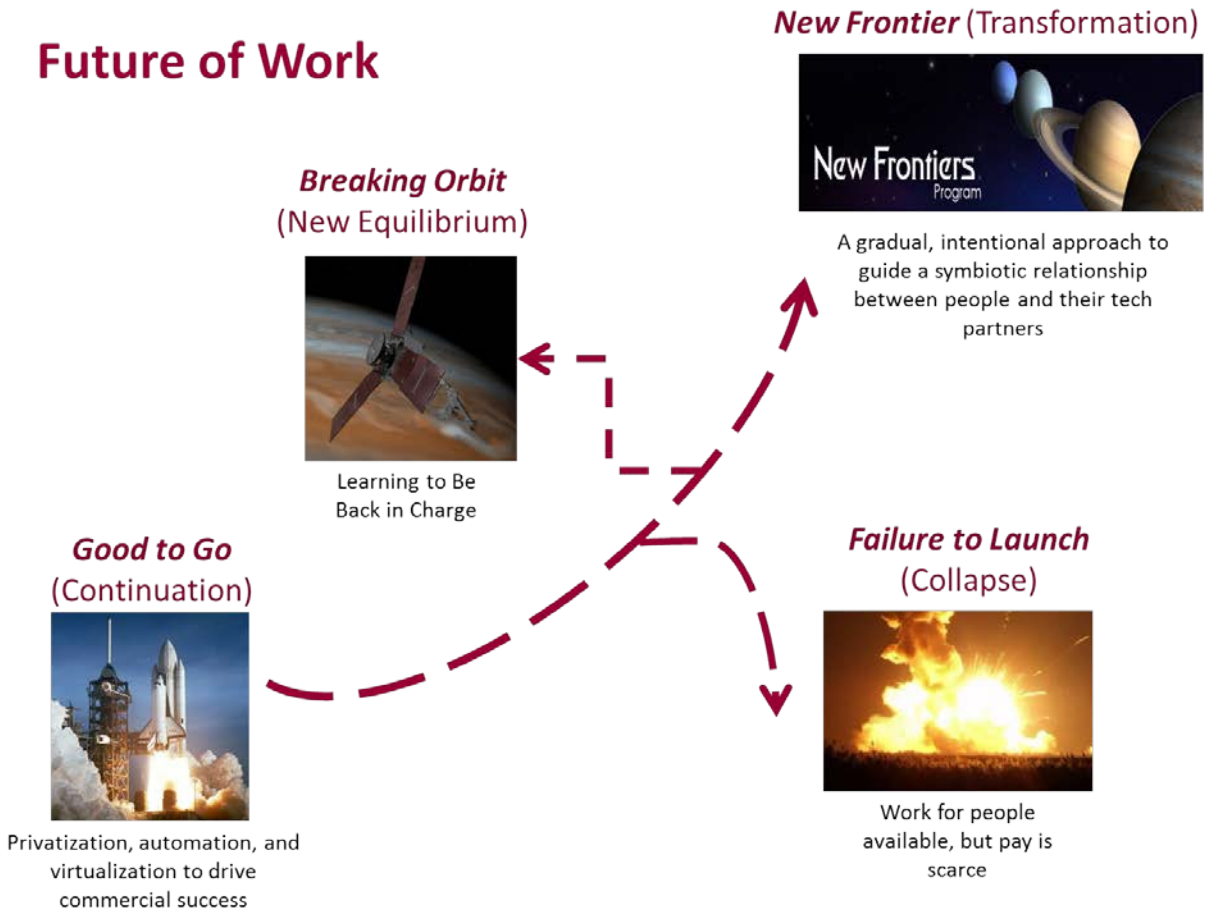
THE FUTURE OF WORK 2050 for NASA LaRC

White Paper



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September 2017

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INTRODUCTION

NASA Langley Research Center (LaRC) would like to test its current planning activities against a longer-term view of the external future. LaRC has been working on facilities plans, workforce plans, and is undergoing a comprehensive digital transformation activity. It believes that these activities would benefit from a separate look at a longer timeframe focusing more on the external future of the organization. The extended context would provide a useful input for revisiting these plans and activities to make sure that they will not be blindsided by unanticipated developments as well ensuring that they are aligned with the emerging future.

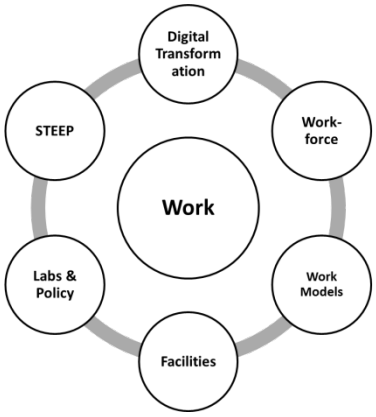
To do this, NASA Langley Research Center has asked the Houston Foresight program to collaborate on the development of a set of longer-term external scenarios on the future of work. These scenarios will be use to "wind tunnel" current plans/activities and enable the team to recommend suggested adjustments as appropriate. The goal was to stretch thinking out to the world of work in 2050 and then "bring it back" to a strategic approach and initiatives that could be started in the present. The principal components of the projects covered in this report include:

- Scanning
- Drivers (variables)
- Scenarios (including Implications, Issues & Options)
- Recommended strategic approach

Scanning

Scanning captures the "signals of change" in a domain, known as scan hits. They may be news or journal articles, blog posts, videos, reports, etc. The team collected over 200 scan hits suggesting changes in the in the future of work. The search was guided by a domain map of key categories to explore. Figure 1 shows the high level domain map of five major work-related categories – the research team developed a more detailed version for their scanning. The six categories:

Figure 1. Domain map



- ***Digital transformation*** includes AI, scientific computing, security, and work "activities" influence by digitization.
- ***Workforce*** includes automation, augmentation, robotics, jobs, and roles.
- ***Work models*** includes business models, partnerships models, and other ways or organizing LaRC's work.
- ***Facilities*** includes the physical and virtual infrastructure of offices, shared spaces, and labs
- ***Labs & Policy*** includes civil service, public funding, policy, and organizations in the system
- **STEEP** includes social, technological, economic, environmental economic, and political factors to cover general developments in the context outside of work.

The domain map provides a guide or framework for organizing the horizon scanning. Individuals were assigned responsibility for scanning for changes within the categories above. Figure 2 show an excerpt of scanning hits from the team's s scanning library in Diigo. Figure 3 shows the tag cloud of top tags, which include the three horizons and the primary categories of the domain map. The prominence of "digital transformation" is noteworthy and is reflected by its prominent role in the scenarios.

