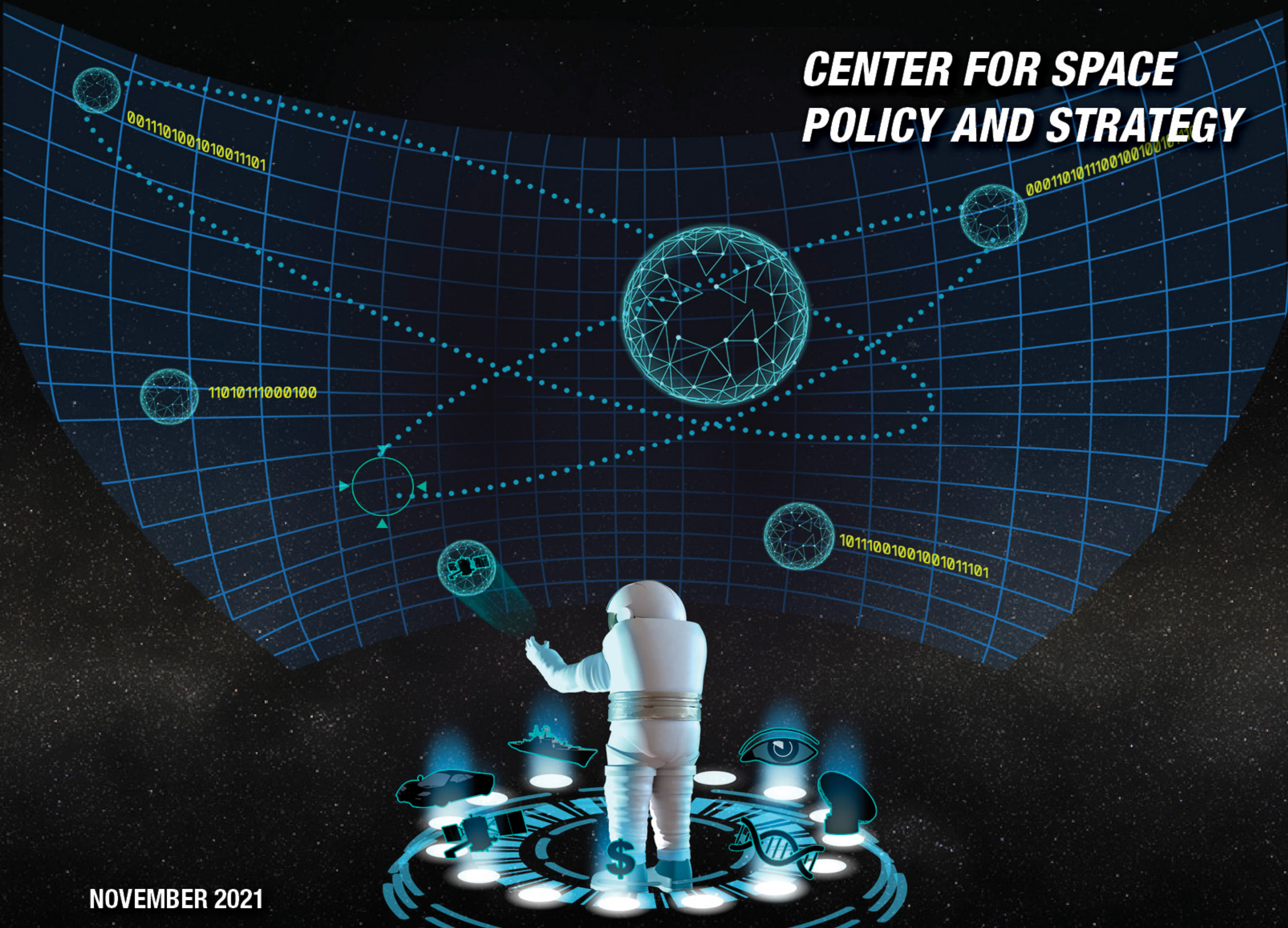

CENTER FOR SPACE POLICY AND STRATEGY

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STRATEGIC FORESIGHT FOR THE SPACE ENTERPRISE

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Summary

Strategic foresight serves as a useful operating system for navigating uncertainty. This paper provides an overview of the perspectives and methodologies behind strategic foresight, and explores how it can be applied to the space enterprise, using just one tool within the foresighting toolkit: the Four Futures Model. By exploring four possible futures for the space enterprise, we can challenge assumptions and begin lines of inquiry into selecting and navigating toward preferred futures and make the most out of uncertainty. Looking ahead, the space enterprise can leverage the insight that foresight approaches offer to drive transformation as humanity strives to expand off-world and deliver greater value back to Earth.

"Foresight turns out to be a critical adaptive strategy for times of great stress."

— Jamais Cascio
American futurist

Foresighting and Its Value to Space

The space enterprise is currently undergoing great transformation and with that comes significant disruption. Fully commercial human spaceflight missions, the potential for a multi-trillion-dollar space economy, and promises of humans returning to the lunar surface in this decade are driving opportunities and challenges that the human race has never before seen. Our world is also becoming increasingly interconnected, leading to new complexities and new behaviors. Arguably, today's global environment, to include the space enterprise, is now volatile, uncertain, complex, and ambiguous (VUCA). Emergent behaviors seen in space are driven by reduced barriers to entry, an influx of private capital and new players, the use of orbital systems and ground systems as a service, and increasing geopolitical competition in space. Cross-cutting challenges and opportunities in the space enterprise are fundamentally different in nature and complexity than has been seen in the past. This signals that new approaches for fielding capability under uncertainty are needed. Strategic foresighting, a still nascent practice focused on enabling better decisionmaking under uncertainty through systemic

Cross-cutting challenges and opportunities in the space enterprise are fundamentally different in nature and complexity than has been seen in the past. This signals that new approaches for fielding capability under uncertainty are needed.

thinking about the future, is particularly valuable for approaching VUCA systems and environments. In a nutshell, decisionmakers need better tools for navigating uncertainty and foresight can help. Space policy issues are prime for strategic foresight analyses because they are highly complex and integrated across a wide range of military, civil, commercial, technological, environmental, and social factors. Policymakers will need to manage these tensions in order to make sound decisions in the short-, medium-, and long-term. If policymaking for space is going to be successful, it must be anticipatory and embrace the fact that the future is inherently uncertain.

