Chapter 1 of
'The Rocket Pioneers'

- William Congreve
and his war
rocket

THE ROCKET PIONEERS

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ILLUSTRATED WITH PHOTOGRAPHS

LUTTERWORTH PRESS
LONDON

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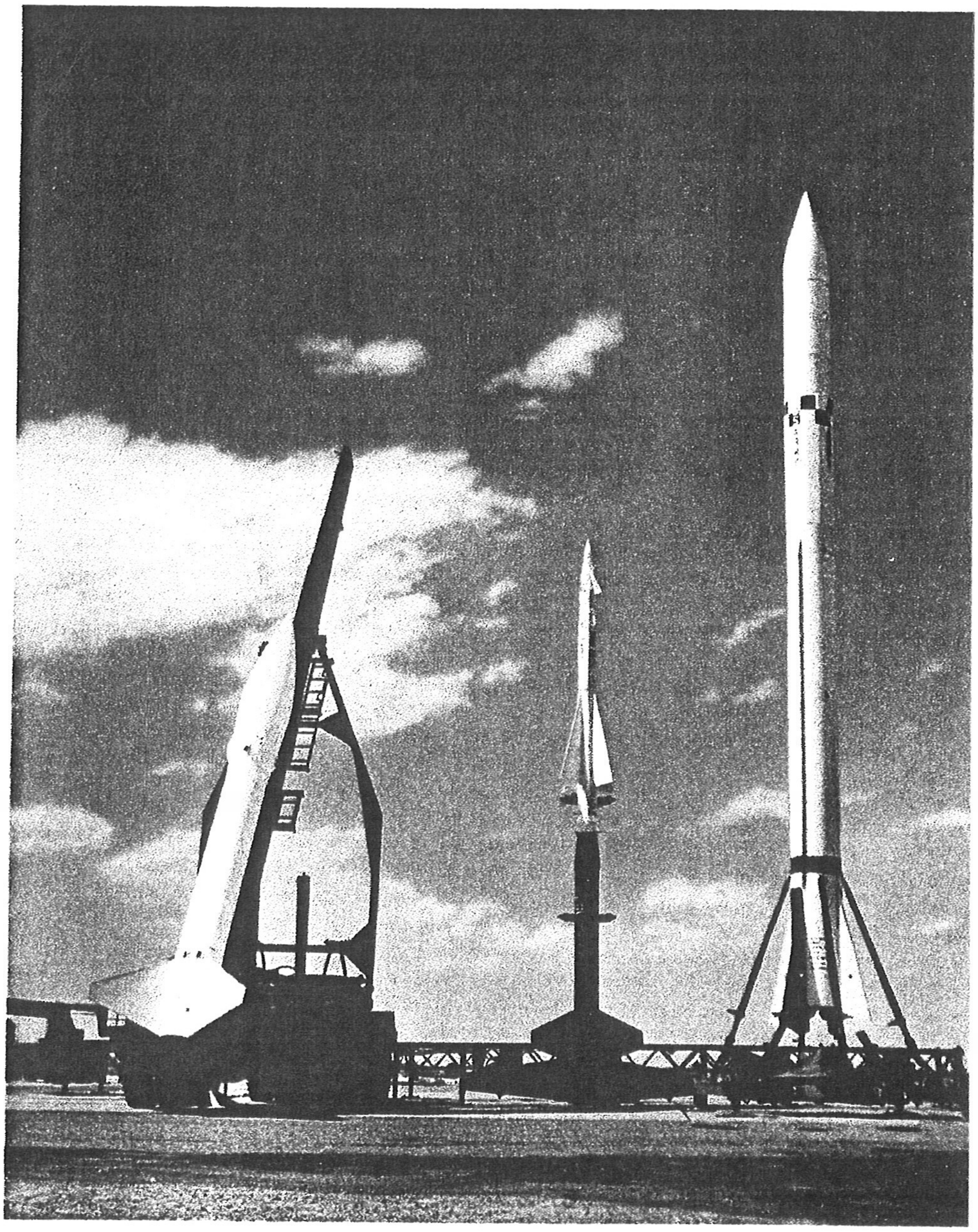

These American rockets, *Honest John*, *Nike* and *Corporal*, are proof of the remarkable strides that have been taken in recent years to develop rocket propulsion. They point dramatically to outer space and vindicate the faith of ' the rocket pioneers '. (*U.S. Army photo.*)

ACKNOWLEDGMENT

The authors are deeply grateful to all the many persons who helped them with this book—who generously supplied information from their own publications, their own files or their own memories, and who read and helpfully criticized the manuscript at various stages. They owe special gratitude to Mrs. Robert H. Goddard, Mrs. James Wyld, Dr. Walter R. Dornberger, James J. Harford, Executive Secretary of the American Rocket Society, J. R. Hillier, Deputy Librarian of the Imperial War Museum of London, Willy Ley, G. Edward Pendray, and John Shesta.

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WHO ARE THE PIONEERS?

The story behind the space-travelling rocket is, in its way, as amazing as some wildly fanciful tale of an earthman's rocket journey to Saturn. And the most amazing thing about it is that it really happened. The rocket's story is true.

No one even attempts to believe a science fiction account of a space ship that zooms at the speed of light across nearly eight hundred million miles of space to the multi-ringed planet of Saturn. But it is necessary to believe—however incredible it seems, on sober thought—that man-made rockets have actually soared two hundred and fifty miles above the earth at the rate of more than a mile a second.

Such rockets existed during World War II, as the people of London learned only too well when the first German V-2 rocket bomb plummetted down upon them so swiftly that the sound of its movement was left far behind. Today's experts are developing rockets that make the V-2 seem antiquated. And the passenger-carrying rockets of the future, capable of flight to another planet, are perhaps already on some scientist's drawing board. Certainly they are already being imagined by men who, if they can translate their vision into reality, will be listed among the pioneers of interplanetary travel.

But the interplanetary rocket, when it finally takes form, will owe a great deal to the rocket pioneers of the past. Those pioneers worked with varying degrees of skill and with various immediate purposes. Not all of them were trying to construct a rocket that would reach another world. Some of them were simply building a bigger and better skyrocket—that pretty little rocket of the fireworks display which is probably the earliest ancestor of all modern rockets. Some were trying to build rocket weapons. But a surprising number of the men who spent their lives making skyrockets to amuse children, or rocket bombs for the destruction of an enemy nation, were nevertheless in their own minds working toward that day when rockets would provide man with a means of transportation into the vast realms of space. What each man hoped for, as well as what he accomplished, is necessarily a part of his story.

No one will ever be able to list all the rocket pioneers of the past. Some of them are lost in the mists of early history. Some of them seemed so foolish, in the eyes of their practical-minded neighbours, that they were laughed at during their lifetimes and quickly forgotten afterward.

But there are certain men who will probably always be remembered—men whose genius erected notable way stations along the mounting road of rocket progress—stations from which other investigators could move on to even higher altitudes. Not even all of these well-remembered geniuses are mentioned in this book; no single volume could recount the records of all their lives. But enough of their stories are crowded into the following pages to illuminate the two bright threads that run through the long history of the rocket's development.

One of these threads is the fact that all rockets—from the tiniest skyrocket to the largest space-seeking giant—operate on the same basic principle. The other is the fact that all rocket pioneers were men of vision—the kind of vision that extended far beyond the confines of the world they lived in. Some of the rockets they built could fly only a brief distance into the air. But the dreams they all dreamed soared far above the earth. And when man himself soars into interplanetary space he will be travelling in the space ships their imagination helped to make possible.

