Written Evidence Submitted by

Anna Watson, Doctoral Researcher, SPRU, University of Sussex and Professor Jim Watson, Research Director, UCL Institute for Sustainable Resources

(RFA0092)

We welcome the opportunity to submit evidence to this timely inquiry on a new UK research funding agency. The recent UKRI Research and Development Roadmap highlights the need to provide *"long-term flexible investment into infrastructure and institutions"* (p6) (HMG, 2020, p6). The announcement of an £800m ARPA style organisation as part of the UK's research and innovation ecosystem is a potentially important development. If implemented carefully, it could address some of the weaknesses of this ecosystem and help to tackle important national and global challenges.

Our expertise is in clean energy innovation, through which we frame our responses to the questions below. Our evidence draws on PhD research by Anna Watson focused on comparing clean electricity innovation organisations in the UK and US, with a specific focus on ARPA-E in the USA and the Energy Technologies Institute (ETI) in the UK. It also builds on Professor Jim Watson's expertise in innovation policies for meeting energy and climate change goals, and his experience as Research Director / Director of the UK Energy Research Centre (UKERC) from February 2013 to December 2019. UKERC is the flagship centre of the UKRI energy research programme.

We have focused on answering those questions for which we are able to provide relevant evidence.

1. What gaps in the current UK research and development system might be addressed by an ARPA style approach?

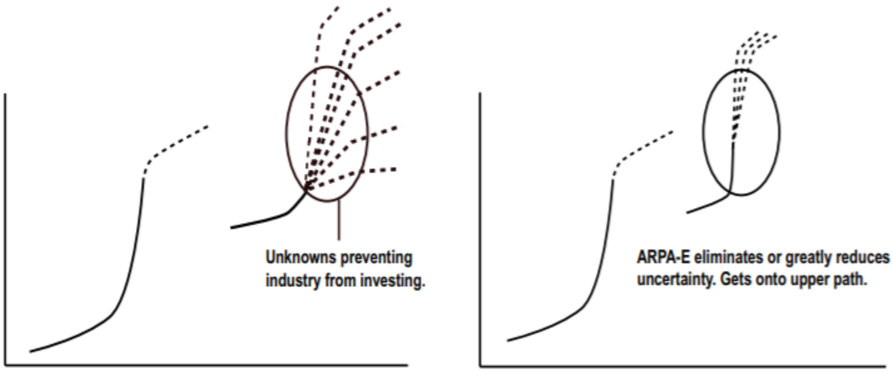
Our response to this question is in two parts. Firstly, what are the key features of an ARPA-style approach? Secondly, could this approach help to address the shortcomings of the UK research and development system?

What are the key features of an ARPA style approach?

The Advanced Research Project Agency (ARPA) approach aims to drive transformational innovation, connecting basic and applied research at Technology Readiness Levels (TRLs) 1-3, and supporting demonstration of larger-scale technologies at TRLs 4-5 (Bonvillian, 2018; Azoulay et al., 2019)**.** Transformative technologies are identified as those that will disrupt the status quo by significantly outperforming existing technologies, causing an industry shift (Alexander, 2009).

The ARPA approach funds these potentially transformative technologies at the 'nascent S-curve' of development, exploring multiple options and eliminating those that perform poorly to accelerate progress toward a dominant design (see Figure 1). A historical example might be skipping Betamax and going straight to VHS. This process is high risk, with failure a recognised part of an ARPA organisation's success (DARPA, 2016). The ARPA approach often focuses on global challenges, where industry and/or government think that transformative innovation is required.

Figure 1: Reducing uncertainty via an ARPA approach (Alexander, 2009)



More detail on the potential structure for an ARPA organisation to achieve this is discussed in greater depth in question 3.

Could this approach address the UK's shortcomings?

The UK research and development system is extensive and complex. It includes a range of programmes, organisations and networks that are designed to support research, development, demonstration and deployment. This includes funding for more 'bottom up' curiosity driven research and major investments in applied research and innovation programmes that address important societal challenges. Within the latter, there has been an increasing emphasis in recent years on mission-oriented research and innovation, often with links to the Industrial Strategy.

The UK's research and innovation landscape has changed significantly over the past few years. This includes the creation of UK Research and Innovation (UKRI) to bring together Research Councils and Research England and Innovate UK, and the establishment of a network of Catapults: organisations intended to support the commercialisation of new technologies in specific areas. In addition to this, the UK research system faces significant uncertainty due to Brexit and the impact of COVID-19 on public finances, universities and other organisations.

