A Technology Countdown Approach To Historical Timelines

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Abstract

For a product to be seen in the market today, the seeds had to be planted a calculable time ago. Important aspects of the ecosystem included communications, advertising, customer discovery, financing, infrastructure and competition. Evolutionary streams interacted. By detailing how a technological capability was achieved, we can learn about the temporal evolution of a civilization. Findings about the Sarasvati Valley's role as trading hub in a global civilization dating back over 7000 years, make this exercise urgent. A survey of the History of Science and Technology clarifies the need for a technological school of research steeped in Bharatiya tradition. Three initial models are proposed. The first is based on a single "exothermic chemical reaction rate" metric based on the Arrhenius rate expression. The second adds a time delay. The third is based on Machine Learning back propagation algorithms. Three examples are explored. This new school of endeavor promises a productive wealth of knowledge about our ancestors and their ecosystems, while advancing modern capabilities as well.

Introduction

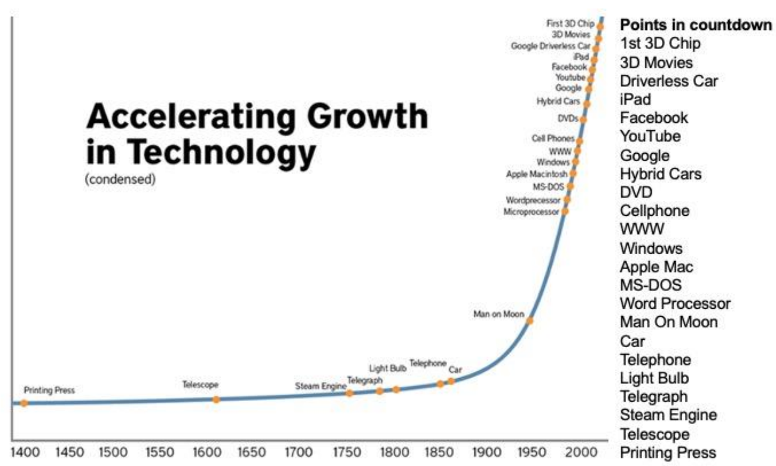

Figure 1: Accelerating growth in technology with years, present era (PE). Courtesy Vivisum Partners LLC [1] . The milestones are listed on the right for clarity.

A simplistic generalization may help make the point of this paper: given good data, technological status can be extrapolated backwards in time. Figure 1, from [1] shows exponential rise in rate of innovations on a timeline from 1400 PE to 2020. Time for an invention to be adopted by 25% of the US population [2], has been decreasing at an exponential rate. Disposable income, transport, comm unications, advertising, and an ecosystem that streamlined the adoption process, all help.

The rate of progress is exponentially slower if we go backwards in time. Suppose a "3D Chip" were found in a fossil in 5000PE, and dated to 2030PE. It also existed for some 20 years before then. The Bactrian Cup is dated to 4000 BPE (Before Present Era). Similarly scaling progress, the technology for it probably existed for another 1000 years before that, given a much slower rate of advancement. In other words, civilization extended much

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further back in time than present archaeology-based point-snapshots indicate. Welcome to the Countdown approach to understand the technologies of ancient times. The aim of this paper is to start a discussion on how to refine this process using patient research, growing knowledge bases and evolving capabilities. What I am proposing is an entire school of study integrating tradition, language, archaeology, technology and the multifaceted disciplines of venture capitalism, machine language and artificial intelligence.

The paper starts with motivations. Why? Why now? Next a swift exploration of need, given the current State of the Art (SOA). Next, a suggestion of analytical methods. And finally, 3 examples: The Aranmula Kannadi, the Bactrian Cup, and Celestial Navigation. Concluding remarks dream of the type of School (community of researchers, not brick and mortar) that is needed.

