

We captured all the questions submitted to the PSV 2050 meeting, and provide answers below to the best of our ability. The listing shows the number of upvotes and the date and time of the question. Some questions required more time and space than we really have available but can likely be augmented through a search of web-based resources. We apologize that we did not have time to address all the questions during the meeting. We hope that the answers below are sufficient.

#	Question	Upvotes	Created At	Moderator Answer
1	What would LUNAR teach us about exoplanets beyond what we can learn from JWST	14	February 27, 6:17am	A lot. e.g., direct imaging. I encourage you to view the presentations from the PSV2050 meeting on LUNAR: you can find all the oral presentations at <a href="https://livestream.com/viewnow/vision2050">https://livestream.com/viewnow/vision2050</a>
2	What types of biological and chemical sensors will be needed that will make this vision a success	13	February 27, 8:05am	The most challenging sensors are likely to be those that can unambiguously determine whether something is living or not. This can be challenging for the lifeforms we know on Earth, but we really don't know what we are likely to find in the subsurface of Mars or in a deep ocean on Europa, for example. Continued remote/in situ observations of such planetary objects are essential in order to improve on these types of sensors.
3	Exciting to hear about all this planned exploration but are there any plans for missions to either Neptune or Jupiter	5	February 27, 8:09am	We currently have a spacecraft (Juno) at Jupiter and a study of possible ice giant missions was presented on day 2 of the meeting (see the video on the meeting page)
4	Do you think there are new elements on these exoplanets	5	February 27, 8:09am	Probably not. We have likely found all the stable elements, as well as generated many that are only stable for very short times. There may be more very heavy elements but these are likely to be largely unstable and only found in facilities designed to generate them.
5	Exciting to hear about all this planned exploration but are there any plans for missions to either Neptune or Uranus	15	February 27, 8:10am	Most certainly. A mission to either Neptune or Uranus is the third highest priority flagship mission in the current decadal survey after the first Mars sample return mission and the Europa Clipper. There was a presentation on Tuesday on a recent mission study for the Ice Giant planets. You can see this presentation at <a href="https://livestream.com/viewnow/vision2050">https://livestream.com/viewnow/vision2050</a>
6	What is the current news on the OSIRIS REX probe	3	February 27, 8:58am	It is operating nominally and is on its way to Bennu by way of an Earth flyby later this year.
7	What about Venus	19	February 27, 9:14am	We had a presentation on Tuesday morning (the next day) on Venus, and many speakers noted the importance of Venus, especially with respect to terrestrial planets in the habitable zones of distant stellar systems (i.e., exo-Venus'). Further study of Venus, by missions and earth-based observations, are essential for a comprehensive study of our solar system.
8	Seriously why nobody mention the benefit of studying Venus	14	February 27, 9:33am	We had a presentation on Tuesday morning (the next day) on Venus, and many speakers noted the importance of Venus, especially with respect to terrestrial planets in the habitable zones of distant stellar systems (i.e., exo-Venus'). Further study of Venus, by missions and earth-based observations, are essential for a comprehensive study of our solar system.
9	Shouldn't the number of terrestrial bodies in the solar system now include Ceres	3	February 27, 10:55am	My understanding of terrestrial objects is that they are composed mostly of silicate and metal components (most objects interior to Jupiter), as opposed to ices and gases (most bodies in the outer solar system). Both Vesta and Ceres and most of the asteroids would qualify as terrestrial objects by this definition.
10	What is the likelihood that organic signatures on asteroid/moon surfaces could survive and be measured given their exposure to the radiation environment	3	February 27, 1:13pm	Excellent question. It does seem that some microbes can survive (but not necessarily thrive) in the vacuum and radiation environment of space. And there remains the possibility that life started elsewhere in the solar system (e.g., Mars) and was transported to Earth.

11	There have been many discoveries of planets in the universe in the last decade What are the next steps in the area	6	February 28, 6:12am	Continue to search, looking for smaller planets and moons and planets further from their host star; characterize the planets surface and atmospheric composition and seek signs of habitability and maybe even life.
12	The deduction of Planet Nine leaves us with more questions Have we really found everything our solar system has to offer	8	February 28, 6:14am	The solar system provides us with exciting new discoveries all the time. And the closer we look at the other bodies in our solar system, the more surprises we find. Pluto is really only the most recent example of being blown away by all the things we did not expect.
