Citizens' Perceptions of Cost, Schedule and Risk: A Participatory Technology Assessment of NASA's Asteroid Initiative

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Cost, Schedule, Risk pt. 1: "How much is too much?"

- **Congress, GAO and the media often criticize the history of cost and schedule overruns at NASA**
- **We know we need to reduce costs, but often there are complex tradeoffs between cost, schedule and risk**
- **Our cost analysis community is good at assessing how much a given task will cost and how long it might take, but it can be hard to assess what level of risk should be taken, and how much cost is too much**
- **Analysts often make recommendations about whether a project plan has too much cost or too much risk. Managers then make their own decision on what to propose**
- **Democracy reigns in the end: Congress and the White House eventually settle on a course of action. But NASA's internal recommendations on "how much is too much" can often be very influential**

Cost, Schedule, Risk pt. 2: "How much is too much?"

- **This presentation focuses on a tool for providing additional context for NASA analysts and NASA managers debating "how much is too much"**
- **What's the right answer to "too much"? Philip Kitcher argues that our engineering goals should reflect what an informed public would choose**
- **The public is much more capable of making complex decisions than they're given credit for (Sclove 2010, Brown 2004)**
  - Involving the public can also help root out biases in internal analysis
- **This presentation explores a proof of concept study in involving the public in proactively assessing NASA decisions surrounding mission planning**
- **The methodology discussed here, *Participatory Technology Assessment (pTA)* is an evaluation approach that involves citizens to do a systematic analysis of technical issues**

Overview: Participatory Technology Assessment via NASA ECAST Citizen Forums

- **What were the citizen forums?**
- **Why did they happen?**
- **Participatory technology assessment of Mars planning**
- **Results and Takeaways**

November 8th and 15th Citizen forums

- **Occurred in Phoenix and Boston**

What was the citizen forum?

- **~90 citizens attended each in Phoenix (Nov 8th) and Boston (Nov 15th)**
- **Participants were asked structured questions, and told that NASA would utilize the information as it made decisions**
  - Citizens were excited to help inform and support NASA
  - Topics included asteroid detection, mitigation, ARM and Journey to Mars
- **Broad demographic diversity (described in backup) covering a range of:**
  - Ages: 17-81, Economic backgrounds, Ethnicities, Educational backgrounds:
  - 40% college degrees in Arizona, 80% in Boston
- **Participants were broken into table groups of 6-8 people**
  - Citizens had to do group answers to questions as well as individual responses
- **NASA was not allowed to speak to citizens or influence discussion**
  - ECAST's museum and academic partners facilitated and led content development. Limited text based Q&A with NASA experts
- **Forum got a diverse group of voices that are outside of traditional NASA stakeholders**
  - Perfect diversity/representation is not possible, and was not the goal of the forum

Citizen Forum Deliberation - Boston

Citizen Forum Deliberation - Phoenix

Why do a pTA Citizen Forum?

- **The citizen forum was one of several ideas submitted in response to NASA's 2013 Asteroid Initiative Request for Information**
  - RFI input was written by the ECAST network (Expert and Citizen Assessment of Science and Technology) and recommended NASA conduct a participatory technology assessment
- **ECAST showed that a Participatory Tech Assessment (pTA):**
  - Is state of the art in public engagement, often done in Europe
  - Provides NASA with diverse public views on the social, economic, ethical, and other dimensions of NASA's asteroid initiative while the initiative is still in formulation, not after the fact
- **Office of Strategy Formulation and OCT pursued, completed and funded a cooperative agreement with ECAST in April 2014.**
- **Representatives from OCT, OCS, SMD, HEOMD, STMD, and OCOMMS held preliminary discussions about the project with ECAST in May 2014.**

Differs from past NASA engagement efforts or public surveys because the participants are *informed* and then asked for their thoughts

Tech assessment topics at the forum

- **Theme One - Asteroid Detection**
- **Theme Two – Asteroid Threat Mitigation/Planetary Defense**
- **Theme Three: Asteroid Redirect Mission (ARM)**
  - ARM Option A vs Option B
- **Theme Four – Journey to Mars**

ARM and Mars themes were related by discussion of the Proving Ground Strategy and the Capability Driven Framework

- **ARM is part of the Journey to Mars**
- **Mars discussion focused on follow-ons to the Proving Ground**

Results from ARM pTA deliberation

ARM Result 1 Top FOM: Planetary Defense, Science, HSF Tied

1 = most important, 7 = least important

Goal (Figures of Merit, FOM)	Massachusetts	Arizona	Combined
Advancing science	2.76	2.51	2.63
Advancing planetary defense	2.54	2.85	2.71
Advancing technology needed for human spaceflight (HSF)	2.65	2.87	2.77
Redirecting an asteroid that no one has been to before	4.01	4.71	4.38
Developing the economic potential of asteroids	4.67	4.36	4.51
Engaging with commercial and	5.00	4.86	4.93

Schedule priorities

Potential NASA Planning Priorities	Average Responses (1 = Not a priority, 7 = Highest Priority)
In the next 10 years, how important is it for humans to travel beyond the International Space Station?	4.82
In the next 50 years, how important is it for humans to travel beyond the International Space Station?	5.42
In the next 10 years, how important is it for a human-crewed mission to orbit Mars or one of Mars' moons?	4.39
In the next 50 years, how important is it for a human-crewed mission to orbit Mars or one of Mars' moons?	5.26
In the next 10 years, how important is it for humans to step foot on Mars?	3.88
In the next 50 years, how important is it for humans to step foot on Mars?	4.96

Follows a logical order – each progressive 10/50 year is a higher priority

Relative difference between 10 and 50 years is not great

Risk metrics – 1 is acceptable, 5 is unacceptable. Slide 1 of 2

Scenario	Boston	Arizona	Combined
The Option A (inflatable bag) probe retrieves an asteroid, but the asteroid is spinning so fast that it can't be controlled. The probe returns to the moon and may be used in future Proving Ground missions.	2.92	2.52	2.72
An ARM probe successfully proves that it can use gravitational deflection to move an asteroid, but it is not able to capture it.	2.12	2.42	2.28
The Option B (boulder removal) probe arrives at a large asteroid to remove a boulder, but the boulder cannot be removed. The probe returns to the moon and may be used in future Proving Ground missions.	2.70	2.55	2.62
A crewed mission is launched without fully qualified life support systems, since this will allow for an earlier launch date to Mars.	4.29	4.26	4.28

ARM Result 2: Motivations for Option Selection

Table 1 – *Group votes for ARM option A or B. Group size ranged from 6-8 participants.*
(Individual votes were similar)

SITE (NUMBER OF GROUPS)	OPTION A	OPTION B	NO CONSENSUS
MASSACHUSETTS (N=12)	0	12	0
ARIZONA (N=15)	4	9	2
COMBINED (N=27)	4	21	2
	15%	78%	7%

