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## Chapter 1

## EARLY ROCKET WEAPONS IN CHINA \*

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It is generally believed that the Chinese were the first to employ rockets as weapons; and particular reference is usually made to the *fei huo tsiang*, or literally, the flying fire lance, used in the battle of Khaifeng-fu (Pienking) by the garrison force of the Tartars against the Mongols in 1232. Positive statements of such a belief are found in the work of many authors, such as Julien,<sup>‡</sup> Reinaud and Fave,<sup>\*\*</sup> Von Romocki,<sup>\*\*</sup> Zim [8], and Ley [11]; and like statements were given by others such as Winter [14, 15], though with some reservation. In the author's previous paper on ancient Chinese rockets [18] this same conjecture was endorsed. However, there are still some doubts about the true nature of these early Chinese rockets, such as the flying fire lance; whether it could be regarded as a reaction-propelled device like the modern Western rockets. This is the opinion shared by Davis and Ware,<sup>\*\*</sup> Needham [19], etc.

In this paper the multitudes of the rocket-like gunpowder-powered firearms appeared in China under the general name *huo chien*, or the fire arrow, and various other names, from the battle of Khaifeng-fu to the later years of the Ming Dynasty in the early 17th century will be examined, and their true nature explored, mainly from the original Chinese sources. The progress of gunpowder technology during the same period will be likewise reviewed. It is hoped that through the evidences brought forth from such study, the prevailing doubts mentioned above may be cleared up, and our general belief about the origin of these rocket weapons reasonably ascertained.

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

‡ French sinologist, original paper in *Journal Asiatique* (1849), translated in English and quoted by Willy Ley in [11], p.71.

\*\* Quoted by Winter in [15], p.6.

## THE CHINESE FIRE ARROW AS A REACTION-PROPELLED DEVICE

The scanty descriptions in Chinese accounts about the *fei huo tsiang* which appeared in the battle of Khaifeng-fu, such as those found in the History of the Chin Dynasty and that of the Yuan Dynasty, were indeed too vague to identify it as a true reaction-propelled device comparable to the modern Western rocket. The only fact we know so far, is that it differed from the traditional fire arrow, in that it was launched without a bow. To explore the true nature of the Chinese fire arrows known by various names since the battle of Khaifeng-fu, we must go to more detailed later accounts in Chinese literature. The following is a passage found in General Chih Chi-Kuang's authoritative book, *Chi-Hsiao Hsin Shu* (A New Treatise on Military Efficiency):\*

The fire arrow is a powerful weapon for both land and naval warfare, not inferior to a bird pistol. However, due to the ignorance of the manufacturer on the correct way of making, and that of the user on the correct way of operating, its effectiveness has not been wholly realized. In general, there are two ways of making the hole on the tube: by drilling or by hammering. Of these two, hammering requires higher skill, hence is more difficult; while drilling is much easier. However, to make a better hole, suitable for the operation, it is hammering which should be preferred. In fact, for successful launching, the key lies entirely in this hole. If it is made upright, the arrow will go straight; otherwise, it will go astray. If the hole is too deep, the flame will leak out; or, if it is too shallow, the thrust will be too weak, and the arrow will fall down quickly.

In this passage the hole on the tube referred to by Chih was for the fuse to go through, as well as the exit for the burning gas to escape. Chih's description clearly indicates that the direction of the fire arrow and its projectile range depend on the straightness and the depth of this hole. This account should be sufficient to show that such a fire arrow was indeed propelled by the reaction of the escaping jet.

Exactly the same passage is found in Mao Yuan-I's book, *Wu Pei Chi* (Treatise on Armament Technology).† It was evidently copied from Chih's book, which was about 50 years earlier than Mao's. However, the latter contains much more information on the design of the fire arrows and the kinds of gunpowder, the so-called fire drugs, used in the Ming Dynasty. In particular, there were several technical terms‡ regarding the fire drugs employed by the fire arrows worth our notice.

