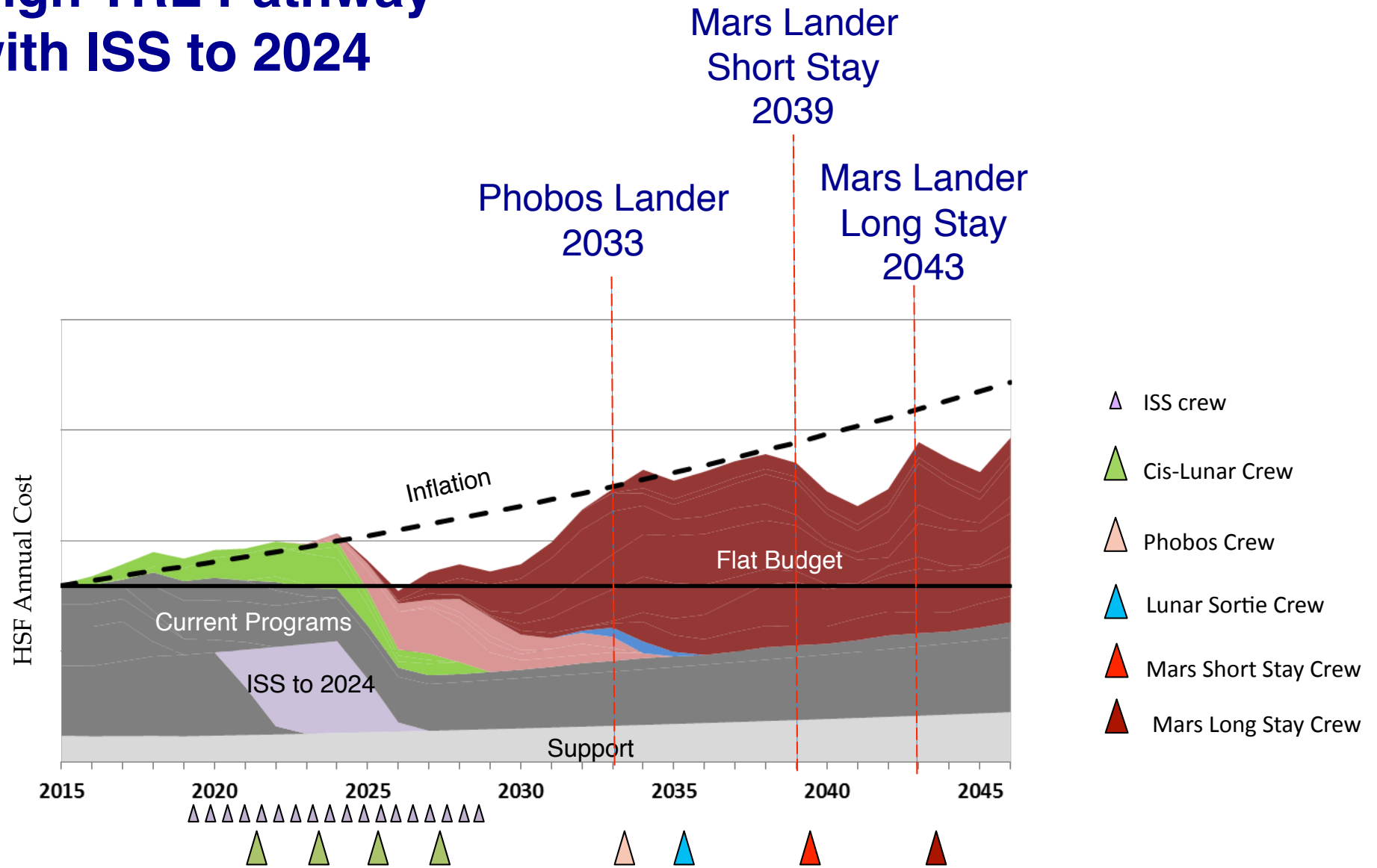




# The High TRL Pathway ISS to 2028



# High TRL Pathway with ISS to 2024





## Implications for Science and Robotic Space Flight

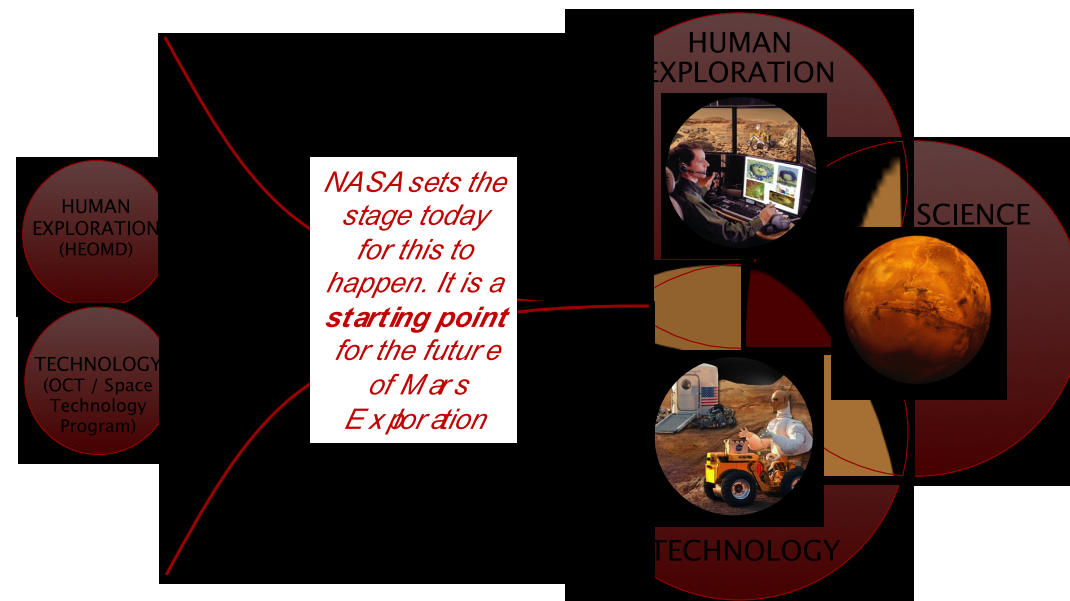
- There is a place for intersection of Human and Robotic spaceflight
  - See NAS/NRC Planetary Decadal Survey
- With proper leadership key figures in the science community will support a collaborative even interdependent program.

Mars Exploration as a Common Goal for NASA



T O D A Y

F U T U R E





- **RELATIONSHIP TO NASA'S HUMAN EXPLORATION PROGRAM (summary page 63)**
- Although humans are not required for the return of samples from the Moon, asteroids, or Mars, if humans are going to visit these bodies, collecting and returning high-quality samples are among the most scientifically important things they can do.
- The robotic and human exploration of space should be synergistic, both at the program level (e.g., science probes to Mars and humans to Mars) and at the operational level (e.g., humans with robotic assistants). Both drive the development of new technologies to accomplish objectives at new destinations.
- However, this effort must proceed without burdening the space science budget or influencing its process of peer-review-based selection of science missions.

# WATER ON MARS



**Past**



**Present**



**Future??**