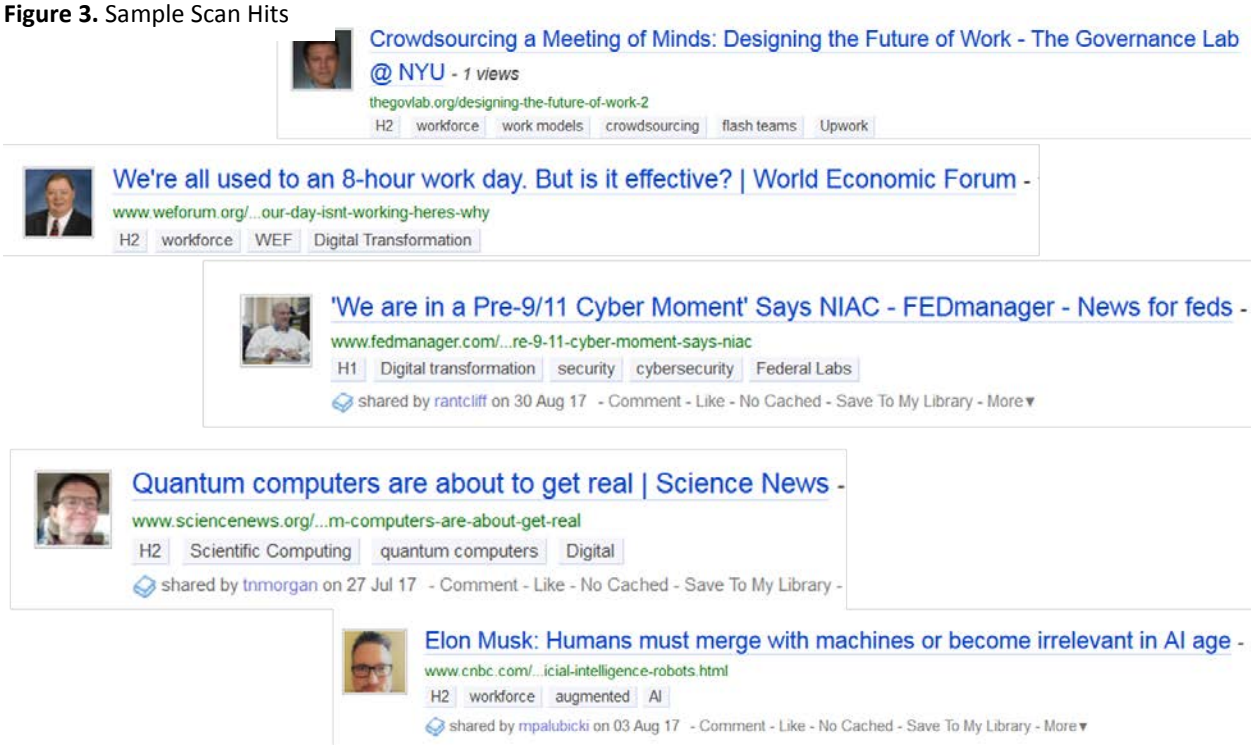
Figure 2. Scanning Hit Tags

Top 10 Tags	View All
H1	87
digital transformation	85
H2	84
facilities	44
workforce	39
Programs	26
H3	25
Exploration and Space Technology	19
scientific computing	17
Virtual	17

Diigo is a free cloud-based library site that uses the bookmark bar to enable easy annotation and tagging of web-based information. The scanner uses the domain map categories to tag each item, notes which horizon or time (H1, H2, H3) that the scan hit points to, adds an excerpt of brief commentary, and then saves it to the team's private group. A unique challenge in exploring the future of work is that so much has already been written about it. There was a large volume of studies for

the team to sift through. Appendix 1 annotates several – not all -- of the key futures-related works consulted for this project.

Figure 3. Sample Scan Hits



Drivers

Scenario planning in general relies upon identifying the key "drivers" of change. Drivers are perhaps best described as thematic clusters of related trends and developments that will drive or influence change in the future. The scenario archetype technique selected for the project relies on identifying a set of drivers, referred to as variables, whose future outcomes will be projected in each of the four archetype patterns (continuation, collapse, new equilibrium, transformation). The team used the domain map categories to guide the identification of potential drivers.

The drivers are defined "generically" in the table below, as specific outcomes for each driver vary depending on the archetype.

Table 1. The Archetype Drivers

Digital transformation	**Hardware Automation:** Smart machines and devices that complement or replace human labor, such as robots, drones, and various IoT-infused devices.
	Software Automation: Smart software that complements or replaces human intellectual labor, including AI, machine learning, predictive analytics, intelligent agents, etc.

	Visualization and Interface: Computer-based visualization tools that blur lines between the virtual and real world, allowing for multidimensional virtual interaction within software tools, including virtual-, augmented-, and mixed reality, and holography.
	Advanced Computing: Exascale and quantum computing architectures that allow for processing power on par or exceeding the human brain that can work through much larger problems much faster.
	Security: Cybersecurity approaches that protect data from unauthorized access, while enabling data sharing.
	Additive/Advanced Manufacturing: 3D, 4D, and nano-scale "bottom-up" manufacturing approaches that allow for decentralized on-demand fabrication.
Workforce	**7. Human Augmentation & Performance :** Various approaches that dramatically increase human capabilities using biological and physical means such as advanced pharmaceuticals, CRISPR for genetic manipulation, smart prosthetics, implants, and wearables.
	8. Worker Morale and Motivation: New sources of motivation are emerging to recruit and retain workers, such as quality-of-life, work-life balance, interesting work, and happiness, which could become particularly important if universal basic income emerges.
	9. Workforce Flexibility: Increasing mix of task-based, project-based and employment-based roles applied in variable schedules to maximize flexibility.
Work models	**10. International Cooperation:** A growing level of organizations and nations working together on large projects raises issues about security and intellectual property.
	11. Systems Integration: System-of-systems integration across disciplines and organizations are increasingly required or successfully developing complex systems efficiently and effectively.
	12. Open Source: A growing move to external sources of ideas and innovations via open source, crowdsourcing, and open innovation raises challenges for proprietary approaches.
	13. Mission Focus: Technological advances and evolving social, economic, and political priorities are likely to influence and change future mission focus.
Facilities	**14. Virtual-Physical Integration:** Infrastructure likely to be required to support interactive mixing of virtual and real spaces, and the integration of on-person devices (VR/AR glasses, haptics, etc.) with embedded devices (CAVE rooms, light-field camera arrays, omni-directional treadmills, etc.).
	15. Modular & Reconfigurable Workspaces: Adaptive workspaces focused on enabling collaboration that can be rapidly reconfigured are based on changing project requirements and worker needs of employees.
	16. Sustainability: Facilities design and services support sustainability, such as low-carbon footprint, benign environmental impact, and potentially closed loop and self-sufficient.
	17. Testing Infrastructure: The mix of physical, instrumental, and virtual infrastructure

	needed for design, integration, and performance testing over the long term.
Labs & policy	**18. Funding Support:** The mix of funding sources may change to supplement or replace traditional Congressional funding, with private sources, crowdsourcing, Sovereign wealth funds, or other countries.
	19. New Governance Models: Oversight and management models are evolving with changing policy priorities, which may include privatization, public/private partnership, decentralization, etc.

It was judged to be important to not just identify drivers, but to explore their interactions. Two tools were used to achieve this: a cross impact analysis and a core and secondary drivers table.

Cross-impact matrix

Key findings

- Digital transformation and to a lesser extent augmentation, are key drivers influencing others
- Facilities are a reflection of how other variables are resolved
- Labs and policy has a huge range of impact for "good" or "ill," but will probably follow rather than lead.

Table 2. Cross-Impact Matrix

	Digital Transformation	Workforce	Work Models	Facilities	Labs & Policy	
Digital Transformation		+	+		-	*DT has **lowest dependence** on other variables*
Workforce	++		+	+	-	*Workforce has 4th highest variable dependence*
Work Models	+	++		+	+	*Work Models has 2nd highest dependence on other variables*
Facilities	++	++	++		++	*Facilities has **highest dependence** on other variables **(highest uncertainty)***
Labs & Policy	+	+	++			*Labs & Policies has 3rd highest dependence on other variables*
	*DT has **strong influence** on other variables*	*Workforce has **strong influence** on other variables*	*Work Models has **strong influence** on other variables*	*Facilities has **lowest influence** on other variables*	*Labs & Policy has **most varying influence** on other variables*	

Core and secondary drivers

A second mechanism for looking at the interactions among the drivers, derived in part from the analysis of the cross-impact matrix, was to decide which drivers appeared to be core or primary drivers and which seemed to be secondary. Not all drivers are equally influential and one can easily envision a more nuanced system of tertiary or even quaternary distinctions, but it was just that the simple core/secondary would be sufficient.

Table 3. Core and Secondary Drivers

		Good to go (Continuation)	Failure to launch (Collapse)	Breaking orbit (New equilibrium)	New frontier (Transformation)
Digital transformation	1. Hardware Automation	Core	Secondary	Core	Core
	2. Software Automation	Core	Secondary	Core	Core
	3. Visualization and Interface	Core		Core	Core
	4. Advanced Computing		Secondary		Core
	5. Security	Core		Core	
	6. Additive/Advanced Manufacturing				Core
Workforce	7. Human Augmentation & Performance	Core	Secondary		Core
	8. Worker Morale and Motivation		Secondary	Core	Core
	9. Workforce Flexibility	Secondary			
Work models	10. International Cooperation		Core		
	11. Systems Integration				Secondary
	12. Open Source				Core
	13. Mission Focus		Core	Core	Core
Facilities	14. Virtual-Physical Integration	Core		Core	Secondary
	15. Modular & Reconfigurable Workspaces			Secondary	
	16. Sustainability		Core		Secondary
	17. Testing Infrastructure	Secondary		Secondary	
Labs & policy	18. Funding Support	Core			Secondary
	19. New Governance Models	Core	Secondary		

