Space shuttle advancements and avionics integration

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Abstract: **The successful exploration of space requires a system that will reliably transport payloads into space and return back to earth; space shuttle was a partially reusable low earth orbital space craft. The space shuttles used at older times were not re-usable. Space shuttle operations are one of the biggest challenges at the time of starting but now days it become a technological challenge in between nations. This paper would be covering the following points: A brief history of the space shuttle, the space shuttle mission, Space shuttle operations, and Advance mental approaches in space shuttle development. However the Space shuttle programme is promising innovation whose innovation will lead to technological growth and so many researches.**

***Keywords*: Air breathing engines, Space transportation system, Orbital maneuver, Avionics**

1. Introduction

The successful exploration of space requires a system that will reliably transport payloads into space and return back to earth, without subjecting them an uncomfortable or hazardous environment. In other words, the space crafts and its pay loads have to be recovered safely into the earth. The space shuttles used at older times were not re-usable. So NASA invented re-usable space shuttle that could launch like a rocket but deliver and land likes aeroplane. Historical transformations which shows the changes in technology by researches.

2. History of Space Shuttle

Near the end of the Apollo space program, NASA officials were looking at the future of the Space program. At that time, the rockets used to place astronauts and equipment in outer space was one-shot disposable rockets. What they needed was a reliable, but less expensive, rocket, perhaps one that was reusable. The idea of a reusable "space shuttle" that could launch like a rocket but deliver and land like an aeroplane was appealing and would be a great technical achievement. At one time both the united states and the soviet union envisioned complex space programs that included space stations orbiting the Earth and reusable shuttle space craft to transport people,equipments to and from these space stations. Because of high cost of flight,however each nations eventually ended up concentrating on only one aspect of this program. The Americans have focused their attention on the space shuttle. NASA began design, cost and engineering studies on a space shuttle. Many aerospace companies also explored the concepts. In 1972 NASA announced that it would develop a reusable space shuttle or space transportation programme (STS)[1]. NASA decided that the shuttle would consist of an orbiter attached to solid rocket boosters and an external fuel tank because this design was considered safer and more cost effective.

3. Challenges faced

At that time, spacecraft used ablative heat shields that would burn away as the spacecraft re-entered the Earth's atmosphere. However, to be reusable, a different strategy would have to be used. The designers of the space shuttle came up with an idea to cover the space shuttle with many insulating ceramic tiles that could absorb the heat of re-entry without harming the astronauts. Descents, some of the most difficult design problems faced by shuttle engineers were those involving the re-entry process. When the aircraft has completed its mission in space and is ready to leave orbit, its OMS fires just long enough to the shuttle by 200MPH (320 km/h). Angle of re-entry is an optimum factor while space shuttle re enty.The portions of the shuttle most severely stressed by heat, the nose and the landing edges of the ings are coated with an even more resistant material carbon-carbon(C-C). C-C made by attaching a carbon-fiber cloth to the body of the shuttle and then baking it to convert it to a pure carbon substance[8].The carbon-carbon coated to prevent oxidation(combustion) of the material during descent.

4. Space shuttle configuration& Operation

Finally, after many years of construction and testing (i.e. orbiter, main engines, external fuel tank, solid rocket boosters), the shuttle was ready to fly. Four shuttles were made (Columbia, Discovery, Atlantis, and Challenger). The first flight was in 1981 with the space shuttle Columbia, piloted by astronauts John Young and Robert Crippen. Columbia performed well and the other shuttles soon made several successful flights. The space shuttle consists of the following major components[1]:
1. Two solid rocket boosters (SRB) - critical for the launch
2. External fuel tank (ET) - carries fuel for the launch
3. Orbiter - carries astronauts and payload

