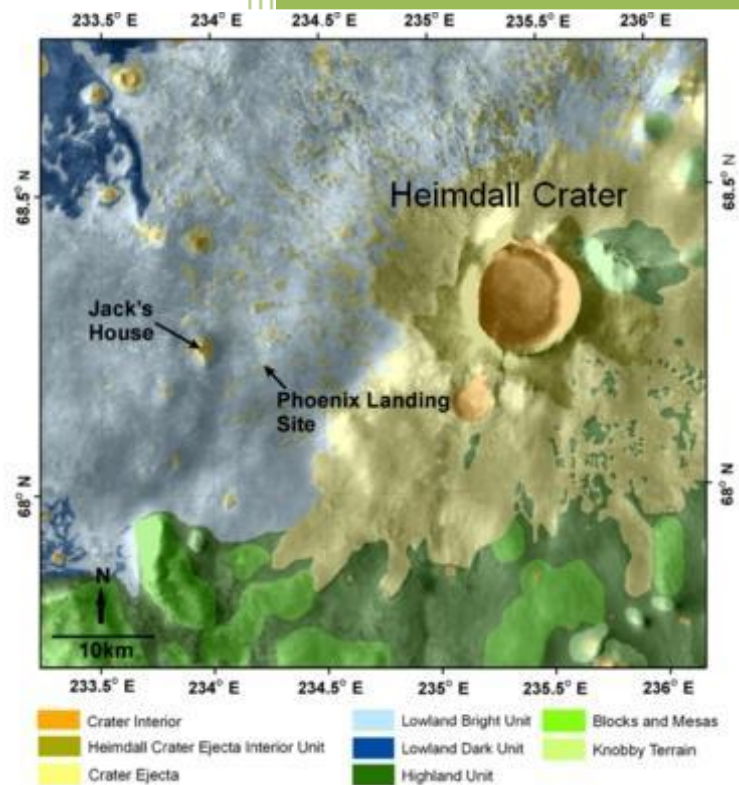


An immersive virtual reality challenge to explore strategies for human spaceflight beyond low-Earth orbit

Expedition Challenge-Based Learning



An immersive virtual reality learning environment prototype.

9/28/2009

Learning Prototype: Expedition challenge-based learning

Introduction: Expedition challenge-based learning involves the use of real-life challenges wherein learners can apply knowledge and problem-solving skills while journeying towards a destination.¹

Effectively designed expedition challenges for learning are those that can successfully engage learners to formulate intuitions about the challenge based on prior knowledge and experiences. Expedition challenges should be designed to help learners uncover important relationships about applying knowledge and present links into several concepts to help the learner differentiate how concepts are used and relate to each other for developing deeper and enduring understanding. Challenges can help the learner to develop:

- Awareness of own thinking
- Effective plans
- Increased awareness of and use of resources
- Improved skills to evaluate the effectiveness of actions
- Skills to take a position when the situation warrants it
- Ability to engage intensely in tasks even when answers or solutions are not immediately apparent
- Increased desire to push the limits of own knowledge and abilities
- New ways of viewing a situation outside the boundaries of standard conventions

Challenge Scenario:²

The nation is facing important decisions on the future of human spaceflight. Will we leave the close proximity of low-Earth orbit, where astronauts have circled since 1972, and explore the solar system, charting a path for the eventual expansion of human civilization into space? If so, how will we ensure that our exploration delivers the greatest benefit to the nation? Can we explore with reasonable assurances of human safety? And, can the nation marshal the resources to embark on the mission?



Given this background, your challenge during this expedition, is to explore strategies for human spaceflight beyond low-Earth orbit by selecting one of the following scenarios and justifying your selection using resources available during the expedition:

