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Rockets in Mysore and Britain, 1750-1850 A.D.

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> I have come to the conclusion that everyone should write history based upon his own selection of sources that appear significant to him, but that no one should read it except to obtain general information in areas of peripheral concern. Oddly, only an amateur can be so detached.
>
> \- Cyril Stanley Smith (1981)

SUMMARY

Rockets, or "fire-arrows" in some form, have been known for a long time: the Chinese are recorded as having used them in 1232 A.D., and the Europeans in the 14th and 15th centuries. After having fallen into disuse with the invention and improvement of cannon, rockets reemerged in the Mysore of Hyder and Tipu in the second half of the 18th century; this spectacular revival provides a curious and fascinating episode in Indo-British technological history.

The Mysore rockets of this period were much more advanced than what the British had seen or known, chiefly because of the use of iron tubes for holding the propellant; this enabled higher bursting pressures in the combustion chamber and hence higher thrust and longer range for the missile. The rockets consisted of a tube (about 60 mm diameter and 200 mm long),

fastened to a sword or 3 m bamboo pole, and had a range of 1-2 km. In the famous battle of Pollilur (1780) in which the British were defeated - a scene celebrated on the walls of Darya Daulat Bagh in Srirangapatna - a strong contributory cause is thought to have been the explosion of Colo Baillie's ammunition tumbrils, touched off by Mysore rockets. Rockets were used in the 3rd and 4th Anglo-Mysore Wars as well; although they caused much confusion and fear especially when used against massed troops or cavalry, they were too inaccurate to tilt decisively the fortunes of battle in favour of Tipu.

But the rockets made an extraordinary impression on the British, and led, from 1801, to what would now be called a vigorous research and development programme (at the Royal Woolwich Arsenal). Sir William Congreve made systematic studies of propellants, analysed performance applying Newton's laws, developed a series of rockets of differen-t sizes and characteristics, made a comparative cost analysis and published three books on the subject. Rockets were soon systematically used by the British during the Napoleonic Wars and their confrontation with the US during 1812-14. What is of interest to us is that, although the technology of the Mysore rockets was superior in 1799, the character of the British effort begun just a few years later was already vastly more sophisticated, bringing to bear on the problem an attitude involving science, engineering and application that was far in advance of anything understood in India at the time. The news of the Mysore rockets arrived at an England where the first wave of the Industrial Revolution had begun to transform radically the attitudes and responses of that nation.

With the further improvement of guns later in the 19th century, rockets fell into disuse again (except as toys during Deepavali or other fireworks displays!). They were to be revived by Goddard in the US in the 1920s; and reappeared in India only in the 1960s, with the beginning of a space programme.

1. INTRODUCTION

The rocket has been known in some form or other for a long time in history. It is generally agreed that it was used in China in the 11th century A.D., perhaps in what we might now term a "rocket-assisted arrow". Similar weapons* were probably used in India as well, as illustrated by a Hoysala sculpture from the Halebid Temple (12th century A.D.), Figure 1. As the rocket became sufficiently powerful to serve as a destructive warhead by itself, the arrow or spear to which it was attached was discarded. It is reported that in 1232 A.D., five years after Genghis Khan's death, Chinese rocket barrages repeatedly repulsed Mongolean cavalry led by his successors in attacks on the city of Kaifeng on the Yellow River (set up as the new capital of the Chin Kingdom after Genghis Khan had sacked Peking

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* We need to distinguish between true 'rockets' which are entirely self-propelled, and 'arrows' (even fire-tipped) which are shot with the energy of a bow-string: a rocket-assisted arrow is a hybrid.

and driven its rulers south; Kaifeng fell in 1233 after a heroic defence, Grousset 1965). The invention travelled rapidly (presumably through the Mongols) to Europe, where it was first mentioned in 1258 A.D., and was experimented with and used upto the 15th century: in England Roger Bacon (1214-1294) had worked on both advanced gunpowder and rockets. However, towards the beginning of the 16th century the cannon (invented around 1300 A.D., after the rocket) had improved so much that the military rocket fell into disuse.

The reemergence of the rocket as a significant military weapon during the 18th century Mysore of Hyder Ali and Tipu Sultan is a fascinating little episode in the history of technology in India; and it is the purpose of this note to narrate how this happened, and the interesting sequel of its development in 19th century Britain, But it must be noted that rockets were in use in India even before Hyder - his father was already commanding 50 rocketmen for the Nawab of Arcot (Forrest 1970) - but I have been unable to trace any material on this earlier history, apart from mythological references to the "agneyastra".

Tables 1 and 2 present brief chronologies relevant to the history of rockets and of industrial development in Britain respectively.

2. THE MYSORE ROCKETS DESCRIBED

The rockets used by the Mysoreans consisted of a metal cylinder ("casing") containing the combustion powder ("propellant"), tied to a long bamboo pole or sword which provided the required stability to the missile (Figure 2; note the strong resemblance to the familiar but much smaller "rocket" one can see during Deepavali to this day). Two specimens preserved in the Royal Artillery Museum, Woolwich Arsenal have these dimensions (von Braun & Ordway 1966):

(i) Casing 2.3 in. O.D. x 10 in. long (~ 58 mm O.D. x 254mm long), tied with strips of hide to a straight 3 ft. 4 in. (~1.02 m) long sword blade.

(ii) Casing 1.5 in. O.D. x 7.8 in. long (~ 37 mm O.D. x 198 mm long), tied with strips of hide to a bamboo pole 6 ft. 3 in. (~ 1.9 m) long.

The metal cylinder used was hammered soft iron; although it was crude, it represented a considerable advance over earlier technology, as European rockets of the time had combustion chambers made of some kind of paste board; e.g. Geissler in Germany used wood, covered with sail-cloth soaked in hot glue (Ley 1958). The use of iron (which at that time was of much better quality in India than in Europe, as we shall discuss further below) increased bursting pressures, which permitted the propellant (gunpowder) to be packed to greater densities; this gave the Mysore rockets a higher thrust and range, as confirmed by later experiments in England (which also we shall discuss below). The range is often quoted as about 1000 yards. There are however other accounts (e.g. Ley 1958) that speak of rockets that generally weighed 3.5 kg, tied to 10 ft (~ 3m) bamboo poles, and with a range of upto 1 1/2 miles (2.4 km): this has been called an "outstanding performance for the time" (Baker 1978).

There was a regular Rocket Corps in the Mysore Army. Beginning with about 1200 men in Hyder's times, this eventually reached a strength of about 5000 in Tipu's army. In the Third Anglo-Mysore War of 1792, there is mention of two rocket units fielded by Tipu, commanded respectively by Qamar-ud-din Khan (120 men) and Purniah (131 men). Forrest (1970) calls attention to an account that "mentions the skill of their [Mysorean] operators in giving them 'an elevation proportioned to the varying dimensions of the cylinder and the distance of the object to be struck'". Furthermore, the rockets could be launched rapidly using a wheeled cart with three or more rocket ramps.

Tipu was an innovator in many ways, and would today have been called a 'technology buff'. Historians speak of his curiosity about European inventions such as barometers and thermometers and his vigorous efforts to promote manufacture of novel devices in various cities of his state. These efforts were encouraged in later years by the favourable impression his weapons made, especially the rockets, on such notables as the Sultan of Constantinople, to whom they had been sent as presents (Rao 1943).

3. THEIR MILITARY EFFECTS

The use of rockets by Hyder and Tipu is mentioned at various places in Wilks's (1810) famous "History of Mysoor". A more recent and readable account of the history of Tipu is Forrest (1970).

The first striking account we have (see Appendix 1 on dates) is that of the Battle of Pollilur, which was fought on 10 September 1780 during the Second Anglo-Mysore War (Wilks 1810): Pollilur is a small village between Kanchipuram and Arakonam (Figure 3). (In July of that year, "Hyder, with 80,000 men and 100 guns, [had come] down upon the plains of the Carnatic, 'like an avalanche, carrying destruction with him'.") Hyder and Tipu achieved a famous victory at Pollilur, and it is widely held (e.g. Forrest 1970) that a strong contributory cause was that one of the British ammunition tumbrils was sent on fire by Mysorean rockets. [Rao (1943) also mentions Tipu's rocketmen, but suggests that the tumbrils were set on fire by French cannon.] The scene is celebrated in a famous mural at Darya Daulat Bagh in Srirangapatna (Figure 4). Writing about this war, Sir Alfred Lyall remarked in 1914 that "The fortunes of the

English in India had fallen to their lowest water-mark" (Majumdar et al. 1958).