WILLIAM CONGREVE AND HIS WAR ROCKET

A century and a half ago the name of William Congreve was known all over Europe. When safety matches were invented and offered for sale for the first time in his native England, the manufacturer called them Congreve matches because he knew the name would catch the public fancy. When people spoke of a rocket in those days they didn't have to explain what they meant. It would be taken for granted that they were talking of one particular kind of rocket—the Congreve war rocket. It was so well established as a weapon of swift destruction that when George Stephenson designed a steam locomotive capable of achieving the then-incredible speed of twenty miles an hour, a horrified citizen declared he would as soon expect people "to suffer themselves to be fired off" upon one of Congreve's rockets "as trust themselves to the mercy of such a machine going at such a rate." Stephenson calmly named his locomotive the "Rocket" and rode it to fame and fortune.

At that time it had occurred to no one to think of a rocket as a literal form of transportation of any kind, and certainly not for a voyage from earth to outer space. To most Englishmen, in fact, before Congreve's time a rocket had been neither a means of transportation nor a weapon of war. It had been simply the little skyrocket which entertained them at fêtes and celebrations—the rocket that streaked through the air with a tail of fire, then burst into a spectacle of golden rain or glittering stars.

Congreve's childhood, however, was spent at the one place in all England where skyrockets and weapons shared the attention of a group of skilled experts, so it is scarcely surprising that he thought of these two things together—and came eventually to think of a combination of the two, of a rocket weapon. When he was eight years old, Lieutenant-General William Congreve, his father, became Comptroller of the Royal Laboratory at Woolwich Arsenal. That laboratory was responsible for the development and improvement of British weapons and also for the fireworks displays that marked royal and national celebrations.

There were not, as it happened, any royal fireworks displays of note during the years that Congreve's father headed the laboratory. Frugal George III knew his predecessor had been scolded in the public press for the lavish sums of money he had spent on such things, and he himself refrained from ordering any elaborate exhibitions. During his reign the best fireworks in England could be seen at public pleasure gardens, where they were a popular form of amusement. And, for that matter, there was little activity in the field of weapons development at the Royal Arsenal during the first decade or more after the elder Congreve's appointment. England was enjoying a period of peace and prosperity she hoped would last for many years, and saw no point in devising new and expensive weapons for which she expected to have no need.

But at a Royal Arsenal, even in peace time, soldiers parade daily and cannons boom their salutes. And young Congreve, living with his family on the Arsenal grounds—an extensive tract along the bank of the Thames, just outside London—learned early to talk of firing ranges and projectiles, and to admire the glitter of a handsome uniform. His playground was the big common facing the new barracks of the Royal Artillery. Near by stood the Royal Gun Factory, the Royal Carriage Department, the Royal Dockyard and similar establishments. A painting made when he was about ten years old shows him standing with his father on the Arsenal common. The elder Congreve, in the full uniform of a Royal Artillery officer, is watching a squad of gunners haul a heavy weapon into place. Beside him, his son is trying to attract attention to the small gun he has set in its rack, proudly positioned for firing at a high angle.

Very little is actually known about the Congreve family, although it was apparently the same family to which the famous English dramatist named William Congreve belonged. But that painting of young William and his father tells more about them than can be guessed at first glance. The artist was a man very well known in his day, the Baron Johann Zoffany, whose favourite subjects were fashionable figures of the London stage and members of the nobility. If the Congreves were considered worthy of his brush, they too were presumably both well-to-do and socially prominent. And young Congreve is said to have attended the Hackney School outside of London—a big gabled building patronized exclusively by the sons of noblemen and highborn gentlemen. It is doubtful if the students there paid very serious attention to their books. Every anniversary of a military victory and every important political event in the House of Lords, where so many of their fathers sat, was regarded as an official excuse for a full holiday. So it was probably here, and later at the Singlewell School among the gently rolling downs of the county of Kent, that young Congreve met the boys who became his regular companions. Together they played at amateur dramatics, talked familiarly of royalty and enjoyed the privileges of wealth and social distinction which their families' positions gave them.

With some of these same young men Congreve eventually entered Trinity College at Cambridge University. He took his bachelor's degree there in 1793 and his master's degree two years later. Then, still following the tradition of the well-to-do young Englishman of his day, he went to London to study law in the ancient institution called the Middle Temple. He lived at Garden Court, where many lawyers had their residence, and after a time he began to edit a political newspaper. That particular venture came to an end when one of the items he published—about a certain Lord Berkeley—resulted in Congreve being prosecuted for libel and fined a thousand pounds.

"Then," a gossipy and sometimes ill-natured friend said of him later, "he took to inventing rockets for the more effectual destruction of mankind."

Congreve's interest in rockets was certainly not as abrupt and inconsequential as that remark indicates, however. For one thing, he had always had a lively and ingenious mind for mechanical devices. And, for another, England was by then at war. Beyond the Channel the revolutionary armies of France, having overthrown their king, had set out to overwhelm their neighbours on every side. England was originally sympathetic toward the French Revolution, but she found she could not stand by when her ally Holland appealed for aid against the invading French forces led by the brilliant and fanatical Napoleon. And so in 1793 England had reluctantly engaged upon what she hoped would be a brief encounter —only to find herself in a heartbreaking struggle that would last almost without a pause for more than twenty years.

There is no record of whether Congreve himself actually marched and drilled with one of the volunteer militia groups that sprang up everywhere in the country when Napoleon first threatened to invade England. It seems likely that he would have been glad to wear the handsome uniform of the Inns of Court Volunteers—scarlet coat with yellow facings, white waistcoat and white breeches. But knowledge of his involvement with the war comes from Congreve's own statement appearing in a technical paper many years later. It was during the early years of the new century, he says, that he put his mind to work on the subject of weapons—powerful long-range weapons that might help England to defeat a powerful foe.

He had his background at the Woolwich Arsenal to aid him. He also had some interesting reports brought home from India by British soldiers who had been fighting there during the previous quarter-century. In the wealthy principality of Mysore, those men had encountered a strange and demoralizing weapon wielded by the troops of Hyder Ali and his son Tippoo Sahib. It consisted of an iron tube about eight inches long and an inch and a half in diameter, fastened to a ten-foot bamboo pole. It could travel a great distance, the British soldiers said, and land spat flame. A corps of five thousand men under Tippoo Sahib, armed with this weapon, had not only terrified the English but had also, according to one account, done much damage to the British cavalry.

Congreve would not have to be told that this weapon was a form of rocket. And it would have been simple enough for him to discover that the native soldiers of Mysore were not the first men to use that kind of war instrument. The rocket weapon, in fact, is much older than that better-known weapon, the gun.

But it is true that the early origins of the rocket are still quite obscure, and Congreve probably knew less about them than is known today. One authority says that the Chinese amused themselves with skyrockets during the Tang dynasty, which lasted from 618 to 907, and it is generally agreed that by the thirteenth century the Chinese were making rockets which they used as weapons. They had learned that a mixture of charcoal, sulphur and saltpetre would burn violently and give off so much gas that it could explode the container that held it. This mixture, of course, is the same one that is known today as gunpowder, although that name did not come into use until the invention of the gun itself. Before that time it was known simply as black powder or explosive powder. The Chinese packed it tightly into round balls or shells, much like a modern explosive mine. They also used it for the rocket weapon they called the "arrow of flying fire."