1. *Tsui-huo* or literally the pushing fire. It was contained in a tube close to the rear of the arrow's shaft. Judging from its name and its position on the shaft, it was the propellant responsible mainly for the forward motion of the arrow. It was also called *hsin huo yao* (the running fire drug), or *sung huo yao* (the sending-off fire drug).
2. *Shao huo*, or literally the incendiary drug. It was contained in a tube close to the arrowhead. Evidently, its main function was not to push, but to cause fire, which was the primary objective of the fire arrow ever since its emergence as a war weapon in the time of the Three-Kingdoms. Its alternative names were *hou huo yao* (the afterfire drug), or *lih huo yao* (the inferior drug).

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\* See [2], Vol. 15, p.32.

† See [4], Vol. 126, pp.3, 4.

‡ See [4], Vol. 126, p.12, Vol. 127, pp.4, 10.

二虎追羊箭

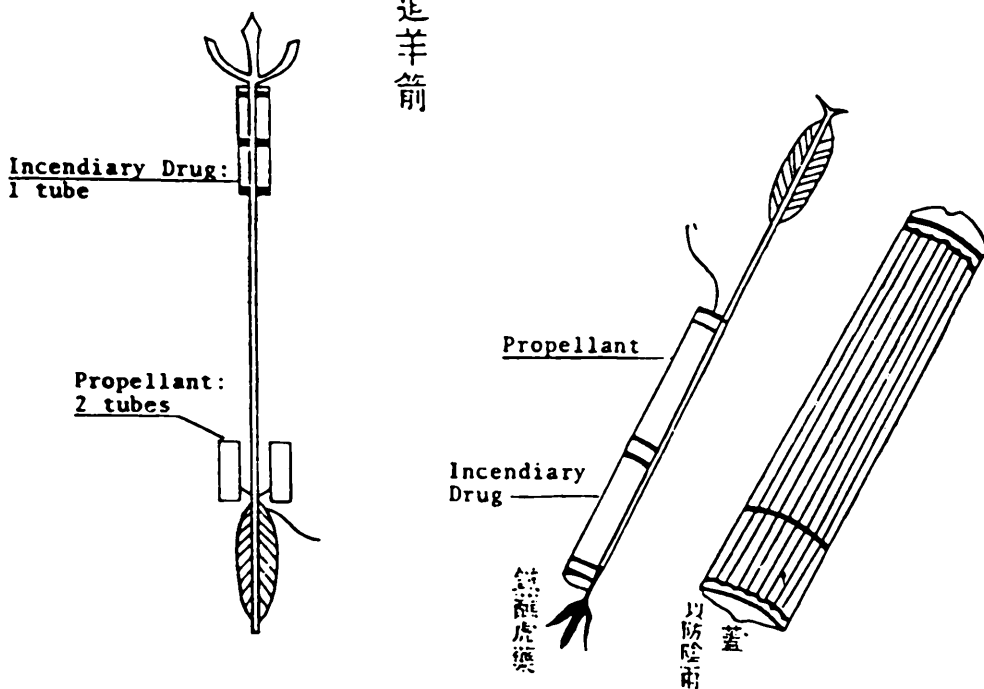


Figure 1 Gunpowder-powered fire arrows with propellant and incendiary drug separately attached.

- (A) Er hu ch'uh yang chien (two tigers pursuing the goat);
- (B) Szeshi jui shi feilian chien (The flying monster with forty-nine arrows).

These two kinds of fire drugs were different in their functions and placed at different positions on the shaft. They could be contained in different tubes, such as those in the *erh hu chui yang chien* (two tigers pursuing the goat), where two tubes for the pushing fire drug were attached to the shaft near the feather at the shaft's rear end, and one tube for the incendiary drug was attached near its head (Figure 1A). They could also be contained in a single tube, such as in the *szeshi jiu shi feilian chien* (the flying monster with forty-nine arrows), in which the incendiary fire drug filled its fore portion, while the pushing fire drug filled its rear portion (Figure 1B). These two kinds of fire drugs were also of different compositions, which will be discussed later. Such distinction of the fire drugs into two different kinds, according to their functions and compositions, were not found in the earlier accounts of the *fei huo tsiang* or those of the earlier fire arrows in the Northern Sung Dynasty. It seems that in the time up to the battle of Khaifeng-fu the two functions, to push and to burn (and explode), were performed by a mixture of fire drugs; that they were separately performed by two different fire drugs contained in different tubes, or in a single tube, but occupying the different parts of it, was a latter development,

clearly an improvement, which shows that the potential of the gunpowder for propulsion besides its inflammability and explosiveness, was now fully realized. This is other strong evidence that the Chinese fire arrow developed up to this time had rendered it a true solid propellant rocket.