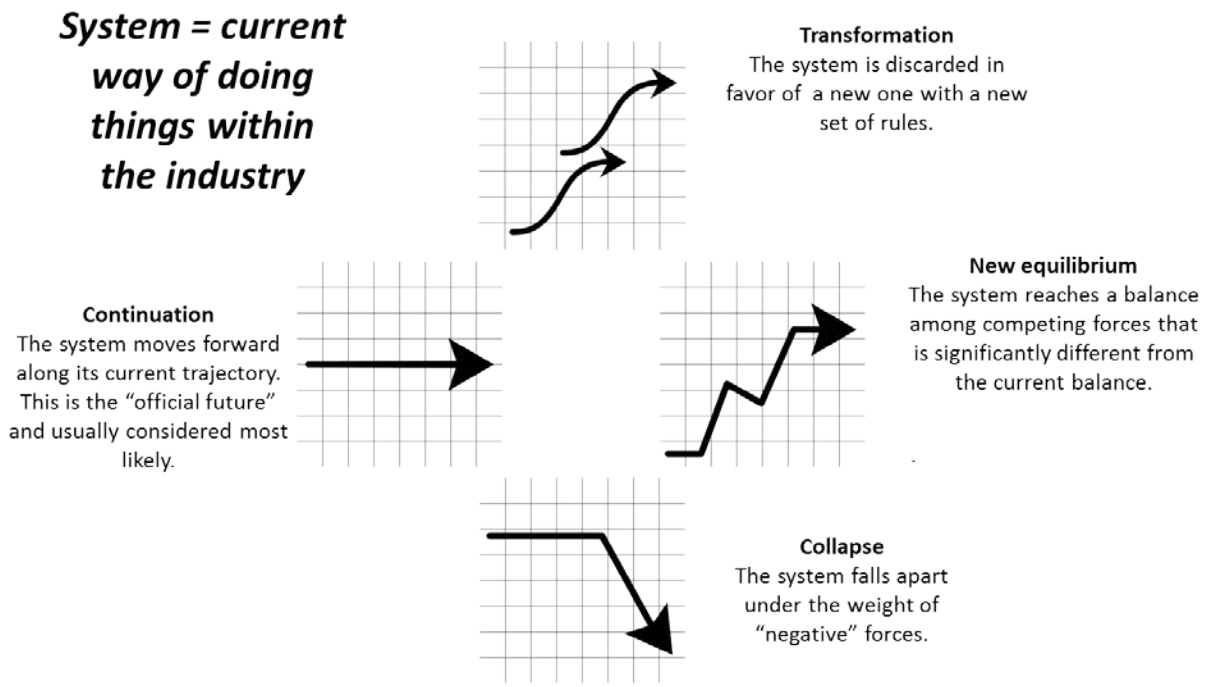
Scenarios

Professor Jim Dator of the Hawaii Futures Studies program developed the scenario archetype approach [see Jim Dator, Alternative Futures at the Manoa School, *Journal of Futures Studies*, November 2009, 14(2): 1 – 18] Essentially, based on his long experience and research with scenarios and alternative futures, he observed four common patterns in how topics evolved over time that we at Houston Foresight have made some small tweaks to. A key assumption underlying this technique is to view the topic as a "system," operationally defined as "the current way of doing things." Four patterns characterize the movement of a system over time:

- Continuation: *baseline extrapolation of present into the future*

    - Present trends continue within the system without any major disturbances, what we call the baseline future, with the joke being that it's the most unlikely future in suggesting no major surprises. The current system continues to grow in the sense that its present trends continue.
- Collapse: *system stuck in dysfunction*
    - A key point is that collapse does not necessarily suggest the apocalypse, but the system regresses or dips into a level of dysfunction, e.g., economic stagnation or recession as the norm. Of course, it can also be an outright collapse as well.
- New Equilibrium: *challenge to system leads to compromise to save existing way of doing things*
    - The key notion here is one of challenge and response. The system is challenged and responds in a way to save itself. It's based on the notion that systems are stable and will tend to — and want to — return to baseline after being disturbed. They will actively seek this return to stability and be willing to make some compromises in order to preserve the essence of the system, e.g., bailing out the banks at the onset of the Great Recession.
- Transformation: *can't save the system, so me rewrite the rules of the game*
    - Entails fundamental change to the system. This transformation could be driven by any number of factors, values, technology, or economics. The key point is that it essentially involves creating new operating rules or guidelines. .

Figure 4. The Four Archetypes



The steps followed in archetype technique for this project included:

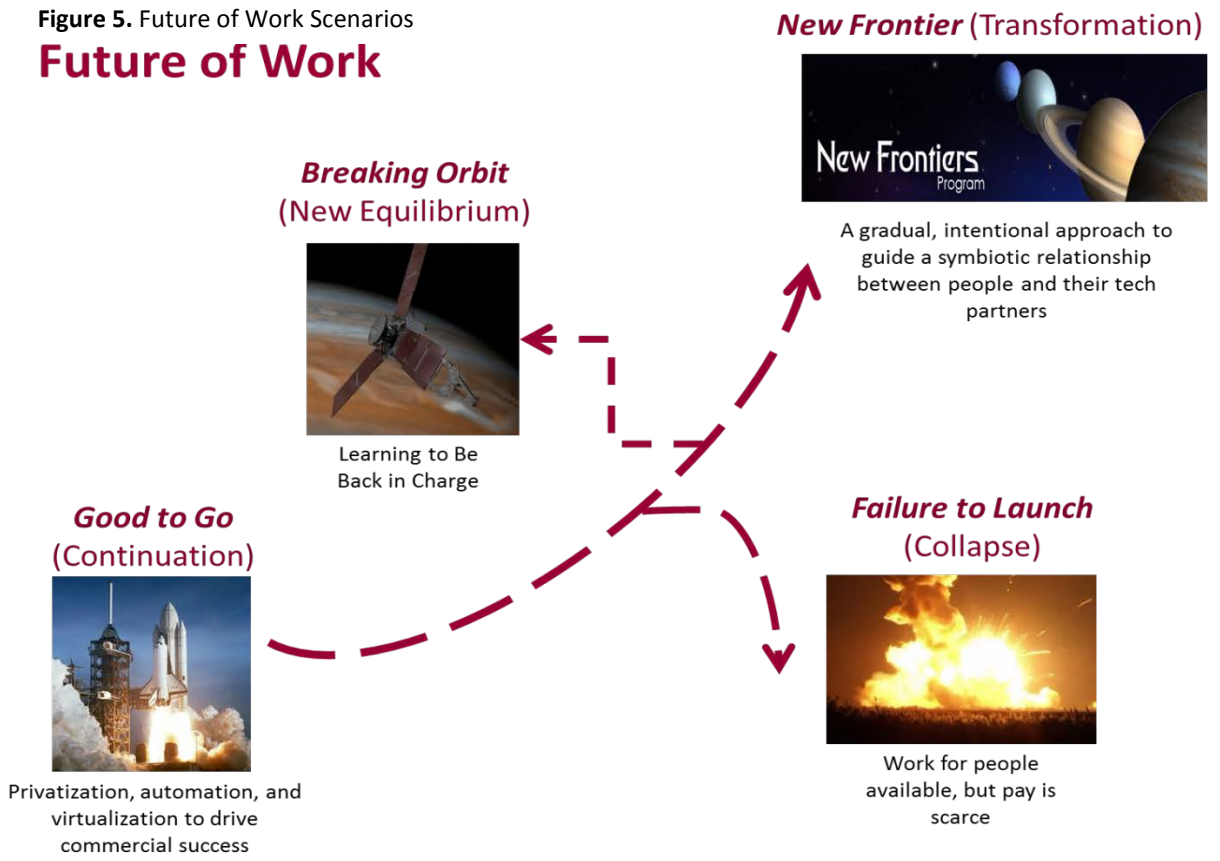
1. Identify variables (aka drivers)
2. Cluster and prioritize drivers, aiming for about 15-20
3. Describe each driver

4. Summarize how each driver plays out in the 4 archetypes (1-2 sentences + paragraph)
5. Cross-impact analysis of drivers
6. Test and tweak the cross-impact matrix for each archetype.
7. Selection of core and secondary drivers for each archetype.
8. Create scenarios
9. Create a table with DM category, variables selected for the archetype with how it looks for that scenario (1-2 sentences), and a summary of the interaction between these drivers for this archetype

The scanning and drivers provide a foundation for developing scenarios. The scenarios suggest how the changes identified in the scanning and the drivers could plausibly come together in a range of future outcomes.

Figure 5 depicts the relationship between the four scenarios. The movement over time into the future if from left to right and bottom to top. The archetype technique starts with continuation – *Good to Go* in our case – in the bottom left. The continuation scenario may persist for a decade or even two before it begins to break down and alternative futures begin to emerge. The graphic suggests that *Breaking Orbit* as a prominent plausible alternative that challenges continuation and forces a significate compromise in the "way work is done" – in our case primarily having to do

Figure 5. Future of Work Scenarios



with the role of AI/automation. Or, the archetype approach suggests the system could collapse and fall

into varying levels of dysfunction (in our case, it is severe). It is possible that the transformation archetype – *New Frontier* – could emerge early, but the team judged it more likely to be closer towards the 2050 time.