13	Given all possible missions should we push NASA to diversify in terms of risk eg riskysmall sats flagships If so how	5	February 28, 8:11am	NASA is already moving to use capable small sats for appropriate science and societal work. The lower price tag does allow more risk tolerance. Encouraging more of these mostly involves coming up with really compelling innovative mission concepts.
14	If NASA had a budget 1020 times larger than it does now would there be the resources and personnel available to fulfill the mission designs imagined here	6	February 28, 8:36am	If it happened tomorrow, we would have serious challenges getting programs up to speed to spend that sort of money on the annual timescale of NASA budgets. However, we have plenty of exciting things to do and no shortage of idea and interested people.
15	Any chance to detect artificial satellitespace stations in an exoplanet	4	February 28, 8:47am	At the moment, we do not have the ability to detect such objects. We are hoping to detect Moons of exoplanets but even these are exceedingly difficult. Something as small as an artificial space station is well beyond current capability or any that is conceived for the near future.
16	How do modeling studies fit into the 2050 vision These are very cheap but highly useful because they fill in data gaps	5	February 28, 10:38am	Modeling studies fit in a variety of places from technology development to research and analysis. They are important as will be noted in the report.
17	do you think it is possible to create a space network based on laser sendingreceiving information thanks	6	February 28, 10:48am	Certainly. Laser communication has been demonstrated and presents major increases in data rates needed for future missions, particularly for streaming high definition video. It is coming.
18	Are we ever going to build a giant spacecraft if something bad happens to Earth and we would have to leave it	11	February 28, 10:53am	We hope someday to have the capability to transport large groups of people to other destinations in the solar system and potentially beyond. However, such an increase in this capability seems highly unlikely by 2050.
19	Can we put disused astronomy assets to work in the search for NEAs Or automate infrequentlyused telescopes for amateur use	5	February 28, 11:02am	Most certainly. Amateurs are already using their own and other telescopes to monitor the giant planets and search for NEOs, and play important roles that complement the work of the professionals. There has been much discussion of this, as smaller telescopes are less used.
20	What is the advantage of sending more humans to the moon rather than sending robots	9	February 28, 11:45am	Humans can do things much quicker than robots - ask Steve Squyres about his experience with the MER rovers. And humans have a wealth of knowledge and experience to make decisions quickly and see things that a robot might not identify as interesting. The Apollo astronauts did notice things and investigate deposits that a robot may well have missed, either working autonomously or commanded remotely. For destinations far from earth, the time delay demands a lot more autonomy from robots, which limits what they can do relative to a human.
21	Are there legal treaty obligations for nations eg planetary protection with respect to human exploration of other worlds	8	February 28, 1:48pm	Yes, there are UN treaties that have been agreed to by many nations which establish ground rules for activities on other solar system bodies, including issues of planetary protection. Enforcing such treaties as resource exploitation and tourism accelerates may be challenging.

22	<p>Hello Question 1 What is the latest news on using nuclear fusion propulsion and what do you think about it</p> <p>Question 2 What do you think about the Trappist 1 discovery and will this discovery motivate scientists and engineers in developing faster propulsion and more Question 3 Do you think the calendars need to be rewritten and remove BCE Before Common Era and CE Common Era</p> <p>Question 4 Is there research in to developing artificial gravity since being in a zero gravity environment for a long time can cause health problems</p> <p>Question 5 How will you protect the crew or passengers from radiation</p>	4	February 28, 2:15pm	<p>1. I don't know of any serious program working on nuclear fusion propulsion. There are programs, notably at Marshall, looking at nuclear propulsion using fission of uranium.</p> <p>2. The Trappist 1 discovery is very exciting and points to future discovery of many more terrestrial planets in the habitable zone of distant stars. Certainly there is great interest in finding ways to send robotic spacecraft to other star systems, and a number of different options are currently being studied.</p> <p>3. I have no real opinion on this question, but suspect such a change would be hard to implement - like changing from imperial to metric units in the U.S.</p> <p>4. There are a number of active astronaut programs to mitigate the effects of zero gravity, including use of treadmills on ISS and various drug therapies. Also, there have been a number of spacecraft designs that use rotating components (see any one of many sci-fi movies) to generate artificial gravity. This is a really tough issue and we have been working on it for many years. We have a ways to go.</p> <p>5. We already have procedures for astronauts to shelter in place on ISS during solar storms in areas where there is greater protection provided by the ISS infrastructure. Solar particles can be shielded against but cosmic particles can have significantly higher energies that will penetrate almost any shielding, and may result in cascades of secondary particles due to scattering. Mitigation of space radiation is a major issue and is a topic of considerable study.</p>