Table 2: The number of times people used the following tangible reasons to construct individual rationales for choosing A vs. B

Tangible Reason for Choice	*Arizona (n = 97 responses)*	*Boston (n = 86 responses)*	*Combined (n = 183 responses)*	*Response most related to A or B*
Going to Mars	12	19	31	B = 100%
Gravity Tractor	12	12	24	B = 100%
Planetary Defense	11	10	21	B = 95.2%
Asteroid Sample	14	4	18	A = 61.1%
Mining	8	7	15	B= 66.7%
Collecting Space Junk/Debris	7	1	8	A = 75%
Rubble	1	2	3	B=100%
Despinning	0	0	0	NA

Goals for Mars pTA discussion

- **Goal was to show 'proof of concept' that you can proactively engage the public prior to making technical decisions**
  - ARM showed ability to deliberate on technical details (see separate paper)
- **Wanted to keep deliberation within the scope of what NASA might be able to make decisions on**
  - Forum did not examine or even allude to debates about other destinations (Moon, Venus, etc) or about broader questions such as human vs robotic
  - Inputs were hoped to be useful to EMC mission planning
- **Deliberation questions were about:**
  - What should NASA's goals be following the Proving Ground? What exploration scenarios should NASA focus on?
  - Should NASA continue with a focus on the Proving Ground/Capability Driven Framework?

Framework and Mars Exploration Scenarios

- **In addition to background on Proving Ground (PG) and CDF, participants were given information on challenges involved in Mars exploration**
- **Citizens were then asked about different scenarios for exploration following the PG timeframe**
- **Notional Exploration Scenarios*: With detailed scenario descriptions on the next slides, the options included:**
  - Robotic and Crewed Orbital/Moon Exploration strategy
    - Includes potential moon missions and robotic teleoperations from crew in orbit
  - Viking "Quick Boots on Mars" Strategy
    - Push for a quick 30 day mission to surface
  - Pioneer "Permanent Settlement" Strategy
    - This as a choice would imply that permanent settlement right away should be 1st goal

**Scenarios (and titles) were developed by ECAST as accessible tools to inform a deliberation and are not meant to reflect NASA policy*

“Robotic and Orbital/Moon Missions”

- “This scenario involves a **much larger array of robotic explorers** being sent to Mars than NASA currently has. In addition, **crewed missions would be sent to orbit Mars and possibly to Phobos and Deimos**. While this option does not involve a crewed landing on the surface of Mars, the astronauts in orbit would be able to remotely operate robots on the surface in a much more efficient and directed manner than teams on Earth.
- Since this is the **least intensive option in terms of scale, it is also the least expensive and involves the smallest amount of risk**. Without the need for human-rated landing and takeoff vehicles, the amount of research and engineering that would need to be undertaken is a fraction of a mission involving a crewed landing, lowering cost and making this scenario possible on a fairly short timescale.
- The absence of setting humans on Mars also results in a substantial reduction in the risk to the astronauts in many respects. The **amount of science that can be done pales in comparison** to any mission with a crewed landing on the surface of Mars. This option also **may be less exciting to the public** than full human exploration missions.”

Viking “Quick boots on Mars” strategy

- “This scenario involves a **small-scale crewed exploration mission that would set down on the surface of Mars and operate for several months before the crew would return to Earth**. Eight astronauts would be selected to make the journey, and it would be launched at a time that would provide for not only a short travel time but also the shortest possible stay on the surface to minimize risk to the astronauts.
- Having astronauts on the surface of Mars would greatly increase the relevance and amount of science data that the mission would yield compared to remote operation of robots. However, **the technical and engineering hurdles that need to be addressed result in a major cost and timeframe increase**. While risk would be minimized, it would still be substantial for all of the astronauts involved.
- Without a permanent habitation plan, there is the risk that the mission will suffer a fate similar to the Apollo Program. That is, once we accomplish a crewed landing on Mars, interest and support in the Mars program may wane to the point of cancelling any future missions.

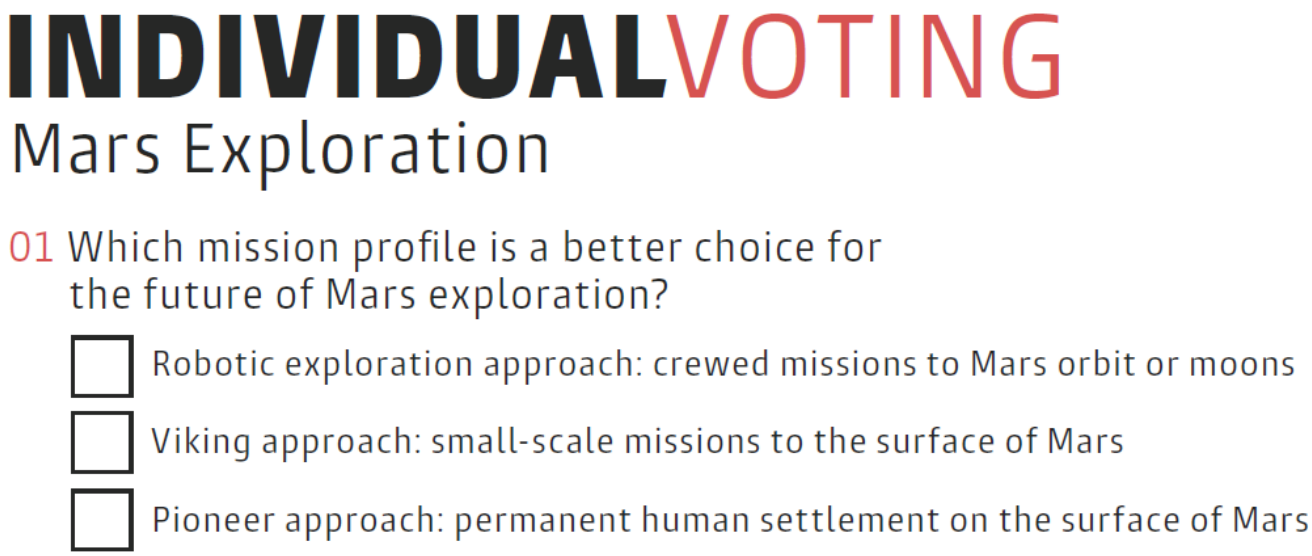
Pioneer “Permanent Settlement” strategy

“This scenario involves **a permanent settlement on the surface** of Mars. This colony would be preceded by a fleet of robotic and supply ships that would deposit food, fuel, and materials on the surface. These robots would also begin preparations for constructing permanent habitats. An initial large crew of human explorers would be refreshed every few months both in terms of supplies and personnel.

A mission of this scale and duration would be able to unlock a large number of the mysteries we have concerning the history of Mars and the entire Solar System. Multiple locations could be settled or scouted, offering opportunities for an abundance of diverse scientific research. Humanity would become ‘Earth-Independent’, meaning that such a mission might no longer require support from our home planet and may become self-sustaining.