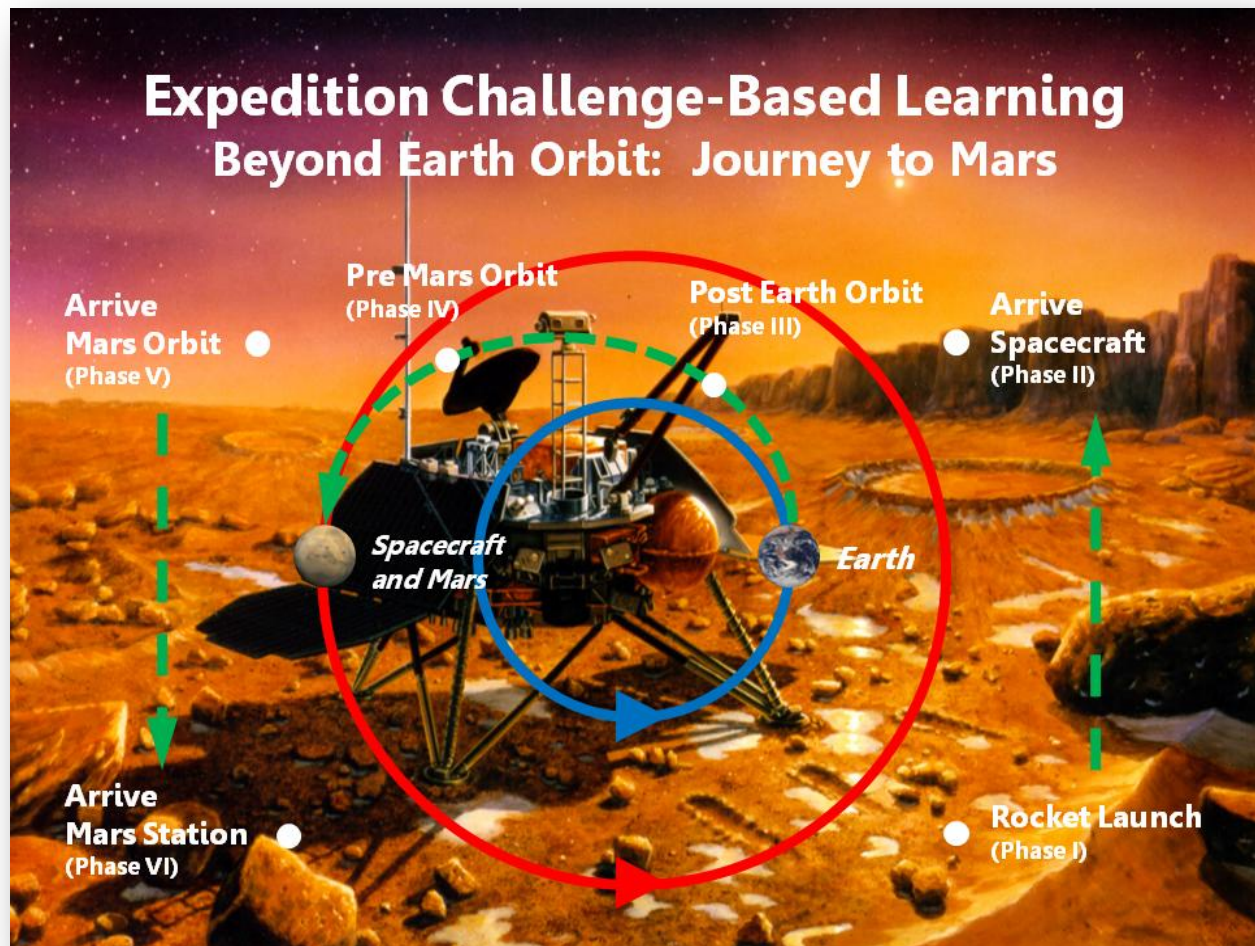
- Mars first, with a Mars landing, perhaps after a brief test of

¹ The underlying design of an expedition challenge is based on situated cognition theory and anchored instruction (see Brown, et. al., 1989; and Bransford, et. al., 1990). Situated cognition theory places importance on engaging learners in authentic contexts to learn and perform involving problem solving to resolve complex or ill-defined problems. Anchored instruction involves the use of goal-based scenarios. Goal-based scenarios involve the use of real-life challenges (anchors) to engage the learner in realistic contexts for constructing and applying knowledge.

² The material used in this challenge comes from a NASA review of U.S. Human Space Flight, published 8 Sep 2009. The simulated challenge takes place within the immersive virtual reality (VR) metaverse of Second Life (<http://secondlife.com>). Note: this prototype expedition challenge can be used by individuals or teams.

equipment and procedures on the Moon

- Moon first, with lunar surface exploration focused on developing the capability to explore Mars
- Flexible path to inner solar system locations, such as lunar orbit, Lagrange points, near-Earth objects and the moons of Mars, followed by exploration of the lunar surface and/or Martian surface.



Challenge Phase I: Pre-mission and challenge introduction

Location: Launch pad facility

Activity: Pre-mission briefing and challenge introduction provided via video and note card.

