CHAPTER 7

INNOVATION, SCIENCE AND TECHNOLOGY

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Abstract

This chapter brings out how new science and technology was created, exploited and flourished in India. It is interesting that even those days, hundreds of years ago, science and technology is seen throughout all facets of life covering Aeronautics, Life Science, Healthcare, Chemistry, Textiles, Metallurgy, Astrology, Astronomy, Water Management, Mathematics and Town Planning. Astonishing facts, postulations, analysis, intellectual creations that have been recorded show that the people those days had a sound understanding of nature and how the same can be exploited in a scientific way for the development and welfare of the people. Even science and spirituality co-existed. India was seen with the envy by the entire world for its creative and scientific knowledge, intellectual capital, physical wealth, philosophy and culture.

Suddenly it appears that most of these vanished over a period of three to four hundred years due to foreign invasions and British rules. Thus once a flourishing country and at the top of the world has got a new name of "developing country" and now all of us are trying to run to catch up with the so called "developed countries". This chapter brings out how the whole thing has happened and in what way the country can gear up to have a development oriented growth along with sustainable science and technology inputs. Issue of whether our heritage knowledge and Indian philosophy can be integrated with today's development oriented growth is also addressed.

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Introduction

Since the dawn of history, civilizations and cults have contributed to different branches of science and technology, often through interactive contacts across cultures separated by large distances. This interactive influence is becoming clearer as the vast extent of pre-colonial global trade and cultural migration is being properly understood by researchers. However, one finds a mainly Eurocentric perspective in the teaching of the history of science. Typically, it starts with Greece, neglecting the influences of others upon Greece. Then it 'fast forwards' many centuries into 1500 CE to claim modern science as an exclusively European triumph, neglecting the influence of others (especially India) on the European Renaissance and the Enlightenment. The European Dark Ages are presumed to be dark worldwide, when, in fact, other regions saw innovation and prosperity. In fact, Europe was at the peripheries, until the conquest of America in 1492.

With the entrenchment of colonialism, the contribution made by others, including India, was ignored. The British colonizers could never accept that Indians were highly civilized as far back as the third millennium BCE when the British were still in a barbarian stage. Such acknowledgment would destroy Europe's intellectual premise for colonization – its civilizing mission. Early British scholars documented Indian thought and its external manifestations as systems competing with their own and thus facilitated the transfer of technology into what became known as Britain's Industrial Revolution. What was found valuable was quickly appropriated and its Indian manufacturers were forced out of business, often through draconian laws enacted by the British. This was, in many instances, justified as civilizing them. Meanwhile, a new history of India was fabricated to ensure that generations of mentally colonized people would believe in the inherent inferiority of their own traditional knowledge. This has been called Macaulayism, named after Thomas Macaulay, the civil servant who became the most prominent champion of such British cultural imperialism strategy starting in the 1830s.

After independence, many Indian intellectuals continued to use the pre-colonial, feudalistic framework of Indian society. In contrast, Arab scholars have brought out the important role of Islamic empires in the transmission of ideas into Europe. However, many discoveries and innovations of India, as acknowledged by the Arab translators themselves, are now often depicted as being of Arab origin, when in fact, the Arabs often retransmitted what they had learnt from India over to Europe. Unfortunately, India is yet to achieve this kind of intellectual repositioning. It continues to be depicted through "caste, cows and curry" images all too often. Indian culture is frequently portrayed as being mystical in the sense of being irrational, and in lacking a sense of advancement in the material plane of society. Often, many Westernized Indians internalize these colonial stereotypes. Amartya Sen expressed his views on this as follows:

"Fear of elitism did not, happily, deter Joseph Needham from writing his authoritative account of the history of science and technology in China, and to dismiss that work as elitist history would be a serious neglect of China's past…

"A similar history of India's science and technology has not yet been attempted, though many of the elements have been well discussed in particular studies. The absence of a general study like Needham's is influenced by an attitudinal dichotomy. On the one hand, those who take a rather spiritual – even perhaps a religious – view of India's history do not have a great interest in the analytical and scientific parts of India's past, except to use it as a piece of propaganda about India's greatness (as in the bloated account of what is imaginatively called 'Vedic mathematics', missing the really creative period in Indian mathematics by many centuries). On the other hand, many who oppose religious and communal politics are particularly suspicious of what may even look like a 'glorification' of India's past. The need for a work like Needham's has remained unmet (Sen, 1997: 32)."

To elaborate on the science and technology contributions of the Indian subcontinent, this chapter gives a detailed account of the Indian heritage, its decline, struggle to revive and the possible way ahead.

Glimpses of Vedas & Shastras

It is well known that Indian scriptures and Sanskrit literature are a storehouse of knowledge. But there are very few attempts to systematically classify them into known branches of knowledge in an illustrative manner to familiarize a lay reader with the richness of Indian past. Very few authors have picked up relevant extracts from literature, like drops picked from the ocean, and compiled and translated them.

Today there is a worldwide interest in these Indian thoughts leading to considerable research in well-known universities across the world. Yoga, meditation and holistic methods enunciated in our scriptures are recognized globally as sure remedies of happy and healthy living.

Vedas, Upanishads, Brahmasutra, Gita, Puranas, Ramayana and Mahabharatha are considered holy texts containing information on all aspects of human activity–physical and spiritual. There are a galaxy of Sanskrit luminaries–Kalidasa, Panini, Bhasa, Bana, Varahamihra, Bhartruhari and many others whose works have inspired and enlightened generations of humankind over centuries. Works of Charaka, Sushrutha, Aryabhatta, Bhaskaracharya, Lilavati and others deal with different aspects of science and medicine. Ramayana and Mahabharatha have innumerable illustrations of science, technology, arts, sports, music, dance, architecture, weaponry, defense, vehicles, textiles, navigation, metallurgy and space craft to name a few. By observing ancient temples, paintings and historical structures, one wonders about the technology prevalent several hundred years ago. For example, the non-rusting iron pillar near Kutub Minar unravels the metallurgical experiences of those times.

Understanding Vedic Literature

Authors and scholars of Vedas have dealt with almost all branches of science and narrates relevant Sanskrit text to prove that several present day findings are not new such as the concepts on gravitation, solar system, the value of Pi and so on. The authors have carefully chosen and discussed many topics from Sanskrit literature which dealt with geometry, chemistry, physics, agriculture, irrigation, rain forecasting, imaging, wave theory, healthcare, energy, cognition, computers, cosmology, quantum mechanics and unified theory. While one may question the validity of some of theirs propositions, none can question the sincerity in mining useful data from earlier Sanskrit literature which may make every Indian proud.

Books containing several interesting comparisons between Vedas and Science have been written . These books are useful reference guides for all those who want to know what is hidden in our scriptures in a readable language. It may be said, that Vedic Science has never been presented to the world in its intimate details and precision whether in the realm of pure mathematics, physics, astronomy, medicine or in civil and mechanical engineering or life sciences. Our ancestors could not have built those marvelous temples if they had no knowledge of architecture and civil engineering, not to speak of geometry and allied subjects. A few modern text books are a delayed tribute to the genius of India which has sustained and empowered the culture and civilization of Bharat for centuries past. These quote with great flair the Vedas and their offshoots like the Sastras on conventional subjects like science and technology but goes beyond them to take note of what the Sastras have said about cognition, artificial intelligence, computer compilers and unified theories. The ancient seers, were they to come back today would surely be stunned to know what present-day technologists have achieved in spite of not being aware of what Indian thinkers had conceived in centuries past! the original Sanskrit verses quoted in full, their transliteration in English and their meaning and significance explained, would be the eye openers. Aryabhatta, Brahmagupta, Baudhayana, Bhaskaracharya, Apastamba, these names are mostly unknown to today's generation of Indian students. It is interesting to know that the theorem generally attributed to Pythogaras was said to be originally conceived by Baudhayana and should be known as the Sulba or Baudhayana Theorem. And it is also revealing to know that even the value of 'Pi' had been studied by a succession of Indian mathematicians right from the time of Mahavira (850 AD). It is no disrespect to Pythogoras to acknowledge that his discovery was preceded by Baudhayana or that long before Galileo, India had a succession of astronomers, eighteen of whose contributions including those of Garga, Narada, Parasara, Varahamihira, Aryabhatta and Bhaskaracharya have been duly acknowledged in the Sastras.

Astronomy

While modern astronomy deals with planets and their movements, Jataka goes a step further and probes as to how their movements affect the living beings on earth. As a lot of calculations are involved in predicting the positions of planets, mathematics understandably becomes prominent. It is usual to attribute the discovery of gravity to Isaac Newton and the apple that fell on his head. But a cursory perusal of our ancient literature brings out stunning information on this topic. Varahamihira, the great astrologer who lived in the 6th century AD, recorded in his Pancha Siddhanta that all objects in the universe attract each other.

About a hundred years before Brahmagupta, another astronomer, Varshamihira had claimed for the first time perhaps that there should be a force which might be keeping bodies stuck to the Earth, and also keeping heavenly bodies in their determined places.