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Strategic foresight provides a diverse set of tools and techniques that help us face the challenge of future uncertainty head-on so that we can make better decisions today.[1] Instead of bracing for uncertainty and change as though it is a looming disaster, strategic foresight helps us to envision preferred futures, identify key events and decision points along the path to those futures, and integrate uncertainty into the planning process from the beginning.[2] Strategic foresight does not predict the future; rather, the aim of applying foresight approaches is to challenge assumptions and prepare for a range of possible futures. This can help policymakers accept uncertainty and take proactive action instead of solely responding to changes and surprises after the fact.

Many space policy issues involve challenging tradeoffs or balancing acts: How do you improve safety and security through regulatory oversight while fostering commercial innovation? How do you protect sensitive information while improving transparency and cooperation in commercial and international partnerships? How do you promote the benefits of increased space activity without exacerbating the challenges of space traffic management and orbital debris? How do you cooperate with certain actors in some space activities while competing with them in others? Strategic foresight does not provide a singular answer to these questions, but does provide tools and frameworks for developing robust analyses and insights that policymakers can then apply to make decisions that deliver effective outcomes within VUCA environments.

A Glimpse Inside the Space Futurists' Toolkit: The Four Futures Model

There are numerous tools and methods that strategic foresighting employs to generate actionable insights for shaping the future through decisionmaking in the present.* We begin our exploration of possibilities of the future with the Four Futures Model (originally conceived by Dr. Jim Dator at the University of Hawaii), which provides four archetypes of future storylines: growth, collapse, discipline (or constraint), and transformation. Once a baseline of drivers and trends is established (by looking at the present), the four futures provide corner cases across which possible investments, technologies, solution approaches, and decisions can be evaluated. Reminiscent of wargaming, this approach allows us to see how decisions could play out across different sets of assumptions. The Four Futures Model challenges us to rethink assumptions, consider

*For those interested in exploring other tools of foresight, see expert resources such as the University of Hawaii at Manoa, Institute for the Future, University of Houston, and Kedge Futures School.

multiple possibilities for the future, and make better decisions today as a result.

Developing a Futures Baseline for Space: Drivers, Trends, and Signals

The graphic below illustrates possible future states, which are divergent storylines that could unfold from the present. In order to understand where the future could go, we need to have a grasp on the present forces that could drive those futures. This section will present the common starting point for each of the four futures. Foundational futures analysis usually identifies both the key drivers and trends that are actively shaping the environment today. A driver is a significant force pushing change and a trend is a tangible vector (with velocity and direction) for which change is characterized. While this is very helpful in establishing starting points for scenario development, it is not sufficient for properly characterizing VUCA environments. Using strategic foresight best practices, the common baseline should also be rooted in real signals of change that are just starting to be identified in present research, news, and current events. In foresighting terms, a signal is a tangible manifestation in the present of what is possible to come in the future. It may not have scaled yet into an emerging or established trend, and may never will, but it offers a valuable potential window to peer into the future.

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Once a baseline is established, we must use the combinations of drivers, trends, and signals, along with imagination to consider a range of possibilities of the future. Looking out, not just a few years, but 10 to 20 years and beyond allows us to see the great waves of potential disruption and

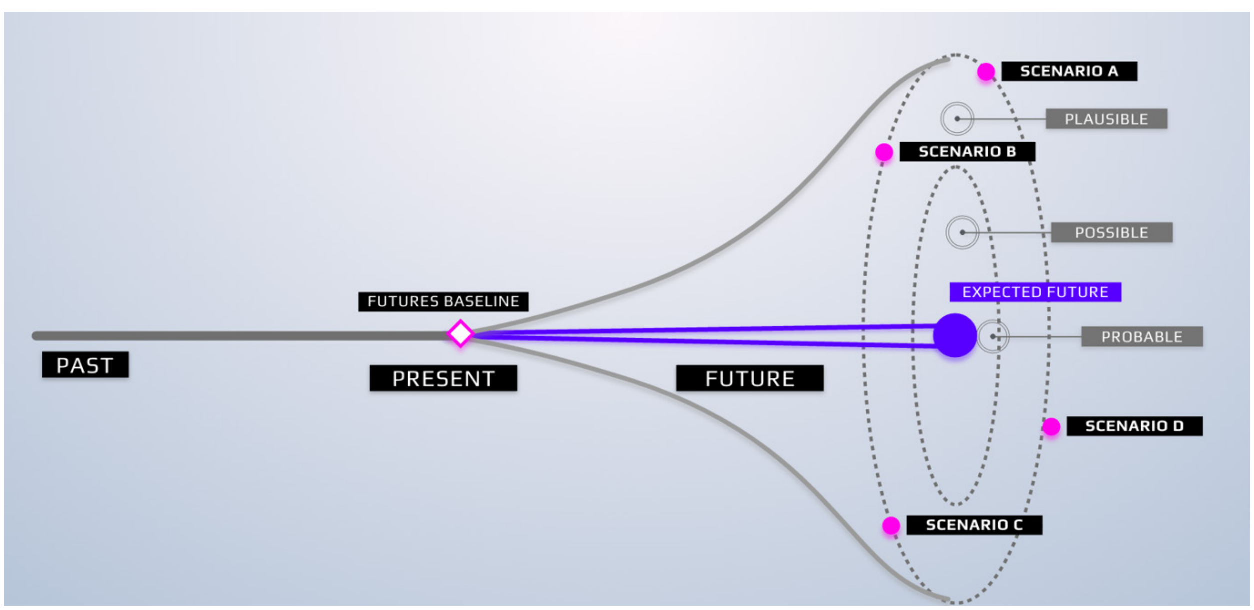


Figure 1: Creating corner cases of the future in the Cone of Uncertainty.

transformation that might be missed if we were only assessing today's projected trends. Hence, for this demonstration, we choose to focus our scenario timelines around 2040. While specific timelines are easier for most to conceptualize, a more effective way of thinking about change is through potential waves of disruption, which can be accelerated or slowed by a variety of complex factors. The timeframe of 2040 is a reasonable timeline for us to consider as we look for the potential next big wave of disruption to happen in space. This could of course come earlier or later, or not at all, given the play in a VUCA environment, but it is a good place to start.