The technology and techniques required for such an undertaking would be **extremely challenging**. Methods of dealing with radiation, extracting water, producing fuel and air, propulsion, habitat construction, and a number of other techniques would need to be vastly improved before this scenario becomes feasible. It would involve a **colossal increase over a smaller-scaled surface exploration mission in terms of cost, risk, and timeframe.**

Deliberating on Exploration Scenarios



- The Proving Ground was defined as a necessary step for going to Mars
- Voting question effectively asks what the follow-on to the Proving Ground would be
- Citizens had one hour to deliberate on this and the following question

Results on Mars scenario deliberation

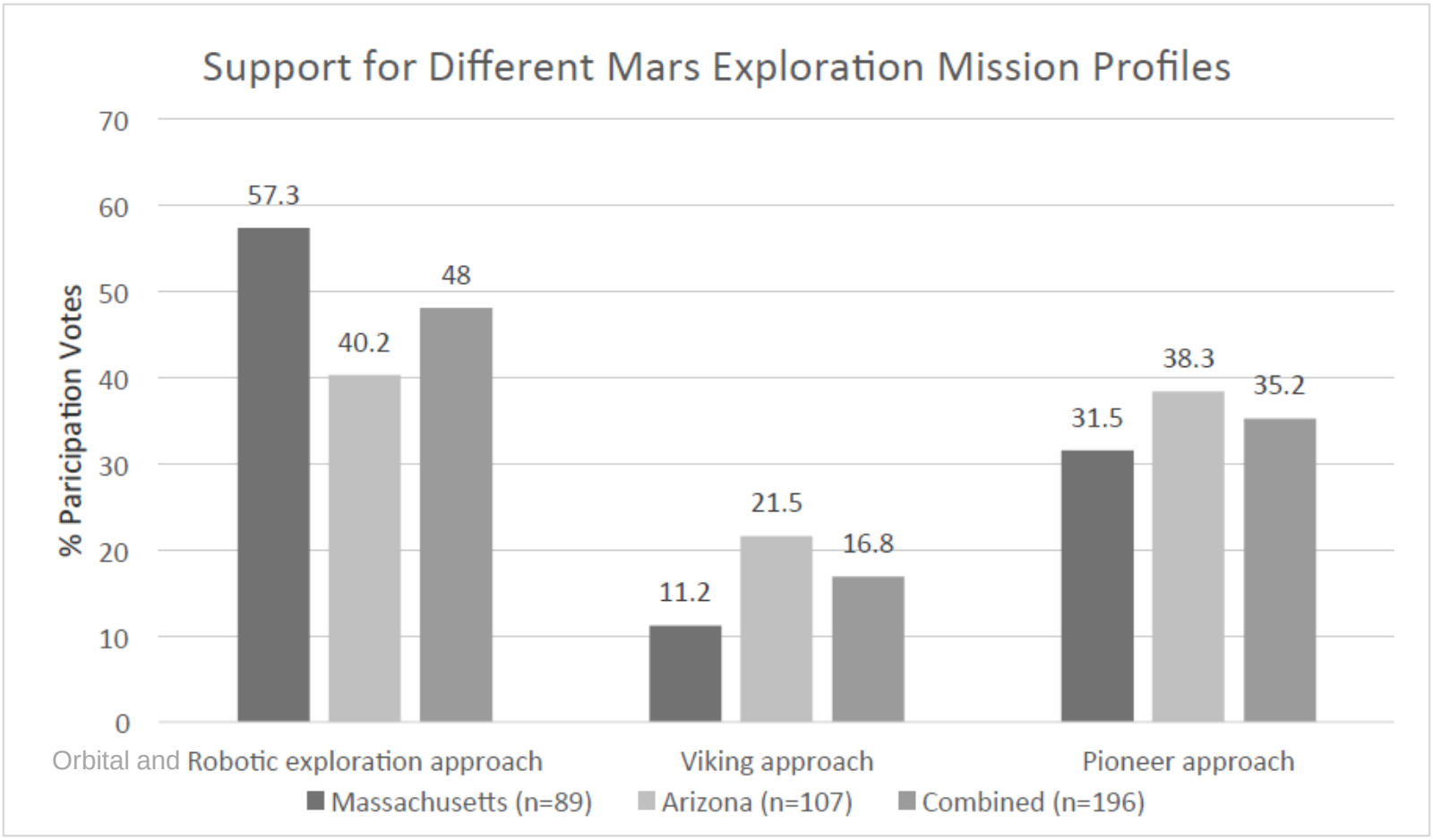


Figure E-1 – Percentage of participants that voted for each of the potential mission profiles for future Mars exploration in Massachusetts (n=89), Arizona (n=107), and both sites combined (n=196).

Crewed Orbital/Robotic Quotes 2/4

More quotes in backup

- It seems like there is a lot to **learn from this and then NASA can create mission priorities** from there.
- Safer; Less expensive. **Would more specific $ details before I move to a colony.**
- Most fiscally responsible option. The engineering required to send infrastructure for other options seems unfeasible.
- **Doing all three in a sequence gives the opportunity to estimate and attempt to mitigate the risk to humans in a manned mission**. The Viking strategy will provide additional opportunity to **assess risks** for a long-term human settlement. Also, I would suggest a manned trip to the moon before the Viking strategy. A Viking mission to the moon.
- Budgetary reasons, human liability and the technology (current) will limit a long term future of Mars exploration. I believe that robotic exploration will be **a better choice when allocating funds to explore the planet (Mars)** and get a better understanding of how to permanently settle a colony.

Viking selected quotes 1/2

- Not clear on the benefits from a colony on Mars.
- Want to see [a] boot on Mars and the boot should be on a woman.
- Get people to Mars. Robots are boring. **We need the human scientists to collect the most data.**
- Safest, smartest, most productive choice.
- Danger to human life.
- **Expense and I feel like there would be much of the same results.**
- 1 - already have had robots up there, so need next step. 2 - Better science can be gathered/collected. 3 - Again, gives us greater amount of science and difficulties to study after. 4 - Pioneer is too costly and robots are less interesting and scientific.
- **It's an acceptable middle-ground.** The trips to the surface would require advanced technologies; they, in turn, would make the pioneer approach possible if conditions on Earth require.
- **You must find out what will work and what won't and what is the best way to go forward after testing it on a small scale**.

Pioneer selected quotes 1/3

- **Go big or go home:** I don't want interest to be waning in the program after a viking type mission. It comes down to who our ultimate question is, **why do we care about Mars?**
- We will learn more by actually doing.
- The possibility that we might go to Mars and then leave like the Apollo missions seems unacceptable to me. **It just ends up being a waste of resources and is reduced to nationalistic pride.** There still may end up being significant value/economic value as we turn to asteroid mining.
- We've been robotically exploring Mars for 45 years. It's high time we started sending people. Money is a human construct, it should not dictate our futures.
- I believe becoming a two-planet species is incredibly important. It is time to advance to that point. **The benefits of a permanent settlement greatly outweigh the cost and risks.**
- Go big or stay home! **Huge potential for collaboration with private industry.**

What do the results mean?