Charaka, Sushruta and Dhanvantari

The Atharva Veda (youngest of the four Vedas) placed in time to around 5000 BC contains hymns on diseases and their treatment. Charaka (1st century BC) of the Atreya School codified the percepts and practices in internal medicine. Sushruta (6th century BC) of the Dhanvantari School codified surgical practices and Vagbhata (6th century AD) of the Kashyapa School dealt with gynaecology and paediatrics. Recalling them and their contribution to medical knowledge is not, as many of our 'intellectuals' would argue, a matter of jingoism. It is merely gracing medical history as it is to its roots. The range of subjects even cover measurement of rainfall in Varahamihira's Pravarshana Adhyaya, cosmic energy and radiation.

Overview of the Prehistoric Science & Technology in the Indian Subcontinent

The history of science and technology in the Indian subcontinent begins with prehistoric human activity at Mehrgarh, in present-day Pakistan, and continues through the Indus Valley Civilization to early states and empires. The British colonial rule introduced some elements of western education in India. Following independence, science and technology in the Republic of India has included automobile engineering, information technology, communications as well as space, defence, and nuclear sciences.

Hand-propelled wheel cart, Indus Valley Civilization (3000–1500 BCE). Housed at the National Museum, New Delhi.

By 5500 BCE a number of sites similar to Mehrgarh had appeared, forming the basis of later chalcolithic cultures. The inhabitants of these sites maintained trading relations with Near East and Central Asia. Irrigation was developed in the Indus Valley Civilization by around 4500 BCE. The size and prosperity of the Indus civilization grew as a result of this innovation, which eventually led to more planned settlements making use of drainage and sewerage. Sophisticated irrigation and water storage systems were developed by the Indus Valley Civilization, including artificial reservoirs at Girnar dated to 3000 BCE, and an early canal irrigation system from circa 2600 BCE. Cotton was cultivated in the region by the 5th millennium BCE—4th millennium BCE. Sugarcane was originally from tropical South and Southeast Asia.

The inhabitants of the Indus valley developed a system of standardization, using weights and measures, evident by the excavations made at the Indus valley sites. This technical standardization enabled gauging devices to be effectively used in angular measurement and measurement for construction. Calibration was also found in measuring devices along with multiple subdivisions in case of some devices. The world's first dock at Lothal (2400 BCE) was located away from the main current to avoid deposition of silt. Modern oceanographers have observed that the Harappans must have possessed knowledge relating to tides in order to build such a dock on the ever-shifting course of the Sabarmati, as well as exemplary hydrography and maritime engineering. This was the earliest known dock found in the world, equipped to berth and service ships.

Excavations at Balakot (c. 2500-1900 BC), present day Pakistan, have yielded evidence of an early furnace. The furnace was most likely used for the manufacturing of ceramic objects. Ovens, dating back to the civilization's mature phase (c. 2500-1900 BC), were also excavated at Balakot. The Kalibangan archeological site further yields evidence of potshaped hearths, which at one site have been found both on ground and underground. Kilns with fire and kiln chambers have also been found at the Kalibangan site.

Based on archaeological and textual evidence, Joseph E. Schwartzberg (2008)—a University of Minnesota professor emeritus of geography—traces the origins of Indian cartography to the Indus Valley Civilization (ca. 2500–1900 BCE). The use of large scale constructional plans, cosmological drawings, and cartographic material was known in India with some regularity since the Vedic period (1 millennium BCE). Climatic conditions were responsible for the destruction of most of the evidence, however, a number of excavated surveying instruments and measuring rods have yielded convincing evidence of early cartographic activity. Schwartzberg (2008)—on the subject of surviving maps—further holds that: 'Though not numerous, a number of map-like graffiti appear among the thousands of Stone Age Indian cave paintings; and at least one complex Mesolithic diagram is believed to be a representation of the cosmos.'

View of the Asoka Pillar at Vaishali. One of the edicts of Ashoka (272—231 BCE) reads: "Everywhere King Piyadasi (Asoka) erected two kinds of hospitals, hospitals for people and hospitals for animals. Where there were no healing herbs for people and animals, he ordered that they be bought and planted."

Archeological evidence of an animal-drawn plough dates back to 2500 BC in the Indus Valley Civilization. The earliest available swords of copper discovered from the Harappan sites date back to 2300 BCE. Swords have been recovered in archaeological findings throughout the Ganges–Jamuna Doab region of India, consisting of bronze but more commonly copper.

Ink drawing of Ganesha under an umbrella (early 19th century). Ink, called *masi*, an admixture of several chemical components, has been used in India since at least the 4th century BC. The practice of writing with ink and a sharp pointed needle was common in early South India. Several Jain sutras in India were compiled in ink.

The inscriptions on the edicts of Ashoka (1st millennium BCE) display this number system being used by the Imperial Mauryas. The religious texts of the Vedic Period provide evidence for the use of large numbers. By the time of the last Veda, the *Yajurvedasaṃhitā* (1200-900 BCE), numbers as high as 10^{12} were being included in the texts. For example, the *mantra* (sacrificial formula) at the end of the *annahoma* ("food-oblation rite") performed during the *aśvamedha* ("horse sacrifice"), and uttered just before-, during-, and just after sunrise, invokes powers of ten from a hundred to a trillion. The Satapatha Brahmana (9th century BCE) contains rules for ritual geometric constructions that are similar to the Sulba Sutras.

Baudhayana (c. 8th century BCE) composed the *Baudhayana Sulba Sutra*, which contains examples of simple Pythagorean triples, such as: (3,4,5), (5,12,13), (8,15,17), (7,24,25), and (12,35,37) as well as a statement of the Pythagorean theorem for the sides of a square: "The rope which is stretched across the diagonal of a square produces an area double the size of the original square." It also contains the general statement of the Pythagorean theorem (for the sides of a rectangle): "The rope stretched along the length of the diagonal of a rectangle makes an area which the vertical and horizontal sides make together." Baudhayana gives a formula for the square root of two. Mesopotamian influence at this stage is considered likely.

Value	0	1	2	3	4	5	6	7	8	9
Western Arabic	٠	١	٢	٣	٤	٥	٦	٧	٨	٩
Eastern Arabic	۰	۱	۲	۳	۴	۵	۶	۷	۸	۹
Devanagari	०	१	२	३	४	५	६	७	८	९
Gujarati	૦	૧	૨	૩	૪	૫	૬	૭	૮	૯
Gurmukhi	੦	੧	੨	੩	੪	੫	੬	੭	੮	੯
Limbu	□	□	□	□	□	□	□	□	□	□
Bengali	০	১	২	৩	৪	৫	৬	৭	৮	৯
Oriya	୦	୧	୨	୩	୪	୫	୬	୭	୮	୯
Telugu	౦	౧	౨	౩	౪	౫	౬	౭	౮	౯
Kannada	೦	೧	೨	೩	೪	೫	೬	೭	೮	೯
Malayalam	൦	൧	൨	൩	൪	൫	൬	൭	൮	൯
Tamil (Grantha)	௦	௧	௨	௩	௪	௫	௬	௭	௮	௯
Tibetan	༠	༡	༢	༣	༤	༥	༦	༧	༨	༩
Burmese	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Thai	๐	๑	๒	๓	๔	๕	๖	๗	๘	๙
Khmer	០	១	២	៣	៤	៥	៦	៧	៨	៩
Lao	໐	໑	໒	໓	໔	໕	໖	໗	໘	໙

The earliest Indian astronomical text—named *Vedānga Jyotiṣa*—dates back to between the 6th and 4th centuries BC, and details several astronomical attributes generally applied for timing social and religious events. The *Vedānga Jyotiṣa* also details astronomical calculations, calendrical studies, and establishes rules for empirical observation. Since the *Vedānga Jyotiṣa* is a religious text, it has connections with Indian astrology and details several important aspects of the time and seasons, including lunar months, solar months, and their adjustment by a lunar leap month of *Adhimāsa*. *Ritus* and *Yugas* are also described. Tripathi (2008) holds that "Twenty-seven constellations, eclipses, seven planets, and twelve signs of the zodiac were also known at that time."

The Egyptian *Papyrus of Kahun* (1900 BCE) and literature of the Vedic period in India offer early records of veterinary medicine. Kearns & Nash (2008) state that mention of leprosy is described in the medical treatise *Sushruta Samhita* (6th century BCE). However, *The Oxford Illustrated Companion to Medicine* holds that the mention of leprosy, as well as ritualistic cures for it, were described in the Hindu religious book *Atharva-veda*, written by 1500–1200 BCE. Cataract surgery was known to the physician Sushruta (6th century BCE). Traditional cataract surgery was performed with a special tool called the *Jabamukhi Salaka*, a curved needle used to loosen the lens and push the cataract out of the field of vision. The eye would later be soaked with warm butter and then bandaged. Though this method was successful, Susruta cautioned that it should only be used when necessary. The removal of cataract by surgery was also introduced into China from India.

During the 5th century BCE, the scholar Pāṇini had made several discoveries in the fields of phonetics, phonology, and morphology. Pāṇini's morphological analysis remained more advanced than any equivalent Western theory until the mid-20th Century. Metal currency was minted in India before 5th century BCE, with coinage (400 BCE—100 CE) being made of silver and copper, bearing animal and plant symbols on them.

