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Chapter 2

ROCKETS AND ROCKET PROPULSION DEVICES IN ANCIENT CHINA*

Fang-Toh Sun†

It is generally recognized that the rocket was originally a Chinese invention. However, a great majority of the Western literature concerning this subject was based not on the original Chinese writings, but on materials inadequately or often mistakably translated from the Chinese. Such general deficiency due to the language difficulties has been noticed by many scholars, Western and Eastern; and concrete examples are found in Needham's authoritative books, *Science and Civilization in China*.‡ The development of rockets and rocket propulsion devices in the past long history of China can be traced by relying mainly on the original Chinese historical documents and various articles in Chinese.

THE FIRE ARROW IN THE EARLY YEARS OF CHINESE HISTORY

The Chinese name *huo chien*, which literally means the fire arrow, and is generally regarded as the translation for the English word rocket appeared in Chinese historical records as early as the period of Three Kingdoms (221 to 265 A.D.). In Chhen Shou's *History of the Three Kingdoms* [A-4]** the following passage describes the battle of Cheng-Chang (228 A.D.):

> "To attack the city of Chen-Chang, Marshal Chuko Liang used the cloud ladders and armoured carriages for a frontal assault, but under the command of General Huh Chao, the defending garrison forces were able to burn the ladders and kill the attackers by shooting them with fire arrows." (A-4, Vol. 3)

From the same book another passage describes the battle of Shouchun thirty years later (258 A.D.) as follows:

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* Presented at the 14th History Symposium of the International Academy of Astronautics, Tokyo, Japan, September 1980. Editors Note: The spelling used by the author (Chinese words) is the one used in the original manuscripts, and it might differ from other papers based on translated material as a reference.

† Institute of Applied Mathematics, National Tsing Hua University Hsinchu, Taiwan, Republic of China.

‡ See Ref. B-2, Vol. 1 pp.4-7.

** Number within the brackets refers to the reference listed at the end of this paper.

"To prevent the rebelling General Chuko Dan and his followers from escaping from the besieged city Shouchun, the army of Generalissimo Ssuma Chao employed the shooting stone carriages together with the fire arrows so that the enemies were burned to death and their armament destroyed." (A-4, Vol. 28)

From this period and until the 13th Century the same words "fire arrow" appeared in numerous war accounts in Chinese history. This shows that the fire arrow was indeed a popular weapon used in battles continually for over thousand years. However, by observing that the word "burn" was always used in describing the effect of such fire arrows, it must be a true incendiary device made of the conventional arrow with some inflammable substance attached to it, not the reaction-propelled rocket in the modern sense. It is assumed that it was launched by a conventional bow or crossbow. Thus, it was propelled by the elastic force, not by the flames it spread. Though no detailed descriptions nor illustrations were found about such early Chinese fire arrows, a few drawings found in Chinese books in 10th Century show the construction of the fire arrows. (Figure 1).

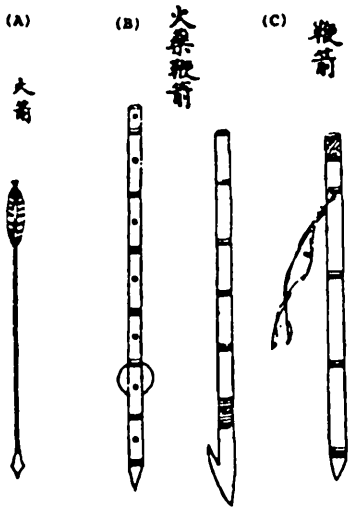

Figure 1 The fire arrows in Sung Dynasty (from Wu Ching Tsung Yao, 1044 A.D.): (A) The fire arrow (huo chien); (B) The whip arrow and its launching pole (bien chien); (C) The whip arrow with gunpowder (huo yao bien chien).

In Chinese military tactics, to attack with fire was a popular war technique used by the Chinese at least as early as the period of the later Chhun Chhiu (772 to 480 B.C.). In the classical book, *Suntza* [A-1] by the great military strategist Sun Wu, about contemporary with Confucius (551 to 479 B.C.), five ways of attacking with fire were described, namely, to burn soldiers in their camp, to burn stores, to burn the baggage trains, to burn arsenals and magazines, and to burn soldiers in array. In fact, in Chinese war history many decisive battles were won by attacking with fire. For example, in the famous battle of Chih-Bih (Red Cliff, 208 A.D.) prior to the period of Three Kingdoms, the fleet of the invading northern forces under Marshal Tshao Tshao was burned to destruction by the defending southern forces under the allied command of Generals Sun Chuan and Lui Pei, who finally established the kingdoms of Wu and Shu, respectively, two of the three kingdoms. Fourteen years later, when war broke out between the kingdoms of Wu and Shu, a great battle was waged along the mountainous region along the bank of the Yantze river,

and attacking with fire again played a decisive role, but this time the loser was Liu's army of the Shu kingdom. However, no reference was made to the fire arrow in any of these two battles, and the fire was set by conventional means of throwing oiled charcoal and dry straws, according to the History of Three Kingdoms. It seems that the fire arrow had not been employed in military operations until a few years later when the battle of Chang-Chang was waged as mentioned before.

