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(Selected Articles)

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IS SPACE NAVIGATION POSSIBLE? (2)

by Yi Lin

How Much Energy is Needed For Space Navigation?

Within the next several decades, following developments in modern science and technology of atomic energy, electronics, metallurgy and macromolecular materials, the first stellar probe will perhaps be a highly developed computerized robot. It will not only be able to automatically complete various stipulated tasks but will also be able to act according to circumstances and alleviate difficulties. Its life span will be the same as that of a human. Its weight will not exceed 100 kilograms which is no greater than a space suit worn by an astronaut. Yet, even if this type of very light probe is allowed to reach one-third the speed of light the needed energy will still be greater than 100 billion kilowatt hours. This energy is approximately equivalent to the total electric output of a modern medium sized advanced nation in a whole year. However, when the actual acceleration reaches to the highest speed, aside from the probe, there are also the huge space rocket structure, engine and guidance system. Their weight far surpasses 100 kilograms and therefore the energy needed for space navigation is 100,000 times greater than 100 billion kilowatt hours.

If chemical fuel is used for such great energy, this is equal to using a match to ignite a hydrogen bomb which is a very ridiculous idea. Where is there a way out? It is to depend on the transformation of mass to create energy. Based on Einstein's formula, there is the following mutual relationship between energy and mass:

energy = mass x (speed of light)

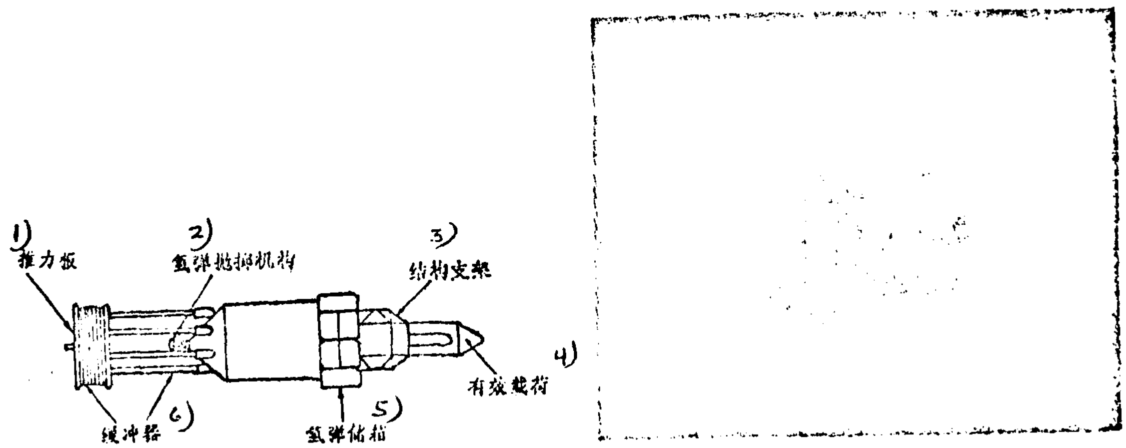
100 billion kilowatt hours of energy is converted into 5 kilograms with its joined mass. This is to say that it is only necessary to "consume" 5 kilograms of mass to be able to have a 100 kilogram weight accelerate to one-third the speed of light. This seems to be very "inexpensive."

Yet, up until now, the transformation of mass as a process of energy can only be partially realized in nuclear fission and in nuclear fusion reactions. In a thermonuclear engine, the energy "consumed" in the transformation of mass is shown in jet speeds. Under ideal conditions, if the jet speed reaches to one-half the speed of light, the "consumed" mass should be 14% of the reaction matter, the jet speed will reach to one-third the speed of light and the "consumed" mass should be 6%. Yet, at present, what we can predict is that in future transformation efficiency, the highest thermonuclear reaction will be a deuterium fusion which will cause a helium reaction. In this reaction, the mass that is transformed into energy does not reach 1% of the total reaction matter and there is one part of the energy that is lost by changing into heat. Therefore, the greatest jet speed reaches to one-twentieth the speed of light which is also 15,000 kilometers per second. This speed is already 4,000 times that of modern rocket jet speeds.

Jet Speed and Mass Ratio

Is a jet speed of 15.00 kilometers per second sufficient to fly towards the closest star? In order to answer this question, we must talk about the fundamental principles of rocket movement.