This "arrow of flying fire" consisted, apparently, of an ordinary arrow to which had been attached a tube packed full of the charcoal-sulphur-saltpetre mixture. A Chinese warrior simply ignited the mixture in the tube (which did not explode the container because the tube was open at the end) and then, as one report says, the arrow "suddenly flew away in a straight line and spread its fire over an area measuring ten paces." At a time when the spear and the ordinary bow and arrow had been man's only extension of hand-to-hand fighting, this weapon must have seemed very frightening. It is known to have terrified China's Mongol enemies in 1232.

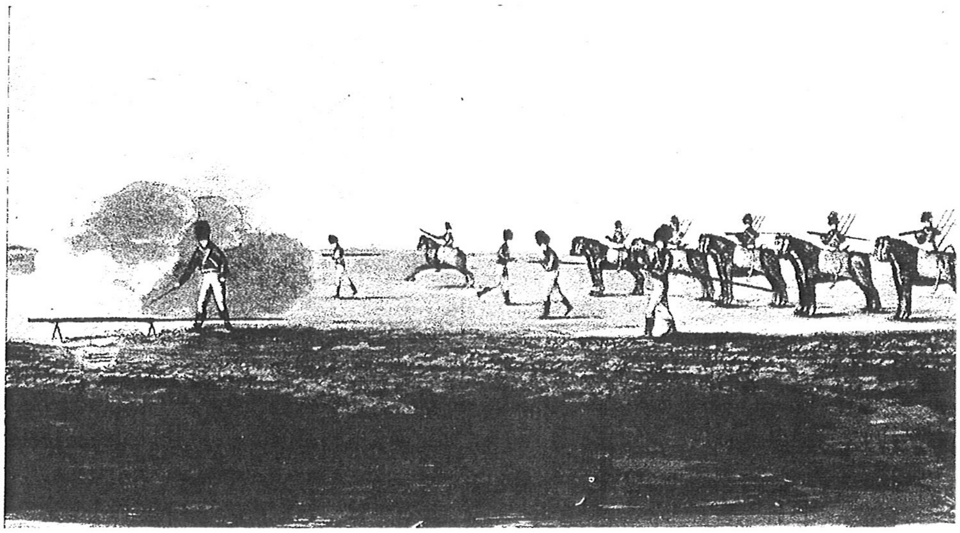
Within that same century knowledge of this explosive powder reached Europe. Some experts say that that brilliant English monk Roger Bacon invented the mixture himself, unaware that it was already known in the Orient. Others say word of the powder came to Europe by way of Arabia. Bacon's German contemporary Albertus Magnus was also writing at almost the same time about a powder made of charcoal, sulphur and saltpetre. And rockets made from this powder were credited with at least one Italian victory before the year 1400.

By that time the gun had been invented. Almost as simple as the rocket itself, it consisted of a metal tube or muzzle, into the bottom of which a quantity of gunpowder was packed. Then a ball of stone or metal was pushed into the tube on top of the powder, and jammed down tightly with a handful of wadding. When the powder was ignited, at the base of the muzzle, the force of the explosion drove the ball out. The first guns were crude and therefore seldom as effective as the even simpler rocket. So ingenious rocket designers, undisturbed, continued for some time to turn out their weapons. Fifteenth-century pirates seem to have found rockets particularly effective against the tarred rigging and the wooden hulls of their victims' ships, and rockets were also valuable as incendiary weapons against wooden fortifications on land.

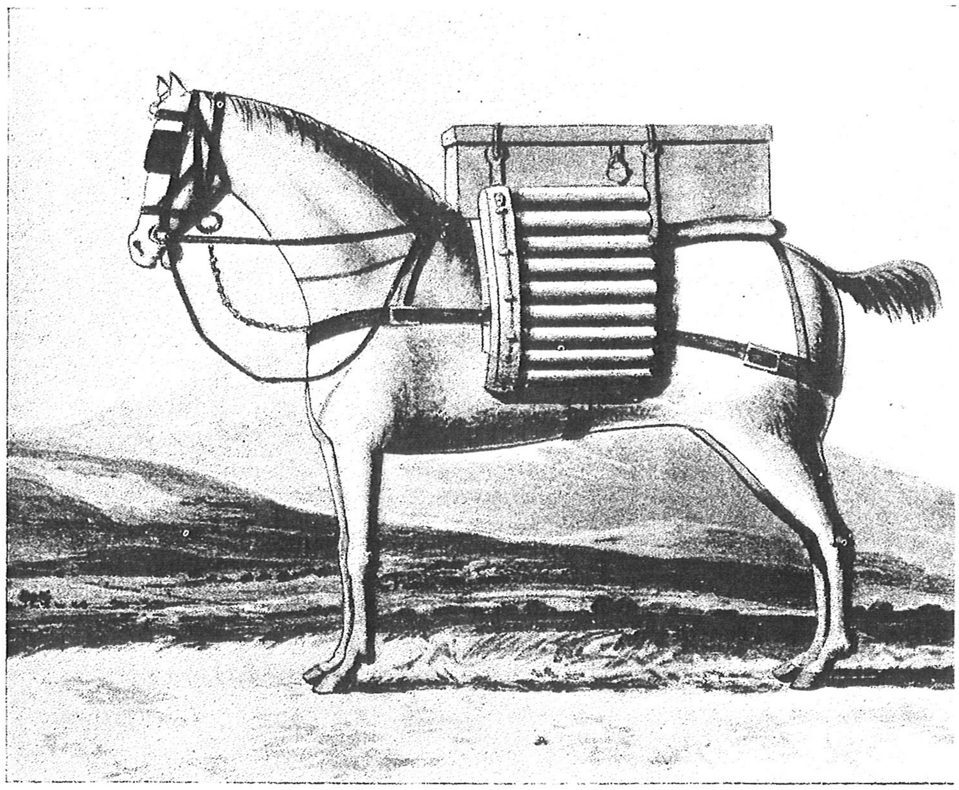
But during the sixteenth century armament makers improved guns to such an extent that rockets were all but discarded. The soldiers and sailors of England's first Queen Elizabeth fought with muskets and cannon. Probably the only rockets they ever saw were the ones their monarch delightedly set off to celebrate their triumphs. Rocket makers still existed, but they were no longer weapon manufacturers. They were toymakers instead, catering to what had become an almost universal love of fireworks displays. And toymakers they remained, almost without exception, until Congreve's time.

Consequently when Congreve decided to make a serious study of the possibilities of the rocket as a weapon, he had to apply to these toymakers for his supplies. He bought the largest skyrockets

Sir William Congreve, inventor of the Congreve war rocket, from a Lonsdale painting portraying him watching the rocket barrage at the British siege of Copenhagen, 1806.



In 1813 the newly-formed Rocket Brigade of the Royal Artillery was sent to Germany a
played an important at the battle of Leipzig. The illustrations show the Brigade in action a
a horse loaded with Congreve rockets. (*Picture Post Library.*)



he could find, paying for them out of his own pocket. His intention was to transform these toys into dangerous tools of war.