FROM THE FIRE ARROW TO THE FLYING-FIRE-LANCE

The use of the fire arrow as an incendiary weapon in land battles as well as in naval battles continued in ancient China from the Three Kingdom period to the Southern Sung Dynasty (1127 to 1279 B.C.) over a span of about 1,000 years. Then, during the later years of the Southern Sung Dynasty, when North China was occupied partly by the Ching Tartars and partly by the Mongols, a new tactical weapon appeared under the name of *fei-huo-tsiang*, or, literally, the flying fire lance, as called by the Tartars. It was used by the Tartars against the invading Mongols in the battle of Pienking, the capital city of the Tartar Chin at that time, known as Kaifeng-fu. The invading Mongolian force was led by Ogotai, the son of the late Genghis Khan, and Pienking was sieged since the early Spring of 1232. Under the fierce attack of the Mongolian forces, the garrison army, led by Tartar's general Chih-Chan Hoghsi, was able to hold the city for sixteen days until the Mongols retreated. The success of the garrison army was attributed to the two new weapons they had in operation. One of them was called *Cheng-tien-Rai*, or "the heaven-shaking-thunder", apparently a form of grenade; and the other was the *fei-huo-tsiang*, or the flying fire lance", which was described in the History of Tartar Chin [A-13] as follows:

> "The defender had also the fei-huo-tsiang at their disposal. Attached to it was some huoyao (gunpowder-like mixture), and upon ignition, flew away abruptly and spread its fire over ten paces. The Mongols dreaded these two weapons very much." (A-11, Vol. 113, p.2496).

This was probably the same passage translated by the French sinologist Stainislas Julien, as quoted by Willy Ley in [B-7]. Similar descriptions were found in the history of Yuan Dynasty, and that of the Mongols [A-17,18] with the name *fei-huo-tsiang* replaced by *feng huo tung chien*, which literally meant the arrow with fire-erupting cylinder. As recorded in history [A-11], this same weapon was used again by the Chin Tartars in the less known battle of Kei-teh about one year after the battle of Pienking, and inflicted also heavy losses on the invading Mongols. The term used this time was *huo tsiang*, which was a shorter name for the *fei huo tsiang* used in the battle of Pienking, and was identical to it.

It is important that the terminology used by the Mongols strongly suggested that, attached to the lance there was a cylinder-shaped container (*tung* in Chinese), which evidently was for the storage of *huo yao*, or gunpowder to be ignited in operation. In fact, the presence of such container was confirmed by the History of Chin, and it was described as being made of heavy yellow paper in sixteen layers with a length of about two feet, and filled with a mixture of willow charcoal, iron dreags, magnetic powder, sulfur, arsenic, etc. [A-13]. Such descriptions not only jus-

tify the terminology the Mongolians employed, but also give roughly the contents of the fire-producing mixture inside the container under the general name, *huo yao*. From these historical accounts we see that this new weapon, the flying fire lance, or the arrow of fire-erupting cylinder, differs from the traditional fire arrow in two essential ways:

1. It was equipped with a container, filled with the gunpowder-like mixture instead of the ordinary inflammable substances directly attached to the arrow.
2. No bow or crossbow or any mechanical launcher was mentioned, and its forward motion was most probably derived from the recoil of the flames erupted from the cylinder after ignition.

Furthermore, in the History of the Mongols* the same passage, which describes the battle of Pienking also says that fire arrows were fired by the Mongols in attacking Pienking while the arrows with fire-spraying cylinder were being fired by the defenders. This clearly indicates that the latter was certainly a weapon different from the traditional fire arrow; and the two essential features of this new weapon as mentioned above justify the conjecture by Julien and many others that the *fei huo tsiang*, as called by the Chin Tartars, or the *fei huo tung chien*, by the Mongols was a reaction-propelled device, comparable to the modern solid propellant rocket, with the attached cylinder acting as its combustion chamber and exhaust nozzle.

At this point a few words about the terminology are in order. In the Chinese language the word, *tsiang* means "lance", which is the hand-operated weapon having a long slender body about six feet in length and fitted with a spearhead; whereas the word, *chien* means "arrow", which is a bow- or crossbow-launched weapon, having a short shaft, say, two to four feet in length, and fitted with an arrowhead. With this in mind the Chin Tartars were correct in calling their new weapon *fei huo tsiang*, but missed the word *tung* to signify the gunpowder container as its important component; whereas the Mongols were correct to insert the word *tung* in the name, but misused the word *chien*, since it was basically a lance, not an arrow. Hence the correct name for this new rocket-like weapon should be *fei huo tung tsiang*, or the lance with fire-erupting cylinder.

THE DEVELOPMENT OF GUNPOWDER IN ANCIENT CHINA

After the long-time use of the popular weapon, the fire arrow, in ancient China the sudden emergence of the rocket-like lance of flying fire in the later years of the Southern Sung Dynasty is of no surprise looking back at the history of the development of gunpowder in China, since the latter held the key to the successful making of rockets. Two of the essential ingredients of an explosive mixture, sulfur and saltpeter, were known to the Chinese in at least as early as the 2nd Century, since both were described in the old Chinese book on pharmacopoeia, *Sen Nung Pen Tshao Ching* [A-3], written by an unknown author of the Later Han Dynasty. The mineral sulfur was known to the Chinese even earlier, since this word appeared in the book, *Huai Nan Tsu* [A-2], edited by Prince Liu An or the Earlier Han

* See [A-17], Vol. 29, p.12.

Dynasty in about the year 120 B.C. Extensive researches on the characteristics of such minerals and their mixtures were conducted privately as well as officially since Liu An's time, or possibly prior to it, many of their findings were found in the old Chinese books of alchemy, most contained in the vast volumes of the Taoists' Patrology, named *Tao Tsang*. The primary purposes of such researches were not aimed at making an explosive mixture, but producing the elixir to prolong man's life, and converting ordinary materials into the valuable gold and silver. The second air was also helpful to the first, as it was believed at that time that to eat and drink with golden vessels would prolong one's life and make one immortal. This was the reason why such researches in ancient China were often supported by the emperor's court as well as conducted by individuals.