Now consider the range of these fire arrows, the record of ten-paces\* for the *fei huo tsiang* is indeed too short for a rocket, if that ten-paces really meant the range of the projectile.† However, in the latter forms of the fire arrows in the Ming Dynasty, many of them reached the range of 100 paces, such as *shenchi chien*, or the magic arrow (Figure 3A); and some of them even reached as far as 500 paces such as the *fei tsiang chien*, or the flying spear arrow (Figure 2C). Such a range greatly exceeded that of an ordinary arrow and was comparable to that of a gun. These forms of the fire arrows were evidently the improved models of the *fei huo tsiang*. Some of them appeared quite early in the Ming Dynasty. For example, the so-called *yi wo feng*, or beehive, was used in the campaign of Jingnan in 1400, according to Liu [17], less than two hundred years after the battle of Khaifeng-fu, but its range had reached 300 paces. Such a great increase of range could only be achieved by the increase of recoil of the escaping burning gas, which resulted from the technical improvement of the fire arrow. Detailed accounts on the ranges of these fire arrows of the Ming Dynasty are available in Mao's book [4], and a summary of them will be given in the next section when various rocket weapons are reviewed.

With all the evidence presented above, such as the dependence of the direction of the forward motion of the arrow and the magnitude of the thrust on the uprightness and depth of the hole for the escaping gas, the separation of the pushing fire drug and the incendiary drug, and the considerable projectile range reached, it seems reasonable to regard the various forms of the gunpowder-powered, bowless, fire arrow which, under different names, appeared in Chinese warfare since the battle of Khaifeng-fu, as the true solid propellant rockets in the modern Western sense, with the *fei huo tsiang* as the crude form of their very prototype.

## CHINESE ROCKET WEAPONS FROM SUNG DYNASTY TO MING DYNASTY

With the understanding of the nature of the early Chinese fire arrows thus reached, we are now in a position to make a general review of the progress of these early rocket weapons from the Sung Dynasty to the Ming Dynasty. As stated in the author's previous paper [18], the introduction of the container for the gunpowder to be attached to the arrow-shaft, instead of its direct application to the arrowhead, was a great improvement, which led the traditional fire arrow from the simple incendiary weapon to the reaction-propelled rocket, following the invention of gunpowder. This improvement might have begun long before the battle of Khaifeng-fu. However, of the many gunpowder-powered firearms in the early years of the Northern Sung Dynasty, as recorded in Wu Ching Tsung Yao (Collection of the Most

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\* 1 pace = 3 feet according to Davis and Ware (see [15], p.6); or 1 pace = 2.5 feet according to Needham (see [13], Note 48, p.122); but in Chinese accounts, it is estimated at 1 pace  $\cong$  5 ft. (see for example, [12], pp.66, 67).

† The ten-paces record many not refer to the true projectile range, but the area over which the weapon spilled its fire, according to Willy Ley (see [11], p.72).

Important Military Techniques) [1], none may be regarded as a rocket weapon, including the so-called *huo yao pien chien*, or whip arrow with gunpowder;\* and the reaction-propelled fire arrow was not widely known until the emergence of the *fei huo tsiang* in the battle of Khaifeng-fu, when its marvelous performance was manifested in that historical fierce battle between the Tartars and the Mongols.

