SMART materials & systems: has embracing uncertainty become vital to commercialisation?

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SMART materials & systems: has embracing uncertainty become vital to commercialisation?

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Abstract. As humans we have a tendency to seek to confirm data and to avoid disconfirming data. COVID-19 that has thrown plans large and small into disarray, but well before then, the pace of change was already challenging the ability of SMART materials and systems to achieve full scalable commercialisation. While plans may not be feasible, what is possible and indeed necessary is planning. In this presentation I will present a toolkit that takes account of and even embraces uncertainty as a planning method directed at a more effective route for commercialisation and market growth.

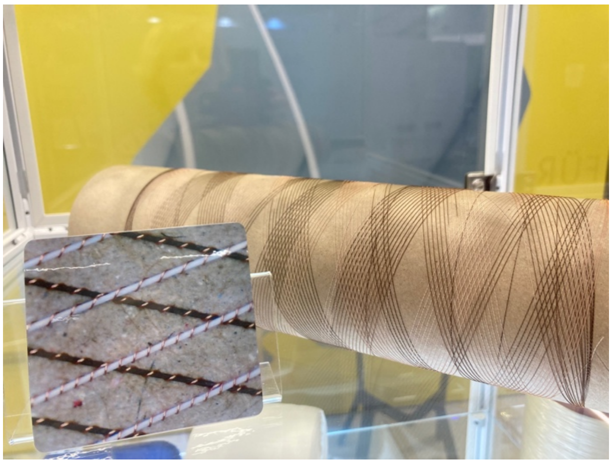

Fig.1. DITF Position-dissolving sensor yarn

1. Introduction

Natural fibers have a long history, so that although undeniably impacted by mechanisation and technology since the First Industrial Revolution, materials such as cotton and wool are inherently 'knowable.' Even as their capabilities are extended, there are inherent qualities, what might be termed a provenance that is singular and so traceable and identifiable. When man-made materials were first developed in the early twentieth century, they looked to mimic natural materials and initially directed at offering low-cost, convenient alternatives to more expensive natural materials such as silk [1]. By the second half of the century their own unique characteristics started to receive attention and their adaptability was seen as offering new design possibilities. This malleability was not without its challenges as Ezio Manzini pointed out in *The Material of Invention* (1989): "a world of nameless materials is taking shape. These materials create a crisis in the traditional relationships that we once had with materials, and they prevent us from attributing to them meanings that once endowed them with cultural and physical depth" [2]. Manzini's book was written as SMART materials and systems were only just beginning to emerge, so that his comments are largely directed at materials that were fixed once they left the factory or studio. SMART materials and systems offered materials and systems that had the capability to change, to sense and respond to changes in their environment.

SMART materials and systems began to emerge in architecture, military and sports in the early 1990s, bringing together a complex network of materials and technologies, each with their own signs, signifiers and systems. Lacking a singular provenance, they instead draw on many materials and technologies, each with its own distinctive provenance to the extent that for the first decade (and arguably longer), they were often dismissed as "solutions looking for problems" [3]. Although the sector now has a more clearly defined identity, the nature and the pace of the technologies and stakeholders means that it exists by necessity in a state of flux, of uncertainty.

It is the contention of this paper that uncertainty in this context is a positive. Used as a driver of innovation to propel the industry towards more timely commercialisation. Without innovation, there is little to interest the consumer, and without commercialisation, funding for new ideas cease to be justified. They are reliant on one another. In the first section of this paper the role of uncertainty in innovation is considered, drawing on literature and thought-leaders from innovation (Christensen), scenario planning (Wade) as well as the theories of Actor Network Theory (ANT) (Latour) and convergence(fusion) (Curren & Leker). The second portion goes on to apply these in the development of a toolkit that is designed to facilitate and harness the potential of uncertainty. The methodology builds on Wade's scenario building drawing on Curren and Leker's convergence(fusion) theory, demonstrating their combined potential in identifying future directions and achieving the timely commercialisation of SMART materials and systems.

2. The necessity of uncertainty

Uncertainty is not comfortable. The natural tendency of humans when faced with it is to try to eliminate it, to replace it with certainty as quickly as possible. Entrepreneur and business author Margaret Heffernan goes so far as to espouse uncertainty, pointing to humans' natural tendency to look for events and information that confirm our pre-existing world view: "We are very attracted to confirming data and we tend to marginalise and trivialise disconfirming data" [4]. The result the author argues is a natural gravitation towards a model of the world that will repel exactly the information that we need to be paying attention to.

In *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (2016), Clayton M. Christensen identifies two forms of innovation: sustaining and disruptive [5]. The former (that constitutes the majority) he classifies as offering improvements to product performance, so that it can be quite incremental. Disruptive innovation is less common, and introduces a very different value proposition to what was previously available. When new technologies emerge in a field it is very rare for the dominant company to retain its position over subsequent generations to the extent that "today's competitive advantage may become tomorrow's albatross unless strategists attune themselves to changes in underlying conditions"[ibid]. The need to consistently question and acknowledge uncertainties is challenging for industry, but for a disruptor there can be the added pressure that a sustaining innovation is not enough, it has to be disruptive once again.

