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REVIEW ARTICLE

Reimagining India's Health System: Technology Levers for Universal Health Care

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Abstract | Just as the COVID-19 pandemic highlighted the inadequacies of our current health systems and rekindled the debate around universal health care, the *Lancet Citizens' Commission on Reimagining India's Health System* was launched in late 2020. As a part of the commission, we articulated how technology can enable universal health care. We begin by stating the foundational values—a set of normative statements—that should underpin the use of technology in our health systems. Then, after summarising the paradigm shifts necessary to achieve citizen-centred universal health care, we articulate five 'technology levers' to enable those shifts. Finally, we describe the intersections and synergies between technology and the other pillars of health systems, namely, human resources, financing, governance and citizens' engagement.

1 Preamble

Our current system of public health infrastructure has its roots in the Alma-Ata WHO declaration of 1978 which "identified primary health care as the key to the attainment of the goal of Health for All".[1] While we have made some progress, the original intent of the declaration for an acceptable level of health care by 2000 for all people remains to be fulfilled. The pandemic experience not only underlined the need to accelerate efforts towards universal health care, but also demonstrated radically new ways to achieve that goal, especially by leveraging technology in various ways.

1.1 Technology in Medicine and Health Care Today

Technology—by which we mean science- and technology-based innovations which have a significant component of engineering, mathematics, physics, or chemistry—has always played an important role in the form of vaccines, drugs, diagnostic tools, and medical devices.

Starting about 2 decades ago, information and communication technologies (ICT) were introduced mainly for administrative tasks in health systems. Computers, internet, and phones, along with software—from programs on PCs to apps on phones—are now ubiquitous in a sense, but their use is mostly fragmented and ill-designed, and they co-exist uncomfortably with manual processes. True digitization and EHR/EMR adoption are in infancy.

Also, about two decades ago, bioinformatics as a discipline started growing tremendously. The Human Genome Project launched a new era. Today, perhaps the pharma industry is its biggest user, but the use of bioinformatics in healthcare is very limited and especially so in countries like India.

The last decade brought in the next wave in digital technologies: highly capable personal computing devices (laptops, tablets, smartphones), cloud storage and computing, high-bandwidth communications, big data analytics and machine learning. They have in turn spurred new approaches in life sciences, deepening our understanding of such complex processes as protein folding.

1.2 Technology During the Covid Pandemic

Even before the Covid pandemic, molecular biology too seemed to have entered a golden era of

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sorts. CRISPR—a gene-editing technology with huge potential (for good and bad)—was dominating the headlines. But it was other innovations in molecular biology—PCR/NAAT diagnostics and mRNA vaccines—that became celebrated tools in managing the Covid pandemic.

Technologies that global consumers had adopted only recently became indispensable tools for pandemic management at scale: video calls (and call centres) helped doctors, nurses and family manage patients at homes and in remote locations; digital platforms like CoWIN-enabled vaccinations at a scale and speed never seen before.

The pandemic has also sparked unprecedented activity in epidemiological modelling (data-driven, mathematical modelling of the spread of diseases) and AI/ML-based screening tools using symptoms, x-rays, CT scans, and even cough sounds.

In summary, the pandemic opened our eyes and lowered our mental barriers to new ways of achieving our collective healthcare goals and to how technology can be a meaningful enabler.

1.3 Systemic Challenges and Technology's Role Going Forward

Given our human resources challenges with a limited number of care providers, technology can play an important amplifier role. A key component we will need is a reimagined digital infrastructure based on the blueprint for digital health which has now been on the roadmap of the national government. Personal health records, digital health lockers, and portability across open health exchanges are some critical components to ensure citizens have access to such services, retain control, and have friction-less experiences.

The introduction of digital technology, over the past two decades, has mostly failed to mitigate the frictions experienced by citizens. Even when interventions make a genuine difference to a large portion—or even a majority—of citizenry, we find that the concerns and constraints of substantial segments of the population without digital access or digital literacy have been unheeded or underestimated. In our quest for progress, we must also not overlook the challenges of affordability and unconscious bias.

