A brief history of the Space Shuttle

By Jim Middleton

Over the next several months, I will be writing articles covering the latest developments in the world of space and science. Hopefully, they won't be too technical and are designed to give you a feeling for what is happening in these fields. In this issue I will cover the history of the Space Shuttle which will lead into my next article, the history of the International Space Station (ISS). Both programs are subjects of entire books, so I'm going to reduce them down to short articles. I will cover the history of the Canadian Space program in a subsequent article, which will then lead into the exciting changes currently under way in space exploration.

Space exploration over the past 60 years has been predominantly led by government organizations such as U.S. National Aeronautics and Space Administration (NASA), Canadian Space Agency (CSA), European Space Agency (ESA), Russian Space Agency (ROSCOSMOS), Japanese Space Agency (JAXA), and China National Space Administration. The mandate of these agencies has been to develop technologies and space exploration missions in support of their particular national space strategies and goals.

The decision by President Kennedy to ?put a man on the Moon and return him safely within the decade? was purely political, in order to demonstrate American technical superiority after Russia successfully launched the first satellite and first person into space. Space access was viewed, at least initially, as purely a military endeavour. The next steps were planned to be manned orbiting laboratories and space planes. The goal to put a man on the moon ultimately placed these programs at a lower priority.

Once the Moon was ?conquered? in 1969, the question arose as to what, if anything, should be the next major goal in space. A debate also raged within NASA as to whether the U.S. should focus solely on unmanned missions and/if/or how manned missions should continue. In all cases, the cost of launch and satellite development was increasing dramatically. What if a reusable launch capability could be developed and what if satellites could be repaired in space or brought back to Earth for refurbishment? Wouldn't that significantly reduce the costs of space?

Getting into orbit is hard! You must accelerate from zero to 18,000 mph in under 10 minutes and get to an altitude greater than 200 miles! Physics and chemistry can't be beat! Science tells you that you can't do it with a single vehicle. The U.S. has considered Single Stage to Orbit (SSTO) and have invested billions with no success. It makes better sense to have at least 2 stages; the first stage, the booster, gets the spacecraft off the ground and part way up and the remaining stage(s) puts the spacecraft into orbit.

Getting down is just as hard. You need to reduce velocity from 18,000 mph to zero by dissipating heat over some 20 to 30 minutes, which creates temperatures in the order of 3,000 degrees on the surface of the vehicle. Your vehicle must transition from flying in space to atmospheric flight at hypersonic speeds, then to landing. This was the challenge taken on by NASA. The program was authorized to proceed by President Nixon in 1972.

The design requirements for the reusable space vehicle were onerous. The state of technology was such that it was to a great extent beyond the state of the art at that time. Nevertheless, NASA had gone to the Moon, therefore it believed it could do anything it was asked to do.

The spaceship fleet, called Space Shuttles, would be capable of flying 40 or more times a year; more like an airline service: fly, land, short turn-around, and be ready to fly again. Other countries were asked to join the program on the basis that it would reduce costs and would be more difficult for Congress to cancel the program if international agreements were in place. The shuttle would become the ?Space Everyman;? launch, replace, and repair the U.S. orbital ecosystem ? akin to the FEDEX of space.

Then reality set in. Shuttles were to be capable of putting up to 32,000 pounds into low earth orbit and return them if necessary. The shuttle design and development became problematic. The main engines used liquid hydrogen and oxygen to develop the required thrust. The turbo-pumps which drove the oxygen and hydrogen into the engines would need to rotate at some 30,000 rpm under extreme temperature conditions. Liquid hydrogen, the fuel to launch the shuttle, is cooled to -250 degrees F! The engines were to be reused over and over again! Failure hell broke out when the engines were tested. The turbo-pumps flew apart and the engines exploded.

The heat dissipating system includes insulating tiles designed to protect the frame of the shuttle from temperatures greater than 350 degrees F and up to 3,000 degrees F during the entry phase of the mission. The areas of the space shuttle covered with tiles include the leading edge and bottom of the wings, the nose and bottom of the shuttle and areas on the sides and tail. There are over 30,000 tiles on each shuttle; each tile individually designed and manufactured and stuck on with a special glue. The tiles would often become dislodged when pull tested.

The initial thrust for the first step into space would be augmented by strap-on solid rocket boosters, which would separate after 2 minutes of flight and be recovered after descending into the ocean on parachutes. They were to be refurbished and reused on subsequent flights. Never before had solid rockets been used on manned spaceflight ? another major concern ? they explode easily.

The large external tank contained the liquid oxygen and hydrogen. It had to be light and well insulated to keep the liquids liquid. The tank would burn up on re-entry into the atmosphere; the only part which wouldn't be reusable.

The shuttle launch weight grew; the engines kept failing, the computer software didn't work and the tiles kept falling off. The program costs started to rise dramatically and the U.S. Congress was getting antsy. Oversight committees were put in place to review NASA's progress, or lack thereof.

Catastrophic failure (as in the loss of shuttle and crew) was estimated to have a probability of 1 in 185 flights. This was considered to be an acceptable risk; once flights got underway the probability of failure would presumably reduce. History was to show this was a very bad assumption.