Scenario planning at its most useful, is carefully constructed with an emphasis on anticipating rather than forecasting the future [6]. The reason being, that with so many variables, or unknowns, no single scenario could be guaranteed. Instead, scenario planning looks to identify an array of possible futures. Woody Wade in *Scenario planning – a field guide to the future* (2012) has identified ten steps

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for scenario planning. In identifying driving forces, he uses a political, economic, societal and technological (P.E.S.T.) model that secures a clear starting point based on what has actually taken place and then moves forward to speculate on future possibilities and scenarios [ibid]. These steps culminate in the generation of four distinct scenarios or possible futures within a 2 x 2 matrix that has two axes and four quadrants. The ten steps are:

1. Framing the challenge
2. Gathering information
3. Identifying driving forces
4. Defining the future's critical "either/or" uncertainties
5. Generating the scenarios
6. Fleshing them out and creating story lines
7. Validating the scenarios and identifying further research needed
8. Assessing their implications and defining possible responses
9. Identifying signposts
10. Monitoring and updating the scenarios over time

Actor network theory (ANT) has a profound interest in how scientific knowledge is socially constructed. To consider this in depth both human and non-human actors need to be accounted for and by extension, activities and observation collected within the scientific laboratory and the wider world. Bruno Latour likens a network to a translation, and in this way offers more subtlety than a system [7]. A system implies a more rigid structure, while a network, or translation, allows for greater mobility. "Science has two faces: one that knows, the other that does not know yet" the need for a methodology that encompasses change and uncertainty is apparent [ibid]. It also points to the relevance of ANT to strategic foresight as a way of bringing together what is known, as well as the future that is as yet, unknowable.

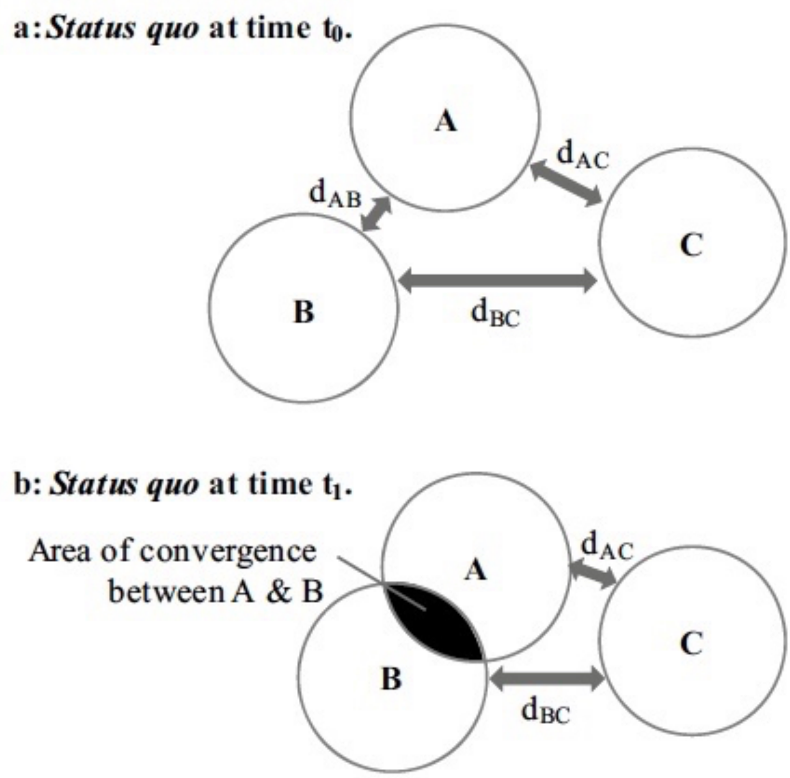

Fig.2. Curren and Leker's convergence(fusion) diagram

Clive-Steven Curren and Jens Leker's theory of convergence(fusion) refers to a blurring of boundaries between at least two hitherto distinct areas of science, technology, markets, or industries [8]. It allows for the creation of a new (sub-)segment in a new spot (the same spot) as a merger of (parts) of the old segments. The term is derived from the Latin "convergere," meaning inclining together as opposed to merging, indicating a retained separateness. This facilitates change, an increase of interchangeability and connectedness between the respective areas. In this way it is the uncertainty that is allowed for, even encouraged, that creates stability. Applying the principles of convergence(fusion) to SMART materials and systems it is possible to identify two distinct industries, the material (flexible) and the electronics (less flexible or hard) industry. This system and theory point to the importance of flux to create momentum and propel innovation and timely commercialisation.

3. The SMART Materials & Systems Toolkit

The challenges inherent in the innovation and commercialisation of SMART materials and systems are multiple, from the hybrid nature of the materials and technologies lacking a single distinctive provenance, to the very different actors required with each bringing their own histories and ways of working. The purpose of this toolkit is to offer a means of effective planning using what is already known for a future that is unknown.

