

DAY ONE PROJECT

How to Unlock the Potential of the Advanced Research Projects Agency Model

Arati Prabhakar

June 2021

The Day One Project offers a platform for ideas that represent a broad range of perspectives across S&T disciplines. The views and opinions expressed in this proposal are those of the author and do not reflect the views and opinions of the Day One Project or its S&T Leadership Council

Drawn from the experiences of a former DARPA Director, these insights represent one perspective on what it takes to succeed in building an ARPA model.

Summary

America faces a host of daunting problems that demand forward-looking solutions. Addressing these challenges will require us to unleash the full potential of our research and development community, leveraging new approaches to innovation that break through both technical and institutional barriers and initiate wholly new capabilities. The Advanced Research Projects Agency (ARPA) model has resulted in exactly this kind of high-impact innovation in defense, intelligence, and energy. This model can be applied to other critical societal challenges such as climate, labor, or health. But an ARPA must have the right core elements if it is to create the fresh solutions the country needs.

The ARPA model is distinctly different from other federal agencies in mission, operations, and culture. ARPA organizations are part of a much broader ecosystem that spans from research to implementation. Their role is to create breakthrough, paradigm-shifting solutions and capabilities. In order to position a new ARPA for success, Congress, the Administration, and the agency's founding leaders must understand the unique properties of an ARPA and the process by which ARPAs approach and manage risk to develop game-changing advances.

To establish a strong foundation for a new ARPA to do this work, Congress and the Administration will need to address four factors:

- Purpose: Clearly and succinctly define the vital national purpose for the new ARPA.
- Operations: Set the agency up to function autonomously, with its own budget, staff, and operating practices.
- Authorities: Give the new ARPA flexible hiring and contracting authorities to draw new and extraordinary talent to the nation's challenges.
- Leadership: Appoint an exceptional leadership team, hold them to a high standard for impact, and create room for them to deliver on the full potential of the ARPA model.

Over the course of a few years, a new ARPA can grow into a powerfully effective organization with people, practices, and culture honed to create breakthroughs. If well implemented, new ARPAs can be extraordinary additions to our R&D ecosystem, providing unimagined new capabilities to help us meet our most essential societal challenges.

Challenge and Opportunity

America faces some daunting problems today. Many millions of Americans are unable to access our nation's rich opportunities, leaving all of us poorer without their contributions. Dozens of other countries have longer life spans and lower infant mortality rates, although we spend more per capita on healthcare than any other country. We are not yet on track to contain the damages of a changing climate or to manage its impacts. Global competition has resulted in more and more U.S. research advances being used to create jobs elsewhere. R&D alone won't solve any of these problems. But every one of these challenges demands creative new solutions.

However, America's phenomenally productive R&D ecosystem—with its half a trillion dollars spent annually by the public and private sectors—is not aimed at these large, society-wide challenges. How do we create a generational shift in our innovation ecosystem so that it contributes as much to meeting this century's challenges as it did for those of the last century? What can we learn from our successful R&D history, and what approaches can we adapt to address the problems that we now face?

One part of the answer lies in the Advanced Research Projects Agency (ARPA) model for innovation. This kind of innovation knocks down both technical and institutional barriers to create transformational new capabilities. ARPA organizations are part of a much broader ecosystem, spanning from research to implementation, in which their role is to create breakthrough solutions and capabilities that fundamentally change what we define as possible. In pursuit of revolutionary advances, they accept and manage a level of risk for which companies and other government agencies have no incentive.

The first ARPA, the Defense Advanced Research Projects Agency (DARPA), was launched in 1958 at the height of the Cold War. DARPA shifted military capabilities from mass bombing to precision strike with GPS, stealth technologies, and integrated combat systems. These innovations recast defense systems, changed military outcomes, and shaped geopolitics over decades. Meanwhile, DARPA's programs in enabling technologies also seeded artificial intelligence, developed advanced microelectronics, and started the internet. In recent years, DARPA programs have built the first ship able to navigate from the pier and cross oceans without a single sailor on board,¹ created a radical new approach to reconfigurable military capabilities to outpace global adversaries,² developed the first systems—now in operation by the Port Authority of New York and New Jersey—for cities to continuously monitor for dangerous nuclear

¹ Joseph Trevithick, "Navy's Sea Hunter Drone Ship Has Sailed Autonomously to Hawaii and Back Amid Talk of New Roles," *The Drive*, February 4, 2019, <https://www.thedrive.com/the-war-zone/26319/usns-sea-hunter-drone-ship-has-sailed-autonomously-to-hawaii-and-back-amid-talk-of-new-roles>.