The greatest speed of a rocket is determined by two factors. One is jet speed and the other is called the rocket "mass ratio." The greater the jet speed or the greater the mass ratio, the greater the largest speed attainable by a rocket. The rocket mass ratio is the ratio of the rocket's initial weight and air-born weight (the weight when the propellant is burned up). This ratio value reflects the specific weight occupied by the propellant in the whole rocket and the greater the proportion occupied by the propellant the greater the mass ratio.



图二　左为脉冲式热核发动机示意图，右为设想图

Chart 2 On the Left is a Schematic Drawing of an Impulse Thermonuclear Engine and on the Right is an Envisaged Drawing

1. Thrust board

2. Hydrogen bomb throw structure
3. Structure support
4. Effective load
5. Hydrogen bomb storage tank
6. Bumper

Therfore, we must think of attaining relatively great speeds. This can be initiated from two aspects, raising the jet speed or increasing the mass ratio but most important is raising the jet speed.

When the required highest speed is at a fixed value, the greater the jet speed the smaller the needed mass ratio. Generally, it is best for the jet speed to be equal to or near the greatest speed required for the rocket. At this time, the required mass ratio is not greater than 5 and this is relatively easy to accomplish. Following the decrease of the jet speed, the mass index ratio law quickly rises. For example, when the jet speed is one-twentieth the speed of light, the greatest speed will reach one-half the speed of light and the mass ratio will increase to 60,000; when the highest speed is one-third the speed of light, the mass ratio will be 1,000. Neither of these can be accomplished. Due to the limitations of materials strength and technological conditions, the greatest mass ratio of a single stage rocket can reach to over 10 and the total mass ratio of a multistage rocket will reach 500.

The following shows the rocket's mass ratio attained at different greatest speeds when the jet speed is one-twentieth the speed of light. It can be seen from the table that the greatest speed in navigation cannot exceed 30% of the speed of light.

Greatest Speed	0.1 C	0.2 C	0.3 C	0.4 C	0.5 C
Mass Ratio	7	56	500	4,700	59,000

Envisaged Space Navigation Engine

We can see from the previous discussion that the key in realizing space navigation lies in raising flight speed and the key to raising flight speed lies in raising the jet speed. The jet speed is determined by the engine and thus in the final analysis the key to whether or not space navigation can be realized is whether or not a super strong space navigation engine can be successfully developed.

Up until the present, space navigation engines have been in the envisaged or predevelopment stage. People have suggested tentative plans for five types of space navigation engines.

1. The Impulse Thermonuclear Engine

In reality, this type of engine is a chain of hydrogen bombs whereby the bombs produce impulse waves and particle flow which spurts in a certain direction and produces a reaction force to propell the space navigation rocket. Chart 2 is a schematic diagram and envisaged drawing of an impulse thermonuclear rocket.

The rocket's gross weight is 400,000 tons, it carries a 40,000 ton spacecraft and uses 300,000 hydrogen bombs for power with a weight of 360,000 tons. The remaining 100,000 tons are the rocket's structure, thrust board and hydrogen bomb storage and throw structure.

Each explosion of a hydrogen bomb provides a speed of 30 meters per second. The force of the hydrogen bomb explosion goes through the thrust board and

and bumper causing the rocket to have a continuous mean acceleration of 1g.

The hydrogen bombs explode at 3 second intervals. They are used up in 10 days, speed reaches 10,000 kilometers per second (one-thirtieth the speed of light) and flying to Centaurus "a" star requires 130 years which is too long. Yet, from the present point of view, among the various types of envisaged space navigation powers, this tentative plan is considered the most realistic. This is because the manufacture, storage and use of the hydrogen bomb have already been successful. Recently, successful tests have also been done using a laser or electronic beam close to the speed of light to excite the hydrogen bomb so as to reach the extremely high temperature needed for explosion and thus need not use the atomic bomb to cause the explosion. This type of hydrogen bomb can be made in a pellet size and thus greatly shrinks the structure of the space rocket.

2. Controlled Thermonuclear Engine

A controlled thermonuclear reaction has still not been successfully tested. The major difficulty is that the temperature during nuclear fusion reaches to several hundred thousand degrees and there is no vessel which can withstand such high temperatures and "accept" it. Aside from this, as soon as the plasma gases produced by the reaction come in contact with the vessel, the temperature immediately drops and the reaction is quickly broken off. Because the reaction gases are all charged with deuterium and tritium ions therefore at present research is being done on using a magnetic field to "accept" it and at the same time uses the magnetic field and electrical field to produce a maintained reaction needed for the extremely high temperatures. This is the so-called "magnetic bottle method." The sealability of the "magnetic bottle" is not good and there exists the problem of the gas "escaping" to the outside. Yet, when used in space navigation, it can be changed from harmful to beneficial. The benefit of using reaction gas to "escape" in a certain direction can produce the jet reaction thrust hoped for.