In the area we know best, energy research and development, the picture is no different. The Energy Systems Catapult was established in 2016, incorporating capabilities from the Energy Technologies institute that ceased operation in 2019. The Industrial Strategy Challenge Fund has funded a number of energy innovation programmes at higher TRLs, including Prospering from the Energy Revolution (a programme focusing on sustainable, local energy systems), the Industrial Decarbonisation Challenge and the Faraday battery challenge.

Apart from Brexit and the impacts of COVID-19, the UK research and development system faces a number of other more perennial challenges. Three challenges seem particularly important for any proposal to establish a new organisation. First, there has been a well-documented weakness in the translation of a world-class science base into commercial products (Dowling Review, 2015; BEIS Committee, 2017). Second, there is a tendency to try to avoid investing in failures (e.g. Policy Exchange, 2020). This second challenge is particularly important for innovation programmes. Arguably they need to embrace failure as a central part of the innovation process, and have processes in place to learn from such failures. This is one of the important features of the ARPA model the new UK agency has been inspired by (NASEM, 2017; DARPA, 2016).

Third, there is sometimes a challenge of co-ordinating multiple organisations and programmes in a particular research area. This is the case for clean energy research, where government and research funders have been attempting to co-ordinate research and innovation across funders and programmes for almost a decade. The most recent manifestation of this is the Energy Innovation Board[1], which is designed to provide 'strategic oversight' of energy innovation programmes. However, there is little public information available about its activities and impact.

In common with many other areas, the Research Councils oversee early stage energy research at TRLs 1-3. This funding is primarily channelled through universities. General issues that have been identified by UKRI in relation to this approach include high levels of bureaucracy and lack of longer term focus on pressing global issues (HMG, 2020). The latter issue applies much less to energy research, where climate change and other policy goals have been key drivers of major funding programmes since the early 2000s.

The Catapult network and Innovate UK are primarily focused on overcoming the commercialisation 'valley of death' at TRLs 3-8. The Catapults receive a third of funding from industry partners, meaning that there could be a tendency for their outputs to be more incremental (Breznitz et al., 2018). The Energy Technologies Institute (ETI) that operated from 2007 to 2019 focused on TRLs 3-6. Whilst the ETI's remit was to develop the revolutionary technologies required in 2030, and it channelled £400m of investment into energy technologies, the influence of private members and the financial crisis of 2008 impeded its ability to pursue this aim (ETI, 2018).

It is debatable whether an ARPA style organisation would complement these existing arrangements in clean energy research and innovation – and make a difference to the UK's ability to meet climate change targets and other energy policy goals. It could offer opportunities for more transformative, long term research and innovation. Furthermore, it could also provide additional flexibility, with more freedom than existing organisations and programmes to take risks and to learn from failures.

2. What are the implications of the new funding agency for existing funding bodies and their approach?

Whilst the UK innovation system includes multiple funding bodies and delivery organisations, the focus of an ARPA organisation could be complementary. It could concentrate on 'technological white spaces' where risks are too high for current funders (Azoulay et al., 2019), which would avoid duplication or competition with the UKRI and Catapults. The presence of ARPA could enhance the UKRI's existing approach by pursuing transformative research beyond traditional approaches (Bonvillian, 2018). The outputs from a UK ARPA could provide a range of technologies and other innovations that could then be supported further by Innovate UK and the Catapults. This could also complement the more specific, focused and industry-led programmes being funded by the Industrial Strategy Challenge Fund.

[1] https://www.gov.uk/government/groups/energy-innovation-board

In the United States, ARPA organisations do not possess their own laboratories (Bonvillian, 2018). We recommend that the UK ARPA takes the same approach. This would mean that academics are engaged within their existing roles and so competition for staff with other organisations would be minimal, beyond attracting a small suite of Programme Managers. Additionally, physical capacity would not be duplicated, with demand for existing research capacity strengthened by new funding opportunities.