Participant Action: After pre-mission briefing rides launch rocket to Red Lion

Expected Duration: 3 to 5 minutes

Challenge Phase II: Generate initial ideas about the strategies to the challenge

Location: Orion capsule (once it docks to Red Lion)

Activity: Audio and note card request participant to select one of the three strategy options and provide brief justification for choice.

Participant Action: Selects strategy option from survey instrument and submits brief justification for choice. After survey is completed the participant is asked to enter Red Lion.

Expected Duration: 3 to 5 minutes

Challenge Phase III: View perspectives on challenge from others

Location: Red Lion main section.

Activity: Audio and note card asks participant to view videos on perspectives for each strategy option. Videos are presented at a crew work station. Summary note cards can also be given to participants on each strategy perspective video.

Participant Action: Participant plays each video.

Expected Duration: 5-10 minutes

Challenge Phase IV: Do additional research (explore Red Lion for research info) and review initial ideas the strategies to the challenge

Location: Red Lion main, command, and crew quarters sections

Activity: Audio and note card instruct participant to consider each strategy perspective by researching each perspective using instructional devices located throughout the Red Lion. (Note: the number and location of each instructional device can be determined and visually coded with a map given to the participant). Instructional devices can include video or note cards.

Participant Action: Each instructional device is visited and material is reviewed.

Expected Duration: 5-10 minutes

Challenge Phase V: Make decision on approach to challenge and justify selection.

Location: Red Lion

Activity: Audio and note card are used to ask participant to complete a survey/

Participant Action: Participant is asked to complete a survey to indicate a final decision on a selected strategy with a brief justification.

Expected Duration: 5 to 10 minutes

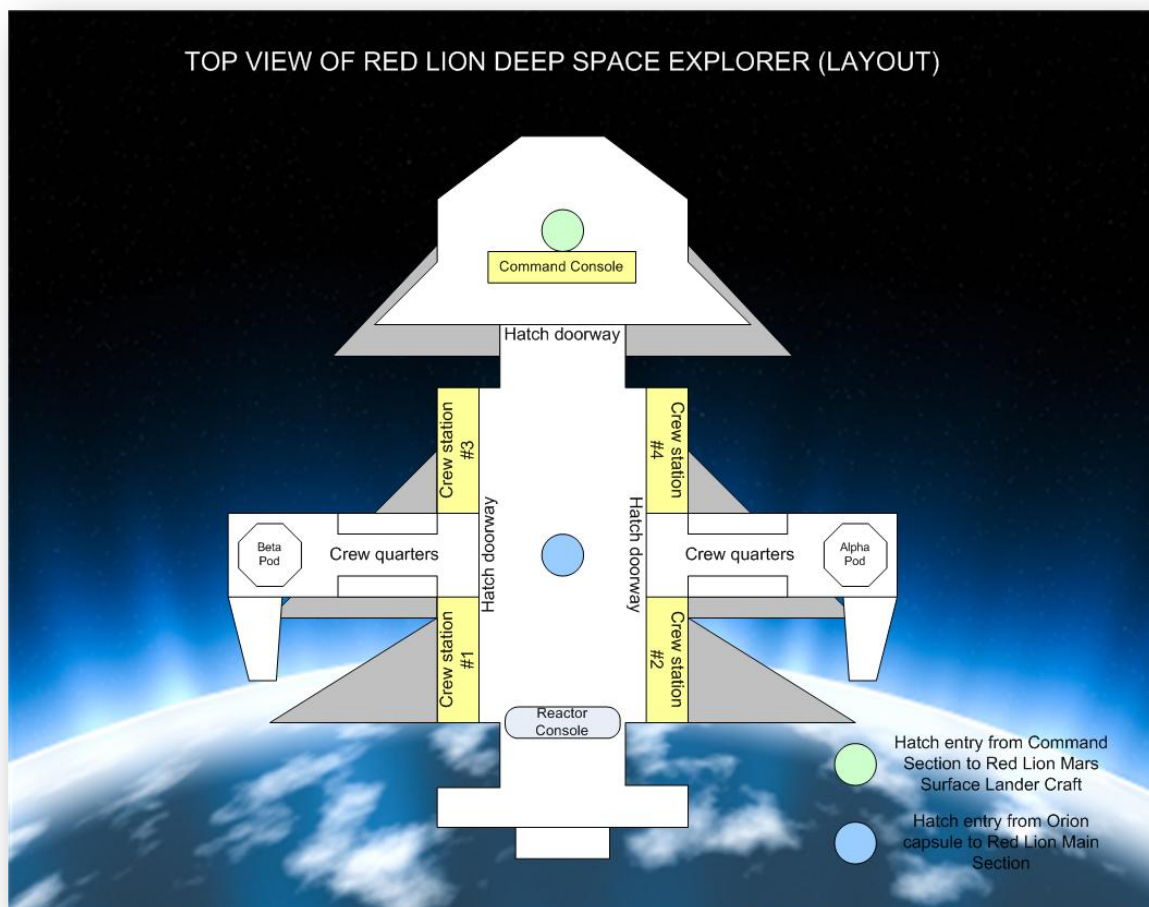
Challenge Phase VI: Obtain feedback about the pros and cons for each strategy.