Accounts of the use of rockets in the Second Anglo-Mysore War appeared in a book by Innes Munro titled "A narrative of the military operations on the Coromandel Coast etc. etc.", published in London in 1789. Munro had spent the period 1778-1782 accompanying British troops on their various campaigns in South India.

Rockets must have been used regularly in many of the battles that were fought in Mysore during those turbulent years, but I have been able to find four specific references that may be worth mentioning. During the Third Anglo-Mysore War, Lt. Col. Knox was attacked by rockets near Srirangapatna on the night of 6 February 1792, while advancing towards R. Kaveri from the north (Figure 5). During the Fourth (and final) War, rockets were again used on several occasions. One of these involved Col. Wellesley, to become famous later as Lord Wellington and the hero of Waterloo. Quoting Forrest,

"At this point [near the village of Sultanpet, Figure 5] there was a large tope, or grove, which gave shelter to Tipu's rocketmen and had obviously to be cleaned out before the siege could be pressed closer to Seringapatam island. The commander chosen for this operation was Col. Wellesley, but advancing towards the tope after dark on the 5th [April 1799], he was set upon with rockets and musket-fire, lost his way and, as Beatson politely puts it, had to 'postpone the attack '. . • until a more favourable opportunity should offer'. ... Wellesley's failure [was] glossed over by Beatson and other chroniclers, but the next morning he failed to report when a force was being paraded to renew the attack. [General] Harris [who led the British forces on the siege] offered the command to Baird, who (by his own account) chivalrously refused to take it in case Wellesley turned up, which in due course he did."

Another account (quoted by Rao 1943 from Hook 1833) says:

"Colonel Wellesley, advancing at the height of his regiment, the 33rd, into the tope, was instantly attacked, in the darkness of the night, on every side, by a tremendous fire of musketry and rockets. The men gave way, were dispersed, and retreated in disorder. Several were killed, and twelve grenadiers (these men were all murdered a day or two before the storm) were taken prisoners."

The 'Sultanpet incident' clearly had a profound and traumatic effect on Wellesley (see Appendix 2); his biographer Guedalla (1940) describes how, even late in his life, after Waterloo, Wellington used to come back to the incident with his own explanations of what happened. Guedalla suggests that this incident might have been responsible for the indulgent view that Wellington often took of "shell-shocked" soldiers, for one of whom he pleaded sympathy noting, "Many a brave man, and I believe some very great men, have been found a little terrified by such a battle as [Waterloo], and have behaved afterwards remarkably well" - just as (presumably) Wellesley himself did after 'Seringapatam'.

Again, in the early hours of 22 April, "Stuart's position on the north bank was attacked in the rear by rocket men." Here is an account of this event, from von Braun & Ordway (1966; see Appendix 1):

"On 22 April [1799], twelve days before the main battle, rocketeers worked their way around to the rear of the British encampment, then 'threw a great number of rockets at the same instant' to signal the beginning of an assault by 6,000 Indian infantry and a corps of Frenchmen, all directed by Mir Golam Hussain and Mohomed Hulleen Mir Mirans. The rockets had a range of about 1,000 yards. Some burst in the air like shells. Others called ground rockets, on striking the ground, would rise again and bound along in a serpentine motion until their force was spent. According to one British observer:

> 'The rockets make a great noise, and exceedingly annoy the native cavalry in India, who move in great bodies, but are easily avoided, or seldom take the effect against our [i.e. British as opposed to Indian units attached to the British] troops, who are formed in lines of great extent and no great depth.'

"The diary of a young English officer named Bayly gives a somewhat different picture of the rockets' effectiveness. So pestered were we with the rocket boys that there was no moving without danger from the destructive missiles . ..'. He continued:

> 'The rockets and musketry from 20,000 of the enemy were incessant. No hail could be thicker. Every illumination of blue lights was accompanied by a shower of rockets, some of which entered the head of the column, passing through to the rear, causing death, wounds, and dreadful lacerations from the long bamboos of twenty or thirty feet, which are invariably attached to them'."

On the afternoon of 4 May when the final attack on the fort was led by Baird, he was again met by "furious musket and rocket fire", but this did not help much; in about an hour's time the Fort was taken; perhaps in another hour Tipu had been shot (the precise time of his death is not known), and the war was effectively over.

Two facts stand out clearly from these accounts: the British were caught off balance by the use of rockets, which at the least caused great fear and confusion; nevertheless, in the later battles they could not tilt the balance decisively in favour of Tipu and his armies. There is however no doubt that the British were extraordinarily impressed, as their effort at developing their own rockets in the decades following Tipu's defeat and death shows: we shall discuss this briefly now.

4. ROCKET DEVELOPMENT IN BRITAIN

A vigorous programme of what we would now call 'research and development' on rockets took place in Britain beginning with the new century. As pointed out by all historians, e.g. Ley (1958), the cause for the revival of this interest did not lie in Europe but came from the reports from India, in particular Munro's book of 1789. Several rocket cases were collected and returned to Britain for analysis (Baker 1978). The development was chiefly the work of Col. (later Sir) William Congreve, who was told (von Braun & Ordway) that "the British at Seringapatam had 'suffered more from them [the rockets] than from the shells or any other weapon used by the enemy." "In at least one instance, an eye-witness told Congreve, a single rocket had killed three men and badly wounded others."

In 1801/2, Congreve bought (out of his own pocket) and tested the biggest sky-rockets then available in London (Ley 1958). Their range was found to be about 500-600 yards, less than half that of the Mysore rockets. He then started developing his own, using the facilities of the Royal Laboratory at Woolwich Arsenal, with the support of such influential men as his father who was Comptroller of the Laboratory and of Lord Chatham, who was Prime Minister during 1783-1801. Congreve first tested various combinations for propellant, and eventually developed a rocket motor with a stout iron case 100 mm dia with a conical nose (Figure 6), weighing about 14.5 kg, attached to a

4.6 m long wooden stick 38 mm in diameter. This cost him about £ 1 (see Table 3).

In 1804 Congreve published a book titled "A concise account on the origin and progress of the rocket system", and claimed that his rocket's "carcass is the largest of the kind that has hitherto been constructed for use", showing that he was ignorant of earlier European work, in particular the much larger rockets (with wooden casings, though!) made by Geissler in Berlin in 1668* Congreve's rockets had iron hoops on one side, making it easier and quicker to fix the stabilizing stick, but later he also tried a configuration where the stick was fixed at the centre of the casing with exhaust gases coming out of orifices around the circumference. He was soon reporting that 13,109 rockets had been manufactured "by August 1806.

It is of special interest to note that Congreve reasoned on the basis of Newton's third law, and recognized that one of the chief advantages of the rocket would be the absence of the recoil force ("to ground", so to speak) that made it so difficult to use cannon on ships. He therefore argued that rockets were particularly suited for sea-borne assault, although he apparently came to feel later that this was not the best method of using them. At any rate, the argument persuaded the Royal Navy to try out rockets in an attack on the French channel port of Boulogne, where Napoleon had been assembling his forces with the intention of taking the war to British soil. (This was the time of the Napoleonic Wars in Europe: Britian and France declared a mutual blockade in 1906, one of whose more durable but less serious consequences was that the French could not import enough coffee, and had to learn to stretch it by adding chicory - but, as Guerard (1957) notes, "No proud nation will ever surrender for lack of coffee"!).

On 18 November 1805, ten British launches fitted with rockets assembled off Boulogne. The attack (during which Congreve was present) was not very successful. The British attributed the failure to the occurrence of a sudden storm; the French on the other hand said the rockets caused so little damage that their "soldiers marched around in the city after the attack, carrying the empty shells of the rockets and making unprintable jokes about them" (Ley).