Thus, the eventual invention of the destructive gunpowder as a by-product of the synthesis of the life-prolonging medicine and the making of artificial gold and silver must be accidental. In fact, the explosive nature of the mixture of sulfur and saltpeter in the presence of some source of carbon was known to the Chinese in the 2nd Century A.D. Warnings against the heating of such a mixture were found in the book, *Chen Yuan Miao Tao Yao Lueh* [A-5], by the pioneer alchemist Cheng Ssu-Yuan (220-300 A.D.), and that men actually got hurt and their houses burnt as a result of heating a mixture of sulfur, realgar, saltpeter, and honey was cited therein. Thus the prototype of gunpowder existed well over one thousand years before the emergence of the first rocket-like weapon, the flying fire lance. Evidently, the urgent desire of having a new powerful weapon by the Hans under the reign of the Southern Sung Dynasty and the Jurchen Tartars under the reign of the Chin Dynasty in their mutual fightings and their struggles against the ferocious Mongols enhanced the development of gunpowder from its proto-form so as to be employed in military operation; and the long time of experimental investigations for over one thousand years had sufficiently advanced the art of gunpowder-making to suit such military purpose. Such historical development also explains why the peculiar name, *huo yao*, or literally the fire drug, was picked up by the Chinese as a general term for the fire-producing and explosive mixture like gunpowder, since it was evolved from the experiments on the making of life-prolonging drugs. With such background knowledge, the emergence of the rocket-like *fei-huo tsiang* in the 13th Century was rather natural.

Several recipes of the gunpowder were found in the book *Wu Ching Tsung Yao*, or *Collection of the Most Important Military Techniques*, compiled by Tseng Kung-Liang and Ting Tu [A-6] of the Northern Sung Dynasty in the year 1044. A comparison of the composition of the Chinese gunpowder with that of the blackpowder of several other countries is shown in the Table 1. A glance at the table shows that the essential ingredients of the Chinese gunpowder and those of the blackpowder by the Arabs and Greeks of the 13th Century, and the modern recipe are the same. The main difference is that in the Chinese recipe a higher proportion of sulfur and lower proportion of charcoal than the corresponding proportions in the Arabic, Greek, and modern recipes. It should be noted that only the three most essential ingredients, the saltpeter, the sulfur, and the charcoal are listed here. Various additives to be applied to the gunpowder according to the specific purposes are described both qualitatively and quantitatively in [A-6].

Table 1
COMPOSITIONS OF THE CHINESE GUNPOWDER
AND THE ARABIC AND WESTERN BLACKPOWDER

	Chinese Gunpowder[1] (11th century)			Blackpowder		
	A	B	C	Arabic[2] (13th century)	Greek[3]	Modern[4] Recipe
Saltpetre	62.0	60.0	65.5	69.5	69.2	61.6
Sulphur	31.0	30.0	34.5	14.8	7.8	15.4
Charcoal	7.0	10.0	0.0	15.7	23.0	23.0
	100.0	100.0	100.0	100.0	100.0	100.0

1. From *Wu Ching Tsung Yao* by Tseng and Ting [A-6], Vol. 11, pp. 27-28, Vol. 12, pp. 58, 65. A: for incendiary ball; B: for smoke ball; C: for incendiary projectile.

2. Hassam er-Rammah recipe, from *Rockets, Missiles, and Men in Space*, by Willy Ley [B-6].

3. Recipe No. 33 *in Liber Ignium* of Marchus Graecus, from [B-6].

4. From Humphries, J., *Rockets and Guided Missiles* [B-3].

The long history of development of gunpowder deserves separate treatment by itself. Comprehensive presentations of this subject may be found in the writings of Needham [B-2]*, Feng [A-19], Li [A-20]†, and Cho [A-21]. Additional materials on gunpowder and gunpowder weapons closely related to the present subject will be given in the section that follows.

THE FIRE ARROW AND ITS VARIATIONS IN THE GUNPOWDER AGE IN CHINA

With gunpowder sophisticatedly developed in the Sung Dynasty, Chinese armament entered its gunpowder age. Historical records show that, in the early years of the Northern Sung Dynasty, long before the battle of Pienking, the traditional fire arrow had already adopted gunpowder to replace the conventional inflammable substances. This was the major improvement of the Chinese fire arrow since the Three Kingdom period, and it occurred at least as early as in the 10th Century, a little over two hundred years before the first emergence of the flying fire lance. However, as shown in Tseng and Ting's book [A-6], on such a new fire arrow the gunpowder was directly applied to the arrowhead without a container (Figure 1). Hence the recoil of the freely spraying flames must be negligible, if any, and such an arrow still had to be launched by a bow or crossbow. Thus, though considerably improved in its destructive power through the use of gunpowder, it was not a reaction-propelled device, like the later flying fire lance. A modified model of the new

* See Vol. IV, Part 3, Sec. 29.

† See Chapter 7.

fire arrow shown in [A-6] was *huo yao pienchien* or the whip fire arrow (Figure 1). It did not differ much from the new fire arrow, except that it had a longer shaft made of bamboo, and launched by a bamboo pole instead of the conventional bow or crossbow. Several simple firearms using the gunpowder also appeared in the same time, as illustrated in the same book by Tseng and Ting (Figure 2). Records on such new developments were also found in the History of Sung Dynasty [A-10], from which a passage is quoted below:

> "New technology of fire arrows was presented (to Emperor Tai-Tsu) in the year 970 A.D. by an officer in the Defense Department, named Feng Chi-Shen; he was awarded after the technology was tested". (Sung Shih, Vol. 196). In the year 1000 A.D. Captain Tang Fu of the Royal Navy presented (to Emperor Tseng-Chung) the fire arrow, the fire ball, and the incendiary thorns he made, and he was awarded."

No details about such new technologies and new armaments were given but they were presumedly those recorded in Tseng and Ting's book as mentioned above.