The rockets he purchased were very similar to the skyrockets in use today, and equally similar to those made several centuries earlier. Each one consisted of a cylindrical case of stiff rolled paper, squeezed together near its bottom to form a narrow neck or choke, then flaring out again below to form a wider nozzle. The rocket's cargo, or pay load—the special kind of combustible material that produced a shower of stars or rain—was packed into the front end of the cylinder, just behind a conical cap. It would be ignited when the rocket had been driven to the peak of its flight. The rest of the rocket was a primitive combustion chamber containing the powder charge—that charcoal-sulphur-saltpetre mixture, pressed into a solid cake with a conical hollow at its base. The reason for the conical hollow was that only the exposed surface of the powder mixture would burn, and if the rocket were fully packed with powder the burning surface would be merely a flat circle the size of the rocket case itself. A conical hollow provided the largest possible burning surface and therefore the most rapid rate of combustion. The gases created by that combustion provided the force that carried the rocket into the air, on a flight guided and balanced by the long guide stick fastened to the rocket cylinder and extending behind it.

Congreve was not scientifically trained, but he lived at a time when educated men understood certain mechanical principles which had been entirely unknown during the rocket weapon's first period of popularity. The most important of these principles had been formulated by that remarkable Englishman Isaac Newton, who had been a student at Cambridge about a century and a quarter before Congreve's day. Newton had explained to the world, for the first time, the nature of the power that made a rocket soar into the air, and the nature of the force that controlled its flight and brought it down again. Early rocket makers had built their weapons without understanding the theories behind them. Congreve therefore had an advantage over them.

The Newtonian theories which are vital to the understanding of a rocket and its flight are the ones usually referred to as the Law of Gravitation and the Third Law of Motion.

Present-day rocketeers talk a great deal about gravity. Almost any discussion of space travel involves mention of the gravitational field of. the earth and the gravitational field of the moon or of whatever planet may be the goal of some contemplated voyage through space. Congreve would not have concerned himself with gravity in this sense. It is likely that he seldom used the word at all in connection with his rockets. But those rockets would nevertheless have to overcome the force of gravity in order to get off the ground, and so he had to take it into consideration whether he actually talked about it or not.

Newton's law of gravitation states that every object in the universe has the power to attract other objects, and that this power increases with the mass of the object and diminishes with its distance. The earth, for example, the largest object in ordinary human experience, has a greater power of attraction than any other object in man's world and therefore attracts all other objects to it. An apple "falls" to the ground because the moment it is released from the tree it is *pulled* toward the ground by this power of attraction.

The earth itself, on the other hand, is attracted by the even greater gravitational pull of the sun. It is this pull—balanced by the centrifugal force which tends to thrust the earth straight out into space—which keeps our planet travelling in its steady orbit around the larger globe of the sun. The same two counterbalancing forces hold the moon in its orbit around the earth.

A man who set out to build a rocket that would reach the moon would have to make a rocket that could fly to that invisible boundary line where the gravitational pull of the moon equals the pull of the earth. From there the rocket would simply "fall" to the moon. This boundary line, of course, is nearer to the moon than to the earth, because the earth, as the larger of the two bodies, has the larger gravitational field.

Naturally Congreve was not even dreaming of such a rocket. His weapon needed only enough gravity-defying force to lift it from the ground and carry it some few hundred yards to an enemy position, where it could wreak its damage as it was pulled back to the earth. But the force that drove his rocket weapon was of the same kind that would eventually drive a rocket into space.

Newton explained this particular kind of force, which is called *reaction,* in the third of the three Laws of Motion he formulated. This law states: *For every action there is an equal and opposite reaction.*

The law and the force itself are best explained this way.

There is a swimmer standing on an unanchored float which rests motionless on the surface of a still body of water. Suddenly the swimmer dives off the float. His body moves through the air at the rate of ten feet per second, landing in the water at the end of a second.

But when he strikes the water the float is not merely ten feet behind him. The float has moved, too. The swimmer's original *action*—the force with which he thrust himself off the float—caused an equal *reaction.* The float was pushed backward as the swimmer plunged forward. If swimmer and float each weighed one hundred pounds, the float moved backward at the same rate the swimmer moved forward—in this case, theoretically, and disregarding the effect of water resistance, at the rate of ten feet per second.

If the float weighed two hundred pounds it would move at only half the hundred-pound swimmer's rate. And if the float weighed four hundred pounds, it would move only one quarter as fast as the swimmer moved. If, on the other hand, the float weighed only fifty pounds, it would move at twice the swimmer's rate.

This illustration of Newton's law can be expressed by a formula which applies equally well to any other illustration. The formula states that mass, represented by the swimmer's body, multiplied by its rate of speed or velocity, invariably equals the float's mass multiplied by its velocity.

Scientists, using the letter M to represent the mass of the acting body, the letter V to represent velocity or speed of that body and the small letters *m* and *v* to represent the mass and velocity of the reacting body, express that formula like this: $MV = mv$.

It would also be possible, of course, to keep the float in continuous motion if a group of swimmers dived from it one after the other.

A rocket zooming through the air is simply another illustration of Newton's law. And the similarity between the moving float and a rocket can be clearly understood by visualizing the rocket, first, as a large cylindrical float sealed at one end and open at the other. If a group of swimmers stood just inside the open end of such a cylinder, and dived off one by one, the cylinder would be thrust into motion in the opposite direction.

A true rocket is thrust into motion in just the same way. It is pushed by the force of objects which "dive" out of its open end. But in the case of the rocket, these diving particles are molecules of gas that are forced out of the cylinder not by muscular power but by pressure. This pressure is built up inside the rocket when the rocket powder burns—when the powder is transformed by heat into billions of gas molecules hurtling in all directions. The gas molecules press against the whole interior wall of the rocket, but they can escape only through its open end. And as they escape—as they "dive" out—they thrust the rocket into motion in the opposite direction.

A single gas molecule, weighing only an infinitesimal fraction of an ounce, has a very small mass compared to the mass of the rocket which is set in motion by its reaction. But the molecules of gas released by burning rocket powder are numbered in untold billions, and they move at enormous speed. In rocket terminology the rocket's *jet* has a high *exhaust velocity*. And, as the formula states, an enormous velocity multiplied by even a small mass can produce a great reactive force.

Only one more aspect of the theory behind a rocket's flight needs to be mentioned here. This is the fact that the gas molecules within a rocket case are not all formed in one single instant. They continue to form as long as the rocket powder continues to burn

—until all the powder has been consumed. They are like a constant stream of divers diving off of a float: they produce a continuous jet for the duration of the burning and keep the rocket in constant motion.

William Congreve learned first of all that the skyrockets he had purchased from the London toymakers could travel only five or six hundred yards—and he knew that the Indian rockets used at Mysore were said to have travelled more than twice as far. So his first task was to increase the range of his rockets, to remodel them so that they travelled farther.

Congreve never published an account of his efforts to do this, probably because he was eager to avoid "any disclosure which might lead to a discovery of the interior structure and combination of the Rocket." He knew that several other Englishmen were also exploring the possibilities of rocket weapons, and he could assume that enemy weapons experts were doing the same thing. He spent several hundred pounds of his own money on his experiments and he followed, as he put it, "various plans." One modern rocket expert suggests that he may have concentrated on his rocket's nozzle, reshaping it in various ways in an effort to increase either the mass or the exhaust velocity of his combustion gases.

By one or more of his "various plans", he finally managed to increase the range of his paper-bound rockets to fifteen hundred yards. Then, because he decided that he could never do any better with his toy rockets, he sought help from the Royal Arsenal. As the son of Sir William Congreve the Royal Laboratory Comptroller, his request was readily granted. Lord Chatham, Master General of His Majesty's Ordnance Board, ordered Arsenal workmen to prepare the larger, sturdier rockets that Congreve desired.