The second attack, mounted on 8 October 1806, turned out to be devastating. "In about half an hour above 2,000 rockets were discharged. The dismay and astonishment of the enemy were complete - not a shot was returned - and in less than ten minutes after the first discharge, the town was discovered to be on fire" (quoted by von Braun & Ordway). Napoleon was forced to abandon all plans for a cross-channel expedition on Britain.

This success was followed in 1807 by a barrage of some 25,000 rockets on Copenhagen, which was also very effective. During the next decade the use of such rockets became routine in British naval operations, which included engagements at Aix, Gallao (1809), Cadiz (1810), Leipzig (1813), and the U.S. (1814).

The Anglo-American "War of 1812" (as U.S. historians call it: see e.g. Nevins & Commager 1956) is of some interest. (This war was also a result of Anglo-French conflict: the British forbade all U.S. commerce with France, and were able to enforce the blockade so effectively - because of their naval strength — that U.S. exports fell by 80%: Congress and President Madison declared war on Britain in 1812.) The Congreve rockets were used in several engagements (see von Braun & Ordway), sometimes with little and on other occasions with great effect: they were still rather unreliable and inaccurate, but had greater range than cannon and could even be fired from row-boats. Indeed they were responsible for the fall of Washington: one account (quoted by Ley) says that on 24 August 1814, at the Battle of Bladensburg,

> "a flight of these ungainly projectiles directed against Stansbury's brigade had caused the regiments of Shultz and Regan to break and flee in wild disorder. As a result, the American flank was turned, and despite stout resistance on the part of the Fifth Maryland Infantry under Sterrett, the day was lost. Thus we may indirectly (or perhaps directly) thank Congreve and his invention for the capture and burning of Washington which followed."

The victims of the "burning" included both the Capitol and White House. Nevins & Commager say about the same battle that "the unheroic defenders gave way after losing ten killed and forty wounded and ran for Washington so rapidly that many Britons suffered sunstroke in trying to keep up."

On the night of 13-14 September Fort McHenry was bombarded from Baltimore harbour; the attack, spectacular but unsuccessful, was watched from on board a British ship by Francis Scott Key, a young American lawyer then negotiating the release of US citizens who, allegedly as British subjects dodging service, had been "impressed" by a Royal Navy that offered such poor wages and cruel treatment to its sailors that not enough of them could be recruited. It was this event at Fort McHenry that led to Key's words on "the rockets' red glare" in the patriotic song that later became the US national anthem.

The main advantages of these rockets were that their range exceeded that of other movable artillery of that time (this is spectacularly true again in the 20th century!), and the absence of recoil which not only permitted their operation from boats (as we have seen) but also eliminated the heavy 'barrel' required to direct other projectiles: Congreve had shown how a rocket barrage could be discharged from collapsible wooden frames (Figure 7). Congreve thought, rather appropriately, that rockets were "the soul of artillery without the body".

Other countries quickly followed the footsteps of Congreve and the British: "Denmark, Egypt, France, Italy, the Netherlands, Poland, Prussia, Sardinia, Spain and Sweden attached rocket batteries to their artillery. Austria, England, Greece and Russia had rocket corps which were independent units . . . The US formed rocket units ..." (Ley),

Congreve's work had an enormous impact on the general public as well. George Stephenson sportingly called his steam locomotive the Rocket, after a critic had scornfully said that the idea of travelling at twice the speed of a horse-drawn coach was "silly and ridiculous ... It may just as well be expected that the inhabitants of Woolwich will consent to ride on a Congreve war rocket than trust their lives to such a machine" (Ley).

To illustrate the character of Congreve's effort, we reproduce two tables from his work. Table 3 makes a cost comparison between rockets and mortars, showing a slight advantage to the former. Table 4 is a list of rocket types developed by Congreve, and published by him in 1817. As these tables suggest, Congreve's achievements were remarkable for their comprehensiveness. Beginning with an application of Newton's laws to understand rocket behaviour, he experimented with a number of black-powder formulas and set down specifications for their composition, standardised construction details, used improved production techniques (the stabilizing stick could be quickly inserted into hoops on the side of the casing and crimped), offered designs permitting either explosive (ball charge) or incendiary warheads (the former could be independently timed by trimming the fuse length before launching), studied the tactics of their use(recommending that they be fired in volleys of at least 20 and preferably 50 rockets once every 30 seconds, to compensate for their dispersion), and designed simple collapsible wooden frames to serve as launchers (dispensing with the heavy wheeled carriages that were so necessary for transporting cannon and made them unusable in difficult terrain). In 1827, Congreve published his third book on the subject, whose cover is reproduced in Figure 8: he had by then succeeded to his father's position at Woolwich and the baronetcy, and been elected to. the Royal Society and Parliament.

At least twenty books on the subject of rockets appeared around the time in Europe.

Although they continued to be used for some more time, the use of rockets had however considerably declined by mid-century, as artillery gained in accuracy and became more effective. Another hundred years or so were to pass before rockets again began to be considered seriously as military weapons.But for a long time they found peace-time application in saving lives from shipwrecks. A light line was fired from shore to ship using a rocket, and used to haul back a heavier line that brought passengers and crew from ship to shore. This system was reported to have saved more than 15,000 lives between 1871 and 1962 (Encyclopaedia Britannica), and was in use in the Netherlands till the late 1960s.

5. CONCLUSION

I hope enough has been said in the above sections of this note to make two points. First, in the 18th century there were still certain products, of which the rocket was one, where Indian technology was superior to the British and was so recognized by them. Secondly, following this recognition, the British effort to understand and master the technology already had the sophistication that we have come to associate with research and development in this age: scientific principles were applied, appropriate designs were made, and suitable products developed, tested and systematically evaluated. This whole process was something about which Indians of the 18th century had no clue whatever.

To understand how this came to happen, we must realize that the period in question was one of extraordinary turmoil and ferment - political, social, cultural - in British history (Trevelyan 1959). Charles Dickens had the year 1775 in mind when he wrote those famous lines, "It was the best of times, it was the worst of times; it was the spring of hope, it was the winter of despair;...". Britain was fighting military engagements at a variety of places around the globe. The East India Company's governor-general Warren Hastings noted, around 1779, "a war actual or impending in every quarter and with every power in Hindustan" (including, of course, Mysore: Majumdar et al. 1958). In Europe - where the period saw first the French Revolution (1789) and later the rise of Napoleon (1795) - and in America, where the former British colonies had fought successfully a war of independence (1776), Britain was involved in numerous battles on land and in the high seas, including the famous one near Trafalgar, won in 1805.

Even more importantly from the present point of view, this period saw what the historians agree was the first wave of the Industrial Revolution, which Derry & Williams (1960) date as lasting from 1750 to 1815. The transformation that took place in Britain during these years can be easily illustrated in terms of a few simple parameters. Figure 9 shows an index of mechanisation (taken from Pacey 1983), constructed from statistics on the number of lathes in general use. It- will be seen that there is a marked rise in the, index beginning around 1600, followed by a remarkable spurt towards the end of our period, namely 1815. Figure 10 (based on Pacey 1976) displays the pig iron production in Britain during the same period: once again we note a steep increase, beginning this time around 1770.

The period saw many interesting developments in science and technology in Britain. Although Newton's famous Principia had been published about 70 years earlier, it was really during the 1760s that the direct relevance of Newton's laws in the solution of practical problems began to be appreciated. For example, the pioneering studies of John Smeaton on wind- and watermills date from this period: his diagrams of water wheels have appeared virtually unaltered in British undergraduate engineering texts down to our own days. In 1776 James Watt's steam engines were in operation at many places. The same year saw the publication of Adam Smith's classic work The Wealth of Nations, which still continues to influence economic thinking in the Western world. Smeaton formed a Society of Engineers in 1771; engineering emerged as a profession, and engineering science as a pursuit, culminating in the foundation of the Institution of Civil Engineers in 1818.

