National Aeronautics and Space Administration

NASA’s Flexible Path for the Human Exploration

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NASA Glenn Research Center

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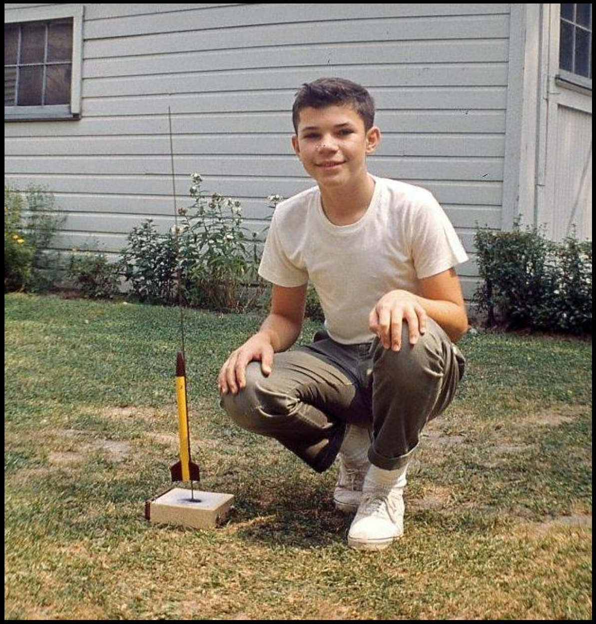
Speaker Introduction

Early Life

- Grew-up in East Cleveland
- Graduated from Shaw High School and Case Western Reserve University
- Space Geek
  - Influenced by Walt Disney & W. Von Braun vision for space stations and exploration
  - Built model rockets
  - Listened to Mercury flights at school on transistor radio
  - Watched on TV Gemini and Apollo Missions



September 1963

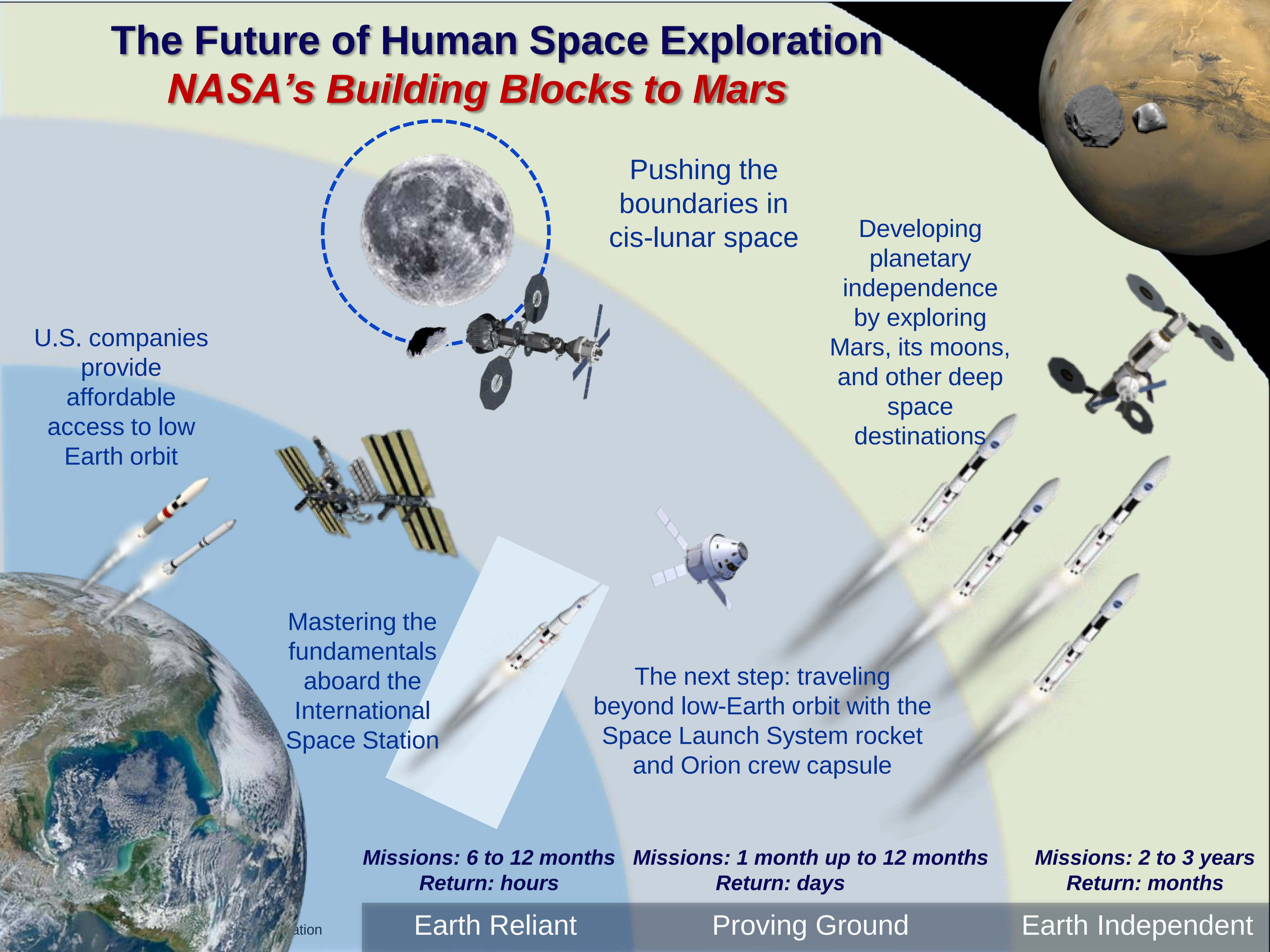
NASA Career Highlights

- Developed digital controls for jet engines
- Managed a NASA Branch that worked design, development and verification of the power system for the International Space Station
- Managed NASA Branch that developed advanced power technologies
- Currently working on power systems for Deep Space Habitats

Interesting Fact – After 40 years with NASA, the only rocket launch witnessed "live" is the one in the picture

Discussion Topics

- What is the Flexible Approach to Exploration?
- Path to Mars
- International Space Station
- Ongoing vehicle developments
- Future Vehicle Developments
- Mars and its Moons
- Evolvable Mars Campaign expansion of capabilities and distance
- Technical challenges
- Take Aways


The Future of Human Space Exploration
NASA's Building Blocks to Mars
Pushing the boundaries in cis-lunar space
Developing planetary independence by exploring Mars, its moons, and other deep space destinations
U.S. companies provide affordable access to low Earth orbit
Mastering the fundamentals aboard the International Space Station
The next step: traveling beyond low-Earth orbit with the Space Launch System rocket and Orion crew capsule
Missions: 6 to 12 months
Return: hours
Missions: 1 month up to 12 months
Return: days
Missions: 2 to 3 years
Return: months
Earth Reliant
Proving Ground
Earth Independent

International Space Station -- ISS

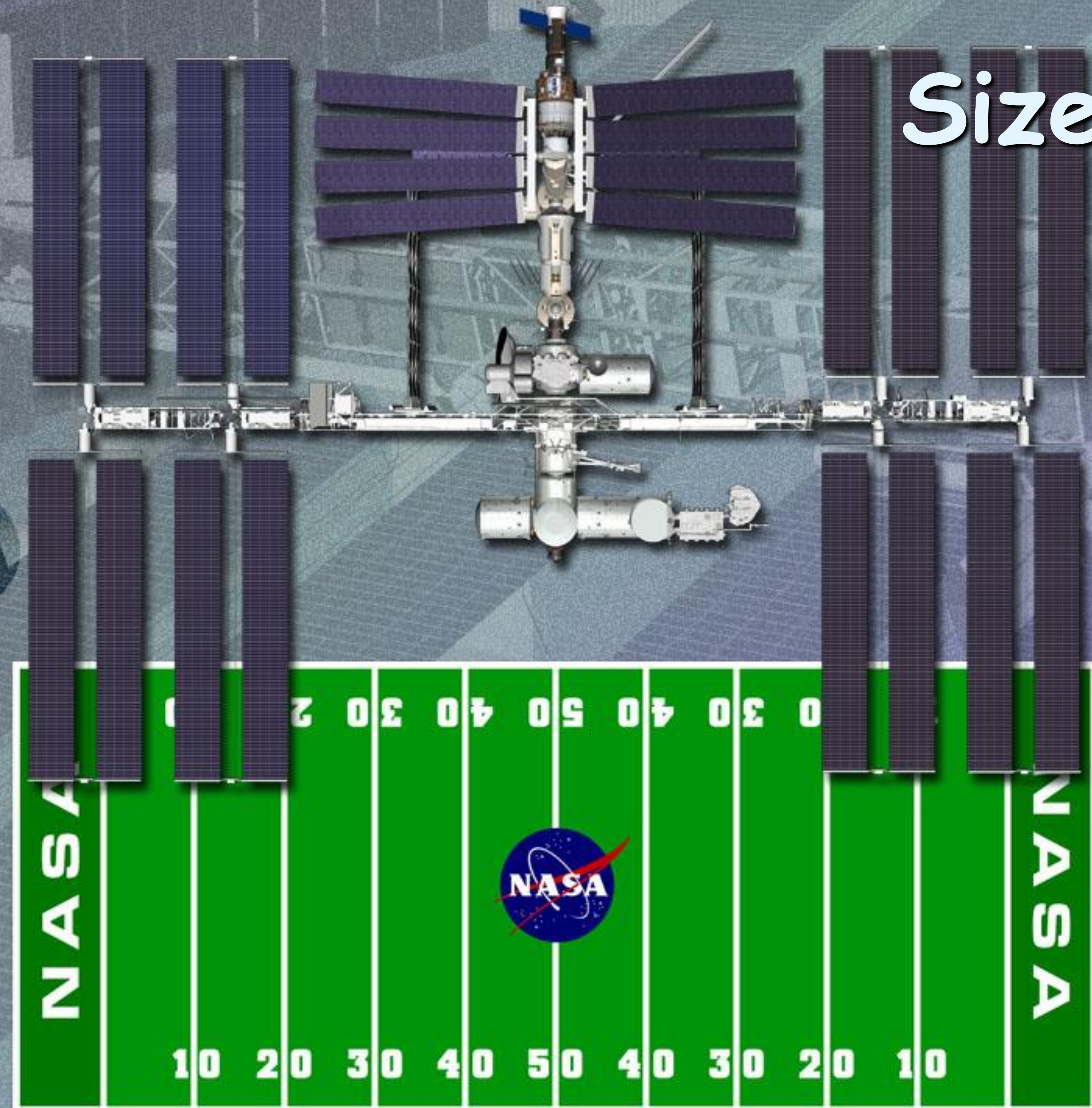
International Space Station

- International crew of 6
- 75 kW of power
  - Solar array and batteries
- Orbits
  - Every 90 minutes
  - 240 miles above earth
  - 17000 Miles per hour
  - 51.6 Orbit inclination
- Weighs 400 tons
- 32000 Cubic feet of Pressurized Volume
- Total footprint is the size of a football field

