Phase 1: Team & Policy Issue

Team Members: Gwen, Rohith, Makayla, Jimmy

Metaphor: “We’re all parts of a rocket”

Payload System: Includes telecommunications and overall group communication.

Guidance System: Includes censors, radars, etc. that leads the rocket on the correct path.

Propulsion System: Includes all parts that make up the engine and thrust the rocket into space.

Structural System: Includes all the parts that make up the frame of the rocket.

All of the systems help create a working rocket, which is us. We will later become space debris which relates to our policy project! This metaphor fails to explain how the systems work together and make the rocket work, however.

Policy Issue: Space Debris

Group’s Initial Reaction (How it made us feel and what we expect to learn): Space debris was our top choice so we were ecstatic that we were able to get this topic. We were excited to learn about the origin of space debris, current events, and possible solutions to combat the issue of space debris. We are very curious to learn more about it!

Phase 2: Systems Thinking Map of Policy Issue

Pop-Up Interview Question: What does space debris mean to you?

1. Stakeholders
    a. Aerospace engineers
    b. Astronauts

c. NASA

d. Legislators

e. Federal Government

f. National Citizens

g. Economists

h. Scientists

i. Foreign affairs

j. Our group

2. Artifacts:

a. Satellites

b. Rockets

c. Rovers

d. Space Suits

e. International space station

f. Human waste

g. Space Telescopes

h. UFOs

i. Asteroids

j. Planets

Labor:

- Produced? Space Engineers
- Where has it traveled to and from? From Earth to several places in space and back

- Histories? First satellite was sent up on Oct 4 1957, and ever since has been further studied and developed
- Who maintains its production? Where? NASA workers watches the activity of space debris
- Actors? People involved in space exploration and sending stuff up to space are involved. Normal citizens are excluded

Phase 3: Data Collection and Reflection

1) Data Collection:

Data Collection Method	Task
Textual Document	1. The Space Debris Problem- http://www.jstor.org/stable/42704771 2. Dish Is First Company to Be Fined by F.C.C. over Space Junk Rule www.nytimes.com/2023/10/03/business/dish-fcc-space-debris-fine.html 3. Forwarding Multilateral Space Governance: Next Steps for the International Community http://www.jstor.org/stable/resrep05015 4. Upcoming Space Mission to Test Purdue-Developed Drag Sail Pulling Rocket Back to Earth www.purdue.edu/newsroom/releases/2020/Q3/upcoming-space-mission-to-test-purdue-developed-drag-sail-pulling-rocket-back-to-earth.html
Visual Representation	1. https://orbitaldebris.jsc.nasa.gov/photo-gallery/_images/fullsize/graphics-leo.jpg 2. https://orbitaldebris.jsc.nasa.gov/photo-gallery/_images/fullsize/graphics-geo.jpg 3. https://orbitaldebris.jsc.nasa.gov/photo-gallery/_images/fullsize/graphics-geo-polar.jpg 4. https://eoimages.gsfc.nasa.gov/images/imagerecords/40000/40173/spacejunk_geo_2009237_lrg.png

Quantification	1. Space debris: a quantitative analysis of the in-orbit collision risk and its effects on the earth https://www.eurekalert.org/news-releases/994289#:~:text=The%20European%20Space%20Agency%20(ESA,stages%20of%20rockets%2C%20satellites%20that 2. Cost and Benefit Analysis of Orbital Debris Remediation https://www.nasa.gov/wp-content/uploads/2023/03/otps_-_cost_and_benefit_analysis_of_orbital_debris_remediation_-_final.pdf 3. ESA's Annual Space Environment Report https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf 4. Orbital debris and the market for satellites https://www.sciencedirect.com/science/article/pii/S0921800923000940
Metaphor Analysis	1. Space debris mitigation resembles ocean pollution clean up. -Debris mitigation in space has a strong resemblance and relation to ocean pollution clean up. Both occur in vast areas, are human caused, and have built up for decades. 2. Space debris surrounds earth like Saturn's rings. -Space debris in earth's orbit starts to form rings similar to Saturn's rings. A myth exists detailing earth as one of Saturn's rings that detached after a cataclysm.
Pop Up Interview	Question: What does space debris mean to you? 1. I think it's means random trash in space. 2. A build up of human waste in space. 3. Space debris is like space trash in the earths orbit. 4. I would say space debris means excess waste in space.
Narrative Analysis	1. When looking at the response to the pop up interview question "A build up of human waste in space" although the response is brief and short it gives a general idea of what sace debris is. It also emphasizes how space debris is human waste primarily in space possibly from failed rockets or other space projects. This connects to how similar to other issues on earth such as climate change humans are one of the big contributors that make these problems. 2. The first visual shows a collection of space debris surrounding earth at low earth orbit (LEO). The white dots are to represent the various space debris within the earths orbit. Although the image doesn't explicitly detail what the space debris is it does out of its way to just show how abundant the debris is. The debris is almost like a close ring around earth and there is still more outside of the clustered ring. The image details the overabundance of space debris and provides a better visual of how big of a problem space