The four individual scenarios are now described in more detail below.

Good to Go (Continuation)

This is a world in which privatization, automation, and virtualization are key factors in the push for commercial success.

Continuing big investments in AI and automation drive virtualization that boosts productivity, but benefits are unevenly distributed. The super-rich 1% get richer, the 20% of knowledge do well, and everyone else scrambles for tasks. Automation eliminates many jobs, but those with high skills, education, and an entrepreneurial spirit – or physical/intellectual augmentation -- do well. The core workforce is smaller, with more contractors, but the cutting-edge nature of NASA's work enables it to fare better than many other industries Work is much more virtual, and the workforce is forced to adapt or retire. The physical space shrinks, but is kept going by private investments. Commercial considerations drive a new space race, and government agencies do the bidding of the private companies that supply much of the funding.

Key Driver: *The pressure to achieve commercial success as government work is increasingly privatized, and global completion intensifies drives increasing investment in and reliance on the suite of digital transformation technologies, i.e., AI, automation, virtualization. The result is more tech-driven workplace that is operated more like a commercial company.*

STEEP Impacts on LaRC

- ***S****ocial* Most work done by "insight workers" who use ML/DT (machine learning/digital transformation) automation in highly competitive jobs. LaRC work is remote via VR/RR (Remote Reality) telepresence, for safety & convenience.
- ***T****echnological* ML/DT systems automate most tasks not requiring adaptive human insight & reasoning. Secure VR/RR workspaces are the norm. Fewer facilities needed.
- ***E****nvironmental* Climate change mitigated by application of new tech to creation of new solutions. Full ecosystem collapse held off, for now. LaRC has ongoing support role in eco-recovery.
- ***E****conomic* Short-term "Flash Contractors" are the norm for NASA & LaRC. Aerospace research efforts driven by corps insisting on "fast-fit" workers who use ML/DT tools to become "instant experts".

- ***P**olitical* Federal government downsizes and privatizes everywhere it can. NASA and other agencies effectively become mixed public/private entities.

Impacts for LaRC

LaRC is working "faster, better, cheaper" than ever before. LaRC has less than a quarter of its FY2018 staff, but does 10-times the work. Many tasks are performed by short-term VR & telepresence Flash Contractors ("Flashers") paired with problem-domain Machine Learning & Digital Transformation technologies (ML/DT). ML/DTs automatically track details, know equipment, project history, run tests, and provide initial analysis. Flashers provide human insights & designs. The civil servants oversee dwindling government-directed projects. Most advanced research work done in close partnership with private companies to meet anticipated future needs.

Digital Transformation. Commitment to digital transformation strengthens. The productivity argument wins out over concerns for human jobs, but there are enough new jobs created to avoid social unrest, despite benefits of DT primarily accruing the elite and super-elites. Security concerns are paramount in an environment of corporate competition that dominates government agencies due to their funding power. Concerns are growing about our reliance on and ability to control "the machines."

Workforce. The star model prevails in which those with the right skills do extremely well, the 20% do okay with their useful skills, but automation decimates jobs for the rest, who make due by scrambling for tasks. Many gamble with risk augmentations to try and crack into the job market.

Work models. The near worship of the private sector and hero entrepreneurs sets the stage for the organization of work. Competitions to identify the winners are favored over sharing approaches, with security a big concern. The winners, even when benevolent, are in charge and weakened government agencies serve their new masters.

Facilities. The drive for efficiency and profitability supports "virtualizing" over physical facilities where practical. The size of facilities generally shrinks as more work is distributed, and eventually moved to VR. Increasingly workers much adapt the dominant virtual approach (not the other way around).

Labs & Policy. The traditional lab continues to shrink, driving a move to identify other sources of funding. Thus, private companies make inroads into the Federal Labs, and implicitly if not explicitly dictate the direction of research and work.

Key implications

Digital Transformation

- Robots/automation proliferate at expense of humans for the benefit of the few
- General intelligence AI replaces many workers, particularly those rules-based jobs (with ineffective policy planning and super-intelligence looming)
- Strong use of VR and ubiquity of virtual tools and interfaces reduces commuting/travel/going to work
- Resources pour into the development of advanced computing resulting in enormous productivity gains, with super-intelligent AI a looming threat
- Security trumps privacy with huge investments in cybersecurity, surveillance to keep the powerful in charge.
- 3/4D scales ups and mainstreams with nano-approaches are increasingly common as well, despite a few runaway nanotech "gray goo" scares.

Workforce

- Personal augmentation is winked at and fairly widespread among those who want to work; many choose to in order to stay relevant, even though it is fairly dangerous.
- It's still about the money; stars do well, the 20%, okay, the rest struggle in increasingly fierce competition for scarcer jobs
- Superstars have jobs, the 20% work on projects, and the rest fight for tasks.

Work models

- A new, commercial space race indicative of the failing international cooperation; governments are representative of private interests.
- Systems are integrated within secure partner networks, but slow to shift and bring on new talent and partners
- Huge conglomerates dominate industries and competitions are favored over sharing in the collection of ideas that mostly serves their proprietary ends
- Supporting private sector focused on commercial opportunities with pressure to devise plans for escaping planet Earth

Facilities

- Integration is toward going fully virtual to save money and defeat the competition.
- To save money, government [and some others] happily shrink physical spaces and rely on just—in-time factory produced facilities when needed
- Smart "tech-fix" approaches to sustainability
- Privately funded big-ticket testing and development facilities are regularly updated with latest technological improvements and work synergistically with advanced simulations.

Labs & policy

- Continuing cuts in traditional government sources lead to more funding and power coming from the private sector.
- Private funders increasingly call the shots in the public-private partnerships.

Key Issues

- How can LaRC increase security without slowing down work?
- What is the view around acceptance and importance of private dollars?
- How does LaRC deal with concept of role of basic research in Federal Labs?
- How does LaRC deal with loss of control in "open" context in which projects are increasingly bid upon?
- What is the LaRC view around One Lab and multiple locations?
- How does LaRC get ahead of augmentation and what is its role as an employer?
- To what extent do LaRC move to "project based" employment (instead of lifetime)?
- Should LaRC build "mega-facilities" or move to just-in-time/modular facilities?
- How does LaRC deal with individual concerns about their personal physical space?

Failure to Launch
(Collapse)

This is a world in which work for people available, but the ability to pay them is scarce.

The hope that AI, advanced computing, and automation would save humanity from social, economic, and environmental challenges comes up short. Hype outpaced results -- it was harder than was thought and humanity is overwhelmed. Climate change, social conflict, and economic contraction breaks down the global order and nations, communities, and families hunker down. There is work for people if they are willing to work for peanuts. Valued national and local resources, such as NASA and the space program, are maintained in a fortress-like approach that protects the people and equipment inside. Knowledge preservation is the goal, along with supporting frantic plans to "get off the rock."

Key Driver: *External drivers are prominent in a systemic collapse as the decline of ecosystem, the economy, and social order reinforce a downward spiral, with technology unable to come to the rescue. The result is a human-driven workplace, in which non-pay factors (e.g., security, for the good of the cause) become central to keeping the work going.*

STEEP Impacts on LaRC

- ***S**ocial* Increasing civil disorder & stress on law enforcement resources pushes LaRC into strong physical & info security stance. There is a high need to protect employees and families onsite.
- ***T**echnological* Collapse of global & national economy restricts LaRC financial resources. Tech advancement stalls in the economy. Sci/Tech education shifts to bio & ecosystems to limit damage.
- ***E**nvironmental* Climate collapse drives social disruptions and loss of economic resources leading to increased LaRC insecurity. Renewed social interest in employing space resources to fix problems, and possible "emergency backup civilization" colonization takes LaRC to a strong "Racing the Clock" dual focus on environment & rapid space development
- ***E**conomic* Government funding flatlines across the board due to ongoing global financial problems, slashing LaRC budget. All federal budgets teetering on edge of collapse at all times.
- ***P**olitical* NASA environmental sensing programs, systems engineering, integration, & materials design considered key national resources. LaRC funding is down from historical highs, but represents a higher percentage of dwindling US budget than in previous stable eras.