Parameters

In this section, we will explore four possible future states for the space enterprise in 2040:

1. **Growth:** Modest Expansion of Space Capabilities
2. **Collapse:** No Escape Velocity from Earth's Problems
3. **Discipline:** Risk Drives Robots (Not Humans) to Mars
4. **Transformation:** Space Serving Abundance for Humankind

Each of the scenarios considered in the exercise below is an evolution from the same projected baseline. The baseline given here is presented through the lens of current U.S. national policy objectives aimed at the most general national goals of peace, prosperity, liberty, and collective American values. We introduce 10 parameters that give a broad picture of the status quo, with a simple three-tiered ranking system for each parameter. These parameters were chosen based on the knowledge and expertise of our team, who are professional practitioners of foresight working across the space enterprise. The parameters merely help qualitatively evaluate considerations across futures and are by no means "exact" in representing the future, which is fluid and changing by its definition. The qualitative assessments of present and future states that are described by these parameters allow us to observe shifts from one state to another, and they also allow us to compare rates of change within a single parameter. These kinds of observations often produce greater insight for decisionmakers than point predictions that only take into account a singular future state based on present facts.

1. **U.S., Allies, and Partners Leadership.** The relative influence of the U.S. and its allies and partners on global norms of behavior and governance.

2. **Global Technological Change.** The nominal or aggregate rate at which technological change is occurring. This hints at the possibility of an "artificial intelligence singularity."[3]

3. **Earth Environmental Stability.** The general state of the terrestrial climate, relative to the "crisis" status quo of 2020.

4. **Commercial Viability.** The economic health and independence of the commercial space sector.

5. **Resilience.** The general ability of space systems to operate through, survive, and recover from adverse conditions (e.g., manmade threats or natural disasters). "Anti-fragile" refers to the ability to grow stronger or more useful as a result of such conditions.

6. **Geopolitical Stability.** The general geopolitical balance of power around the world and the nature for which it is in competition and conflict.

7. **Scientific and Exploration Interest.** The overall drive that the human race possesses to invest in science and space exploration.

8. **Sustainable Human Presence.** The maturity of extraterrestrial human civilization.

9. **Usability of Space.** The extent to which space debris or other environmental challenges have hampered our ability to use orbital space for designed purposes.

10. **Economic Prosperity.** The relative, overall equality and economic well-being of all humans, on Earth and in space.

These 10 parameters were chosen to provide a mechanism for describing a wide variety of possible futures — even futures in which fundamental assumptions about today's status quo may be questioned. However, it is possible that years from now, there may be a different set of parameters that could be chosen to describe more aptly the status quo, and the fact that this may be so illustrates the challenge of comparing possibilities of future worlds across long timelines in a VUCA environment.

Baseline

The 2021 status quo may be described by the ratings shown in Figure 2. These ratings are based on expert assessment of signals by The Aerospace Corporation's Strategic Foresight Team.

In 2021, the U.S. and its allies and partners are still widely viewed as being among the top leaders on the global stage, in media, and in the political sphere. Technology development is ever-increasing; its progression is more intense than merely linear, but we have not yet reached the sort of "intelligence explosion" that is speculated to arrive with artificial general intelligence (AGI), the point at which machines are able to understand the world at the same level as humans. Moore's Law regarding improvements in transistor manufacturing and computational capability is being questioned, but there is no consensus on whether we have outgrown

ARCHETYPES OF POSSIBILITY

BASELINE

POSSIBLE VARIABLES IMPORTANT TO SPACE ENTERPRISE LEADERSHIP			
U.S., Allies, and Partners Leadership	U.S., etc., Trails	Global Parity	**U.S., etc., Leads**
Global Technological Change	Linear	**Accelerated**	Exponential
Earth Environmental Stability	Uninhabitable	**Crisis**	Healing
Commercial Viability	Fully Dependent on Government Funding	**Partially Commercially Sustained**	Could Operate Independent of Government Funding
Resilience	**Brittle**	Robust	Anti-fragile
Geopolitical Stability	Unrestrained Competition	**Predictable Competition**	General Acceptance of Status Quo
Scientific and Exploration Interest	**Limited Community**	General Population	Global Imperative
Sustainable Human Presence	**Temporary Visits**	Space-Steading	Interplanetary Societies
Usability of Space	Inaccessible/Inoperable	**Constraining Hazards**	Hazard Reduction
Economic Prosperity	Exacerbating Inequality	**Earth Status Quo**	Abundance for All

Figure 2. The 2021 Baseline.

it completely. Public discourse on climate change is lively, and many operate from a position of "crisis mode." Commercial space has met significant milestones, such as fully commercial crew launches, but it is currently far from accessible to the general public. In its whole, space infrastructure (including its ground components) is considered brittle rather than robust. The 2021 formation of the Department of Homeland Security Cybersecurity and Infrastructure Security Agency (CISA) Space Systems Critical Infrastructure Working Group is an indicator of the current state of affairs in that regard.[4] With respect to geopolitical competition, the major players are known, and emerging states have been identified. Public interest in space science and exploration has increased in recent years, but the general world population is by no means focused on extraterrestrial civilization as a top priority for humanity. Human presence in space is limited to suborbital flights or long-duration stays on LEO space stations. Space debris continues to impact LEO operations but not to the extent that key orbits have become unusable. Finally, terrestrial standards of living have increased dramatically over the last century, and yet significant portions of the population remain in poverty. All of these considerations set the stage for the following discussion of possible futures.