Zinc mines of Zawar, near Udaipur, Rajasthan, were active during 400 BC. Diverse specimens of swords have been discovered in Fatehgarh, where there are several varieties of hilt. These swords have been variously dated to periods between 1700-1400 BCE, but were probably used more extensively during the opening centuries of the 1st millennium BCE. Archaeological sites in such as Malhar, Dadupur, Raja Nala Ka Tila and Lahuradewa in present day Uttar Pradesh show iron implements from the period between 1800 BC - 1200 BC. Early iron objects found in India can be dated to 1400 BC by employing the method of radio carbon dating. Some scholars believe that by the early 13th century BC iron smelting was practiced on a bigger scale in India, suggesting that the date of the technology's inception may be placed earlier. In Southern India (present day Mysore) iron appeared as early as 11th to 12th centuries BC. These developments were too early for any significant close contact with the northwest of the country.

Post Maha Janapadas—High Middle Ages

The iron pillar of Delhi (375–413 CE). The first iron pillar was the Iron pillar of Delhi, erected at the times of Chandragupta II Vikramaditya.

The *Arthashastra* of Kautilya mentions the construction of dams and bridges. The use of suspension bridges using plaited bamboo and iron chain was visible by about the 4th century. The *stupa*, the precursor of the pagoda and torii, was constructed by the 3rd century BCE. Rock-cut step wells in the region date from 200-400 CE. Subsequently, the construction of wells at Dhank (550-625 CE) and stepped ponds at Bhinmal (850-950 CE) took place.

During the 1st millennium BCE, the Vaisheshika school of atomism was founded. The most important proponent of this school was Kanada, an Indian philosopher who lived around 200 BCE. The school proposed that atoms are indivisible and eternal, can neither be created nor destroyed, and that each one possesses its own distinct viśeṣa (individuality). It was further elaborated on by the Buddhist school of atomism, of which the philosophers Dharmakirti and Dignāga in the 7th century CE were the most important proponents. They considered atoms to be point-sized, durationless, and made of energy.

By the beginning of the Common Era glass was being used for ornaments and casing in the region. Contact with the Greco-Roman world added newer techniques, and local artisans learnt methods of glass molding, decorating and coloring by the early centuries of the Common Era. The Satavahana period further reveals short cylinders of composite glass, including those displaying a lemon yellow matrix covered with green glass. Wootz originated in the region before the beginning of the common era. Wootz was exported and traded throughout Europe, China, the Arab world, and became particularly famous in the Middle East, where it became known as Damascus steel. Archaeological evidence suggests that manufacturing process for Wootz was also in existence in South India before the Christian era.

Evidence for using bow-instruments for carding comes from India (2nd century CE). Early diamonds used as gemstones originated in India. Golconda served as an important early center for diamond mining and processing. Diamonds were then exported to other parts of the world. Early reference to diamonds comes from Sanskrit texts. The *Arthashastra* also mentions diamond trade in the region. The Iron pillar of Delhi was erected at the times of Chandragupta II Vikramaditya (375–413). The Rasaratna Samuccaya (800 AD) explains the existence of two types of ores for zinc metal, one of which is ideal for metal extraction while the other is used for medicinal purpose.

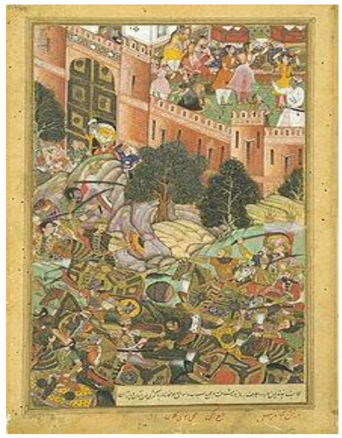
Model of a Chola (200–848 CE) ship's hull, built by the ASI, based on a wreck 19 miles off the coast of Poombuhar, displayed in a Museum in Tirunelveli.

The origins of the spinning wheel are unclear but India is one of the probable places of its origin. The device certainly reached Europe from India by the 14th century CE The cotton gin was invented in India as a mechanical device known as *charkhi*, the "wooden-worm-worked roller". This mechanical device was, in some parts of the region, driven by water power. The Ajanta caves yield evidence of a single roller cotton gin in use by the 5th century CE. This cotton gin was used until further innovations were made in form of foot powered gins. Chinese documents confirm at least two missions to India, initiated in 647, for obtaining technology for sugar-refining. Each mission returned with different results on refining sugar.

Pingala (fl. 300-200 BCE) was a musical theorist who authored a Sanskrit treatise on prosody. There is evidence that in his work on the enumeration of syllabic combinations, Pingala stumbled upon both the Pascal triangle and Binomial coefficients, although he did not have knowledge of the Binomial theorem itself. A description of binary numbers is also found in the works of Pingala. The use of negative numbers was known in early India, and their role in situations like mathematical problems of debt was understood. Consistent rules for working with these numbers were formulated. The diffusion of this concept led the Arab intermediaries to pass it to Europe.

The decimal number system originated in India. Other cultures discovered a few features of this number system but the system, in its entirety, was compiled in India, where it attained coherence and completion. By the 9th century CE, this complete number system had existed in India but several of its ideas were transmitted to China and the Islamic world before that time. The concept of 0 as a number and not merely a symbol for separation is attributed to India. In India, practical calculations were carried out using zero, which was treated like any other number by the 9th century CE, even in case of division. Brahmagupta (598–668) was able to find (integral) solutions of Pell's equation. Conceptual design for a perpetual motion machine by Bhaskara II dates to 1150. He described a wheel that he claimed would run forever.

The trigonometric functions of Sine and 'Versine, from which it was trivial to derive the Cosine, were used by the mathematician, Aryabhata, in the late 5th century. The calculus theorem now known as "Rolle's theorem" was stated by mathematician, Bhāskara II, in the 12th century.



Akbarnama—written by August 12, 1602—depicts the defeat of Baz Bahadur of Malwa by the Mughal troops, 1561. The Mughals extensively improved metal weapons and armor used by the armies of India.

Indigo was used as a dye in India, which was also a major center for its production and processing. The *Indigofera tinctoria* variety of Indigo was domesticated in India. Indigo, used as a dye, made its way to the Greeks and the Romans via various trade routes, and was valued as a luxury product. The cashmere wool fiber, also known as *pashm* or *pashmina*, was used in the handmade shawls of Kashmir. The woolen shawls from Kashmir region find written mention between 3rd century BC and the 11th century CE. Crystallized sugar was discovered by the time of the Gupta dynasty, and the earliest reference to candied sugar comes from India. Jute was also cultivated in India. Muslin was named after the city where Europeans first encountered it, Mosul, in what is now Iraq, but the fabric actually originated from Dhaka in what is now Bangladesh. In the 9th century, an Arab merchant named Sulaiman makes note of the material's origin in Bengal (known as *Ruhml* in Arabic).

Evidence of inoculation and variolation for smallpox is found in the 8th century, when Madhav wrote the *Nidāna*, a 79-chapter book which lists diseases along with their causes, symptoms, and complications. He included a special chapter on smallpox (*masūrikā*) and described the method of inoculation to protect against smallpox. European scholar Francesco I reproduced a number of Indian maps in his magnum opus *La Cartografia*

Antica dell India. Out of these maps, two have been reproduced using a manuscript of *Lokaprakasa*, originally compiled by the polymath Ksemendra (Kashmir, 11th century CE), as a source. The other manuscript, used as a source by Francesco I, is titled *Samgraha'.*

Late Middle Ages

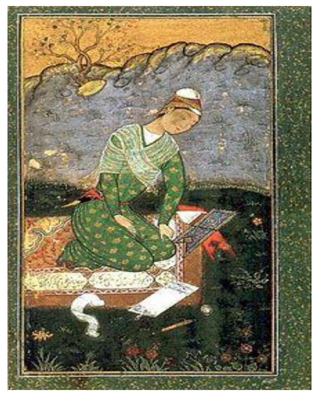
Jantar Mantar, Delhi—consisting of 13 architectural astronomy instruments, built by Jai Singh II of Jaipur, from 1724 onwards.

Madhava of Sangamagrama (c. 1340-1425) and his Kerala school of astronomy and mathematics developed and founded mathematical analysis. The infinite series for π was stated by him and he made use of the series expansion of arctan *x* to obtain an infinite series expression, now known as the *Madhava-Gregory series*, for π. Their rational approximation of the *error* for the finite sum of their series are of particular interest. They manipulated the error term to derive a faster converging series for π. They used the improved series to derive a rational expression, 104348 / 33215 for π correct up to nine decimal places, *i.e.* 3.141592653. The development of the series expansions for trigonometric functions (sine, cosine, and arc tangent) was carried out by mathematicians of the Kerala School in the 15th century CE. Their work, completed two centuries before the invention of calculus in Europe, provided what is now considered the first example of a power series (apart from geometric series).

Shēr Shāh of northern India issued silver currency bearing Islamic motifs, later imitated by the Mughal empire. The Chinese merchant Ma Huan (1413–51) noted that gold coins, known as *fanam*, were issued in Cochin and weighed a total of one *fen* and one *li* according to the Chinese standards. They were of fine quality and could be exchanged in China for 15 silver coins of four-*li* weight each.