Background

Civilizations are often “dated and rated” by measured or speculated age of fossils and artifacts found in their ruins. Broad classifications such as “Bronze Age” mark their owners’ lives. The lack of a unifying thread leads to endless controversy, driven by various agendas. For instance the frameworks that we were taught in school textbooks miraculously fit belief systems imported and imposed on our own traditional knowledge. They have been largely debunked – but are still taught! In the end, such controversies produce little useful knowledge. For instance, we have read somewhere that “The Ancient Maya built huge temples on top of high mountains”, or “our ancestors knew how to navigate the oceans”. But do we know how that was done? Very few have any idea how to do the same today even with modern trappings.

Understandably, most people aspire to believe that they descended from the most advanced civilization. The Single Point Origin Theory of human development fits certain religious beliefs, usually ignoring contributions from the Bharatavarsha region. Thus for instance we keep hearing how fossilized remains of the “First Human” must somehow be traced to arid areas in the Mediterranean/West Asia. Even if found in the Australian desert. These models are tied to timelines as scientific pillars. The Gulf of Mexico asteroid hit that “killed the dinosaurs”, and Jebu supervolcano “constriction event” are examples.

I propose a different avenue that is potentially more useful. It takes a finite time for an invention or discovery to lead to mass use. Going forward from a given invention leads to the instability of an Initial Value Lagrangian approach, particularly given the five phase oscillation of the Gartner Hype Cycle [3]:*“Technology Trigger, Peak of Inflated Expectations, Trough of Disillusionment, Slope of Enlightenment and Plateau of Productivity”*. Instead I suggest a Back Propagation. A Countdown. In brief, if X was observed in 2020, when did it have to be invented? My eventual focus is on the period from 100,000 to 2,000 BPE.

Motivation

My motivation comes from 3 sources:

1) The Sarasvati Valley research set off by satellite images and well water readings in 1974, debunked the prevailing Aryan Invasion Theory of Indus Valley Civilization. The Sarasvati was exactly where Puranas placed her. The major civilization was not isolated in a few villages, but looked East. Research has uncovered a vast continuity of contacts, industry and trade "from Hanoi to Haifa" with major *trading* centers in the Sapta Sindhu Valley. The civilizations in Mesopotamia, Egypt, Syria and Persia are in this continuity. The implications are quite stunning in scope, but little appreciated in or outside India.
2) The US National Science Foundation showed that over 93 percent of "Startup Ventures" which win competitive funding from Venture Capitalists, go out of business within two years. This should trigger some introspection. US-based Venture Capitalists are extremely well-organized and draw on a vast eco-system of expertise in anything they desire. Once they fund a company, they guide it along a well-honed path to large return on investment. How can such a failure rate be explained? One difficulty is in estimating and reaching customers who will actually pay for products and sustain growth over many years.
3) My high school Social Studies textbooks glorified destructive social misfits who mass-murdered, looted and burned hard-working "lesser" peoples who were described if at all, with utter disdain. I wondered about "Phoenician Traders" who preceded the celebrated "civilizations". Who built their ships? How did they find things to trade? Who built those? Who taught them? Perhaps a history is needed, written from our native sense?

The relevance is to explore the ecosystems in which the technologies behind the Bharatiya civilization glimpsed in the Sarasvati Valley, grew to such a huge extent. It was an era where travel and communication were slow and difficult; where non-verbal communication used stone inscriptions, pictorial and 3-dimensional artifacts. It boils down to this: *How long did it take for that discovery or invention to become widely adopted back in ancient times?*

Prior Work: History of Science and Technology (HoST)

I am not even a novice in this field and am keenly aware of rushing in where The Wise fear to tread. However, I tried to learn a bit in what I summarize here. Singer [4] is cited in [5] from the "Pirke Avoth, the Ethics (or Sayings) of the Fathers, a compilation of popular teachings of the Rabbinic Sages written circa PE15. This wonders how,*"if every pair of metal tongs needed another pair of metal tongs to make it, how was the first pair made?"* Bunch and Hellemans [6] is an extensive compilation of actual HoST, a volume of great value as a data source. Arnold [7] cites the Surya Siddhanta as having been composed circa 400 PE and having chapters on the motions of heavenly bodies, and astronomical instruments such as the armillary sphere. Studies on ceramics in Africa [8] and about the

Phoenicians [9,10,11,12,13,14] are listed as sources of data for our knowledge base: these were the early connections to pre-Greek European centers.