The projected baseline (that is, where we might reasonably expect to be in 2040 if current trends continue unabated) shifts from the 2021 baseline in three of the 10 identified areas, as shown in Figure 3. First, global leadership shifts from being led by the U.S. and like-minded nation-states to relative parity with China and its allies. Second, the global technological change rate will increase from "Accelerated" to "Exponential," especially as key enabling space technologies in data analytics and artificial intelligence, propulsion, manufacturing, resource extraction, and more importantly the convergence of all of these factors, will be used to augment human endeavors. Finally, Geopolitical Stability starts to potentially shift from "Predictable Competition" to "Unrestrained Competition," which reflects the increasingly competitive nature of

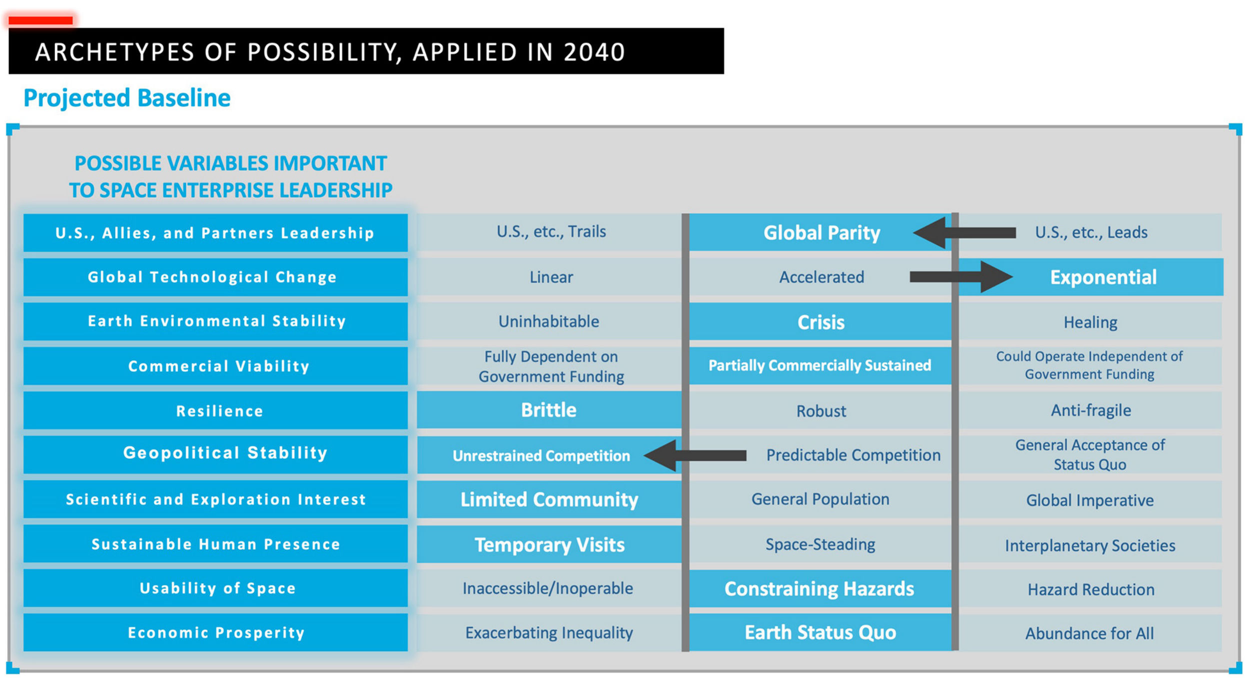


Figure 3: The 2040 Projected Baseline.

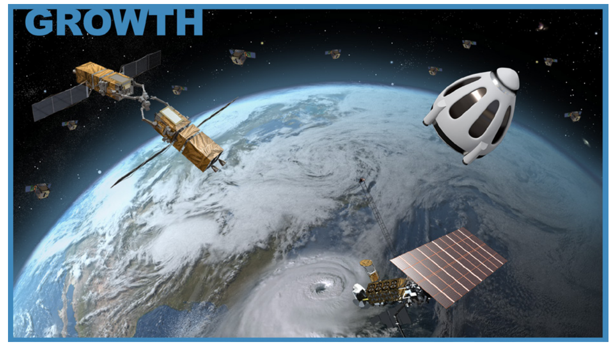
the space environment with respect to international bids for influence and market share of an emerging space economy. This projection is by no means a prediction; it merely provides a common starting point from which to explore possible deviations, four of which are given below.

The Four Futures

The value of foresight is to force the difficult question: What would we do to thrive in each of these possible futures?

In the following four futures, consider how the U.S. might proceed in its development and investment decisions with respect to the space enterprise. These scenarios are not intended to be inherently "good" or "bad"; even the "collapse" scenario is not "bad." Different parties can thrive or struggle in any of these possible futures, depending on the choices they make. The value of foresight is to force the difficult question: What would we do to thrive in each of these possible futures?

Additionally, we encourage the reader to suspend disbelief in any assumptions in a future state that may be considered outlandish. Do not fight the scenario; go along with it. Predictions will be wrong. Strategic foresight is most valuable when "corner cases" can be thoroughly evaluated under their own weight and then used to challenge assumptions in the present.