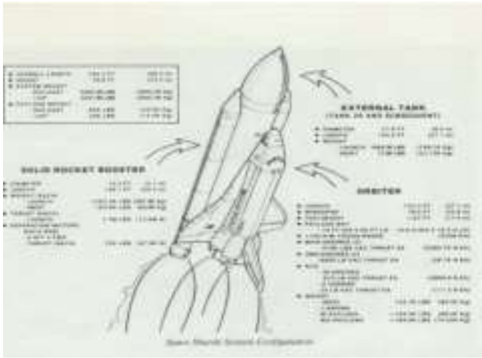

Figure 1: Space shuttle configuration

5. The orbiter

The orbiter, which is firstly manufactured by Rockwell International's. The approximate the size of a commercial DC-9 jet, with a length of 122 ft (37 m), a wing span of 78 ft (24 m), and a weight of approximately 171,000 lb(77,000 kg). Its interior, apart from the engines and various mechanical and electronic compartments, is subdivided into two main parts: crew cabin and cargo bay. The crew cabin has two levels. Its upper level literally "upper" only when the shuttle is in level flight in Earth's atmosphere, as there is no literal "up" and "down" when it is orbiting in free fall is the flight deck, from which astronauts control the spacecraft during orbit and descent, and its lower level is the crew's personal quarters, which contains personal lockers and sleeping, eating, and toilet facilities. The crew cabin's atmosphere is approximately equivalent to that on the Earth's surface, with composition 80% nitrogen and 20% oxygen. The cargo bay is a space 15 ft (4.5 m) wide by 60 ft (18m) long in which the shuttle's payloads carries the modules or satellites that it ports to orbit or back to Earth are stored. The cargo bay can hold up to about 65,000 lb (30,000 kg) during ascent and about half that amount during descent [8].

The shuttle can also carry more habitable space than that in the crew cabin. In 1973, an agreement was reached between the U.S. National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) for the construction by ESA of a pressurized, habitable workspace that could be carried in the shuttle's cargo bay. This workspace, designated Spacelab, was designed for use as a laboratory in which various science experiments could be conducted. Each of Spacelab modules is 13 ft (3.9 m) wide and 8.9 ft (2.7 m) long. Equipment for experiments is arranged in racks along the walls of the Spacelab. The whole module is loaded into the cargo bay of the shuttle prior to take-off, and remains there while the shuttle is in orbit, with the cargo-bay doors opened to give access to space. When necessary, two Spacelab modules can be joined to form a single, larger workspace

6. Propulsion systems

The power needed to lift a space shuttle into orbit comes from two solid-fuel rockets, each 12 ft (4 m) wide and 149 ft (45.5 m) long, and from the shuttle's three built-in, liquid-fuel engines. The fuel used in the solid rockets is compounded of aluminum powder, ammonium perchlorate, and a special polymer that binds the other ingredients into a rubbery matrix. This mixture is moulded into a long prism with a hollow core that resembles an 11-pointed star in cross section. This shape exposes the maximum possible surface area of burning fuel during launch, increasing combustion efficiency.

The two solid-fuel rockets each contain 1.1 million lb (500,000 kg) at ignition, together produce 6.6 million pounds (29.5 million N) of thrust, and burn out only two minutes after the shuttle leaves the launch pad. At solid-engine burnout, the shuttle is at an altitude of 161,000 ft (47,000m) and 212 miles (452 km) down range of launch site. (In rocketry, "down range" distance is the horizontal distance, as measured on the ground that a rocket has travelled since launch, as distinct from the greater distance it has travelled along its actual flight path.) At this point, explosive devices detach the solid-fuel rockets from the shuttle's large, external fuel tank. The rockets return to Earth via parachutes, dropping into the Atlantic Ocean at a speed of 55 miles (90 km) per hour. They can then be collected by ships, returned to their manufacturer (Morton Thiokol Corp.), refurbished and refilled with solid fuel, and used again in a later shuttle launch.

The three liquid-fuel engines built into the shuttle itself have been described as the most efficient engines ever built at maximum thrust they achieve 99% combustion efficiency. (This number describes combustion efficiency, not end-use efficiency. As dictated by the laws of physics, less than half of the energy released in combustion can be communicated to the shuttle as kinetic energy, even by an ideal rocket motor.) The shuttle's main engines are fueled by liquid hydrogen and liquid oxygen stored in the external fuel tank, which is 27.5 ft (8.4 m) wide and 154 ft (46.2 m) long. The tank itself is actually two tanks—one for liquid oxygen and the other for liquid hydrogen—covered by a single, aerodynamic sheath. The tank is kept cold (below -454°F [-270°C]) to keep its hydrogen and oxygen in their liquid state, and is covered with an insulating layer of stiff foam to keep its contents cold. Liquid hydrogen and liquid oxygen are pumped into the shuttle's three engines through lines 17in (43 cm) in diameter that carry 1,035 gal (3,900 l) of fuel per second. Upon ignition, each of the liquid-fueled engines develops 367,000 lb (1.67 million N) of thrust [8].

The three main engines turn off at approximately 522 seconds, when the shuttle has reached an altitude of 50 miles (105 km) and is 670 miles (1,426 km) down range of the launch site. At this point, the external fuel tank is also jettisoned. Its fall into the sea is not controlled, however, and it is not recoverable for future use. Final orbit is achieved by means of two small engines, the Orbital Maneuvering System (OMS) engines located on external pods at the rear of the obiter's fuselage. The OMS engines are fired first to insert the orbiter into an elliptical orbit with an apogee (highest altitude) of 139 miles (296 km) and a perigee (lowest altitude) of 46 miles (98 km). They are fired again to nudge the shuttle into a final, circular orbit with a radius of 139 miles (296 km). All these figures may vary slightly from mission to mission [1].