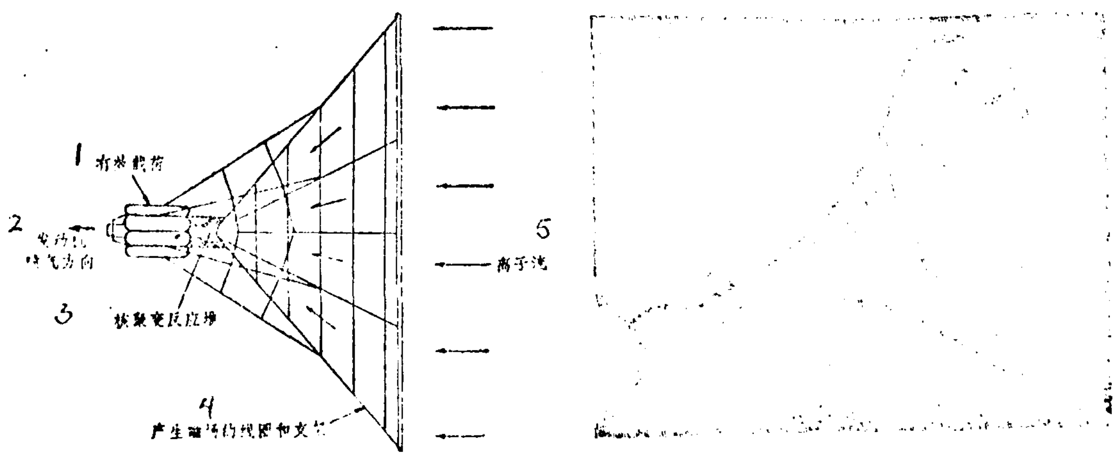
At present, it is hoped that most of the various predeveloped and tentative plans for space navigation can be based on successful testing of controlled thermonuclear reaction engines. Now, people are enthusiastically carrying out development work and the day of mankind's controlling of thermonuclear reactions is not far off; the controlled thermonuclear engine will become the future hope of the greatest space navigation engine.

3. The Impulse Space Navigation Engine

Because the jet speed ratio of the controlled thermonuclear engine is much smaller than the greatest flight speed, the mass ratio needed by the rocket is very large. When a space rocket leaves the solar system, it must carry several hundred thousand tons of nuclear fuel. In order to resolve the problem of the excessive weight of the fuel, people are researching the impulse space navigation engine. Its special feature is that it only has a nuclear fusion reaction pile and the nuclear fuel needed for fusion - deuterium, is exacted from outer space.

Vast outer space is empty yet is not without anything. Everyplace in outer space is filled with minute interstellar matter and is composed of hydrogen ions and atoms. The most dense places do not exceed 1,000 atoms per square centimeter which is 1% of that of the atmospheric density of an altitude of 1,000 kilometers above the earth. Places where density is small have only one per square centimeter. Among the interstellar matter, there is one deuterium atom per 8,000 hydrogen ions. The impulse space navigation engine calculates the use of these deuterium for fusion fuel and because the density of interstellar matter is extremely small it is necessary to have a very large intake opening to absorb the interstellar matter.

Chart 3 is an envisaged drawing of this type of engine. The space navigation rocket resembles a large, open-mouthed cosmic shark, one end swims forward and the other is a large mouth swallowing interstellar matter. The front side has a funnel shaped large mouth. Places where the density of interstellar matter is great, the largest diameter is 60 kilometers; in places where density is small the diameter reaches 2,000 kilometers. It is a difficult problem to build this type of funnel. It cannot use any tangible materials because the interstellar material collide at speeds of several thousand kilometers per second so that the funnel can very quickly lose strength and performance. It can only be of a tunnel shaped large magnetic field and use magnetic power lines to catch hydrogen ions.