In 1500, Nilakantha Somayaji of the Kerala school of astronomy and mathematics, in his Tantrasangraha, revised Aryabhata's elliptical model for the planets Mercury and Venus. His equation of the centre for these planets remained the most accurate until the time of Johannes Kepler in the 17th century.

The Seamless celestial globe was invented in Kashmir by Ali Kashmiri ibn Luqman in 998 AH (1589-90 CE), and twenty other such globes were later produced in Lahore and Kashmir during the Mughal Empire. Before they were rediscovered in the 1980s, it was believed by modern metallurgists to be technically impossible to produce metal globes without any seams, even with modern technology. These Mughal metallurgists pioneered the method of lost-wax casting in order to produce these globes.



Portrait of a young Indian scholar, Mughal miniature by Mir Sayyid Ali, ca. 1550.

It was written in the *Tarikh-i Firishta* (1606–1607) that the envoy of the Mongol ruler Hulegu Khan was presented with a pyrotechnics display upon his arrival in Delhi in 1258 CE. As a part of an embassy to India by Timurid leader Shah Rukh (1405–1447), 'Abd al-Razzaq mentioned naphtha-throwers mounted on elephants and a variety of pyrotechnics put on display. Firearms known as *top-o-tufak* also existed in the Vijayanagara Empire by as early as 1366 CE. From then on the employment of gunpowder warfare in the region was prevalent, with events such as the siege of Belgaum in 1473 CE by the Sultan Muhammad Shah Bahmani.

In *A History of Greek Fire and Gunpowder*, James Riddick Partington describes Indian rockets, mines and other means of gunpowder warfare:

The Indian war rockets were formidable weapons before such rockets were used in Europe. They had bam-boo rods, a rocket-body lashed to the rod, and iron points. They were directed at the target and fired by lighting the fuse, but the trajectory was rather erratic. The use of mines and counter-mines with explosive charges of gunpowder is mentioned for the times of Akbar and Jahāngir.

By the 16th century, Indians were manufacturing a diverse variety of firearms; large guns in particular, became visible in Tanjore, Dacca, Bijapur and Murshidabad. Guns made of bronze were recovered from Calicut (1504) and Diu (1533). Gujarāt supplied Europe saltpeter for use in gunpowder warfare during the 17th century. Bengal and Mālwa participated in saltpeter production. The Dutch, French, Portuguese, and English used Chāpra as a center of saltpeter refining.

Colonial era

The armies of Sultan Hyder Ali of Mysore employed rockets whose gunpowder was packed in metal cylinders instead of paper ones.

Physicist Satyendra Nath Bose is known for his work on the Bose-Einstein statistics during the 1920s.

Early volumes of the *Encyclopædia Britannica* described cartographic charts made by the seafaring Dravidian people. In *Encyclopædia Britannica (2008)*, Stephen Oliver Fought & John F. Guilmartin, Jr. describe the gunpowder technology in 18th century Mysore:

Hyder Ali, prince of Mysore, developed war rockets with an important change: the use of metal cylinders to contain the combustion powder. Although the hammered soft iron he used was crude, the bursting strength of the container of black powder was much higher than the earlier paper construction. Thus a greater internal pressure was possible, with a resultant greater thrust of the propulsive jet. The rocket body was lashed with leather thongs to a long bamboo stick. Range was perhaps up to three-quarters of a mile (more than a kilometre). Although individually these rockets were not accurate, dispersion error became less important when large numbers were fired rapidly in mass attacks. They were particularly effective against cavalry and were hurled into the air, after lighting, or skimmed along the hard dry ground. Hyder Ali's son, Tippu Sultan, continued to develop and expand the use of rocket weapons, reportedly increasing the number of rocket troops from 1,200 to a corps of 5,000. In battles at Seringapatam in

1792 and 1799 these rockets were used with considerable effect against the British.

Civil Engineering

From complex Harappan towns to Delhi's Qutub Minar, India's indigenous technologies were very sophisticated. They included the design and planning of water supply, traffic flow, natural air conditioning, complex stone work, and construction engineering.

Most students learn about the ancient cities of the Middle East and China. How many have even a basic understanding of the world's oldest and most advanced civilization – the Harappan or Indus-Sarasvati Valley Civilization in India? The Indus-Sarasvati Civilization was the world's first to build planned towns with underground drainage, civil sanitation n, hydraulic engineering, and air-cooling architecture. While the other ancient civilizations of the world were small towns with one central complex, this civilization had the distinction of being spread across many towns, covering a region about half the size of Europe. Weights and linguistic symbols were standardized across this vast geography, for a period of over 1,000 years, from around 3,000 BCE to 1500 BCE. Oven-baked bricks were invented in India in approximately 4,000 BCE. Over 900 of the 1,500 known settlement sites discovered so far are in India.

Since the Indus-Sarasvati script is yet to be decoded, it remains a mystery as to how these people could have achieved such high levels of sophistication and uniformity in a dispersed complex and with no visible signs of centralized power.

For instance, all bricks in this civilization are of the ratio 1:2:4 regardless of their size, location or period of construction. There are many pioneering items of civil engineering, such as drainage systems for water (open and closed), irrigation systems, river dams, water storage tanks carved out of rock, moats, middle-class style homes with private bathrooms and drainage, and even a dockyard; there is evidence of stairs for multiple-storied buildings; many towns have separate citadels, upper and lower towns, and fortified sections; there are separate worker quarters near copper furnaces; granaries have ducts and platforms; and archeologists have found geometric compasses, linear scales made of ivory. Indians also pioneered many engineering tools for construction, surgery, warfare, etc. These included the hollow drill, the true saw, and the needle with the hole on its pointed end.

The rich knowledge and concept of town planning has been recorded in the history of India. It may be true that the plans were based on the technology and requirements at that point of time, but they certainly catered for longevity and against calamities that would have been experienced in the era of their conceptual designs. The simple pumping system to the complicated distribution system are minutely designed and laid. Designs and strategic locations to cater for defence against climatic conditions and external threats are clearly visible in our architecture, and have a lot to offer to the modern day civil engineering.

Water Management:

Given the importance of fresh water in India, it is no surprise that the technologies to manage water resources were highly advanced from Harappan times onwards. For example, in Gujarat, Chandragupta built the Sudarshan Lake in late 4^{th} century BCE, and was later repaired in 150 BCE by his grandson. Bhopal's Raja Bhoj Lake, built in 1014-1053, is so massive that it shows up in satellite images. The Vijayanagar Empire built such a large lake in 14^{th} – 15^{th} century CE that it has more construction material than the Great Wall of China. What some historians call the “Persian Wheel” is actually pre-Mughal and indigenous to India.

Scientists estimate there were 1.3 million man-made water lakes and ponds across India, some as large as 250 square miles. These are now being rediscovered using satellite imagery. These enabled rain water to be harvested and used for irrigation, drinking, etc. till the following year's rainfall.

If it was so in the age when there was no water shortage, why can we not have it today. The obvious issue is the population and land limitation. The highrise concrete structures and conversion of forest land to residential are all contributing to depletion of rain and ground water levels. The modern day harvesting techniques may get a supportive direction from the heritage and may be the young minds can innovate to preserve water for the future. Our scriptures directed us to worship rivers, not to pollute them. The spirit was to respect the rivers knowing their importance in providing drinking water and also to facilitate low cost transportation what have we done in the name of urbanization and industrialization? It is time that we start respecting them again in our own good old way.

Shipping and Shipbuilding:

Shipbuilding was one of India's major export industries until the British dismantled it and formally banned it. Medieval Arab sailors purchased their boats in India. The Portuguese also continued to get their boats from India and not Europe. Some of the world's largest and most sophisticated ships were built in India and China.

The compass and other navigation tools were already in use in the Indian Ocean long before Europe. ("*Nav*" is the Sanskrit word for boat, and is the root word in "navigation" and "navy".) Using their expertise in the science of seafaring, Indians participated in the earliest-known ocean-based trading system.

Few people know that an Indian naval pilot, named Kanha, was hired by Vasco da Gama to captain his ships and take him to India. Some of Europe's acclaimed "discoveries" in navigation were in fact appropriations of a well-established thriving trade system in the Indian Ocean. Contrary to European portrayals that Indians knew only coastal navigation, deep-sea shipping had existed in India as Indian ships had been sailing to islands such as the Andamans, Lakshdweep and Maldives around 2,000 years ago. Kautilya describes the times that are good and bad for seafaring. There is also extensive archival material on the Indian Ocean trade in Greek, Roman, and Southeast Asian sources.

Docks of Lothal – Gujrat,India and ancient Indian Ship as shown by Fara Mauro map in 1460

In the Arthashastra, Kautilya codifies the entire spectrum of a state's maritime concerns and activities. The Admiralty is the nodal office under the Navadhyaksha, the superintendent of ships.