Not many historical accounts concerning this new weapon are found after the battle of Khaifeng-fu in 1232, and that of Keiteh, one year later. In the early years of the Yuan Dynasty, established by the Mongols in China, it was found in some Japanese accounts that a sort of firearm like the *fei juo tsiang* was used by the invading Mongolian force on the Japanese coast of Kyushu in 1274 [7], 42 years after the battle of Khaifeng-fu, but not much about this kind of weapon was heard afterwards during the short reign of the Mongolian government. Probably the rocket technology transmitted to the Mongols from the Hans and the Tartars was neglected in favor of the more powerful barrel cannons brought to China from the Arabian countries. However, rocket weapons became active again at the beginning of the Ming Dynasty after the fall of the Mongols. Fire arrows were listed among the standard equipment for land and naval forces† ever since the time of Ming Tai-Zu, the founder of the Ming Dynasty; and the construction of the fire arrow and its testing were described in General Chih's book.‡ The rocket weapon called *yi wo feng*, which appeared in the early years of the Ming Dynasty, as mentioned in the preceding section, was in fact a kind of multiple rocket, which consisted of thirty-two fire arrows in one wooden barrel with all their fuses tied to a single fuse.\*\* Later in 1464, during the campaign of Luchuan, when the government's army tried to pacify the rebellious Miaos, a barbarian tribe in the mountain region of Southwestern China, another kind of multiple rocket appeared, called the *juì lung tung*, or *juì lung chien*, literally, the nine-dragon arrow, which consisted of nine fire arrows in one package.†† They were so effective, that their use for the national defense by all garrison troops on the border was ordered by the emperor. In fact, many other rocket weapons were in use in the Ming Dynasty. Among the numerous kinds of gunpowder-powered firearms found in Mao's *Wu Pei Chi*, and Sung's *Tien Kung Kai Wu*, (The Exploitation of the Work of Nature) [5] quite a number were rocket weapons. They may be classified into four categories as follows:

### The Single Rocket

It consisted of a single shaft, attached with a single tube for the gunpowder. In comparison with the earlier fire arrows in the Sung Dynasty, those appearing in the Ming Dynasty were of larger dimensions and had particularly designed shapes for

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\* See [1], Vol. 12, pp.60, 61; and [18], p.295.

† See [2], Vol. 6, pp.11, 12; and [3].

‡ See [2], Vol. 6, p.6; Vol. 15, p.32.

\*\* See [4], Vol. 127, pp.16, 17; and [17], pp.48, 49.

†† See [6], Vol. 92, pp.2264-2265; and [7], Vol. 141, p.6233.

the head instead of the ordinary arrowhead. In Mao's book four types were listed: the flying-knife arrow, the flying-spear arrow, the flying-sword arrow and the swallow-tailed arrow, all named according to the shapes of their heads (Figure 2). Each of them had a shaft length of about 6 feet with a tube length of about 8 inches.\* They were all supposed to be able to pierce through armor and reach a range of more than 500 paces. Evidently they were the direct descendants of the *fei huo tsiang*, but each had a larger size, stronger head and longer range, hence they were more powerful. The so-called "two tigers pursuing the goat" mentioned in the preceding section also belongs to this category.