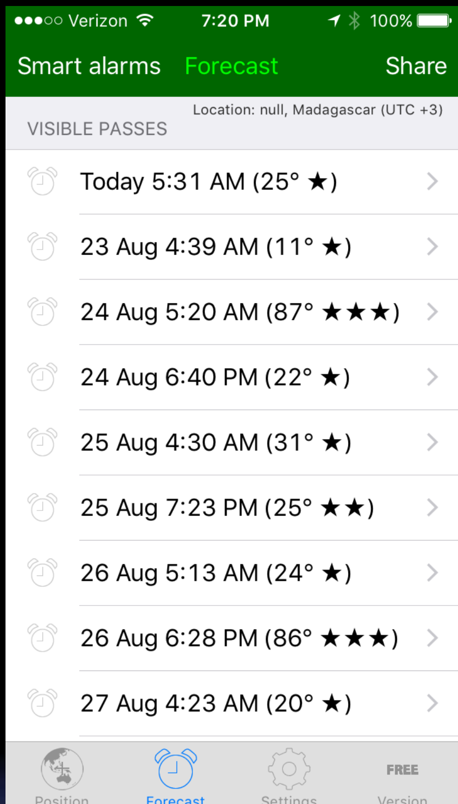
Size

Width: 108 meters
Length: 80 meters

Weight:
456,279 kilograms



How can I see the ISS?



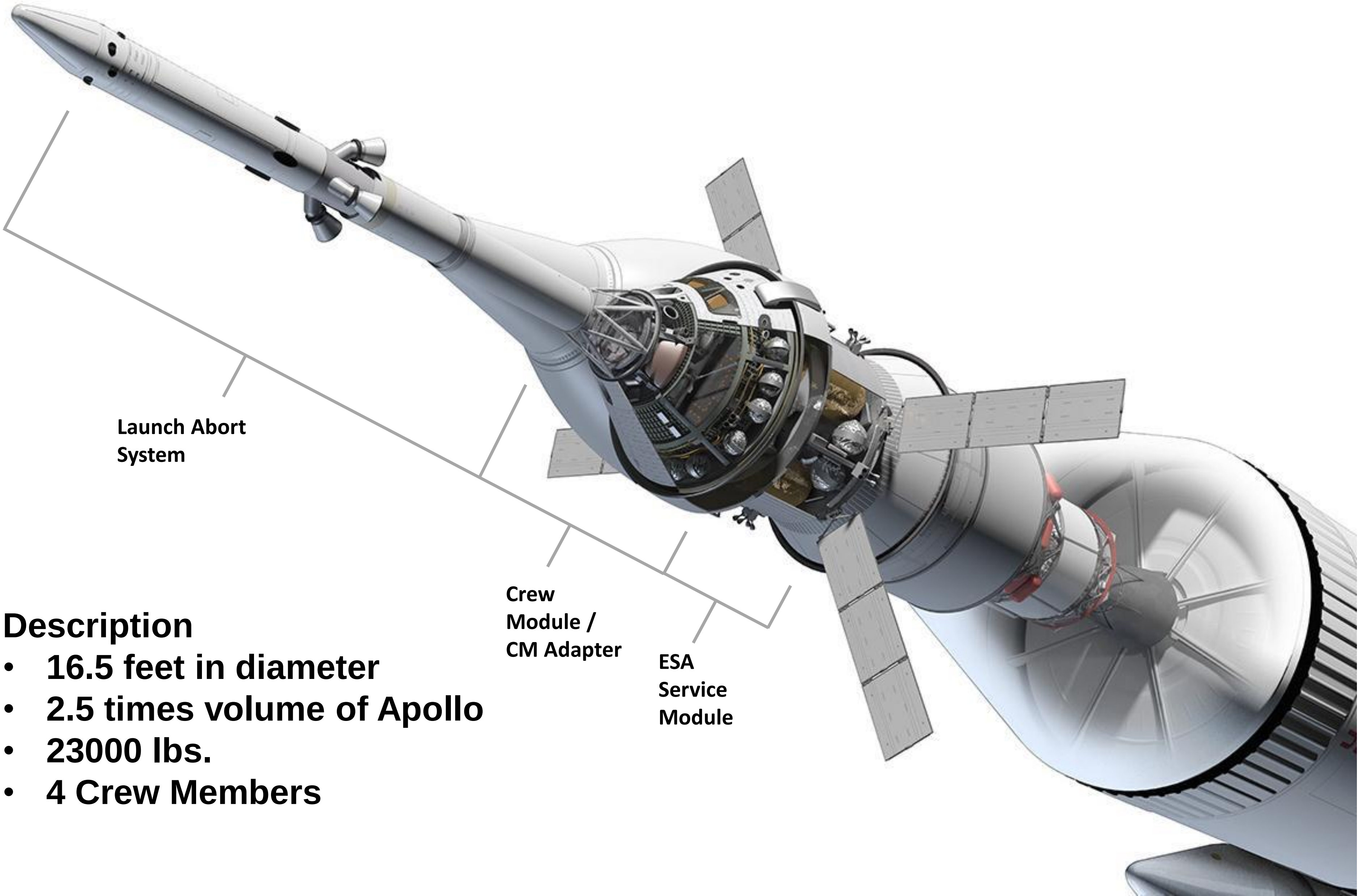
Space Station Tracker APP
"ISS Spotter"
iPhone and Android

Time of next visible pass
***** Are the best**

Orbit Location

Vehicle Developments to Support Exploration

The Orion Spacecraft



Description

- **16.5 feet in diameter**
- **2.5 times volume of Apollo**
- **23000 lbs.**
- **4 Crew Members**

The Space Launch System (SLS)

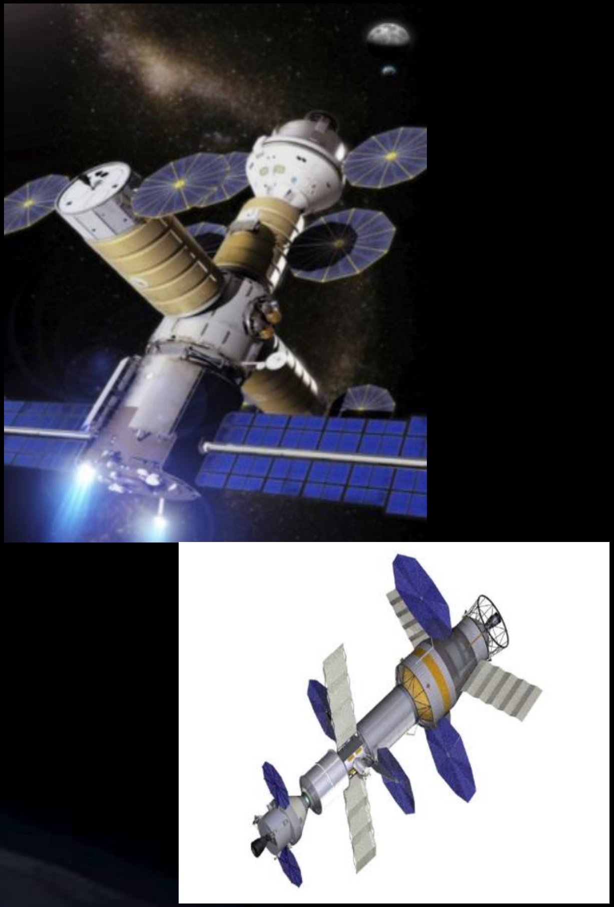
- **Designed to carry the Orion spacecraft, cargo, equipment and science experiments to Earth's orbit and destinations beyond.**
- **The SLS will have an initial lift capacity of 70 metric tons and will be evolvable to 130 metric tons.**
- **It will use a liquid hydrogen and liquid oxygen propulsion system, which will include the RS-25 from the Space Shuttle Program for the core stage and the J-2X engine for the upper stage.**
- **SLS will use solid rocket boosters for the initial development flights, follow-on boosters will be competed based on performance requirements and affordability considerations.**

Initial 70 metric ton configuration

Potential Future Vehicle Developments

Potential Deep Space Vehicle

- Crew of 4 to 6
- Provide living space for long duration missions
- Solar Array / Battery System
  - 24+ KW
- Potential to be operated in Low Lunar Orbit, Near Rectilinear Orbit or Deep Space
- Provides docking accommodation for multiple vehicles – resupply as well as landers
- Platform for the checkout and validation of advanced technologies
  - Closed loop life support systems
  - Advanced automation systems
  - Etc.



Deep space vehicle concepts

What is Solar Electric Propulsion?

This:

Dawn Spacecraft

Ion Engine

- A low mass / high efficiency propulsion system typically used for reconnaissance of planets and asteroids
- Results in very long travel times for missions – Not high speed intercept
- Real ion propulsion develops fractional Newton's or fractional lbs of thrust

Not That:

Twin Ion Engine (TIE) Fighter from Star Wars

Solar Electric Propulsion (SEP)

Description

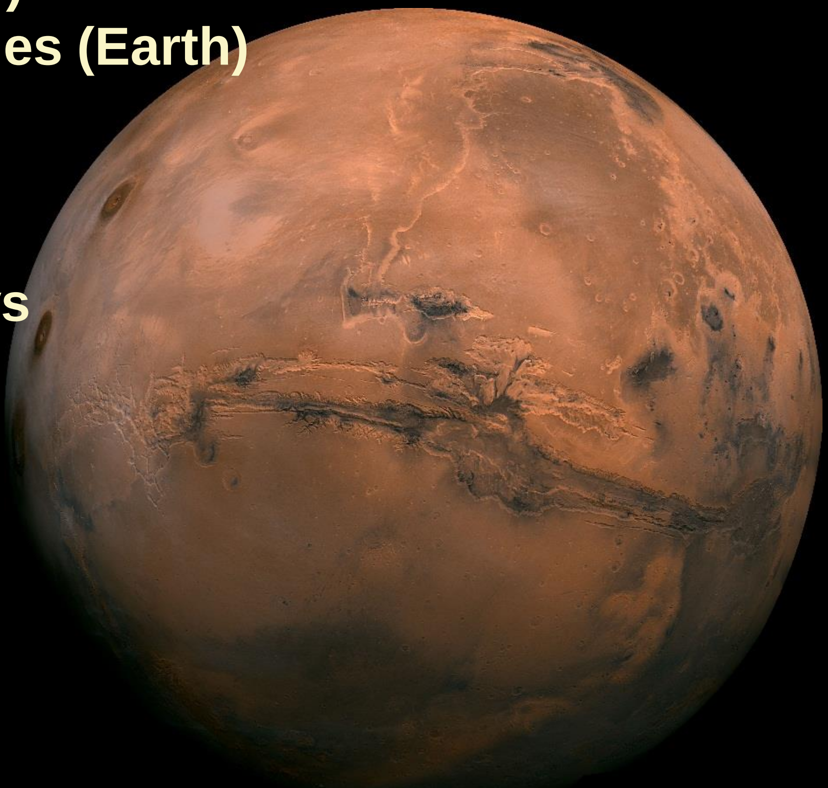
- **Provides high propellant efficiency or ISP = 3000 vs 450 for H2 / O2 Prop.**
- **Fuel -- Xeon gas**
- **Reduced launch mass over chemical systems**