On the east coast, the Kalingas, the Cholas and the Andhras were equally active at sea. Such excellence can only happen at sea when the vessels they are ferrying in are sturdily constructed. Ancient ships in India thus were absolutely made under serious motives, in presence of scholarly men. There is a tradition in Orissa, inherited from the old kingdom of Kalinga, which takes thousands of local celebrants to the coasts on Dassera day between Puri and Balasore. There they float tens of thousands oil lamps in paper boats on the water to commemorate the days when great convoys of ships set out each year on Dassera day, towards Suvarnabhoomi. In many lands of Southeast Asia, Indians are still known as Kalings.

The model of the Chola ship, rebuild by the ASI

50 years before Independence India was one of the largest ship building countries in the world. Indian shipbuilding was centered along the Western Coast in Kalyan, Bhivandi and Mumbai, in South India at Narsapurpeta (near Masulipatnam) and in Bengal at Chittagong and Hooghly. The "modern era" began with the building of a dry dock at Bombay about 1750, a second was erected in Calcutta about 1780. During the 19th century, the industry was in a period of expansion and prosperity. However, for the last 100 years, the yards have been in a general decline.

During Shivaji's reign, as per estimates, more than 300 ships of 300 tons Capacity were launched. The Wadia's alone built more than 350 ships (during 1735-1863) 170 war vessels for the East India Company, 34 man-of-war Defence vessels for the British Navy, 87 merchant vessels for private firms, and three vessels for the Queen of Muscat at Bombay docks. After the Bombay Port Trust was formed in 1870, the shipbuilding on the Western Coast moved to Mumbai. In 1872, Jamshedji Wadia, from a Parsi ship-building family, constructed the "Cornwallis", a frigate with 50 guns, bought by the East India Company. This led to several orders from the British Navy.

Bengal was the other major port where ship building was for global markets. Chittagong was the center for shipbuilding (now in Bangladesh). The Turkish Navy (a major world power till WWI) was a major customer. The Mughal and British navies were the other significant defence customers. Merchants cargo ships were in significant demand. Ma Huan, the famous chronicler and interpreter of Zheng He (also called Cheng Ho) voyages, during the Ming dynasty, studied boat building in Bengal during the early 15th century (1400-1410).

The third major center for ship building was Narsapurpeta (near Masulipatnam) port – which was a major center of exports of steel, diamonds, saltpetre (potassium nitrate, for gunpowder, to kill Indians, Negroes, Aborigines and Red Indians with) from the Deccan plateau.

These buyers preferred Indian ships, because of better jointing technology and elimination of metal sheeting. Indian shipbuilders had a special system where wood was seasoned in partial vacuum with oils for timber improvement. British shipbuilders, colonialists ensured through tariff and other barriers, that Indian shipbuilding *"was prevented from continuing to develop,, even though it had a proven ability to adapt to changing technological needs"* – and thus finally killing it. British naval superiority rested on Indian ships – and paid for by exploitation of Indian resources.

In 1498, Vasco da Gama's ocean-going ship, the *Sao Gabriel* came to India. The Portuguese caravels are well-known. But what do the Portuguese call their ocean-going ships? Nau. Yes, *nau* as in Hindi, for boat. Few of these Indian built ships have been recovered in various parts of the world. Indian shipbuilding expertise ruled the world till colonialism killed it.

But while on one hand the Indian shipbuilding industry suffered a backlash, construction of several British ships were awarded to the Indian ship yards which kept alive the hopes and promises of the Indian ship construction industry in the chaotic times. During the British period in India, ancient shipbuilding took a dramatic turn, in which the `white men` encouraged shipbuilding in Bombay. This was perhaps because they were by that time firmly established in India and were ready to meet east India Company and of the Royal Navy. A large proportion of them were built in Bombay, where the Company had established a small shipyard. In 1736 Parsi carpenters were brought in from Surat to work there and, when their European supervisor died, one of the carpenters, Lowji Nuserwanji Wadia, was appointed Master Builder in his place.

Wadia oversaw the construction of thirty-five ships, twenty-one of them for the Company. Following his death in 1774, his sons took charge of the shipyard and between them built a further thirty ships over the next sixteen years. The Britannia, a ship of 749 tons launched in 1778, so impressed the Court of Directors when it reached Britain that several new ships were commissioned from Bombay, some of which later passed into the hands of the Royal Navy. In all, between 1736 and 1821, 159 ships of over 100 tons were built at Bombay, including 15 of over 1,000 tons. Ships constructed at Bombay in its heyday were said to be 'vastly superior to anything built anywhere else in the world'.

Later, with the arrival of steam and iron in place of sail and timber, they were equally prompt to suppress the Bombay enterprise, lest it competed with the shipbuilders at home.

Aerospace Engineering

The ancient vimanas described in the Vedic and Puranic literature of India are so fabulous in their capabilities and construction, one might, with good reason, wonder if such things were actualities, especially those in particular which seem to savor of *daiva* (myth). However, good evidence does exist indicating that more modest versions were actually built in ancient times by the aeronautical engineers of India, Mesopotamia, and a few other places. Especially is this true when details of construction, materials used, and theory of operation are given. Propulsion systems are addressed in a deliberately obscure fashion.

A manuscript, composed in Sanskrit by King Bhoja in the 11th Century A.D., deals with techniques of warfare, and in particular with certain types of war machines. The work is called *Samarangana Sutradhara*, or "Battlefield Commander"(sometimes abbreviated "the Samar"), and the whole of chapter is devoted to the construction and operation of several kinds of aircraft having various methods of propulsion.

King Bhoja, who used the Sanskrit term *yantra* more often than the more familiar *vimana*, claims his knowledge was based on Hindu manuscripts which were ancient even in his time. Some of the techniques of manufacture described therein have been in use by British and American aircraft companies since World War I, and have been found to be sound aeronautical principles even though described nearly a thousand years earlier in this old Sanskrit work. The Sanskrit term *vimana* is used only once in the following passages, in spite of the proliferation of the term in some English translations I have seen.

In looking over the complete text, it is perfectly clear that several types of aerial machines are being described in some detail. Those described below are limited to the atmosphere; yet some of these machines are said to be capable of flying into the *Suryamandala* (Solar sphere), and others even of interstellar travel i.e., the *Naksatra mandala* (stellar sphere). Below is my translation of the 11th century Sanskrit text.

SAMARANGANA SUTRADHARA "Battlefield Commander" translated from the Sanskrit by R. Cedric Leonard have the following details:

"Strong and durable must the *yantra's* body be made, of light material and having wings joined smoothly with invisible seams. It can carry passengers, it can be made small and compact, it can move in silence. If sound is to be used successfully, there must be great flexibility in the driving mechanism, and all must be put together flawlessly. In order for it to accomplish its intended purpose, it must be extremely durable, it must be well covered in . . . it must not become too hot, too stiff, nor too soft, and its sharp-pointed battering ram must also be in-destructible. Indeed, the machine's main qualities, which are remembered by one and all, include unending motion—which is to say perpetual motion. Smoothness is one of the machines supreme qualities; thus, the workings of the machine must be versatile, complete, not given to expansion, never complaining, and always applicable to the task."

At this point the text becomes most interesting, *but also the most difficult*. It is evident that essential elements in the propulsion system are deliberately vague—or completely left out. The reason for this is explained later in the text. It has been brought out that the following has never appeared in any of the current English translations.

"At the critical time the beam of fire must be released, which will make the action possible. The time-beam expands, accompanied by the thunder of the expanding medium. This resultant expansion performs work like an elephant in an endless cycle."

Further along in the text is a paragraph which mentions using wood as a potential building material in the construction of one of these amazing machines (a *yantra*); then it immediately launches into a description of a propulsion system using a combustible fuel similar to gasoline.

"The manufacturing of a conquering *yantra* is greatly to be desired using light-weight wood to build a great air-going machine of a strong-bodied type. In the central container is the liquid consumed by the engine, which gradually burns away during complete combustion."

Immediately following is a list of the possible motions and maneuvers available to the pilot. Several of these would have been deemed incredible by modern aircraft engineers until the introduction of the "hovercraft" and the more recent British aircraft commonly known as the Harrier.

"Fully renown are the techniques for mastering the following motions: vertical ascent; vertical descent; forwards; backwards; normal ascent; normal descent; slanting; progressing over long distances through proper adjustment of the working parts . . . its air-rending sound and roaring thunder can easily drown out the trumpeting of an elephant in panic—but it can also be moved by musical tones.

"Shining in every direction, their machine (*yantra*) could travel wherever the imagination dictated. From their great height they saw stimulating dances, drama plays, and pristine ritualistic ceremonies. Their *yantra* gained renown among Royal dynasties and various nations. In such a manner the High-Souled ones flew, while the lower classes walked. All those friends succeeded in their much-deserved acquisition of a *yantra*, by means of which human beings can fly in the air, and non-earthling, Celestial Beings, can come down to mortals when visiting the Earth."