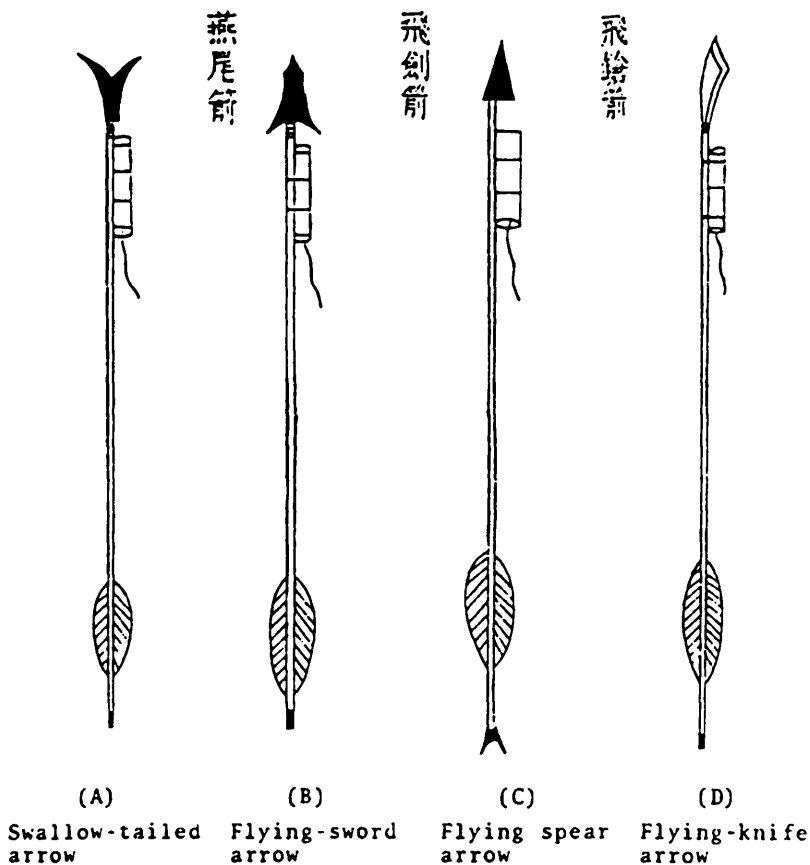


Figure 2 The single rocket

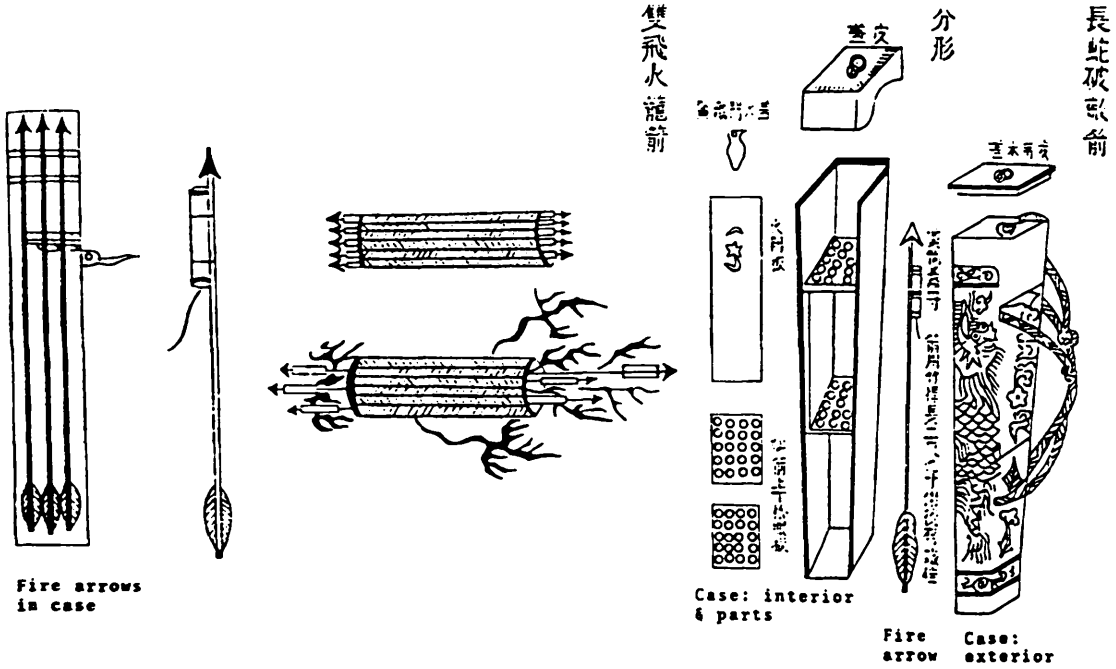
### Multiple Rockets

These were devices consisting of a number of rockets packed into a single unit. The fuses of the individual rockets were all connected to a single main fuse, and when the latter was lit, all rockets were launched simultaneously, thus delivering much greater destructive power than a single rocket. The number of rockets in one

\* Detailed data on dimensions are available in [4], Vol. 26, pp.6, 7.



package could range from two or three, like the *shenchi chien*, (magic arrow) to a hundred, like the *pei hu chiben chien* (hundred tigers racing abreast). The range of these multiple rockets was from 100 to 500 paces according to Mao [4]. The flying monster with forty-nine arrows, the beehive and the nine-dragon arrow mentioned in the preceding sections all belong to this category. For details, see Figure 3 and Table 1.