GRC Role

- **Block I vehicle power 50kW (BOL) and 42kW (EOL)**
- **Extendable to 150kW**
- **Operates over a range from 0.8 AU to 1.7AU**
- **Applicable to a wide variety of missions**

Mars and Its Moons

Mars Characteristics



- ½ the size of earth (0.533 earth radius)
- Solar distance 143 MMiles Vs 93 MMiles (Earth)
- Insolation = 43% of Earth
- Surface gravity = 0.376g
- Average temperature = -81degrees F
- Length of day / year = 24hrs / 687 days
- Axis tilt = 25 degrees
- Roundtrip Communications delay
  - 15 to 45 minutes
- Atmosphere is mostly CO_2
  - Mean Pressure 0.8 inches of Hg
  - 22 miles above Earth sea level
- Polar Ice Caps
  - North – Permanent H2O -- temporary cap of CO_2 in Winter
  - South – Permanent H2O -- a year round cap of CO_2
- Magnetic Field – None -- solar wind continuously strips away pieces of the Martian atmosphere

Mars’ Moons

Deimos (Terror / Dread)

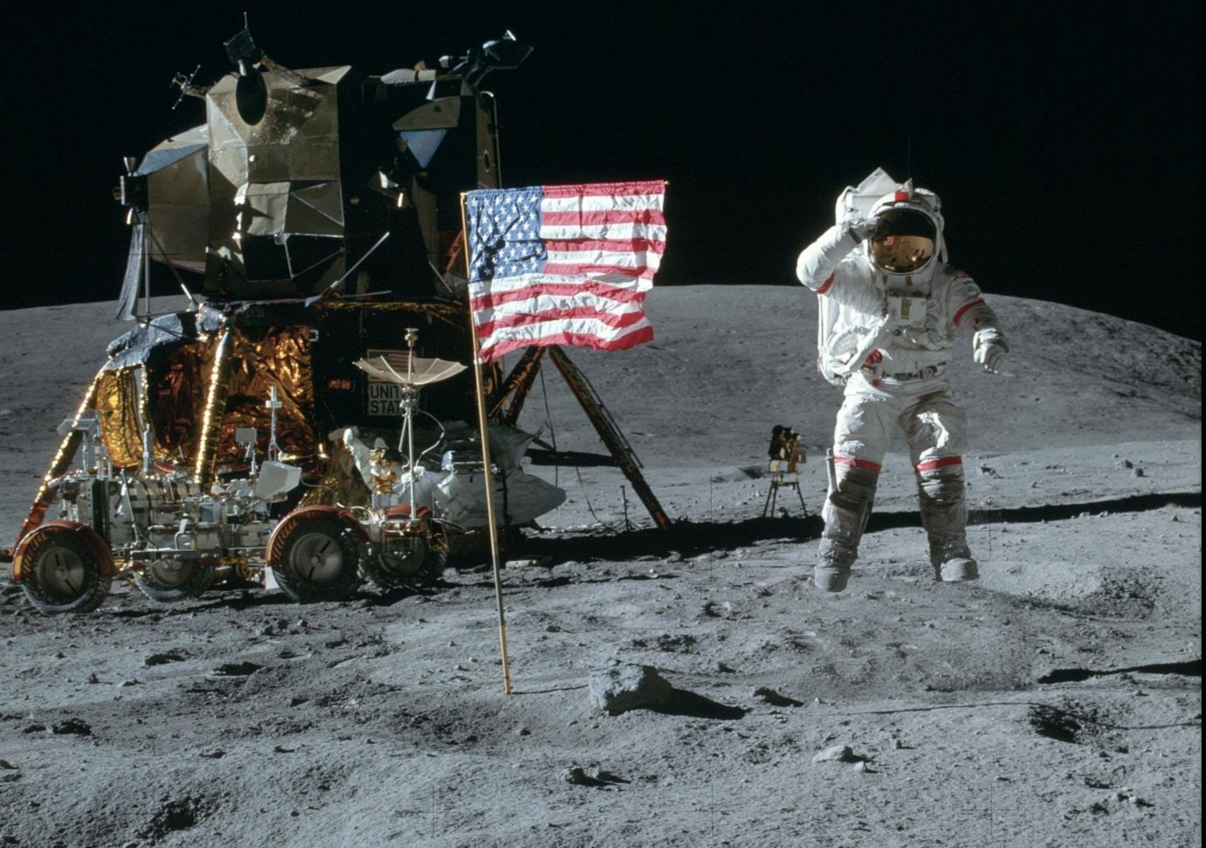
- Orbital Period = 30 hrs.
- Orbital radius = 14,600 miles
- Size =15 x12x11 km
- Surface gravity = 0.0003g

Phobos (Panic / Fear)

- Orbital period = 8 hrs.
- Orbit radius = 5,800 Miles
- Size = 27x22x18 Km
- Surface gravity = 0.00058g
- Mars occupies a large amount of Phobos sky
  - Can shield astronauts from cosmic rays & solar radiation for 2/3 of every orbit
- Provides a base for real-time robotic exploration of Mars

Maximum Vertical Jump –

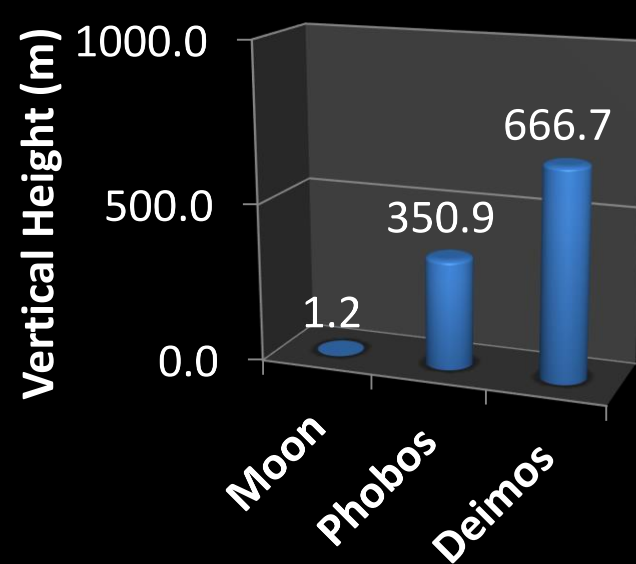
650 lb. Suited Crew (crew + suit + jetpack)



Weight on Phobos	lbf
Crewmember in a Suit	0.3
SEV (6,000 kg)	7.7
Habitat (15,000 kg)	19.2
Lander (50,000 kg)	63.9