Simultaneously there was a marked decline in the technological capabilities of India. In the decades following the Battle of Plassey (1757) India's famed textile industry faced total ruin, as the British imposed stiff duties against Indian imports and started flooding India with textiles from Manchester of steadily improving quality. Pacey (1976) points out that "iron made in India was of a high quality too, even though Indian furnaces were oper.ated inefficiently as compared with those of Europe. Samples of Indian iron were sent to Sheffield, because it was 'excellently adapted for the purpose of fine cutlery', and it was difficult to obtain such good iron in England, except through imports from Sweden". There are reports that "in the 1790s the British started importing [Indian iron] to reduce their dependence on Swedish iron". But as Figure 11 shows iron production in India had started to decline already and almost vanished in the 1850s, to pick up again only a few decades later, but this time using British technology. Again, the British were surprised about certain agricultural implements which had been in regular use in India for a long time. Some of them "including a plough and a seed drill, were sent from India to the British Board of Agriculture in 1795". Sir Thomas Munro, who fought as a subaltern in the Second Anglo-Mysore War and rose to be Governor of Madras, testified before the House of Commons in 1813 that "India equalled Europe in many things - manufacturing and agricultural skill, elementary schools in every village, the treatment of women..." (emphasis mine).

To summarize, therefore, there were products of Indian technology that in the second half of the 18th century were still superior to those available anywhere else in the world. But India was untouched by the vast transformation that Britain and the rest of Europe were experiencing: production here still remained a craft, whereas it was rapidly becoming(Singer et al. 1958) an industry backed by science, research and development in Britain.

We conclude by noting that it took India another 150 years before rockets made in the country were comparable or superior to those made in Britain,

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TABLE 1 SOME DATES IN THE HISTORY OF DEVELOPMENT AND USE OF ROCKETS

11 century	Rockets used in China.
1232	Chinese rocket barrage used at Kaifeng against Mongol invaders.
1258	First mention in Europe.
1668	Col. Von Geissler tests 50 lb and 120 lb rockets near Berlin; rocket casing of wood covered with sail-cloth soaked in hot glue.
1780	British defeated by Hyder and Tipu in the Battle of Pollilur, during the Second Anglo-Mysore War, Lt. Col. Baillie's surrender being hastened when his ammunition tumbril was set on fire by a rocket (scene in Darya Daulat Bagh).
1789	A narrative of the military operations on the Coromandel Coast, etc. etc. by Innes Munro, published in London, reports use of rockets by Indians.
1792	Third Anglo-Mysore War. Lt. Col. Knox attacked rockets near Srirangapatna on night of 6 February, while advancing towards R. Kaveri from the north.
1799	Fourth Anglo-Mysore War. Col. Wellesley (later Lord Wellington) attacked by rockets after dark on 5 April at Sultanpet; Col. Staurt attacked in the early hours of 22 April on the North Bank; Gen. Baird attacked afternoon of 4 May, two hours before Tipu was shot.
1801/2	Col. William Congreve starts experimenting with rockets at Woolwich Arsenal, England.
1804	Congreve publishes A concise account of the origin and progress of the rocket system.
1806	Boulogne in France bombarded by British rockets, suffers devastating fire.
1807	Copenhagen burnt, by British attack with 25,000 rockets.
1813	Dantzig attacked similarly, setting city's food stores on fire and resulting in surrender.

1814	British use of rockets in Battle of Bladensburg, leading to fall of Washington; "rockets' red glare" at attack on Fort McHenry.
	Congreve publishes The details of the rocket system.
1827	The Congreve Rocket System published in London.
1828	Congreve dies.
1800-1830	At least 20 books on rockets published in Europe.
Mid-century	Most European Rocket Corps dissolved as artillery improved.
1915	Rocket experiments started by Goddard in US.
1960s	Rockets again made in India.

TABLE 2 SOME DATES IN TECHNOLOGICAL HISTORY.

11th century	Chinese knew about role of nitre in what later came to be called gunpowder.
1660	Founding of Royal Society.
1661	Boyle's Sceptical Chymist.
1676	Water-driven gunpowder mill, Germany.
1687	Isaac Newton's Principia published.
1750-1815	The first wave of the Industrial Revolution.
1757	"Every master-manufacturer has a new invention of his own" - J. Tucker.
1759	Beginning of scientific studies of engineering machinery by Smeaton.
1764-69	Key developments in textile spinning.
1765-1776	Watt's improvements to the steam engine.
1768	Wind-driven saw-mill in Limehouse wrecked by mob, for fear of unemployment.
1771	Society of [Civil] Engineers formed, led by Smeaton.
1776	Adam Smith's Wealth of Nations published. Watt's steam engine in use.
Last decades of 18th century	Growth of iron working in Scotland and England. Beginning of the English canal network.
1818	Institution of Civil Engineers founded.
1825	First railway (Stockton-Darling).

TABLE 3 GONGREVE'S COST ANALYSIS

Rockets	£	s.	d.	Ten-inch Mortars	£	s.	d.
Case complete	0	5	0	Carcass charge	0	15	7
Cone	0	2	11	Powder charge	0	6	0
Stick	0	2	6	Catridge, etc.	0	1	0
Rocket charge	0	3	9				
Carcass charge	0	2	3		1/2/7		
Labour, paint, etc.	0	5	6	(Plus the cost of the mortar)			
	1/1/11						

TABLE 4 CONGREVE'S ROCKETS

Designation	Type of projectile carried	Extreme range in yards	Minimum elevation for extreme range
42-lb carcass rocket	Large: 18-lb carcass Small: 12-lb carcass	3000 3000	60 60
42-lb shell rocket	Large: 12-lb spherical bomb	3000	60
	Small: 55-lb spherical bomb	3000	60
32-lb carcass rocket	Large: 18-lb carcass Medium: 18-lb carcass Small: 8-lb carcass	2000 2500 3000	60 55-60 55
32-lb shell rocket	9-lb spherical bomb	3000	50
32-lb case shot rocket	Large: 200 carbine balls Small: 100 carbine balls	2500 3000	55 55
32-lb explosive rocket	5-12 lb powder	2500 3000	55
12-lb case shot rocket	Large: 72 carbine balls Small: 48 carbine balls	2000 2500	45 45
Flare rockets equipped with parachutes			

APPENDIX 1

Note on certain dates

Some of the dates cited In the sources used in this paper are clearly in error, and have therefore been corrected; the instances concerned are here discussed.

The Encyclopaedia of Aviation and Space Sciences refers to an engagement between Hyder Ali and the British in the following words. "In 1760 Hyder Ali threw a 1200 man rocket corps at a crack British cavalry regiment at Guntor [= Guntur] turning back the British with very heavy casualties." I have been unable to find, in any history of India, a record of any engagement between Hyder and the British at Guntur in 1760. It is true that in that year "Hyder despatched troops to Pondlcherry to assist the French who were then fighting the British on the succession to the Nawabship of the Carnatik" (Rao 1943). It may be. recalled that the British and French took sides in this war supporting rival contenders to the throne. But from the accounts available in either Rao (1943) or Wilks (1810) there is no mention of any major engagement, and certainly not at Guntur. Even the First Anglo-Mysore War is dated by historians (for example Majumdar et al.) only to 1767-69.

In fact Guntur appears In the events of this period as the place from which the British troops started moving during the second Anglo-Mysore War (1780-84). For example Wilks (1810) reports, "The corps under Col. Harper in Guntor, afterwards commanded by Col. Baillie, was directe to move southwards by the route of Calastry ad Tripetty..." It was these troops that under the command of Baillie, were later defeated at Pollilur by Hyder and Tipu. I have therefore concluded that the references to a battle in Guntor in 1760 have to be replaced by one to the battle in Pollilur In 1780.

Similarly in the account by von Braun & Ordway, it is implied that the attack on British troops cited in the text of the paper occurred in the 1792 battle (Second Anglo-Mysore War). The date quoted in this account is 22 April; but the Second Anglo-Mysore War had already been over by then, and all hostilities had ceased Tipu having signed a treaty with the British on 23 February. The events described by von Braun & Ordway must actually have taken place in the final Anglo-Mysore War in 1799. Wilks's history clearly mentions the attack on April 22 of this year along the same general lines that are indicated in von Braun & Ordway's book.