The Arsenal's employees were probably unaccustomed to making rockets by that time. But there may have been a few among them who remembered working under Thomas Desaguliers, predecessor of Congreve's father. Desaguliers had supervised many fireworks displays during his term of office and had been something of an expert on rockets. In any case several good textbooks on fireworks had become available by then. Fireworks makers, once careful to keep their methods secret, as magicians conceal their tricks even now, had finally published most of their designs and their powder formulas. Even the proud Ruggieri family of Italy and France, who had displayed their pyrotechnic skill before half the crowned heads of Europe, had been forced by war-reduced circumstances to reveal the mysteries of their art. *Elements of Pyrotechnics,* by Claude-Fortuné Ruggieri, had been published in 1801.

What Congreve wanted was a rocket that would travel the greatest possible distance and do some damage to its target. For the latter purpose he would have wanted to replace a skyrocket's pay load of "stars" with some kind of charge that would cause a fire or an explosion when his rocket landed.

So the Arsenal prepared for him a rocket cylinder made of heavy sheet iron measuring three and one-half inches in diameter and forty and one-half inches in length. This would hold a considerable amount of powder and would be strong enough not to explode if the powder burned with a near-explosive force. There was probably a clay disc or diaphragm at the mouth of the nozzle, with a hole in it so that the gas could escape. There was probably another clay diaphragm, also with a centre hole, between the charge of powder and the pay load in the rocket's tip. This pay load consisted of a canvas container holding a mixture of saltpetre, sulphur, antimony sulphide, tallow, rosin and turpentine—a highly incendiary compound that would burn for some time. Congreve's container seems to have been spherical in shape, but in earlier rocket weapons these charges were cylindrical bags bound with strap iron hoops. Because the hoops gave them the appearance of a ribbed human body, they became known as carcass charges. A copper hoop, held in place by two smaller iron hoops soldered to the cylinder, attached Congreve's rocket to its sixteen-foot long guide stick.

Congreve launched his rocket by sliding it into a thin-walled copper tube, lighting the fuse that protruded through its nozzle and letting it rise out of the tube into the air.

On the wide marsh that formed the firing range at the Woolwich Arsenal Congreve carried out numerous experiments. Desaguliers had left notes on the most effective angle at which a rocket could be launched, to obtain the best distance. Congreve studied those notes and then proved to himself that the best angle for his own rockets was one of 55°.

He also developed a technique enabling him to use a more explosive powder than the "lazy" or slow-burning mixtures used by the skyrocket makers. This highly-explosive powder would of course generate larger volumes of gas than could be obtained from "lazy" powder, and give his rockets greater speed and range. But for safety's sake the high-explosive mixture had to be tightly compacted into a solid cake so that only the surface of the cake could burn. Loose grains, or cracks in the cake, would permit such rapid combustion that the rocket would explode its case. Congreve dampened his powder with alcohol so that it would have a pasty consistency that would permit it to be jammed into the cylinder as tightly as was necessary. Each cylinder had to be immersed in cold water while it was being packed, in order to reduce the danger of that operation, and it then had to be subjected to a four-month drying period. But the improved performance of the finished rocket compensated for the expenditure of time and effort involved.

By 1805, when Congreve could send a six-pound rocket a distance of two thousand yards, he sought official recognition of his weapon. (The phrase "a six-pound rocket," incidentally, does not mean that the rocket weighed six pounds. It means, in the vocabulary of the skyrocket makers, that the rocket cylinder was presumably of a size to admit a lead ball weighing six pounds.) Congreve was, he says, "resolved to lay before Mr. Pitt a plan for the annoyance of Boulogne by fire rockets."

Congreve's choice of a target was obvious. Napoleon had massed a fleet of ships and landing barges at that French port, and constantly boasted that he would send them across the Channel at the first favourable opportunity. And of course it was understandable that Congreve wanted to display his plan to William Pitt who was then the Prime Minister. But Congreve's strategy for winning the Minister's attention was one that would have been possible to few young inventors.

Congreve was a friend of the Prince of Wales, who liked to surround himself with good-natured young men and pretty women. His parties were famous. His friends said they were marvellously gay, his enemies said they were shamefully rowdy. And the Prince of Wales had plenty of time to enjoy them. Unlike his brother the Duke of York, then commanding soldiers in the field, his position as heir to the throne prohibited him from exposing himself to the dangers of war. But he liked to talk of battles and of weapons, and when Congreve sought an audience at the royal summer residence in the seaside resort of Brighton, the Prince received him joyfully.

The Prince of Wales was instantly captivated by the roaring, whooshing rockets Congreve showed him. To prove his admiration he sent Congreve to call upon Pitt—in his own handsome cutter. Congreve was thereafter able to round up a distinguished audience for the rocket demonstration he conducted on the Woolwich firing range. Lord Castlereagh, one of Pitt's ablest adherents, was there. So was Lord Mulgrave, an experienced soldier.

Neither of those men would have been much impressed by the fact that the Prince of Wales had expressed his enthusiasm for Congreve's weapons. They knew he was inexperienced in fighting and that he made a point of deriding his father's generals and Pitt's conduct of the war. But Castlereagh and Mulgrave were competent enough to make up their own minds. And besides, Congreve had more to show them than just his rockets.

For one thing Congreve was able to point out that in his opinion a rocket of sufficient size would attain a range of three thousand yards. With their lordships' encouragement, he explained, he would continue his experiments until he had reached that goal. He knew Castlereagh and Mulgrave didn't have to be reminded that a ten-inch mortar could send its bomb a distance of only two thousand yards. Furthermore the seven-pound pay load of his rocket—its carcass charge—would be equal in destructive power to the bomb or explosive shell which a ten-inch mortar could fire.

Congreve was also able to point out three other advantages of the weapon he was developing. First, a rocket was essentially a light weapon. British soldiers knew only too well the difficulties of dragging a heavy cannon over muddy or marshy ground. But a single soldier could easily transport, over his shoulder, the light copper tube through which a rocket was fired. And this tube could be set up, on a collapsible tripod, at almost any point and within a few seconds.

Second—and this too was a telling factor—rockets were cheaper than mortar and shells. As proof of this Congreve had drawn up lists of the expenditures required for both. A single ten-inch mortar shell cost the government one pound, two shillings and seven pence, apart from the high cost of the heavy iron mortar or cannon from which it had to be fired. The price of a rocket was only one pound, one shilling and eleven pence, and the expense of its firing tube was negligible. After more than a decade of fighting, which had already forced Pitt to levy the first income tax British citizens had ever known, a cheap weapon seemed a welcome addition to England's artillery.

Third, a rocket had no recoil. It could, therefore, be used on a small boat where ordinary mortars or cannon would be unusable, because their powerful recoil might rock a small boat to the point where it would be swamped. A small boat fitted with rocket-launching tubes would be in no such danger. Congreve disliked the idea of firing his rockets from a boat, but naval experts had convinced him of the value of such a procedure. England's navy, which had been bearing the brunt of the war, was in serious straits. Many ships were held on duty far from the Channel, protecting the English colonies in the New World and harrying the French colonies there. Numerous large vessels were laid up for repair. If rockets could give even a small boat the firing power of a large warship, the British navy would be vitally strengthened.