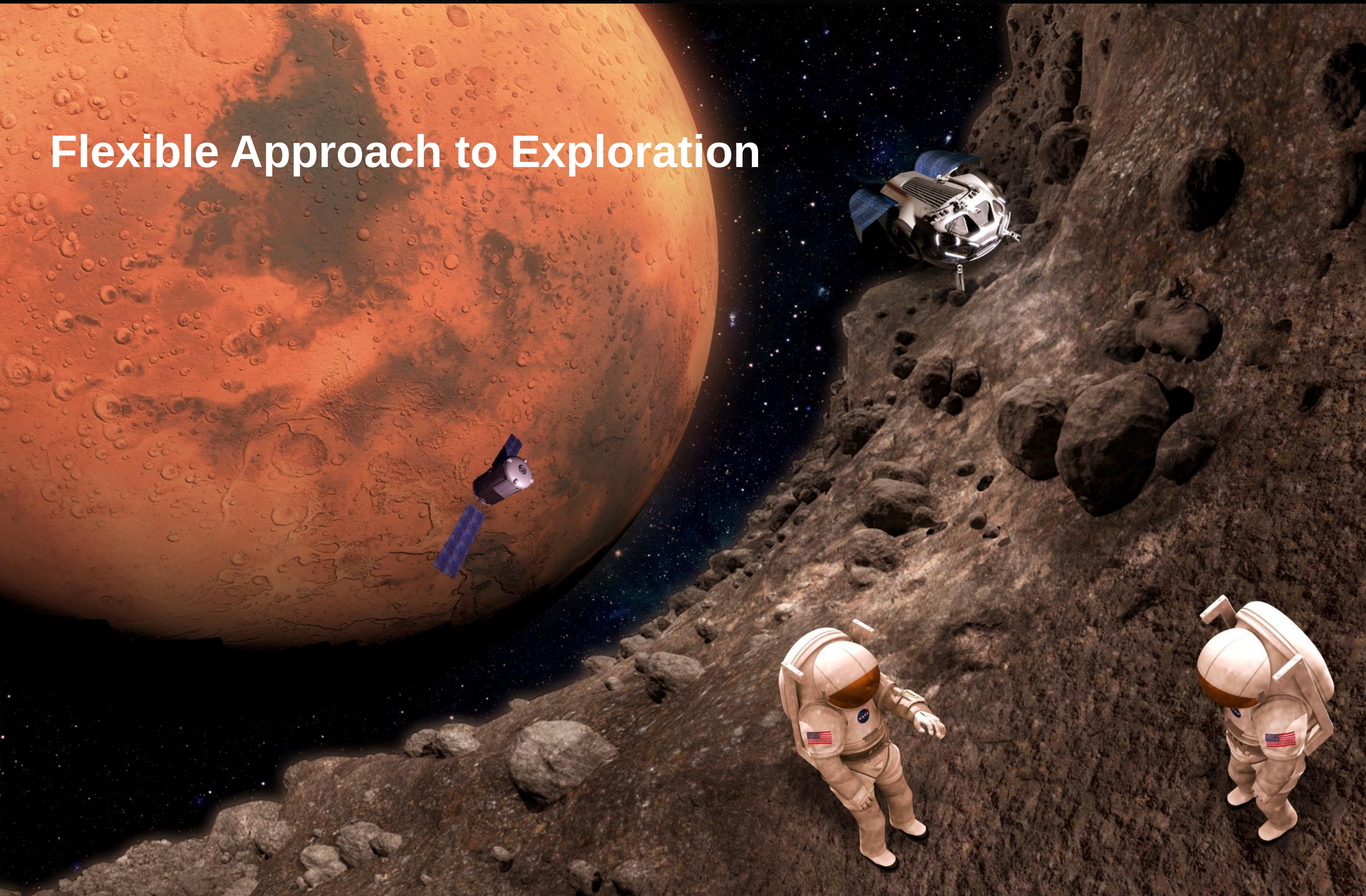
Apollo 16 – John Young's Jump Salute

Maximum Vertical Jump w/ 2 m/s Take-Off Velocity

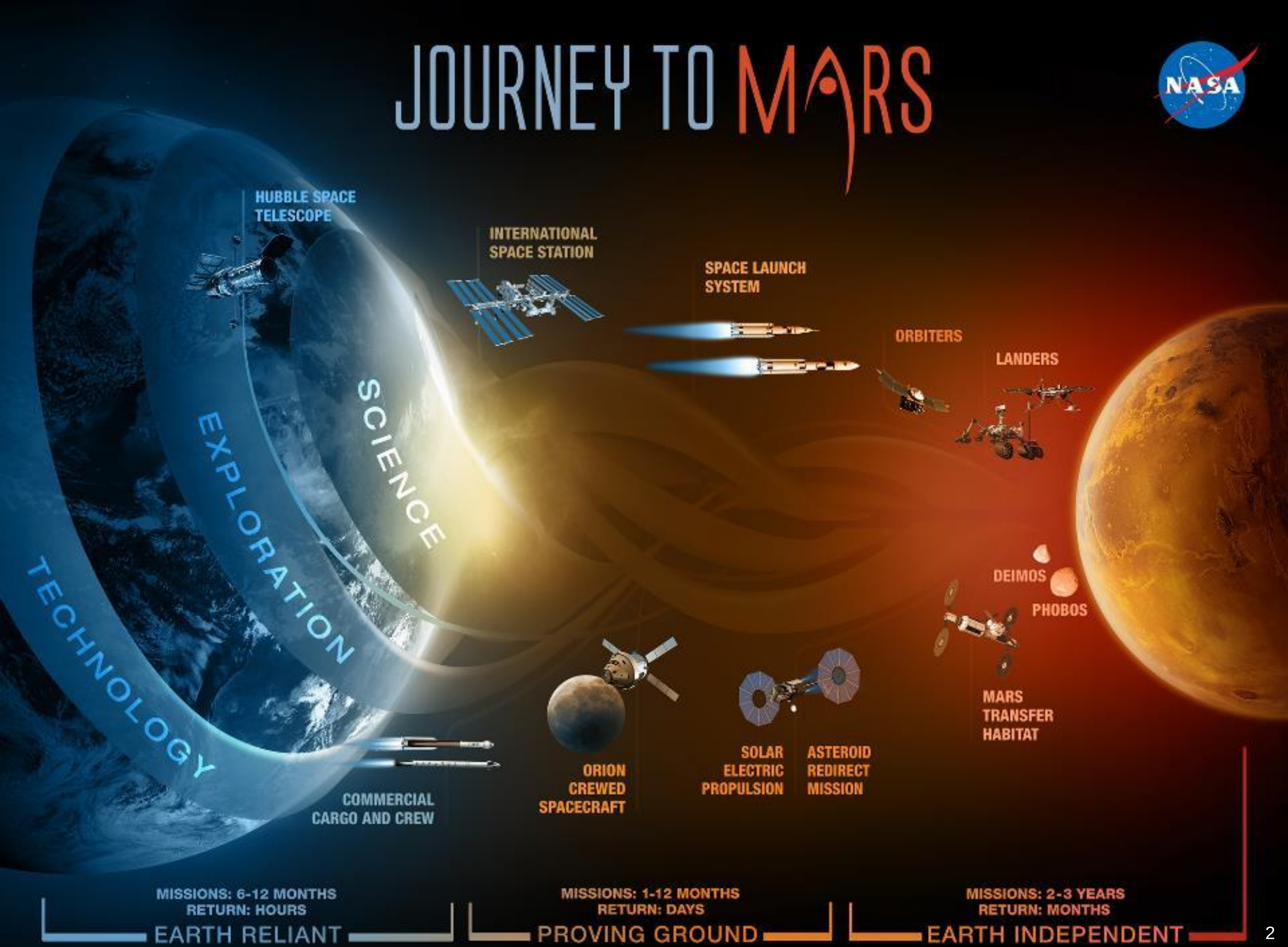


	Time of Flight
Moon	2.5 sec.
Phobos	11.7 min.
Deimos	22.2 min.

Flexible Approach to Exploration



Evolvable Mars Campaign Expansion of Capabilities and Distance



JOURNEY TO MARS
NASA
HUBBLE SPACE TELESCOPE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
DEIMOS
PHOBOS
MARS TRANSFER HABITAT
ORION CREWED SPACECRAFT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
COMMERCIAL CARGO AND CREW
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1-12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2-3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

GETTING TO MARS
via split-mission concept

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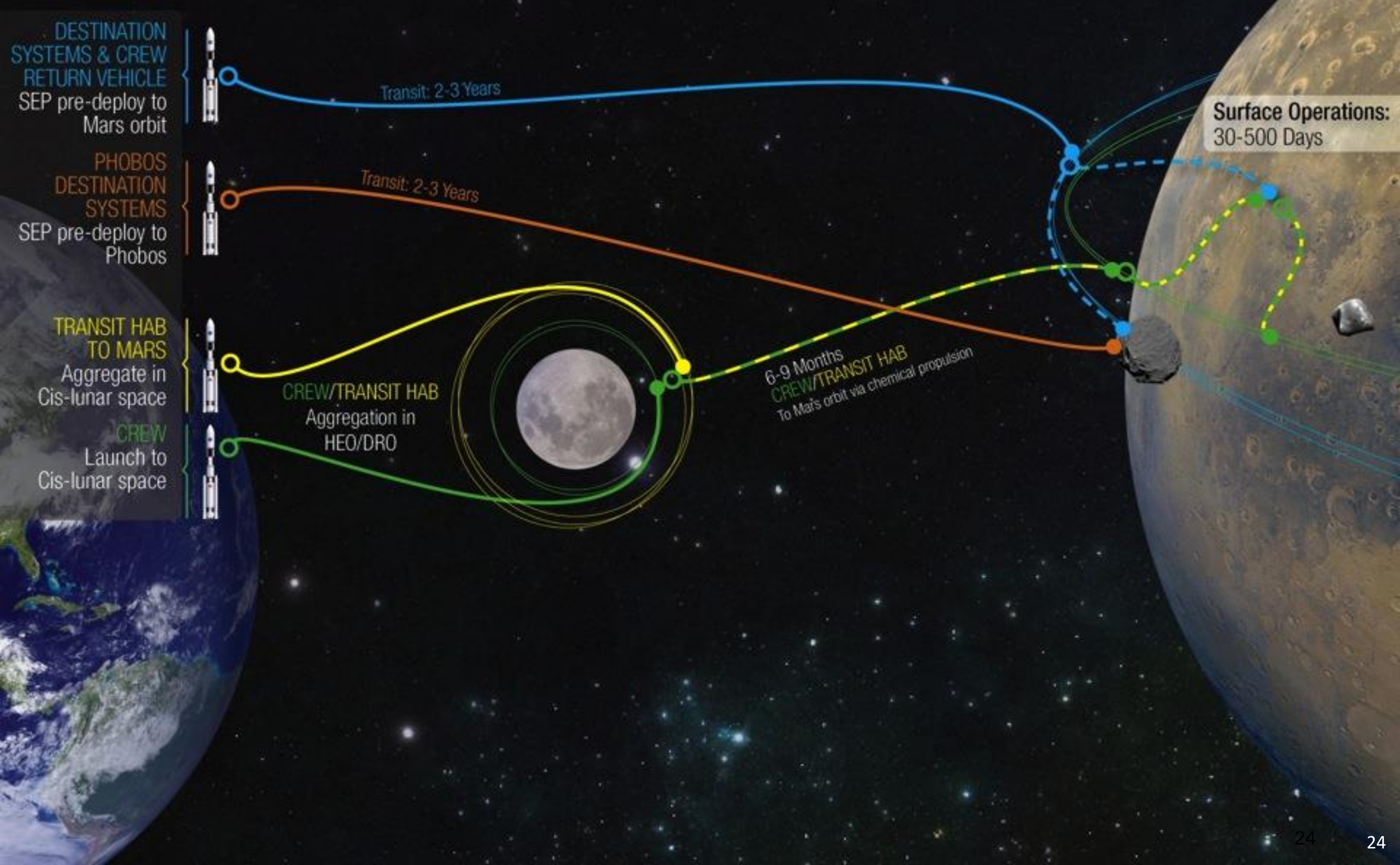
GETTING TO MARS