We have come to see health care through the lens of facilities or levels of specialisation: community, primary, secondary, and tertiary. Administratively convenient, perhaps, but that approach has fractured care into silos to the detriment of patients. It also created a hierarchy that deprioritized needs in prevention and earliest stages of illnesses. One disastrous consequence has been healthcare intervention mostly in late-stage illnesses and resulting high costs.[2–4]

A major focus has to be the spend on prevention and diagnosis. This will require a complete realignment of our public health economic priorities from an 80–20 focus on remedial actions on the "provider infrastructure and human resources" to an 80–20 focus on preventative care and diagnoses. Radical as it sounds and particularly so for countries with entrenched, legacy health systems, it is actually a coherent allocation for best outcomes of social welfare.[5,6]

We must reimagine and redesign our health systems to align with the citizens' journeys, taking into account the types of services needed at each stage, and ensuring they are seamlessly provided by leveraging technology as connecting tissue for evidence-driven coordination of the health system resources and building on the evidence synthesis that is being gathered for this Lancet commission.

One approach is to reimagine health journeys—for citizens of all types—as a way to articulate what success looks and feels like when universal health care is achieved. Then, probe what interventions are required to get there. We need to design for 2030. There are many challenges today. But let's ask how the world might be different. As an example, can we imagine a transformation of our frontline health workers from ASHAs and ANMs into community health aide practitioners who are empowered—by aligning policies, incentives, training, tools and technology—to provide substantial primary care to citizens much in the way that 550 such aides do so in 170 rural locations of Alaska today.[7]

We begin with a clear statement of values that the technology workstream prescribes to. These normative statements are an implicit statement of the goals and targets for a technology-elevated reimagined health system to realise universal health care for India. The specific interventions, assumptions, indicators and interim outcomes to realise these targets are then described. We

[A] The term *point-of-care* technologies typically connotes a provider location such as a clinic. In its place, we propose the term ***pervasive*** technologies, devices or diagnostics to better represent the need for such tools in homes and with frontline health workers in the field.

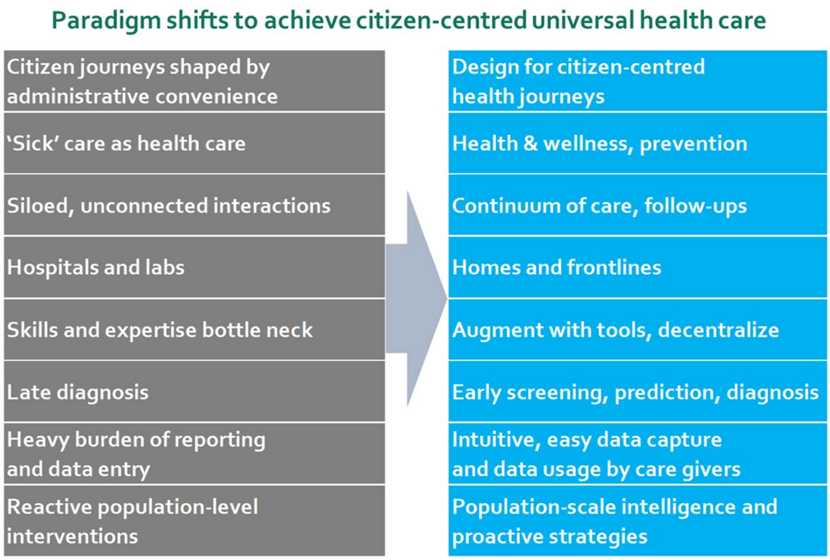

Figure 1: Paradigm shifts to achieve citizen-centred universal health care.

conclude with an indication of perceived linkages of technology to the other workstreams.

2 Normative Statements

1. To *use technology that is accessible* for/by even the most economically disadvantaged individuals in the population, and in doing so to create a cascade effect of virtuous changes.
2. To *focus on empowering citizens* and providing them with the ability to identify what is in their best interest. This helps them to "*pull*" whatever help they might need from the system in a customised manner and reduces the need to push generalised solutions across the system.
3. To put sharing of personal health data under the *citizen's control* for all clinical use-cases. This offers flexibility to the citizen to keep reproductive health and mental health information separate from other regular health information, a need in many communities today.
4. To ensure *health information protection* through federated data stores, confidential compute rooms, and state-of-art certifications.
5. To enable other stakeholders in the healthcare industry, especially healthcare providers, to *elevate their healthcare outcomes* using cutting-edge technology.
6. To reduce the cost of *innovation in pervasive*[A] *diagnostics* by levelling standards, public technology platforms, and open multi-party protocols.
7. To make it easy to guide the system through scientific nudges and behavioural economics towards *early detection and preventive care*.
8. To create *innovative regulation* that targets malpractice in the healthcare industry, which arises from misaligned incentives between different stakeholders. In doing so, empowering the patient to make his/her own choices rather than falling victim to a referral system.
9. To build systems based on interoperability and non-discrimination to *minimize the creation of monopolies* over time.
10. To leverage technology such that there is *transparency* both of the rule-making process and of the rules.