Location: Mars Station

Activity: Participant is taken to Mars station via the Mars Lander craft and asked (using audio and note card) to go to the mission debrief room. At the Mars mission debrief room a video and note card are used to highlight the pros and cons for each strategy. After the mission debrief, the participant is encouraged to explore the Mars station to learn more about human space exploration and related challenges. The expedition ends when the participant makes a selection from a kiosk located at the Mars station.

Participant Action: Participant watches the mission debrief video, explores the Mars station and then selects to end the expedition by using a kiosk.

Expected Duration: 10 to 20 minutes



EXPLORATION CHALLENGE PHASE SCRIPTS

Challenge Phase I: Pre-mission and challenge introduction

Location: Launch pad facility

Activity: Pre-mission briefing and challenge introduction provided via video and note card.

Participant Action: After pre-mission briefing rides launch rocket to Red Lion

Expected Duration: 3 to 5 minutes

Phase I Script for Video clip/note card

(Note: avatar speaker can be used for video clip)

Avatar Speaker: The nation is facing important decisions on the future of human spaceflight. Will we leave the close proximity of low-Earth orbit, where astronauts have circled since 1972, and explore the solar system, charting a path for the eventual expansion of human civilization into space? If so, how will we ensure that our exploration delivers the greatest benefit to the nation? Can we explore with reasonable assurances of human safety? And, can the nation marshal the resources to embark on the mission? Given this background, your challenge during this expedition, is to explore strategies for human spaceflight beyond low-Earth orbit by selecting one of the following scenarios and justifying your selection using resources available during the expedition:

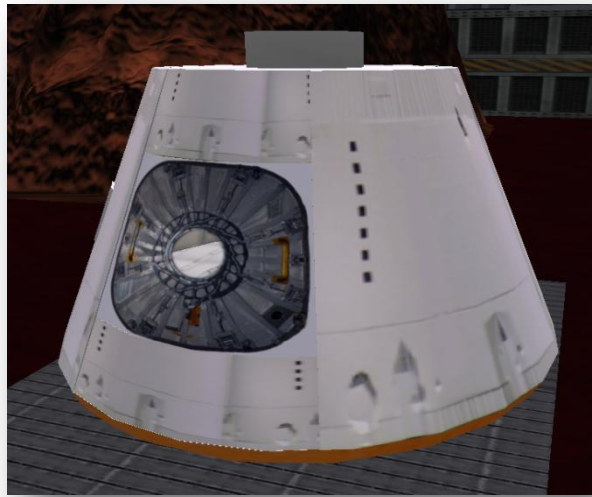
- Mars first, with a Mars landing, perhaps after a brief test of equipment and procedures on the Moon
- Moon first, with lunar surface exploration focused on developing the capability to explore Mars
- Flexible path to inner solar system locations, such as lunar orbit, Lagrange points, near-Earth objects and the moons of Mars, followed by exploration of the lunar surface and/or Martian surface.

There are three main stages to this expedition (involving multiple phases; see challenge phase diagram above):

- 1) Trip to the Red Lion Deep Space Explorer using the Orion rocket on this launch pad.
- 2) Trip to the planet of Mars on the Red Lion Deep Space Explorer.
- 3) Trip to the surface of Mars to visit a futuristic Air Force station.

During each phase you will be asked to provide input to enhance your thinking about which of the three strategies for human spaceflight is best to pursue.

When you're ready enter the Orion capsule by clicking on it with your mouse and selecting to ride the rocket. A launch sequence will start when your avatar is seated in the capsule...enjoy the ride to the Red Lion.