via split-mission concept



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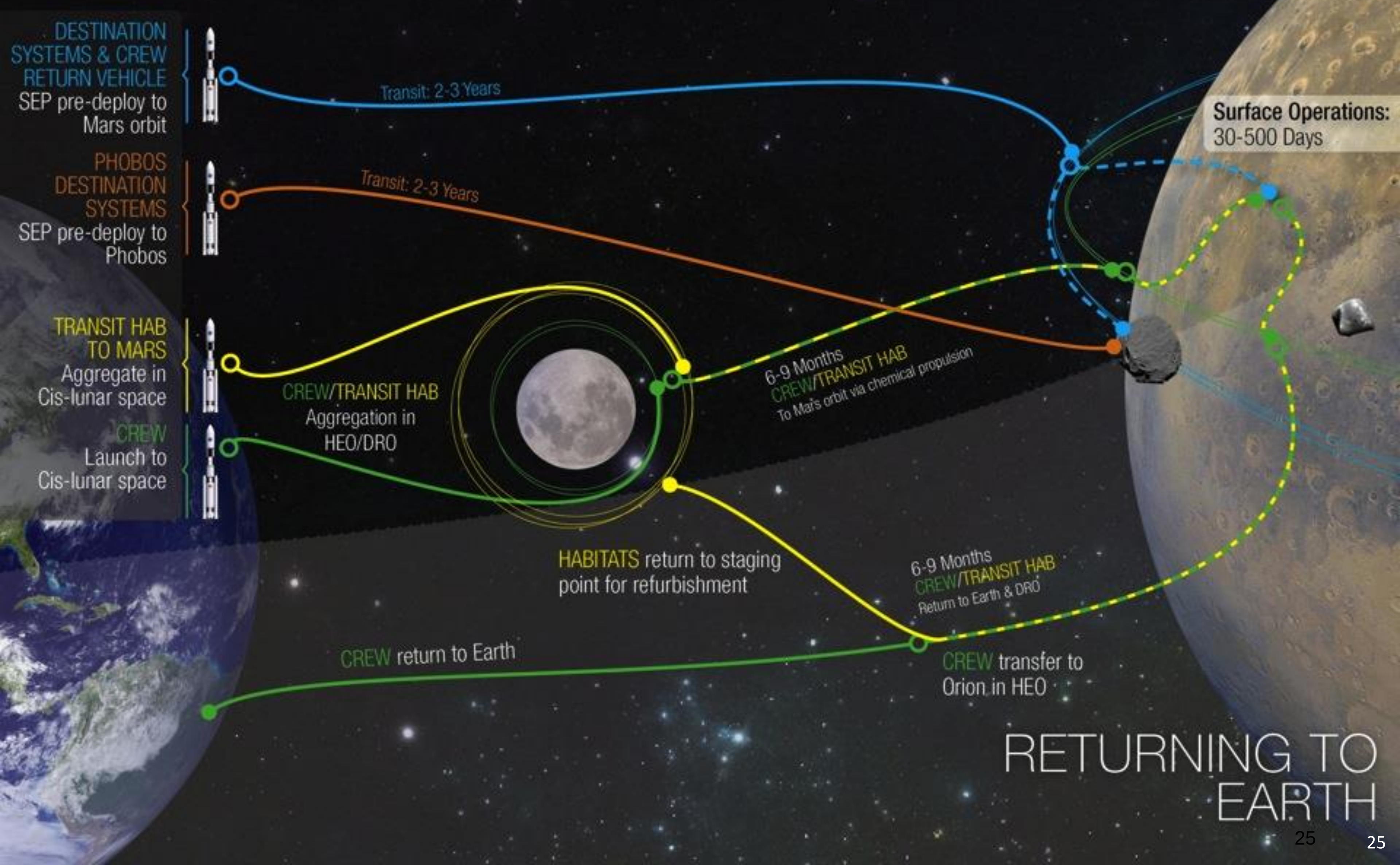
GETTING TO MARS
via split-mission concept



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Key Technical Challenges

Key Challenges

There and Back

- Ability to launch a powerful rocket
- High reliability space craft systems
- Size requirement for crew capsule
- High thrust in-space propulsion systems
- Deep space navigation
- Rendezvous and docking
- Life support systems
- High speed re-entry

Happy and Healthy

- Air, food and water
- Waste containment
- Psychological impact
- Low / no gravity
- Medical emergencies
- Bone loss
- ***Radiation***
- Ocular degeneration
- Hygiene

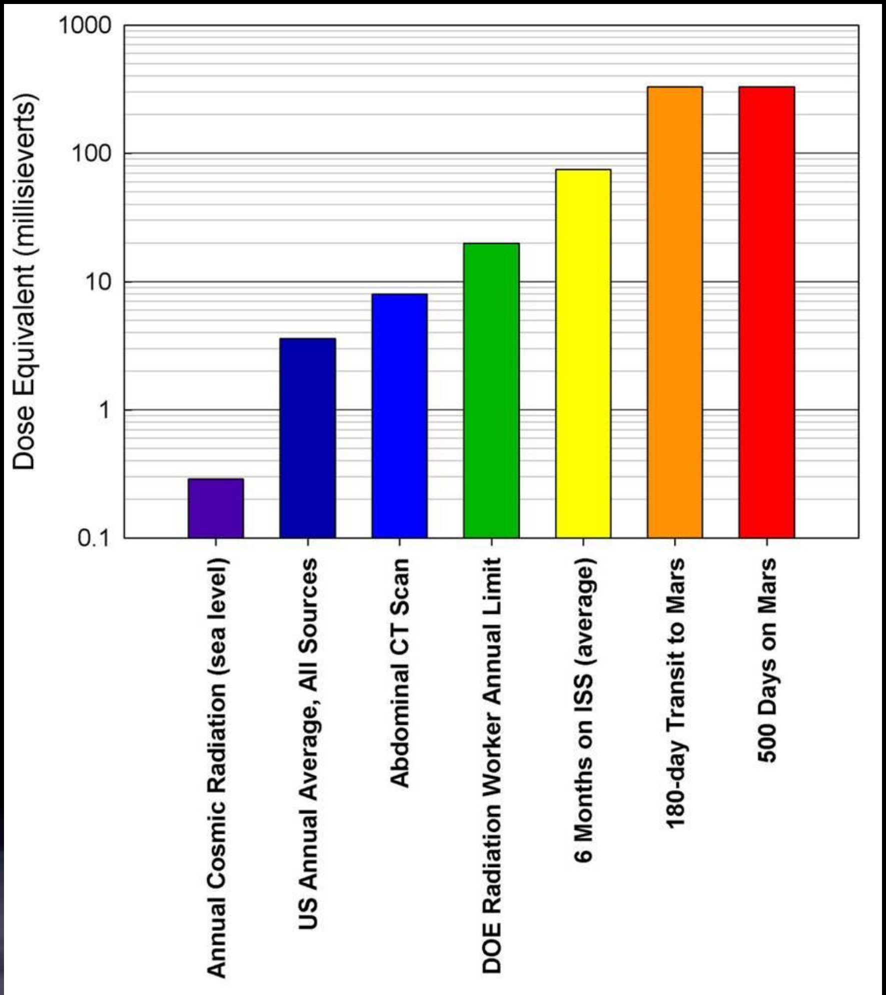
Well Equipped and Productive

- High power surface systems
- ***Situational awareness and decision making***
- ***Behavior Health (Crew Relationships)***
- Training and Tools
- Mission Planning
- Space suits

Radiation Dosage

Radiation Exposure on a trip to Mars is a big Issue

- 2.4 to 3.4 mSv/year is natural radiation dose on earth
- 0.2 mSv/ round trip between NY and Tokyo
- 6.9 mSv / time for a CT scan
- 75 mSV for 6 months on the ISS
- 350 mSV for 180 day trip to Mars or 500 day stay on the planet
- Upper limit dose for radiation workers -- 250 mSv/ year



1 SV = 100 REMs= 1 joule / Kg

Behavioral Health

- Behavioral areas susceptible to increased risk over a one year mission:
  - (1) sleep loss, circadian desynchrony, workload and fatigue
  - (2) stress, morale and mood changes*
  - (3) cognitive functioning
  - (4) interpersonal conflicts*
  - (5) motivational challenges*
  - (6) family separation and personal communications

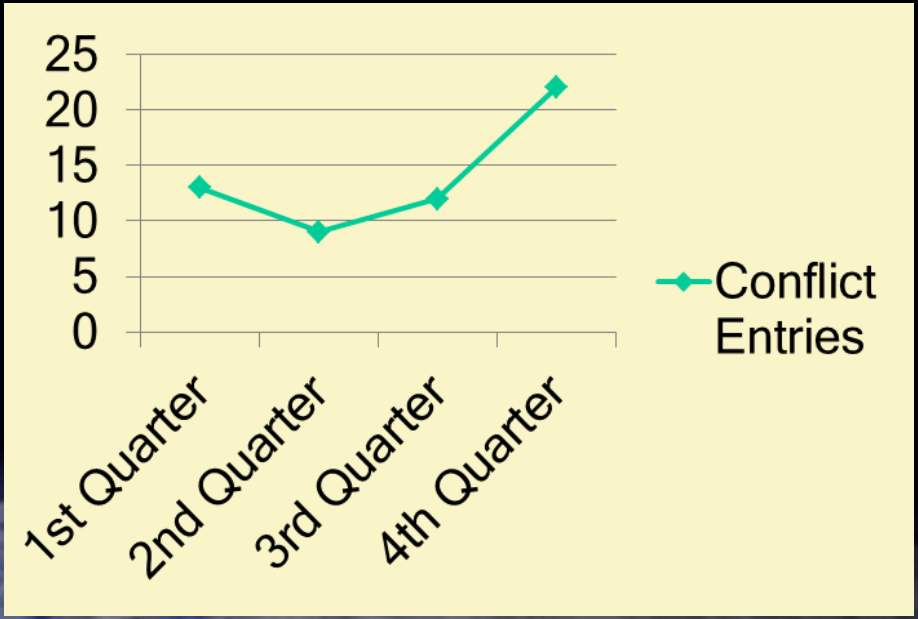
- Desire realistic environment and population to validate countermeasures.

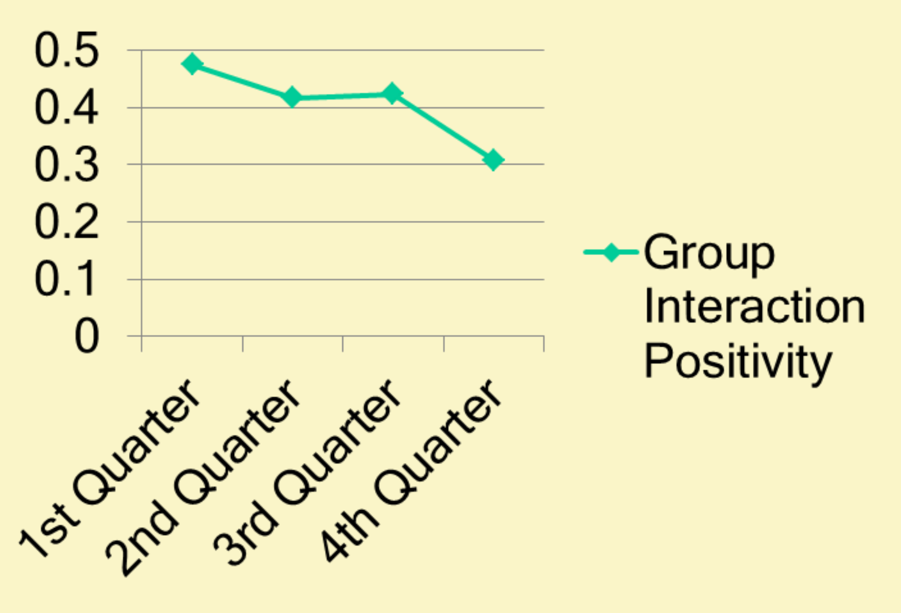
- Preliminary analysis for ISS (ongoing study):
  - Available measures of subjective stress, sleep quality, and vigilance
    - ✓ <u>not all monotonic</u> with mission time
    - ✓ do not plateau by six months
  - Sleep quality and vigilance have similar trends which suggest increasing performance deficits for longer missions.