Figure2: shows the space shuttle operations

7. Orbital Maneuvers

For making fine adjustments, the spacecraft depends on six small rockets termed vernier jets, two in the nose and four in the OMS pods. These allow small changes in the shuttle's flight path and orientation. The computer system used aboard the shuttle, which governs all events during takeoff and on which the shuttle's pilots are completely dependent for interacting with its complex control surfaces during the glide back to Earth, is highly redundant. Five identical computers are used, four networked with each other using one computer program, and a fifth operating independently. The four linked computers constantly communicate with each other, testing each other's decisions and deciding when any one (or two or three) are not performing properly and eliminating that computer or computers from the decision-making process. In case all four of the interlinked computers malfunction, decision-making would be turned over automatically to the fifth computer.

This kind of redundancy is built into many essential features of the shuttle. For example, three independent hydraulic systems are available, each with independent power systems. The failure of one or even two systems does not, therefore, place the shuttle in what its engineers would call a "critical failure mode"—that is, cause its destruction. Many other components, of course, simply cannot be built redundantly. The failure of a solid-fuel rocket booster during liftoff (as occurred during the *Challenger* mission of 1981) or of the delicate tiles that protect the shuttle from the high temperatures of atmospheric re-entry (as occurred during the Columbia mission of 2003) can lead to loss of the spacecraft[3].

8. Avionics in space shuttle

Avionics are the electronic systems used in space shuttle space craft etc. Avionics is the combination of aviation and electronics. Avionic system includes communications, multiple systems, navigation systems, head up display etc. Before the entrance of avionics there are wired construction in between electronic components. It very difficult to operate while maintance. After the introduction of avionics, end to end construction becomes popular. The end to end construction which works with the help of data bus. The space shuttle avionics system controls or assists in controlling most of the shuttle systems. Its functions include automatic determination of the vehicle's status and operational readiness; implementation sequencing and control for the solid rocket boosters and external tank during launch and ascent; performance monitoring; digital data processing; communications and tracking; payload and system management; guidance, navigation and control; and electrical power distribution for the orbiter, external tank and solid rocket boosters. Automatic vehicle flight control can be used for every phase of the mission except docking, which is a manual operation performed by the flight crew. Manual control-referred to as the control stick steering mode-also is available at all times as a flight crew option[2].

The avionics equipment is arranged to facilitate checkout, access and replacement with minimal disturbance to other systems. Almost all electrical and electronic equipment is installed in three areas of the orbiter: the flight deck, the three avionics equipment bays in the middeck of the orbiter crew compartment and the three avionics equipment bays in the orbiter aft fuselage. The flight deck of the orbiter crew compartment is the center of avionics activity, both in flight and on the ground. Before launch, the orbiter avionics system is linked to ground support equipment through umbilical connections.The space shuttle avionics system consists of more than 300 major electronic black boxes located throughout the vehicle, connected by more than 300 miles of electrical wiring. There are approximately 120,400 wire segments and 6,491 connectors in the vehicle. The wiring and connectors weigh approximately 7,000 pounds, wiring alone weighing approximately 4,600 pounds. Total weight of the black boxes, wiring and connectors is approximately 17,116 pounds.

The black boxes are connected to a set of five general-purpose computers through common party lines called data buses. The black boxes offer dual or triple redundancy for every function. The avionics are designed to withstand multiple failures through redundant hardware and software (computer programs) managed by the complex of five computers; this arrangement is called a fail-operational/fail-safe capability. Fail-operational performance means that, after one failure in a system, redundancy management allows the vehicle to continue on its mission. Fail-safe means that after a second failure, the vehicle still is capable of returning to a landing site safely.

9. Data processing system

The space shuttle vehicle relies on computerized control and monitoring for successful performance. The data processing system, through the use of various hardware components and its self-contained computer programming (software), provides the vehicle with this monitoring and control. The DPS hardware consists of five general-purpose computers for computation and control, two magnetic tape mass memory units for large-volume bulk storage, a time-shared computer data bus network consisting of serial digital data buses (essentially party lines) to accommodate the data traffic between the GPCs and space shuttle vehicle systems, 19 orbiter and four solid rocket booster multiplexers/demultiplexers to convert and format data from the various vehicle systems, three space shuttle main engine interface units to command the SSMEs, four multifunction CRT display systems used by the flight crew to monitor and control the vehicle and payload systems, two data bus isolation amplifiers to interface with the ground support equipment/launch processing system and the solid rocket boosters, two master events controllers, and a master timing unit.

