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Abstract. 'Five Regions of the Future' was written in 2005 by two Futurists, Joel A. Barker and Scott W. Erickson, before the rise of social media, smartphones, and the advent of Industry 4.0. They proposed a framework for technological development based around five 'regions': Super Tech; Limits Tech; Local Tech; Nature Tech; and Human Tech, which they called TechnEcologies. The paper examines how collaborative networks can either complement or potentially disrupt this framework and sets out some areas that could form the basis of future collaborative research in Barker and Erickson's TechnEcologies.

Keywords: Collaborative Networks, Future Technologies, Industry 4.0

1 Introduction

In 2005 two Futurists, Barker and Erickson published a book called *"Five Regions of the Future: Preparing Your Business for Tomorrow's Technology Revolution"* [1]. For over twenty-five years they studied and catalogued tens of thousands of articles, and held hundreds of meetings, leading up to their book's release. They proposed a new framework based around five 'regions', each of which they termed a TechnEcology. These were:

1. Super Tech (ST): Bigger, better, more. (e.g. fusion power)
2. Limits Tech (LMT): Use what you've got. (e.g. aerogel insulation)
3. Local Tech (LOT): Smaller and local. (e.g. electric wind turbines)
4. Nature Tech (NT): At one with nature. (e.g. organic plastics)
5. Human Tech (HT): What lies within us. (e.g. stem cells)

They described a TechnEcology as a *"complex ecosystem of technology. The individual elements are made up of the tools and techniques invented by humans that interact in both mutualistic and competitive manners to increase the variety of technologies and the complexity of interaction."* [2]. HT cocoons the other four regions, because humans exploit them or coexist with them. Finally, Universal Technologies (UTs) live at the heart of Barker and Erickson's model (Figure 1). Their proposed UTs were: Aerogel (super light insulation); Thermal Depolymerization (carbon-based waste recycling); Advanced computers;

Chronobiology (mapping human patterns over time); 3-D printing for manufacturing; Hydrogen fuel cells; Holography; Lab on a chip; Nanotubes; Space satellites; Computer simulations; and E-books.

Several of their UTs are viable in 2018, including the 3-D printing of houses. With the benefit of hindsight some of these UTs may appear obvious. However, they were not when the original research was being developed. Their original UT predictions pre-dated the latest technologies such as smart phones, high powered graphical tablets, and e-books, by over a decade. Some of these UT's are having a profound impact on personal activity, such as highly accurate time-based GPS tracking, digital imaging and photography, crowd-sourcing of data and internet search activity. This has also created a politically charged environment on data security, data management, abuse, and governance.

Barker and Erickson's research indicated that the United States and Japan were heavily reliant on, and advocates of, Super Tech and predicted that Denmark was migrating towards Local Tech. This was in the pre social media and Industry 4.0 era, when basic shared platforms and intranets were the dominant collaboration technologies. This paper examines how collaborative networks can either complement or potentially disrupt Barker and Erickson's model and sets out some areas that could form the basis of future collaborative research within the respective TechnEcologies.

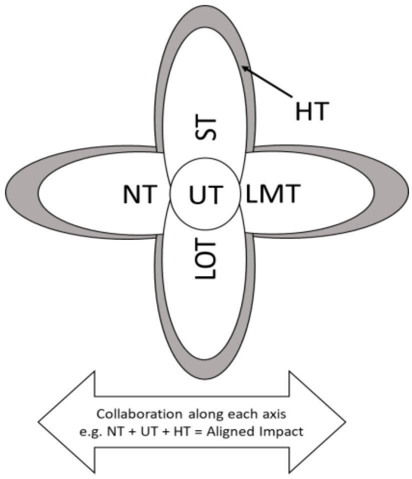

Fig. 1. Barker and Erickson's model updated for the aligned impact of collaboration

2 Collaboration Futures

Table 1 shows the approximate segmentation of papers by TechnEcology from the Proceeding of PRO-VE 2014 (Collaborative Systems for Smart Networked Environments) [3], PRO-VE 2015 (Risks and Resilience of Collaborative Networks) [4], PRO-VE 2016 (Collaboration in a Hyperconnected World) [5], and PRO-VE

2017 (Collaboration in a Data-Rich World) [6]. The conferences' dominant themes related to software, systems, and processes in support of Super Tech. These were typically in manufacturing, transportation, and logistics. There were relatively few publications on social/healthcare, food/agriculture, and the green/circular economy.