23	<p>Can we expect to see a renewed focus on Venus robotic missions now that GRC has developed hightemperaturecompatible chipsets Might this be added to the 2022 VISE mission or is that design frozen already</p>	16	March 1, 6:31am	<p>There were several Venus mission proposals in the most recent Discovery mission call, including 2 that made it to Phase A study, one orbiter and one probe/lander. Neither included the high temperature/pressure electronics you are referring to. It seems likely that there will be a couple of New Frontiers missions proposed shortly, but it is unlikely that they will include these technologies either as the instruments that would use these technologies are mostly insufficiently developed. We can hope that these new technologies will progress to a point where we see a significant technology-enabled increase in the likely science return from landed missions, but it may still take a bit of time for the technologies to be sufficiently robust.</p>
24	<p>Is there any programlevel interest in artificial gravity capable spacecraft</p> <p>What risksrewards would this bring to longduration missions like Mars and perhaps even the Jovian moons</p>	9	March 1, 6:36am	<p>We would love to find a way to generate artificial gravity. At present the only viable way I know of is to use a rotating spacecraft as you see in many sci-fi movies. Such artificial gravity can at least partially mitigate against bone and muscle loss during long durations in space.</p>
25	<p>What do the models suggest caused the massive loss of Marss atmosphere</p> <p>Is it likely that 3 billion years ago Mars had a molten core that generated a planetary magnetic field but this solidified over time</p>	7	March 1, 7:16am	<p>There are numerous published papers on the issues that you raise, and many different opinions. I really cannot do justice to this topic in this Q&amp;A, but can point you to appropriate folks if you contact me. I would also encourage you to use the web to find some of the excellent articles on these topics.</p>
26	<p>As technology has improved is it time to return to Venus with a robust lander that can conduct measurements on its surface</p>	15	March 1, 7:23am	<p>There have been major advances in the technologies needed for sustained operation of landers on the surface of Venus performing a variety of tasks, including measurements of rock composition, Venus weather, seismology and others. However, there are still challenges and we are looking forward to demonstration of operational instruments at Venus surface conditions. We are making great progress.</p>
27	<p>What should early career scientists and students be doing to support and enable the next 30 years of space exploration</p>	22	March 1, 7:32am	<p>There are numerous ways for early career scientists and students to support and enable sustained exploration, from congressional visits to outreach and engagement to participation in research and development activities to mission roles and participation on advisory and planning committees. There are numerous opportunities out there if you look for them and are prepared to put in some effort. Mostly, these opportunities won't come looking for you.</p>

28	Is there the possibility of wholly or partially crowd funded missions in the near future Allowing all humans from all walks of life the chance to invest in and support this exploration and research	2	March 1, 8:23am	There are already a number of examples of attempts in the commercial sector to crowd-fund missions, both robotic and human. So, clearly the answer is yes.
29	Without the capabilities to monitor and enforce law in space shouldnt we be concerned that corporations who exclusively follow their stakeholders interests by definition may grow out of hand	12	March 1, 8:51am	You raise an excellent point. This remains a very challenging issue as we look to increased activity for commercial and international ventures in outer space. Space law does provide some guidance but resource and property ownership and policing remain problematic. NASA continues to work closely with its commercial partnerships in order to help build a strong American space economy.
30	How would you involve private sector in giantouter planetKBO exploration	8	March 1, 8:59am	This is rather tricky as the hook for the commercial sector is more often resource exploitation, tourism, etc. It is hard to see a sufficient market for robotic spacecraft to the outer solar system beyond what we currently have. Recall also that the major contractors to NASA are private sector companies and do much of the technological and spacecraft work.
31	How can citizens contribute to science whether through actions or donations	13	March 1, 9:10am	Citizens have a huge role to play in advancing science. From encouraging young people to view careers in science and technology positively, to speaking with congressional representatives of the importance of science for our nation and for civilization, to directly participatimng in scientific endeavors through citizen science activities, to providing support of all kinds, financial and otherwise, and for worthy scientific endeavors.