图三　左为冲压式航宇发动机示意图，右为设想图

Chart 3 On the Left is a Schematic Drawing of the Impulse Space Navigation Engine and on the Right is an Envisaged Drawing

1. Effective load
2. Engine jet direction
3. Nuclear fusion reaction pile
4. Produced magnetic field coil and support
5. Ion flow

4. Laser Power

When a light shines on an object this can produce pressure. Even though this pressure is very minute it only needs to shine on a large enough surface and the produced pressure will be able to be used to propel the airship.

Some people envision building a huge laser array in the nearest inter-stellar space and directly transform solar energy into a laser (chart 4). The diameter of the laser array must be as large as 250 kilometers to be able to guarantee that the light beam is transmitted a distance of 6 light years and it is unlikely to be distributed too strongly. A large sail is fitted on the spacecraft to directly receive laser irradiation and the diameter must also be 250 kilometers. The sail is made of thin, light and solid materials which must completely reflect the light rays so as to attain the greatest light pressure. It is estimated that the weight of the sail cannot be less than 1,000 tons.

Chart 4 Envisaged Chart of Laser Propelled Sacecraft

When the spacecraft is not very far from the solar system, it can first use a 10 kilometer diameter laser array as the power source..

The plan to use the laser to directly propel seems a little imaginary, yet, because it does not require complex nuclear reaction pile equipment it can save several hundred thousand tons of nuclear fuel. Because of this, it has gained people's attention. A relatively realistic plan is the use of the laser beam for the energy source, thermonuclear fuel,, excitation of nuclear fusion and the production of jet thrust as mentioned previously.

5. The Anti-Matter Engine

Based on the law of the unity of opposites in material dialectics, since the objective world has matter, its opposite, anti-matter, must also exist. The continuous appearance of anti-electrons (positive electrons), anti-matter and anti-neutrons provides an experimental basis for the creation of anti-matter.

When matter and anti-matter interact it resembles what was pointed out in Einstein's formula; all of the matter transforms into energy. Energy is radiated in the form of gamma rays, neutrino, high energy electrons and positive electrons (electrons with a positive charge). Yet, within this, half of the energy is quickly taken away by the neutrino and there is also a small portion that changes into heat and is lost. Jet speed can be raised to one-fifth the speed of light. In order for the spacecraft's highest speed to reach one-third the speed of light, mass ratio must be 6. Anti-matter only needs to occupy 2% of the take-off weight.

In a large scale, high energy accelerator, the use of a super strong proton flow bombardment of 1,000 trillion protons per second can produce anti-protons. Yet, the most anti-protons that can be produced each year is several kilograms which is used in high energy physics experiments. We need to attain a number that can act as propellants but the earliest this is possible is the 21 st century. Furthermore, even more difficult than producing anti-matter is storing it, controlling decay and realizing an anti-matter engine. These are all the newest research problems confronting modern nuclear technology.

The above discussion focused on introducing the conditions in space navigation plans and tentative plans of engines for interstellar space navigation. Yet, the realization of interstellar space navigation is involved in resolving these problems. For example, the problems of guidance and communications in interstellar space navigation still await resolution.

The next issue will take one hypothetical space navigation journey as an example and discuss the course of space navigation.

THE UNIT STRUCTURE

by Hong Debin

At present, when the United States, England or France design new engines they usually use unit structures which is very advantageous for the fast installation, dismantling and safeguarding of engines and has important significance for raising the operation rates of aircraft.

Why is it Necessary to Use the Unit Structure?

Power equipment for an aircraft requires an engine with a small area, that is light in weight and that emits the required thrust. The work conditions for engines are very harsh. Parts for the combustion chamber, turbine and afterburning combustion chamber work under very high temperatures. In the afterburning turbine fan engine turbines used by the military, the temperatures are very high and even reach 1,370°C and has a tendency to rise. However, the parts for the fan, gas compressor and turbine also work at very high rotation. Taking the American's newly developed F100 engine as an example, the tangent speed of the long and thin fan blade tip has already reached 400 to 470 meters per second.

In order to guarantee that the engine work normally and reliably under poor conditions and as far as possible extend its life span. The design and development of modern engines not only require that a great deal of theoretical and experimental work be done to guarantee the product's quality but after it is installed, it is also required to regularly and carefully service it. One engine is usually composed of several thousand components, for example, the afterburning Sibei (?) engine used by the military has over 5,000 components and among these several thousand components, there are certain component damages including the relatively small standard parts damages of closed and sealed parts. All of these can cause serious damage to the whole engine and even the whole aircraft.

