'Make in India': lessons from G. Suryan's NMR research

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'Make in India' is the new mantra of the Indian Government. It is being presented as 'a major new national programme' aimed at transforming the Indian economy. The lion, with its body made of mechanical wheels, which is the symbol of the programme, leaves little to doubt that techno-scientific research and innovation are its central elements. The programme is being touted not merely as an initiation of 'new processes', 'new infrastructure' and 'new sectors', but also a 'new mindset' – 'an attitudinal shift' (note 1). This focus on 'new', although it may seem necessary and useful, betrays a broader post-colonial ambivalence towards science and technology and their history in India – an anxiety for a new future whose rhetorical force is evidently based on the debris of the past/present. And yet the 'old' (past/present) that needs to be transcended remains obscure and largely invisible in such debates.

There is a vast literature on sociology and history of science and technology in post-colonial India[1–12]. *Current Science* has carried a longstanding debate on the status of scientific research in India[13–16]. The present paper emphasizes the necessity to document particular trajectories of scientific practices and their multi-level entanglements, both nationally and internationally. In the absence of such data, policy initiatives such as 'Make in India' can hardly be effective. In particular, this paper focuses upon the nuclear magnetic resonance (NMR) research of G. Suryan and its relationship with other NMR researches in India and abroad. It uses this case study to highlight how even when innovative techno-scientific trajectories emerge – which are internationally acknowledged and utilized – they often remain disconnected trails within India[17].

Historians and sociologists rarely document such researches, possibly because none of the NMR researchers in India have received any major awards nationally or internationally. There is, for example, apart from a short description of NMR research in the literature[18], little discussion on the history of NMR in India[18–21]. Such historiographic elisions are also reflective of exclusions of Indian scientists as a result of Euro/West-centrism. The *Encyclopedia of Nuclear Magnetic Resonance*[22], for example, has biographical essays by most major NMR researchers from across the world. However, there is no such essay from any Indian scientist. There could have been a biographical essay by Suryan, for example, who was alive when the *Encyclopedia* was published, and as I show in this paper his contribution to NMR research definitely merited such an inclusion. Through a focus on the work of Suryan, I argue that we excavate particular trajectories of scientific practice (not just through bibliometric and scientiometric analyses) in order to highlight and figure out how we can prevent scientific researches in India from remaining disconnected trails, which can go a long way in making 'Make in India' successful.

NMR research at the birth of post-colonial India

'The huge gear-box, with all different gear ratios between adjacent shafts, which were approximately equally spaced… was a remarkable achievement of Suryan.'[21] Rajgopala Chidambaram, former Ph D student of Suryan and presently the Principal Scientific Adviser to the Government of India, is referring to *Chitralekha* – 'a magnetic storage system… for Fourier Synthesis in X-ray crystal structure analysis'[21] – that Suryan developed while working at the Indian Institute of Science (IISc), Bengaluru. *Chitralekha* 'was a great leap forward from the Beevers–Lipson strips' that crystallographers used at that time and a global frontrunner 'for Fourier synthesis, along with Ray Pepinsky's machine in Pennsylvania State University'[21]. Although the digital computing devices that emerged in the 1950s outdid *Chitralekha*, it was a striking example of innovative bricolage that Suryan managed with meagre resources.

Suryan combined the set-up described above with a technique that he had devised to overcome the limitations of 'integrating property of photographic materials' that were proposed in the late 1940s for NMR studies. 'The need for a device to extract small signals from an obscuring irregular background became acute in several fields at about the same time' and Suryan built one of the first such devices in the field of NMR[23]. 'By means of a small magnetic recording head similar to those used in sound recording,' Suryan reported, 'nuclear magnetic resonance signals…[could be] recorded in a close spiral on the steel cylinder…as it rotates'[24].

Suryan, as he did for other NMR studies as well, built the apparatus with the available tools and expertise, and operated on a shoestring budget. The recorder drum, for example, 'was part of an aircraft and was used because it was easily available'[25]. A set of two articles that Suryan published in the *Journal of the Indian Institute of Science* in 1953, nicely illustrates bootstrapping and bricolage of concepts and artifacts through which he devised this technique and built the experimental set-up[25,26]. The magnetic recorder was one of several pathbreaking researches that Suryan conducted. Another of his studies, namely investigation of NMR in flowing liquids, eventually became a precursor to several important technological innovations.