	debris is. 3. The metaphor “Space debris surrounds earth like Saturn's rings” helps to paint the visual similar to how the images portray of the large abundance of space debris that does surround earth. Unlike Saturn's icy rings, space debris consists of nonfunctional human-made litter, defunct satellites, spent rockets, and explosion fragments chaotically orbiting Earth in a hazardous cloud. Although saturns rings may be beautiful to look at a ring of space debris is not. 4. The metaphor “Space debris mitigation resembles ocean pollution clean up” helps to emphasize how the long term contribution to space debris in the earths orbit is similar to humans long term contribution to pollution in the ocean. With how abundant the amounts of pollution are it makes it more difficult to reverse the main problem.

2) Data Reflection:

Collecting interview data posed challenges for all members, potential participants lacked time or interest to provide detailed perspectives on space debris. When Gwen interviewed, it could’ve been an exam day as she didn’t yield many willing participants. Jimmy and Rohith got some responses however, several interviewees gave vague answers. Government and research sources provided quality background information on space debris. The STS postures most group members collectively used listening intently to responses, improvisation around confusion interviewees had on the topic. Makayla used metacognition to better understand the responses collected and Rohith used making meaning when analyzing statistics regarding space debris.

Phase 4: ARTIFACT DRIVER ANALYSIS (A.K.A Implosion Method)

Driver	Influence on Artifact (25-50 words, complete sentences)	Connection to Data Collection
Bodily/Identity	Space suits are worn by astronauts to protect them from space dangers and give them oxygen. Some aspects of space suits are handmade while more intricate parts are machine made. Astronauts of all genders and race have become accustomed to and worn space suits.	When researching space debris, but more specifically space exploration, it is important to understand any historical context such as different countries and therefore ethnicities launching space programs and also the functionality of different space suits.
Historical	The history of rockets is very complex and runs through different paths. Starting from the space race between the US and Soviet Union from 1957-1975, countries have continued to evolve rockets to travel further and be safer.	Space debris is created by rockets, so understanding their functions and evolution can lead to further understanding of how space debris formed.
Material	The materials used to build a satellite are very specific and important. Space organizations have to pick the right materials in order to keep the satellite intact during takeoff and orbit. They also have to keep things like degradation in mind.	When researching space debris, we found that a lot of space debris are dismembered parts of satellites and rockets, and the materials these things are made of is important in order to find a solution.
Economic	The potential economic impact of the space industry is promising with space tourism on the horizon, and space waste threatens the safety of space tourism, which would in turn affect the economic potential of the space industry	When researching space debris and how we could clean it up, I came across the economic problem of cost. Cleaning up the majority of the space debris because the cleaner rockets would be operating in space without human control.
Educational	Space debris isn't discussed in early education. Most people first learn about it casually through news or entertainment. Some may study it in physics or engineering if pursuing related careers. Broadly, there are gaps in public knowledge on tracking/modeling debris, mitigation technologies, and policy issues.	When researching space debris I noticed how most people when looking at the pop up interviews there was a lack in general knowledge that people had regarding space debris.
Textual	Space agencies and astronomers produce technical debris reports, legal treaties establish debris prevention policies; and academic journals provide occasional review. Public awareness relies on the sporadic mainstream coverage of collisions and mitigation debates, broader outreach on mounting	When researching space debris I found that a lot of the texts were from established companies or government organizations to provide

	debris issues over decades of launches faces funding and distribution barriers despite import.	reports or general information on the topic of space debris.
Symbolic	The presence of space debris demonstrates the symbolic representation of humans interfering and negatively impacting new places. The human footprint is evident all throughout earth, shown through aspects like climate change and land transformation. As humans explore and discover untouched lands, we also disturb and destroy those lands. Space debris shows the result of humans discovering space, which is unfortunately making space even more dangerous.	During the pop up interview, we recognized how a lot of people thought of space debris as a result of human technology. This supports the idea that space debris is a symbol of human disturbance in untouched lands once again.