Growth: Modest Expansion of Space Capabilities

In the Growth scenario, technology advances quickly but predictably and is not revolutionary enough for other countries to overtake U.S. investment and experience in space. This pairs with the strengthening of trade and security cooperation agreements between the United States and its allies such that they remain geopolitical leaders both in space and terrestrially, while Russia and China remain strong but relatively isolated geopolitically. The United States continues to improve the resilience of its space architectures in an attempt to decrease the risk presented by the competitive, but relatively stable, space environment: conflict in space is a risk but has remained in the gray zone between peace and open warfare. Compared to the bounded political competition, economic competition and growth in space is significant, though not revolutionary. The space economy triples in size to $1.4 trillion by 2030, but industry does not manage to become fully independent of government financial support. A small but dedicated community pursues commercial exploration and development beyond LEO: by 2040, only 30 "tourists" in history have traveled more than 1,000 miles from Earth, and it still costs hundreds of thousands of dollars for civilians to visit space. Despite the steady expansion of human presence in space, only some benefits from space activities—like high-speed internet and navigation services—are felt directly by the general population. As a result, space is not widely recognized as a domain that could provide significant solutions to societal problems, like income inequality and climate change. Many policymakers and lawmakers invest in space activities in search of solutions to the ongoing climate crisis. However, they focus on proven space services, such as environmental and weather monitoring, and by 2040 there are still no revolutionary space-based solutions to reverse the overall threat from climate change.

As compared to the 2021 baseline, key changes are an improvement in space enterprise resilience from "brittle" to "robust" and an expansion of human presence in space that qualifies as "space-steading." In this future, it is the successful risk management related to international economic competition that drives both changes. The rate of technological advancements and dynamics generated by geopolitical shifts remain pervasive challenges, with no radical transformations in either domain.

ARCHETYPES OF POSSIBILITY

GROWTH

POSSIBLE VARIABLES IMPORTANT TO SPACE ENTERPRISE LEADERSHIP			
U.S., Allies, and Partners Leadership	U.S., etc., Trails	Global Parity	**U.S., etc., Leads**
Global Technological Change	Linear	**Accelerated**	Exponential
Earth Environmental Stability	Uninhabitable	**Crisis**	Healing
Commercial Viability	Fully Dependent on Government Funding	**Partially Commercially Sustained**	Could Operate Independent of Government Funding
Resilience	Brittle	**Robust**	Anti-fragile
Geopolitical Stability	Unrestrained Competition	**Predictable Competition**	General Acceptance of Status Quo
Scientific and Exploration Interest	**Limited Community**	General Population	Global Imperative
Sustainable Human Presence	Temporary Visits	**Space-Steading**	Interplanetary Societies
Usability of Space	Inaccessible/Inoperable	**Constraining Hazards**	Hazard Reduction
Economic Prosperity	Exacerbating Inequality	**Earth Status Quo**	Abundance for All

Figure 4: Attributes of the "Growth" future.

Collapse: No Escape Velocity from Earth's Problems

In the Collapse scenario, numerous crises on Earth become too serious for many states to take a long-term approach to investing in space activities, with technology not improving fast enough for space to be seen as a significant outlet to help resolve Earth-bound issues. Over the next 15 years, states are bankrupted by the catastrophic effects of climate change, recurring pandemics, and drastic shortages in resources like clean water. Tension around the globe heightens particularly over food insecurity and scarce resources like water and energy, with local conflicts for control over these resources escalating to political, economic, and military confrontation between states. These tensions result in a missile and nuclear proliferation cascade among sets of neighboring adversaries (such as India and Pakistan, North and South Korea, and Saudi Arabia and Iran). Several of these states decide to demonstrate their new capabilities through irresponsible and harmful high-altitude nuclear testing that ultimately makes very low Earth orbit (VLEO) impossible to use without extensive shielding, raising satellite mass and reversing the trend of decreasing launch costs. American leadership in space becomes a liability in this case, as the U.S. has the most to lose. Due to these circumstances, the space economy peaked at $500 billion annually in 2030, declining to $200 billion by 2035. A small community of the space enthusiasts continues to argue that the only solution to problems on Earth is to move away from Earth, attempting to set up outposts on the moon and Mars, made significantly more difficult by the damaged VLEO environment through which all launches must pass. But these are only accessible to the wealthiest entrepreneurs and such efforts exacerbate inequality gaps with the poorest Earthbound individuals.

As compared to the 2021 baseline, the instability of the global environment has led to significant shifts, both in terms of how people live their daily lives and in terms of the primary concerns of policymakers and decisionmakers. Both terrestrial and near-Earth space environments have become significantly less usable, at least with known techniques and methods. This presents both a challenge and an opportunity to rethink how even the most basic daily needs can be met for large segments of the population. The shift from predictable to unrestrained competition may be a silver lining of opportunity in that regard. Note the narrow window of opportunity to develop off-world human presence in space, and the "single point of failure" that wealthy space entrepreneurs have become, in the context of this future: Can they rally humanity around the common aim of lunar settlements? Will they behave philanthropically? Autocratically? What impact could that have on global stability? And will that dynamic be more important or less important than the geopolitical tensions that have already risen to the point of high-altitude nuclear testing? The Collapse future, although perhaps undesirable for some players, can help us ask good questions to begin to prepare today.

ARCHETYPES OF POSSIBILITY

COLLAPSE

POSSIBLE VARIABLES IMPORTANT TO SPACE ENTERPRISE LEADERSHIP			
U.S., Allies, and Partners Leadership	U.S., etc., Trails	Global Parity	**U.S., etc., Leads**
Global Technological Change	**Linear**	Accelerated	Exponential
Earth Environmental Stability	**Uninhabitable**	Crisis	Healing
Commercial Viability	Fully Dependent on Government Funding	**Partially Commercially Sustained**	Could Operate Independent of Government Funding
Resilience	**Brittle**	Robust	Anti-fragile
Geopolitical Stability	**Unrestrained Competition**	Predictable Competition	General Acceptance of Status Quo
Scientific and Exploration Interest	**Limited Community**	General Population	Global Imperative
Sustainable Human Presence	Temporary Visits	**Space-Steading**	Interplanetary Societies
Usability of Space	**Inaccessible/Inoperable**	Constraining Hazards	Hazard Reduction
Economic Prosperity	**Exacerbating Inequality**	Earth Status Quo	Abundance for All

Figure 5: Attributes of the "Collapse" future.