One-Year ISS Missions Behavioral Concerns

Interpersonal Conflicts

- **ISS Journal entries on conflict by mission quarter**
- **ISS Group Interaction Positivity Ratings by mission quarter (244 entries)**

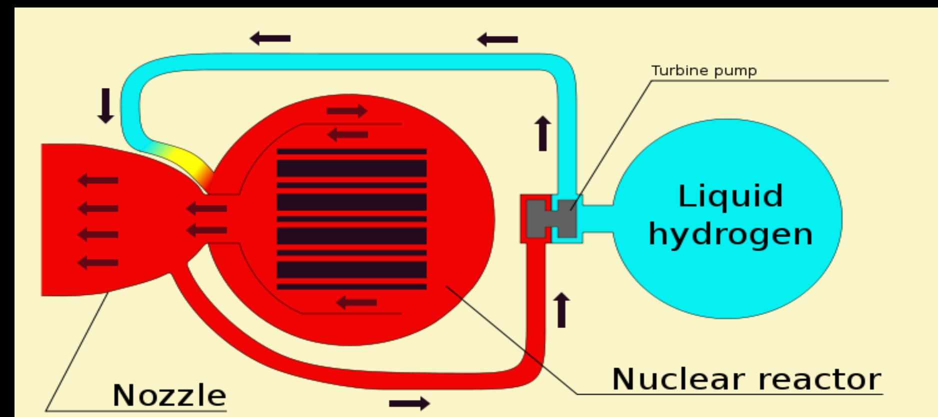




Interpersonal conflict can impact crew performance and mission success (De Dreu & Weingart, 2003)

Nuclear Thermal Propulsion Systems

- Vehicle has crew size of between 4 to 6 for a multi—month voyage
- Docking ports for 2 Multi-Purpose Crew Vehicles
- Propellant heated directly by a nuclear reactor and thermally expanded / accelerated through a nozzle
- Low molecular weight propellant – typically Hydrogen
- Propellant mass approx. ¼ of standard chemical stages



Costs and Politics

What are the Realities of Going to Mars

- Going to Mars is a long term expensive undertaking
- What is the cost? – Don't ask questions that you don't want to know the answer
- Considerable increase in the NASA budget will be needed to realize a human mission to Mars
- The road to Mars will need a political commitment through multiple administrations to reach the goal

Interesting Video on Exploration

- http://vimeo.com/108650530

Take Away's

- Going to Mars will require and array of new technologies to overcome the inherent challenges and obstacles that the journey imposes
- The journey will require a major investment in $ and "political will" over several decades to achieve the goal
- Ultimately space is the "final frontier" and it is human destiny to go to Mars

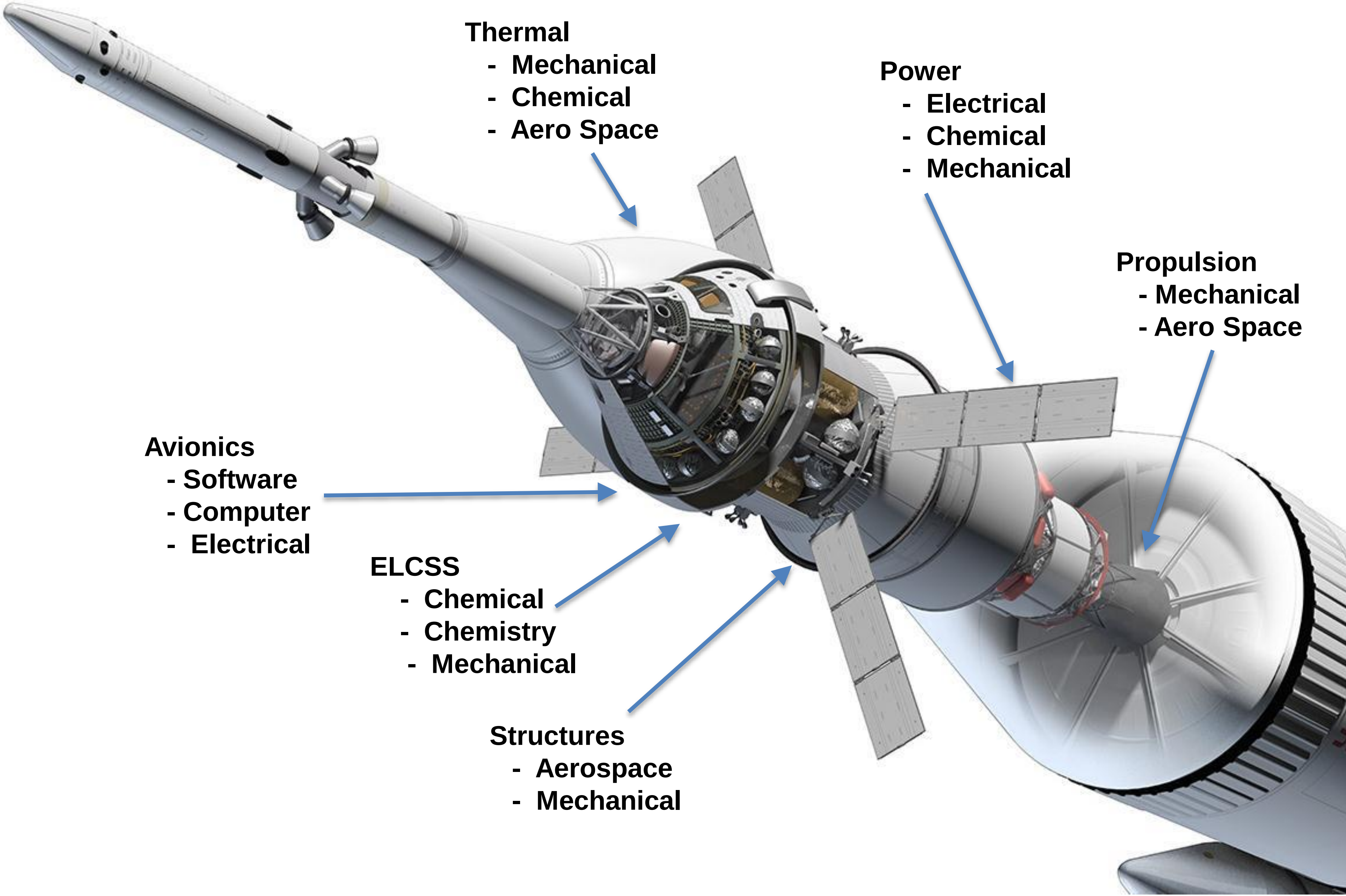
Questions?

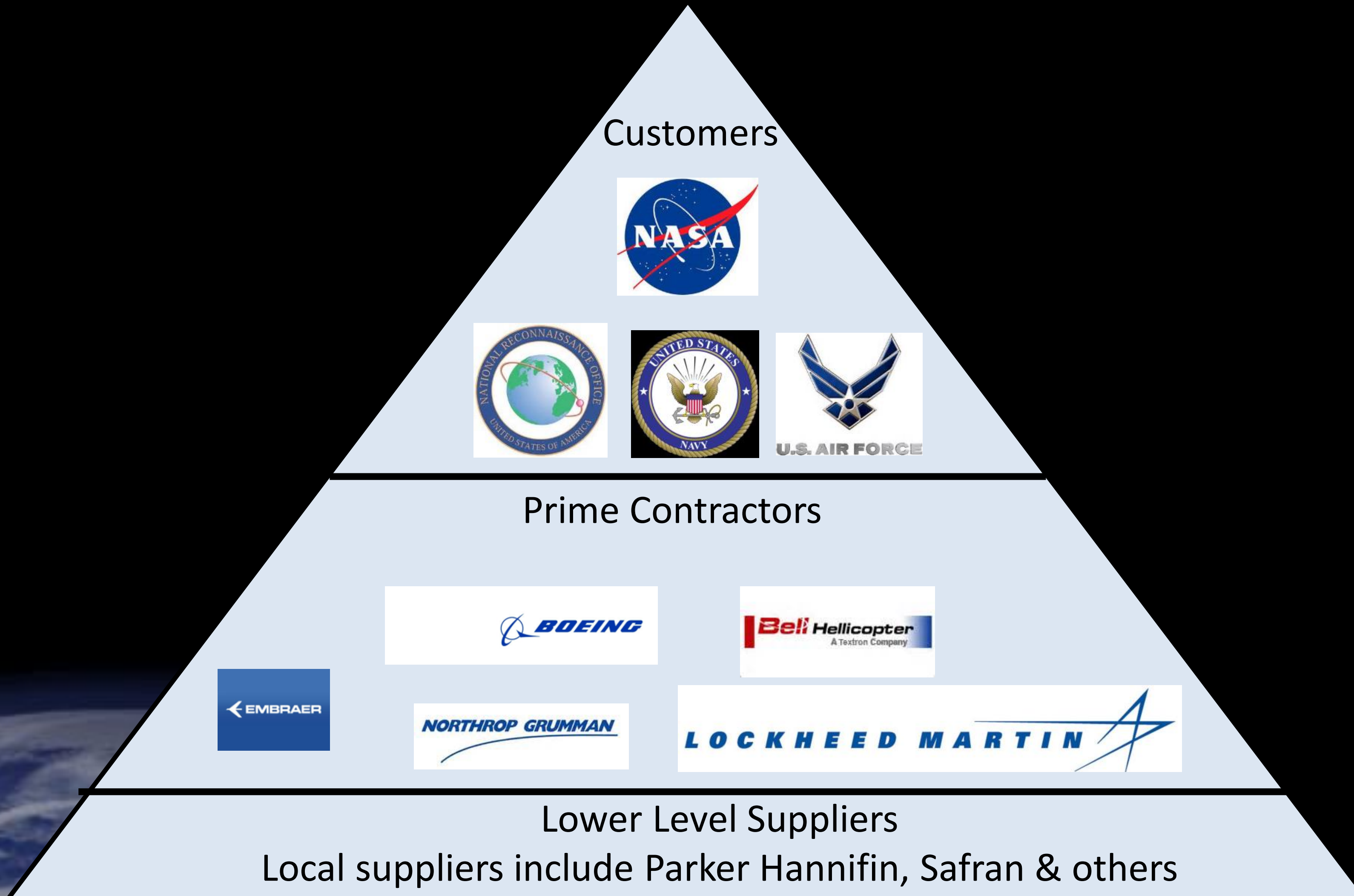
Aerospace Careers

Careers and Education

- **Individuals with skills in science and technology are necessary if the United States is going to remain competitive in the global economy**
- **Opportunities are better in engineering and computer science that hard sciences like biology / chemistry / physics**
- **Students need to understand and be proficient in the basics of math and science.**
  - **Algebra, geometry, trigonometry, *calculus***
  - ***Chemistry and physics even biology***
- **Presentation Skills (Presentation development and public speaking)**
- **Ability to write and communicate – media driven culture.**
- **Ability to work as part of a team.**
- **Understand the political, business and financial components as well as the technical component to all solutions**