(A) Shenchi Chien  
(The Magic Arrow)

(B) Shuang fei huolung chien  
(Caged fire arrows in counter directions)

(C) Chang shao poh di chien  
(Long serpent's attacking arrow)

Figure 3 The multiple rockets

**Table 1**  
**ROCKET WEAPONS IN THE MING DYNASTY**

CATE- GORY	NAME			RANGE in paces	DESCRIPTION
	Chinese	English Translation			
		Phonetic	Literal		
Single Rocket	飛刀箭	Fei tao chien	Flying-knife arrow	500+	Large-size fire arrow with knife-shaped head
	飛槍箭	Fei tsiang chien	Flying-spear arrow		-do- with spear-shaped head
	飛劍箭	Fei jien chien	Flying-sword arrow		-do- with sword-shaped head
	燕尾箭	Yen wei chien	Swallow-tailed arrow		-do- with swallow-tailed tip
	二虎追羊箭	Erh.hu chui yang chien	Two tigers pursuing the goat		A single shaft equipped with two tubes for the propellant and one tube for the incendiary drug
Multiple Rockets	神機箭	Shenchi chien	Magic arrow	100+	One bamboo barrel, housing 2 or 3 fire arrows fired simultaneously through a single main fuse
	五虎出穴箭	Wu hu ch'u hseuh chien	Five tigers out of the cave	500+	-do-, but with 5 fire arrows
	九龍箭 (箭)	Jiu lung chien (or tung)	Nine-dragon arrow		-do-, but with 9 fire arrows
	七筒箭	Chi tung chien	Seven-tube arrow	200+	7 bamboo barrels bounded together, with one fire arrow in each, all connected to a single main fuse
	雙飛火籠箭	Shuang fei huolung chien	Caged fire arrows in counter directions		10 fire arrows in one cage, made of bamboo splints and open at both ends; after the main fuse is lit, five arrows are shot out simultaneously through each end in opposite directions
	長蛇破敵箭	Chang shao poh di chien	Long serpent's attacking arrow	200+	One wooden barrel, housing 30 long fire arrows fired simultaneously through a single main fuse
	一窩蜂	Yi wo feng	beehive	300+	One wooden barrel, slightly cone-shaped, housing 32 magic arrows fired simultaneously through its larger end
	群豹橫奔箭	Chun pao heng-beng chien	A flock of leopards running crosswise	400+	One cone-shaped case, housing 40 arrows fired simultaneously through its larger end, so that they will fly out in array, spanning a wide front of about 40 meters
	四十九天飛廉箭	Szeshi jiu shi feilian chien	The flying monster of forty-nine arrows		One cylindrical case made of bamboo splints, housing 49 fire arrows fired simultaneously, with one tube on each shaft, containing the incendiary drug in its fore portion, and the propellant, its rear portion.
	群鷹逐兔箭	Chun yin chuh t'u chien	A flock of hawks pursuing the rabbits	100+	A single cylindrical case, open at both ends, housing 60 short fire arrows, with 30 of them shot out simultaneously through its one end, and then another 30, through the other end.
百虎齊奔箭	Pei hu chibeng chien	Hundred tigers racing abreast	300+	A single cylindrical case housing 100 short fire arrows fired simultaneously.	
Winged Rocket	飛空擊賊震天雷砲	Fei kong jizei zhantian leiphao	Flying brigand-striking heaven-shaking thunder projectile	300 meters	Spherical shape, made of bamboo splints, attached with two wings outside and a tube inside, containing the propellant and explosives, etc.
	神火飛鴉	Shenhuo feiya	Flying crow with divine fire		Bird-shaped, made of bamboo splints, filled with incendiary drug and explosives, and attached with 4 fire arrows underneath the body for propulsion purpose.
Rotating Rocket	萬人敵	Wen jen di	A match for ten thousand men		Hollow sphere made of wood and clay, filled with gunpowder; when ignited, the gas escaping through a hole on its surface, causing it to rotate, spreading flames and smoke in all directions.

## Winged Rockets

Among the rocket weapons recorded in Mao's book, two were equipped with artificial wings:

(1) The *fei kong jizei zhantian lei phao* (flying brigand-striking, heaven-shaking thunder projectile)

It was spherical in shape, made of woven bamboo splints. Inside the body there was a tube containing the propellant with a priming cap fixed on top, and on its outside two wings were attached (Figure 4A). Upon ignition in a favorable wind it would fly right into the enemy's fortifications or their array of troops; and after burnout of the propellant the charge would explode, producing blast, smoke and mist, thereby delivering a heavy blow to the enemy. Though its Chinese name, *phao*, suggests its being a sort of trebuchet, it was actually a winged rocket, whose range was greatly augmented by wind speed.