² Jared Serbu, "DARPA's contribution to JADC2: 'Mosaic' warfare," *Federal News Network*, December 29, 2020, <https://federalnewsnetwork.com/defense-main/2020/12/darpas-contribution-to-jadc2-mosaic-warfare/>.

DAY ONE PROJECT

and radiological materials,³ and created a rapid-response mRNA vaccine platform⁴ that enabled the astonishingly fast development⁵ of today's mRNA vaccines for COVID-19.

We are also starting to show that the ARPA model can be successfully adapted to other national purposes. In 2006, the Intelligence Advanced Research Projects Activity (IARPA) was formed to serve the intelligence community. One of IARPA's programs has developed methods to overcome individual cognitive biases by weighting and synthesizing the judgments of many analysts. This approach provides important gains in prediction and is a new paradigm for forecasting events in a complex world. In 2009, the Advanced Research Projects Agency–Energy (ARPA-E) launched in the Department of Energy. Its programs have created new power semiconductors, new battery technologies, and new methods to improve appliance efficiency, making vital contributions to our clean energy future. Both ARPAs have invigorated R&D communities by connecting them to hard, important problems and giving them a pathway to drive impact.

Implementing the ARPA model to meet other critical challenges could have enormous impact. Indeed, President Biden has already proposed ARPAs for health and climate,⁶ and others have advanced visions for ARPAs for agriculture,⁷ labor⁸ and education. In addition, the Endless Frontier Act⁹ takes inspiration from the ARPA model in its vision for an expanded technology function at NSF to address economic competitiveness.

Behind each call for an "ARPA for X" is a yearning for R&D that throws open new doors to radically better solutions. But the ARPA model is very different from other federal agencies and unlocking its potential will require much more than affixing the name. The starting point is an understanding of how ARPAs generate their outsized advances.

Though specifics vary according to the mission of a new ARPA, the essential operating model is based on these elements:

- An ARPA designs and conducts programs that run for limited periods, typically 3-5 years. Each ARPA program sets out to achieve a specific, bold goal that may seem impossible but that, if demonstrated, can initiate a major advance. Each ARPA program contracts

³ "DARPA's SIGMA Program Transitions to Protect Major U.S. Metropolitan Region," DARPA: Defense Advanced Research Projects Agency, September 4, 2020, <https://www.darpa.mil/news-events/2020-09-04>.

⁴ Paul Sonne, "How a secretive Pentagon agency seeded the ground for a rapid coronavirus cure," *The Washington Post*, July 30, 2020, https://www.washingtonpost.com/national-security/how-a-secretive-pentagon-agency-seeded-the-ground-for-a-rapid-coronavirus-cure/2020/07/30/ad1853c4-c778-11ea-a9d3-74640f25b953_story.html.

⁵ David Adler, "Inside Operation Warp Speed: A New Model for Industrial Policy," *American Affairs* V(2), Summer 2021, <https://americanaffairsjournal.org/2021/05/inside-operation-warp-speed-a-new-model-for-industrial-policy/>.

⁶ "Summary of the President's Discretionary Funding Request," Office of Management and Budget, Executive Office of the President, April 9, 2021, <https://www.whitehouse.gov/wp-content/uploads/2021/04/FY2022-Discretionary-Request.pdf>.

⁷ "Societies Urge Agriculture Secretary to Prioritize Ag Research Pilot Program," *American Society of Agronomy*, April 14, 2021, <https://www.agronomy.org/news/science-policy-news/societies-urge-agriculture-secretary-prioritize-ag-research-pilot-program/>.

⁸ Joshua Schoop, Arati Prabhakar, Jeff Kaplan and Andrew Sosanya, "Creating an Advanced Research Projects Agency (ARPA-L) for the Department of Labor, Day One Project, March 2021, <https://www.dayoneproject.org/post/arpa-l>.

⁹ "Senator Pump Brakes on Endless Frontier Act," *Science Policy News from AIP*, Bulletin 36, American Institute of Physics, April 16, 2021, <https://www.aip.org/fyi/2021/senators-pump-brakes-endless-frontier-act>.

DAY ONE PROJECT

with companies, universities, and other organizations to execute R&D efforts. It also engages the parties who can implement and scale successful program results.