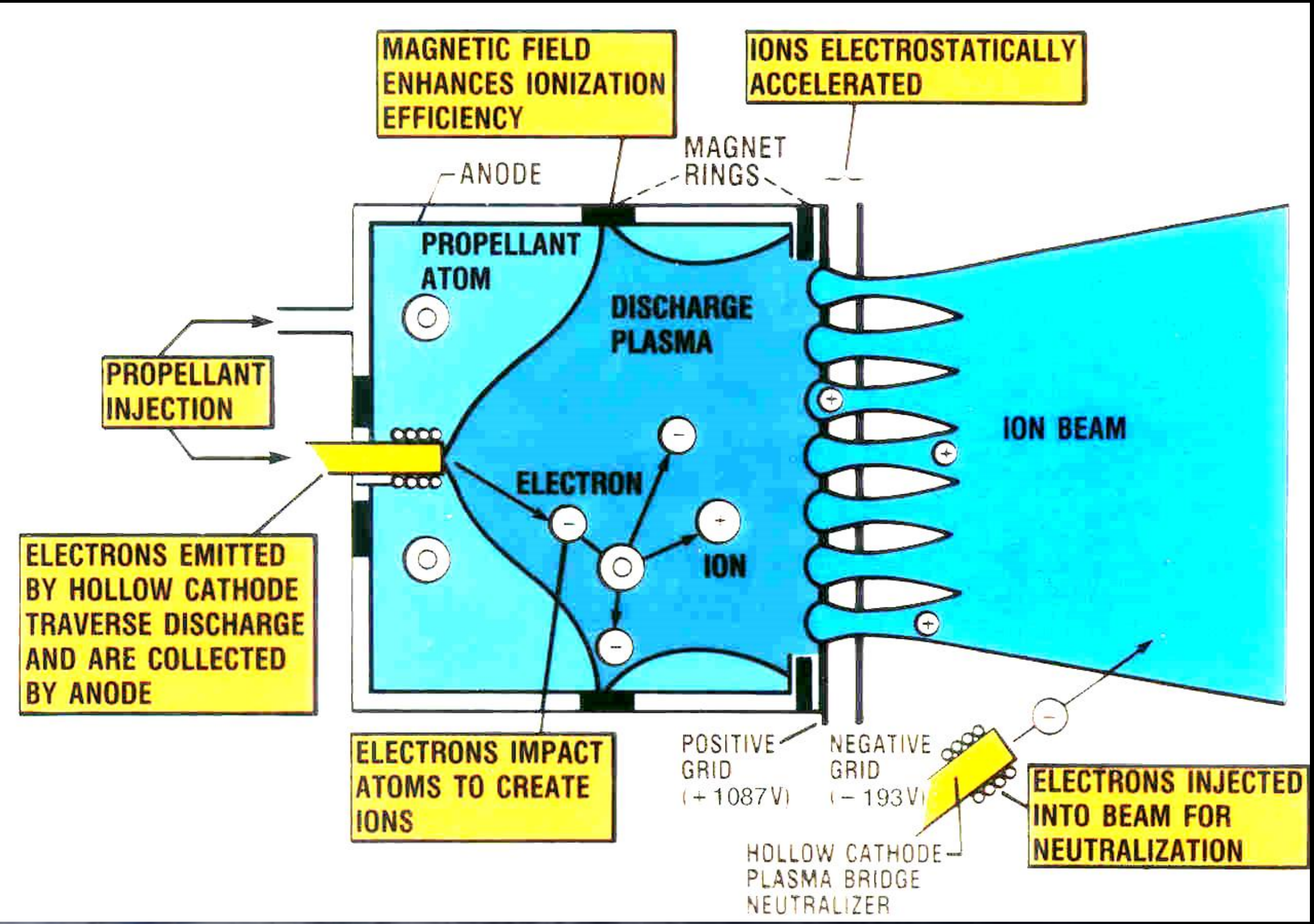
Aerospace Careers



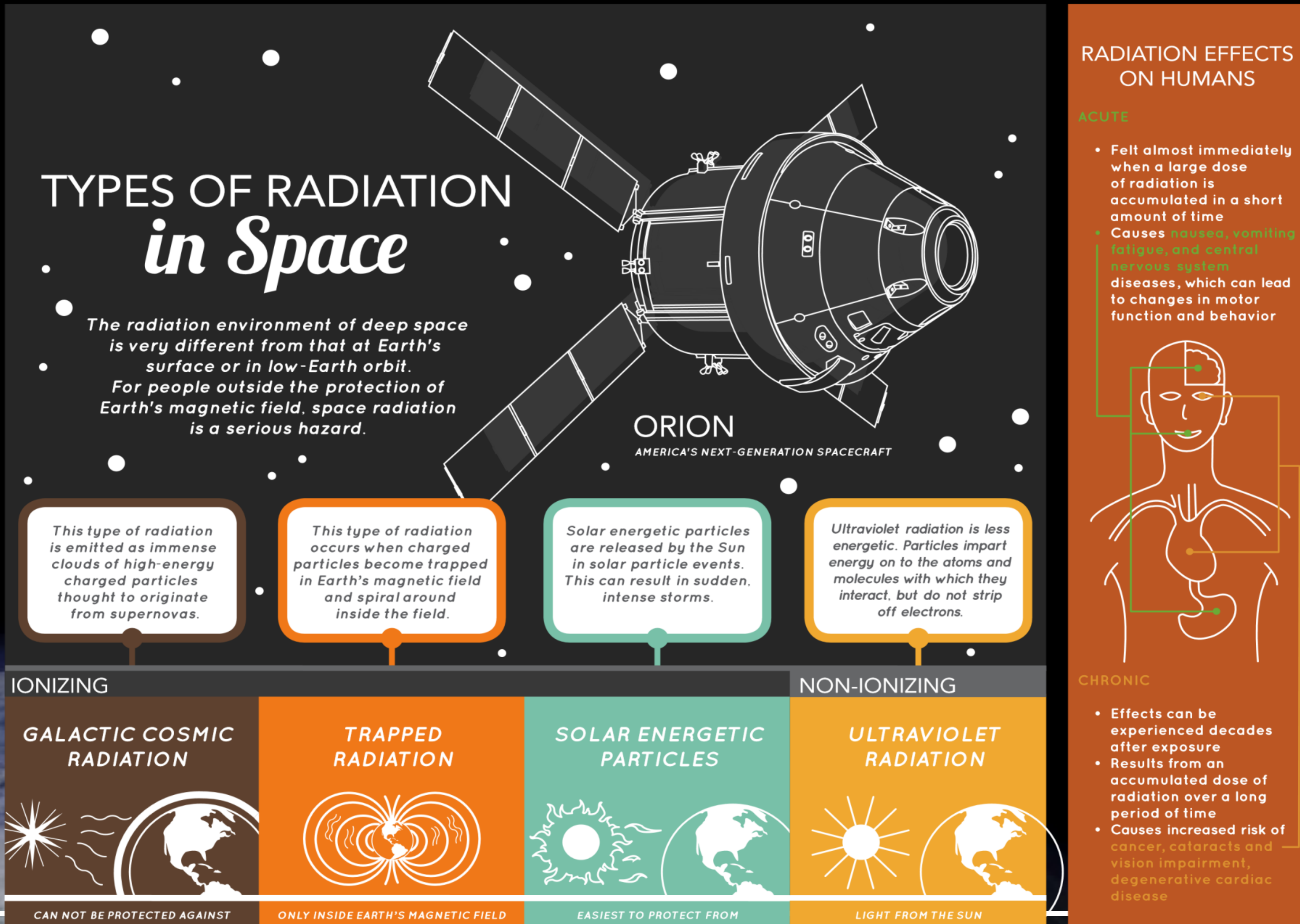

Customers
NASA
U.S. AIR FORCE
Prime Contractors
BOEING
Bell Helicopter
A Textron Company
EMBRAER
NORTHROP GRUMMAN
LOCKHEED MARTIN
Lower Level Suppliers
Local suppliers include Parker Hannifin, Safran & others

Back-up Slides

Ion Propulsion



National Aeronautics and Space Administration



www.nasa.gov

What does it Cost?

- **No costing exists for current initiative**
- **In 1989 President G.H.W. Bush asked for a NASA estimate**
- **Total overall cost was $500 billion in 1991 dollars**
- **NASA Baseline budget was assumed to $15B in 1991 dollars -- $24B today $ (actual budget $18B)**