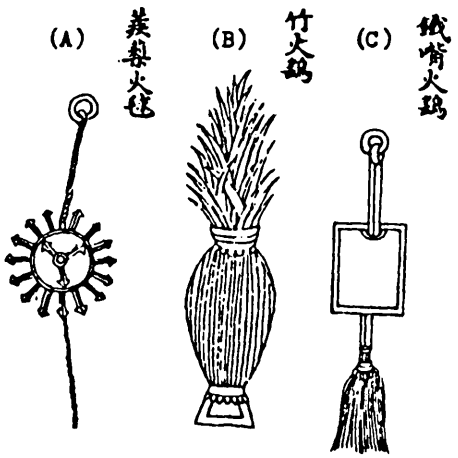

Figure 2 The gunpowder weapons (from Wu Ching Tsung Yao, 1044 A.D.): (A) The thorny fire ball (chi-li huo chiu); (B) The bamboo incendiary sparrow hawk (chuh huo yao); (C) The incendiary sparrow hawk with iron beak (ti tsui huo yao).

It is believed that these new gunpowder firearms were in continual use from the early Northern Sung Dynasty to later years of the Southern Sung Dynasty, occasionally undergoing some minor improvements, up to the battles of Pienking and Kei-teh. It should be noted that the gunpowder used in these firearms was basically incendiary, rather than explosive. Although the name, *huo pao* appeared quite early in the Sung Dynasty, it was not the explosive weapon like the cannon in modern sense. True explosive weapons like the barrel cannon and grenades did not appear in Chinese history until the later years of the Southern Sung Dynasty, and the heaven-shaking thunder, which was one of the two weapons of the Chin Tartars dreaded by the Mongols, was an example of such.

After the battles of Pienking and Keiteh, the Chin Dynasty of the Jurchen Tartars and the Southern Sung Dynasty of the Hans fell successively under the Mongolian attacks in about forty years' time, and the Yuan Dynasty was established in China by the Mongolians from 1260 to 1368 A.D. What became of this new weapon, the *fei huo tung chien* during the period of this new dynasty is not known, owing to the lack of information. It seems that the barrel cannon, like the famous

Mohammedan cannon, which was presumedly brought from the Arabic countries, and went into action in the battle of Hsiangyang [A-13] on the eve of the fall of the Southern Sung Dynasty, was the favorite of the Mongolians, owing to its great explosive power, while the one dreaded weapon, the arrow with fire-erupting cylinder went into oblivion.

This trend continued in the years after the Mongolians were driven out of China by the Hans. However, while many forms of the barrel cannons and guns, mostly of Western origins, were popular, in the Ming Dynasty and Chhing (Manchu) Dynasty the Chinese pioneer rocket weapon, the *fei huo tung chien*, also made some advances under the old name of the fire arrow and the fire lance. As shown by the drawings found in the book *Wu Pei chi (Treatise on Armament Technology*, 1628 A.D. [A-13] by Mao Yuan-I, the fire arrow of the Ming Dynasty differed from that of the Sung Dynasty in that the gunpowder used was stored in a container firmly attached to a conventional arrow instead of being directly applied to its arrowhead (Figure 3). A similar design was found in the Ming fire lance where the arrow was replaced by the conventional lance. Thus, both were the direct descendants of the arrow with fire-erupting cylinder or the flying fire lance, and may be classified as rocket propulsion weapons. The particular fire lance presented in Mao's book was one with a six-foot body and a head of little more than one foot, equipped with two fire-spraying cylinders connected in tandem, so that after ignition, they would be operative in succession (Figure 3). Thus it was actually a primitive form of a two-stage rocket. The range of such new fire arrows was mentioned by Mao in his poetic article, *Huo Yao Fu* [A-18] as more than three hundred paces for each ounce of the gunpowder applied. Such range was much longer than that of the *fei huo tung chien* used in the battle of Pienking, showing that good progress had been made during the centuries following that battle. Another progress made was the appearance of multiple rockets, launched by a common launcher, as illustrated in Figure 4. The techniques of gunpowder-making made also considerable progress, and more about the nature of the ingredients of gunpowder revealed. For example, in the book, *T'ien Kung K'ai Wu* (*The Exploration of the Work of Nature*) 1637 A.D. Sun Ying-Hsing made the following keen observations:

> "Saltpetre is a forward projecting agent, while the sulphure, a lateral one. The gunpowder for straight shooting is composed of 90% of saltpetre and 10% sulphur; whereas that for explosion consists of 70% saltpetre and 30% sulphur. As to the auxiliary component, the ash, it is produced by burning the wood of willow, pine, or birch roots, bamboo leaves, hollyhocks, or eggplant stalks, among which the bamboo leaf is the most firey." (A-15, Vol. 15, p.267)*

Similar statements about the nature of saltpeter and sulfur are also found in Mao Yuan-I's article, *Huo Yao Fu* (*A poetic presentation of Gunpowder*) [A-14]. Details on the techniques of manufacturing and handling of these ingredients are available in Sun's book. As to the techniques of attack with fire, Sun made in the same book the following classifications; the poisonous fire, the divine fire, the magical fire, the scorching fire, and the spraying fire; and he proceeded to explain in detail the incendiaries required for each kind of fire.

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* Based esentially on the translation by E-tu Zen Sun and Shiou-huan Sun [A-15].

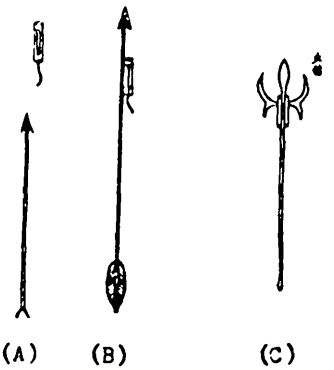

Figure 3 The fire arrow (huo chien) and fire lance (huo tsang) in Ming Dynasty (from Wu Pei Chih 1628 A.D.): (A) Fire arrow and its flame ejector; (B) Fire arrow assembled with flame ejector; (C) Fire lance with double flame ejector (huo tsiang).