Table 1. Classification of the PRO-VE Proceedings from 2014 to 2017 by TechnEcology

Proceedings	ST	LMT	LOT	NT	HT	Totals
PRO-VE 2014	61	4	5	0	3	73
PRO-VE 2015	47	7	5	0	2	61
PRO-VE 2016	46	7	0	0	4	57
PRO-VE 2017	52	10	2	1	3	68
Totals	**206**	**28**	**12**	**1**	**12**	**259**

At the PRO-VE 2016 Conference [5], ten younger researchers were asked to propose one or two future collaborative scenarios and the potential challenges they could anticipate with their proposals [7]. Of the ten researchers who presented:

- Five selected Super Tech scenarios: customized 'smart' production for limited run items such as legacy parts; globally democratized manufacturing and assembly; virtual and augmented reality in e-participation; regulation of 5G mobile technologies; and, smart personal assistance for elderly care.
- Three chose Limits Tech scenarios: collaborative sharing of vehicle capacity in self-organizing supply networks; constraints on the future employment options for millennials, if traditional large employers reduce in numbers; and, the co-creation and management of disaster relief services.
- One chose a Local Tech scenario: localized power generation using renewables, with local energy storage and decentralized power grids.
- One chose a Human Tech scenario: mapping emotions in collaborative networks.
- None chose a Nature Tech scenario.

Their predictions were weighted towards Technology and Computing related collaboration. This is a similar segmentation of research published in the recent PRO-VE conferences. Given the conference titles and thematic topics [3,4,5,6], this may not be a surprise. However, it does give the expert collaboration community a chance in the short to medium term (now to 20 + years), to steer towards a more multi-disciplinary and integrated approach to collaboration research and development.

2.1 Collaboration within Super TechnEcologies

As at 2018, Industry 4.0 is dominantly located within the Super Tech region and the UT hub. In 2017 Camarinha-Matos et al. [8] described the position of collaborative networks as core enablers for Industry 4.0. They looked at collaboration issues and proposed some outline solutions to six dimensions within Industry 4.0, namely: vertical integration of smart production systems; horizontal integration through global value chain networks; through engineering across value chains; accelerating manufacturing; digitization; and new business models. They also listed a series of related research challenges for collaborative networks. These mainly related to the Super Tech region, covering some aspects of Universal Technologies, except for *"seek inspiration in nature, towards optimized solutions"*. This is Nature Tech, which is discussed in 2.4 below.

Barker and Erickson cited possibilities for Super Tech such as: mile high cities with 90% of the world's population living in them; smart homes that order food, cook meals, and water plants; 3-D TV and holography; hybrid sports with real and robot athletes. These are all highly aligned to the current trends in construction; smart buildings and Building Information Management (BIM) [9]; occupancy management; smart white goods; smart entertainment and leisure systems; people tracking; security and 'crowd' management, such as the 'Bristol is Open' project [10].

Industry 4.0 and the interconnectedness of living and working environments can support this 'vision' if people are prepared to live this way. However, there are significant risks to this TechnEcology that need more collaborative research. The risks illustrate the principal challenges on human vulnerabilities, especially in highly concentrated ecosystems and environments, as highlighted by a recent World Health Organization report [11]. In planning and managing life in this 'region', more research and solutions will be needed for: fire risk; drought; famine; contagious and airborne diseases; civil unrest and crime; along with the likely polarization of wealth and power. Super Tech also needs to address collaboration in agriculture; food storage and distribution; energy; water security; and, social wellbeing as highlighted by Montgomery [12].

Evidence from China, where supercities have sprung up in the past two decades, already illustrates some of the challenges with airborne pollution; traffic congestion and some polarization of wealth and related personal wellbeing. Planning for a new supercity in the Pearl River Delta, with a population of 42 million, has highlighted these issues [13]. Hence, more research is needed into: social inclusiveness; community and individual healthcare; the psychological benefits of green spaces within buildings; fitness; leisure; and, personal space management as proposed by Montgomery [12]. Whilst collaborative networks as enablers are already established within expert communities, more research is going to be needed for the establishment and protection of critical infrastructure, hazards and disaster relief, food security and material supply. Risks and threats can become concentrated. It is recommended that these be investigated over the short to medium term (now to 10 + years). A paper by the Institute of Technology summarizes these hazards [14].

2.2 Collaboration within Limits TechnEcologies

One of the most controversial propositions within Limits Tech is the potential need for population management to enable conservation of critical resources. In 2009 Lovelock [15] assessed the implications of unrestrained population growth and the effect on the earth as an ecosystem. The political and humanitarian implications of this are far reaching and beyond the scope of this paper. However, future collaborative research into the impact and consequences of rapid population growth has validity in the medium to longer term (10 to 20 + years).