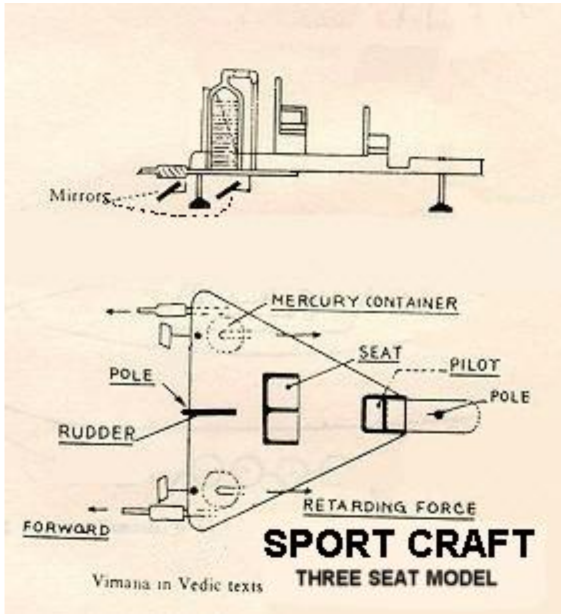
Certain of the aircraft described seem to be winged like a modern aeroplane; but such a craft could not go backwards, nor could it ascend or descend vertically. The term "dual-winged" without doubt appears in the following text in conjunction with some sort of air, or jet, propulsion.

". . . Thus, inside one must place the Mercury-engine; and properly mounted beneath it, the iron heating apparatus. Men thusly set the dual-winged, driving whirlwind in motion; and the concealed pilot, by means of the mercury-power, may travel a great distance in the sky."

Then what follows is the description of a much larger, more complex *vimana*, which is powered by four mercury-engines.

"An extremely swift and nimble *vimana* can be built, as large as the temple of the God-in-motion. Into the interior structure four strong mercury containers must be installed. When these have been heated by a controlled fire from iron containers, the flying machine develops thunder-power through the mercury, becoming a highly desirable *yantra*. Moreover, if this iron engine with properly welded joints be filled with fluid [mercury?], when ascending or descending over land it generates power with the roar of a lion.

The machine's construction and operating details are not publicly disclosed. For if their motivative power be made known publicly to others—giving out results described elsewhere—elements of these machines could be wrongly used."



Drawing of small, delta-winged, Solar-Mercury powered "vimana" reportedly based on a medieval original

Ancient Blueprint of Airship From J. S. Churchward's "The Children of Mu" Ives Washburn, New York, 1931 state:

"These are the most detailed accounts I have found about the airships of the Hindus 15,000 to 20,000 years ago, *except one which is a drawing and instructions for the construction of the airship and her machinery, power, engine, etc. The power is taken from the atmosphere in a very simple inexpensive manner. The engine is somewhat like our present-day turbine in that it works from one chamber into another until finally exhausted. When the engine is once started it never stops until turned off. It will continue on if allowed to do so until the bearings are worn out.* These ships could keep circling around the earth without ever coming down until the machinery wore out. *The power is unlimited, or rather limited only by what metals will stand.* I find various flights spoken of which according to our maps would run from 1000 to 3000 miles." (NOTE: Italics are Churchward's). Col. J. S. Churchward was assigned to India in 1868, where he spent twelve years assisting in famine relief. He became good friends with a Rishi in a Temple School Monastery where he was able to familiarize himself with the history, religion and customs of ancient India. He was enthusiastic and undoubtedly sincere in his efforts, but was often lead astray by con men and charlatans in the field of archeology. However, since the above description is in conformity to what numerous other people have found in India, and being a basically honest person, he is most likely describing something he actually saw. I see no reason to doubt the authenticity of his report.

Think the stories, myths, and claims of the ancient Sanskrit chronicles are nothing more than children's fairy tales? After nearly a thousand years of technical development, the two most advanced nations in the modern world combined their efforts to develop a Vertical-Take-Off/Landing vehicle using the so-called "thrust vectoring" technique similar to that utilized a thousand years ago in India.

The Harrier Jump Jet, sometimes referred to as simply the "Harrier", is a British designed military jet aircraft capable of Vertical/Short Takeoff and Landing via thrust vectoring. The Harrier family is the only truly successful design of this type emerging from the various attempts in the 1960s.

The problem of vertical takeoff and landing was first approached by the Bristol Engine Company in 1957, who were planning a directed thrust engine. Hawker Aircraft came up with a design for an aeroplane that could meet the NATO (North Atlantic Treaty Organization) specifications. Work on an early prototype, called the P-1127, began in the early 1960s.

These started flying in 1964 and were assessed by the "Tri-partite Evaluation Squadron" which consisted of British, American, and German pilots. The RAF (British Royal Airforce) ordered a modified P-1127 as the Harrier I in 1966. The AV-8B is the second generation Harrier, and the BAE (British Aerospace Engineering) Harrier II is the British version.

Just as the modern Harrier utilizes wings for lift, after rising vertically or for short runway takeoffs, certain of the ancient vimanas were described as using wings. But more commonly they utilized what we now term "thrust vectoring" in order to accomplish several innovative maneuvers. Vimanas (like the Harrier) were often described as producing a thunderous roar.

With designs like the above in existence, and proving themselves extremely successful (the Falkland Islands Incident), it is no longer a stretch of the imagination to believe the venerable Sanskrit reports of successful aeronautical accomplishments in ancient times. Maybe we are just now beginning to catch up. The Indian Areospace program is slowly picking up with several missile and satellite launches. However, the aircraft and aero engine program is far from existing. It leaves us thinking whether our documents did have the aerospace technology or they were mere fiction.

Metallurgy and Chemistry

The history of civilization is in many ways linked to the story of the use of metals in a given era. Although modern metallurgy has seen an exponential growth since the Industrial Revolution it is interesting that many modern concepts in metallurgy have their seeds in ancient practices that pre-date the Industrial Revolution. The commonly used metals include gold, silver, copper, iron, tin, lead, zinc and mercury.

The noble metals, **gold and silver**, are found in the native state, and as is well known, gold and silver were used to make jewelry and sheet metal due to the great ductility and lustre of the pure metals. Early gold and silver ornaments from the Indian subcontinent are found from Indus Valley sites such as Mohenjodaro (ca 3000 BC). India has the distinction that the deepest ancient mines in the world for gold come from the Maski region of Karnataka with carbon dates from the mid 1st millennium BC. A rather delightful piece of conjecture is that tales of Herodotus, the Greek, about 'gold-digging ants' from India refers to marmot, a type of rodent found in Afghanistan, who dig up the river sand which could then have been panned for gold by the inhabitants. Prof. R.K. Dube has produced literary evidence that the ants gold, refer to in the epic Mahabharath must have been actually produced by ants, if the size of the gold powder is any indication.

Apart from noble metals, earliest firm evidence for the production of metallic **zinc** is from India. Zinc is one of the most difficult to smelt since zinc volatalises at about the same temperature of around 1000^{o}C that is needed to smelt zinc ore. As a result it would form as a vapour in the furnace which would immediately get reoxidised and hence lost. Hence metallic zinc is seldom reported in world history. However, in India there is unique evidence for the extensive and semi-industrial production of metallic zinc at the Zawar area of Rajasthan. An ingenious method was devised of downward distillation of the zinc vapour formed after smelting zinc ore using specifically designed retorts with condensers and furnaces, so that the smelted zinc vapour could be drastically cooled down to get a melt that could solidify to zinc metal. The *Rasaratnakara,* a text ascribed to the great Indian scientist Nagarjuna, of the early Christian era describes this method of production of zinc.

Another remarkable artistic innovation by Indian metalworkers of the past was the use of zinc in making highly elegant *bidri* ware, an inlayed zinc alloy, which came into vogue under the Muslim rulers of the Bidar province in the Hyderabad region from about the 14th century. AD Several impressive vessels, ewers, pitchers, vessels, huqqa bases etc. were made of *bidri* ware with patterns influenced by the fine geometric and floral patterns and inlayed metal work of the Islamic world where decorative metalwork reached some its most exquisite heights, for instance in the metalwork of the Ottoman empire.

India has been reputed for its **iron and steel** since Greek and Roman times with the earliest reported finds of high-carbon steels in the world coming from the early Christian era, while Greek accounts report the manufacture of steel in India by the crucible process. Wootz is the anglicized version of *ukku* in the languages of the states of Karnataka, and Andhra Pradesh, a term denoting steel. Literary accounts suggest that steel from the southern part of the Indian subcontinent was exported to Europe, China, the Arab world and the Middle East. In the 12th century the Arab Idrisi says *'The Hindus excel in the manufacture of iron. It is impossible to find anything to surpass the edge from Indian steel'.*

Iron and steel are reflected in abundance in the Indian context of science and technology. Since iron has a high melting point of around 1550^{o}C it was commonly produced in the Old World by reducing the ore to metal in the solid state to produce iron which was then wrought to give low carbon wrought iron (0.1-0.2 % C). Iron has been used in India from about the late second millennium BC and iron smelting and the use of iron was especially well established in the south Indian megalithic cultures of this period.

The forging of wrought iron seems to have peaked in India in the first millennium AD. The earliest large forging is the famous iron pillar at New Delhi dated by inscription to the Gupta period of the 3rd c. AD at a height of over 7 m and weight of about 6 tons. The pillar is believed to have been made by forging together a series of disc-shaped iron blooms. Apart from the dimensions another remarkable aspect of the iron pillar is the absence of corrosion which has been linked to the composition, the high purity of the wrought iron and the phosphorus content and the distribution of slag.