A review article published in the *American Journal of Roentgenology*[27] on magnetic resonance (MR) angiography – a cutting-edge MR technique used to visualize blood flow in the body – candidly states at the outset: 'The capability for studying blood flow noninvasively with MR was recognized long before the implementation of the first MR imaging systems.' The key study among the early investigations of flow using NMR that the article refers to is the one conducted by Suryan. 'The first report of NMR in the presence of flowing liquids, appeared in 1951 when Suryan, in India, showed that the arrival of fresh, polarized sample at the rf [radio frequency] coil decreased saturation and resulted in a more intense NMR signal'[19] (note 2)[28].

The experiments that led to this study of NMR in liquids were conducted in the late 1940s (note 3). Suryan observed that when 'liquid is passed through the oscillation coil the increase of the NMR signal is easily perceived'. He realized that 'this increase of signal will depend on the speed of flow of the fluid'. When liquid is flowing 'two most striking effects are noticed. First, there is a large temporary rise in signal strength, which subsides quickly. Secondly, there is a relatively larger signal obtained when the liquid is flowing steadily'[29]. Suryan published his findings in the *Proceedings of the Indian Academy of Sciences* – a journal that started publication in 1934, when the Indian Academy of Sciences was founded with C. V. Raman as the President (note 4).

It is not that this study was ignored and later discovered as an important basis for investigation of flow using NMR.

In the late 1950s, Vsevolod Kudravcev, in collaboration with Robert Bowman, developed an NMR flowmeter at the National Institutes of Health (NIH), Bethesda, USA. 'The flow meter was based on the amplitude change of the NMR signal during the flow of an NMR-susceptible liquid through the NMR probe.' 'This effect,' Kudravcev wrote in the summary of his progress report for 1958–60 at the NIH, 'was first observed in 1950 by Suryan' (note 5). The results of Suryan were further substantiated in experiments that were conducted in different parts of the world (see for example, Hirschel and Libelo[30]). Later, in the second half of the 1960s, in collaboration with the Medical College of Wisconsin, clinical applications of NMR flowmeter techniques were developed, in particular for non-invasively 'measuring regional intracranial blood flow to facilitate studies of intracranial atherosclerosis and stroke' (note 5). Such studies of blood flow using NMR eventually formed the basis for the emergence of MR angiography.

Another experiment that Suryan devised to study dissipation of energy of precessing nuclei 'due to the presence of a resonant circuit', similarly received widespread attention as a pioneering research. 'As far back as 1949,' a review article on radiation damping in NMR experiments states, 'Suryan first proposed the interaction of an RF coil with the bulk magnetization of a sample as an explanation for the discrepancy between theoretical predictions of relaxation times and experimental observations'[31]. This article of Suryan was published in another journal that was based in India, i.e. *Current Science*. Nevertheless, it caught the attention of scientists all over the world. Bloembergen and Pound[32], collaborators of Edward Purcell, who, along with Felix Bloch, received the Nobel Prize for his NMR research in 1952, acknowledged, 'Suryan has first called attention to the importance of this type of damping.'

These pioneering studies were conducted by creatively utilizing available resources: 'the equipment available were absolutely meager and I had to use extremely simple apparatus with whatever electronic equipment I could get in the market,' Suryan informed me. Some of 'these items were available from cheap Second World War scrap, particularly electronic tubes of various kinds of communication receivers' (see also Abraham[2]). On another occasion, Suryan borrowed 'an electromagnet made out of transformer core' from the Electrical Communication Engineering Department at IISc, where he worked, and through innovative bricolage built a 'highly sensitive circuit' to create and measure quenched oscillations that he used 'for much of…[his] early work'.

Suryan was not an exception in this regard. In the 1950s, in fact until the first industrially manufactured NMR spectrometer became available in the early 1960s, scientists in India regularly devised NMR apparatus and experiments to conduct their studies. Also, these studies were widely acknowledged and pursued further internationally. However, within India, this culture of innovative bricolage of techniques, ideas and resources largely resulted in disconnected trails.