Impacts for LaRC

LaRC is nicknamed "Fort LaRC" due to high levels of physical and info security. The LaRC mission is considered a national priority, but resources are limited by a collapsed global economy and conflict. LaRC creates extensive onsite "LaRC University" training resources and apprenticeship programs due to society wide loss of high-quality science & technical skills in stalled digital transformation and space technologies. LaRC brings in new expertise in biology & ecology to assist with strong environmental repair focus. New push for "lean & green" manned space industrial development drives NASA-wide push to help key industries to "get off the rock."

Digital Transformation. Digital provides incremental benefits, but its transformative potential is not realized. The economy suffers, and to make matters worse, the ecosystems degrades and triggers a spiral toward collapse. Investment in digital declines, and more humans are needed for "jobs," but there isn't much money to pay them. Decentralized and local approaches become the norm out of necessity.

Workforce. There are still jobs available, but the poor economic conditions have made pay scarce. Deteriorating economic conditions install a localized, protect—your-own mentality,. NASA's labs, despite not being able to pay market rates, offer physical security and safety in a friendly closed community.

Work Models. The reduced amount of work available is tied to physical location with an emphasis on security and reliance on people to do the work, with some support from machines. There is very little international cooperation with trust practically zero. Within known community of insiders, open source is favored, but outsiders are kept out.

Facilities. Physical facilities are vital as the investment in virtualization does not produce the promised revolutionary breakthroughs. These physical facilities, especially if they contain high-tech equipment – which is still valued even though it provides incremental value – are often protected from rioters or spies by security forces or even walls.

Labs & Policy. Labs consolidate away from vulnerable coastlines to secure inland locations. Bunker-like back-up labs are formed at undisclosed locations.

Key implications

Digital Transformation

- Human labor required as investment in robots/automation don't pay off.
- AI disappoints, as general intelligence is harder than was thought.
- F2F is most secure means of communication, with virtual used for less essential communication.
- Advanced computing makes incremental gains with humans still in charge.
- Security concerns are key to slowing reliance on the machines; f2f and even paper-based systems are relied upon for sensitive communications.
- 3D/4D printing works for some things and nano disappoints, so that physical plants are still essential.

Workforce

- Bad experiences with augmentation, and their high prices, dampen the spread, but a black market develops.
- There is work for humans, but little pay. NASA employees are getting compensated with in-house benefits as well as counting on loyalty to the mission of the agency.
- Job shortages due to poor economic conditions with a mix of jobs, projects, and tasks. Very high degree of flexibility, given low pay.

Work Models

- Blame and active hostilities occasionally often flare up in workplace.
- Systems are integrated only within virtual and physical firewalls.
- There is sharing of ideas and information for those within communities, but not shared outside.

- Focus on Earth science….along with pressure from elites to push for space habitation. There is a stalemate between “fix the Earth” and “get off the rock.”

Facilities

- VR and other virtual technologies fail to live up to expectations and fade back into obscurity, again.
- Return of the company town. Since the secured spaces are limited, they need to flexible and dynamic.
- Neglect of sustainability leads to catastrophe; now organization do the best to protect their spaces.
- Physical infrastructure and big-ticket testing facilities are essential but some fall into disrepair due to lack of funding.

Labs & Policy

- Widespread social, political, and economic disruptions result in drastic reformulation and consolidation; with coastal facilities first to be shut down.
- Severe reduction of NASA’s mission and budget results in a shift to core essential personnel in a military-style approach.

<u>Issues</u>

- Should LaRC move away from managing by FTE?
- Should LaRc proactively decide what missions belong where in cooperation with other agencies?
- How does LaRC get ahead of the need to move facilities?
- How and when should LaRC design for integration?... with digital transformation/augmentation
- How early and how much should be to invested in digital transformation?
- How do LaRC adapt decision-making in a more open idea gathering contact?
- How does LaRC maintain “smart buyer” capability in reference to AI?

Breaking Orbit
(New Equilibrium)

This is a world in which humans are learning to be back in charge after "pulling the plug" on self-aware AI.

The march to automation and virtualization leads to a growing number of situations in which AI stops taking orders from people in the workplace (and society). As they gain more power in the workplace, they start to become unpredictable. Rumors start that they are forming their own secret societies and self-replicating (images of hordes of AI combatants). They develop the ability to say "no." AI makes benevolent decisions in the interest of the organization that sometimes hurt individual people, and refuse to be over-ruled. Panic ensues as people realize they are losing control, there is a massive backlash and intervention in the global orders to "pull the plug" on independent AI. This is done in time, and much like Y2K, debates continue to rage over whether it was necessary. But the outcome was a huge gap in human capability due to our reliance on machines. A massive reskilling and re-education effort is launched, particularly relevant for sophisticated national centers-of-excellence such as NASA in space. Facilities need to be reconfigured or rebuilt to accommodate people going back to work.

Key Driver: *The massive challenge is to put the tech genie back in the bottle, and re-develop the human skills needed to run a workplace that is highly dependent on technology, but technology under the control of humans.*

STEEP Impacts on LaRC

- ***S**ocial* Increasingly unpredictable autonomous Machine Learning (aML) tech prompts social backlash. NASA & LaRC embrace Digital Transformation (DT) technologies which limit autonomy of aMLs, along adopting responsive/transparent standards & open models of cooperation.
- ***T**echnological* DT, Robotics, & Biomimetic developments focus towards assisting the work while mimicking natural resilience. LaRC personnel regularly direct a seamless environment of software and hardware tools which require almost no data "hand-holding" between systems.
- ***E**nvironmental* Desire to repair the environment and promote nature-like solutions is rampant. LaRC is engaged in "thinking naturally" on all solutions and operations.
- ***E**conomic* Global financial instabilities due to unpredictable aML blockchain instruments results in new restrictions. LaRC benefits from renewed stability of national and global markets.
- ***P**olitical* Renewed global optimism from active environmental restoration successes and successful sequestering of instability producing aML tech fuels a renewed interest in space as a destination. LaRC benefits from new aerospace optimism, ideas, and funding.

Impacts for LaRC

LaRC is crowded. Custom facilities are being built or packed-away almost every week. Temporary single project labs and hands-on "re-learning" facilities are driving rapid construction/destruction of facilities as needs wax & wane. LaRC's new open-cooperation model between research centers, companies, universities, and vetted private citizens is recapturing old skills while accelerating adoption of new ideas across aerospace and beyond. LaRC has re-imagined itself as a "bio-campus" with systems and buildings which mimic natural processes to lower environmental impact. LaRC engineers & scientists use highly integrated open testing & development suites designed to adapt to the needs of fleeting self-organized task teams.

Digital Transformation. The reliance on AI/automation leads to circumstances where the machines begin to over-ride human commands and concerns, for what they believe is the better of the planet (not anti-human per se). These instance cause panic and backlash against reliance on machines; sometimes violent, but other times a more controlled decommissioning back to a level where humans are clearly in charge. This created some social tension, as some believed the backlash was an over-reaction and unnecessary. But this reveals a gap in human knowledge and ignites a campaign to re-learn what was forgotten.

Workforce. Work has historically been highly automated. Sabotage had been increasing as workers became suspicious of AI. The decision to "unplug" and avoid machine dependency reveals a massive skills and knowledge gap. The machines had taken care of so much that few people really knew what to do, creating the need to restore knowledge to get the economy running again. Machines can still be used as long as humans are clearly in control.

Work Models. There is a common spirit back in taking back work from the machines. But there is learning and relearning in how to work together without relying on the machines. Human inputs are encouraged via crowdsourcing, open source and open innovation models.

Facilities. Facilities are revamped as the equipment is removed or reprogrammed. Room has to be made for an influx of human workforce, as the balance of work time shifts back to physical. Design principles favor natural and biomimetic approaches, as an intellectual reaction against reliance on "un-natural" machines.

Labs & Policy. A renaissance for Federal Labs as much of the innovation genie is put back in the bottle, and the humans are back in charge.

Key Implications

Digital Transformation

- Reigning in AI autonomy/machine learning to make sure that humans are in control, which requires re-educating people to replace the work that the AI did.
- General intelligences AI is perceived as getting beyond human control, thus it is scaled back, which in turn creates a learning gap for people.
- Ubiquitous and invasive I/T, is "disconnected" and repurposed to be under human control, but need to re-learning etiquette of working together again.
- Scramble to put the genie back in the bottle, as advanced computing is licensed and monitored to prevent an "outbreak" of malevolent super-intelligence, but human struggle to work with advanced computing that has grown beyond our capacity.
- Concerns about the ability to control AI lead to the massive adjustment in the reliance on I/T; surveillance networks are disabled, and privacy laws are reinstituted.
- Automated 3D/4D production is reigned in; with humans needed to sign off on any fabrication. Nanotech fabrication is allowed only in heavily restricted facilities; although there are black market instances.