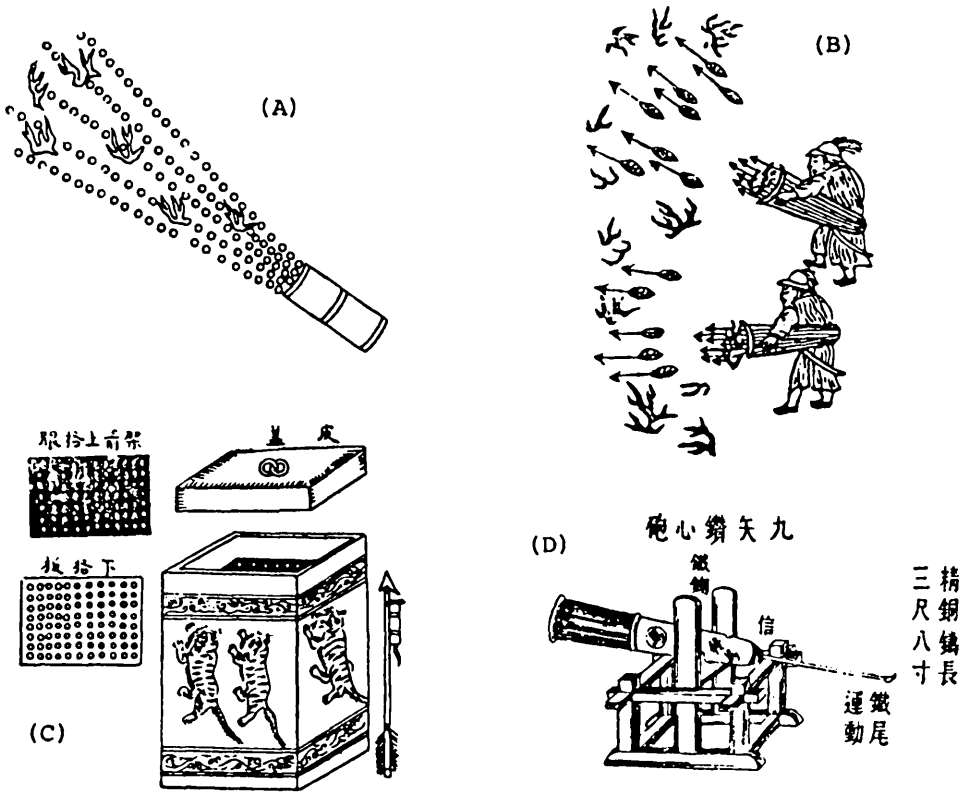

Figure 4 The multiple fire arrows and the launcher (from Wu Pei Chih, 1628 A.D., except (D): (A) Meteor shower ejector (mann tien hsin feng chien tung) or swarm of bees (i-wou feng); (B) Fire dragon arrows (huo lung chien); (C) Multiple arrows like hundred-running-tigers (pei hu chi peng chien); (D) Heart-penetrating nine-arrow cannon (chui shih tsuzn hsin pao).

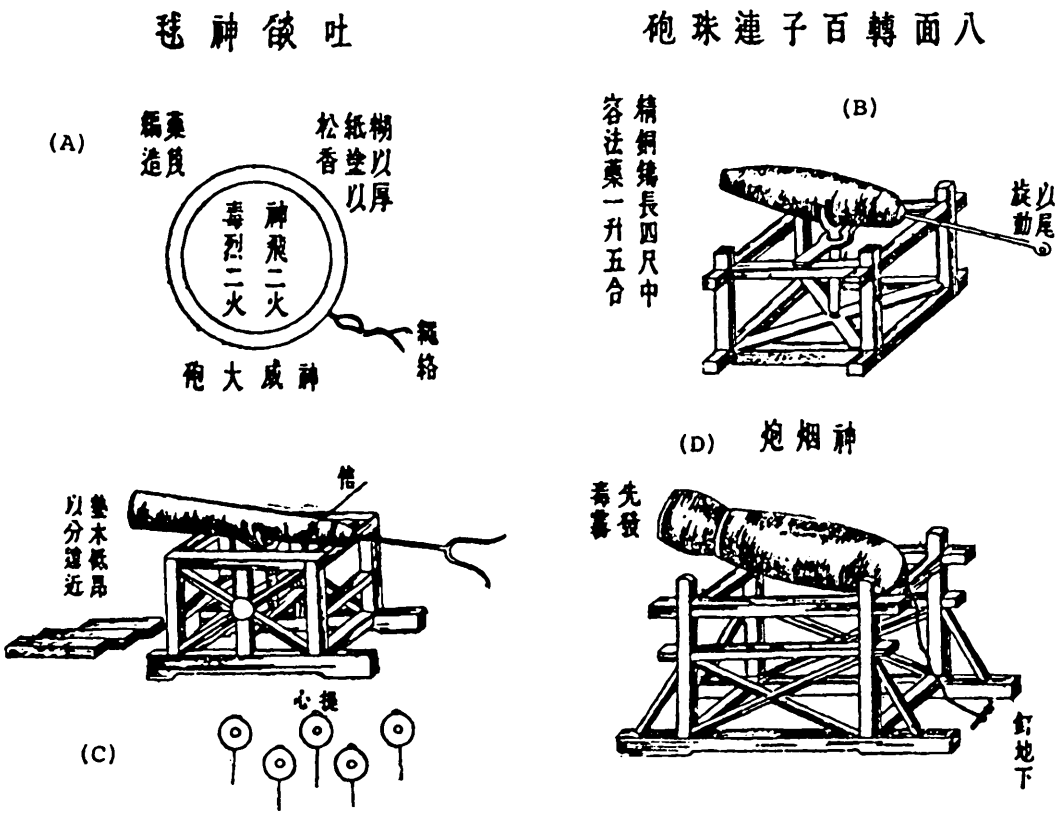

Figure 5 Some firearms in Ming Dynasty (from T'ien Kung K'ai Wu, 1637 A.D.) (A) Flame-erupting divine ball (tu yen sen chiu); (B) Rotating cannon firing string of hundred bullets (pa-mien chuan pei-tze lien chu pao); (C) Great awe-inspiring divine cannon (sen wei ta pao); (D) Divine smoke cannon (sen yen pao).