(Screen snapshot of simulated Orion crew capsule)

Challenge Phase II: Generate initial ideas about the strategies to the challenge

Location: Orion capsule (once it docks to Red Lion)

Activity: Audio and note card request participant to select one of the three strategy options and provide brief justification for choice.

Participant Action: Selects strategy option from survey instrument and submits brief justification for choice. After survey is completed the participant is asked to enter Red Lion.

Expected Duration: 3 to 5 minutes

Phase II Script for Video clip/note card

(Note: avatar speaker can be used for video clip)

Avatar Speaker/Note card: The Orion capsule has successfully docked with the Red Lion. Please proceed through the Orion hatch to the main section of the Red Lion to await further instructions. Welcome aboard!

(sensor triggers when avatar enters Red Lion main section)

Avatar Speaker/Note card: While preparations are being made for the journey to Mars on the Red Lion please take time now to indicate your strategy selection and provide a brief justification using the survey provided at crew work station 1 (see map of Red Lion ship). The survey can be accessed by clicking on the survey button located next to the screen display.

(survey appears when button is selected; the survey provides the 3 strategy options along with an input window for writing a brief justification)



(Screen snapshot of simulated Orion docked with Red Lion Deep Space Explorer)

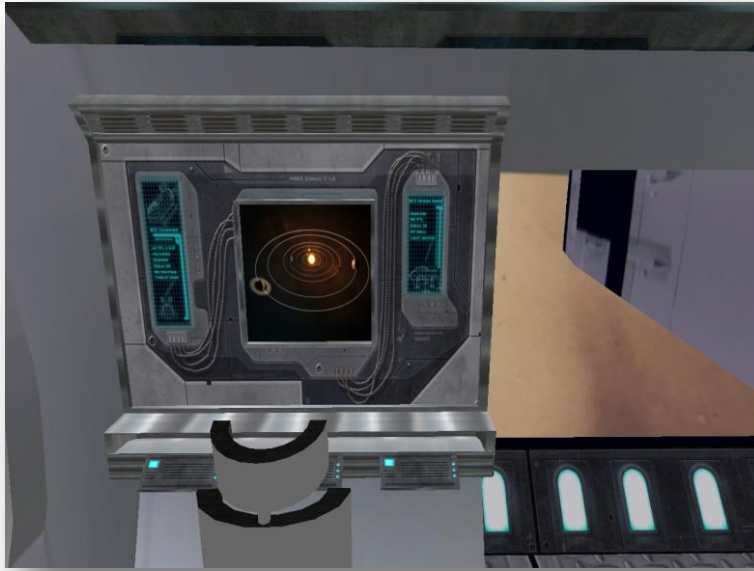
Instructions provided on the survey screen:

Your challenge during this expedition is to explore strategies for human spaceflight beyond low-Earth orbit by selecting one of the following scenarios and justifying your selection using resources during the expedition:

- Mars first, with a Mars landing, perhaps after a brief test of equipment and procedures on the Moon
- Moon first, with lunar surface exploration focused on developing the capability to explore Mars
- Flexible path to inner solar system locations, such as lunar orbit, Lagrange points, near-Earth objects and the moons of Mars, followed by exploration of the lunar surface and/or Martian surface.

Please briefly justify/explain your rationale for the selection.

Avatar Speaker/Note card (after the survey is completed): Please visit the Red Lion Crew Station #2 to view video perspectives for each strategy.



(Screen snapshot of Red Lion Crew Station #1)

Challenge Phase III: View perspectives on challenge from others

Location: Red Lion main section.

Activity: Audio and note card asks participant to view videos on perspectives for each strategy option. Videos are presented at a crew work station. Summary note cards can also be given to participants on each strategy perspective video.

Participant Action: Participant plays each video.

Expected Duration: 5-10 minutes

Avatar Speakers/Note card (at Red Lion Crew Station #2):