Reimagining 'Make in India'

In an influential article titled, 'A model of innovation, technology transfer, and the world distribution of income', Paul Krugman[33], who received the Nobel Prize in 2008 'for his analysis of trade patterns and location of economic activity,' states at the outset:

> 'There are two countries, innovating North and non-innovating South. Innovation consists of the development of new products. These can be produced at first only in North, but eventually the technology of production becomes available to South. This technological lag gives rise to trade, with North exporting new products and importing old products.'

It cannot be denied that Krugman's claim, which forms the basis for his 'general equilibrium model of product cycle trade,' is commonly accepted as a self-evident reality. After all, even Suryan's research that resulted in several innovations did not lead to development of new 'products' in India. It is not that Suryan did not try.

In the 1960s and thereafter, Suryan, for example, collaborated with A. R. Vasudeva Murthy to develop silicon compounds. And in 1971, they started to work with Mettur Chemicals and Industrial Corporation (MCIC) in Mettur, Tamil Nadu, for industrial production of silicon compounds. MCIC was not only successful in industrial development of these products, it also started exporting the silicon compounds, particularly silicon tetrachloride and ethyl silicate, to several countries, including Britain, the United States and Australia.

In the early 1980s, by which time MCIC had undergone some changes and a few other companies had emerged, the Government of India decided to establish a National Silicon Facility. The committee that was set up to oversee the establishment of this Facility decided that the technology for high-purity polysilicon was not good enough in India and so it had to be imported. The Government of India signed a contract with Hemlock, a United States-based company, which, however, could not fulfil the contract, because the US Government denied permission for the technology transfer. Eventually, 'Govt. of India decided to encourage Mettur as a centre for silicon development,' but by then it had also lost US$ 6.7 million that was already paid to Hemlock and could not be returned, even though Hemlock did not fulfil the contract[34].

Innovation and product development, thus, have complex entanglements, and a linear and reductive connection between the two cannot be assumed. Slippages between techno-scientific innovations and development of new products elide not only the transnational political economy of scientific research (including something as basic as the need for visas to travel or foreign exchange reserves to buy a high strength magnet), but also the role of Euro/West-centric 'imaginative geographies' – that intensify the difference and distance between the West and the non-West[35]. In the 1970s and the early 1980s, for example, many MRI innovations, which led to the emergence of MRI as a clinical tool, occurred in Britain, but after Picker International was sold to Philips in 1989, there has been no manufacturing of machines in that country. Moreover, many of the countries that are considered a part of the North or the West have made negligible contributions to the development of MRI[17,36].

The concern for me, thus, is not simply empirical/historical investigations of particular trajectories of techno-sciences. The empirical/historical cannot be abstracted from the 'imaginative,' particularly Euro/West-centric imaginative geography. Ignoring of scientific researches such as that of Suryan, for example, is inextricable from the way many academics and policy makers 'imagine' the role and place of Indian science internationally. 'Make in India' and similar initiatives need to focus on particular trajectories of sciences and invest in making them connected, i.e. successful trails. This, however, requires a shift in the West-centric imaginative geography of science as well.

Notes

1. http://www.makeinindia.com/policy/new-initiatives/ (accessed on 1 February 2015).
2. Erwin Hahn's article is also cited among these early studies. Hahn, however, provided a technique, namely spin-echo, for the measurement of nuclear magnetic resonance and he conducted his experiments in a liquid because 'self-diffusion effect in liquids of low intensity… [offered] a means of measuring relative values of the self-diffusion coefficient D, a quantity which…[was] very difficult to measure by ordinary methods'[28].
3. Interview with G. Suryan on 21 May 2002. The quotes of Suryan that follow, unless stated otherwise, are based on this e-mail interview.
4. http://www.ias.ac.in/academy/history.html (accessed on 5 February 2015).
5. V. Kudravcev, Development of NMR flowmetering technique (LTD-NHLI and Biophysical Laboratory of MCW): summary of progress from 1958–1960 and notes on further developments, Office of History, NIH, USA.

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