

There are three short answer questions on this Exam. Not all questions are worth the same number of points so plan to spend your time accordingly. There is one question per page. You are encouraged to use bullets or numbered partial sentences or tables or illustrations to answer these questions.

1. **(35 points)** In class, we discussed two early science policy reports that were highly influential: Vannevar Bush's *Science: The Endless Frontier* report in 1945 and James Killian's *Introduction to Outer Space* from 1958.

- a. Briefly describe 2 of the recommendations from **EACH** report.

One of the recommendations from Bush's report was for civilian scientists to continue doing research for national security. Civilian scientists doing research directly for national security proved essential to winning World War II. Bush advocated that we must keep these efforts in peacetime as to continue to improve our capabilities and not have to play catchup at the outset of the inevitable next conflict. Another recommendation from the report was to invest in higher education for science and engineering. The report identified that the US had a deficit regarding the amount of science and technology graduates. This deficit is not one easily overcome as it is a long pipeline to produce a scientist or engineer with a PhD. Further, the Government should provide education opportunities to anyone as to help attract candidates from all of society as opposed to just those who can afford an advanced education.

The first recommendation in Killian's report was that we explore space for the sake of exploring. It was identified that humans have a seemingly unending desire to explore. As a larger percentage of Earth is considered explored, space is the next logical place for exploration. Being that we are currently debating which place in space should be explored next, and not if we should explore, this desire does not appear to have an end. Killian's report also recommended research for national security by asserting there is a "defense objective for the development of space technology." The recommendation was that space may become militarized and we must be prepared for this outcome. As the Cold War's temperature was rising, the need to be prepared on this front was clear.

- b. Discuss how elements of these two reports may have influenced the *National Aeronautics and Space Act of 1958* which created NASA.

One does not have to look far to see the influence of the two reports on the National Aeronautics and Space Act of 1958. The very first line of the act highlights the goals of conducting research, "To provide for research into problems of flight within and outside the Earth's atmosphere, and for other purposes." Both reports strongly advocated for conducting research both practical and pure. The act also highlights how the "expansion of human knowledge" regarding space is a driving reason for its creation. Killian's report covered this well, highlighting how our quest for outer space leads to our enhanced "knowledge and understanding of the Earth, the solar system and the universe."

The influence of Bush's report can be seen in the act as it calls for advances to be made available to the national defense sector. Bush advocated for civilian research on behalf of national security and this act codifies this relationship by directing that information which may have a military application to be shared with

the military. These are only two examples of how these reports influenced the act, but there are many more.

- c. In what ways are these reports still relevant for issues facing the U.S. space program today?

While it is debatable as to the relevance of these reports to today, ample evidence suggests they are. Both reports highlighted the very real need to continue investment into scientific research for the benefit of humanity. Bush's report specifically highlighted research in medicine. The report highlighted how advances in medicine drastically reduced our death rate not only from war but also from disease. Today, with the surge of anti-vaccination proponents, our investment into medical research couldn't be more important. This research can also include how to best communicate it to the public, as to calm fears due to a lack of sufficient understanding of the science.

Regarding fears of science, investing in STEM education is just as relevant today as it was when these reports were written. Many problems facing us today were identified due to scientific research. A lack of understanding of basic scientific principles leads to confusion and disbelief of these very real issues. Climate change denial and the anti-vaccination movement are likely two of the most readily identifiable consequences of a poor understanding of basic scientific principles. Investing in STEM education, especially for people who will never be scientists, is imperative for the progress of our nation.

2. (35 points) Apollo and Artemis – 50 years apart.

- a. Describe the *major motivations for the creation of Apollo AND today's Artemis program*. How are they similar or different?

Perhaps the most obvious reason for pursuing astronautics research during the 1960's and ultimately landing humans on the Moon was the threat of the Soviet Union. After the launch of Sputnik and success of Yuri Gagarin's flight, there was fear that the U.S. was falling behind the Soviet Union. Sending humans to the Moon through the Apollo program would place the U.S. back on top in the "space race," which in the context of the Cold War was seen as extremely important. John F. Kennedy laid out another justification for the Apollo program in his famous speech at Rice University in 1962. A mission to the Moon represents a challenge which humans are compelled to pursue. Although one may wonder if this was Kennedy's true justification for the massive investment in NASA and the Apollo mission, the desire to explore is still commonly cited as a rationale for human space exploration.