The trials on the Woolwich marsh had the effect Congreve hoped for them. Castlereagh and Mulgrave recommended to Pitt that the rockets be put to use. It was decided that a barrage of rockets would be sent against the French flotilla lying off the port of Boulogne.

Unfortunately that first use of the rockets was not a complete success, although accounts of it differ. Ten ships, fitted up as rocket launchers, were sent off from England's coast and drew near their target three evenings later. Congreve accompanied the expedition and he wrote afterward that the wind, which had been favourable all day, shifted toward the northwest at about eight that evening. It blew so violently then, that the boats had to back out to sea without firing a single weapon. Other historians, perhaps less prejudiced, say that two hundred of Congreve's rockets were actually sent off that night, but that the total damage they inflicted was to set fire to three houses in the town.

Regardless of what actually happened at Boulogne, the leader of that little British expedition somehow acquired a vast admiration for Congreve's rockets. Commander Sidney Smith talked constantly of the rockets' potential strength against the enemy. He explained to his fellow officers that each one contained a liquid incendiary compound which squeezed out through many holes in the rocket's head at the moment of impact with the target. The liquid set afire any wooden object it touched, and the pointed nose of the rocket kept the projectile firmly impaled upon whatever it struck. Even Lord Nelson, then commanding the British fleet off the Spanish coast, heard of Smith's enthusiasm and sent home a request for some Congreve rockets for use against ships in the port of Cadiz. His supporters at home urged Castlereagh to agree to the request. They pointed out that the threat of an invasion from Boulogne had passed—Napoleon had drawn his forces off to another front—and that it would be wiser to expend rockets against menacing battleships than against deserted landing barges. But in the confusions and stresses of the time Nelson never received the supplies he asked for.

During the winter of that year, 1805, war-weary England was forced to consider an armistice. There was little fighting for some months. But by the following year the long battle was on again, and now England was more desperate than ever. Staggered by the unexpected death of Pitt, and by the defeat at Austerlitz of her temporary allies Russia and Austria, she once more lived in hourly expectation of an invasion from France. Again it was decided to attack Boulogne with a barrage of rockets.

During that anxiously watched second raid on the French port, Congreve's rockets turned the city into a fiery furnace. "In about an hour," Congreve reported, drawing from his own memory of the event, "about two hundred 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."

The prime purpose of the raid, of course, had been to destroy the French fleet. The wind that carried the rockets over the land instead was therefore disastrous from the English point of view. But the burning of a major enemy port was still a reason for considerable rejoicing.

The next year the rockets proved even more effective during the British siege of Copenhagen, which the Danes had refused to surrender. Opening fire at nightfall, from ships lined up off the coast, the British poured a rain of shells and rockets upon the beleaguered town. Well over half of Copenhagen burned to the ground, under a sky lit up as bright as day for five miles around. Fifteen Danish battleships and thirty similar vessels fell into English hands that night—a great victory for England and a great loss to one of Napoleon's allies. Congreve himself had directed the launching of twenty-five thousand of his projectiles during the battle. Later he had a painting made of himself against the background of the flaming city, his great coat flaring wide, his beaver hat raised at arm's length to shield his handsome face from the glare.

Lord Gambier, one of the British admirals who had taken part in the siege, was horrified at what seemed to him a diabolical form of warfare, the use of "infernal machines" against an anchored fleet. He was not the only one who took this attitude. The Duke of Wellington, England's great general, declared that "I don't want to set fire to any town, and I don't know any other use of rockets"—although years afterward he changed his opinion of the weapons. Many civilians, too, after reading the account of the bombardment of Copenhagen, protested that rockets should be outlawed in warfare between civilized nations. And when Congreve took part in the expedition against flat, fertile Walcheren, a Dutch island then in French hands, one of the British soldiers fighting in that engagement wrote in his journal that the "luminous train of the rockets, darting toward and falling into the flames, conveyed an idea to my mind so appalling that I turned away and shuddered."

Other British officers objected to the projectiles for another reason—not because they were hideously effective, but because they were not effective enough. Inaccuracy was one of the faults they complained of. Another was the fact that even a light wind might swing the long guide sticks around and send the blazing weapons back upon the men who had fired them. That catastrophe did actually occur more than once. Nevertheless certain influential military experts—and the non-military-minded Prince of Wales—stanchly supported the value of Congreve's weapon.

In 1813 England finally organized a special Rocket Brigade within her Royal Artillery. There had been talk of such a brigade for several years, and talk that Congreve would be put in charge of it. However a Horse Artillery captain was named head of the brigade and sent with it across the Channel to serve with the Allied forces during the closing months of the war. By then Nelson's victories at sea and Wellington's hard-won successes on land had earned new friends for Britain. Russians, Austrians, Prussians and Swedes were ranged alongside the English troops that drew up outside the city of Leipzig for a mass attack on the Grand Army of France.

The new Rocket Brigade went into action early. Its barrage against the enemy emplacements laid the groundwork for the direct assault that followed. The battle lasted for three days, Napoleon accepting defeat at last. Scarcely a third of his men had managed to escape to safety. The way was at last open for the final and complete conquest of the nation England had been fighting since 1793.

By then Congreve had won all sorts of honours for his contribution to England's war effort. When the Prince of Wales was named Regent, in place of the ailing old king, George III, he made Congreve his equerry and a member of his royal household. Congreve was also appointed to a lieutenant-colonelcy in the Hanoverian Artillery.

This was not a part of England's own artillery, but a branch of the German soldiery that owed personal allegiance to King George because he also ruled the province of Hanover. Congreve seems to have resented the distinction between his command and one in the Royal Artillery, and apparently English military men resented him. There were complaints that he tried to assume authority beyond his due—and the complaints grew louder in 1814, when Congreve's father died and he inherited the first Sir William's title and position. As the new Sir William Congreve, Comptroller of the Royal Laboratory and Inspector of Military Machines, he had frequent conflicts with the Royal Artillerymen who served at the Arsenal. They saw no reason why they should take orders from a man whose actual military rank gave him prestige only among the Hanoverian forces, and the result was a lack of *esprit de corps* at the Arsenal which a visiting Frenchman found shocking.

But the non-military honours which Congreve had acquired by then probably made up to him in part for the slights he received from officers in the British ranks. His portrait had been included in a well-known picture called "Scientific Men of the Day—1807-08." He was named to membership—as "a gentleman well versed in various branches of natural philosophy"—in the Royal Society. He ran for Parliament in 1812 and was elected. After the resounding victory at Leipzig the Czar of Russia decorated him with the Order of St. Anne, and the King of Sweden presented him with the Sword of Sweden. And across the Atlantic, in England's former colonies, he won a curious kind of immortality. To this day Americans who sing in their national anthem about "the rockets' red glare" are singing about William Congreve's rockets.

The story of the engagement that inspired that song is not quite as exciting as the song itself suggests. The United States had declared war against England in 1812, provoked by the fact that her vital trade with Europe had been desperately curtailed by the British blockade of continental ports. There was little fighting at first, and most of it was along the Canadian border. But after Wellington's defeat of Napoleon, when British reserves could cross the ocean to join the fray, the American forces—which had fought half-heartedly until then—rallied to meet them. On Lake Champlain British ships submitted to Thomas Macdonough, the dashing young American commodore. But farther south, at Bladensburg, Md., a small British force fired a barrage of Congreve rockets at untrained American regiments and caused them to "break and flee in wild disorder" from "these ungainly projectiles."