A new organisation may add to the challenge of coordination discussed in question one, particularly if it funds new research programmes in areas such as clean energy where there are a significant number of established organisations and programmes. There is some evidence that it could help to meet important societal goals such as the need to transition to net-zero emissions by 2050. Such a mission-oriented approach, which already characterises the Industrial Strategy Challenge Fund (for example) could benefit from a plurality of approaches to supporting innovation (Hekkert et al., 2020). Work by Karo & Kattel (2016) for example identifies that decentralised, flexible and specialised organisations as more effective in delivering innovation policy than monolithic, hierarchical approaches. ARPA could therefore represent a piece of the jigsaw in facilitating mission- oriented innovation (Policy Exchange, 2020). The way in which ARPA connects with the innovation system is key, and discussed further in our response to question 5.

3. What should be the focus be of the new research funding agency and how should it be structured?

Our response to this question is mainly concerned with how a UK ARPA could be structured, but we also make some comments on its focus. Evidence from ARPA organisations in the United States suggests that their structure is an important determinant of their performance. Key features have been well documented in the US context (Alexander 2009; NASEM, 2017). They include:

- **Positioning**. ARPA organisations are traditionally positioned at arm's length from government departments, reporting directly to a responsible Minister. This is the so called 'island-bridge' approach, which creates a protected 'island' on which to experiment away from political interference whilst maintaining a direct 'bridge' to a key politician able to champion the organisation and provide it with the resources it needs (Bonvillian & Atta, 2011). This is a difficult balance to strike. If the UK were to follow this model, a key decision would be whether to position UK ARPA inside or outside UKRI. Positioning it outside UKRI could enable a focus on risk taking and distance the government from high levels of failure that are likely to be associated with this approach (NASEM, 2017; Breznitz et al., 2018; Haley, 2017). However, it has been argued by former science minister Jo Johnson that situating the organisation within UKRI would have advantages, including the speed with which it could begin operation and avoiding it being viewed as a *"pet quango"* by subsequent politicians (Policy Exchange, 2020: p:45). Whatever decision is taken on positioning, the government needs to be aware of the longer-term consequences and risks – and not just the apparent short-term advantages.

- **Mission**. ARPA organisations tend to formulate an aspirational, sector specific mission for delivery over at least ten years (Alexander, 2009). UK ARPA could be more general, and incorporate programmes that address a number of missions. Choices would need to be made, however, because the envisaged budget is unlikely to enable substantial funding for a large number of missions. A mission-oriented approach could help to attract high quality staff inspired to work on achieving this challenge (Haley, 2017), whose skills are well matched to realising its ambition (ETI, 2018). In the clean energy innovation area, a focus on the challenge of meeting net-zero emissions would make a good high-level mission (Policy Exchange, 2020).However, given the scale and breadth of this challenge, it would make sense for UK ARPA to choose some more specific missions that target particularly difficult elements of net-zero (e.g. reducing emissions from aviation, agriculture and some industries).

- **Operation**. ARPA organisations aim to reduce bureaucracy by adopting a flat structure, consisting of a Director that oversees the development of project areas by a series of Programme Managers (NASEM, 2017; Bonvillian & Atta, 2011). Directors are recruited from backgrounds that include entrepreneurial experience, enabling them to develop an agile vision for the organisation (Alexander, 2009). Programme Managers are empowered to select, actively manage and cut projects in a timely fashion in line with the organisational mission (Bonvillian, 2018; Azoulay et al., 2019). This approach to active project management, in combination with high risk tolerance has been demonstrated to enhance the productivity of ARPA-E (Goldstein & Kearney, 2020). Furthermore, the Director and programme managers are recruited on time limited contracts of 3-5 years, which creates urgency and a sense of mission around project development whilst keeping the organisation open to new ideas and approaches. This in combination with the organisation's flat structure means that it remains flexible in recognising, moving away from and learning from unsuccessful projects (Azoulay et al., 2019).

4. What funding should ARPA receive, and how should it distribute this funding to maximise effectiveness?

The government has committed £800m to set up UK ARPA. As the UK Research and Development Roadmap notes, this will represent a relatively small proportion of the overall UK budget for research and innovation (HMG, 2020). In their report on visions for UK ARPA, Policy Exchange suggest how an annual budget of £250-300m could be allocated (see figure 2).