Avatar Speaker for Strategy One: Mars is unquestionably the most scientifically interesting destination in the inner solar system, with a history much like Earth's. It possesses resources, which can be used for life support and propellants. If humans are ever to live for long periods on another planetary surface, it is likely to be on Mars. To get there, a heavy-lift launch to low-Earth orbit and beyond will have to be constructed. No one knows the exact mass or dimensions of the largest piece that will be required for future exploration missions such as going to Mars, but it will likely be significantly larger than 25 metric tons in launch mass to low-Earth orbit that is ceiling with current launchers. New heavy-lift launchers would have to be developed to support deep-space missions. Potential approaches to developing heavy-lift vehicles are based on experience with NASA Shuttle, Apollo, and expendable launch vehicles. Expendable launch vehicles have the least lift capability and would require almost twice as many launches when compared to the Apollo-era evolved Ares family of launchers. A shuttle-derived system would also be less capable than the Ares family of launchers and have higher recurring costs. An

adaptation of an Ares launcher involves the use of an Ares to launch the Orion crew capsule along with the Altair surface landing craft (as simulated on this expedition). Crew safety is also a major factor in heavy-lift vehicle system choices. Currently, however, not enough is known about any of the potential launcher-plus-capsule systems to distinguish their levels of safety in a meaningful way. Also, new space systems funding is essentially flat or decreasing through 2014. Thus, significant funding increases would be necessary, to support the development of new heavy-lift vehicles and systems, for this strategy to be implemented in the near future.

Avatar Speaker for Strategy Two: By first exploring the Moon, we could develop the operational skills and technology for landing on, launching from and working on a planetary surface. In the process, we could acquire an understanding of human adaptation to another world that would one day allow us to go to Mars. There are two main strategies for exploring the Moon. Both begin with a few short sorties to various sites to scout the region and validate the lunar landing and ascent systems. In one strategy, the next step would be to build a base. Over many missions, a small colony of habitats would be assembled, and explorers would begin to live there for many months, conducting scientific studies and prospecting for resources that could be used as fuel. In the other strategy, sorties would continue to different sites, spending weeks and then months at each one. More equipment would have to be brought on each trip, but more diverse sites would be explored and in greater detail.

Avatar Speaker for Strategy Three: The flexible path strategy involves visiting multiple sites never visited before to extend our knowledge of how to operate in space while traveling greater and greater distances from Earth. Successive missions would visit:

- Lunar orbit
- The Lagrange points (special points in space that are important sites for scientific observations and the future space transportation infrastructure)
- Near-Earth objects (asteroids that cross the Earth's path)
- Orbit around Mars---most interestingly, humans could rendezvous with a moon of Mars, then coordinate with or control robots on the Martian surface.

The flexible path strategy would help us to learn how to live and work in space, to visit small bodies, and to work with robotic probes on the planetary surface. It would provide the public and other stakeholders with a series of interesting "firsts" to keep them engaged and supportive. Most important, because the path is flexible, it would allow many different options as exploration progresses, including a return to the Moon's surface, or a continuation to the surface of Mars.

Challenge Phase IV: Do additional research (explore Red Lion for research info) and review initial ideas the strategies to the challenge

Location: Red Lion main section

Activity: Audio and note card instruct participant to consider each strategy perspective by researching each perspective using instructional devices located throughout the Red Lion.
(Note: the number and location of each instructional device can be determined and visually

coded with a map given to the participant). Instructional devices can include video or note cards.

Participant Action: Each instructional device is visited and material is reviewed.

Expected Duration: 5-10 minutes

Avatar Speaker/Note card: Importantly, human spaceflight beyond low-Earth orbit is dependent on lowering the cost of space exploration along with gaining increased understanding and capabilities for how to operate in space. Please visit Red Lion Crew Stations 3 and 4 to review additional research on the three strategies related to cost and capabilities necessary for successful space exploration.

Red Lion Crew Station #3:

Avatar Speaker/Note card: The cost of exploration is dominated by the costs of launch to low-Earth orbit and of the in-space systems. The United States needs a way to launch astronauts to low-Earth orbit, but it does not necessarily have to be provided by the government. As we move from the complex, reusable Shuttle back to simpler, smaller capsule, it is an appropriate time to consider turning this transport service over to the commercial sector. This approach is not without technical and programmatic risks, but it creates the possibility of lower operating costs for the system and potentially accelerates the availability of U.S. access to low-Earth orbit by about a year, to 2016.

It seems improbable that significant reductions in launch costs will be realized in the short term until launch rates increase substantially...perhaps through expanded commercial activity in space. How can the nation stimulate such activity? In the 1920s, the federal government awarded a series of guaranteed contracts for carrying airmail, stimulating the growth of the airline industry. Perhaps an architecture for employing a similar policy has the potential to stimulate a vigorous and competitive commercial space industry. Such commercial ventures could include supply of cargo to the International Space Station (ISS), which is already underway, transport of crew to orbit and transport of fuel to orbit. Establishing these commercial opportunities could increase launch volume and potentially lower costs.