The stated goals and justifications for the Artemis Program are much more focused on scientific exploration and economic benefits. Artemis missions aim to explore regions such as the poles, which may hold water ice in permanently shadowed craters, and the farside, which contains many geologically interesting sites, which may help us understand the formation of both the Moon and the Earth. Beyond scientific endeavors, some hope that the Artemis program will facilitate a space economy, where private companies are able to take advantage of resources on the Moon.

Although Apollo may have had more significant geopolitical implications, both Apollo and Artemis aim to increase our understanding of the Solar system through human exploration. One major difference, however, between the Apollo and Artemis programs is the desire to sustain human presence in outer space and

expand beyond the Moon. While the Apollo program was shuttered after only a handful of human missions to the lunar surface, Artemis hopes to sustain a more permanent presence and facilitate human exploration further into to the Solar System.

- b. What were *lessons learned from Apollo that might be applied to new missions to the Moon with Artemis?*

Perhaps the most important lesson that can be learned from Apollo is how to create a sustainable human exploration program. While Apollo achieved the goal set by John F. Kennedy to put a man on the Moon by the end of the decade, 50 years later humans have not returned to the Moon. One lesson that is clear is that in order to ensure a long-lasting human presence on the Moon, the entire Artemis program must be designed with sustainability in mind. Rather than racing to be first, Artemis must focus on longer-term goals.

- c. **Science on the Moon**

- i. Discuss what you feel was the *most important scientific discovery made by Apollo.*

In my opinion the most important discovery made by the Apollo missions was the chemical analysis of lunar material, which showed that the Moon and the Earth share common material. This led to the hypothesis that early in the history of the Solar system the Earth was involved in a large collision, the remnants of which eventually coalesced to form the Moon. The similarity of the materials that compose the Earth's crust and the lunar surface was a revelatory discovery at the time.

- ii. What do think is the *most important science goal for Artemis?*

I believe the most important science goal for Artemis is the exploration of the lunar polar volatiles. These volatiles, including water ice, exist in "cold traps" in permanently shadowed craters near the poles. Studies can provide insight to the distribution and history of volatiles throughout the Solar System. Additionally, these volatiles could potentially be used as resources for long-term human missions to the Moon or further targets such as Mars.

3. **(30 pts). NASA's Budget**

- a. In class, we said that NASA's funding drives space policy. So, given NASA's budget, describe what the priority areas are for NASA and the funding devoted to these areas.

NASA's total budget for FY22 is about \$24 billion. The largest portion of NASA's budget, about 30%, is devoted to science. A sizable part of the budget is also given to deep space exploration systems (28%) as well as space operations (17%), including LEO and the ISS. After space operations, the next largest draw on the budget is safety, security, and mission services which is 13% of the budget. This includes funding for the NASA centers across the country, safety and oversight of missions, as well as cyber security. A small portion of the budget is also allocated to aeronautics, STEM engagement, as well as construction and environmental restoration.

Clearly, NASA is devoted increasing scientific understanding of the universe whether that is through missions to other planets such as the Mars rovers or science

instruments such as JWST. Although there is discussion of transitioning the ISS the private sector, NASA still devotes lots of money to sending astronauts to the ISS via the Russian Soyuz. Finally, the funding appropriated to deep space exploration systems indicates a desire to move human spaceflight beyond low earth orbit.

- b. Do you see any inconsistencies from the rhetoric about goals for the nation's space program espoused by the Biden White House and the appropriated funding? If so, what are they?

A major message from the White House is the desire to send manned missions to both the Moon and Mars in the near future. Although over a quarter of NASA's budget is devoted to deep space exploration systems, this is not nearly enough to develop and build the technology needed for these missions. A conservative estimate of the cost of a mission to Mars is \$500 billion dollars. If the goal is to get to Mars by 2033, we would need to spend over \$40 billion dollars per year, which is far greater than the total NASA budget today. Even with increased funding for the Artemis program, this will be nowhere near \$30 billion per year. NASA's budget would need to be increased by over \$15 billion, and this assumes that the entire budget would go to a Mars mission so in reality the increase would need to be much more. If the White House was serious about making these missions reality, they should be advocating for an even greater increase in NASA's overall budget.