APPENDIX 2

Guedalla's account of the Sultanpet incident

'His [Col. Arthur Wellesley/Wellington's] spirits rose a little as they [the British troops] penetrated deeper into Mysore - "There is not now a doubt but that we shall bring that monstrous equipment to Seringapatam, and, in that case, we shall certainly take the place." They had a brush with the Mysoreans in the last week of March [1799], and the Thirty-third charged with the bayonet. His tone was higher now - "We are here with a strong, a healthy, and a brave army, with plenty of stores, guns, &c. &c., and we shall be masters of his place before much more time passes over our heads." But Arthur's health was slightly affected. His trying spell of duty in Madras left him a little low; and the heat of Mysore in April combined with bad water to bring on dysentery, "which did not confine me" (so Richard [Marquess Wellesley, brother and Governor-General at Calcutta] was informed), "but teased me much. I have nearly got the better of it, and I hope to be quite well in a few days." Before it left him though, he was tried harder than is entirely good for any man with dysentery. For on the very night he wrote about his health to Richard, the Colonel was in charge of a small column engaged in clearing the approaches to Seringapatam. The night was "dark as pitch forward, and in the rear towards our camp the fires and lights burnt brilliantly, which increased the darkness in front." The column stumbled through the night into a little wood, which nobody had reconnoitred. Entangled in the darkness, they were heavily fired on and lost formation; the gloom filled suddenly with shots and shouting; a spent ball struck him on the knee; somewhere in front the leading files were captured in the night, and as confusion deepened, the Colonel - a trifle unaccountably - left them to report his failure. Shaken and unwell, he reeled back to camp. It was not far from midnight; and the exhausted man, his nerves all frayed, flung himself face down across the mess-table to sleep. Attacking in the morning, he retrieved himself and carried the position; but the nightmare of the little wood had left him with the bitter flavour of defeat - "mad," as an officer recorded, "with this ill success" - explaining ruefully to Richard his "determination, when in my power, never to suffer an attack to be made by night upon an enemy who is prepared and strongly posted, and whose posts have not been reconnoitred by daylight." And forty years away he could still draw a sketch-map in explanation of the affair at Sultanpet Tope. For the unpleasing night lived in his memory. Such lapses are occasionally final. Arhur's, happily, was not. That icy rigour of control, it seems, which led his countrymen to an unkind suspicion that nerves had been omitted from his composition, came to him only by degrees. He was not born, but made himself, the unmoving soldier of later years; and learning his lessons as they came, he learned some of them (since night attacks are a rough school of war) that night at Sultanpettah.'

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Figure 1

A Hoysala sculpture (around 12th century A.D.), showing what are possibly fire arrows.

Figure 2

A rocketeer in Tipu Sultan's army carrying the kind of rocket used by the Mysoreans in 1792.

Figure 3

Map of a section of South India showing the approximate location of Pollilur (starred at right) and Srirangapatna (starred at left).

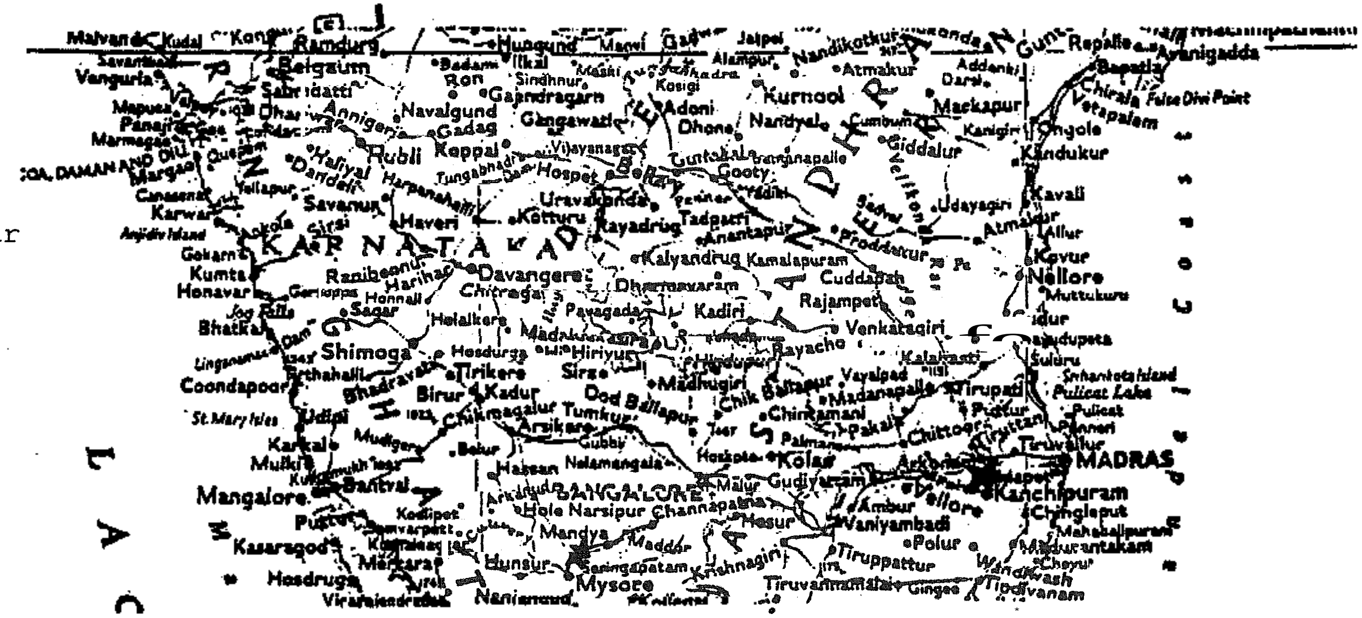


Figure 4

A mural from Darya Daulat Bagh in Srirangapatna celebrating the victory of Hyder and Tipu in 1780 over the British. Col. Baillie is seated in a palanquin in the middle of a square formed by British troops. An ammunition tumbril on the top left corner of the square is seen to have caught fire.