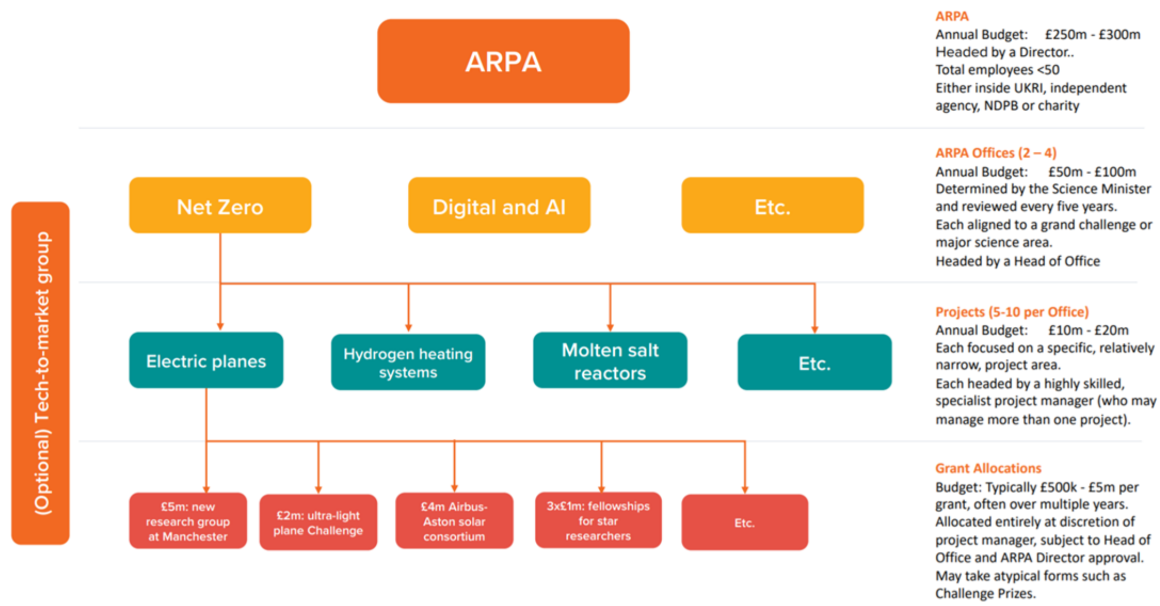
To give a sense of scale, ARPA-E in the US received an initial $400m of funding via the 2009 American Recovery and Reinvestment Act after the 2008 financial crisis[2]. Its annual budget started at $180m in 2011, and rose to around $300m per year in the late 2010s. Initially it was recommended that the ARPA-E budget should rise to $1bn a year after 4 years (Alexander, 2009).

Funding for ARPA-E projects is set aside at the start, at an average of $2.7m. If a project is particularly successful then ARPA-E may consider extending funding. However the main goal is for a project to attract onward funding from another source. This is different to the strategy of other offices in the Department of Energy that seek to continue to fund technology development to a later stage (NASEM, 2017).

This experience suggests that the UK ARPA budget would need to be focused on a few key priority areas or missions if it is to have the impact the government envisages. An early priority for this new organisation will be to set up processes to make decisions on which areas to focus on. We suggest that all areas should be aligned with societal challenges or missions such as achieving net-zero emissions – and not on sectors or areas of technology that are more generic.

[2] ARPA-E's budget requests can be found here: https://arpa-e.energy.gov/?q=arpa-e-site-page/arpa-e-budget

Figure 2: Illustrative structure of UK ARPA (Policy Exchange, 2020)



5. What can be learned from ARPA equivalents in other countries?

To the authors' knowledge, the ARPA model has not been replicated exactly outside of the United States. In learning lessons from US ARPA organisations, it is important to acknowledge that they are embedded in (and supported by) the US research and innovation system and that this system has important differences to that in the UK (e.g. a strong network of national labs).

The ARPA model was initially pioneered by the US Defence ARPA (DARPA) in 1958. This organisation has since been credited for contributing to the development of the internet, GPS and the world's fastest aeroplane. The model has since been replicated for energy (ARPA-E), intelligence (IARPA) and homeland security (HSARPA). Whilst these organisations have only run for some ten years in comparison to DARPA's 62, an independent review of ARPA-E indicated that its current operation is making progress toward its mission of producing transformative outputs (NASEM, 2017). IARPA has also seen a success in transitioning technologies to at least one intelligence agency (Policy Exchange, 2020).

Drawing upon our expertise in energy innovation and ARPA-E, we provide some lessons here that can be learned for the UK, particularly if UK ARPA includes a focus on clean energy and/or net-zero.