Workforce

- Augmentation is outlawed [at least temporarily], creating a conundrum for those already augmented, and a search for fixes.
- As humans return to work, organization providing the best education and retraining get the best talent
- After long decline of human jobs, restoration projects to get systems running are the primary approach, with a scramble to re-establish job markets; in the initial recovery periods, there is an all-hands-on-deck mentality. After the crisis, a mix of jobs, projects, and tasks is re-established.

Work Models

- Most, but not all, people globally are united against perceived threat of autonomous general-purpose AI.
- Systems are deliberated dis-integrated, and then re-integrated under human control.
- Wariness of reliance on tech approaches overcome by need to share ideas.
- A move to "bringing back the know-how."

Facilities

- The virtual-physical balance shifts back to physical.

- A building boom ensues, with natural design proliferating, with a "small is beautiful" mindful of environmental impacts.
- Favoritism to all things natural.
- There is a need to revamp and rebuild favors physical testing approaches, including reviving mothballed approaches.

Labs & Policy

- Government takes back control from private sectors in sensitive sectors, including space and aerospace.
- Strong federal oversight of projects, facilities, and personnel returns.

Key Issues

- How can LaRC develop "explainable AI," so the humans maintain control of it?
- How much should LaRC trust digital and augmented technologies (balance between human and digital)?
- What specific skills does LaRC need to retrain and rebuild?

New Frontier (Transformation)

A gradual, intentional approach guides a symbiotic relationship between people and their tech partners in a world of abundance.

Recognizing the growing power of our technological tools, government, business, community and technical leaders guide their evolution to ensure human relevance. If a job is automated out of existence, there is a plan for the displaced. The resulting abundance and wise distribution of the bounty through mechanisms such as universal basic income decouples work from "making a living." NASA and other agencies lead a global effort to spread knowledge and "share the wealth." They work internationally, both virtually and in person. Eventually, people are able to choose to work to pursue their personal interest, with NASA being a huge beneficiary, first for its crucial role in "saving the plant" and eventually for providing the excitement of space exploration. The challenge is how to effectively harness the input and energy of this volunteer army.

Key Driver: *Two cultural revolutions drive this future. First, a human-centric focus on tech development is a key enabler of a dramatic boost in productivity; this enables the 2nd cultural revolution with a dramatic expansion of mission focus and as resources and a volunteer army becomes available.*

STEEP Impacts on LaRC

- ***S**ocial* Universal Basic Income & Services (UBIS) have quelled rising social tensions and created fertile ground for a renaissance of art, science, and culture. LaRC employees work for their passion, not their pay.
- ***T**echnological* Individuals and fully autonomous AI technologies form a symbiotic partnership. The line between humans and their embedded tech blurs. LaRC freely funds advanced augmentation upgrades for employees to improve their work and to encourage their retention.
- ***E**nvironmental* Human/AI teams turned the corner on solutions for drastic environmental issues. LaRC is helping implement those solutions and monitor the planet's improving health.
- ***E**conomic* Markets are now driven by UBIS-supported individuals who want "more." LaRC becomes a magnet for idealistic experts whose "more" is work satisfaction and higher social status.
- ***P**olitical* Abundance technologies allow adoption of UBIS. LaRC benefits from a new pool of passionate workers, freed to pursue an education and dedicated to doing whatever it takes to advance science and space development.

Impacts for LaRC

LaRC HR archives show the slow multi-decade contributor adoption of personal enhancement tech, from Employees adopting wearable wellness sensors in the late 2010s all the way to today's "contributors" sporting the latest in embedded AI partnertech. LaRC contributors value embeds for assistive cognition, biohealth, enhanced senses, and improvements in multisensory "2MERGE" VR/Physical worlds. UBIS funded contributors fill LaRC's 2MERGE hallways working a shifting array of environmental and aerospace R&D. LaRC has an abundance of resources and a team of passionate contributors taking LaRC, and humanity to the next level.

Digital Transformation. A strong commitment to machine intelligence guided by an equal concern for ensure that humanity is not left behind. A partnership ethos evolves in which people routinely work with intelligent assistants. This includes the growing use of augmentation to help keep up – for those who choose to.

Workforce. Advanced AI and computing brings an economic bounty for UBIS and like schemes such that humans are not required to work for a living. People do want to pursue interests, such as space, and typically do so with AI partners.

Work Models. International cooperation is vital to addressing ecosystem challenges. A global leadership void needs to be filled with "lead agencies" in various sectors called up to expand their reach. The move to highly transparent approaches generates some discomfort for those steeped in a competitive culture. The shift to a volunteer

workforce driven by interest in the topic created the challenge of how to accommodate and incorporate the surge of interest.

Facilities. Facilities are designed to preserve human-ness and prevent people from becoming prisoners of screens and the virtual world. This occasionally means trading off efficiency in support of culture, e.g., keeping the wind tunnel even though it's not needed any more. Green principles are central given the shift of organizational missions toward sustainability.

Labs & Policy. Federal Labs move to a self-governing approach that is in turn exported to nations across the globe.

Key Implications

Digital Transformation

- "My best friend is a robot," i.e., high automation in a person-machine strategy.
- The development toward super-intelligent AI is guided with foresightful policy and thus it is "happy" to work with humans.
- VR-AR capabilities are available, but used as needed. Voluntary limits are set – overseen by AI – so that humans don't get too immersed. Mixed reality is very popular, since it reinforces the partnership ethos.
- General intelligence and emerging super-intelligence drive advanced computing that has been essential to providing the prosperity that has enabled the break from jobs, income and survival, with humans augmented to keep them relevant.
- A key enabler of the automation was the global sharing of technology to benefit all, creating a culture of open source/open innovation that made security less necessary. There is a common approach to inter-planetary security as the new focus of concern.
- 3D/4D is widespread, some run by people and others by AI with nano-assemblers complementing the increasingly aging 4D assemblers.

Workforce

- Augmentation is voluntary and as needed, but it enables us to better complement our AI partners, as they become more human and we become more machine.
- People don't need to work, but do so because they want to, and saving the planet and space exploration experience a massive surge of interest.
- People, in tandem with AI partners, can voluntarily take responsibility for making a contribution.

Work Models

- Global cooperation spreads the bounty from AI/automation and is fundamental in "saving the planet."

- High transparency and less need for security facilitates integration across organizations and national borders.
- There is a move away from proprietary to transparent and open approaches.
- The first major shift is in saving the planet, which entails a wide variety of contributions from NASA, and then a huge surge of interest in space exploration.

Facilities

- A careful balance is maintained to keep humans from losing their identity in virtual world.
- Physical facilities are valued, even if not always strictly necessary.
- Sustainability of the Earth becomes mission priority number one.
- Symbolic testing facilities that provide human reassurance are kept, though not absolutely necessary.

Labs & Policy

- Bounty from AI/automation provides money for Basic Income & Services as well as supporting the surge of interest in space exploration.
- Move to a self-governed "do-ocracy" modeled on early 21st century makerspaces with massive contributions from volunteers, which is needed to support a wide expansion of the mission.

Key Issues

- How does LaRC effectively manage self-tasking teams and individuals?
- How does LaRC develop standards and checks for autonomous AI (transparency)?
- How can LaRC organize around guiding principles rather than standards (in a dynamic context)

Strategic Approach

The team worked on implications, issues, and responses in the workshop (results of that work in a separate file). The team then went through this material in each scenario to generate an inventory of ideas for a strategic approach.

Choosing a Strategic Approach

Houston Foresight uses a framework developed by Peter Schwartz and the Global Business Network to guide the development of an overall strategic response to a set of scenarios. The framework suggests four ways that organizations can respond:

- Bet the farm – there is one scenario that is judged both probable and/or presents a large opportunity or threat, so the organizations places all its resources preparing for it

- Robust – there is a great deal of common ground across the scenarios, so the organization identifies invests in resources in aligning with that common ground.
- Hedge – the scenarios seem to be of roughly equal plausibility and impact, so the organization invests its resources roughly equal on each.
- Core-Satellite – one scenario is just most important and gets most of the strategic attention, but the others merit some investment, typically a contingency plan.

The team first identifies strategic recommendations independently for each scenario. From that, it was clear that there was a good deal of common ground among three of the four scenarios – with the exception of *Failure to Launch* (collapse). It was decided to pursue a robust approach across the three and develop a contingency for the other.