The earliest designed engines did not use unit structures and examination and service was very strenuous. All internal breakdowns were always difficult to discover beforehand. When a breakdown occured, especially damage to the internal components and it was necessary to repair and replace parts they had to take the engine down from the aircraft, transport it to a repair factory and then take it apart and repair it. As for rotating parts such as the gas compressor and turbine, after replacing components, it was necessary to again balance them, have trial runs and send them back to the airfield to be fitted on the aircraft. Not only were safeguard costs high but a lot of time was wasted. An engine is a costly machine, its life span is relatively short and there are many chances for breakdowns. If there is a lack of a sufficient number of spare engines this can effect the rate of aircraft put into operation and the aftereffects are not difficult to imagine.

In order to resolve the above mentioned contradictions, in recent years, England, the United States and France have newly developed some engines which commonly use unit structure designs or standard component structure designs.

The unit structure is a type of new and original design form. The whole engine is divided into a small number of components, about 6 to 10 large independent sections. These large sections are interrelated and each part stands on its own. Each large independent section is called a unit. For example, the fan unit of the RB211 engine can be divided into the fan blade, disc and axis untis.

Each unit can be dismantled and installed on the aircraft which does not effect the other units and does not effect the balance of the rotor or the performance of the whole engine.

In using the unit structure engine, when certain components and parts are damaged and require replacement, the components which need to be replaced in a certain unit can be taken from the engine in the airfield or even directly from the aircraft and the new unit can be put in. Because the rotating part units are balanced well beforehand, the unbalanced weight is seriously controlled within a certain range. Therefore, when a unit is replaced, it is not necessary to rebalance and it is also not necessary to have a performance trial run. Generally, it is only necessary to examine the engine once by driving it.

The French State Operated Engine Research and Development Company began developing the turbine fan engine M53 in 1969. It is composed of 10 units which are the low pressure gas compressor, the gas compressor heavy casing, the high pressure gas compressor, the combustion chamber, the high pressure turbine guide, the turbine, the turbine heavy casing, the afterburner diffuser, the afterburner tube and the jet nozzle.

The power of the modern large model wide body passenger DC-10 has a large scale CF6 turbine fan engine and its single thrust is over 20,000 kilograms. The unit structure of this engine which is shown in chart 1 below is composed of 5 units: a fan, a high pressure gas compressor, a combustion chamber and high pressure turbine, a low pressure turbine (including the casing) and an accessory transmission.

The unit structure of the modern RB211 turbine fan engine is composed of 7 units: a low pressure fan rotor, a medium pressure gas compressor, a medium pressure and low pressure turbine, a high pressure system, the middle casing of a medium pressure/high pressure gas compressor, a fan casing and an outer transmission casing.

In order to guarantee that after installation the balance of the rotor is not ruined in a RB211 engine, each joining part in the rotor uses curved face hitch couplers. Their function is to allow each joining part to have good concentricity and be convenient for fast installation and dismantling. Naturally, the machine precision for this type of coupler hitch must be quite high.

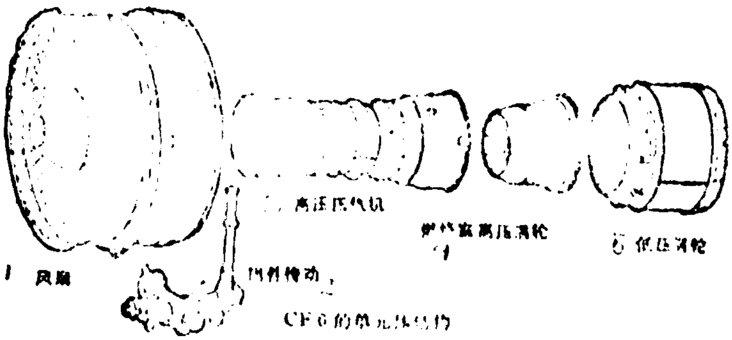


Chart 1 Unit Structure of the CF6

1. Fan
2. Accessory transmission
3. High pressure gas compressor
4. Combustion chamber high pressure turbine
5. Low pressure turbine

The Unit and Visual Maintenance

The aim of using the unit structure is to improve the maintenance performance of the engine. For the non-unit structure engine, there is usually formulated a repair life span. The so-called repair life span is the amount of time from when the engine officially leaves the factory to before it returns to the factory for repairs. In the repair life span of an engine, it must be taken out of the aircraft, packaged and sent to the repair factory to be dismantled, examined and repaired by improving the decreased performance or replacing components. During the process of packaging and moving in inclement weather or installing and dismantling there is the possibility of other components being damaged. However, after using the unit structure in the engine it is convenient to realize positive visual maintenance techniques.