FIVE STS QUESTIONS

Phase 4: Complete by Monday, December 4

STS Question framed with STS analytical approach	How you derived from data collection and driver analyses. Identify what driver(s) helped you develop the question.	Potential Consequences for your policy issue
Which countries or governments will mitigate space debris and how? (Locating power)	Methods such as active and passive debris removal are primary ways governments hope to mitigate space debris. The political driver asks us to question jurisdiction: who will clean space debris?	Countries may not want to work together to solve the space debris problems and could create political tensions.
Are continuous space exploration activities such rocket launches that contribute to space debris ethical?	While researching space debris and its origins, it is important to examine the economic driver. Continuous pollution of space will lead to economic increase for cleaning and advancement.	As space becomes more polluted, governments and companies may need to spend more money to mitigate debris or change/advance developments of rockets.
How can space agencies and policymakers better model and predict debris propagation over the coming decades given exponential launch rates?	When looking at the policy side of the effects of space debris a lot of the rules are out dated and need updating. Implementing stronger guidelines or laws requiring post-mission disposal for satellites ending life would curb future debris generation.	If regulations are more strict it may pose an issue for all countries working together to see eye to eye.
What have we done in the past that has caused the space debris problem to become so bad? (Seeking stories)	While researching space debris and how the problem became so big, I read that some space debris is from dismembered parts of rockets such as boosters. If we answer this problem completely, we can come	If we find out what habits caused space debris in the past, we can make sure to not to repeat the same mistakes

	up with ways to stop space debris from getting worse.	
When having conversations about space debris, what should people look for in opposing viewpoints?	Space debris is a very political and strongly-viewed topic. There are those in favor of debris mitigation and against it. When debates between these people rise, it is important to listen and highlight valid points.	Debates in the government or between people of power can create tension and further delay any solution or action taken to mitigate space debris.

Phase 5: Technoscientific Policy Memo Requirements: It should include the following sections:

Issue Background – What is the main issue? What basic technical information do we need to understand it? What artifact(s), stakeholders, and activities are at the center of this issue? How are they related to the issue? Who is harmed? (200 words)

Space activities produce millions of pieces of lingering equipment and metal fragments called space debris that can be lethal to future space projects. According to Beihang University Astronautics' Shenyan Chen, these "small particles can be very destructive in a collision due to their high orbital speed". Objects in low-Earth orbit travel at speeds "greater than 7 km/second", easily fast enough to pierce a space suit and the human body. Even on Earth, space debris has its effects. Immediate economic consequences are dealt with by the common citizen. Institutions that produce rocket ships and conduct space exploration require a labor force and funding. Job changes, increased taxes, and fluctuating stocks are all results of erratic space exploration and technology development. Although it has been a year-long problem, space debris is not easily removable as it is first, in space, and second, poses the risk of producing even more space junk. The United Nations has brought it upon themselves to ask all companies to remove their satellites from orbit. This is difficult to carry out as satellites often fail. Some solutions have been suggested including dragging satellites in low-orbit earth into the atmosphere where they will be destroyed automatically. As time progresses, companies are figuring out ways to solve the debris of smaller satellites which are not as easily catchable with their method of grabbing the satellites.

Three STS Questions – From Phase 4, elaborate on three STS questions. Each of the questions should be framed by a different analytical approach (locating power, making

meaning, seeking stories, or finding ethics in artifacts). Describe why this is an important question to address, what stakeholders are affected by it, and how they are affected. Create a sub-section for each STS question. (200 words)

Q1 (Locating Power): How can space agencies and policymakers better model and predict debris propagation over the coming decades given exponential launch rates?

This is an important issue that affects all spacefaring nations and commercial entities. Better modeling is needed to understand debris risks, set policices, and mitigate hazards. Key stakeholders are governmental space agencies that launch rockets, commercial satellite operators, astronomers who depend on orbital assets, and countries without space programs but at risk from uncontrolled reentries. Without addressing exponential debris growth, essential satellite services and launches could become difficult to sustain long-term.

Q2 (Seeking Stories): What have we done in the past that has caused the space debris problem to become so bad?