Participants prioritized the following options:

1. Robotic and Crewed Orbital/Moon Exploration strategy
2. Pioneer “Permanent Settlement” Strategy
3. Viking “Quick Boots on Mars” Strategy

- **Why did Orbital and Robotic Exploration ‘win’?**
  - Arizona tended more towards crewed landing, Boston to Orbital/Robotic
  - We think they wanted a major success sooner – were willing to accept an interim goal that is less technologically ambitious
  - People seemed to prefer it more as an intermediate step on the way to do something more ambitious
- **People seemed to be able to process programmatic data:**
  - Middle ground on cost and schedule was prominent in the written rationales

Public Values: Summary of rationale themes

- **Practical justifications:**
  - General feasibility concerns
  - Safety
  - Middleground on cost and schedule
  - Want to do all three approaches
- **Value of the destination:**
  - Just like it - no description of why
  - Unsure of need: want research on if Mars is worth going to
  - Boots on Mars is desired
  - Settlement of Mars is desired
  - Goal for a multi-planet species is desired
- **Value of the mission:**
  - Tech development for future exploration
  - Need a human for repairs or science
- **Benefits for society:**
  - Tech development for society
  - Obtaining resources for humanity
  - Planetary Defense capabilities
  - Science

Political and Social Values:

  - Other priorities are more important than Mars
  - Inspiration
  - Political Viability
  - Involving the private sector
  - Ethical problems with affecting an unknown world

This analysis is NASA's interpretation of written data, assessing what high level themes repeated

Results on “moving forward with Proving Ground”

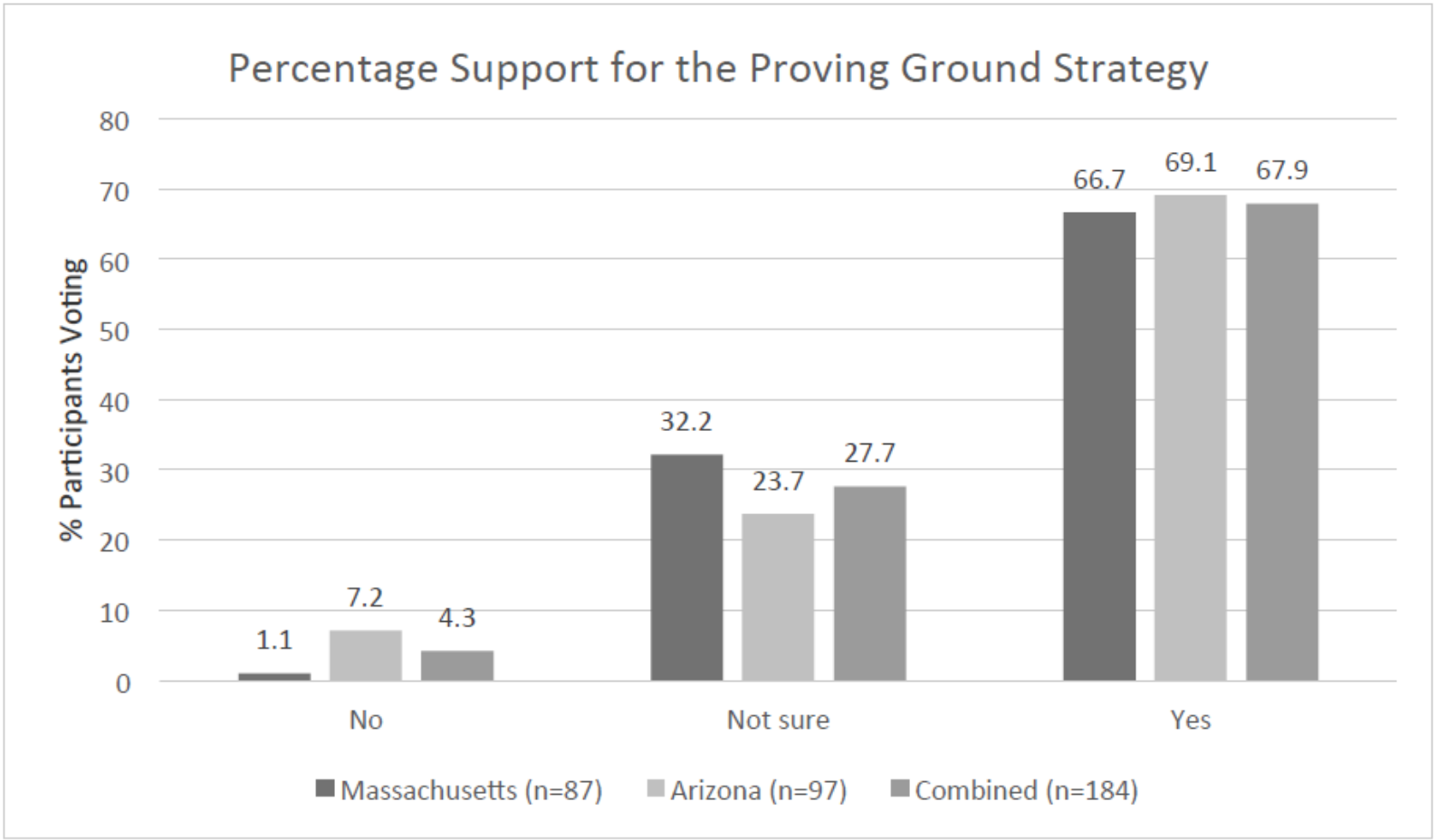


Figure E-2 – Percentage of participants voting on whether they support moving forward with the proving ground strategy in Massachusetts (n=87), Arizona (n=97), and both sites combined (n=184).

Assessing "How much" using Participatory Tech Assessment as a Method

- **Final ECAST report discussing all topics (detection, mitigation, Mars) will be released imminently**
- **NASA Insights on the method:**
  - Citizens successfully engaged with technical content, found it enjoyable and survey shows significant learning
  - Different research formats could be used to assess technically deep questions, including more specifically addressing cost, schedule and risk
  - Additional experiments could use tangible cost numbers instead of qualitative descriptions as was used here
- **Analysts and managers can reflect on the public's thought processes and values as they create their own answer to "how much".**
  - Public perspective should not directly dictate decisions, but it can be a positive contribution to the discussion
- **Future Applicability:**
  - pTA/Citizen Forums could be used to assess other major decisions, including issues of cost, schedule and risk
  - Can also assess public desires for programmatic and technical risk, help assign goals/FOMs for NASA decision-making

Backup

Demographics

Broad mix of age ranges, economic backgrounds and ethnicities.