The software stored in and executed by the GPCs is the most sophisticated and complex set of programs ever developed for aero space use[4]. The programs are written to accommodate almost every aspect of space shuttle operations, including orbiter checkout at Rockwell's Palmdale, Calif., assembly facility; space shuttle vehicle prelaunch and final countdown for launch; turnaround activities at the Kennedy Space Center.and eventually Vandenberg Air Force Base; control and monitoring during launch ascent, on-orbit activities, entry and landing; and aborts or other contingency mission phases. A multicomputer mode is used for the critical phases of the mission, such as launch, ascent, entry, landing and aborts. Some of the DPS functions are as follows: support the guidance, navigation and control of the vehicle, including calculations of trajectories, SSME thrusting data and vehicle attitude control data; process vehicle data for the flight crew and for transmission to the ground and allow ground control of some vehicle systems via transmitted commands; check data transmission errors and crew control input errors; support annunciation of vehicle system failures and out-of-tolerance system conditions; support payloads with flight crew/software interface for activation, deployment, deactivation and retrieval; process rendezvous, tracking and data transmissions between payloads and the ground; and monitor and control vehicle subsystems[6].

10. Space planes and replacement of space shuttle

To replace the space shuttle NASA is planning to launch a series of space planes that named as X series planes. Some X series planes are given below 1. The X-37, which will test many space plane technologies, including re-entry capabilities. 2. The X-34, a sub orbital vehicle that will test technologies to reduce cost, time and personnel for space launches. 3. The X-33, a reusable launch vehicle (RLV) that is a prototype for a space shuttle replacement. In this the third one that is X-33 is the one that will replace the space shuttle in the future. Despite the shuttle's many accomplishments, the fact remains that it is extremely expensive to launch into space. Each pound of payload in the shuttle's bay costs $10,000 to launch [5]. According to NASA, each of the space shuttle's two solid rocket boosters carries about 1 million pounds (453,592 kg) of solid propellant. The large external tanks hold another 500,000 gallons of super cold liquid oxygen and liquid hydrogen. These two liquids are mixed and burned to form the fuel for the shuttle's three main rocket engines. The cost of this huge amount of propellant, and of recovering and replacing the solid rocket boosters for every mission is extremely expensive. NASA's solution to the problem is the X-33. The X-33 is a prototype for a unique single-stage-to-orbit vehicle. Its wedge like shape is unlike any spacecraft that has preceded it. At its base, the X-33 is 77 feet (23.5 m) wide, and the vehicle is 69 feet (21 m) long. The purpose of this design is to allow the spacecraft to hold all of the needed propellant onboard the ship, thus eliminating the need for solid rocket boosters. By eliminating the boosters and the main fuel tank, NASA will trim much of the liftoff weight that makes space shuttle missions so expensive. Launch costs for the X-33, or a derivative of the X-33, are expected to be only a tenth of the cost of launching the space shuttle. Two more tests will follow, and successful testing could lead to a more efficient space-access vehicle. NASA officials say that the scramjet engine would be a major step forward for NASA and would arguably provide a safer, more flexible, less expensive way to get people and cargo to space