3 Paradigm Shifts

Achieving citizen-centred universal health care will require several paradigm shifts for our health systems (see Fig. 1).

4 Technology Levers to Transform Public Health

To achieve the above shifts, technology will manifest in various ways. They are categorised below as five levers (see Fig. 2).

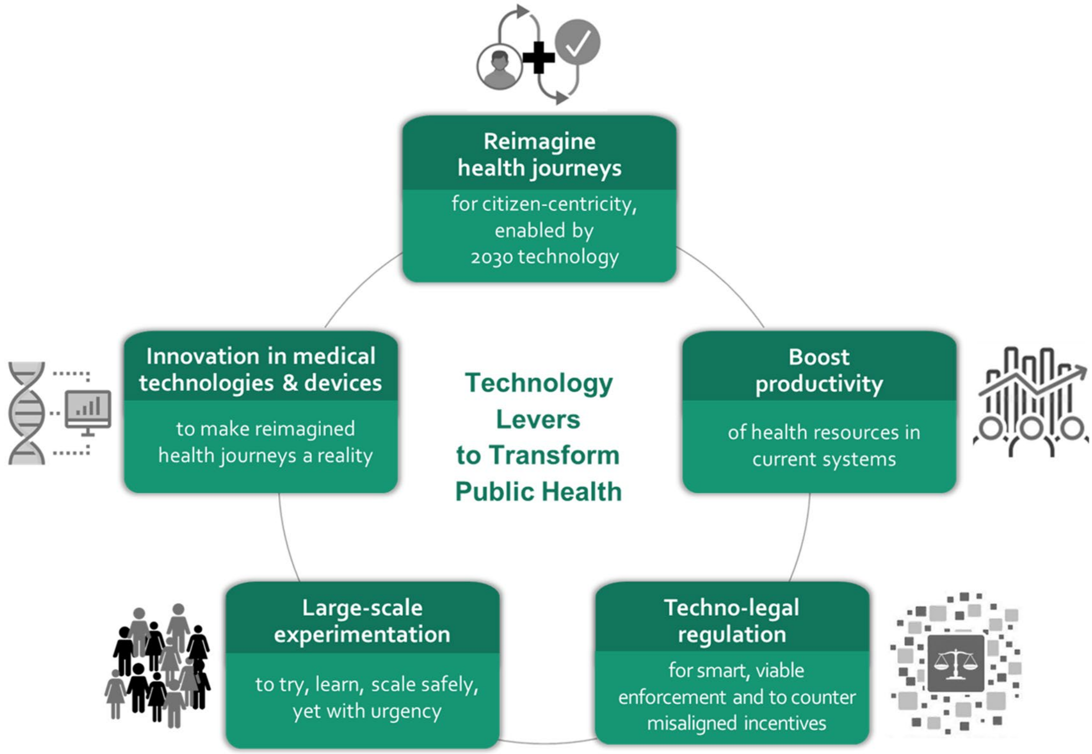

Figure 2: Technology levers to transform public health.

4.1 Reimagined Health Journeys

Early adopters of electricity—factory owners that first switched from steam engines—tended to be disappointed by the cost savings and productivity. That was because they used their electric motors the same way as they used steam engines, simply replacing one with the other in their old systems and ways of working.

Steam-powered factories were laid out based on the logic of the drive shaft, subsidiary shafts, belts and gears. Entire plants were run by massive steam engines that never stopped. Electric factories could instead be designed to suit the needs of production. Workers could turn smaller electric motors on and off, and optimise workflows. Plus, there were savings in not having to build sturdy structures to support steam engines and huge steel shafts. It wasn't until factory owners understood this and embraced changes in architecture and production processes that savings and productivity truly leaped.[8,9]

We are at a similar juncture with respect to the use of technology in our health system. If healthier and happier citizens are what matter, how might we wield technology to deliberately redesign the systems architecture and workflows for citizen-centred universal health care, where there is more emphasis on wellness, prevention, and early detection of conditions without overdependence on expensive facilities and specialists?