- An ARPA requires exceptionally talented program managers with a rare combination of expertise, vision, and the ability to execute and deliver results.
- ARPA leadership approves a series of individual programs, constructing and overseeing a full and diversified portfolio.

ARPA Programs. An ARPA generates major advances through intelligently managed risk-taking. The fundamental unit of work for an ARPA is a solutions-oriented R&D program that aims at achieving a previously unimaginable goal. Each program has a fixed term, typically 3-5 years, and each is designed, executed, and transitioned by an ARPA program manager.

Design. The program manager designs the program to achieve a bold goal—one that may seem impossible but that, if demonstrated, could catalyze a major advance. They build a rigorous plan to achieve the goal. A set of questions known as the Heilmeier Catechism¹⁰ (from an iconic DARPA director in the 1970s) guides program development:

- What are you trying to do? Articulate your objectives using absolutely no jargon.
- How is it done today, and what are the limits of current practice?
- What is new in your approach and why do you think it will be successful?
- Who cares? If you are successful, what difference will it make?
- What are the risks?
- How much will it cost?
- How long will it take?
- What are the mid-term and final “exams” to check for success?

These questions are easy—even obvious—to ask, but surprisingly difficult to answer well. Program managers typically grapple with them over 6-12 months to design a strong program, and agency leaders use them to guide their judgement about the potential of a new program for approval. The questions also guide program execution.

Execution. Once a program is launched, the program manager contracts with whichever organizations are needed to achieve the program’s goal. That typically means companies, universities, nonprofits, other parts of government, and other organizations with the talent and capacity to conduct the necessary R&D. Contracting this work has the obvious benefit that the ARPA doesn’t have to hire staff and provide facilities for this R&D. But even more important is the fact that this approach mobilizes individuals and organizations. Over the course of the program, these participants become a community that not only delivers the program vision but can help drive it forward beyond the term of the ARPA program.

¹⁰ “The Heilmeier Catechism,” DARPA: Defense Advanced Research Projects Agency, <https://www.darpa.mil/work-with-us/heilmeier-catechism>.

DAY ONE PROJECT

The work of the program is to weave the threads of research from multiple domains together with lessons from the reality of use and practice in order to develop and demonstrate prototype systems or capabilities. The program rigorously evaluates how well its innovation works, how it works in specific environments, and how it can be scaled.

An ARPA program often draws on basic research and often generates fresh research, but research is an input rather than the objective. Unlike the management of basic research, these programs drive to a specific goal. They may sometimes resemble product development, but for a prototype product that serves a public purpose rather than a visible market opportunity. Often, they require a much higher degree of risk than product development because they reach for a barely feasible goal.

An ARPA program aims to demonstrate that a powerful new approach can work despite the risk inherent in trying something radically different. This requires actively managing the multiple efforts within the ARPA program. An ARPA program manager accelerates lines of work that show great promise and redirects or stops work that is not yielding results. They nimbly reallocate resources to keep wringing out risk and driving to the program's objective.

Transition. In parallel, the program manager engages the decision makers who can advance, adopt, implement, and fully scale the results of the program. If the breakthrough will require commercialization, that could include additional companies, investors, and entrepreneurs. If full-scale implementation requires changes in policies and practices, that means engaging regulators, policy makers, and community organizations. Understanding the needs and realities of implementers is important from the early stages of program design. It is sometimes the case that these implementers are skeptical about the program's bold goal at the start. As the program unfolds, they are invited to program reviews and demonstrations. The program strives to address their concerns and may even provide support for their internal analyses, evaluations, and trials. When these engagements work well, the ARPA program manager is able to bring implementers along on the journey from wild dream to demonstrated reality. Successful transition starts when they change their minds about what's possible. And the ultimate societal impact of the ARPA program comes when these implementers have fully scaled the ARPA breakthrough.

A fully successful program ends with a convincing demonstration of a new capability; a community that can carry it forward; and decision makers who are ready to support and fund implementation in products, services, policies, and practices.

DAY ONE PROJECT

Example: The structure of a hypothetical ARPA program

A labor-oriented ARPA program aimed at a new training approach might fund (1) a handful of university and company teams to advance promising research, (2) a company to develop a prototype that integrates research results into a practical system, and (3) a nonprofit to conduct and evaluate trials with people seeking to upgrade their skills. In parallel, the program manager would engage other agencies at the Department of Labor and other levels of government, both to learn from their perspectives and, as the program develops, to show them the progress and possibilities if the program is successful. The program manager would also engage companies and investors that can commercialize tools coming from the program. A fully successful program would demonstrate a training approach that is far more effective, takes a fraction of the time, and costs significantly less than current approaches, with robust evidence about how it works for people with different backgrounds and for different kinds of training. The program would end with companies, workforce boards, DoL, community organizations, and employers energized to implement the new approach and taking steps to scale it.