ARPA-E differs from the dominant DARPA design as its outputs need to be commercialised within a legacy sector, whereas at least 50% of DARPA projects are publicly procured. ARPA-E originally planned to use venture capital markets to help commercialise the technologies it supported. However the venture capital market for clean energy technology collapsed in 2011 (Hart & Kearney, 2017; Singer & Bonvillian, 2017). To overcome this difficulty, ARPA-E has since developed two key approaches to engaging with the energy innovation system to drive commercialisation. Firstly, it now has a memorandum of understanding with the Department of Defense, the US's largest energy consumer, to test, validate and offer initial markets that enable technologies for energy access in remote areas (Hart & Kearney, 2017; Haley, 2017). Secondly, a technology-to-market (T2M) team has been implemented, in which consultants work with ARPA-E projects to align outputs with industry and broader innovation system actors – and to make it more likely that they will continue development beyond project completion (NASEM, 2017).

The T2M team represents just one way in which ARPA-E aims to interact with the broader energy innovation system, which is an essential condition for its long-term success (Bonvillian, 2018). Building these networks effectively is therefore contingent on the presence of other strong energy innovation actors which possess complementary strengths and capabilities. The US has a strong National Lab infrastructure focused on energy innovation, with which ARPA-E has built relationships. ARPA-E has experienced some difficulty in engaging these Labs because they have large bureaucracies and their own priorities. However, ways of working are emerging between ARPA-E and the National Renewable Energy Laboratory (NREL) that replicate the entrepreneurial networks that venture capital initially sought to create. For example, lab equipment is being made more easily available to ARPA-E technologies[3] and other small companies[4], whilst NREL scientists are able to explore their riskier ideas via ARPA-E engagement[5]. Additionally, the US innovation system supports much greater collaboration levels with universities within these networks, with many world class test facilities available to ARPA-E projects via this route (Policy Exchange, 2020).

Other organisations have continued to emerge in the US to support and connect early stage energy technology development, such as Cyclotron Road[6] and a network of state-level clean energy incubators and accelerators (see Doblinger et al, 2019). These add further to the energy innovation system, and provide the funding and support needed to move technologies toward commercialisation.

ARPA-E's success is therefore supported by a strong element of public procurement, the development of T2M capabilities and the presence of strong national energy innovation infrastructure and funding to ensure technology outputs are brought the next step towards commercial markets. Some lessons can be drawn from this for UK ARPA, particularly if some of its activities are focused on legacy sectors.

First, public procurement has the potential to play a key role in providing certain markets for the development of nascent technologies. There may be opportunities for this in relation to clean energy and other technologies required to meet net-zero. Examples include using the government estate to trial novel technologies for building energy efficiency and low carbon heating and testing innovations in vehicle fleets.

The US innovation system has a strong network of nationally funded labs and other publicly funded networks, which facilitate collaboration at the next stage of technology development once an ARPA project is complete. The UK lost much of its energy laboratory infrastructure after the energy sector privatisation in the 1990s. Whilst funding and organisational capacity has been rebuilt since then, testing and laboratory facilities remain fragmented and less visible (Energy Systems Catapult, 2019). Furthermore, it has been argued that the more 'porous boundaries' between academia and industry in the US are not present in the UK context (Policy Exchange, 2020: p22). This supports responses above, in that UK ARPA can only be part of the UK's strategy for developing a more effective innovation system. Enhancing existing organisations and the co-ordination of the innovation system will be as important to UK ARPA's success as its design and implementation. In the energy sector, the role of the Energy Innovation Board will be particularly important.

---

[3] https://www.oemoffhighway.com/electronics/power-systems/batteries-capacitors/news/10854612/nrel-and-arpae-electric-vehicle-battery-research-projects
[4] https://www.nrel.gov/news/press/2018/nrel-wells-fargo-innovation-incubator-in2-announce-new-participants.html
[5] https://www.nrel.gov/news/features/2019/arpa-e-investment-nrel-pays-dividends-advancing-energy-tech.html
[6] https://www.cyclotronroad.org/

Finally, there are lessons from aspects of ARPA-E that could be improved. Whilst ARPA-E benefits from high levels of autonomy from political interference in day-to-day operation, its position within the broader policy environment has led to a lack of stability in securing ongoing public funding. Whilst it has been able to secure a stable level of funding from Congress for the last three years, the Trump administration's attitude to climate change and government engagement in markets has put ARPA-E at risk of losing funding.