Understanding the historical decisions, policies, and behaviors that led to the current uncontrolled debris propagation is key to creating solutions. There is no binding international framework addressing space sustainability, despite early warnings from scientists about collision risks from derelict satellites and debris. Key stakeholders affected are governmental space agencies, commercial satellite operators, astronauts, and advocates calling for change. Looking back on past mindsets and decisions leading to the debris problem informs present-day policy and technology solutions. It also serves as a cautionary guide, reminding key players how even benign behaviors like leaving inert rockets to drift can amass into dire issues over decades

without sustainable management. Understanding the emergence of the problem is thus a crucial context for stakeholders debating binding mitigation standards

Q3 (Finding Ethics in Artifacts): Are continuous space exploration activities such rocket launches that contribute to space debris ethical?

This issue balances humanity's drive to explore with environmental stewardship. Supporters argue scientific knowledge gained justifies debris created. However, space is a shared global commons and, soon be crucial for commerce and security. With no binding remediation policies, growing debris hazards could restrict access, especially for nations without debris-clearing technology. Assessing ethics forces reconciling equal access against unchecked exploration. Key stakeholders are governmental space agencies, commercial satellite operators, astronomers, countries without indigenous space launch capability, and advocates for sustainability. All must weigh if unrestricted launches and debris creation violate collective morality to preserve space for peaceful uses and prosperity. With exponentially increasing launch rates, there are calls for binding international guidelines and technology standards before uncontrolled debris propagation begins hindering space utilization.

Audience – Who is the audience for this memo? (100 words)

Since no singular country or organization has control of outer space, its environment is of free use. Right now, there are organizations like ClearSpace-1 whose mission is to “remove space debris and…make space a safer place for future generations”. This company is part of the European Space Agency, who is also “play[ing] a significant role in advancing the global effort to ensure the long-term sustainability of space activities”. National governments have started to

take accountability for their actions and work towards cleaner orbits. But as time passes, the answer to “who” will remove space debris is broad but confident: everyone. Common citizens must push their country’s government and private companies to work together to clear the land of the stars.

1. What level of government: local, state, U.S. Congress, Executive Branch (President’s Office), government agency? And why? (Could be multiple but doesn’t have to be all.)

The level of government that this is targeted towards is the US Congress, mainly because the main organization that can counter against space debris is NASA, which is a federally funded organization. Due to this, the only way we can increase funding for NASA’s space debris research and missions is if congress decides to increase NASA’s budget.

2. Who else? What are two non-governmental stakeholders that should hear about this? Why? These are not the people you are speaking for but people that should hear about the issue.

   Two non-governmental stakeholders that should hear about space debris are teachers who teach the subjects related to it and college students. This is to ensure that future scientists who work in the field of creating satellites that go up into space are informed about the risks they are posing to the satellites that are already in space. In doing so, they can develop new solutions/ideas to fix the growing problem and combat the risk that their satellite poses. College students should also learn about it as they are going into the future fields that design those

satellites. Since they are the next generation to go into the workforce, their unique and new ideas could possibly fix the problems brought by space debris.

Recommendations - What actions should be taken? What body/mind dispositions (at least 2) will be involved with enacting these recommendations? (150 words)