ARPA program managers. None of this can happen without exceptionally capable program managers. An ARPA organization hires program managers on fixed terms to design, manage, and transition these high-impact programs. ARPA leadership coaches program managers, helps build partnerships and remove obstacles, and approves and oversees all programs. But it puts enormous responsibility and authority on the shoulders of program managers.

ARPA program managers come from backgrounds in companies, universities, nonprofits, and other parts of government, and they serve at different times in their careers. They bring a “head in the stars, feet on the ground” blend of these key characteristics:

- The program manager is an expert in a relevant area.
- They see the big picture and navigate easily from details to strategic outcomes.
- They are driven to achieve a major impact. Sometimes this is manifested as a constructive impatience with the limitations of conventional organizations and approaches.
- They are able to project a vision.
- They are able to build and lead a community to accomplish goals.
- They have a sound ethical core.

ARPA portfolios. ARPA leadership approves a series of individual programs, constructing and managing a full portfolio that is diversified to maximize total impact despite the risk inherent in each program. Every program learns, not all succeed, and failure is accepted as integral to the mission.

Plan of Action

Based on these core elements of a successful ARPA model, we offer four recommendations for policy makers as they establish new ARPA organizations.

Purpose: Clearly and succinctly define the vital national purpose for the new ARPA. An ARPA exists to create breakthroughs for an important public need. For DARPA, this is national security. For ARPA-E, it is economic and energy security, and for IARPA, it is national intelligence.

Operations: Set up the agency to function autonomously, with its own budget, staff and organization, and operating practices. An ARPA is a deliberate counterpoint to work already underway, originating from a recognition that something more and different is needed to achieve our national goals. An ARPA will not succeed if it is tightly integrated into its parent organization. Ironically, it may be more difficult to start a successful new ARPA in an area that already has robust federal research, because of the inclination to fit the square-peg ARPA into round-hole traditional research methods. The ARPA model is completely different than our well-honed approach to sponsoring fundamental research. The ARPA solutions-driven approach would not work well for greatly needed and highly valued basic research, and conversely, funding methods for fundamental research will not lead to ARPA-scale breakthroughs for our societal problems. This work is different, and it will require different people, different practices, and a different culture to succeed.

Independent funding is also necessary. To develop a portfolio of programs with the potential for high impact, an ARPA requires funding that is sufficient to achieve its programs' objectives. ARPA programs are sized not just to generate a new result, but to convincingly demonstrate a new approach, often across a variety of circumstances, in order to prove that the method can succeed and scale.

The agency's chain of command and Congressional authorizers and appropriators provide important oversight. However, the ARPA organization itself must bear the responsibility for designing, selecting, managing, and transitioning its programs. A new ARPA should report directly to the cabinet secretary to maintain independence and secure the support needed to achieve its mission.

Authorities: Give the new ARPA flexible hiring and contracting authorities to draw new and extraordinary talent to the nation's challenges. Flexible hiring mechanisms have proven to be very valuable in allowing ARPAs to attract the rare combination of expertise, vision, and execution required in great program managers. In addition, program managers must be able to contract with exceptional people and teams in companies, universities, nonprofits, and other government entities to achieve their aggressive program goals. ARPAs have used flexible contracting mechanisms to move fast and work effectively with all kinds of organizations, not just those already designed to work with government.

DAY ONE PROJECT

Flexible hiring and contracting authorities are extremely helpful tools for an ARPA organization. It's worth noting, though, that flexible authorities by themselves do not an ARPA make.

Leadership: Appoint an exceptional leadership team, hold them to a high standard for impact, and create room for them to deliver on the full potential of the ARPA model. A new ARPA's director will be responsible for building an organization with people, practices, and culture honed for the mission of creating breakthroughs. This person must bring fresh and creative ways of looking at seemingly impossible problems, a rigorous approach to managing risk, a drive to achieve outsized impact, and an ability to lead people. A strong ethical orientation is also essential for a role that will grapple with the implications of powerful new capabilities for our society.