As with many engagement activities, not possible to get complete diversity

Output of forum should be seens as embodying perspectives from voices NASA doesn't traditionally talk to

Category	US population	AZ + MA Participantss	AZ Population	AZ Participants	AZ Applicants	MA population	MA Participants	MA Applicants
Total population (1)	309,138,711	13,319,448	6,626,624	96	286	6,692,824	87	180
Sex (2)								
Male	49.2%	50.8%	49.7%	56.3%	57.7%	48.4%	44.8%	54.7%
Female	50.8%	49.2%	50.3%	43.8%	42.3%	51.6%	55.2%	45.3%
Age (3)								
Median	37.2		36			39.1		
18-24	13.1%	22.4%	13.3%	30.2%	45.5%	13.1%	13.8%	35.4%
25-44	35.0%	41.5%	35.3%	32.3%	32.2%	33.9%	51.7%	40.1%
45-64	34.6%	28.4%	32.8%	26.0%	17.5%	35.2%	31.0%	20.4%
65 plus	17.3%	7.7%	18.6%	11.5%	4.9%	17.7%	3.4%	4.1%
Education (4)*								
No HS degree	14.4%	2.2%	14.6%	3.1%	1.0%	10.9%	1.1%	0.9%
HS degree	28.5%	11.5%	24.4%	18.8%	21.3%	25.9%	3.4%	15.2%
Some college, no degree	28.9%	27.9%	34.4%	36.5%	37.4%	24.3%	18.4%	29.8%
Bachelor's degree	17.7%	34.4%	16.9%	28.1%	26.9%	22.2%	41.4%	32.4%
Graduate degree	10.4%	24.0%	9.7%	13.5%	13.3%	16.8%	35.6%	21.7%
Race/Ethnicity (5)								
White	63.7%	59.0%	57.7%	46.9%	60.1%	76.3%	72.4%	63.9%
Black	12.2%	5.5%	3.8%	5.2%	3.8%	6.2%	5.7%	5.6%
Asian	4.7%	6.6%	2.7%	8.3%	9.1%	5.4%	4.6%	8.8%
Mixed/other	2.4%	6.0%	1.7%	4.2%	8.4%	1.7%	8.0%	6.9%
Hispanic	16.3%	23.0%	29.7%	35.4%	18.5%	9.6%	9.2%	14.8%

Demographics

Strong mix of economic backgrounds

Very few participants come from a NASA context

Category	US population	AZ + MA Participantss	AZ Population	AZ Participants	AZ Applicants	MA population	MA Participants	MA Applicant
Household Income (6)								
Prefer Not to Disclose	n.d.	18.6%	n.d.	20.8%	21.7%	n.d.	16.1%	17.8%
Less than $25,000	24.9%	21.9%	23.6%	29.2%	25.2%	20.0%	13.8%	21.5%
$25,000 to $49999	25.0%	21.9%	26.2%	16.7%	19.2%	18.7%	27.6%	21.2%
$50,000 to $99,999	30.1%	25.1%	30.9%	20.8%	20.6%	29.3%	29.9%	25.1%
$100,000 or more	20.0%	12.6%	19.4%	12.5%	13.3%	31.8%	12.6%	14.4%
Occupations								
Employed		56.8%		49.0%	42.3%		65.5%	52.6%
Unemployed		8.2%		9.4%	8.0%		6.9%	7.9%
Retired		6.6%		10.4%	5.9%		2.3%	4.5%
Student		18.0%		25.0%	37.8%		10.3%	27.3%
Other		10.4%		6.3%	5.9%		14.9%	7.7%
NASA Related								
Attend NASA Social?		7.1%		6.3%	7.0%		8.0%	10.1%
Member space advocacy grp?		4.9%		7.3%	10.1%		2.3%	8.4%
Aerospace professional?		1.6%		1.0%	5.9%		2.3%	6.0%
Political Orientation (7)								
Very conservative	10%	0.0%		0.0%	0.3%		0.0%	0.2%
Conservative	30%	11.5%		14.6%	12.2%		8.0%	11.8%
Moderate	35%	38.8%		40.6%	39.5%		36.8%	38.2%
Liberal	15%	34.4%		25.0%	31.1%		44.8%	35.0%
Very liberal	6%	3.3%		3.1%	4.5%		3.4%	4.9%
No opinion	4%	12.0%		16.7%	12.2%		6.9%	9.9%

Risk metrics – 1 is acceptable, 5 is unacceptable. Slide 2 of 2

Scenario	Boston	Arizona	Combined
A crewed mission is launched without fully qualified life support systems, since this will allow for an earlier launch date to Mars.	4.29	4.26	4.28
Injuries occur during the broad campaign of Mars exploration.	1.72	2.49	2.13
Loss of life occurs during the broad campaign of Mars exploration.	3.02	2.81	2.91

Background given on CDF

"What is a Capability-Driven Framework (CDF)?

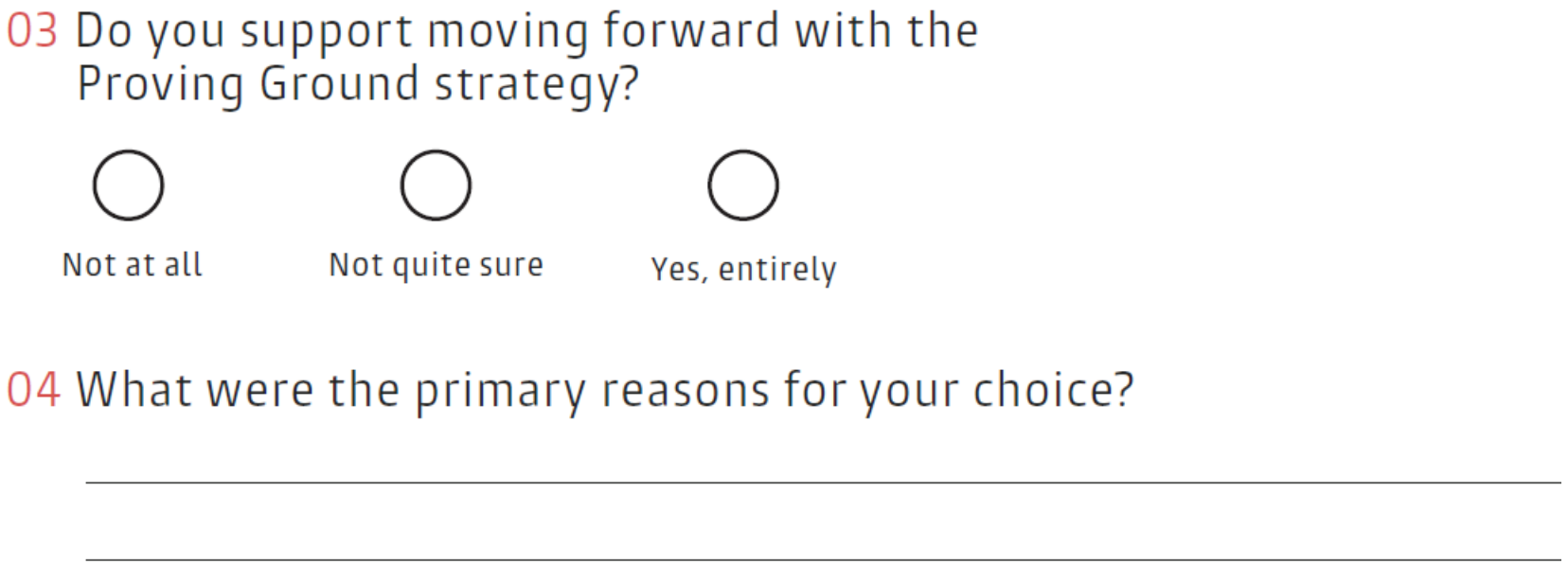
- **One of the development strategies for the advancement of human exploration of the Solar System is to follow a capability-driven framework. NASA's capability-driven framework is a departure from the traditional space mission model. Instead of selecting a destination – like the moon or the International Space Station – and building the transportation vehicles to get there, this approach develops the vehicles and capabilities that can go to a broad range of destinations. As these vehicles and capabilities mature, increasingly complex missions can be selected to destinations farther and farther into the solar system.**
- **This means that missions are funded, designed, and carried out as NASA's budget and capabilities dictate. Rather than a detailed start-to-end plan, such as the Apollo Program had for lunar exploration in the 1960s, this approach does not need final, fixed goals in place before initial missions are carried out.**
- **This method has the potential to be more efficient and cost-effective, as the path towards the eventual goal of Mars exploration is flexible. Technologies can be developed, tested, refined, and perfected in a lower-risk environment than a crewed Mars mission."**