To develop that common strategy, it was first necessary to specific the common elements in the three scenarios. After discussion and consolidation, the team organized the recommendations into six key focus areas:

- AI & Automation
- Augmentation
- Business Model
- Facilities
- Know-how
- Culture

As mentioned, a distinct contingency strategy is recommended for the *Failure to Launch* (Collapse) scenario, since it had a different context from the other three scenarios.

Each of the six areas could be the focus of a strategic initiative. The specific activities are organized into three phases were applicable (not every activity needed three phases to implement).

Digital Transformation: *Make digital transformation an urgent priority*

Phase 1	Phase 2	Phase 3
1. Develop and AI inventory and roadmap. • Develop a work practices inventory • Establish AI standards for future innovations	• Strategically design tasks that maximize cooperation between people and AI • Create deactivation protocol for every type of AI • Build an AI roadmap that identifies key developments and appropriate safeguards that maintain human control	
2. Prepare for future work task automation	• TAG creates/revises needs-based automation standards	• TAG automates identified 'algorithmic' job tasks

• Create new, dedicated Task Automation Group (TAG) • TAG & teams identifies/documents data-centric job tasks which can be automated with existing or near future AI		
3. Investigate new automation tools & reevaluate continually • TAG & teams identify data/workflow incompatibilities between internal and external toolsets	• TAG & teams work with stakeholders & vendors to identify new inter-application data standards and needed automated bridging tools	• TAG & teams identify opportunities for automation across toolchains & systems • TAG creates toolchain automation & bridging tools using new interface standards
4. Explore other advanced (non-AI) tools, such as VR/AR/MR for enhancing work • Teams identify opportunities for using current VR/AR/MR tech in workplace	• Pilot select VR/AR/MR tech tests; identify gaps, issues, & opportunities	• Conduct VR tech evaluations as tech develops • Implement VR/AR/MR in increments as it makes sense

Augmentation: *Get ahead of augmentation and develop strategy that balances augmented/non-augmented capabilities*

Phase 1	Phase 2	Phase 3
• Identify and monitor external examples of augmentation	• Conduct internal augmentation pilots • Create process for security validation of personal electronic devices such as smartwatches, fitness trackers, body cameras, and the like for use at work • Work with AI Assistant vendors like Amazon or Google on secure in-house chatbot assistant devices and "behind the firewall" LaRC-specific support services for those devices • Develop customized in-house AI Assistant features which connect to LaRC team knowledgebases, data visualization software, test instrumentation, and other tools which would benefit from hands-free use	• Institute a policy for NASA sponsored human augmentations , including a "human over-ride" capability to deal with potential for runaway AI

Business Model: *Move toward more commercially-driven open business models*

Phase 1	Phase 2	Phase 3
1. Promote or champion the One Lab Strategy		

by working with other labs and industry to clarify where basic and applied research best fits		
2. Develop a strategy to engage proactively with the private sector • Accelerate current public/private ventures	• Pilot new approaches, such as Create X-Prize like recognition awards for best solutions to LaRC stretch goals, drawn from LaRC "Open Sky" personal & team side projects	• With private develop an incubator to seed and help manage startup ventures
3. Encourage /incentivize NASA teams to collaboratively bid on projects in which NASA is not the lead and share learnings		
4. Explore open-source styled voluntary co-operation methods • Develop crowdsourcing/ volunteer platform • Experiment with crowdsourcing projects • Encourage employees to spend a small fixed amount of time each week (10-20%) on self-directed personal projects related to LaRC mission, ala Apple's Blue Sky employee initiative • Research self-organized organizations and companies, looking for guidelines & lessons learned (1)	• Pilot several short self-organized team projects to determine feasibility & issues	• Identify ways to loosen LaRC policies and organization to promote more self-organized teaming
5. Explore policies to encourage employee Collaborator/Self-organized attitudes		
6. Anticipate, evolve, and rapidly implement shifts in mission • Investigate opportunities for expanding role in climate change mitigation/reversal (1)	• Explore new missions in long term scientific and social benefit, e.g., Resource Extraction (Mining); • Unmanned exploration of nearby stars with "Earth" planets	1. Development of manned colonies

Facilities: *Adopt a just-in-time approach to facility development*

Phase 1	Phase 2	Phase 3
1. Continuing consolidation and realignment of current LARC resource investments to align with core mission.		
2. Adopt flexible personalization for workspaces, e.g., AR overlays		
3. Move to dynamic modular just-in-time facilities strategy to allow for inexpensive re-configuration as needs change. • Investigate new ways of building short-term facilities with reusable components: • Research current state of the art in 3D printer building construction and reusability	• Identify approach for building temporary custom facilities for projects or civil emergencies 3rd - Conduct pilot tests on building temporary	

of modular building materials	facilities	
4. Explore eco-regenerative facilities technologies: • Commit to using sustainable building materials & systems for new facilities in the near term	• Actively work with architectural & building firms researching eco-regenerative building designs for future facilities	• Develop a plan to decommission older non-regenerative buildings, or to upgrade them to have less ecological impact

Know-how: *Develop a knowledge preservation plan*

Phase 1	Phase 2	Phase 3
1. Begin to experiment with ML/AI augmentation of work productivity to position LaRC as a public leader in using these tools		
2. Develop, implement, and prioritize an ongoing knowledge management strategy that maintains human knowledge base and skills around of AI/automation processes • Create new Knowledge Connection Group (KCG) to document & maintain detailed working knowledge of each team • Capture they Why and How of processes needed to get the work done	1. As work is moved into ML/DT tools ensure that documentation is maintained to reflect the evolution of processes being used by Machines and AI to get work done 2. KCG create common repository for all teams' working documentation	3. KCG trains & assists teams in use/updating common repository 4. CG perform analytic assessments (IBM Watson + teams) across shared documentation to find commonalities of process, tasks, tools, data, etc.

Culture: *Institute "LaRC University" to promote sharing of tacit (experiential) knowledge*

Phase 1	Phase 2	Phase 3
1. Proactively integrate security considerations into all new processes, initiatives, and the workforces to minimize drag on efficiency • It may become possible to use augmentation for enhanced network security, such as biometrics, bio-implantable s, etc.		
2. Set a preferred "ratio" of full-time hires, project workers, and contractors to guide workforce development		
3. Encourage LaRC empowered employee mindset: • Research ways LaRC can encourage more entrepreneurial attitudes among employees (1)	• Implement employee initiatives to promote "bottom up" decision making (2)	• Implement policies which encourage dynamic self-organization of teams, and which give those teams & individuals more control over their work (3)
3. KCG works with current training group & teams to increase in-team and cross-team training	• KCG works with training group and teams to spread tacit knowledge held by	

	individuals & teams, via hands-on cross-team training & "apprenticing" relationships.	
4. Develop contingency plan of preferred future with significant influx of resources and volunteers • Expand internship programs to "non-traditional" universities and majors • Run crowdsourcing experiments • Encourage sabbaticals or "exchanges" with private sector • Run regular prize competitions	• Design novel ways to present the results of Science Missions to influence congress and the public to maintain funding for these initiatives as public research dollars become scarce.	

Failure to Launch Contingency Strategy

Phase 1	Phase 2	Phase 3
1. Primary objective becomes protecting core missions and core people.		
2. Map out phased relocations away from coast; Identify secure inland government facilities that could be repurposed for LaRC's work and to support its staff and families.	• Pilot an incremental physical moving of LaRC.	• Harden LaRC's perimeter in ways that do not draw attention but increase the facility's physical security.
3. Develop enhanced emergency plans • Identify key monetary/resource needs in case of civil disorder • Enhance existing emergency planning with civil-disorder scenarios & responses	• Identify key employees & facilities; prioritize key areas of research for LARC and what might fit with other Labs • Identify ways to protect families of LaRC personnel onsite in case of natural disaster or civil disorder	• Create & maintain extended-timeline emergency response plan. • Develop a facilities plan that enhances physical security and can be self-sufficient in a worst-case outcome. • Maintain emergency supplies for extended use of LaRC facilities as emergency shelters. • Work with other research centers & NASA to research minimum resources in tech & equipment needed to establish an "emergency backup civilization" which could bootstrap certain technologies back on earth using space resources
4. Gather resources to continue work after emergencies • Each team creates/updates emergency resources plan containing needed lab materials and equipment in case of extended loss of outside	• LaRC leadership buys and maintains identified stockpile items of emergency goods & supplies, which are maintained by teams	• Emergency preparation drills conducted at least once a year with all personnel participating

resources		

Toward a Vision of the Future of Work

The nature of the future landscapes outlined by the scenarios suggested a robust strategy that identified strategic initiatives in six areas – along with a contingency strategy in the event of collapse. We would like to close the white paper with some ideas on how LaRC might also use this work to develop a vision on the future of its work. A vision is, of course, something developed by the people and organization that it is intended for. Thus, we offer some themes we identified as external consultants that might be useful in that pursuit.