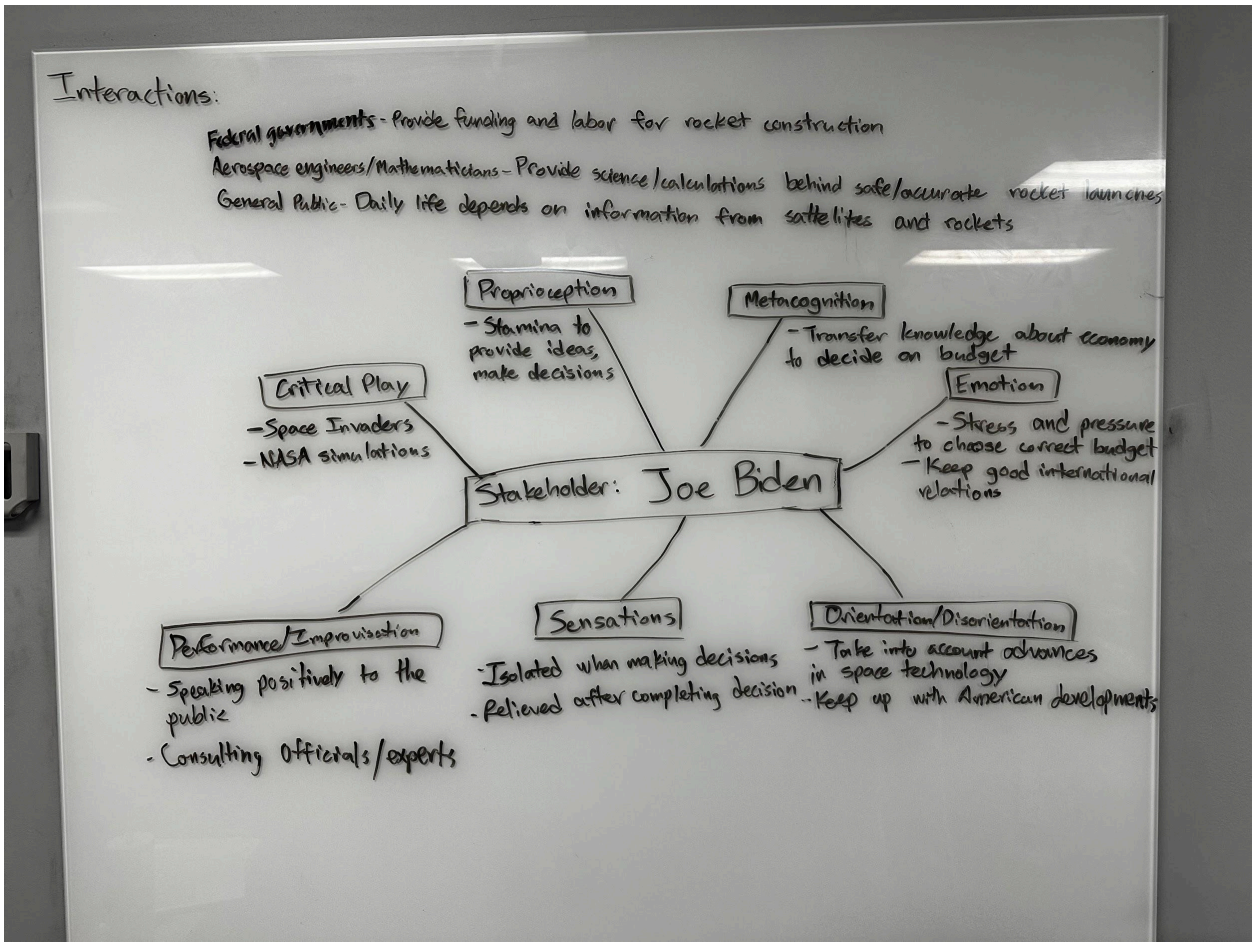
Retrograde thrusters, introduced by Brooke Shellabarger's thesis at Morehead State University, is a "subsystem [that] would use thrusters in the opposite direction of the propulsion system." By doing this, the satellite or rocket's velocity decreases, lowering its orbital altitude. A lower altitude would allow the spacecraft to enter Earth's gravitational field more easily and decay naturally. The system relies on the idea of useless devices being able to leave orbit and reenter the Earth's atmosphere. Earth's gravitational pull then accelerates that object's velocity to the point where it creates enough heat to disintegrate itself. Passive debris removal (PDR) is used for smaller pieces of debris in space. Drag sail deorbiting technology is an example of PDR that attaches a drag sail to space devices. At the Purdue University School of Aeronautics and Astronautics, David Spencer describes how "once the vehicle reaches the end of its operational lifetime, the sail would deploy, using aerodynamic drag as a deorbiting force…work[ing] independent of spacecraft propulsion." Essentially, a dead device will deploy its drag sail to send it back into Earth's atmosphere and disintegrate without the use of thrusters or propulsion.

Phase 6: Artifact that Sparks Conversation

Artifact + Caption:

Caption: Our artifact is a model rocket. Since our research topic is space debris, a rocket illustrates the concept, cause, and effects of space debris all in one. As these machines are launched into the atmosphere, they leave behind both big and little fragments of metal or other solid material. As time goes on, these pieces of debris clog the Earth's orbit, making it dangerous for new rocket launches and future space endeavors.

Mind Map:


Interactions:
Federal governments - Provide funding and labor for rocket construction
Aerospace engineers/Mathematicians - Provide science/calculations behind safe/accurate rocket launches
General Public - Daily life depends on information from satellites and rockets
Proprioception
- Stamina to provide ideas, make decisions
Metacognition
- Transfer knowledge about economy to decide on budget
Critical Play
- Space Invaders
- NASA simulations
Emotion
- Stress and pressure to choose correct budget
- Keep good international relations
Stakeholder: Joe Biden
Performance/Improvisation
- Speaking positively to the public
- Consulting Officials/experts
Sensations
- Isolated when making decisions
- Relieved after completing decision
Orientation/Disorientation
- Take into account advances in space technology
- Keep up with American developments