In Europe the use of cast iron was not appreciated until after about the 14th c. AD when it was used for making cannons. By the end of the 18th century cast iron began to be used extensively in England in building and construction. The famous Mysore Palace in Mysore near Bangalore built by the Wodeyars at the turn of the century was the first royal palace in India to make use of cast iron in architectural construction.

Studies on Wootz indicate that it was an ultra-high carbon steel with between 1-2% carbon and was believed to have been used to fashion

Damascus blades with a watered steel pattern (Srinivasan and Griffiths 1997). Experimental reconstructions by Wadsworth and Sherby in the 1980's have demonstrated that ultra-high carbon steels with about 1.5% C can be used to simulate blades and that these exhibit fascinating superplastic properties. Superplasticity is a remarkable phenomenon which allows a material to change its external shape to a very great extent without changing within. . Wootz was an 'advanced material' of the ancient world used in three continents for well over a millennium. Neither its geographic sway nor its historic dominance is likely to be equalled by advanced materials of our era.

Mercury is a metal that has been of great alchemical importance in ancient times. Some of the earliest literary references to the use of mercury distillation comes from Indian treatises such as the Arthashastra of Kautilya dating from the late first millennium BC onwards. Vermilion or cinnabar i.e. mercuric sulphide has had great ritual significance, typically having been used to make the red bindi or dot on the forehead usually associated with Hinduism.

Copper is thought to have been the first metal used by man and may have used in ancient Turkey. Early copper artifacts of about the sixth millennium BC are also reported from the pre-Indus Valley sites of Baluchistan in the northwestern part of the Indian subcontinent close to the Iranian border. There is also some evidence for smelting furnaces from the Harappan civilizations of the northwestern part of the Indian subcontinent. There is fairly extensive evidence for the ancient mining of copper ores from the Khetri region of Rajasthan in northwestern India dating to about the 3rd-2nd millennium BC. Arsenical copper was also in use in Mesopotamia, prior to the use of tin bronzes, of which the most famous and extraordinary examples are the bronze bulls of the third millennium BC where the enrichment of arsenic at the surface is found to give it a shiny coating.

Tin ore occurs as alluvial deposits as well as ore bodies. Amongst the earliest bronze castings in the world is the well executed statue of a dancing girl from Mohenjodaro from the Indus Valley, while beautiful bronzes are also known from ancient Egypt such as the famous cat which are thought to have been executed by the lost wax technique. Some of the most beautiful and well executed bronze castings in the world are the icons from the Chola period in the Tanjavur area of south India (ca 10th c. AD). South Indian bronzes were mostly solid cast whereas images from Southeast Asia are mostly hollow cast. Mirrors were made of bronze in different part of old world including India. Investigations by Srinivasan show that that the earliest and continuing use of artifacts of rapidly quenched high-tin bronzes is from the Indian subcontinent.

Agriculture

Agriculture in India has a significant history. Today, India ranks second worldwide in farm output. Agriculture and allied sectors like forestry and logging accounted for 16.6% of the GDP in 2007, about 50% of the total workforce and despite a steady decline of its share in the GDP, is still demographically the broadest economic sector and plays a significant role in the overall social-economic development of India.

India is the largest producer in the world of fresh fruit, anise, fennel, badian, coriander, tropical fresh fruit, jute, pigeon peas, pulses, spices, millets, castor oil seed, sesame seeds, safflower seeds, lemons, limes, cow's milk, dry chillies and peppers, chick peas, cashew nuts, okra, ginger, turmeric guavas, mangoes, goat milk and buffalo milk and meat. India is also the largest producer of sorghum and millets, locally known as Jowar, Bajra and Ragi. It is second only to China in the production of rice. India is the 6th largest coffee producer in the world It also has the world's largest cattle population (281 million). It is the second largest producer of cashews, cabbages, cotton seed and lint, fresh vegetables, garlic, egg plant, goat meat, silk, nutmeg. mace, cardamom, onions, wheat, rice, sugarcane, lentil, dry beans, groundnut, tea, green peas, cauliflowers, potatoes, pumpkins, squashes, gourds and inland fish. It is the third largest producer of tobacco, sorghum, rapeseed, coconuts, hen's eggs and tomatoes. India accounts for 10% of the world fruit production with first rank in the production of mangoes, papaya, banana and sapota.

Many interesting findings have recently come out about the way forests and trees were managed by each village and how a careful method was applied to harvest medicines, firewood and building material in accordance with natural renewal rates. There is now a database being built of 'sacred groves' across India. Once again, it's a story of an economic asset falling into disuse and abuse because of the dismantling of local governance and disrespect for traditional systems.

Furthermore, when scholars try to explain India's current ecological disasters, they seldom mention the large-scale logging of Indian timber by the British in order to fund the two world wars and various other industrial programs of the empire.

Indian farmers developed non-chemical, eco-friendly pesticides and fertilizers that have modern applications. These traditional pesticides have been recently revived in India with excellent results, replacing Union Carbide's products in certain markets. Crop rotation and soil technology that has been passed down for thousands of years are traditional practices which India pioneered.

Historically, India's agricultural production was large and sustained a huge population compared to other parts of the world. Surpluses were stored for use in a drought year. But the British turned this industry into a cash cow, exporting very large amounts of grain even during food shortages. This caused tens of millions of Indians to die of starvation in the 19^{th} century.

Astronomy and Mathematics

Ancient Indians' interest in astronomy was an extension of their religious preoccupations and inasmuch, astronomy and mathematics ran parallel. Both were faithful to the needs of objectivity and subjectivity. Astronomy began as mere wonder at what was observed in the heavens above, grew into a systematic observation and speculation, hence forward into scientific inquiry and interpretation, finally emerging as a sophisticated discipline. Mystical interpretations of the movement of stars and planets developed into astrological science, and astronomy grew into a major factor in the intellectual pursuits of different cultural periods.

The chief sources of astronomy-related information are the Vedic texts, Jain literature, and the *siddhantas* (texts), as also the endeavours in Kerala. Some seals of the Indus Valley period are believed to yield information of the knowledge available to those early settlers, as also the orientation of certain constructions clearly governed by such considerations. An interesting aspect is the Jantar Mantar observatories built by Sawai Jai Singh of Jaipur. There are 5 such structures for measuring time and for astronomy-related calculations, at New Delhi, Varanasi, Jaipur, Mathura and Ujjain. These eighteenth century astrolabes are important for both scientific and architectural reasons.

Sawai Jai Singh, in his determination to provide accurate astrological tables, ordered these gigantic structures of stone. The Jaipur observatory includes the largest sundial in the world with a 90 feet high projecting arm (the gnomon). The measurements achieved by these Jantar Mantars were particularly impressive for their time - the astronomical table was very accurate and in some instances, better than contemporary western ones. This table was published in Persian and Sanskrit as the Zij Muhammad Shahi. The time was and is calculated by a study of the shadows cast by the central straight walls on to the curved walls beyond. The weather forecasts and other information provided by these sundials are very much in use at present, for religious and practical purposes.

Prof. C.K Raju, a renowned scholar, has researched the “clash of epistemologies” that occurred in European ideas about numbers. When Europeans started to import Indian ideas about **mathematics**, what had been natural to Indian thinkers for a long time was very hard for Europeans to accept. He divides this into three periods:

1. The first math war in Europe was from 10th to 16th centuries, during which time it took Europe 500 years to accept the zero, because the Church considered it to be heresy.
2. The second math war was over the Indian concept of indivisibles, which led to the theory of real numbers and infinitesimals, paving the way for the development of calculus. This war lasted three centuries, from the 17th to 19th centuries.
3. The third math war is now under way and is between computational math (Indian algorithmic approach) and formal math (Western approach).

Additionally, Indians developed many important concepts including the base-ten decimal system, now in global use, and crucial trigonometry and algebra formulae. They made several astronomical discoveries. Diverse schools of logic and philosophy proliferated.

Mathematical thought was intertwined with linguistics. India's Panini is acknowledged as the founder of linguistics, and his Sanskrit grammar is still the most complete and sophisticated of any language in the world.

Discussions

The above text from literature available from various sites and books reveal that there is growing evidence to suggest that ancient Indians have also made major contributions which deserve their place in history of the world along with other great civilizations of the world. India had enormous amount of knowledge in Chemistry, Metallurgy, Surgery, Medicine, Agriculture, Architecture, Food Processing, Astronomy and Physics. In fact there are a number of documents (certainly not complete) with recorded information on Mathematics, aeronautics, metallurgy and astronomy. There are recorded information (authenticity and correct interpretation questionable) regarding different types of aircraft including passenger aircraft, missiles with homing guidance, nuclear powered missiles called Brahmastra, space travel including low earth orbit and high altitude orbits. Virtual reality as mentioned in Mahabharata (Duryodhana and Mayagriha) has surprised not only Indians but many foreigners. Similarly ‘Ashariravani’ which is nothing but ‘Wireless Communication’ has been talked of in innumerable episodes. ‘Antardhana’ has been mentioned in many stories (They can be called only stories for lack of authentic real data). It represents sudden vanishing of person or objects including airplane! What is this? Nothing but today’s concept of ‘Stealth’ which is just in the beginning!Many of the documents which contained all these details which were mostly in Sanskrit have been lost during invasions of various foreign elements and also whisking away from India to European Countries either openly or secretly.