It is time we design our workflows, technology tools, and user interfaces (e.g., speech recognition, local language interfaces) for ease, usefulness, and even delight, for all its users—the citizens, the frontline workers and the healthcare professionals. An elderly specialist doctor's acceptance and expectations of a decision support system will be very different from those of a frontline worker. Sustainable adoption will require attention to this diversity of interactions and preferences, by building in flexibility.

Here are some ways in which technology can help reimagine health journeys:

- Make mobile-first/virtual modes of initiating and providing basic health consultations and screening a routine.
- Bring primary health care into homes and communities, leveraging mobile phones, health workers, and appropriate tools, so that there is less dependence on doctors and specialists.
- Extend "health care" to "wellness" and "prevention" by embracing technology for con-

tinuous management, especially for chronic conditions.

- Bring traditional healing systems such as yoga and Ayurveda into the mainstream of evidence-based medicine in a scientific way, and sustainably using technology.
- Compress "triage to treatment". Early screening/triaging for appropriate referrals or start of treatment.
- Data should be available on-demand to the citizen and to whomever they want to provide access to.
- Financing (incl. insurance) and cashless payment mechanisms should be integrated seamlessly.

4.2 Productivity

Currently, frontline health workers spend a lot of time filling forms.[10] Unverifiable data gets entered by operators, with time lags well beyond actionable windows. Doctors, if they are lucky, get to search for relevant information in polythene bags stuffed with past health records. Healthcare facilities and specialists are concentrated in urban areas, while rural populations go under-served.[11,12]

These are just some examples of inefficiencies that compromise both quality and quantity of health services we provide. Even without major changes to workflows or systems design, there are several ways in which technology can help better utilisation of our existing healthcare assets: people, supplies, information, and money.

- Public digital infrastructure, including Health Stack, as foundational elements.
- Standards to catalyse the creation of multiparty systems (e.g., UPI).
- Ensure portability and protection of data via policy, standards, tech infrastructure.
- Digitise processes so that data is captured digitally.
- Adopt tools to minimise manual entry and enable robust data capture.
- Standardise and drive adoption of electronic health/medical records (EHR/EMR).
- Leverage telemedicine to connect supply and demand.
- Transition to connected diagnostics for all settings.
- Design pull systems for pharmaceuticals and medical supplies at the front lines of primary health care.

4.3 Techno-legal Regulation

Often, people and businesses say one thing and do another. Hence checks and balances are needed in any system. Regulation enforces many of these checks and balances, and effective regulation of this kind is particularly important in health care as human lives are involved.

India needs a leapfrog in its healthcare regulation. Doctors and labs need to be better regulated. Both in private and public health systems, self-regulation has had suboptimal results. At the same time, extensive regulations without the tools that make enforcement of the regulation feasible, do not make for effective safeguards. One way to make this leapfrog happen is to enlist technology for smarter regulation.

As any system goes digital, its auditability improves dramatically. It becomes easy to determine whether regulations, covenants, and terms of service have been followed. Furthermore, technology can be used to prevent employees from undertaking actions that would be illegal. In this way, technology acts as a guardrail and can be actively used to enforce good behaviour.

Let us look at data governance as an example. Even in the best-designed systems, ensuring use-limitation of data is a challenge because it is difficult to enforce with the currently available technology. However, advances in technology provide for the possibility of a technological solution to guarantee use limitation. One such public-technology solution developed in India is the confidential computing environment in which the data user gets to process the data and extract the results of the analysis but not the personally identifiable information data themselves. Because data never leaves the execution environment, this architecture provides a high degree of assurance regarding use-limitation. Technology-enabled tools such as this can enhance both dignity and privacy of citizens.

As we have seen here, techno-legal regulation involves developing public-technology infrastructure and policy framework together. Applying this approach can help us bring smart regulation to various health system sectors, thus reducing market failures substantially.

- Use of standardised protocols for common therapeutic areas can be achieved by use of thoughtful techno-regulation.
- As pathology testing and pervasive diagnostics improve dramatically, new patterns that

aid diagnosis will become visible. Establishing specific mandates that are enforceable using techno-legal regulation shall provide the balance that is needed between patient privacy and public good.