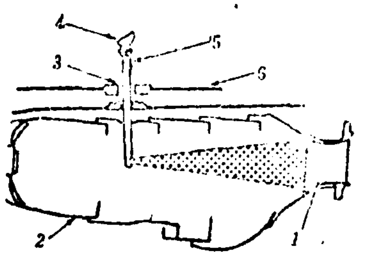
The use of visual maintenance techniques does not stipulate the maintenance life span of an engine but gives serious supervision and control for the important parameters of the engine, for the prediction of the discovery of breakdowns, for accurately appraising problems that occur in the unit and based on conditions replace units that are below the safety coefficient. Before discovering signs of breakdowns, no matter how long the work time, all can be continuously employed. There are antecedants, annotated models, series numbers and the amount of time used for each unit including each occasion of repair and the content of replacing components. It is necessary to separate and

and repair replaced units and after attaining a stipulated technical performance it can enter the warehouse as a spare unit.

The work conditions for each unit in the engine are different. For example, the heat tip combustion chamber, turbine and afterburner operate under high temperatures and the chance for breakdowns is greater than cold tip components (gas compressor and accessory transmission) and there should be more spare units. Visual maintenance can be directed at concrete situations or treated separately which is better than using the repair life span. Aside from this, units are easier to transport and storage than whole engines and they are very convenient under war conditions.

How can visual maintenance be done well whereby the various signs of breakdowns in the engine are perceived? This requires experienced and careful control of engine work and reliance on the "conditions control" system for completion. Conditions control is generally divided into flight and ground control. Flight control includes cockpit indicators and aerial recorders. The cockpit indicators are used to control the parameters of engine thrust (or power), rotational speeds, turbine temperatures, oil pressure and vibration. Aerial recorders are used to record the condition parameters of the engine and following this there is processing and analysis and at the proper time it examines the major signs during the initial period of a breakdown. Ground control is the examination and discovery of breakdown signs on the ground including the following forms.

Visual examination of the position of the fans, exhaust system and external pipes, The use of a detector to investigate the important parts inside the engine such as the burner tube, turbine guide, turbine blade and gas compressor blade. The detector can be rigid or flexibie, it can sense perceive or be angular and sometimes can also take pictures. The detector investigates by being inserted in a hole on the engine's casing into the engine. The quantity and position of the detector determines the structural conditions of the engine, yet, it is necessary to guarantee that the above mentioned important components are examined. The chart below shows the use of a detector to investigate a high pressure turbine guide blade.



用孔探仪检查涡轮导向叶片

1. 涡轮导向叶片　2. 燃烧室
3. 检验孔　4. 目镜　5. 孔探仪
6. 发动机机匣

Chart 2 The Use of a Detector to Investigate a Turbine Guide Blade

1. Turbine guide blade
2. Combustion chamber
3. Investigation hole
4. Eyepiece
5. Detector
6. Engine casing

The use of a gamma ray source to take pictures by going into the empty part of the engine's low pressure rotor axle so as to measure the size and measurement changes in the clearances of the key parts.

The use of a magnetic pin pickup (also called a magnetic spiral stopper) to examine whether the important components of the necessary lubricated bearings and gears are damaged. The magnetic pin pickups are all fitted on the outside so that the hand can easily take them out.

At present, the control systems of aviation engine conditions are still being developed and we believe that following the great strides in science and technology they can be gradually improved.

Conclusion

The first engine in the world to use the unit structure was the British Yilande (?) turbine propeller engine built during the 1950's. Yet, for various reasons it was not given much attention. After over 10 years, this type of new and original design idea was used in the American JT-9D engine and was shown to be superior. It was quickly expanded to many of the major engine manufacturing companies in the West. After that, many newly developed military and civil aviation engines used the unit structure design.

It is worth noting that the unit structure not only resolved the problem of the exchangeability of similar units in the same type of aircraft but also opened up vistas for the standardization for many of the engine parts and components which were considered difficult in the past. At present, nations in which aviation industries are advanced all use the advanced core engine and take it as the basis for the development of a series of derived engines. Even though these engines of the same family are a changed form of the same core engine, the units can be interchanged. This expands the "three changes" range and is highly significant both economically and militarily.

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