On the positive side, Limits Tech promotes the benefits of: durable clothing; the revival of handicrafts, giving both personal satisfaction and saving transport; earth restoration; energy reduction and efficiency; highly efficient and insulated homes; the revival of trains and public transport, in preference to cars and lorries; and, the importance of the UT – hydrogen fuel cells.

Within the PRO-VE community there has been some well-targeted research into Green Virtual Enterprise Breeding Environments by Romero et al. [16] in 2015. By 2017 Romero et al. [17] had developed this concept and linked it to a Limits Tech related framework called RESOLVE [18]. Additional research by Shamsuzzoha et al. [19] on waste reuse, Falsafi and Fornasiero [20] on waste electronics and Jansson [21] on ship refurbishment have all contributed to this theme. This whole area of mapping circular economies and promoting a culture of scarcity, sustainability, reuse, and repurposing is likely to provide dividends as highlighted by the UK based WRAP organization [22]. In the author’s technical fields of asset management, engineering and infrastructure maintenance, there are three growing trends that have potential for the future promotion of collaboration within Limits Tech: the need to extend the useful life of critical infrastructure for financial or scarcity reasons [23]; the need for repurposing of former offices and commercial buildings into habitable environments for people [24]; and, the large increase in knowledge and enthusiasm for sustainable futures driven by younger people’s desire to live in a healthier environment [25]. The author believes that fruitful areas for research and the practical application of Collaborative Networks and Virtual Enterprises are:

- The design and management of circular economies with SMART environmental performance targets on a macro and micro scale (micro economies can also be designed for Local Tech);
- Greater modularization with reuse options built in (container-based housing);
- Better Building Information Management (BIM) systems and reporting [9];
- The adoption of BREEAM for master planning and sustainability measurement for both large and small-scale development [26];
- Integrated and energy efficient transport systems;
- Renewable energy, recycling, low carbon design and product distribution;
- Sustainable procurement linked to carbon/mileage;
- Modelling intergenerational resource usage and fairness more effectively, as highlighted by Lloyd in his case study on the City of Hamilton [27]; and,
- A significantly greater focus on durability and critical asset management [23].

This is a long list with major global opportunities for the collaborative research community in the short to medium term (now to 10 + years).

2.3 Collaboration within Local TechnEcologies

For many advocates of Super TechnEcology, Local Tech could be viewed as either archaic or potentially post-apocalyptic. Indeed, some of the scenarios envisaged are a fruitful source for the fiction and film industries. However, humans have survived and thrived for millennia based around physical and locally sustainable, communities where people know and trust each other, especially in times of scarcity and conflict, as highlighted by Dent [28]. So how can Local Tech based communities make best use of Universal Technologies, where they are available, and what are the implications for collaborative research?

Barker and Erickson referred to the work of Schumacher [29] and the choice of appropriate technology that could be most effectively supplied and used locally with the concept that *"production from local resources for local needs is the most rational way of economic life"*. They then pointed out the importance of appropriate scale – not too big to be dehumanizing and not too small to miss the 'variety of life'. A market town or larger village has many of the relevant facets of Local Tech, especially when combined with local supply chains and effective low or even net zero carbon forms of transportation and energy use.

Some communities are forced down this route through access challenges, driven by geography such as island, valley, mountain, or fjord based communities. Others have elected to live this way, such as the Lammas project. It is based at the ecovillage Tir y Gafelin in West Wales. Lammas *"combines the traditional smallholding model with the latest innovations in environmental design, green technology and permaculture. The ecovillage was granted planning permission in 2009 by the Welsh Government and is currently part-way through the construction phase. At its heart it consists of 9 smallholdings positioned around a Community Hub building, and it is supported by a range of peripheral projects and networks."* [30]. Whilst being a prototype, this is typical of small scale Local TechnEcology.

Local TechnEcology does not mean primitive living and collaboration is a critical facet of success. Hence, more people-centered systems such as Dent's partnering [28] and Covey's trust-based models [31] are important to a community's success. Their adoption for business based collaborative communities is also described by the Welsh Government's Joint Bidding Guide [32]. Local market modelling is also useful, such as the system proposed by Dupont et al. [33], especially when dealing with fairness of trade and risk spreading. Hernandez et al. [34] looked at links between location, risk and the agricultural value chain and Taurino described the use of resources for SME based clusters [35]. All of these give a useful collaborative context for Local Tech.

More research into collaboration within the context of Local TechnEcologies will be useful, especially for the developing world, to help the maintenance of local and village communities and related agriculture and craft. It is recommended that this be more thoroughly researched in the short to medium term (now to 10 + years) as a potential response to the pull of the supercities in 2.1 above.