A few themes were apparent. Early work actually explored and catalogued artifacts and pondered their significance. Recent work considers the problem solved. Their Eurocentric model is divided between Greeks (via Al Sikandar) as the first civilized humans, and [15] Victorian England. The more recent fashion [16] is a lament over the lack of Eastern focus and a claimed "refusal of the Indians to meet our gaze" unlike "congenial" East Asian scholars [17]. I saw some resonance [18] with the notion of delving into the realities of the times, versus staying at superficial ideological levels. However, most still focus on Kings. Science and technology must focus on engineers, artisans and traders, the foundations of the Imperial structure. Modern HoST [19] spends more time on the history of historians, and the need [20] to waste more of the curriculum on paying them.

My friends inform me that Leslie White [21] articulated his Cultural Evolution, formulating an equation relating technology (T), energy (E) and culture (C): $T \times E = C$. The school of Technological Determinism [22] relates civilization to the technology available to society. Lenski advanced an Ecological-Evolutionary Theory [23]

Some facts are assumed. For example, the Romans "knew" how to build long aqueducts over undulating terrain. Indians "knew" how to build marble edifices. But what do these pieces imply about other things? How did they get there? Where else did they go with that knowledge? How did the knowledge transfer? I find few answers, curiosity or empathy in HoST.

We now know better. The continuum of habitation and development is at least 140,000 years old in most of India. When an ancient artifact is discovered, there is no need to invent theories for its appearance based on Greek or British "science". There must be a progression through aeons of experimentation, failure analysis, innovation driven by pain, advances driven by the imperative of excellence, and so on. Let us try browsing the process, in the context of a few artifacts.

Approach

History estimates the basic evolution timeline of human Science and Technology. Those who lived 2.6 million years ago "knew" to and manipulate fire. Soil and later wood were used for structures, tools and weapons. Stone tools were used around 250,000 BPE; Iron tools circa 1200 BPE [24] in Europe. The finely-evolved metallurgy of the Iron Pillar of Delhi, reputedly stolen from Jain temples near Bhubhaneshwar, stands mutely questioning that, as does [25], tracing steel to at least 2500 BPE. Brass, copper, alloy steel, ceramics (porcelain), aluminum, silicon followed. Tin is ignored, but was huge in Asia. Blogs at [26] contain my amateurish take on the first 12 billion years and down to around 100,000 BPE.

The technology level around 4000 to 5000 BPE can be discerned from the Sarasvati Valley findings. So my focus is on the period from 4000 BPE to 100,000 BPE. The

Sarasvati knowledge base is vast and rapidly growing [27]. As this project advances, a Technology Canvas can no doubt be developed, that connects the various artifacts with the now-decoded significance, and the common communication medium of those times. This process will have error bounds, which our research must strive to reduce. Below I present 3 levels of analysis.

Simplistic Model for Market Acceptance Delay: The Arrhenius Rate Expression

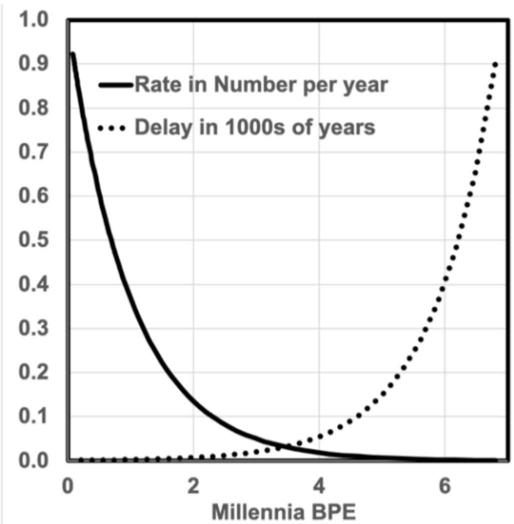

Figure 2: Rate of Market Events per year, and Delay per event in millennia, plotted against millennia BPE, illustrating the analogy with the Arrhenius Reaction Rate expression.