With the continual development of the gunpowder during the Ming Dynasty, a great variety of gunpowder firearms also appeared in much more complicated structures than those of the Sung Dynasty. Several such firearms are illustrated in Figures 5 and 6. In particular, the defense weapon, *wen jen di*, or "a match for ten thousand men" is worth special notice as it was really a rotating rocket. Detailed description about this interesting weapon is found again in Sun's book as follows:

> "It consists of a hollow sphere made of dry clay, strengthened by a wooden frame, and filled with saltpetre sulphur gunpowder, mixed with the poisonous firepowder and divine fire powder through a small hole in the sphere... When a city is being attacked the defender lights its fuse, and throw it outward down to the ground. Flames and smoke are then erupted from the small hole on the sphere, causing it to rotate in all directions. When it rotates toward the city, its flames and smoke are screened by the city wall from hurting the defenders; however, when it rotates outward, the enemy and their horses are both killed. Hence it is the best weapon for city defense." (A-15, Vol. 15, pp269-270)*

From such descriptions it is seen that the *wen jen di* was really a rotating grenade operated by the reaction principle.

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* Based essentially on the translation by E-tu Zen Sun and Shiou-huan Sun [A-15].

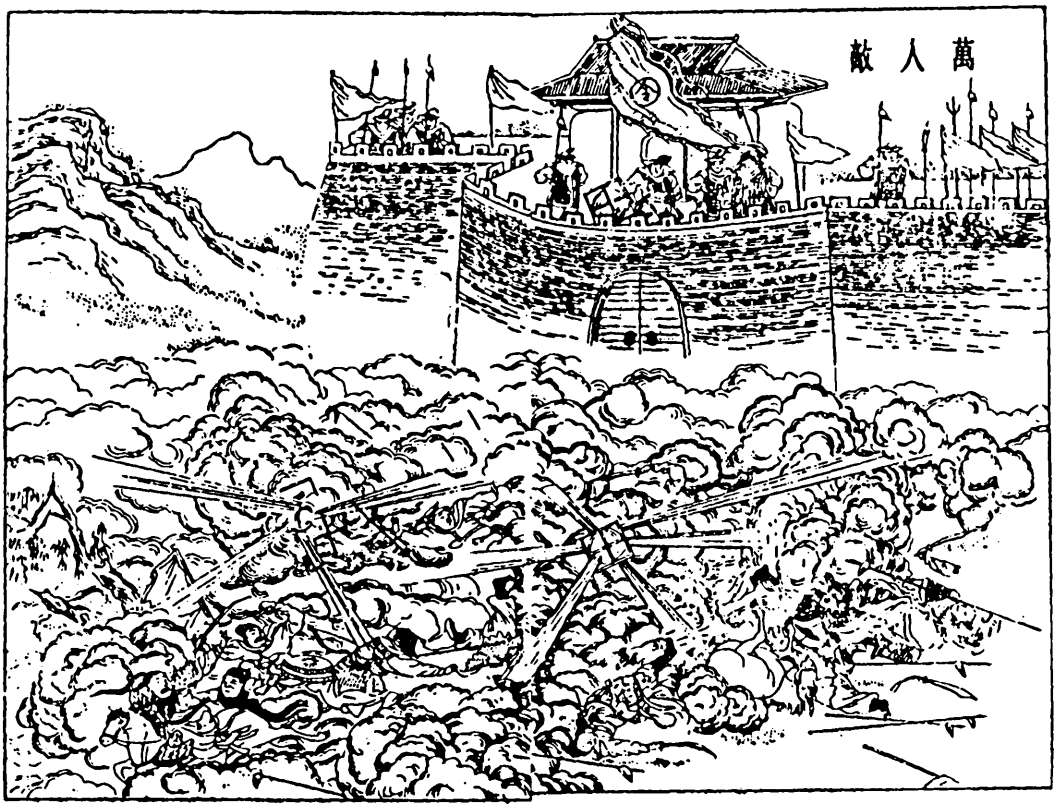

Figure 6 Rotating rockets in action: a match for ten thousand men (Wan Jen Di, from T'ien K'ai Wu, 1637 A.D.).

THE DEVELOPMENT OF PYROTECHNICS IN ANCIENT CHINA

Rocket propulsion also found its peaceful applications in fireworks in China even before the emergence of the first military rocket, the *fei huo tsiang*.

The simplest fireworks were the crackling bamboos, or *pao chuh* in Chinese. They were made simply by cutting the bamboo into a number of sections, and putting them over the fire. It was believed that the crackling noise generated would frighten the devils and drove them away. Hence they were widely used by the Chinese on New Year's Eve, or New Year's Day. Such a custom is believed to prevail in China since the 1st Century, according to Chao [A-23]. However, it had nothing to do with rocket propulsion. The early, simple Chinese device showing the reaction principle was the firecrackers, which were evolved from the crackling bamboos. They consisted of short paper tubes of small diameter, and filled with the gunpowder-like mixture. The jerking and springing of these tiny tubes upon ignition illustrated clearly the recoil from exhaust smokes. However, it is still the great noise they made that attracted people's attention, and they were used to substitute the old crackling bamboo for the same purpose of frightening the devils. Many Chinese

anecdotes* showed that such firecrackers were popular since the later years of the Northern Sung Dynasty in the 12th Century. This was the time when the early Chinese *huo yao* was in good shape. In fact the firecrackers are still popular in China today, and used by the people not only on New Year's Eve, or New Year's Day but also on many special occasions like the wedding ceremony, or the welcome of a heroes' return, etc.