(2) The *shenhuo feiya* (flying crow with divine fire)

It was also made of woven bamboo splints, but shaped like a crow, with head and tail and two paper wings on its two sides (Figure 4B). Underneath the body four large fire arrows were attached, two under each wing, with their fuses all tied together, and, inside, the body was filled with explosives. In operation the fire arrows were ignited first, and the crow would fly over a distance of a thousand feet or more; then the body would explode when it was about to land, producing a great fire so as to burn the enemy's camp or ship. Thus it was another type of the winged rocket, like the thunder projectile mentioned above, but it had a much longer range, due probably to its better shape of being bird-like rather than round. In modern language, it had a more streamlined contour, hence less atmospheric drag and covered a greater flying distance.

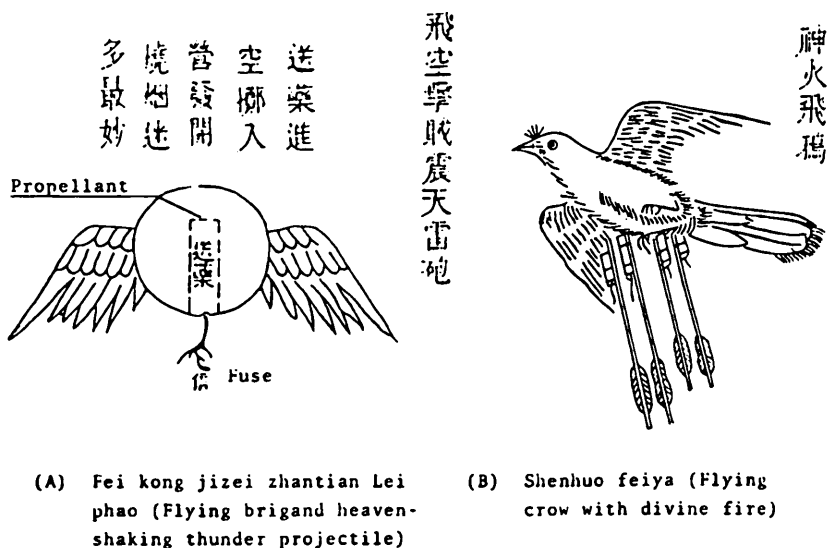


Figure 4 The winged rocket

These two devices were actually miniature missiles. Detailed descriptions are available in *Wu Pei Chi*.\*

### The Rotating Rocket

The last kind of rocket weapon is the so-called *wen jen di*, or, literally, the match for ten thousand men. It was a defensive device, essentially a rotating rocket, since, instead of going forward upon ignition, it would rotate continuously, spreading fire in all directions, under the recoil of the escaping hot gas. A detailed description and illustration showing its action in battle is given in the author's previous paper [18], based on Sung's *Tien Kung Kai Wu* [5], hence it will not be repeated here.

In summary, information on Chinese rocket weapons after the battle of Khaifeng-fu up to the later years of the Ming Dynasty (~1621), based on Chinese records, mainly *Wu Pei Chi* and *Tien Kung Khai Wu*, is shown in Table 1.

### THE PROGRESS OF GUNPOWDER TECHNOLOGY SINCE THE BATTLE OF KEIFENG-FU

The great increase of the ballistic range shown by the rocket weapons in the Ming Dynasty was most likely due to the improvement of the gunpowder since the battle of Khaifeng-fu. In *Wu Ching Tsung Yao*, composed in the earlier years of the Northern Sung Dynasty, though it recorded several recipes for the gunpowder, not much was said about the nature of its various ingredients. However, in the later years of the Ming Dynasty, Sung Ying-Hsing once stated explicitly that, of the three principal ingredients of a gunpowder, the saltpeter was a forward projecting agent, the sulphur a lateral one; whereas the ash was an auxiliary agent, and the ratio of saltpeter to sulphur should be 9 to 1 for straight shooting or 7 to 1 for explosion. A detailed description and explanation are found in [5], and are quoted in English in [18]. A similar statement is given earlier in Mao's *Huo Yuo Fu*,<sup>†</sup> which says, "the saltpeter has the nature of going straight, whereas the sulphur goes sideways." In fact, in Mao's exposition, he went on to further categorize the gunpowder into three principal classes according to its composition and function, as summarized in Table 2.