Discipline: Risk Drives Robots (Not Humans) to Mars

In the Discipline scenario, technological capability improves at a much faster rate than social and political structures, causing governance to fall behind without hope of catching up. At first, the changing technology and its rapid proliferation allows other state actors to reach parity to many U.S. space capabilities, most notably due to affordable and at-scale self-replication and on-orbit manufacturing, but the lack of established norms and regulations leads to chaotic competition and instability in space. Although advancement of intelligent systems and integration of autonomy aids individual operators in collision avoidance, different companies and countries each use their own standards to set priorities and assumptions, which result in increasingly unpredictable interactions between incompatible systems. This results in several collisions between small satellites from different mega-constellations and accidents during rendezvous and proximity operations due to miscommunication between participants. The unrestrained competition and accidents caused by miscommunication escalates beyond robotic operations and low Earth orbit to human activities on the moon. In 2032, a commercial astronaut is killed on the moon during a dispute between two companies over lunar mining—the first ever murder in space—and confusion over jurisdiction and international law prevents her killer from ever facing trial or prison. Ultimately, these incidents and accidents increase debris, and lead to fear and mistrust between space actors, which eventually prevents the establishment of a safe, stable commercial market. Many space companies return to reliance on government funding in order to offset the substantial risk, while withdrawal of investment and venture capital due to heightened risk gradually forces many start-ups out of business. This results in a poorly regulated space economy made up of fewer companies and worth $900 billion in 2030. Robotic exploration of the solar system continues but human exploration efforts are consistently delayed, underfunded, and fail to capture the imagination of the broader population the way the Apollo program did in the 1960s. Instead, the general population notes the uneven distribution of benefits from space and pushes for investment elsewhere to resolve other crises on Earth.

As compared to the 2021 baseline, we first note that while technology is evolving more rapidly, social and political structures fall behind, and U.S. influence is decreased. In a nutshell, technology advancements alone do not guarantee the future success of space. Without smart policy constructs that guide both technology use in a positive way and international establishments of norms, we still may not see the growth and development that we would like. This alerts us to the constraints that surface as a result: fewer exploratory missions with human crews, more accidents in space, and a lack of unified vision for the U.S. space program. (Or did the lack of vision lead to the lag in U.S. influence? Our foresighting process has prompted another key discussion!) Also note the combination of exacerbating inequality and the dependence of commercial space on government funding presented in this future. What framework may be used to prioritize government spending given this scenario? Limited budgets are common across all futures, but the discussion drawn out by this future brings the topic of budgetary priorities front and center.

ARCHETYPES OF POSSIBILITY

DISCIPLINE

POSSIBLE VARIABLES IMPORTANT TO SPACE ENTERPRISE LEADERSHIP

U.S., Allies, and Partners Leadership	U.S., etc., Trails	**Global Parity**	U.S., etc., Leads
Global Technological Change	Linear	Accelerated	**Exponential**
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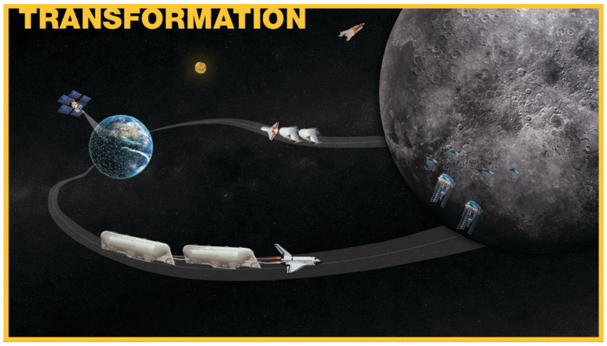
Economic Prosperity	**Exacerbating Inequality**	Earth Status Quo	Abundance for All

Figure 6: Attributes of the "Discipline" future.



Transformation: Space Serving Abundance for Humankind

In the Transformation scenario, the development of revolutionary space technologies leads to global recognition that space can be used in many ways to solve problems on Earth. Other spacefaring nations have bolstered their space programs significantly, and some are as large as or larger than that of the U.S. by 2040. International efforts help to develop safe and sustainable norms of behavior, which bound this competition and keep the geopolitical balance in space relatively stable and predictable. This allows for a significant expansion in the overall level of activity in space, and the integration of intelligent systems, human/machine teaming, and other automated labor increases efficiency and allows for innovation to occur quickly across the space enterprise. Technologies developed in space science and exploration as well as increasing satellite-based environmental monitoring and response services provide information and capabilities helpful both in reducing the climate crisis and in reducing hazards in the space environment. In the late 2020s, the United Arab Emirates (UAE) leads an international team to conduct the first successful test of powering a city using solar power collected and distributed via satellite. By 2035, the UAE model of satellite-based solar power becomes mainstream, and many countries shift investment from non-renewable resources, such as oil and coal, to this innovative form of solar. Additionally, mega-constellations of satellites provide internet to billions of people across the globe, and commercial companies recognize satellite-based internet as a critical and lucrative market. These immersive and integrated networks are self-healing and proactively repair and protect against anticipated disruptions and threats. As a result, space becomes a $5 trillion industry by 2040. Commercial activity comprises most of the space economy, and there is no longer dependence on government funding. The space workforce has an incredibly high demand for labor, but can attract needed talent due to the exciting and wide-ranging career opportunities it provides. Students learn skills necessary to enter the sector as early as grade school and a more diverse subset of the population participates in the advancement of space due to intentional outreach and educational programs that were put in place.

Because space is considered a key resource for energy, communication, and other critical space-based technology, many spacefaring nations have developed means to defend their space objectives militarily. Geostationary orbit, the Lunar South Pole, and key positions between the moon and Earth all become particularly hot pockets of focus. Warfare has not broken out in space, but the possibility and feasibility of such conflict is much greater due to increasing entanglement between human activities in space and on Earth.