11. Hyper sonic planes with air breathing engines

The futuristic X-43A prototype looks like a flying surfboard. It’s thin, has a wingspan of 5 feet (1.5 m), measures 12 ft (3.7 m) long and 2 ft (0.61 m) thick and weighs 2,800 pounds (1,270 kg). A working version of the X-43A will be about 200 ft (61 m) in length but still relatively lightweight, en most unique feature of the X- 43A is its engine. Ableing it to carry heavier loads into space. But the most unique feature of the X-43A is its engine. Fig 4.1: The dimensions and views of the X-43A The best way to understand an X-43A’s air-breathing engine is to first look at a conventional rocket engine. A typical rocket engine is propelled by the combustion created when a liquid oxidizer and a hydrogen fuel are burned in a combustion chamber. These gases create a high-pressure, high-velocity stream of hot gases. These gases flow through a nozzle that further accelerates them to speeds of 5,000 to 10,000 mph (8,047 to 16,093 kph) and provides thrust. The disadvantage of a conventional rocket engine is that it requires a lot of onboard oxygen. For example, the space shuttle needs 143,000 gallons of liquid oxygen, which weighs 1,359,000 pounds (616,432 kg). Without the liquid oxygen, the shuttle weighs a mere 165,000 pounds 74,842 kg. NASA has determined that it can easily drop the weight of a vehicle at launch if they were to take away the liquid oxidizer, which would quickly drop the weight of the vehicle to about 3.1 million pounds [4]. That's still a heavy vehicle, but it would mean a huge reduction in cost of launching a vehicle into orbit. Solution to this is its air-breathing engine. An air-breathing engine requires no onboard oxygen. The X-43A will scoop up oxygen as it flies through the atmosphere. In an Earth-to-orbit mission, the vehicle would store extra oxygen onboard, but less than what a space shuttle requires. The scramjet engine is a simple design with no moving parts. The X-43A craft itself is designed to be a part of the engine system: The front of the vehicle acts as the intake for the airflow, and so, if you remove the liquid oxygen, wouldn't the fuel be unable to combust and provide thrust. You have to think outside the normal operation of a conventional rocket engine. Instead of using liquid oxidizer, an air-breathing rocket, as its name suggests, will take in air from the atmosphere. It will then combine it with the fuel to create combustion and provide thrust. An air-breathing rocket engine, also called a rocket-based, combined cycle engine, is very similar to a jet engine. In a jet engine, the compressor sucks in air. The engine then compresses the air, combines it with a fuel, and burns the product, which expands and provides thrust. A jet engine can only be used for up to Mach 3 or 4 before its parts will begin to overheat.

In a supersonic combustion ramjet, or scramjet, an air inlet draws in air. The air is slowed and compressed as the vehicle speeds through the atmosphere. Fuel is added to the supersonic airflow, where the two mix and burn. Fuels most likely to be used with the air-breathing rockets include liquid hydrogen or hydrocarbon fuel

12. Air breathing engines

As mentioned before, scramjet-powered aircraft don't carry oxygen onboard. That means that they can't lift off like conventional spacecraft. The X-43A will require a booster rocket to get it up to a hypersonic speed, at which point it will be released and sent flying on its own. This rocket boost is necessary for the scramjet engine to work. As efficient as air-breathing rockets are, they can't provide the thrust for liftoff. For that, there are two options being considered. NASA may use turbojets or air-augmented rockets to get the vehicle off the ground. An air-augmented rocket is like a normal rocket engine, except that when it gets a high enough speed, maybe at Mach two or three, it will augment the oxidization of the fuel with air in the atmosphere, and maybe go up to Mach 10 and then change back to normal rocket function. These air-augmented rockets are placed in a duct that capture air, and could boost performance about 15 percent over conventional rockets. Further out, NASA is developing a plan to launch the air-breathing rocket vehicle by using magnetic levitation (maglev) tracks. Using maglev tracks, the vehicle will accelerate to speeds of up to 600 mph before lifting into the air. Following liftoff and after the vehicle reaches twice the speed of sound, the air-augmented rockets would shut off. Propulsion would then be provided by the air breathing rocket vehicle, which will inhale oxygen for about half of the flight to burn fuel. The advantage of this is it won't have to store as much oxygen on board the spacecraft as past spacecraft have, thus reducing launch costs. Once the vehicle reaches 10 times the speed of sound, it will switch back to a conventional rocket powered system for a final push into orbit. Because it will cut the weight of the oxidizer, the vehicle will be easier to Maneuver than current spacecraft. This means that traveling on an air-breathing rocket-powered vehicle will be safer. Eventually, the public could be travelling on these vehicles into space as space tourists.

13. Conclusion

In this paper, we have described the techniques used for overcome space shuttle operations. We can see that an evolutionary changes in the construction of space shuttle. Besides having obvious advantages over conventional rockets. Air breathing engine reduces launch cost, it will helps in technological up gradation. Air breathing engine vehicle will be easier to maneuver the current spacecraft. Another advantage over conventional rockets is Air-breathing rocket-powered vehicle will be safer than conventional rockets. Additional satellites are scheduled for launch that will enable new communication systems to be used around the world. Advances in the new Satellite Technology have made people no more than a phone call away. Satellites can send messages from one continent to another and also from one planet to another. Satellite technology brings us the weather, cellular phones, wireless cable, and direct broadcast television. Satellite communication companies are expecting these services to be offered all over the world in the very near future. At the end of 30 years of space shuttle programme, each nations would lead to inventions in space shuttle like. The developments would lead because of failures; Challenger disaster and Columbia disaster. The concept of NEXT GENERATION SPACE SHUTTLE arises for journey to Mars, Crew Space Transportation, and International Space Station.

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