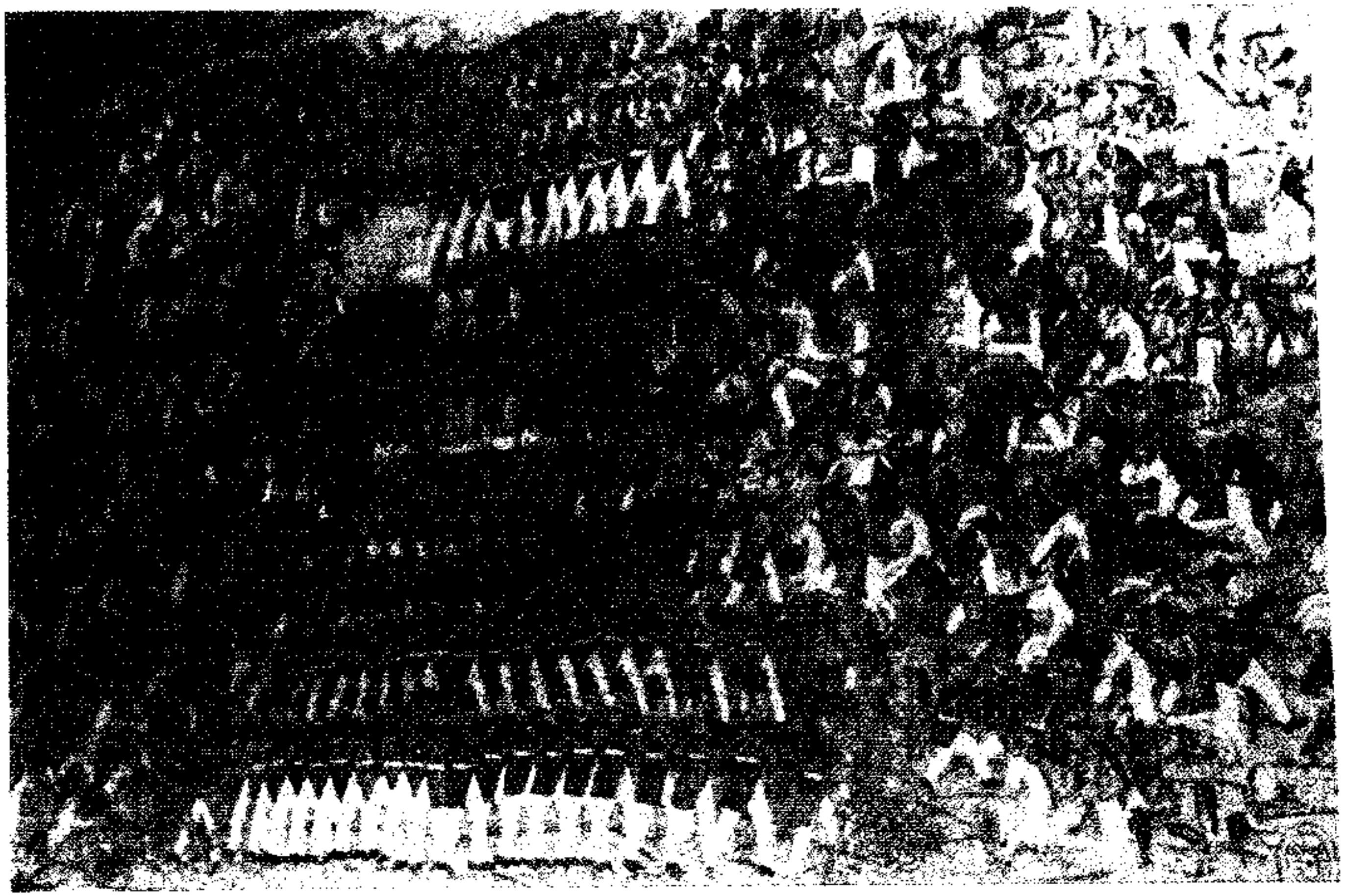


Figure 5

A map of the area around Srirangapatna showing the places where use of rockets has been recorded during the wars of 1792 and 1799.

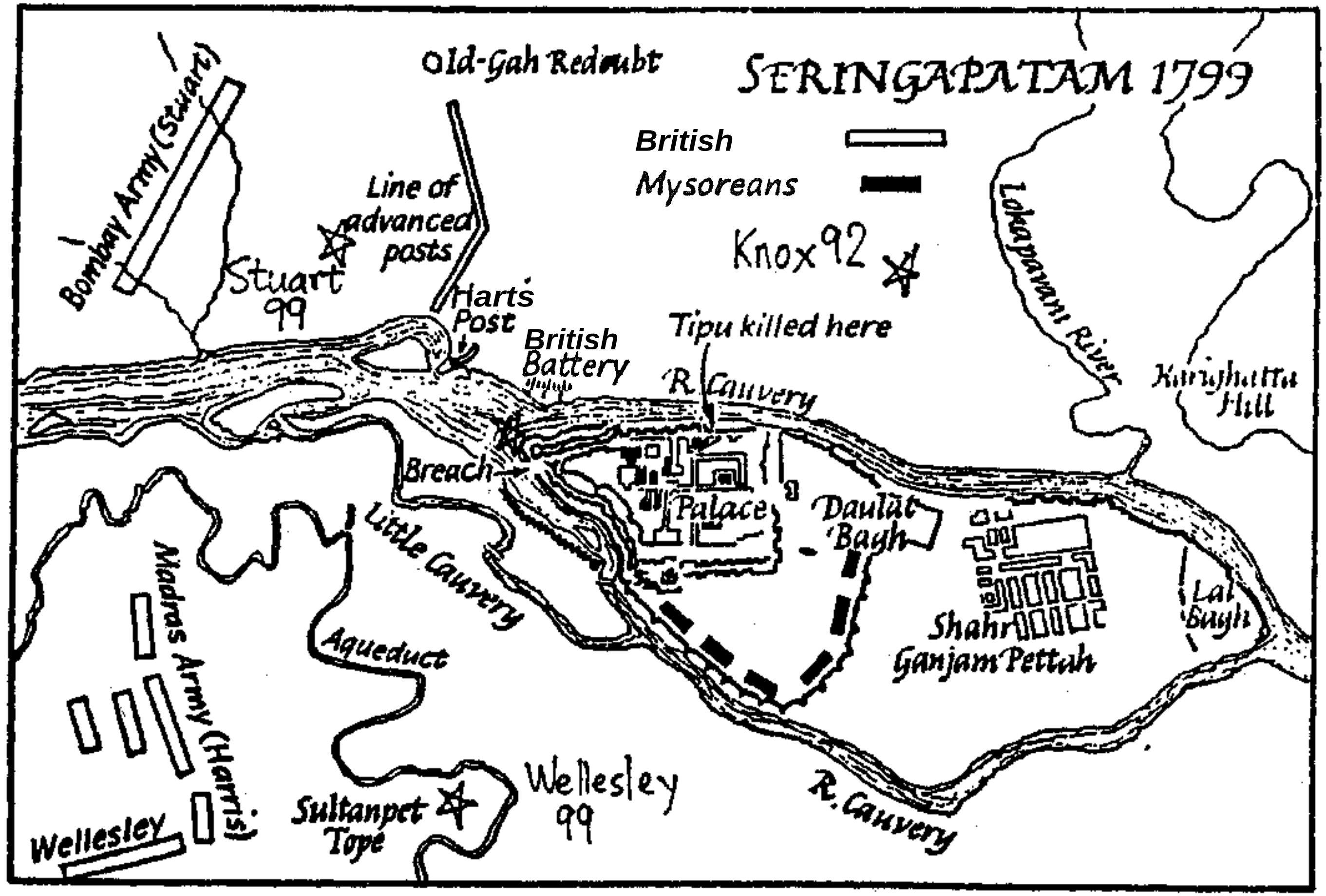


Figure 6

Examples of the kind of rockets designed by Congreve in England.

Figure 7

Congreve's scheme for launching rockets from collapsible wooden frames.