The person to whom the ARPA director reports also plays an essential role. This individual must actively prevent others from trying to set the agenda for the ARPA. They enable the ARPA organization to hire program managers who don't look like other department staff, undertake programs that conventional wisdom decries, manage programs actively, and develop a culture that celebrates bold risk-taking in pursuit of a great national purpose. They hold the ARPA organization accountable for the mission of creating breakthroughs and create room for the unconventional methods needed to realize that mission.

Note that these four recommendations about purpose, independence, authorities, and leadership are interconnected. All are necessary to build the foundation for a successful new ARPA, and cherry-picking the easy ones will not work.

Conclusion

A total of 87 years of experience across three different ARPA organizations have provided many lessons about how to build and run an organization that creates breakthroughs for an important national purpose. In establishing any new ARPA, both Congress and the Administration must create the space and allocate the resources that will allow it to flourish and realize its mission.

Like its programs, a new ARPA will itself be a high-risk, high-reward experiment. If our challenges were modest, or if our current innovation methods were sufficient, there would be no need to try these kinds of experiments. But the problems we face today demand powerful new approaches. Adapting the ARPA model and aiming it at the most critical challenges ahead can create breakthroughs that redefine what is possible for our future. Let's do everything possible to start new ARPAs on the right track.

Frequently Asked Questions

What is an Advanced Research Projects Agency (ARPA)?

ARPAs create radically better approaches to hard problems by conducting solutions-oriented R&D. The Department of Defense (DOD)'s Defense Advanced Research Projects Agency (DARPA), now in its seventh decade, conducted the pivotal R&D for new military capabilities such as stealth and precision strike and, more broadly, for new information technologies ranging from the internet to artificial intelligence. DARPA's track record inspired the establishment of the Department of Energy's ARPA-E and the Office of the Director of National Intelligence's IARPA. Both of these new ARPAs are well underway, with robust portfolios of R&D programs and encouraging results. They show that it is possible to adapt DARPA's model for different public purposes.

Who leads an ARPA? Who will this person report to?

For the independence, authority, and responsibility that a new ARPA requires, its Directorship should be a senior appointment reporting directly to the Secretary of the appropriate department. If this role is filled by a Senate-confirmed Presidential appointment, it will be important for stability to have a civil servant to serve as the Deputy Director.

How does an ARPA coordinate its work with other organizations?

ARPA leaders and program managers communicate with their entire ecosystem: other parts of government, the R&D community, and the entities that can implement and scale ARPA results. An ARPA holds the responsibility for selecting and executing its programs.

DARPA and ARPA-E create new technologies, but that's not what we need for social problems. How does the ARPA model apply to these very different challenges?

For any new ARPA, the model needs to be adapted to its context. For example, a promising solution for a social problem may come from implementing new insights from behavioral science. It is helpful to think about the desired future state a program will aim to realize, and then work backwards to the new approaches, methods, or tools that could enable it, as well as the institutional changes that will be needed. These solutions may or may not involve technology.

How can a new ARPA be successful without a customer like the Department of Defense to procure what it creates?

For DARPA programs that create revolutionary prototypes of military systems, DOD is indeed the customer. But the internet, miniaturized GPS receivers, microelectromechanical systems, and new waves of artificial intelligence did not make their mark through Pentagon

DAY ONE PROJECT

procurement. As part of the design of an ARPA program, the program manager needs to think through how their advance could be adopted and fully scaled. That could involve a government agency that procures a product or service, companies that commercialize the results, policy makers or regulators who can design rules and laws that are more effective because of the program's results, and/or other avenues.

DAY ONE PROJECT

About the Author



Arati Prabhakar is the founder and CEO of Actuate, a nonprofit organization to research and demonstrate breakthrough solutions for societal challenges. Arati has been a fellow at the Center for Advanced Study in the Behavioral Sciences at Stanford University, director of the Defense Advanced Research Projects Agency (DARPA), a partner at U.S. Venture Partners, and director of the National Institute of Standards and Technology (NIST). She holds a B.S. in electrical engineering from Texas Tech University and an M.S. in electrical engineering and a Ph.D. in applied physics from the California Institute of Technology. She is a member of the National Academy of Engineering.



About the Day One Project

The Day One Project is dedicated to democratizing the policymaking process by working with new and expert voices across the science and technology community to develop actionable policies that can improve the lives of all Americans. For more about the Day One Project, visit dayoneproject.org