Please visit the Red Lion Crew Station #4 to learn about issues surrounding capabilities.

Red Lion Crew Station #4:

Avatar Speaker/Note card: Ares I was designed to a high standard in order to provide astronauts with access to low-Earth orbit at lower risk and a considerably higher level of reliability than is available today. To achieve this, it uses a high-reliability rocket and crew capsule with a launch-escape system. But other potential combinations of high-reliability rockets and capsules with escape systems could also provide that reliability. Other issues to consider include concerns about the International Space Station. The station, which could be used to help stage human space explorations may be vulnerable after Shuttle retirement projected for 2010. The station was designed, assembled and operated with the capabilities of the Space Shuttle in mind. After Shuttle retirement, the station will rely on a combination of new, and as yet unproven, international and commercial vehicles for cargo transport. Now that the station is nearly completed and is staffed by a full crew of six, its future success will depend on how well

it is used. Up to now, the focus has been on assembling the station, and this has come at the expense of using the station. As of now, the expected retirement of the station is 2016. It seems unwise to de-orbit the station after 25 years of assembly and only five years of operational life. Not to extend its operation would significantly impair U.S. ability to develop and lead future international spaceflight partnerships. Further, the station's full potential should be realized as an enhanced test bed for technologies and operational techniques that support human exploration of space, and as a framework that can support expanded international collaboration. Thus, it would be important enhance the extension of the station's life to 2020. Current schedule work on the Ares I and Orion project shows that it can be ready to support the station in 2015, five years after the scheduled Shuttle retirement. This means that Ares I and Orion will not reach the station before its currently planned termination, and the length of the gap in U.S. ability to launch astronauts into space will be no less than seven years.

Many concepts are possible for crew-exploration vehicles, and the U.S. clearly needs a new spacecraft for travel beyond low-Earth orbit. There are higher recurring costs, however, with the Orion. The Orion capsule, which can seat up to six crew members, is considerably larger and more massive than previous capsules (e.g., the Apollo capsule), but there is some indication that a smaller and lighter four-person Orion could reduce operational costs. However, a redesign of this magnitude would likely result in over a year of additional development time and a significant increase in cost, so such a design change should be considered carefully before being implemented.

Please now proceed to the Red Lion Command Station Console.

Challenge Phase V: Make decision on approach to challenge and justify selection.

Location: Red Lion Command Station Console

Activity: Audio and note card are used to ask participant to complete a survey/

Participant Action: Participant is asked to complete a survey to indicate a final decision on a selected strategy with a brief justification.

Expected Duration: 5 to 10 minutes

Avatar Speaker/Note card: While preparations are being made for entry into Mars orbit, please take time now to indicate your final decision on a strategy selection and provide a brief justification using the survey provided at this Command station. The survey can be accessed by clicking on the survey button located next to the screen display.

(survey appears when button is selected; the survey provides the 3 strategy options along with an input window for writing a brief justification)

Instructions provided on the survey screen:

Your challenge during this expedition was to explore strategies for human spaceflight beyond low-Earth orbit by selecting one of the following scenarios and justifying your selection using resources during the

expedition. On the basis of your research and review of the strategies, please indicate your final decision.

- Mars first, with a Mars landing, perhaps after a brief test of equipment and procedures on the Moon
- Moon first, with lunar surface exploration focused on developing the capability to explore Mars
- Flexible path to inner solar system locations, such as lunar orbit, Lagrange points, near-Earth objects and the moons of Mars, followed by exploration of the lunar surface and/or Martian surface.

Please briefly justify/explain your rationale for the selection.

Avatar Speaker/Note card (after the survey is completed): Please enter the Red Lion Mars Lander located below the Command section in preparation for landing on the surface of Mars at the futuristic Air Force station located at Heimdall Crater. Once you arrive at the station a review of the pros and cons for each strategy will be provided to you at the station's mission briefing room.

(sensor indicates when participant arrives at the mission debrief room)



(Screen snapshot of Mars Lander cockpit)

Challenge Phase VI: Obtain feedback about the pros and cons for each strategy.

Location: Mars Station

Activity: Participant is taken to Mars station via the Mars Lander craft and asked (using audio and note card) to go to the mission debrief room. At the Mars mission debrief room a video and note card are used to highlight the pros and cons for each strategy. After the mission debrief, the participant is encouraged to explore the Mars station to learn more about human space exploration and related challenges. The expedition ends when the participant makes a selection from a kiosk located at the Mars station.