Background given on Proving Ground

- **“Merriam-Webster defines “proving ground” as a place where things or people are tested or tried out for the first time; a place where scientific testing is done. NASA refers to the Proving Ground as a phase of human and robotic missions that prepare for and prove our ability to safely live and work away from Earth for extended periods of time. The proving ground is centralized in cis-lunar space, but encompasses activities conducted aboard the International Space Station, and robotic missions on and around the moon, Mars, and farther into the cosmos.**
- **NASA’s capabilities will continue to mature through missions in the Proving Ground, leading to the ability to go to Mars. As such, the Proving Ground and the Capability Driven Framework are related, as the final destination and mission concept for human exploration is not defined for the Proving Ground. The Proving Ground can be viewed as a method of moving NASA from earth-dependent to earth-independent in smaller increments and in full before attempting a mission to Mars.”**

Deliberating on Proving Ground/CDF

- Background text: **“[W]ould you like to see an entire strategy laid out now, or are you comfortable with a series of Proving Ground missions** (such as the Asteroid Redirect Mission) that are undertaken as budgets and capabilities dictate?”
- This question was translated into the below question for each individual’s voting form



Proving Ground Yes 1/3

More quotes in backup

- **Seems like the logical way to go about undertaking such a monumental task - in small steps, proving necessary technologies and techniques along the way.**
- The strategy outlines multiple important technologies that will be very important on the way to Mars.
- **It makes sense to learn to walk before you try to run and to be efficient and not waste resources and efforts and time.**
- We need to perfect and develop the technology before we can effectively explore Mars or the rest of the solar system.
- Proving Ground strategy let you analyze step by step how to logically proceed.
- **Limited budgets at this time. Much can and will be accomplished with pragmatic logistics.**
- **Rational. Reflective of our current political/economic times. Concerned it might truncate or constrain the full potential of Martian investment (ie succumb to political change…)**

Proving Ground No

- Going to mars necessitates overcoming many obstacles to gather. These solutions can be applied to all kinds of space exploration. Get the asteroids threatening Earth first.
- **It is a distraction. Asteroids are a detour. And the lack of a true goal make the programs targets for lawmakers to cut.**
- **We need to proceed with Mars exploration now. We need a plan to begin mounting a human Mars mission, and need to begin implementing that plan immediately.**
- I think that we are starting to realize that Earth is vulnerable as is life as we know it, so we need to seek other habitats to thrive in.
- We need to keep moving forward, developing new technology, practicing in new scenarios. Having this "stepping stone" is important.
- I don't believe that this part of exploration is currently necessary.
- Politically motivated. Avoid the grand strategy.
- **NOT ARM!!! I support colonizing the moon first. It will be easier than Mars, cheaper, and has economic benefit. You can build a platform on the moon to launch to Mars.**

Observations

- **This question served as a good proxy for whether the public accepts the Capability Driven Framework**
- **There is support for PG amongst a public that had time to learn and deliberate about it**
  - >65% support for the Proving Ground – support was roughly constant across both Phoenix and Boston
  - Boston had more people who were unsure than Arizona
  - 1 person in Boston rejected PG, a handful rejected in Phoenix
- **Support gives some credence to idea that public accepts CDF**
- **Additional data about risk tolerance and schedule preferences.**
  - More analysis is needed on how to integrate this mix of programmatic preferences

ARM Result 1 Top FOM: Planetary Defense, Science, HSF Tied

1 = most important, 7 = least important

Goal (Figures of Merit, FOM)	Massachusetts	Arizona	Combined
Advancing science	2.76	2.51	2.63
Advancing planetary defense	2.54	2.85	2.71
Advancing technology needed for human spaceflight (HSF)	2.65	2.87	2.77
Redirecting an asteroid that no one has been to before	4.01	4.71	4.38
Developing the economic potential of asteroids	4.67	4.36	4.51
Engaging with commercial and international partners	5.00	4.86	4.93
Performing an exciting mission	6.05	5.68	5.86

Major difference between top three and bottom four goals

The voting in Massachusetts and Arizona are fairly consistent.