2.4 Collaboration within Nature TechnEcologies

Camarinha-Matos et al. [8] briefly mentioned this region. Nature TechnEcology is a very fertile 'region' for future collaborative research and development, as highlighted by Thompson [36] in his Bioteams models and Benyus [37] in the book on Biomimicry. As more bioscience is explored, the links between humans and their natural environment are becoming more symbiotic.

One recent example, that demonstrates how Nature Tech can work with Universal Technologies and ingenuity, is the research into the production of Galantamine which reduces the acceleration of dementia in humans. The drug is extracted from Daffodils. It has been found that harsh growing conditions for Daffodils, due to cold and altitude, create more of the valuable compound. Hence a hill farmer in Wales has changed the use of much of his estate from animal farming to grow Daffodils from which he abstracts the drug. He collaborates with two universities, and the UK Government Department DEFRA, to research the optimum time to plant and harvest his Daffodils, to maximize the Galantamine yield [38]. A second example is the research by a team at the University of Leeds into the substitution of synthetic and potential carcinogenic hair dyes by anthocyanins extracted from the solid waste stream of a major blackcurrant drinks manufacturer in the UK [39].

Working in true collaboration with nature to mimic and enhance natural processes, reduce aspects of pollution, develop medicines and new products is a very positive way forward. This will be fruitful in the medium and longer term (5 to 20 + years) but needs far more collaboration between scientists, biologists, botanists, zoologists, the agricultural communities, virtual learning and collaboration experts to succeed.

2.5 Collaboration within Human TechnEcologies

As stated in the introduction, Human Tech cocoons the other four regions. It combines the physiological and psychological aspects of humans (body and mind). Barker and Erickson pointed out that *“only recently have we begun to understand the scope and power of these technologies in any conscious way.* Their four primary rules of HT are:

1. *The real needs of humans are not material needs;*
2. *Science is only now learning how to measure human technology;*
3. *God or mother nature or evolution, depending on your point of view, has endowed us with extraordinary capabilities; and,*
4. *Our true work is to know ourselves.”*

In their book they refer to a series of developments in the understanding of Human Tech such as: bilateral symmetry (natural selection); earwax (linkages to breast cancer); tears (toxin reduction); pheromones (chemical communication); gene therapy (long before recent advances in mapping and treatment); chronobiology (body clock and ageing); stem cells; and antibiofilm secretions (lactoferrin to prevent bacterial infections). These are rich areas for research using collaboration systems and theories, data modelling, large scale experiments and statistical validation but more likely for the medium to longer term (5 to 20 + years). The author has classified this as HTa.

On the wellbeing side, Barker and Erickson promoted collaborative traits such as organizational management, creating and using microloans (promoting self-sufficiency), teamwork and leadership. These are more developed up to and including an international standard on collaborative working [40]. However, the standard needs more research into the classic areas of trust, mutual benefit, and mapping of inputs and outcomes. This needs short-term research (within 5 years) to get more grounding in human ‘reality’ as opposed to collaboration systems theory. The author is researching in this area, aligned to overall competencies and system integration and has classified this as HTb.

3 Conclusion and the Way Forward

At the outset, this paper set out to examine how collaborative networks can either complement or potentially disrupt the Barker and Erickson model and identify some areas that could form the basis of future collaborative research in the respective TechnEcologies. Each TechnEcology was described in the overall context of collaboration research, applications, and linkages to both Industry 4.0, where appropriate, or human factors. The overall proposed timelines for research consideration were also proposed. These are summarized in Table 2.

Table 2. Potential Timelines for Collaboration Research into TechnEcologies

TechnEcology	Timeline for Potential Research		
	Within 5 Years	5 to 10 + Years	10 to 20 + Years
Super Tech (ST)			
Limits Tech (LMT)			
Local Tech (LOT)			
Nature Tech (NT)			
Huma Tech (HTa) Physiology			
Human Tech (HTb) Behaviors			

Over a decade of changes and developments in technologies, societies and collaboration systems have impacted Barker and Erickson's original predictions and propositions. Many of their predictions are appearing as reality, especially in the areas of Super Tech and Limits Tech. One of their final recommendations was that humans need to strike a balance between the capitalist and resource hungry world of Super Tech and the other TechnEcologies. This paper has proposed how the collaborative research and development community can support the various regions, with some potential timelines.

As a final offering, in his major work on Partnering Intelligence, Stephen M. Dent opens with the statement that *"For as long as humans have populated the planet, we have struggled to survive. Along the way we have learned that prosperity comes from banding together, determining what is in our best mutual interest, and moving forward in partnership."* [28]. This is still the driving force for human advancement and social stability. This paper has raised potential areas for research into advanced collaboration system and some ideas of which TechnEcology regions the research community can productively support and some recommended timescales.

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