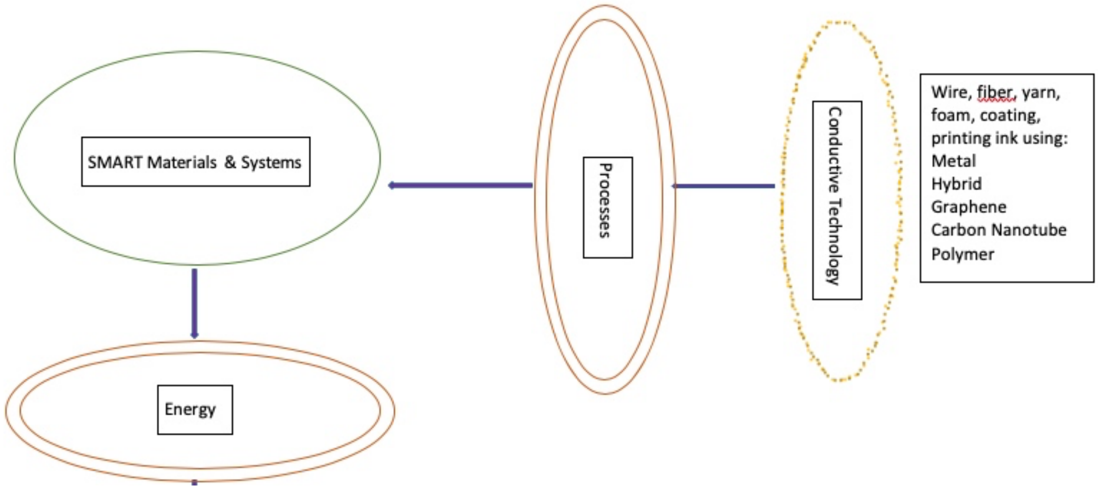

Fig.3. Object notation used to indicate a 'weighting' of their importance for each actor: mutable despite permanence (fluid, single line), a stable state (immutable mobile, double line) and unpredictability (fire, broken line)

The first portion of the toolkit is scenario building, typically using two timelines with the first date sufficiently near-term that some indicators can be reasonably identified. The second is long-term for a technology-related industry because of the rapid evolution of technologies. Employing ANT, the stakeholder is both human and non-human, and as internal and external actors, the stakeholder is not a fixed lens. Planning for the unknown must include the unanticipated future stakeholder who may also be a disruptor. The ten identifiable steps in scenario building proposed by Wade are taken as a starting point with the principles of convergence(fusion) introduced to allow for the hybrid nature of the materials, technology and systems.

The first step is framing the challenge, defining the stakeholders and the timelines to be applied. This is followed by information gathering, and the mapping of smart materials and systems within convergence(fusion) to provide a 'weighting' of their importance to each actor. The third stage is identifying driving forces gathering data and using a P.E.S.T. model. The fourth looks at critical extremes and the varying degrees of importance given to each in different circumstances. These are based on the driving forces identified in the P.E.S.T. analysis where each carries a potential impact, ranging from high to low. The level of impact and degree of uncertainty determines their critical uncertainty and from that identifies the two that are the most 'critically extreme.'

The fifth step is the development of four scenarios based on Wade's X-axis horizontal used to plot the uncertainties, with the intersecting Y-axis vertical to indicate the potential impact. In the sixth step, narratives are created with four storylines to generate possible alternative future plans. The seventh step is assessing implications and defining possible responses looking to allow for the greatest degree of flexibility. In the eighth step signposting is utilised to offer a process (flexible) rather than a fixed series of predictions. The ninth step is an outline for future monitoring and updating the scenarios using an annual P.E.S.T. analysis. The final tenth step is using the convergence(fusion) based scenario toolkit, proposing it as a starting point and itself subjected to revision and adaptation.

The value in this toolkit is predicated on the absence of a fixed outcome. The greatest challenge facing SMART materials and systems in industry and academia is not a disruptive technology or new actor, but instead the ability to embrace a network that is not fixed and where its stability and success is reliant on this.

4. Conclusion

The value of uncertainty has a long history in the sciences and problem-solving. Richard Feynman addressed it many times in his career, arguing for it as a necessity:

"All scientific knowledge is uncertain. This experience with doubt and uncertainty is important. I believe that it is of very great value, and one that extends beyond the sciences. I believe that to solve any problem that has never been solved before, you have to leave the door to the unknown ajar. You have to permit the possibility that you do not have it exactly right. Otherwise, if you have made up your mind already, you might not solve it."[9]

Certainty on the other hand points to something that is regarded as being a conclusive fact that is firm, and not open to further consideration. The door is closed. As the issue of commercialisation in SMART materials and systems is unresolved, this is problematic. Taking account of uncertainty, introducing it, managing and even embracing it offers a path to continuing innovation and bringing it to market in a timely manner.

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