ARM Result 2: Motivations for Option Selection

Table 1 – *Group votes for ARM option A or B. Group size ranged from 6-8 participants.*

(Individual votes were similar)

SITE (NUMBER OF GROUPS)	OPTION A	OPTION B	NO CONSENSUS
MASSACHUSETTS (N=12)	0	12	0
ARIZONA (N=15)	4	9	2
COMBINED (N=27)	4	21	2
	15%	78%	7%

Table 2: The number of times people used the following tangible reasons to construct individual rationales for choosing A vs. B

Tangible Reason for Choice	*Arizona (n = 97 responses)*	*Boston (n = 86 responses)*	*Combined (n = 183 responses)*	*Response most related to A or B*
Going to Mars	12	19	31	B = 100%
Gravity Tractor	12	12	24	B = 100%
Planetary Defense	11	10	21	B = 95.2%
Asteroid Sample	14	4	18	A = 61.1%
Mining	8	7	15	B= 66.7%
Collecting Space Junk/Debris	7	1	8	A = 75%
Rubble	1	2	3	B=100%
Despinning	0	0	0	NA

Schedule priorities

Potential NASA Planning Priorities	Average Responses 1 = Not a priority 7 = Highest Priority
In the next 10 years, how important is it for humans to travel beyond the International Space Station?	4.82
In the next 50 years, how important is it for humans to travel beyond the International Space Station?	5.42
In the next 10 years, how important is it for a human-crewed mission to orbit Mars or one of Mars' moons?	4.39
In the next 50 years, how important is it for a human-crewed mission to orbit Mars or one of Mars' moons?	5.26
In the next 10 years, how important is it for humans to step foot on Mars?	3.88
In the next 50 years, how important is it for humans to step foot on Mars?	4.96
In the next 10 years, how important is it for humans to establish a permanent presence on Mars?	3.58
In the next 50 years, how important is it for humans to establish a permanent presence on Mars?	4.51

Follows a logical order – each progressive 10/50 year is a higher priority

Relative difference between 10 and 50 years is not great

Risk metrics – 1 is acceptable, 5 is unacceptable. Slide 1 of 2

Scenario	Boston	Arizona	Combined
The Option A (inflatable bag) probe retrieves an asteroid, but the asteroid is spinning so fast that it can't be controlled. The probe returns to the moon and may be used in future Proving Ground missions.	2.92	2.52	2.72
An ARM probe successfully proves that it can use gravitational deflection to move an asteroid, but it is not able to capture it.	2.12	2.42	2.28
The Option B (boulder removal) probe arrives at a large asteroid to remove a boulder, but the boulder cannot be removed. The probe returns to the moon and may be used in future Proving Ground missions.	2.70	2.55	2.62
A crewed mission is launched without fully qualified life support systems, since this will allow for an earlier launch date to Mars.	4.29	4.26	4.28

Additional Citizen responses

- **Next slides have additional citizen responses**
- **<u>These are not the complete set of responses</u>, but are Pirtle's selection of ~50% of the responses that seemed most interesting.**
  - All responses will be included in the final ECAST report in May 2015
- **Future analysis will involve looking at transcripts of the table and following flow of conversation during the day.**

Crewed Orbital/Robotic Quotes 1/4

- Can be implemented quickly, low cost, less risk to human space travelers.
- **Baby steps**
- Doing all three in a sequence gives the opportunity to estimate and attempt to mitigate the risk to humans in a manned mission. The viking strategy will provide additional opportunity to assess risks for a long-term human settlement. Also, I would suggest a manned trip to the moon before the viking strategy. **A viking mission to the moon**.
- Budgetary reasons, human liability and the technology (current) will limit a long term future of Mars exploration. I believe the robotic exploration will be a better choice when allocating funds to explore the planet (Mars) and get a better understanding of how to permanently settle a colony.
- Need continued and expanded robotic exploration before any crewed exploration. Right now, we don't have the technology to safely or effectively send crew.

Crewed Orbital/Robotic Quotes 3/4

- Although I want to support human exploration on Mars, I am unsure of the moral and ethical validity of creating inter-planetary colonies. Any strategy needs a great "big picture" engagement strategy for public support.
- I agree space and Mars exploration is important, especially for encouraging and fostering the drive of scientific advancement and scientific creativity, **but I feel it is selfish to consider further exploration when there are so many issues** and concerns present that are so pressing and urgent in our world.
- Since there is no life in Mars, not necessary to send human body there.
- Robotic is a stepping stone to future Mars **- it will be less costly and faster.** Can establish colony on Phobus/Deimos as a staging area testing zone for future landing on Mars. Would get people excited about future colonies.

Crewed Orbital/Robotic Quotes 4/4

- More needs to be learned about the Martian environment and ways found to counteract the biologic negative before colonization (even by scientists) can be undertaken. Scenario 2 is too much like our moon race, from which nothing followed. **Next time, horse before cart.**
- Not enough data yet - "what if" unforeseen dangers exist
- It is cheaper and will give us more exp. **Safer to have men on the moons of Mars.**
- .

Viking selected quotes 2/2

- Vikings will have to use robots anyway and gives us better samples and information pertinent to deciding if a human settlement is even possible.
- **I chose this because I want to see a manned mission to Mars but I don't see the point of the pioneer option from a fiscal standpoint.**

Pioneer selected quotes 2/3

- **The viking approach may lead to the same disinterest** that followed landing on and then leaving the moon. Also, the Earth is reaching a carrying capacity, so we can use space and resources on Mars.
- **Not have all our eggs (humans) in one basket (Earth).**
- Human Earth independence. Advancing our proving ground farther so that we may move our frontier even further out!
- Go big or stay home! **Huge potential for collaboration with private industry.**
- Colonizing another planet will be important for our civilization in terms of learning about the possible future of Earth and own solar system as a whole.
- **The human experience** of living on Mars, a human waking, living, solving problems, writing poetry, making art, yearning for Earth make colization, the risks and costs seem trivial. Robots don't love Mars or Earth.

Pioneer selected quotes 3/3

- Because it's awesome! Make the solar system seem smaller, get human eyeballs seeing Mars and science excitement, future social impact and technological advances will follow. We should do this regardless of the cost.
- So much innovation and discoveries waiting to be made! Incredibly expensive and ambitious, but in encapsulates the human spirit.
- **Single point failure -** if humans only live on Earth, they are less likely to survive than if humans live on multiple planets. Human exploration of Mars will increase public awareness of space, and it seems like the penultimate goal of human to spread to other worlds. **We should terraform Mars!**

Votes against Mars 1/2

- (NONE) **There wasn't a real goal as to why we should go to Mars** when there isn't enough technology to support a comeback trip and specific outcomes other than it is new. **Proving Ground strategy seems better.**
- This will provide info needed for the other two types of missions. Frankly I have a hard time supporting the idea of deep space exploration while **there is so much that still needs to be done on Earth to solve the problems of resources to sustain life on this planet.**
- Manned exploration is too **expensive**

Votes against Mars 2/2

- None of the above. I don't really see Mars exploration as worthwhile on the whole. I think it's worth it to test our technological limits and take actions to be about to travel and explore further. **I don’t get the motivation for exploring Mars more. What could we learn that we don't know from rovers? I think evidence for life is a huge motivation for the public, but I don't see that with Mars.**
- I agree space and Mars exploration is important, especially for encouraging and fostering the drive of scientific advancement and scientific creativity, but I feel it is selfish to consider further exploration when there are so many issues and concerns present that are so pressing and urgent in our world.
- Since there is no life in Mars, not necessary to send human body there. It is not worth since **no one around our discussion table wanted to go to Mars.**