As a result of this skirmish the British were able to enter the city of Washington, only six miles away, and burn the White House and the Capitol building in retaliation for the American burning of the Canadian city of York, later renamed Toronto. An American army officer, writing about the occasion more than a century later, paid grudging tribute to the war rocket designer when he said, "Thus we may indirectly (or perhaps directly) thank Congreve and his invention for the capture and burning of Washington."

The sequel to this event—the actual inspiration for Francis Scott Key's song—came two days later when the British tried to follow up their victory at Washington with an attack on Baltimore. As darkness fell on September 13, 1814, the British fleet began to bomb Fort McHenry with rockets fired from several ships. During that night young Key, who had gone aboard a British ship earlier in the day to arrange for an exchange of prisoners, witnessed the bombardment from the water. Anxiously he watched the "bombs bursting in air" against the night sky. And his relief at the sight of Fort McHenry's flag still flying in "the dawn's early light" expressed itself in the verses he scribbled on his way back to shore the following morning. Fort McHenry had in fact been in little danger. American artillery barrages had sunk one of the rocket barges and caused the rest to retreat. But the spectacular quality of the rockets had won them undying fame. Key's words, set to an old British tune then widely popular, long outlived the weapons they celebrated.

At the time, however, those words probably seemed dramatically descriptive of one of the worst terrors of war. By the year 1814, when England's long war with France was finally ended, Congreve's rockets were considerably more destructive than they had been at the occasion of their first use.

They were no longer simple incendiary weapons that might, with luck, start a fire at the place where they fell. Some of them carried explosive charges that detonated on contact, by a firing arrangement that was set off when the rocket head struck the ground. The sizable battery of rocket weapons which Congreve had developed, over the years, ranged from a small twelve-pound rocket carrying a charge of forty-eight carbine balls to a forty-two-pound rocket that carried a carcass charge weighing eighteen pounds—or a spherical bomb that weighed twelve pounds.

By then Congreve was making other improvements on his rockets in addition to increasing their size and varying their charges. For one thing, he was changing his cylinder into a conically shaped case, slanting inward toward the back. The Italian fireworks expert Ruggieri wrote angrily some years later that the idea had been stolen from the book he published in 1801. Actually the idea was even older than that. It had been described in a treatise on pyrotechnics written by a Frenchman named Frézier and published in 1741. Napoleon had carried a copy of that book with him on his campaign of conquest in the East, presumably so that his men could prepare suitable fireworks displays to celebrate his victories in Egypt and India. So it seems more than likely that Congreve knew of the book, too.

At any rate the conical case had one advantage, whether Congreve foresaw it or not. Because it was not possible to mount a guide-stick along a slanting case, the stick was thereafter screwed into the centre of a metal plate at the rocket's base. Five holes in that base, surrounding the stick, served as five small nozzles for the escaping gases. This design improved the rocket's accuracy to a point where it equalled the accuracy of guns in use at that time.

Congreve had become convinced that his rocket would eventually replace all artillery. He repeatedly emphasized its cheapness. But the fact that it did away with the need to lug cumbersome cannon from place to place, or to build large ships for the mounting of large guns, seemed to him of paramount importance. He pointed out that a gun capable of throwing a twelve-pound shell weighed approximately a ton, whereas a tube for firing a rocket of the same size weighed only twenty pounds. A rocket, Congreve said, in a phrase rocketeers would remember for years, was "ammunition without ordnance; it is the soul of artillery without the body."

When he published his plan for attaching rocket artillery units to the cavalry, Congreve obtained permission to dedicate it to the Prince of Wales in deference to His Royal Highness' "consummate knowledge" of such matters. But he was also able to refer to the approval of another man whose opinion would be more impressive to military experts. The English admiral Lord Cochrane, Earl of Dundonald, had declared that neither men nor horses could "stand a repetition" of rocket fire. That fire was, Cochrane said, "much more terrific" than the whistling of howitzer shell or cannon ball.

Congreve was proudly aware all during the war that military men in other lands had been trying to obtain samples of his rockets in order to discover the secrets of their manufacture. When peace was finally established in Europe many of these men came to England to purchase rockets for their own arsenals, or to learn enough about them so that they could build their own rocket factories. Naturally they sought out Congreve and flattered him with their compliments and their attentions.

Under the circumstances he might have been contemptuous of the role his country expected him to play during its victory celebrations: as Comptroller of the Royal Laboratory he was expected to furnish fireworks displays to mark England's triumph over Napoleon. But as equerry and close personal friend of the Prince Regent, and therefore accustomed to arranging parties and fêtes of all kinds, Congreve probably welcomed the task as an amusing gesture of homage to his gaiety-loving monarch.

He didn't attempt to have all the materials for the displays prepared at the Arsenal. He ordered most of them from the professional pyrotechnists then becoming more numerous in Europe. And he didn't try to equal certain fabulous exhibitions of the past, such as the occasion in 1749 when the famous Ruggieri family—at the special invitation of George II—had startled London with eleven thousand soaring skyrockets and thousands of other kinds of fireworks. Nevertheless the 1814 Victory Fête in the nation's capital was a memorable event much enjoyed by the Prince and his people, who had not witnessed such a sight in many long years. The Prince Regent, unlike his father, was not afraid to spend public money on amusement. He had ordered not one but several displays to be presented on the night of August 1 in Hyde Park, Green Park and St. James's.

At Hyde Park there was a mimic naval engagement on the Serpentine, followed by aquatic and aerial fireworks. At St. James's Park a yellow and black Chinese pagoda and bridge were illuminated with gas jets. A display of fireworks was set off from the pagoda's roof to climax the exhibition—although the actual climax proved to be a fire which consumed the pagoda and injured several people. The conflagration was blamed on the fireworks, but it was probably caused by the heat of gas jets set too close to the flimsy structure.

At Green Park a squat turretted structure known as The Castle was transformed, by a "grand Metamorphosis," into the "Temple of Concord." Transparent paintings, slowly illuminated from within, seemed to change the sturdy stone walls into a gilded and festooned fantasy that glittered in the gold glow of bursting skyrockets. The gentle essayist Charles Lamb, although distressed by the unruly crowds trampling over the lawn that night, wrote that "the fireworks were splendent—the Rockets in clusters, in trees and all shapes, spreading about like young stars in the making, floundering about in Space (like unbroken horses) till some of Newton's calculations should fix them. . . ."

But there was no reason for Congreve to suspect that when people were still reading Lamb's essays a hundred years later, and still delighting in starry skyrockets, his own rocket weapons would be entirely forgotten. Rocket factories were being erected in Warsaw, Turin, Toulon and Metz, and almost every country in Europe would soon form its own rocket brigade. As time went by, some of those foreigners made their own improvements on Congreve's design, while Congreve added still others. He experimented with the substitution of a weight and chain, or a cord, for the guide stick—an idea he had adopted from Frézier.

In 1826 Congreve patented still another Frézier idea, a method for attaching two or more rockets together, with the head of the first touching the base of the second. When the first rocket burned out—at the moment when it would normally be igniting the pay load in its head—the last bit of fire served instead to ignite the second rocket, thus giving the projectile a new source of power for further flight. But this idea—on which all rocket experts today base their hope of obtaining extreme altitude or extreme range—was not even new when Frézier suggested it. A fireworks maker named Johann Schmidlap, who published a description of fireworks construction methods in 1591, in Nuremberg, had written that a pyrotechnist could obtain an interesting effect by building a small rocket inside the head of a large one—the first so-called step rocket ever described.