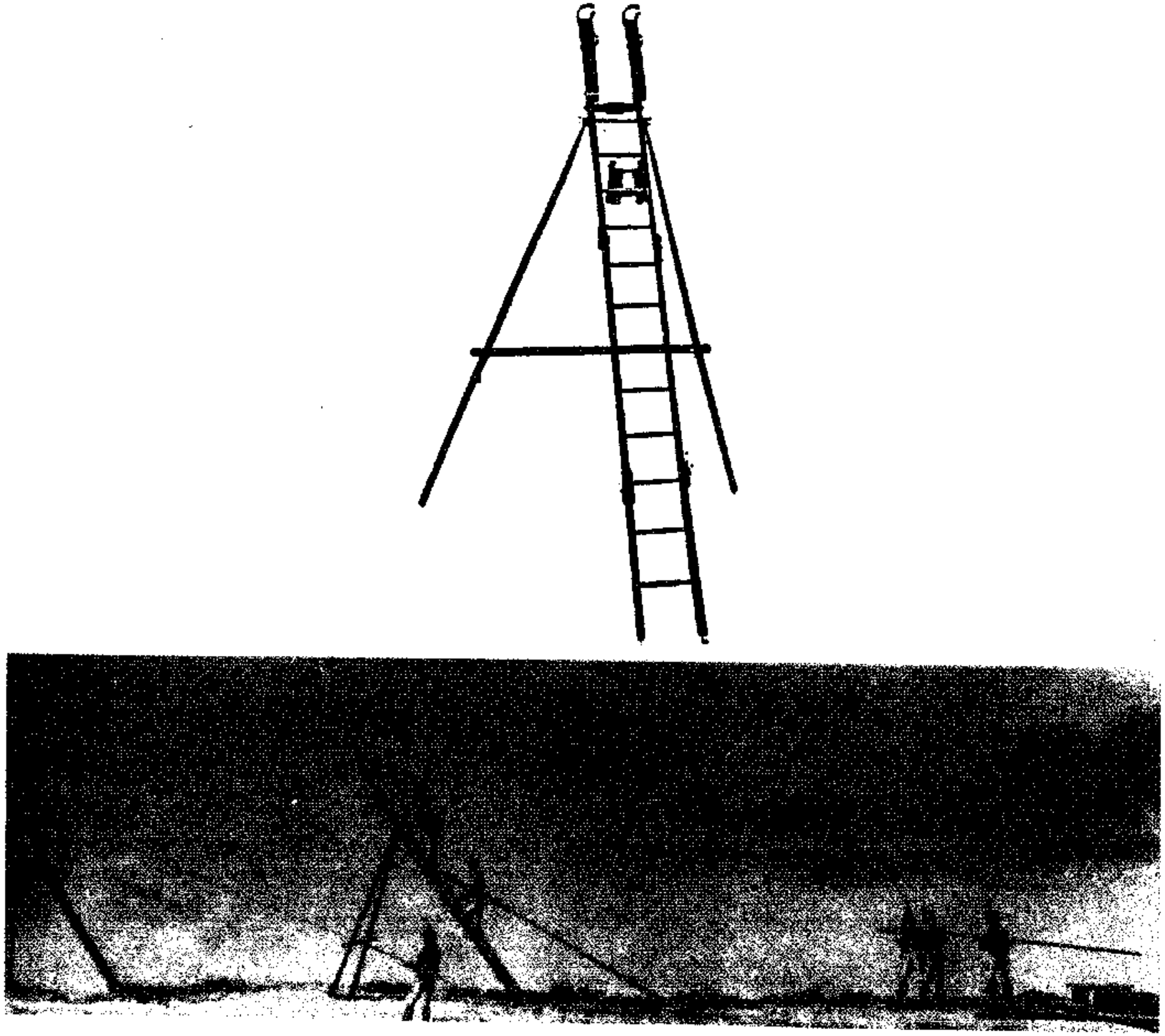


Figure 8

Cover page of the book published by Congreve in 1827.

A

TREATISE

ON THE

GENERAL PRINCIPLES, POWERS, AND FACILITY OF APPLICATION

OF THE

CONGREVE ROCKET SYSTEM,

AS COMPARED WITH ARTILLERY:

SHOWING

THE VARIOUS APPLICATIONS OF THIS WEAPON,

BOTH FOR SEA AND LAND SERVICE,

AND ITS DIFFERENT USES IN THE FIELD AND IN SIEGES.

ILLUSTRATED BY

PLATES OF THE PRINCIPAL EXERCISES AND CASES OF ACTUAL SERVICE.

WITH

A DEMONSTRATION

OF

THE COMPARATIVE ECONOMY OF THE SYSTEM.

BY

MAJOR-GEN. SIR W. CONGREVE, BART. M.P.

F.R.S., &c. &c. &c.

AND DEDICATED TO HIS MOST GRACIOUS MAJESTY, GEORGE THE FOURTH.

LONDON:

PRINTED FOR LONGMAN, REES, ORME, BROWN, AND GREEN,

PATERNOSTER-ROW.

1827.

Figure 9

Indices of mechanisation in Britain during the last five centuries (taken from Pacey 1976).

Addenda Corrigenda

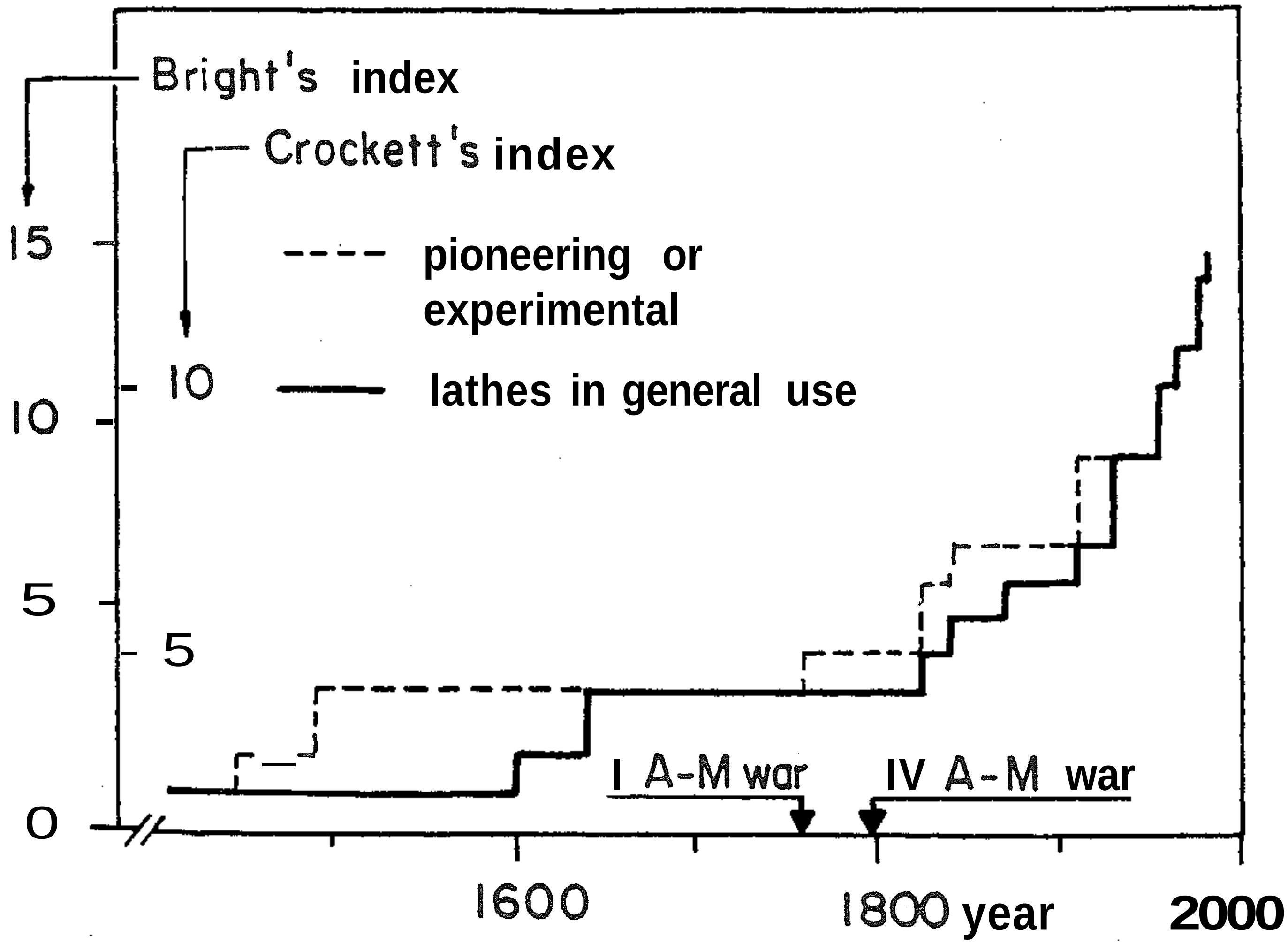


Figure 10.