An exothermic (heat-releasing such as combustion) chemical reaction appears to be very simple: A molecule of hydrogen and an atom of oxygen react to produce a molecule of water and release heat. The simplest model of this reaction consists of at least 5 sub-reactions and 7 different species. Each step also has a forward and reverse reaction. The slowest of those steps determines the reaction rate, which is the rate of product (water) formation. At the microscopic level, many events must precede these sub reactions. Two molecules or in rare cases three, must collide. Only collisions that occur with a sufficient relative velocity and within a narrow range of orientations might result in reaction. All told, a huge unknown "steric factor" occurs in the reaction probability. But on a gross level, the overall reaction rate can be modeled with just 3 variables: A "pre-activation factor" A, an "Activation Energy" E, and the temperature T (multiplied by a constant R). The rate of product generation is:

$$k = A \exp(-E/RT)$$

The factor (E/R) is the aggregate "obstacle" to be surmounted for reaction to occur. As temperature T increases, energy of molecules increases, making the obstacle seem smaller. This is why one should not smoke at gasoline stations. It also explains why milk curdles. Temperature is a measure of kinetic energy, and related to how fast molecules zip around. Given a population density, it measures how fast "information" spreads: i.e. the Speed of Sound. Table 1 indicates the analogue.

Table 1: Analogue between chemical reaction and innovation

Parameter	Chemistry	Innovation History
E/R	Activation Energy normalized	Obstacle to implementation
T	Kinetic temperature	Proportional to Time
1/k	Inverse of Reaction Rate	Time delay between changes
t	Ignition Delay	Unexpected delay in 2-parameter model

The philosophical equivalent shows why sales of a consumer device "ignite" when certain conditions are met. Population density helps, as do an energized (wealthier) population, faster communications and travel. This "temperature" has been rising perhaps linearly with time. The ratio of "energy obstacle" to time has come down over the ages: it was large in olden times. Reaction rate k measures events (chemical reactions or innovations) per unit time. Thus (1/k) measures delay between events (time per event). Figure 3 shows k and 1/k versus time in Millennia BPE. In olden times k was tiny, and 1/k was measured in Millennia. Parameters for Figure 1 are arbitrary, chosen to fit a simple figure. But the *status quo* in technology remained unmoved for centuries or even millennia!

Two-Parameter Model

A separate "ignition delay" models the relatively slow reaction that generates "radicals" that are key to the reaction. In innovation, long delays are due to bureaucracy, the hunt for funding, development etc. Two important parameters to model technological change are: 1) Time for a given innovation to reach market acceptance and 2) time for a better alternative to succeed. The former depends on the eco-system available to bring out a new system, e.g. the first portable fire- starter. The latter depended on eco-system but also had to overcome market resistance and competition. The first is a time of dynamic "reaction". Slow change can be modeled as a flat delay.

As time progressed, innovators and marketers strove to reduce obstacles and delay. Venture Capitalists streamlined the process, slashing time-to-market. But there may be surprising "rate-limiting steps" that vastly increased time for a great idea and product to "catch on" in the marketplace. A beautiful Bactrian Cup definitely placed to 4634 BPE, means that technology behind it existed for perhaps 1000 years before, and perhaps 500 after.

Back Propagation Algorithms of Machine Learning

Other events may have sped up change. There may have been multiple paths, not evident to us now. We switch from the sheer randomness of Combustion reactions to the weighted paths of Back Propagation algorithms in Machine Learning and Artificial Intelligence (ML/AI). Figure 3 shows multiple paths from many inputs, through intermediate layers, to the output layer of present outcomes. The process starts by assigning random 'weights' to each path, and iterating forward and back until most probable paths are established, giving some relation between the input and the output, too complicated for human brains but easy for silicon chips. The output depends on all that went before reaching it, but with different levels of dependence or influence. Given sufficient 'training' data, these algorithms achieve miraculous results. The key then is the training data set.