The Origin of rituals

It is acknowledged that general level of education and knowledge was lacking in the country and there was large percentage of uneducated or minimally educated people. However, there were small percentage of high intellectuals scattered across who compensated for this general lack of education and knowledge. These intellectuals did all the thinking and prepared ground rules, policies, guidelines, do's and don'ts etc., for the masses. Of course there was always the issue of how masses will understand such sophisticated guidelines when their own education or intellectual level is relatively low and weak. A practical solution evolved at that time was to bring in strict discipline and ensure that the common man follows the guidelines of the intellectuals without questioning and almost blindly. Most of the rituals stipulated in the form of scriptures, slokas, sutras etcwere on these lines. Ordinary men and women were told what to eat, when to eat, how to maintain cleanliness, how to take care of health, how to take care of hygiene and beauty, how to live in society etc. These were instructions in Sanskrit for common man almost like a semi literate soldier being instructed by the commanding officer. There were Kings and Kingdoms and the Rajas and Mantris and intellectuals who did all the thinking for the public. In the beginning, the meaning of most of the rituals were probably understood to a large extent andthe scientific basis was also made known by the intellectuals. However, over hundreds of years not only the scientific basis was forgotten or misinterpreted, the rituals also went on getting modified, sometimes diluted to suit the common man in the society and practical difficulties prevailing locally. It is one of the reasons the Indian Science did not thrive and blossom into its full potential in most of the branches. There have been number of attempts by various pundits across the country who tried to reconstruct our age old Science and Wisdom through painful understanding of these coded scriptures. Unfortunately the pundits who could read Sanskrit and interpret hardly had any Science background and who were technology leaders could not understand Sanskrit which is a very tough language and the slokas fully coded.

Damages due to invasions and foreign rule

As India was a fragmented country before Mughal and British periods, there was no consolidation of efforts in innovations, science and technology which were taking place in many kingdoms of the country. The knowledge generated and accrued were either destroyed or exploited by invaders and foreign rulers and India as an entity went on losing all its treasures both physical wealth, intellectual capital of coded scriptures and marvelous infrastructure created till British rule.

With colonialism, the contribution made by others, including India, was ignored. This era came as the decline of innovation and the progress of science and technology in the Indian subcontinent. The period of slavery to the freedom struggle led to the brain break of the Indian intellectuals, and while the west took the available knowledge to develop, putting India behind by almost ten decades. The education system almost came to a grinding halt, barring a percentage of privileged. Post independence we have come a way ahead; gone are the days when India was totally depended on the western world for all that's "cutting-edge". Today, India is a proud member of the science & technology high table.

India's commitment to the use of science & technology as a key instrument in national development has been clearly articulated time and again in various policy documents right from the early years of independence. And indeed, the progress made by our country since then in attainment of the stated goals in policy and plan documents has been substantial.

Despite achieving a lot in the last 50 years, what is of paramount importance in the present context of fast changing technological scenario is to keep the momentum going and further the efforts in science and technologicalR&D.

The main challenge is to keep pace with the technological changes so as to ensure that the S&T developments are used for socio-economic development and help India develop into a country that can stand tall even amongst the tallest of the all.

Today's Picture

Let us see today's picture. We have a fairly large number of Science & Technology graduates coming out of University system every year. Government is spending about 1% of GDP towards Research & Development. The three strategic departments, defence, space and atomic energy is carrying lion's share of R&D closely followed by CSIR, DBT and ICAR.

Though percentage and quantum of money for R&D is small, the impact in terms of return on investment is highest in the world. Elsewhere 3 to 5 times the amount is spent in India would be spent in other countries for the same output. The scientists in India are highly committed, working long hours and frugal in spending. Quality of work is comparable. Probably more equipment and facilities need to be established for faster realization of results. National Innovation Foundation and many initiatives from Centre and State Governments are in place to promote and harness creativity. Science education has been given a big boost to build stronger foundation. More I.I.Ts are coming up, N.I.I.Ts are being upgraded IISERs are established and huge number of private universities and institutions are bringing in world class education and infrastructure. Indian management education and managers are sought after world over. Young, energetic and restless youth are bringing in new ways of learning and doing business.

Many international collaborations are taking place in education, R&D, manufacturing, marketing and product support. Indians seem to be everywhere and all the time. The numbers, age group and knowledge have become a heady mix of success and entrepreneurship.

Networking India

Let us see the attitude of government. While Science & Technology was being talked only in academy and R&D labs, the State and Central governments were running their various departments by ill-equipped politicians who were mostly lawyers and bureaucrats who were mostly arts and history graduates. Industries were run by Lalas and family members with hardly any professionalism or knowledge of technology or management. Screwdriver technology and crude manufacturing were being pursued. There was a big divide between these three elements.

Things are totally different today. Politicians are highly educated, I.T. savvy, and many are trained abroad in advanced disciplines. They are excellent communicators and managers. Bureaucrats themselves have changed. Most of them now are graduates and post graduates in professional courses in engineering, medicine, finance, commerce and management. Coming to industry leaders, they are third generation entrepreneurs. They are as good engineering graduates and post graduates as our own scientists! They not only understand engineering and manufacturing, they are also well versed with quality, management, networking and many soft skills. The ecosystem has completely changed.

S & T in Governance

Government of India, especially Planning Commission has drawn out plans for synergizing these three main streams for changing India. S&T will cross flow into governance of all departments whether it is education or steel or coal or petroleum or non conventional energy or health or fisheries or transportation or civil aviation or railways or law or commerce or tourism or culture or urban development or rural upliftment or agriculture or infrastructure or shipping or finance!

Embedding S&T in all areas is going to be mandatory and with such an integration every ministry or department would do better in its performance. Bureaucrats and politicians will integrate with scientists and technocrats. Same is applied in every State and State department. There would be innovation centres across the country for encouraging creativity and spreading knowledge. Knowledge network will carry large volumes of data and information seamlessly and instantaneously.

Subcritical to Supercritical

One of our banes was subcritical funding for developing new science and technology in large number of institutions. There would be hardly any worthwhile output because of subcritical, divided and isolated efforts at large centres. This is changing. Country is embarking on large size programs, adequately funded and well coordinated to ensure tangible outputs in realistic timeframes. This is seen in aerospace, defence, atomic energy, DST, DBT, MNE, Department of Earth Sciences and many national missions.

Visibility, accountability and recognition go hand in hand. Market will expand to cover the entire globe. Competition will force India to innovate in all spheres and India is ready for that!

We should harmonize, synergize, fuse and integrate the well established features of Indian analytics, intellect and way of life with Western discipline, professionalism, team work and industrialization. This should come as a revolution from industrialists, individuals, parents, teachers, common man, students, housewives, villagers and of course qualified Scientists and Technologists instead of all the time looking up to government and foreign help.

Heritage S&T to assist contemporary challengies in Development

So we have studies and analysed to some depth strengths of an heritage S&T. of course a large percentage of this knowledge has been lost. But can we leverage whatever we have acquired and leftwith to solve today's development problems. Some attempt has been made here to give some lead and bringout some effort that is already on.

Take materials, we need high strength and high hardness but light metal alloys for tank and body armour. A Vedic centre in Hyderabad called Sri Maharshi Vedic Technology Centre is preeisely doing this. They are digesting Vedic literature and trying to meet requirements of tanks, soldiers, aircraft engines and rocket motors.

The same Institute is also trying to recreate and put together dietary supplements to soldiers in the field, inside submarines and in air. Any success in their efforts will be breakthrough even in today's environments.

When we look at modern day health care products and beauty care creams and lotions, what do we find? Our Great Great Great Grandfather's heritage recipes build around Tusli, turmeric, neem, gooseberries, clove, herbs and leaves! Vedic Knowledge is being very much exploited in these latest high tech, high cost products developed based on low tech, low cost natural ingredients and processes.

Let us look into the world of synthetic fibers, colours and finishes. Again today's scientists are travelling back to thousand years to bringback the goodness of natural fibers, dyes, paints and chemicals concocted out of nature and elements. It is also interesting to note that all ageold processes whether they are dealing with metallurgy or chemistry are all done at relatively lower temperatures than temperature levels used in modern day processes. The technologies were automatically greener and safer.

The magic of yoga, meditation, pranayam and chanting have been rediscovered throughout the world. Solutions to many human problems which could not be found even after using high end and expensive modern technologies have been found through our own zero cost, zero technology innovations and that too with no side effects!

There is every possibility that we find the latest of the stealth technologies for aircraft by understanding oldest of the Vedic Knowledge!

Way Forward

Let the Revolution begin! It is seen that Sustainable solutions in the Indian context can in vedic be borrowed from the Indian Heritage and knowledge process available literature. As is recorded for ages, Indian solutions have been and are still believed to be environmentally sustainable than any western solution. A blend of two could be the right choice. Focused sector wise knowledge banks can be created, which should take up need based blending of the modern day science with the Indian Vedic knowledge, for a sustainable technological solution. Let the revolution begin! After it can only gain momentum.

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