Proving Ground Yes 2/3

- **If a plan is laid out and a step isn't arrived at on time, human interest is lost because they will doubt the whole plan will be completed.**
- Moving forward with Mars colonization, in incremental proving ground steps, seems feasible, logical, and crucial.
- Cost-effectiveness and I truly believe that we need to focus on one thing at a time to understand the next thing.
- Possibility
- **Hard to get funding for a big project. Easier to get funding for smaller projects with short-term goals that are attainable.**
- I love advancements in science. The proving ground could be adjusted as our ideas and needs change.
- Not really sure, but sounds like a good idea.
- **Logical to move in smaller steps to develop new goals.**

Proving Ground Yes 3/3

- We need to do this so generations to come can benefit out of it.
- I think the proving ground strategy would set the ground work to achieve Mars exploration.
- **I like the idea of trial and error** instead of a step plan of full force mars exploration. If the asteroid plan works, then people would be more willing to support the Mars plan.
- **Practice makes perfect.**

Proving Ground maybe 1/4

- It seems to be a primitive, yet it's working thus far. **I think it's like a bandaid that's been working for so long.**
- **I fear that any step in the process people could lose interest/pull tax funding and therefore going to Mars immediately would be better.**
- I support it, but I desire accelerated scheduling/execution as it leads toward the "pioneering" scenario.
- The short-term projects allow for measurable progress/success. That is valuable when seeking funding or public support. I don't necessarily agree with long-term Mars colonization, though.
- I believe in the power of goals and milestones, but the scope of this project must be flexible to accommodate new advances in the available technologies.
- **I'm not certain that the proving ground strategy is specific enough**. It seems too regularly described for something so important and expensive.
- I'm just not sure.

Proving Ground maybe 2/4

- Too many unknowns. Need to prove many technologies, before manned Mars missions are possible. Need to demonstrate technologies in Earth orbit and on the moon.
- **Safety and expense**
- Not enough information
- Because it makes more sense to me to do the robotic exploration because it is more sensible and cost effective.
- **"Proving ground" can be inefficient use of money; many technical deadends or non-relevant experiments; could be "technology sandbox" if not focused/directed research.**
- **I like the idea as I understand it as I think it is responsive to what we many not yet know.**
- **Has room for improvement, but at least leaves room to cut your losses at any time towards the ultimate end goal. However, lack of motivation towards an end goal may lead to infficiency.**

Proving Ground maybe 3/4

- The proving ground strategy makes sense if each intermediate step builds towards longer-term goals. Too far on one side on flexibility could mean an endless chain of "successful" missions that don't advance toward a longer-term goal.
- I am not sure of any of this.
- **I'm afraid that piecemeal approach lacks accountability. It's easy to just give up.**
- I'm not sure how worthwhile it is. I think studying asteroids and how to manipulate them can be very valuable.
- Because it makes more sense to me to do the robotic exploration because it is more sensible and cost effective.
- **I feel that hard deadlines will have less (illegible) of losing public support like apollo did. It also removes the excuse of needing to look for the "right time" where funding and public sentiment align**.

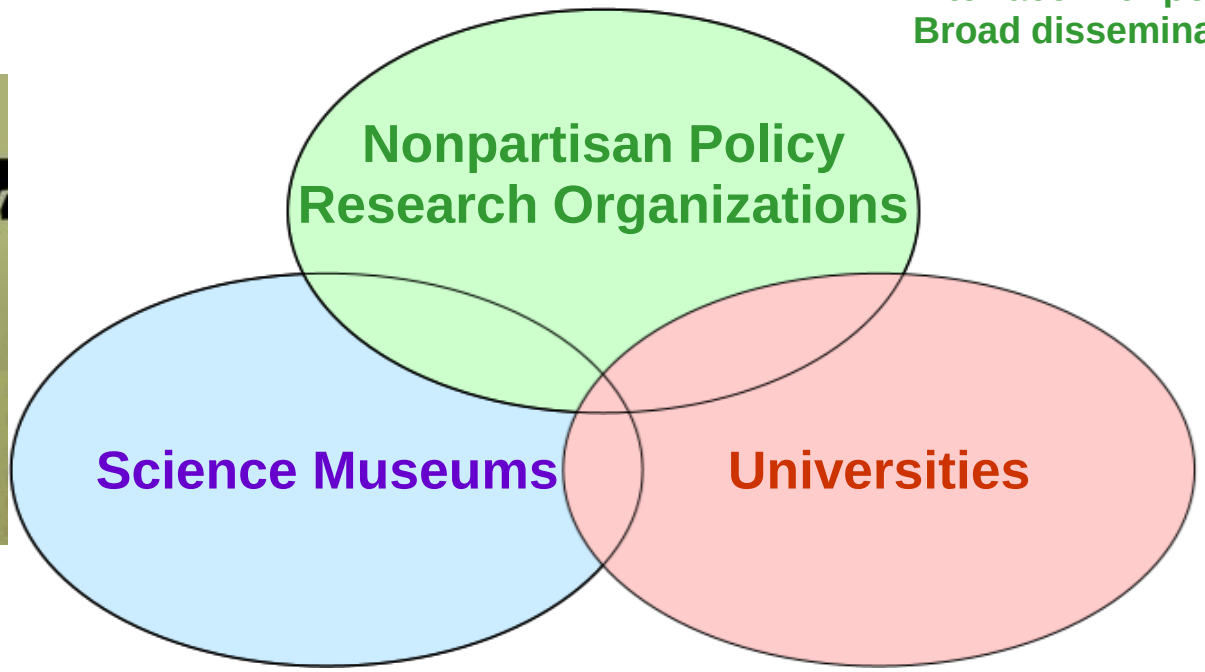
Proving Ground maybe 4/4

- **I don't support the asteroid process in terms of the proving ground strategy because it takes away from time, money, and resources that could be devoted to Mars.**
- I find a disconnect between the ARM Mission and the Mars mission.
- **I don't think the exploration of asteroids is directly related to a mars mission. I like the idea of asteroid study to learn more about how we can utilize them and prevent collisions, but I view the mars mission as a separate project that should be tested in the stages from question 1.**

Backup on ECAST

Expert and Citizen Assessment of Science and Technology (ECAST)

Policy relevance
Interface with policy-makers
Broad dissemination



Direct public interface
Trusted public educators
Innovation in citizen-friendly pedagogy

Innovation in TA concepts/methods
Research, analysis and evaluation
Training of researchers/practitioners

ECAST
Expert & Citizen Assessment of Science & Technology

WORLD WIDE VIEWS ON Biodiversity

Results reported instantly to a website and compared across age groups, countries, regions and continents as they are produced.

Analyzed and communicated in documentary films and policy reports about the process and results.

Disseminated through educational and outreach activities in formal and informal settings.

Presented at UN Convention on Biological Diversity Meeting (COP11) in India on October 2012.

Used as an important baseline for research, education and design of future awareness raising initiatives.

Past ECAST effort