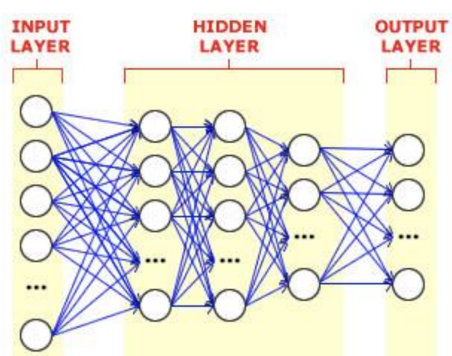

Figure 3: A simple neural network. Courtesy Prof. Rao Vemuri, course notes on Machine Language and Artificial Intelligence

Leap-Frogging Using Traditional Knowledge Bases

Back propagation algorithms rely on massive numbers of iterations to find the most probable paths. This may be the only way at first, and may guide us to look in "unexpected" places. As our knowledge base and ability to understand, classify and use it improve, we can find weights of given paths with much better certainty. This is the realization that drove this paper. Meanwhile researchers may try developing rules for various delays, as illustrated in Table 1 – but this is a long way from being satisfactory: much remains to be done for such detail.

Table 2: Rules-based delay in Years, extrapolated from modern Indian experience

Step causing delay	Modern delay	5000BPE	50,000 BPE
Bureaucracy involved	1 to inf.	10 to inf.	0
Disagreement	20	50	1
Communication per 100 km	1/365 constant	3/365	
Travel per 100 km	4/8760	3/365	5/365
Each Discipline Interaction	2	10	100

Aranmula Kannadi

The value of precious stones and ornaments, lies not in the special properties of the substances from which they are made, but in a carefully protected narrative centered on emotion. This is why a beautiful crystal of Cubic Zirconia does not fetch a fraction of the price of a tiny piece of carbon, called a diamond. "Kannadi" means Dancing Eyes, or a mirror. Aranmula is in coastal Kerala.

Figure 4: Modern Aranmula Kannadi. Courtesy aranmulakannadi.org/ tag/valkannadi/

The Aranmula Kannadi, an example shown in Figure 3, is an ornate, metal mirror, polished as smooth as glass. It is a front-surface mirror with excellent hardness and corrosion resistance, lasting for decades if not centuries. How and why did this tradition arise? The Sarasvati explorations link the metal expertise to the metal trade of 3000+ BPE. I hold that the mirror was a crucial element of Customer Discovery for the trade in precious metals and jewelry. It must have caused an exponential leap in the value of colored mineral pieces and shiny yellow metals, in turn boosting that entire line of work and enriching its artisans and merchants. It provided wealth to develop and fund mining for gems and precious metals, and furnaces and bellows to achieve needed temperatures. Fine tongs to hold molten metal without melting took a careful classification of metals by hardness and melting/softening points, spawning another branch of metallurgy. It funded research to grind metal surfaces and polish to a mirror gleam. The technique to polish the mirror must have developed concurrently if not before, jewelry became so expensive.

Metal composition of the Aranmula Kannadi is said to be similar to that of “speculum”[28], chemical formula Cu_4Sn: 68.21% copper and 31.7% tin. This is interesting. Tin deposits are not native to India, but plentiful in Vietnam. Copper is plentiful in India. So how did this discovery happen? Southeast Asian tin reached south India. How much refinement and experimentation preceded a mirror-smooth finish? Each variation of alloy composition required a hot experiment involving furnaces, molten metals and the extensive labor of polishing. Someone had to realize its value as a face-admiring personal mirror. It’s consumer appeal had to be enhanced by shaping the mirror as a circle or ellipse (no square Aranmula Mirrors are known). An ornate frame and ergonomic handle suited to the hands of intended customers had to be developed. As popularity of the mirrors rose, so did the narrative which made it a mandatory part of temple rituals as well as part of the “Ashtamangalyam” or 8 auspicious items required at the “Here Comes The Bride!” phase of Kerala weddings.