32	Thanks Great Panels	1	March 1, 9:18am	Thank you.
33	By 2050 the population on Earth will reach near 10 billion and nearly 400 million in the US Given increasing stresses on resources environment and societies and ultimately fiscal availability as a result of these population related issues how has or does this community foresee its ability to acquire sufficient funding	7	March 1, 9:26am	Civilization thrives when it has challenges and sees tangible outcomes for such things as exploration. Such exploration is also a key driver for new technologies that feed back into quality of life issues on Earth. While we may not always communicate the less tangible benefits of the space program, they are definitely real. We do need to improve our outreach activities to build sustainability into our programs.
34	Throughout the workshop many people have mentioned the need to increase the diversity of scientists in the field Will this be included in the PSV 2050 report	30	March 1, 9:31am	The report will include discussion of all important aspects of workforce, including the importance of building and maintaining a diverse workforce in terms of expertise, ethnicity, nationality, gender, etc.
35	Which space propulsion technologies show the usefulness for human space exploration and when will they be used eg fusion propulsion	3	March 1, 10:37am	We are continuously pushing the limits for new propulsion technologies seeking the most effective way to move spacecraft long distances quickly (especially for human missions where you want to minimize travel times for reasons of astronaut health). Chemical propellant such as used in the space shuttle and most robotic missions is still the best demonstrated propulsion system. However Solar Electric Propulsion, Nuclear Propulsion (fission) and other technologies are actively being pursued and we have had in-space demonstration (e.g., the Dawn spacecraft) for some of these systems. I am unaware of any current development of fusion technologies for propulsion; recall that we have been unable on Earth to demonstrate sustained fusion for power systems.
36	What methods and technologies will be used to protect the space travellers and technology on their journey	3	March 1, 10:43am	For many years we have been looking at strategies for protection of astronauts in long duration space travel, including studying ways to mitigate bone and muscle loss, immune system issues, eye problems, and radiation issues. We do have a variety of strategies that involve exercise regimens, spacecraft design, drug therapies, etc. to at least partially address these issues, but more work is underway to both understand the human response to the rigors of space travel and mitigate effects as best possible.

37	What is the fastest space propulsion currently and being researched When will these be used	2	March 1, 10:46am	Chemical propulsion is still the most used and effective way to get spacecraft around the solar system, though new technologies are increasingly being used for robotic spacecraft. Nuclear propulsion and other more advanced technologies are being investigated and we will certainly see a number of these being used before 2050.
38	What new technologies are being researched that will be able to repair spacecrafts at great distances	3	March 1, 10:52am	Robotic in-space repair has been a topic of study and testing for quite a while, both from the defense and civil space sides. A simple google search found numerous articles on actual programs. Of course, we have demonstrated astronaut repair on station and notably on Hubble.
39	What new communication and power source technologies will be used	2	March 1, 10:55am	We are used to seeing high definition video for everything these days, which requires high data transfer rates. This is particularly challenging from places in the outer solar system and requires more than the radio frequency communications systems we have routinely used. Laser communications have been demonstrated from as far away as the Moon, and are an area of active study for future missions. Stay tuned. In terms of power systems, solar power has been a mainstay of robotic exploration out to destinations as far as Jupiter, but power generation is limited by solar panel size and efficiency as well as distance from the sun. We continue to improve solar power capability. For higher power needs or destinations where solar energy is too weak (e.g., beyond Jupiter) or not available (e.g., the dark side of Mercury), we have used radioisotope power systems (e.g., the GPHS-RTG system on New Horizons or the MMRTG on MSL), where the fission of <sup>238</sup> Pu generates heat that is transformed into electrical energy. We have increased efficiencies significantly over the years, but there is a functional limit to how much electrical energy can be generated this way. For higher energy systems, space reactors seem a logical next step, especially for support of sustained human exploration on the Moon or Mars, but the various programs over many years have generally been cancelled due to lack of funding.
40	How would you design a spacecraft for deep space exploration	2	March 1, 10:57am	The requirements for deep space human and robotic missions are very different. Assuming that we are talking about robotic missions, the approach right now is to look at ways to accelerate very small spacecraft to very high velocities so that transit times to distant stars are minimized. There are a number of approaches currently under study.
41	Outer planets missions are some of the longest term projects that NASA does What processes should be in place to see that they happen more frequently	16	March 1, 11:02am	Planetary science at NASA has a broad portfolio with different mission classes across multiple targets in the solar system, research and analysis activities, technology development, ground-based facilities, etc., with an annual budget of around \$1.5 billion. The main thing that we need to get more of is money if we want to fly more missions to the outer solar system. Our ambitions for future missions are high, and the costs are increasing as we try to answer more challenging questions, such as seeking evidence of living organisms in the outer solar system.