- Real-time auditability of labs will allow verifiability of the sensitivity and specificity claims of labs thus increasing public confidence in their operations.
- Health data privacy is a fundamental right of citizens of India and hence the data protection techno-legal regulation should be structured to provide adequate protection of this right.
- Online pharmaceuticals have become a reality and will only grow in usage. Regulatory oversight for both quality assurance and ethical stewardship (e.g., AMR) requires appropriate techno-legal infrastructure.

4.4 Large-Scale Experimentation

Solutions, unified by purpose, not uniform in design, will likely address our diverse and complex challenges in Health. In the coming years, we need to unlock a Cambrian explosion[13] of new field solutions. Many of these will work in small pockets. Others will scale to States and regions.

When every software company needed its own dedicated data centre, there weren't software startups coming up. But cloud computing changed that.[14,15] It allowed a small 2-person startup to rent a data centre and scale it elastically at low cost as needed.

Let's take chronic care for diabetes as an example. Any field solution will involve pervasive testing, handling patient health data, tuning medication, and more. Let's say that everybody implementing such field solutions can upload their patient data anonymously to a disease sandbox to verify how their field solution is going. If things are going really well, it will be possible to secure more funding and support. If things are only ho-hum, then quiet improvements can be tried out. Either way, a national effort can be unleashed to promote many experiments on chronic diabetes management.

We must collaborate as a system to deliver social improvements at scale. Thinking of technology as an enabler of large-scale experimentation across many healthcare sectors can bring new innovation to the fore.

- Establishing a Field Experiments Registry (FER), as a public good managed by the community, will ensure that a complete view of field experiments is accessible to all those involved in health care decision making. This will improve transparency and collaboration.[16,17]
- Ignition grants for new field experiments should be encouraged. Regimen adherence for TB and other chronic diseases can benefit dramatically from such efforts. Logistics optimization for pharmaceuticals and vaccines would need experiments as well.
- Collaboration between AYUSH and allopathic systems has the potential to improve chronic care in ways that are not obvious.[18–20] .Encouraging field experiments in this area would be beneficial.
- Integrated service delivery for mothers and children from pre-pregnancy to delivery, the immediate postnatal period, and childhood has been of most help. Field experiments that take the continuum of care idea to chronic diseases in rural settings can be encouraged.
- Formalisation of OPD centres can result in optimal use of para-health workers, pervasive diagnostics and doctors for many treatment modalities. Field experiments can bubble up the models that work shortening the time it will take for widespread adoption.

4.5 Innovations in Medical Technology & Devices

The Human Genome Project cost \$2.7B and took almost 14 years to complete.[21] In 2010, the first commercially available solutions were offered at \$50,000 per person.[22] Today, that's down to about \$1000 (flat for the last 4 years because of market dynamics).[23] With competition, it is very conceivable that we could be at a \$20 per human genome by 2030.

It is fortuitous that we are living at a time of such acceleration of technology because pushing screening and diagnosis out of hospitals and labs and into the hands of citizens and health workers will require creation of new tools that don't exist today. They can only be developed through deliberate investments.

Medical technologies have historically followed a predictable path: first developed in the west, later adopted in Indian hospitals serving the richest, and ultimately cost-engineered by Chinese and Indian manufacturers driving adoption in private hospitals and labs for middle-income customers.[24] This will not do anymore because the tools we need at the frontlines are unique to our settings. New types of screening and diagnosis such as genomics, digital biomarkers, and machine learning cannot just be borrowed, they should be developed and validated for our population.

- Vaccines as preventive interventions.[25]
  - Rapid response to novel pathogens.
- Mobile and mobile-connected methods.[26]
- Sensors: phone, peripherals, wearables, lab-on-a-chip, miniaturisation.[27,28]
- (pervasive devices for frontline workers, individuals and continuous monitoring)
- Shift from symptom-based to biomarker-based diagnosis (precision population health).[29]

  - Digital biomarkers.[30]
  - Bioinformatics and omics.[31,32]
- Pharmaceuticals: access and quality; technologies for traceability—bar codes, RFID tags, blockchains for ensuring quality of meds in the supply chains across the country.[33,34]
- Data science, AI/ML driven: language, predictions, decision support.[35]
- Data/datasets for innovation and validation: individual and population; clinical and beyond.[36]
- Robust, transparent, predictable processes for validation of new generation of tools in screening and diagnosis.[37]
- Decision support systems for early detection and augmenting knowledge/skills of health workers and health professionals including physicians.[38]
- Unlocking innovation (hence data) without compromising privacy: Federated data stores, consent, confidential compute / "clean room".[39]
- Digital population health – surveillance (example: pathogen detection in wastewater).[40,41]

5 Technology Levers—Intersections with Key Aspects of Health Systems

Technology, at the end of the day, is a tool to achieve the health system's objectives in the hands of various stakeholders. Technology can play a synergistic role with stakeholders in amplifying human resources, enabling appropriate governance, aligning incentives (including financial), and ultimately to serve citizens. Hence, there are many linkages with other dimensions of health systems to be considered.