Figure 5: The Bactrian Cup

Bactrian Cup

The Bactrian Cup is an amazing piece of art as well as a nice silver drinking mug. The name denotes its presumed origin in Bactria north of Afghanistan. The detailed art on it has been identified as Sarasvati Valley metal trade code. Table 2 is a crude attempt to guess the Countdown timeline that led to the “Bactrian Cup” appearing in Bactria. Per Figure 3 and these numbers the Cup’s technology is much older. Or if the age is accurate then the timeline was shorter? How many generations did it take to do each step?

Celestial Navigation

Traders travelled all the way between East Asia (Vietnam and Korea if not Japan) and modern-day Israel. Coastline travel must have been shortened by cutting across open water between Kerala and points both north and south of the Equator. Travel was in Dhows made from Kerala teakwood, equipped with sails. For navigation, the sailors used the North star when north of the Equator and other stars when south of it. Note that back in those times the present Polaris, 430 light years (LY) away, was not the North Star: Thuban (Alpha Draconis), 305 LY in the Dragon constellation, was closer to the true north in 6000-4000BPE and Vega (Alpha Lyrae), 25LY in 11,000 BPE. Today Vega can be seen north of 51 degrees South Latitude. The device used to take readings looks amazingly simple: A rectangular piece of wood with a knotted string through its center. A sailor stood at the prow, extended his arm to so that the bottom of the wood was on the horizon and the top came just up to the star, and counted the number of knots in the string between the wooden piece and his teeth where he held the other end of the string. This measurement was quickly converted to latitude. The device was made possible by empirical fit to a very accurate astronomical knowledge base.

Table 2: Countdown to Delivery of the Bactrian Cup.

Step	**Delay, years**	**Step**	**Delay, years**
Deliver Cup to Bactria	0	Arrange Funding	3
Start Voyage from SV	1	Customer Discovery	5
Shipment Ready	0.3	Metal Artist connected	5
Reaches SV	0.1	Prior model refined	10
Starts from factory	0.5	Prior gen	20
Produced	0.3	Tech developed	10
Materials Arrive	0.1	Furnace tech	30
Materials Shipped	1	Silver metallurgy	30
Materials Ordered	1	Silver extraction	30
Contract rec'd	1	Mining tech	30
Item refined	5	Digging tool dev	50
		Total	**233.3**

The method is a linearized approximation of trigonometry, valid for small angles of latitude above the Equator. It clearly came from someone with a thorough understanding of vastly more sophisticated astronomy. Those who developed it knew that sailing towards the horizon would not make you fall of the edge: they knew the planet was spherical, and the sky changed periodically with the time of day and the seasons. How long did it take to develop that method? And how long to do the research [29] that enabled such a simple device to be developed from the results? How did traders interact with artisans and middle-people? How did they prepare and equip themselves for long voyages? How did they know how to do this? As with our other examples, numerous disciplines, trades, skills and needs had to intersect.

Cross-Linking Artifacts

From the above examples, one sees that the Aranmula Kannadi, the Bactrian Cup and Celestial Navigation technology were very interlinked. The Cup advertised the State of the Art (SOA) in technical and artistic capabilities. The Kannadi was also subtle advertising in its own right, but a crucial market multiplier and huge price booster for jewelry and cosmetics, from trinket to must-have level. Considering the mass ratio between a human-wearable ornament and a human-portable box of goods, one can imagine the immense boost in profit margin for jewelry vendors and the attendant need for investment in security and military escort. The Cup and the Kannadi thus must have funded development of shipbuilding and navigation technology, and in turn the navigation system opened up the entire African continent and South/Southeast Asia islands, if not Polynesia and points west.