With the further advance of gunpowder-making and the art of pyrotechnics beautiful fireworks appeared in China during the later years of the 12th Century on [A-8, 9, 12], about one hundred years before the battle of Pienking. They were called *yen huo*, which literally meant smokes and fire; and unlike the firecrackers, they were used for entertainment, rather than to frighten the devils. A great variety of *yen huo* were developed after that time, ranging from the small ones for children's play to those of large-scale and complicated structure, emerging in the air like a floating stage, displayed in various Chinese stage shows. Such spectacular amusement devices, usually fired during festivals or special occasions for celebration were not only a favorite of the Chinese people, but also used to entertain the Emperor and his court in ancient China. The ascending motion of the *yen huo* and its jerks and twist were evidently caused by the recoil of the exhaust gas; hence it was operated by the reaction principle just like the rocket. A Chinese article written in the Southern Sung Dynasty tells an interesting story about the lively fireworks in the Emperor's court as follows:

> "During the royal banquet in the palace, the Empress-dowager was entertained by the Emperor (Li Chung) with *yen huo* fired in the court. Suddenly a ground rat ran quickly to the Dowager and went beneath her chair. She was so frightened and angered, that the banquet was called off. The responsible eunuches were put to jail, and the Emperor apologized." (A-9, Vol. 11, p.22)

The so-called ground rat here actually referred to a piece of the firework, and its fast motion was due to the exhaust gas it ejected. Such ground rats were still active in the Ming Dynasty as told by Sir Henry Yule in a Chinese anecdote he collected [B-1] that in 1419 some Persians came to Peking on the Lantern Festival Day, and were greatly impressed by the thousands of lanterns hanging all over the palace, with a rat running around to light them up. This was evidently the same sort of firework which frightened the Empress-Dowager a couple of hundred years earlier. In fact, the use of *yen huo* for entertainment is still popular in China today just like the firecrackers, and the piece of firework like the ground rat can still be found in modern China under various names. In the author's childhood, he often played with the small firework, called the "shuttling phoenix among the peony" which was a tiny piece of firework with a string going through its body. When it was hung by tying the ends of the string on some poles and trees, and ignited, it would go swiftly along the string, and issue simultaneously a streak of colorful fire and smokes appearing like its tail. Such is evidently a beautiful model of the ancient ground rat.

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* See for example [A-7, 8].

The essential ingredients of the gunpowder for such pyrotechnics were the same as those for the military gunpowder, but the additives were quite different. Various kinds of additives to be used were selected according to the type of the firework, and the colors of the smoke required. Information on the kinds of compositions of these additives, and the techniques of making fireworks are found in the book *Huo Hsi Lueh*, or *Outline of Pyrotechnics* [A-16].

Table 2
CHINESE FIRE ARROWS AND ROCKET-TYPE FIREARMS

Name	Years	Nature	Propulsion
Early fire arrow (huo chien)	3rd to 10th century	incendiary, no gunpowder.	elastic
Sung fire arrow whip arrow with gunpowder (huo yao pien chien)	10th to 13th century	incendiary, slightly explosive, gunpowder used.	elastic
Flying fire lance (fei huo tsiang Arrow with fire-erupting cylinder (feng huo tung chien)	1232 (battle of Pienking), 1233 (battle of Keiteh)	ditto	rocket
Ming fire arrow (huo	14th to 17th century	ditto	partly elastic, partly rocket.
Ming fire lance (huo tsiang)	ditto	ditto	rocket
A match for ten thousand men (wen jen di)	ditto	incendiary and explosive	rotating rocket

CONCLUSIONS

Based on the material presented here a few conclusions may be drawn as follows:

1. The fire arrow (*huo chien*) in the early Chinese history from the period of Three Kingdoms up to the Northern Sung Dynasty (about 3rd to 10th Century) was a pure incendiary weapon, using conventional inflammable substances, and launched by a bow or crossbow; hence not to be regarded as a rocket.

2. The fire arrow in the Sung Dynasty prior to the battle of Pienking (from 10th Century up to 1232) marked a significant advance in that the gunpowder was employed in place of the conventional inflammable substance; but by directly applying the gunpowder mixture to the arrowhead, the thrust generated from the recoil of the spraying flames must be negligible, if any, and it was still launched by a bow or crossbow as the early fire arrow, hence not a rocket.

3. The flying fire lance (*fei huo tsiang*), as called by the Chin Tartars, or the arrow with fire-erupting cylinder as called by the Mongols, used in the battles of Pienking and Keiteh had the gunpowder mixture stored in a hollow cylinder tightly attached to the lance and required no bow or crossbow for its launching. Its forward motion was presumedly derived from the recoil of the hot gases erupted from the cylinder, hence it may be regarded as a primitive form of solid propellant rocket.

4. The fire arrow in the Ming Dynasty was a further improved model of that of the Sung Dynasty in that, instead of applying the gunpowder directly to the arrowhead, a cylindrical container was used, resembling the construction of the *fei huo tung chien*. The fire lance in the Ming Dynasty had similar construction except that a lance was used in place of the arrow. Thus both were the decendants of the *fei huo tung chien* or *fei huo tsiang* of the Chin Tartars, and they were rocket-type firearms.

5. Other advanced firearms of the rocket-type in the Ming Dynasty were the two-stage fire lance, the multiple rocket-like arrows launched by a single launcher, and the rotating rocket, and *wen jen di*, etc.

6. Despite these developments of rocket-type firearms after the battle of Pienking, they never played a major role in Chinese armament as the barrel cannons and guns did. This trend continued to the Chhing (Manchuria) Dynasty.