The engine problems were slowly solved along with the software. The tile issues remained somewhat problematic but they tended to not fall off as often as before.

The first shuttle flight would be ?all in? to coin a phrase. It would be a manned flight, with 2 crew on board. The Columbia shuttle would launch from Florida and land in California. No intermediate testing of the flight vehicle ? there was no choice but ?go for it.?

The initial launch attempt was scrubbed on April 10, 1981 due to a software problem. The 2nd attempt to launch on April 12th was successful. The flight lasted a little over 30 hours.

Several ?anomalies? occurred during the flight, two of which were particularly interesting as a portent to the future. During ascent, it was noted that white flecks were hitting the pilot's window. This was shown later to be white paint and insulation flecking off the large fuel tank/thermos. Once in orbit it was noted some tiles had fallen off the back of the shuttle. There was major concern that tiles had fallen off the bottom which could have catastrophic consequences during entry. Visual observation through ground and space based military telescopes and radar confirmed there was no significant problem and landing could proceed as planned.

There were 5 shuttles built in total ? Columbia (the 1st), Challenger, Discovery, Atlantis, and Endeavour, all named after famous sailing ships. There were 5 CANADARMs built for the shuttles; one was lost on the Challenger flight disaster. In all, 135 space shuttle missions were flown between 1981 and 2011.

Confidence in the shuttle capability continued to grow over time although the launch rate never exceeded 8 per year. Typically, 5-6 was the norm. The tiles continued to be problematic; many of them had to be removed and replaced after each flight. Engine refurbishment took many months.

Shuttle missions became routine up until the loss of Challenger and its crew on Jan. 28, 1986 as a result of an explosion 73 seconds after launch. I won't go into the details of the cause other than to say it is generally regarded as a failure on the part of NASA and contractor management to not accept the recommendations of the technical community to cancel the launch because of freezing temperatures resulting in the potential failure of the seals on the solid rocket boosters. This was the ultimate cause of the explosion.

The next shuttle launch did not occur until 25 months later to allow time to identify and correct other critical failure modes and also correct the root causes of the explosion. A replacement shuttle was built named ?Endeavour? at a cost of $4 billion.

As a result of the Challenger accident the U.S. restarted production of unmanned rockets for missions not requiring astronaut

support.
One of the major successes of the shuttle program was the launch on April 24, 1990, and subsequent upgrade missions through the next decade, of the Hubble Space Telescope, one of the great achievements in astronomy! The Hubble telescope was specifically designed to be launched and repaired/upgraded by the shuttle, one of the primary goals of the shuttle program. We have all seen some of the spectacular images of the universe captured by this telescope over the last 20 years!
Ultimately, the major shuttle goal became the assembly and logistics supply of the International Space Station (ISS), a program I will cover in a future article.
Things proceeded nominally over the next decade, until that fateful day in January 2003. Assembly of the space station was under way pretty much as planned, however, the cost of each shuttle mission was in the order of $500 million.
Columbia was launched on Jan. 16, 2003. It was observed during launch that a piece of foam insulation from the fuel tank had broken off and hit the shuttle wing. Foam ?shedding? had been observed on several previous flights which did not cause observable problems. After much consideration by mission management, it was felt that this was more of the same, contrary to recommendations for detailed imaging of the wing leading edge from engineering. How wrong they were!
Destructive re-entry commenced over California, with the remains of the shuttle spread over large areas of Texas and Louisiana. The piece of foam had shattered the tiles on the leading edge of the wing permitting high temperature gasses to enter and melt key parts of the wing and hence the vehicle was destroyed.
It was decided that loss of vehicle risk was too high and the tiles were too fragile, although significant changes were made to increase safety. The decision was made that the shuttle program would come to an end with the last delivery of elements of the ISS in July 2011.
The U.S. reached an agreement with the Russians that astronauts would be transported to and from the International Space Station for the foreseeable future at a cost of $490 million from 2015 to 2019.
The three remaining shuttles are now on display; one at Kennedy Space Center in Florida, another at the California Space Center in California and the third at the Smithsonian Air and Space Museum in Virginia. The original test model, Enterprise, is on display at the Intrepid Sea, Air and Space Museum in New York City. I highly recommend a visit to view one of the shuttles if you get a chance.
So what is the legacy and what can we learn from the Shuttle program? The Shuttle program was a tremendous technical achievement even though it did not meet its original goals.
We now know mixing ?manned and unmanned? missions adds prohibitive costs and complexity. NASA has returned to its original goal of research and development and space exploration and turned the transportation business to Earth orbit over to commercial ventures.
The world of space is changing rapidly, driven by program costs, delays and government inertia. Entrepreneurs are taking over many of the key space activities. Stay tuned!

Jim Middleton is a ?semi-retired? aerospace engineer with over 50 years of experience in the U.S. and Canadian space programs. He has worked on the Space Shuttle and Space Station programs for over 25 years. He is currently involved in Canadensys Aerospace Corporation, a space company located in Bolton.