Mao's description shows clearly that of the three classes, the class I gunpowder is a sort of solid propellant, in which the saltpeter is the principal ingredient responsible mainly for propulsion, hence its higher percentage; the class III has a higher sulphur content, assisted by the ash, which is responsible mainly for burning; while the class II is an intermediate between classes I and III. Hence the class I gunpowder is the main agent in the running fire drug, the pushing drug and the priming drug; whereas the class III gunpowder is the main agent in the incendiary drug, the after fire drug or the inferior fire drug.

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\* See [4], Vol. 123, p.23; Vol. 131, p.13; or, for English translation, see [17], pp.51, 52.

† See [4], Vol. 119, pp.6-9.

**Table 2**  
**CLASSIFICATION OF THE GUNPOWDER IN MING DYNASTY**

Class	Composition			Description
	Saltpeter	Sulphur	Ash	
I	81.1	2.7	16.2	For propulsion, used on fire arrows, shooting stars <sup>†</sup> , ground rats <sup>††</sup> , fuses, etc.
II	83.4	8.3	8.3	Intermediate class, used for bird pistols, barreled cannons, etc.
III	60.0	20.0	20.0	Incendiary purpose, used on the head of the fire arrow, or in metallic cannons, etc.

† a kind of firearm, see for example [4], Vol. 126, p. 13.

†† a kind of firework, see [18], p. 302.

Judging from these records, it seems that, during the time from the later years of the Southern Sung Dynasty to the later years of the Ming Dynasty, a much better understanding of the nature of the various ingredients of the gunpowder was achieved, hence a better technology of gunpowder making was developed, and the ballistic ranges of the rocket weapons were greatly improved. As estimated by Mao,\* the average range was about more than three hundred paces for each ounce of the gunpowder applied.<sup>†</sup> Nothing was said about the projectile's weight in the same statement by Mao. But later, in his description of some gunpowder-powered fire arrows with a range of 300 paces, he did mention its total weight as more than two chins ( ),<sup>‡</sup> or about 1.2 kilograms. Such data would give some indication of the propulsive power of the gunpowder at that time.

Finally, it should be mentioned that, as well as the three main ingredients, the saltpeter, the sulphur and the ash, there were numerous auxiliary ingredients, under the general name *tsung yao*, each of which had a specific function, such as the production of smoke, or mist or poisonous gas, etc., as described in *Wu Ching Tsung Yao* [1] and *Wu Pei Chi* [4]. Discussion of such ingredients, however, is beyond the scope of the present paper.

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\* See [4], Vol. 126, p.9.

† A Chinese ounce is about 37.3 English ounces, see [12], p.73.

‡ A Chinese weight unit, 1 chin = 16 Chinese ounces, or about 0.6 kilogram, see [12], p.73.

## CONCLUSIONS

Based on the observations presented above, we may now summarize our conclusions as follows:

1. The development of Chinese fire arrows entered its gunpowder age in the early years of the Sung Dynasty (beginning +960), but the reaction-propelled fire arrows did not appear until the battle of Khaifeng-fu in 1232.
2. The fire arrows emerging in Chinese warfare since then were truly reaction-propelled solid propellant rockets in the modern Western sense, with the *fei huo tsiang* as the crude form of their very prototype.
3. The rocket weapons, after a short standing-still period during the Yuan Dynasty (1277-1368), were reactivated in the Ming Dynasty and made good progress in many aspects; notably:
  - A. The separation of the propellant and the incendiary drug from the gunpowder mixture as applied to the arrow hitherto;
  - B. The advance of the projectile range from 100 to 500 paces, with the accompanying increase in the arrow's size and weight, and the stronger arrowhead of specially designed shape;
  - C. The development from the single rocket to the multiple rockets, ranging from two or three up to a hundred fire arrows in one unit, with a great increase in destructive power;
  - D. The introduction of a great variety of diversified designs for the rocket weapons including the winged rockets and the rotating rocket, as well as the many types of the multiple rockets. In particular, the addition of the wings to the flying brigand-striking, heaven-shaking thunder projectile and the divine fire flying crow; the bird-like design for the body of the latter actually led the rocket weapon from a simple reaction-propelled projectile to an aerodynamically assisted flying missile, which was, therefore, the pioneer of the modern military aircraft, though extremely primitive in form.

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