In the meantime in 1817, Congreve had become senior equerry to the Prince Regent. Three years later George III died and the Regent, now George IV, formally acceded to the throne. Congreve, still his equerry, probably spent much of his time at court, at least until his marriage in 1824 to the widowed Mrs. Henry Nisbett M'Evoy. In 1820 he was re-elected to Parliament as the member for Plymouth, a position he held for eight years until his death. Nevertheless he still exercised his mechanical bent on various ingenious inventions, some involved with rocketry, some widely divorced from that field. As early as 1813, when England was, as someone said, canal-mad, Congreve invented a hydropneumatic canal lock and sluice. In 1819 he published his description of *A New Principle of Steam Engines*. In the years that followed he worked out a method for consuming smoke, which he installed in the Royal Laboratory; a gun-recoil mounting and a time fuse; a clock in which time was measured by a ball rolling on an inclined plane; a process for inlaying and combining metals; a gas meter; and a perpetual motion machine.

Another quite different field interested Congreve, too. He devised and patented a paper on which unforgeable bank notes might be printed, and he developed a process of colour printing that became widely popular in Germany.

Two of his other ideas obviously derived from his experience with rockets. One was an improvement in the process of gunpowder manufacture. The other, developed in collaboration with a Lieutenant J. M. Colquhoun, was a method for killing whales by the use of rockets. The subsequent use of whale harpoons carrying explosive charges proves that this particular plan was basically workable, although Congreve's rocket was not eagerly adopted by the whalers of his day. Probably its major disadvantage lay in the fact that rockets still could not be fired with any great accuracy.

This failing of Congreve's rockets—of any war rockets of that period—is the real reason why they were eventually abandoned. By 1870 most of Europe's still-young rocket brigades were already disbanded. The rocket was losing ground* with military experts because the gun was gaining ground. And the reason for this latter development was that the idea of rifling had been introduced.

A gun or a cannon with a rifled bore—a spiralled groove cut into its inner wall—could achieve an accuracy that soldiers had only dreamed of before that time. The projectiles fired from such a bore had a rotary movement that carried them straight toward their objective.

* With the great advances in rocketry military opinion has now come full circle: a guided weapons regiment has been formed within the Royal Artillery, and the American Navy is in the process of abandoning the gun in favour of guided missiles.

Rocket makers too began to try to impart a rotary motion to their projectiles. The most successful was William Hale, who designed a completely stickless rocket—which Congreve had been working toward. Hale's projectile was stabilized by three metal vanes set at an angle into the exhaust nozzle. The idea behind those vanes was perfectly sound. The gas escaping past them caused the rocket to spin with the rotary motion Hale desired. A few countries adopted Hale's rocket, but not for long. It was too late. Rifled artillery was proving its worth. The "body" of artillery, which Congreve believed he had made totally unnecessary, had become the source of a projectile's greatest value. The last recorded use of war rockets, in Congreve's century, was by the Russians in their war against Turkestan in 1881.

It is true that the nineteenth century saw other valuable uses for rockets. Congreve designed an illumination flare that was carried up into the air by a rocket and suspended there temporarily by a parachute released at the peak of the projectile's flight. It was a useful tool for a commander seeking an enemy's position at night. It was equally useful as a primitive floodlight to illuminate fortification-building or other chores that an army must often perform despite the coming of darkness.

The line-carrying rocket and the signal rocket were two other versions of the skyrocket which nineteenth-century inventors developed to a high degree of usefulness. Both were designed to save lives and property rather than to destroy them.

An idea for the first occurred to a Cornish cabinetmaker named Henry Trengrouse, as he watched the frigate *Anson* driven aground during a storm. Her crew, separated from safety by only sixty yards of raging water, perished to a man. Trengrouse, pondering a means for rescue in such a situation, hit on the idea of using a variation of the skyrockets he had enjoyed on Guy Fawkes Day and other holidays. He tried to persuade the British government of the soundness of his idea that a rocket fired from a musket barrel could carry a line to a foundering ship. The musket would give the rocket a certain velocity even before it ignited, thus increasing its range. After Trengrouse had spent three thousand pounds of his own money, and staged a demonstration in Hyde Park, the government ordered twenty sets of his apparatus in 1818. But most coast guard stations continued to use other and less effective life saving devices, until the rocket itself became a more powerful projectile.

Then, in 1855, an artillery officer named Edward M. Boxer developed a step rocket for carrying lines from coast guard stations to ships foundering near the shore. The more modern apparatus which replaced it, and which is still in use today, was designed by William Schermuly. It is a line-carrying rocket fired from the opposite direction—not toward a foundering ship, but from the ship itself to the shore. The line it carries is a light one, but a heavier line can be drawn to the ship once the light line has reached land.

Signal rockets were much in use in the nineteenth century too, before the development of radio made them obsolete. Most shipping lines had their own rocket signals, distinguished by a variety of colour patterns. From far out at sea British vessels could announce their safe arrival to the shore station maintained by Lloyds, the maritime insurance firm. One importing line, specializing in bananas, developed a highly elaborate code by which a captain could send advance warning of the cargo he was bearing to port. Soaring coloured rockets announced the number of bunches of fruit in his hold, and the fruit's condition, whether green, ripe or "ripe and turning." And the firm's agents, alerted by such messages, could take orders for the fruit before the ship itself was even in sight.

But long before the nineteenth century was ended the general public once more thought of rockets as Congreve undoubtedly thought of them in his childhood. Except for their specialized uses as line-throwers and signalling devices, rockets had returned again to the hands of the toymakers. The word rocket again meant a skyrocket, a pretty plaything that carried with it no threat of destruction.

This development would undoubtedly have been a bitter blow to Congreve if he had lived to see it. But when he died on May 16, 1828, just four days before his fifty-sixth birthday, he still believed firmly in an increasingly glorious future for the weapon he had made famous. His faith in the rocket was one of the few things left to him by then.

He had lost the use of his legs, although he still managed to get about in an ingenious wheel chair he devised, that could also serve as a bed. Few of his industrial ventures had proved successful. Finally, in an effort to recoup his failing fortunes, he had become involved in one of the South American mine exploitation schemes which characterized the torrent of speculation in England in the twenties. Like many such schemes it brought collapse and shame to those who took part in it. Congreve was accused of fraud before the Court of Chancery and was unable to clear himself completely of the charge. His position as a Member of Parliament was not enough to save him. Neither was his long-established place at the side of the King, whose own unpopularity probably reflected on his senior equerry. Congreve left England in disgrace, to spend the rest of his life in exile. He died just three months later in France, in the city of Toulouse, and was buried there.

Among the papers found after his death were plans for a rocket with an eight-inch diameter, and hopeful notes on the possibility of rockets weighing as much as five hundred and one thousand pounds. But though no models were ever built from those notes and those plans—and probably could not have been built in his century—Sir William Congreve had already served a real function in the development of the rocket. He had pushed the powder-fuelled rocket to the limits of its capabilities within the knowledge and the fuels available to him. And he had paved the way for the men who would come after him—men whose imaginations would visualize a new role for the rocket, and whose ingenuity would supply it with the power it needed to play that role.

Today the unhappy and frivolous aspects of Congreve's life are almost forgotten. But his contributions to rocketry will assure him a permanent place among the pioneers of that science.