7. Chinese fireworks illustrate a peaceful application of the gunpowder and rocket principle, and the development of pyrotechnics in China has a history even longer than that of gunpowder firearms.

REFERENCES

A. CHINESE BOOKS AND JOURNAL ARTICLES

(in chronological order: "+" = A.D.; "-" = B.C.)

1. Sun Wu (∿ -520) Suntzu or Suntzu Bing Fa 孫武 孫子兵法 (Principles of Military Tactics), Chapter 12.
2. Liu An (-120) Huai Nan Tzu 劉安 淮南子 (The book of Huai Nan: Compendium of Natural Philosophy), Vol. 3, p. 85.
3. Shen Nung Pen Tshao Ching (2nd century) 神農本草經 (Classical Pharmacopoeia of the Heavenly Husbandman), (writer unknown), Vol. 1, p. 6; Vol. 2, p. 59.
4. Chhen Shou (+290) San Kuo Chih 陳壽 三國志 (History of the Three Kingdoms), Vols. 3 and 28.
5. Tao Tsang: Chen Yuan Miao Tao Yao Lueh (3rd century) 道藏：真元妙道要訣 (The Taoist Patrology: Classified Essentials of the Mysterious Tao of the True Origin), attrib. Chen Shih-Yuan , p. 3.
6. Tseng Kung-Liang and Ting Tu (+1044) Wu Ching Tsung Yao 曾公亮 丁度 武經總要 (Collection of the Most Important Military Techniques), Vol. 11, p. 28; Vol. 12, pp. 58, 61, 65, 66; Vol. 13, p. 3.
7. Meng Yuan-Lao (+1187) Tung Ching Meng Hua Lu 孟元老 東京夢華錄 (Dreams of the Glories of the Eastern Capital), Vol. 7, p. 139.
8. Cho Mih (∿ +1269) Wu Ling Chiu Shih 周密 武林舊事 (Old Anecdotes of Wu Ling), Vol. 3.

9. Chou Mih (∿ +1269) Chi Tung Yeh Yu 周密 齊東野語 (Country Talks of Eastern Chi), Vol. 11.
10. Tho-Tho (+1345) Sung Shih 脫脫 宋史 (History of the Sung Dynasty), Vol. 197.
11. Tho-Tho (+1345) Ching Shih 脫脫 金史 (History of the Ching Dynasty), Vols. 113, Vol. 16.
12. Tien Lu-Chen (+1584) Hsi Hu Yiu Nan Chih Yu 田汝成 西湖遊覽志餘 (Anecdotes About the West Lake), Vol. 3, p. 55.
13. Mao Yuan-I (+1628) Wu Pei Chih 茅元儀 武備志 (Treatise on Armament Technology), Vols. 126-129.
14. Mao Yuan-I (∿ +1628) Huo Yao Fu 茅元儀 火藥賦 (A Poetic Presentation of Gunpowder), Ku Ching Thu Shu Chi Chheng 古今圖書集成 Vol. 96. +1726.
15. Sun Ying-Hsing (+1637) Thien Kung Khai Wu 宋應星 天工開物 (The Exploitation of the Works of Nature), Vol. 15. (English translation by E-Tu Zen Sun and Shiou-Chuan Sun, The Pennsylvania State University Press, University Park and London, 1966).
16. Chao Hsueh-Min, (+1770) Outline of Pyrotochnics 趙學敏 火戲畧 (English Translation by Davis, T. L. and Chao, Y. C., American Academy of Arts and Science, Vol. 75, No. 4, +1943, pp. 59-107).
17. Tu Chi (∿ 1912) Mongul Shih, 屠寄 蒙元兒史 (History of Monguls), Vol. 29.
18. Kho Shao-Min (+1922) Hsin Yuan Shih 柯劭忞 新元史 (New History of the Yuan Dynasty), Vols. 122, 177.
19. Feng Chia-Sheng (1947) The Discovery of Gunpowder and Its Diffusion 馮家昇 火藥的發現及其傳播 Historical J., Nat'l Peiping Academy, Vol. 5.
20. Li Chao-Pin (+1955) The Chemical Arts of Old China 李喬苹 中國化學史 The Commercial Press, Taiwan, China, Vol. 1, pp. 106-136.
21. Chao Tieh-Han (1978) The Invention of Gunpowder 趙鐵寒 火藥的發明 National Institute for Compilation and Translation, Taipei, Taiwan, China.

B. BOOKS AND JOURNAL ARTICLES IN WESTERN LANGUAGE

(in Chronological order, all A.D.)

1. Yule, H., and Cordier, H., (1913-15), Cathy and the Way Thither, London, Vol. 1, p. 82.
2. Needham, J., (1954, 1976), Science and Civilization in China, Cambridge Univ. Press, Vol. 1, pp. 4-7; Vol. lV, Part 3, Sec. 29, p. 576.
3. Humphries, J., (1956), Rockets and Guided Missiles, MacMillan, pp. 20, 27.
4. Sutton, G. P., (1956), Rocket Propulsion Elements, Wiley, New York, pp. 24-56.
5. Arakawa, H., (1960), Rockets Fired by the Mongol Forces in 1274 A. D., Proc., 2nd International Symposium on Rockets and Astronautics, Tokyo.

6. Emme, E. M., (1965), A History of Space Flight, Holt, Rinhart, and Winston, N. Y., pp. 64-67.
7. Willy Ley, (1968), Rockets, Missiles, and Men in Space, Viking, New York, pp. 70-76, 107, 582.
8. Winter, F. H., (1976), On the Origin of Rockets, Chemistry, Vol. 49, No. 2, pp. 8-12.
9. Winter, F. H., (1979), The Genesis of the Rocket in China and Its Spread to the East and West, XXXth Congress, IAF, München.