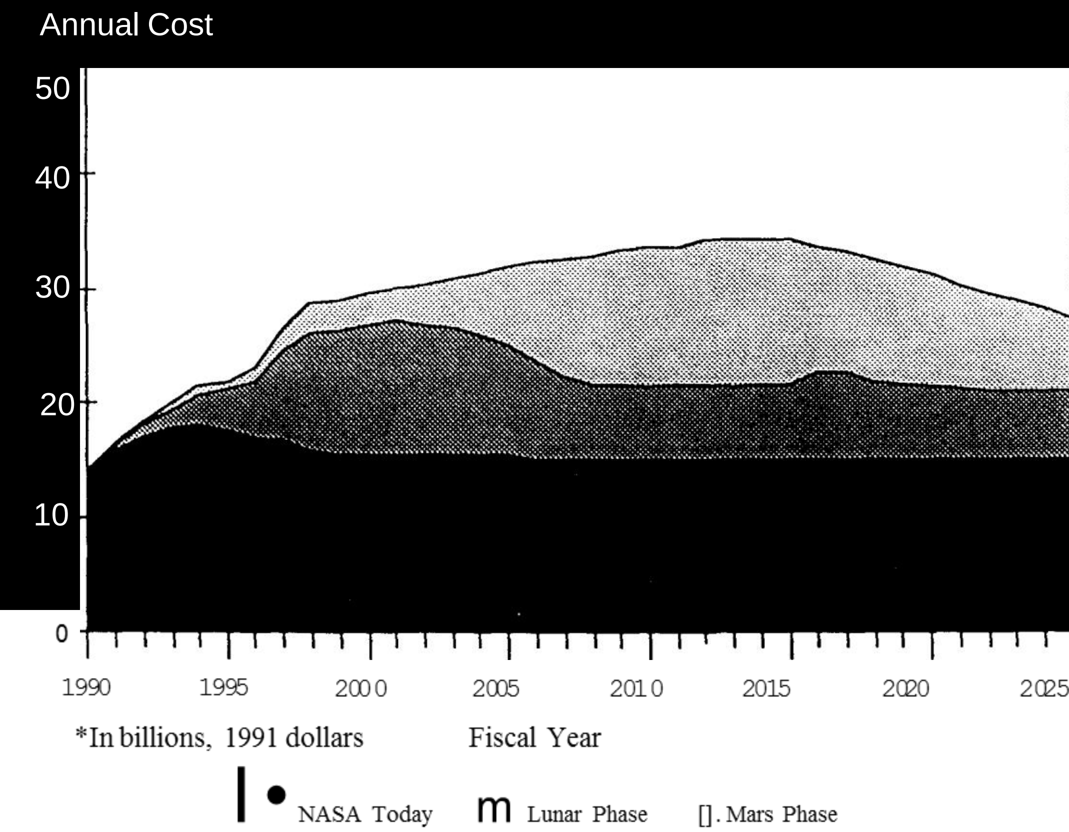
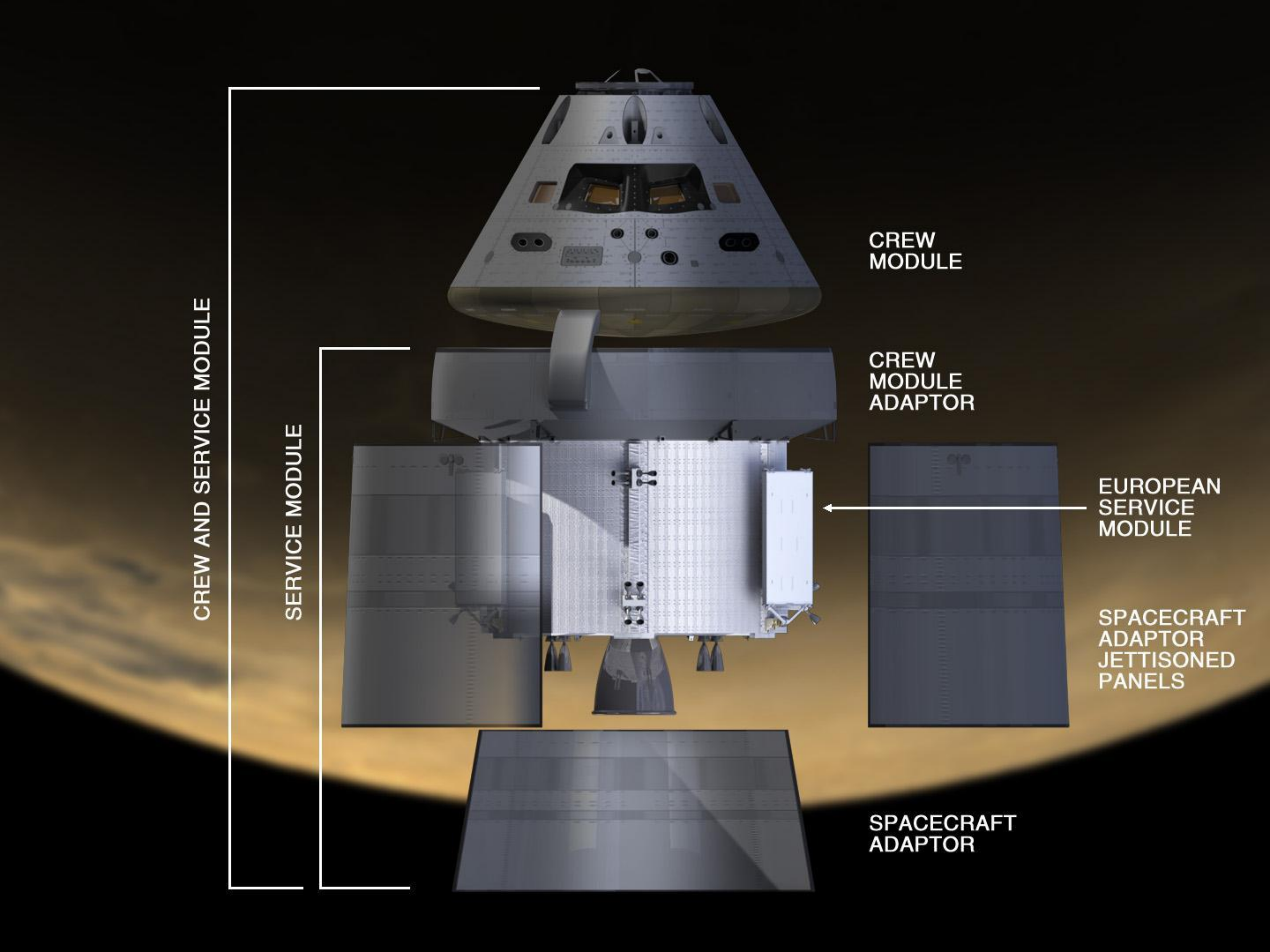
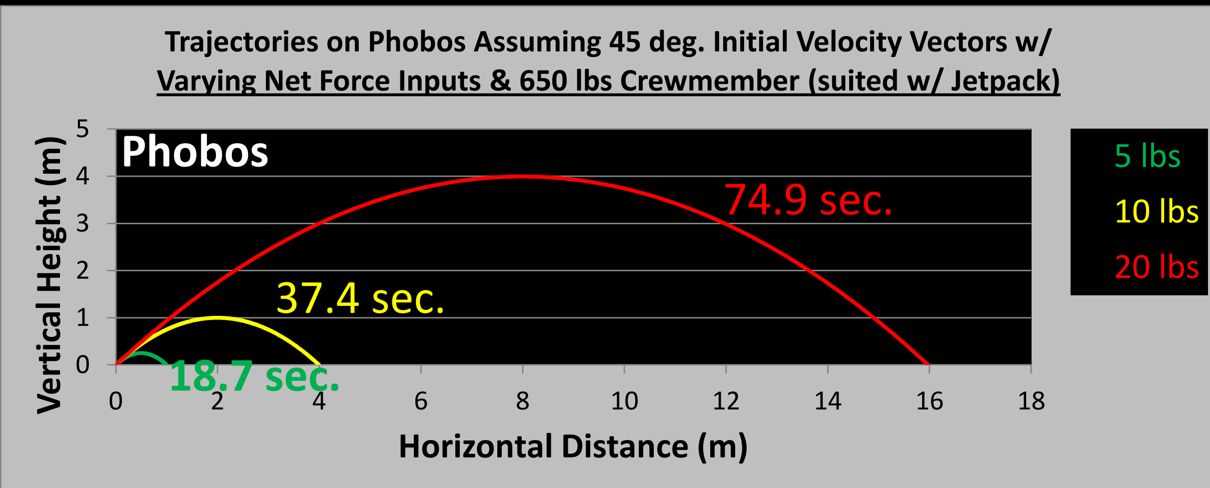


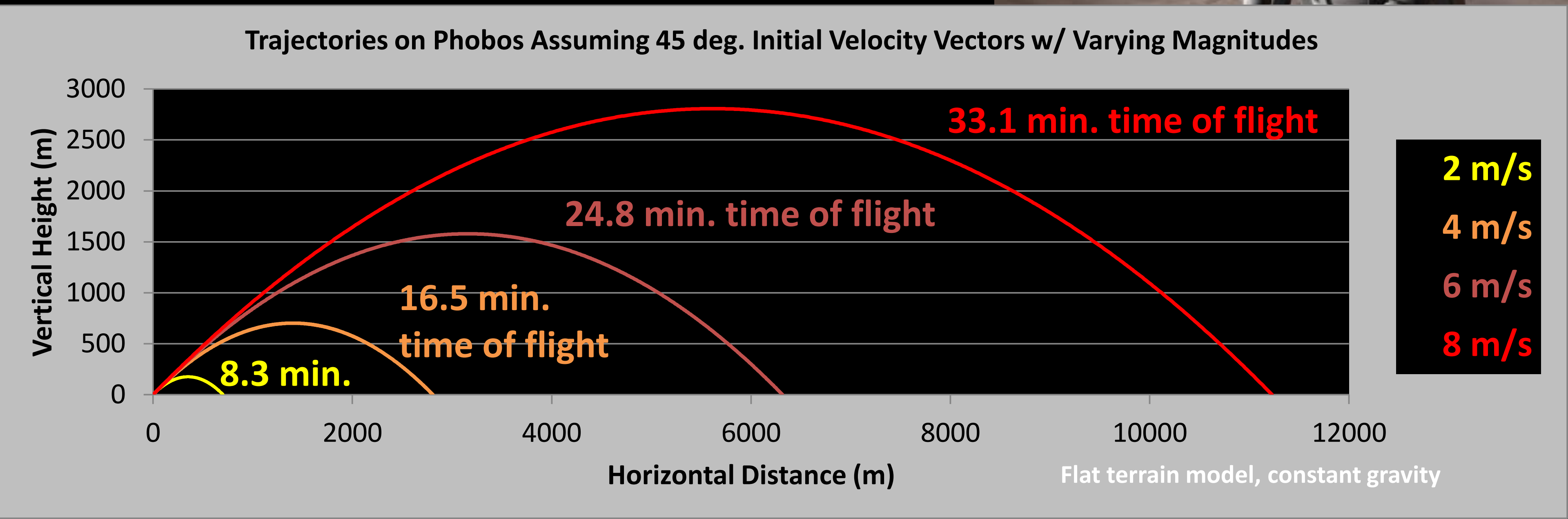
Figure 2 Reference Approach E

	hitial Capability		Emplacement and Operations		Totals*
	$*	FY	$*	FY	
Lunar	98	1991–2004	137	2005–2025	235
Mars	160	1991–2016	76	2017–2025	236
Totals	258		213		471


CREW AND SERVICE MODULE
SERVICE MODULE
CREW MODULE
CREW MODULE ADAPTOR
EUROPEAN SERVICE MODULE
SPACECRAFT ADAPTOR JETTISONED PANELS
SPACECRAFT ADAPTOR

Phobos Trajectories and Times of Flight for Different Force Inputs (Net Force)





Situational Awareness and Decision Making

- Communication and recovery times are longer than any previous experience
- Communications bandwidth is a factor of 100 less than ISS

Mission	Communications Bandwidth	Communications latency time
Deep Space Hab	< 2 Mbps (DSN)	15 to 45 minutes
Apollo / Orion	< 2 Mbps (DSN)	1- 2 seconds
ISS	300–800 Mbps (TDRS)	Real-time

- Power Is Most Critical System On Board Vehicle
  - Every system on the vehicle needs power
  - System will need a high level of availability
  - System will need to operate autonomously for long periods of time