As compared to the 2021 baseline, in this future it seems we are headed in a utopian direction for many. Rather than dismiss this as fanciful thinking, foresight practitioners can use this as an opportunity to connect the dots from where we are to where we want to go. In this case, several signposts of significant change turned out to be fruitful: the development of space-based solar power, the international acceptance of norms of behavior in space, the efficacy of STEM education, and the proliferation of a commercial space economy. Foresight practitioners should ask: What policies or decisions early on led to these signposts coming to fruition? And although the Transformation future seems utopian, we should also ask: Does a rising tide really raise all boats or are there players who do not "win" in this future? Who are they, and what's preventing them from thriving in this scenario?

ARCHETYPES OF POSSIBILITY

TRANSFORMATION

POSSIBLE VARIABLES IMPORTANT TO SPACE ENTERPRISE LEADERSHIP			
U.S., Allies, and Partners Leadership	U.S., etc., Trails	**Global Parity**	U.S., etc., Leads
Global Technological Change	Linear	Accelerated	**Exponential**
Earth Environmental Stability	Uninhabitable	Crisis	**Healing**
Commercial Viability	Fully Dependent on Government Funding	Partially Commercially Sustained	**Could Operate Independent of Government Funding**
Resilience	Brittle	Robust	**Anti-fragile**
Geopolitical Stability	Unrestrained Competition	**Predictable Competition**	General Acceptance of Status Quo
Scientific and Exploration Interest	Limited Community	General Population	**Global Imperative**
Sustainable Human Presence	Temporary Visits	**Space-Steading**	Interplanetary Societies
Usability of Space	Inaccessible/Inoperable	Constraining Hazards	**Hazard Reduction**
Economic Prosperity	Exacerbating Inequality	Earth Status Quo	**Abundance for All**

Figure 7: Attributes of the "Transformation" future.

Cross-Futures Themes and Analysis

Each of these futures has been presented to demonstrate the different kinds of issues and questions that can be raised across different sets of assumptions. This ensures that a wide range of possibilities are considered and, therefore, more resilient and future-ready strategies and plans can be constructed. The looking glass across multiple futures illustrates the unpreferred futures states and the means of reducing the risk of ending up there, but also encourages us to identify aspirational futures and the tangible paths towards them.

For example, one common theme across all four futures is the impact of the size of the space economy on the health of the larger space enterprise and benefits to humanity. Whether it was steady growth through government investment, individual entrepreneurs making big bets, or explosive growth associated with off-world internet, the economic health of the space sector was a vital indicator of expansion across these futures. This prompts a second layer of questions, such as "What actions could be taken in each of these futures to gird up the economic health of the space sector?"

Another insight that can be distilled across these futures is that the pace of activity continues to increase, and therefore a sense of urgency must be manifested in order to develop and deploy capabilities at the speed of relevance. Higher risk tolerance—or at least different approaches to risk (and opportunity!) management—in space system development may be necessary to meet the need for speed. This insight is further amplified with the observation that many capabilities may become commoditized as the space economy matures (for example, navigation or energy/power). When more space-based capabilities are offered "as a service," what will that mean for government investments in space systems and technologies?

This leads to a final observation of another "critical uncertainty": geopolitical power shifts, which include nation-states and other non-state entities like large corporations. Which parties will be most influential in shaping the culture, the norms of behavior, and the standards of the future space enterprise? Is this inevitable? Which parties *ought* to shape these elements of the enterprise, and why?

Disruption and "Surprise"

"It is change, continuing change, inevitable change, that is the dominant factor in society today. No sensible decision can be made any longer without taking into account not only the world as it is, but the world as it will be…This in turn, means that our statesmen, our businessmen, our everyman must take on a science fictional way of thinking."

– Isaac Asimov

Relying solely on projections from the present is a dangerous practice if we expect to be resilient and prepared in the future, and furthermore if we expect to actually shape the future into something better beyond the status quo. Thinking about multiple futures serves as a fruitful exercise to expand mindsets beyond today. However, if we expect to be future-ready, we must supplement with additional approaches. There are several kinds of surprises or "shocks" that need to be considered. The first are the "known knowns," the current and emerging issues that we know are there. Perhaps the perceived likelihood and impact varies, but we choose to do nothing about it. Systemic supply chain weaknesses, space debris, and cyber vulnerabilities are great examples of "known known" shocks that could disrupt the space enterprise. The scenarios presented above primarily incorporated these known knowns. This was intentional as to try to instill confidence in the reader that there is a systematic and data-driven approach to thinking about the future. However, without considering wild cards and other system shocks, one could form potential blind spots and brittle points in strategies and plans that are conceived from such future exercises.

There are also "known unknowns," things that are not necessarily tangible manifestations already in today's world, but that are on our radar for what *could* happen. For example, Earth's first contact with an alien arrival, a massive asteroid impact that could wipe out humanity, an unexpected scientific breakthrough like unbreakable encryption, teleportation, general artificial intelligence, or genetic modification that helps humans optimize for living and working in space. These are often the shocks that are dismissed as fanciful, yet are also the most useful when thinking about possible future disruption. While we refrained from inserting any perceived "ridiculous" shocks into our scenarios, they are extraordinarily valuable and a critical component of good futures work. We will not be prepared if we do not explore these possibilities.

Finally, there are the "unknown unknowns," often referred to as Black Swans[†], the truly core-shaking, paradigm-shifting shocks that we never imagined and never saw coming. While the future is inherently uncertain and will hold these unknown unknowns, foresighting can help uncover more of these possibilities so that they are considered and incorporated into planning for resiliency against them.

Relying solely on projections from the present is a dangerous practice if we expect to be resilient and prepared in the future, and furthermore if we expect to actually shape the future into something better beyond the status quo.

[†]A "Black Swan" is an event that is difficult to predict but has very large impact. Often such events are viewed as predictable in hindsight. See Nassim Taleb's 2007 book, *The Black Swan*.