42	Thoughts on development of technologies currently outside of small cube etc sats For example Earth reentry drilling	3	March 1, 11:03am	It is not clear what Earth reentry drilling means in this context, sorry. Certainly NASA is looking beyond the confines of the cubesat architecture for small sat utilization with a variety of applications, including planetary science.
43	What do you think about the Trappist 1 discovery and will this discovery motivate scientists and engineers in developing faster methods of propulsion and more	2	March 1, 11:08am	The Trappist 1 discovery is very exciting and points to future discovery of many more terrestrial planets in the habitable zone of distant stars. Certainly there is great interest in finding ways to send robotic spacecraft to other star systems, and a number of different options are currently being studied.

44	TRL has different meaning depending you talk to Any way to clarify this important metric	16	March 1, 11:22am	I suggest you take a look at: <a href="https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html">https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html</a> for a reasonable description of the various TRL levels
45	What is the role of modeling in space exploration Models are needed to plan analyze and understand missions	3	March 1, 11:53am	Modeling activities are a critical component of all NASA's activities, from spacecraft and mission design to data utilization and application.
46	Will the Orion Spacecraft get upgraded with newer technologies	2	March 1, 12:48pm	As long as the Orion program is sustained, it is certain that technological advances will be incorporated, as they become available and are tested.
47	Adopt a region is an awesome idea	4	March 1, 1:05pm	Any way to get citizens more engaged in the space program is a great thing, and yes, it is a neat idea
48	Is there going to be an organic sampler on the Mission Lander to Europa	3	March 1, 1:54pm	I believe that the lander mission is still in pre-formulation phase, and so there is no definitive selection yet. Nonetheless, JPL does have a notional architecture and a detailed report has been prepared. That report discusses drilling down into the ice and analyzing for organic and inorganic contents. There will be a workshop on this at the LPSC meeting on March 19, 2017.
49	Is there an initiative to further study our closest Star The Sun Namely to enhance the currently capability to provide SDO with some new satellites	3	March 1, 2:26pm	This topic is clearly an important one both scientifically and societally. However, it is under the purview of Heliophysics rather than Planetary Sciences, and I would refer you to the planning documents for the Heliophysics Division in SMD at NASA headquarters.
50	What is the plan to find new power sources to reduce dependency on Plutonium238 to fuel future deep space missions	9	March 1, 7:49pm	The Europeans are looking at Americium as an alternative radioisotope, as they have lots of it, but that only solves the supply problem and plutonium is still the better isotope for RPS systems. Current work at JPL and other places is looking at better conversion technologies to improve RPS efficiencies and there is work looking at alternative architectures, like the ASRG. However all RPS systems have relatively low power outputs and are relatively heavy. There has been work in the past on reactor systems that provide much greater power output, but those programs were terminated for funding reasons. If we are to sustain humans on the Moon or Mars, we will need such higher power systems, as RPS and Solar will not be sufficient.
51	Spacecraft and rovers controlled by Artificial IntelligenceAI will perform better with a higher success rate Any comment	9	March 1, 9:36pm	Yes, and autonomy is hugely enabling for distant places where time lags make semi-autonomous control slow and inefficient.
52	Shouldnt the PSV 2050 report discuss how missions impact on STEM education science and technology advancement and society	9	March 1, 9:57pm	Yes, and it will
53	What is PSDs plan to promote the international collaboration and cooperation in funding science and technology	9	March 1, 10:09pm	PSD is working hard on international collaboration, particularly with participation of US scientists on foreign missions, US instruments on foreign missions and vice versa.
54	How the vision 2050 is going to reach every students who has a dream about the future world around the world	2	March 2, 3:07am	We have plans for dissemination of the vision in a variety of forms through conventional and new media, so we can reach as broadly as possible. This is still a matter of discussion and we welcome input on how best to achieve the greatest reach.
55	Can we explore the possibility to launch spacecraft from future colonies beside earth such as Moon Mars Phobos and Deimos	4	March 2, 1:07pm	We have already launched human spacecraft from the Moon during Apollo, and have studied new vehicles to launch from the Moon during Constellation; designs for robotic Mars ascent vehicles have been studied for Mars sample return, and potential future human return. There have been studies of possible human missions to all of the targets you discuss, though colonization is still rather distant.