In the UK, there is broader political consensus on the need to tackle climate change and opportunities for government to shape markets, most recently via the Industrial Strategy. Ensuring that UK APRA receives cross party political support will be essential if it is to receive stable funding over the long period required to support transformational innovation. It has also been recommended that ARPA-E adopt long term success metrics to ensure that public accountability is maintained. Therefore, whilst flexibility and agility are important for UK ARPA, it will be important for outputs to be aligned with its long-term mission (NASEM, 2017).

References

Alexander, J. (2009). An Energy Future Transformed: The Advanced Research Projects Agency – Energy (ARPA-E) –R&D Pathways to a Low-Carbon Future. Clean Air, Cool Planet. Available at: http://www.environmentportal.in/files/ARPA-E_AnEnergyFutureTransformed.pdf

Azoulay, P., Fuchs, E., Goldstein, A. and Kearney, M. (2019) "Funding breakthrough research: promises and challenges of the “ARPA Model”." Innovation Policy and the Economy 19, no. 1: 69-96.

Bonvillian, W. B. (2018). DARPA and its ARPA-E and IARPA clones: a unique innovation organization model. *Industrial and Corporate Change, 27(5), 897-914.*

Bonvillian, W. B., & Van Atta, R. (2011). ARPA-E and DARPA: Applying the DARPA model to energy innovation. *The Journal of Technology Transfer*, *36*(5), 469.

Breznitz, D., Ornston, D., & Samford, S. (2018). Mission critical: the ends, means, and design of innovation agencies. *Industrial and Corporate Change*, *27*(5), 883-896.

Business, Energy and Industrial Strategy Committee (2017) Industrial Strategy: First Review. HC616. London: House of Commons

DARPA. (2016). Innovation at DARPA. July 2016. Available at: https://www.darpa.mil/attachments/DARPA_Innovation_2016.pdf

Doblinger, C., Surana, K., & Anadon, L. D. (2019). Governments as partners: The role of alliances in US cleantech startup innovation. *Research Policy.*

Dowling Review (2015) The Dowling Review of Business-University Research Collaborations. Report to the Minister of State for Universities and Science. London: BIS.

Energy Systems Catapult (2019) A Guide to Energy Sector Testing & Demonstration Facilities. Updated 2019. Available at: https://es.catapult.org.uk/brochures/a-guide-to-energy-sector-testing-demonstration-facilities-updated-summer-2019/

ETI (Energy Technologies Institute). (2018). The ETI Journey - Review of Learnings 2007-2018. Available at: https://www.eti.co.uk/insights/the-eti-journey-review-of-learnings-2007-2018

Goldstein, A. P., & Kearney, M. (2020). Know when to fold 'em: An empirical description of risk management in public research funding. *Research Policy*, *49*(1), 103873.

Haley, B. (2017). Designing the public sector to promote sustainability transitions: Institutional principles and a case study of ARPA-E. *Environmental Innovation and Societal Transitions*, *25*, 107-121.

Hart, D. M., & Kearney, M. (2017). ARPA-E: Versatile Catalyst for US Energy Innovation. *Information Technology and Innovation Foundation, November*, *15*.

Hekkert, M. P., Janssen, M. J., Wesseling, J. H., & Negro, S. O. (2020). Mission-oriented innovation systems. *Environmental Innovation and Societal Transitions*, *34*, 76-79.

HMG (2020). UK Research and Development Roadmap. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/896799/UK_Research_and_Development_Roadmap.pdf

Karo, E., & Kattel, R. (2016). How to organize for innovation: entrepreneurial state and organizational variety. *Working Papers in Technology Governance and Economic Dynamics Tallinn University of Technology*.

NASEM (National Academies of Sciences, Engineering, and Medicine). (2017). An Assessment of ARPA-E. Washington, DC: The National Academies Press. https://doi.org/10.17226/24778

Policy Exchange. (2020). Visions of ARPA: Embracing Risk, Transforming Technology. Edited by Iain Mansfield and Geoffrey Owen. Available at: https://policyexchange.org.uk/wp-content/uploads/Visions-of-Arpa.pdf

Singer, P. L., & Bonvillian, W. B. (2017). Innovation Orchards": Helping Tech Start-Ups Scale. *Information Technology & Innovation Foundation: Washington, DC, USA*.

(July 2020)