Participant Action: Participant watches the mission debrief video, explores the Mars station and then selects to end the expedition by using a kiosk.

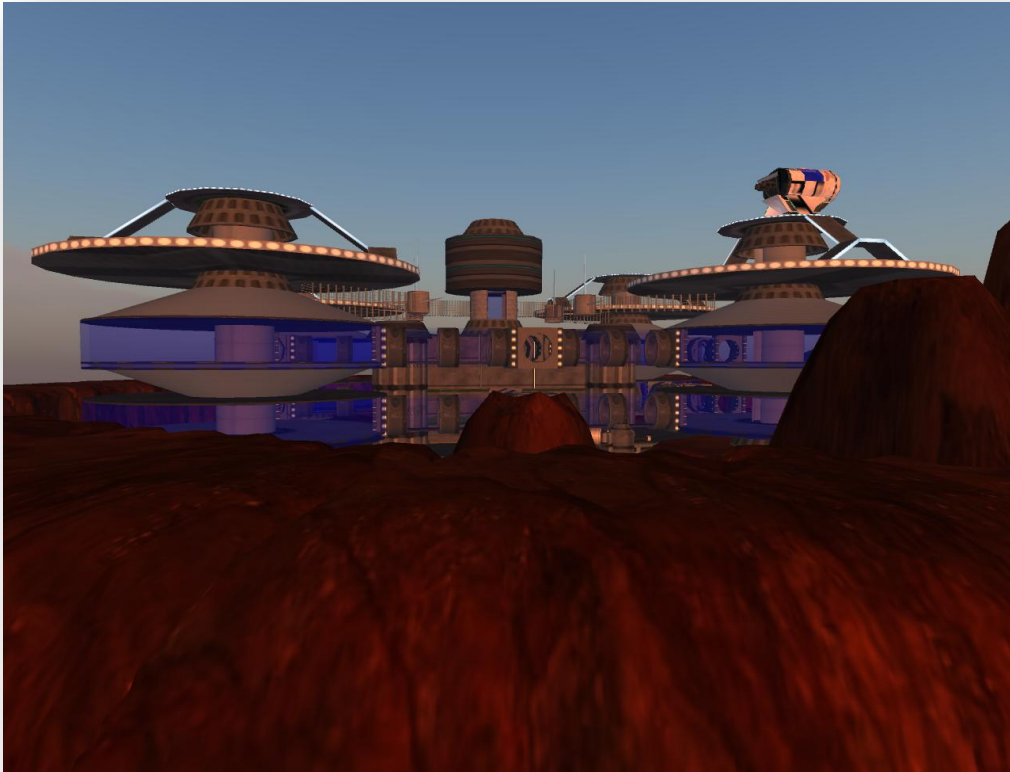
Expected Duration: 10 to 20 minutes

Avatar Speaker/Note card: Studies conducted by NASA finds that Mars is the ultimate destination for human exploration; but it is not the best first destination. Both Moon First and Flexible Path s are viable exploration strategies. It also finds that they are not necessarily mutually exclusive; before traveling to Mars, we might be well served to both extend our presence in space and gain experience working on the lunar surface. Think about your strategy selection. Did your outcome match NASA's conclusion? Were contributing factors such as challenges associated with heavy-lift launch capability to low-Earth orbit, the 7-year human-spaceflight gap to launch astronauts into space, and issues surrounding the lifespan of the International Space Station play a part in your thinking about the best strategy?

Thank you for participating in this expedition. We hope your experience on this simulated journey to Mars was helpful for introducing challenged-based expeditions for learning in immersive virtual reality environments.

(Note: at this point offer a survey for the participant to provide feedback on the expedition).

(Note: once the expedition survey is completed, a conclusion button can appear to remove the expedition hologram).



(Screen snapshot of futuristic Air Force Mars Station)

References

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- NASA, (2009, Sep). Review of U.S. Human Space Flight. Publication of the Review of U.S. Human Space Flight Plans Committee, NASA Summary Report:
http://www.nasa.gov/offices/hsf/related_documents/summary_report.html

Disclaimer:

The opinions and viewpoints expressed in this paper are solely those of the authors and do not reflect official policy or position of the US government or the Department of Defense (DoD), NASA/Jet Propulsion Laboratory, Colorado Technical University, the United States Air Force, or Air University.

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