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The infinite possibilities of the future in a VUCA world may seem so daunting as to preclude meaningful action to prepare for the future. However, keep in mind the goal is not to be "correct" in prediction; the goal is to "widen the aperture" of what can be placed on the table for discussion to enhance the decisionmaking posture. The methods of strategic foresight enable us to challenge assumptions before we become beholden to them. It also prevents us from "bike-shedding," focusing precious limited resources on marginal issues which could inhibit our ability to address the core issue.[‡] One goal of foresighting is to focus the conversation on the most important questions—which may also at times be the most unsettling ones to face.

Throughout history, there have been numerous examples of shocks that shaped humanity for centuries to come. Such shocks include, but are not limited to, natural disasters, diseases, technological breakthroughs, social movements, conflicts and wars, deaths of significant people, and economic recessions/growth periods. These disruptions, both positive and negative, can be traced back to thousands of years ago. Take the Justinian Plague[5], for example. In the years 541 to 542, this disease killed a quarter of the Byzantine Empire population, weakened their ability[6] to defend against their enemies, and played a role in the termination of slavery in the area since a shortage of labor enabled slaves to leverage freedom. A disease this impactful would have been hard to predict, but proper foresighting and preparation may have mitigated some of the consequences. The Industrial Revolution also represents a critical shock in history. The introduction of industrial processes streamlined production and increased quality of living for many. However, it also triggered wealth inequality, child labor[7], irreversible effects on the environment, and even parts of the Women's Suffrage Movement. Ultimately, history exemplifies how shocks in any system can lead to chain reactions that are significant and unpredictable. Foresighting is a valuable tool to prepare for a wide range of outcomes like these. If we can spot undesirable outcomes ahead of transformation and disruption, we can design and bake-in solutions so that outcomes are better for all.

Think we haven't been shocked in space? Think again. The Soviet Union's launch of Sputnik, the first of Earth's orbiting artificial satellites, in 1957 was a shock felt around the world. In more recent

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[‡] "Bike-shedding" refers to the tendency to focus narrowly on things we can understand rather than things we consider too complex, at the expense of solving the most important problems. The name derives from a parable in which a government council spends the same amount of time talking about a $1,000 bike shed as they spend discussing a $30,000,000 nuclear reactor.

There is a significant chance that someday soon, humans will live on Mars, babies will be born in space, and tourists will regularly visit the moon. Are we planning our contributions to the future space enterprise with these things in mind?

years, China's destructive anti-satellite (ASAT) test in 2007 is an example of a single event that quickly became cited as disruptive and continues to be cited in discussions today as a significant milestone in the history of the use of space. Any anticipation of that event or prior planning around its consequences was not manifested into mainstream space operations; space strategists and operators were reactionary and had to adjust their thinking and their actions after the fact. In another example, SpaceX has drastically reduced the cost of launch with its approach in reusable rockets. How many space experts would have said 20 years ago that this was a possibility? How many other potential "space shocks" could change the way business is done today? Our sister product, Aerospace's "Pathfinder's Guide to the Space Enterprise"[8] creatively explores similar disruptive potential in more depth. Will we let ourselves be tossed by the winds and waves of happenstance or will we alter our thinking to enable us to proactively prepare for such disruptive eventualities? There is a significant chance that someday soon, humans will live on Mars, babies will be born in space, and tourists will regularly visit the moon. Are we planning our contributions to the future space enterprise with these things in mind?

In the context of today's space enterprise, consider the complex relationships among existing and emerging stakeholders, including civil space agencies, commercial ventures, national security missions, and international players in collaboration and competition. Our Four Futures have illustrated the potential impact of different governance models for space activity: whether the U.S. leads in behavioral norms and whether commercial space ventures thrive, leading to quite different states of affairs. It is likely that in no scenario do all of these players fare better than baseline, nor is it likely that all would simultaneously fare worse than baseline. But each player can make decisions today to prepare for any of these futures, to ensure they fare better than they otherwise might.

Finally, the futures we presented in the above exercise are simplified snapshots in time. It is important to recognize that the thread that connects us between now and the future is highly connected and driven by the *dynamics* between all of the players and systems in the ecosystem. Spending time incorporating plans not just against foreseen futures, but also against imagined disruption and surprise through dynamic future models can further those efforts.

Conclusion

"Be stubborn about your goals, but flexible about your methods."

– William A. Donohue
Managing Interpersonal Conflict (1992)

The Four Futures model is just one of many foresight tools within the Space Futurists' toolkit that can better shape our perceptions and plans for future preparedness. But even in this brief illustration, several critical points have been raised, including the importance and impact of various governance models for space activity, and how the governance models of 2040 and beyond may be impacted by policy and investment decisions made today.

To apply foresight methods successfully, we must understand our own aims and explore creative ways of arriving at those ends. While foresight tools and methods exist that can help uncover and reframe these goals, ultimately they must be championed and utilized by decisionmakers. In the space enterprise, who will be calling the shots? Foresighting methods empower first movers: those that chart their North Star aspirational futures will be best postured to make it a reality. These methods encourage diverse perspectives and multidisciplinary thinking to be brought to bear against some of the most challenging problems. For example: What could daily life look like on the first permanent lunar and Martian settlements? What are the critical enablers for those possible outcomes? Will we even get there at all? And what are the stakes and implications for humanity if we do not?

The possibilities for the future space enterprise range from exciting to boring to terrifying and beyond. Foresighting empowers the agility and adaptability needed to proactively navigate these futures to stakeholder advantage and build opportunity and value beyond what exists in today's baseline. Strategic foresight serves as a useful operating system for navigating uncertainty. However, it is up to the great leaders and doers across the space enterprise to integrate such insights and put them into action. As we look forward, the space enterprise will need bold leadership to leverage what foresight can bring to the table to drive transformation as humanity reaches for the stars.

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