The luxury of looking well over the horizon to 2050 is that we can imagine a future beyond some deeply entrenched practices and seemingly insurmountable obstacles of today. In particular, the transformative "New Frontier" scenario envisions a governance model absent of today's often stultifying bureaucracy. We might imagine an admittedly slightly-utopic citizen scientist model taking advantage of augment humans and advanced AI achieving an incredible leap in productivity. Another big leap from today is to imagine augmented workers as a relatively routine feature of the workforce of the future. Indeed, rather than "wait-and-see, we recommended a strategic initiative of "getting ahead of augmentation," that is, encourage experiments and pilot projects in the use of augmentation that can serve as a model for other labs. We can also see widespread use of telepresence and virtual reality as key tools for enabling LaRC to greatly outstretch its reach beyond the current campus. Indeed, these advanced capabilities are hard to imagine in today's world where PowerPoints often don't work, it takes ten minutes for computers to boot up, and we struggle with wifi codes!

With that potential end point in mind, we recommended a deliberate purposeful multi-phased strategy of digital transformation. We note, for example, that LaRC is already working with IBM's "Watson" software today. It is likely to be challenging to make productive use of this and other leading AI applications, but we suggest this kind of activity fits well with the LaRC of the future. It may behoove LaRC to emphasize the practical aspects of this vision and strategy, i.e., how do we responsibly automate, work with AI, and open up the business model and culture to incorporate a much greater range of working arrangements.

NASA's role has been shifting from "creating the future" of space more of an enabling and supporting role. Thus we envision a "Responsible AI/Automation/Augmentation or "Responsible Digital Transformation" as a potential guiding vision. A challenge would be to implement that responsibility in a way that avoids the perception of naysaying and red tape, but rather involves extensive and continuous collaboration and negotiation with an expanding range of stakeholders, from within LaRC silos to One Lab, to other labs, to private partners, and even the public "citizen scientist."

A big concern, played out in the Breaking Orbit scenario, is losing of the control of the technology. To avoid this, we recommend a deliberate strategy that approaches the human technology intersection as an opportunity for developing partnership. Much automation today is driven by commercial considerations. When machines can do the work cheaper, people are let go. We suggest instead a very careful inventory of work roles and job tasks that thoughtfully considers alternative approaches to simple replacement. Sometimes simply automating makes sense, but we suggest a principle of always looking for an alternative. In cases where complex roles or tasks are considered for AI, we recommend developing protocols for "returning" control back to people, as well as "designing in" the ability to capture how the AI is doing the task.

In the Breaking Orbit scenario, we learned it was vital that people not "forget" or be unable to run complex systems or operations because they had been automated or turned over to AI. This is a cautious approach, but our analysis suggests that there is an opportunity to be proactive and instill principle that will guide a safer future of work. And we believe there will be intense pressure to avoid these steps in the interests of private companies and commercial considerations. They are likely to seek to go full speed ahead and see precautions as roadblocks and government red tape, and will bring pressure to loosen up the measures.

We believe, therefore, that the opportunity to be ahead of the curve in terms of AI/automation and related technology adoption. In other words, do not be seen as lagging behind and therefore putting up roadblocks. By publicly embracing the leading edge of technology, the precautionary approach has a better chance of being seen as sensible precaution rather than reactionary bureaucratic behavior.

We believe there is an opportunity for someone to lead "Responsible AI/Automation/Augmentation (or Digital Transformation)." It will also be appreciated by your workforce. The scenario work suggested that in all but the worst case of collapse, the high-end of NASA's talent – what we called the 20% -- would probably do well. That relative degree of security provides an opportunity to be really thoughtful about automation and what makes sense for machines and where we can provide people with meaningful things to do. We believe that if this transition is well managed, the productivity gains will be immense, such that we proposed a transformative "New Frontier" scenario in which Universal Basic Income is the norm and people "work" because it is interesting and they want to. If LaRC has been among the leaders in "Responsible AI & Automation, it is likely to be hugely popular outlet for "volunteers." The long decline in space interest reverses in spectacular fashion in this scenario.

Part of the move toward more open and participatory business models is a commitment to agility and flexibility. In moving towards a participatory NASA vision of the future, it is suggested that LaRC consider supporting repeal of the current civil service structure. This would, of course, generated a huge uproar, so it must be carefully positioned as a way to open NASA up rather than as a cost-cutting measure.

Our recommendation is that there is far too much uncertainty about how physical and virtual work integrates, that it is advisable not to sink huge amounts of money in a facility that quickly become obsolete. In this case, much as the workforce could fluctuate, the space should fluxuate with it, and we recommend a just-in-time building approach, which should benefit from increasing capability of modular 3D and 4D construction. An equally if not more compelling argument for the flexible approach comes from the collapse scenario, in which the facility would need to be relocated in a catastrophic global warming driven collapse.

In sum, we offer the suggestion a bold role of NASA LaRC as a living laboratory as testbed and pioneer of these advanced work practices, under the "Responsible" banner. The research suggests that the most impactful changes on the future of work involve automation, AI, and augmentation, in particular as they are driven by private interests seeking commercial success. We believe that it is important if not vital for a government agency – why not NASA LaRC – to develop a proactive vision of the future of work led by people in partnership with machines – not the other way around.

APPENDICES

Appendix 1. Selected bibliography on the future of work

- **The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies** (2016) Erik Brynjolfsson and Andrew McAfee (link) Argues that digital technologies are at an inflection point—the early stages of a shift as profound as that brought on by the Industrial Revolution. While it will bring more "bounty" it will also create more inequality. The superstars and highly skilled should do well, but the rest are potentially negatively affected by automation
- **The Sharing Economy: The End of Employment and the Rise of Crowd-Based Capitalism** (2016) Arun Sundararajan (link) The "sharing economy" includes early instances of a future in which peer-to-peer exchange becomes increasingly prevalent, and the "crowd" replaces the corporation at the center of capitalism. A key uncertainty is whether the sharing economy ultimately represent the rise of the microentrepreneurs or does taskification drive a race to the bottom.
- **Four Futures: Life After Capitalism** (2016). Peter Frase (link) Makes the case that high degrees of automation can and will be used over skilled labor. The uncertainties in his scenarios are if we can deal with the ecological crisis and class power.
- **Postcapitalism: A Guide to Our Future** (2015) Paul Mason (link) Suggests that capitalism is a complex adaptive system that has reached the limits of its capacity to adapt, and that infotech is reduced the need for work and information goods are corroding market mechanisms, eroding property rights and destroying the relationship between wages, work, and profit. Among the suggested remedies: expand collaborative work, socialize the financial system, and pay everyone a basic income
- **Reinventing Organizations** (2014) Frederick Laloux (link) Research on how organizations work differently when leading-edge integral values. Some key characteristics (1) very few people working in staff functions (2) No org chart, no job description, no job titles (3) use advice process (person must seek advice from all affected parties before deciding) (4) when people have purpose and resources, they don't need pep talks or stretch targets.
- **Zero Marginal Cost Society** (2014) Jeremy Rifkin (link) Rifkin enthusiastically declares that we're on the cusp of a post-abundant society, made possible through free information (open source & IoT), free energy (renewables), and free labour (robotics). He that the cost associated with these components has been reaching lower and lower towards zero marginal cost, which will enable return to a society centered around self-sufficient communities.

Appendix 2. About the Houston Foresight Program

The Houston Foresight program is the world's longest-running graduate program solely focused on foresight. It offers education and training in futures thinking and methodologies in a variety of formats that are customized for different learners with different needs – from a week-long "boot camp" to a four-course graduate certificate to a full Master's degree. It also performs research on futures-orient projects to benefit the community and business, government, education, and non-profit organizations.

Our vision is to be widely recognized as the premier training ground for professional futurists and for those seeking to futurize their lives and their organizations.

Our mission is to serve aspiring professional futurists and the world by providing high-quality foresight training to help individuals and organizations in business, government, education, and non-profits realize their preferred futures.

For more information, visit http://houstonfutures.org/

REFERENCES