Discussion

Modeling all of the above will be a huge pan-disciplinary project, perhaps the center of Bharatiya Itihasa. This paper is the first step in a different approach to such long-span history. The approach presumes that technological advancement does not consist of flashes of inspiration such as the legend of Archimedes. It is a long-drawn-out process where an invention is slowly developed to satisfy a need, the spark coming when the inventor realizes that there is a technology available, that enables something that no one had anticipated. It then spends a long time in limbo with few listening, fewer caring or understanding. It eventually gains credibility, gets refined and tested before it is adopted by even a few people. Adoption usually occurs because a Pain Point exists, and the Value Proposition for which it is adopted is often very different from the originally intended purpose. Propagation from there is often a painfully slow process of Customer Discovery. Delays can be assigned to each step.

The eventual path has to be complete to be valid: even one missing step would invalidate it. This fact provides a Closure Check. So when done with rigor this process will produce a time- and space-resolved technology map of the ancient world where all holes are filled. At minimum, this process will vastly improve our understanding of our ancestors, and of the galaxy of technologies that are woven into our current world.

A broader question that I pose is how to use this fundamental investigation of Bharatiya Civilization as the nucleus and integrative center of a modern university. It is clearly pan-disciplinary, so that all elements in the university have a role to play in its advancement. In turn, such a focus unifies disciplines and lends empathy if not excellent ideas for modern development. The third element of such a focus, at the formative years of students, is the humbling yet inspiring realization of how much their ancestors could do. The basic skills that built such a civilization should still be required as part of basic education at some level, though of course not to the artisan levels required at the times when they were crucial to survival. This thought has often struck me when I see lists of “Classical Knowledge” that are required before a modern citizen can be considered “educated”, “cultured” etc. This list is extremely occidental-centric and hence seemed very narrow to me. For instance, which is more important to a modern Indian to know: *“The Boy Has Asked For More!!”* or *“Tat tvam asi”* ? The poetry of Byron, or that of Kalidasa? Today it is relatively easy to find Indian-educated people who know all of the above, but I doubt that more than a very small percentage of western-educated people can say the same. A thought to pass on to those designing Revolutionary Change in Indian Higher Education, by copying the present status of Top Western Universities without requiring the Why and How of the indubitable excellence of those institutions. Someone with a top-notch education in, say, 2035 should have a highly integrated and clear realization of the past, as well as the capability to excel in the present and future.

Concluding Remarks

This is a massive long term endeavor, far beyond my own capacity or time. The paper lays out reasons for the approach, explores some avenues of promise, and suggests routes for others to explore. The complexity of the picture has become tractable with modern research tools such as the Internet and ML/AI processing. Traditional archaeology and History of Science and Technology provide many artifacts and development records for recent times. Three levels of analysis are proposed for long-span history. The first simple model uses ideas from combustion chemistry, a 2-parameter model with an added "ignition" delay, and finally an approach based on ML/AI back-propagation algorithms, suitable for empirical training data. Each must be combined with patient empiricism and exploration. The massive and growing Sarasvati knowledge base provides crucial linkages, and contains much of the needed information to build a global picture, going back at least 10,000 years BPE. Examining how those communities reached a given level of capabilities at a given time will lead to understanding the preceding 100,000 years, and so on to the 2.65 million BPE presumed origin of humans or human-precursors on Earth.

Some results can be stated already. The advanced products and capabilities seen in 4000BPE mean a development path over many millennia. Given the evolution of human lifespans, we see why artisan skills stayed in families: it took many generations to drive product development before market demand ever "went viral" justifying mass-production – and given communication difficulties, mass production stayed localized. The geographical extent and pan-disciplinary interaction implied by the artifacts found all over Asia-Europe are thus inexplicable unless the civilizations that produced them extended far, far back in time, beyond the assumptions generated from isolated findings of artifacts. Today's fragmented systems of higher education are inadequate to explore these things A new pan-disciplinary school is needed, where the study of our own civilization forms the integrating core and driving focus for all the disciplines.

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