Building capacity not just in infrastructure, but also in **human resources**, is critical to success of any systems redesign and associated introduction of technology.

- In amplifying human resources for health care, technology can enable creative new ways of training of frontline health workers in the use of physical and digital tools with mobile-driven multimedia and augmented reality content that do not require high literacy or the consultation of complex operating manuals.
- Technologies that can reduce data entry burden, tools for measuring various health parameters of the patient, decision support for screening, knowledge and expertise built into the tools. The intent could be for making data and derived information useful for frontline workers at the point of care while traditionally, they (ASHA, ANMs et al.) have been mostly generators of data for reporting.

In enabling appropriate **governance**, we believe that leveraging technological frameworks to regulate inappropriate use of technology is perhaps the most effective approach.

- The accountability on data security and protecting privacy of citizens is perhaps the most important regulatory challenge in this regard and the techno-legal mechanisms would be a critical lever to achieve governance of health data.
- From an appropriate use of technology levers to assist governance that encourages continuity of care, compliance, surveillance, alerts based on data patterns (e.g., excessive use of public funds for unrequired C-sections), traceability of medicines (tracking with barcodes/RFIDs etc.) and tracking outcomes of health system interventions would be a number of positive uses of technology levers described in this paper.

The interplay of technology and **finance** in easing transactions and implementing incentives that are aligned between payers, providers, and patients have a plethora of reimagined health journeys that would provide meaningful progress in universal health care.

- Some specific applications that come to mind are direct benefits in the form of e-vouchers to citizens that get encashed for prescribed services and cannot be abused by family members or miscreants for inappropriate diversions.
- Another would be for financial incentives tied to outcomes-based mechanisms or for

public–private partnerships in infrastructure for health systems.

- Technology levers in creating digital marketplaces for health services e.g., extraordinary efforts during the pandemic to create affordable telemedicine services and population scale diagnostics enabled through unified health interfaces.

Finally, technology can enable **citizens' engagement** to listen to and take note of their needs, preferences or fiduciary interests. The use of new text-, language- and multimedia-processing technologies to enhance qualitative research have been in use for all five tenets of qualitative research: ethnographic, narrative, phenomenology, grounded theory and case studies.[42] An exciting future is one in which we might hope that community-based organisations and qualitative researchers in public health and citizen's engagement will partner with technologists to build solutions that capture the intent of research in improving outcomes towards universal health care.

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Declarations

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Sharad Sharma has been leading ecosystems and companies through orbit changes for three decades. He co-founded iSPIRT Foundation a non-profit technology think tank that has conceptualized India Stack, Health Stack and other digital public goods. As a Commissioner of the Lancet Citizens' Commission on Reimagining India's Health System, he co-chairs the technology workstream. He is also a member of SEBI's Financial and Regulatory Technology Committee. Sharad co-founded Teltier Technologies, a wireless infrastructure startup now part of CISCO. An active angel investor, he was instrumental in the success of India's first IP focused fund, India Innovation Fund. An alumnus of Delhi College of Engineering, he previously held R&D leadership positions at Yahoo, VERITAS, Symantec, Lucent and AT&T.

Raghu Dharmaraju President at ARTPARK at IISc, has been bridging innovations and societal impact for two decades. He is a Fellow of the Lancet Citizens' Commission on Reimagining India's Health System. Raghu was a founding leader of Wadhwani Institute for Artificial Intelligence, where he built a portfolio of AI-based solutions in global health and agriculture with over 40 partners such as Ministry of Health and WHO. The portfolio included two firsts for India—a winner of the global Google AI Impact Challenge an AI Xprize shortlisted entry. Previously, he scaled the award-winning Embrace infant warmers from first users to over 300,000 babies in 20 countries.