Increase In pig iron production during the 18th century in England and Wales (from Pacey 1976)

Addenda Corrigenda

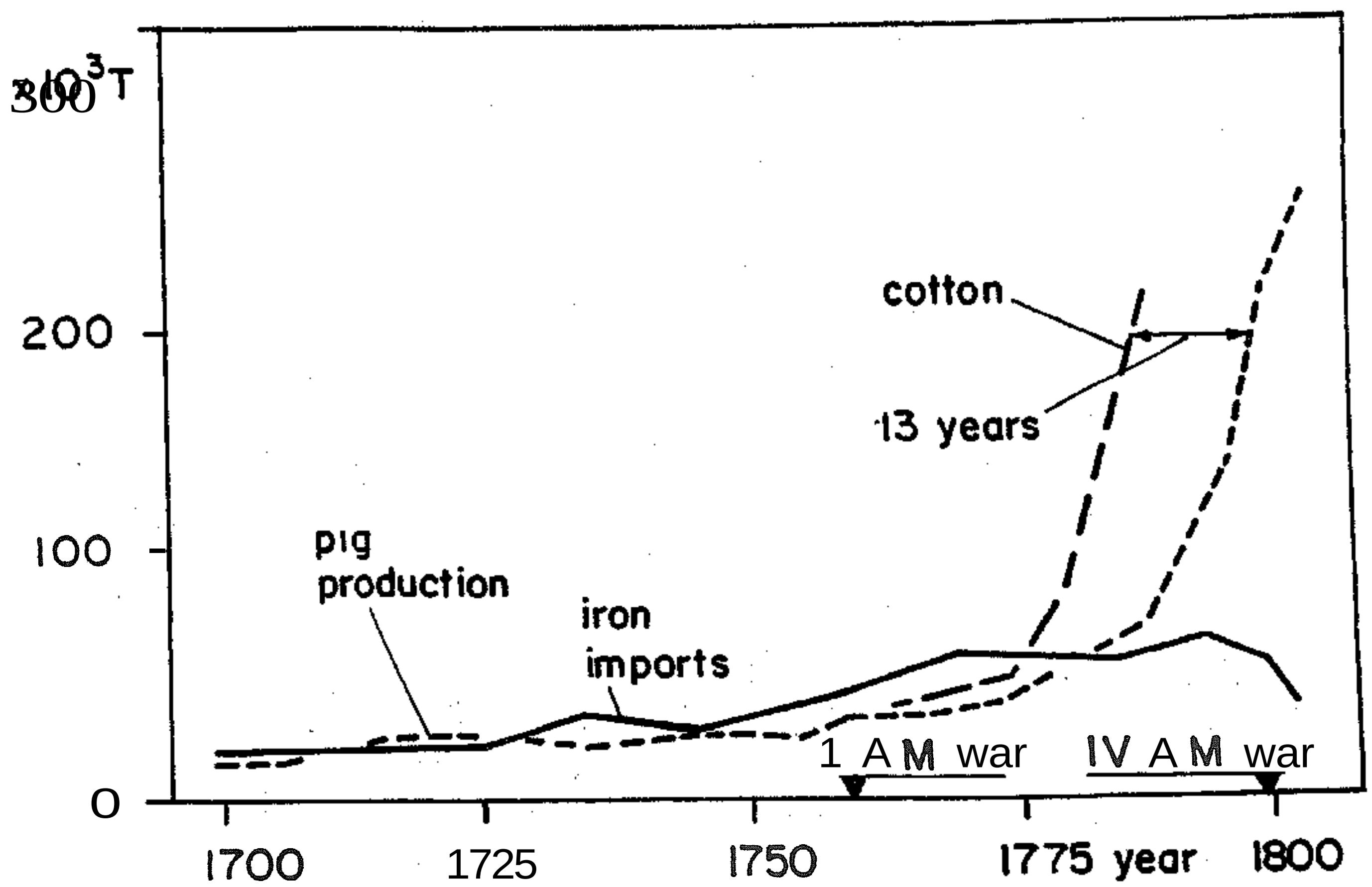
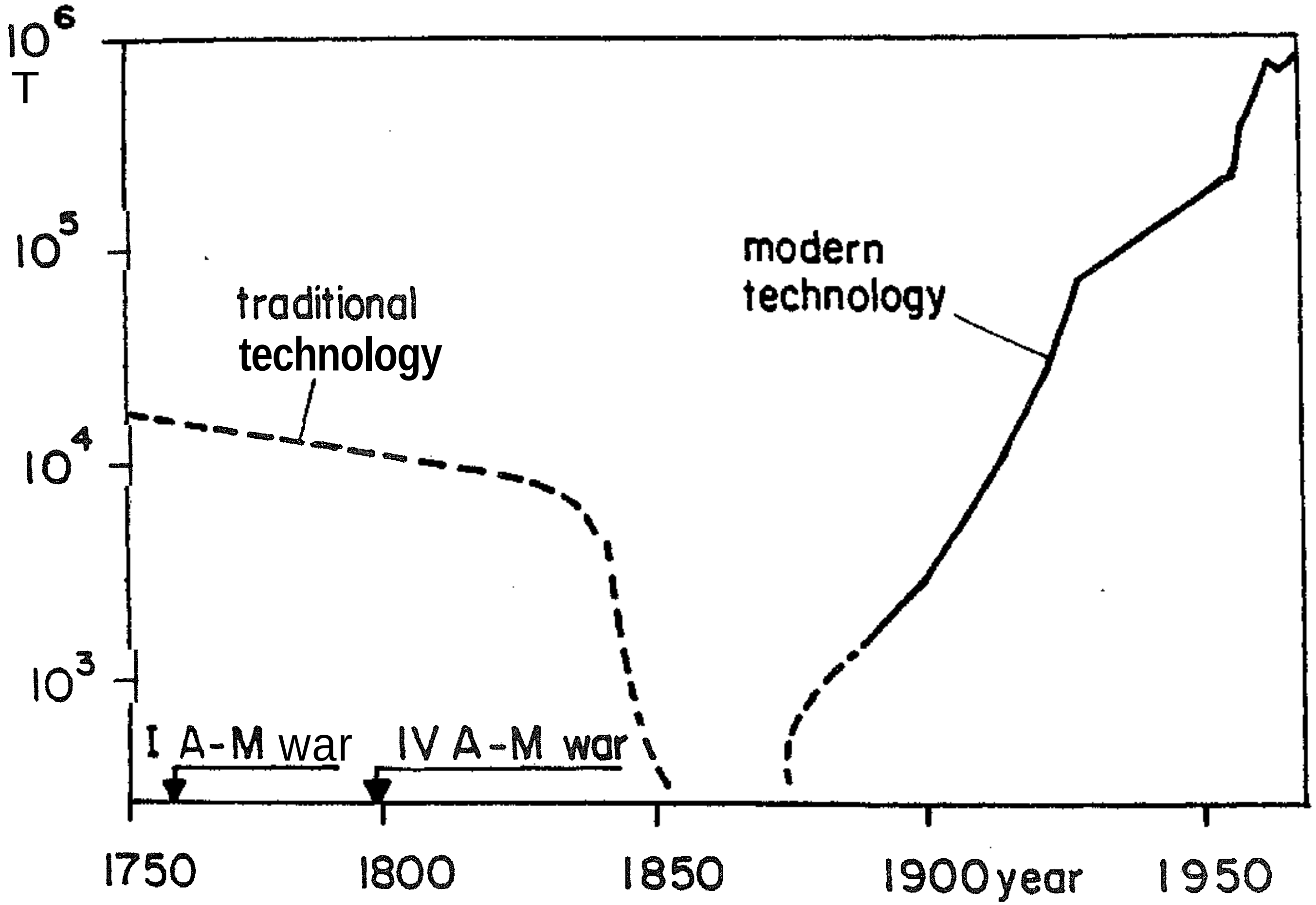


Figure 11
Iron production in India during the last two centuries.

Addenda, Corrigenda



Addenda, Corrigenda

Roddam Narasimha (1985)

Rockets in Mysore and Britain, 1850-1850 A.D., Project Document DU 8503, National Aeronautical Laboratory, Bangalore

Serial No.	Location	As revised
1.	Figure 9 caption, line 5	(after Pacey 1983: 21, figure 4).
2.	Figure 10 caption, lines 5, 6	and Wales (after Pacey 1976:230, figure 36).
3.	Figure 11, caption, lines 3, 4	India since mid-18th c (after Pacey 1976, p.280 figure 41).
4.	Figure 11, ordinate	• Label T should be replaced by T/a (for tons/annum) • Marks on ordinate should be raised by a factor of 10, i.e. 10^3 should be corrected to 10^4, 10^4 to 10^5 etc.

These corrections and additions follow a query I received on 30 June 2008 from Dr Yogesh Mishra, Centre for the History of Science, Technology and Medicine, Imperial College, London. I am grateful to Dr Mishra for drawing my attention to missing references on the figures.

Roddam Narasimha