November 2019 lecture review by Richard Godley

Speaker : **Andrew Norman of the European Space Agency (ESA)**

Subject : **Materials Used for Manufacturing Spacecraft and Satellites - Surviving in Space**

Andrew Norman is a Materials and Process Engineer for ESA.

A video was shown at the start, which included President Kennedy announcing America's lunar ambitions, which culminated in the Apollo 11 landing. We also saw clips from Thunderbirds. Some things thought of as science fiction in the 1960s have gone on to become science fact.

The ESA has 22 member states, with 5,000 employees. The UK is the 4th biggest contributor. The overall budget is about 6 billion Euros and the organisation is based in Paris.

It is a procurement agency, not a manufacturer. Its function is to consider projects, decide which ones to support and then to manage the outsourcing of the tasks required to make a project happen and to be a success.

ESTEC, the European Space Research and Technology Centre, is ESA's heart. 2,000 people are based there, at Noordwijk in the Netherlands, on the coast south-west of Amsterdam.

What defines space? 100 km above the Earth's surface is where it starts, at the Karman line. Above that line we have to think about Ultra-Violet radiation and X-Rays, and of working in a vacuum and at extreme temperatures.

A satellite is a body placed in orbit around an astronomical object, such as the Earth and the moon, and which sends back data. A spacecraft is the vehicle that gets a satellite to where it needs to be. A launcher is what sends it up there from the Earth.

There are various satellite orbits. High Earth Orbit is at around 36,000 km. Medium Earth Orbit at around 20,000 km is where Galileo is, and GPS satellites and communications satellites are placed here. Low Earth Orbit at around 600 to 800 km is where geo-stationary satellites go, and this orbit has many satellites, including those for mobile phone networks.

ESA doesn't just launch satellites to orbit the Earth. Solar Orbiter is due for launch on February 6th, 2020. Andrew has worked on this mission for 10 years. BepiColombo was recently launched to go to Mercury. Venus Express and Mars Express were both ESA projects. The ESA has had less fortune with Mars missions than NASA has, for some reason.

Another ESA project is the JUICE mission to Jupiter, which is due to launch in 2022. The Cassini Huygens mission to Saturn was a major success for ESA. So was the Rosetta mission to the comet 67P/Churyumov-Gerasimenko. Other ESA projects include Gaia, Herschel and the James Webb Space Telescope, which is due for launch in 2021, and Planck.

1. Putting a payload into space

Of the four men considered to be founding fathers of rocket technology only Robert Goddard actually launched any rockets, starting in 1926, and eventually one of his rockets achieved an altitude of 2.6 km. The other founding fathers are noted for their theoretical work only.

In the early days rocket science was seen as a curiosity. Military applications were first thought of by Nazi Germany. A German rocketeer had asked Goddard for some of his papers and he obliged, not knowing what use would eventually be put to them. In the latter part of the Second World War Britain would suffer first from the V-1 (Doodlebug) and then from the V-2 rocket, designed by Wernher von Braun. The Germans did a lot of testing and development. About 4,000 V-2s were launched. On June 20th, 1944 a V-2 became the first man-made object to go into space having reached a higher altitude than the Karman line.

After the war von Braun went to the USA. Other German rocket scientists worked for the Soviet Union, which also gained the manufacturing facilities that the Germans had used. Both sides wanted to know how the technology worked. The U.K. got a few German scientists and started the Skylark and Blue Streak programmes.

The launch of Sputnik 1 caught the US by surprise. Then came Vostok 1, and the US responded with manned space flights of its own.

In Europe, France, Italy and others were each going it alone, but it was realised that co-operation would be better and the forerunner of the ESA was established in 1962. A base was opened at Darmstadt in Germany. Most launches are made from Kourou in French Guiana with the Ariane 5 rocket, but some are launched from Kazakhstan. The organisation also worked with NASA on Skylab. A merger with an affiliated organisation in 1975 led to the organisation being renamed the European Space Agency (ESA).

New rivals have emerged in the form of Elon Musk's SpaceX project, founded in 2002. They are very much risk-takers in comparison to ESA and NASA, but they also have some NASA support. SpaceX can also launch payloads at a much cheaper rate than the older organisations. ESA are developing the Ariane 6 rocket, which will help it compete with SpaceX.

Once a satellite has been launched it has to work. Apart from some repairs done to the Hubble Space Telescope and the Space Shuttle there is not much that can be done to fix a satellite once it has been launched. Repair is not normally an option. ESA's manufacturing is very low volume compared to, for example, aircraft manufacturers. It is very expensive to develop new technology, but sometimes you need to develop something new.

Properties of material, optimal performance and thermal conductivity are among the things to be considered. Common materials used include Aluminium, Titanium, Teflon, bolts, rivets and welding of various kinds. Carbon fibre sheets, Velcro, Araldite and other adhesives and glues are amongst materials with frequent usage. Honeycomb structures are stiff yet light.

Manufacturing spacecraft requires subsystems for propulsion, for thermal characteristics and for communications. It is all modular in construction and then put together. How does a craft know where it is in space? It uses star trackers and solar sensors.

The propulsion subsystem requires a fuel in titanium tanks. Solar cells are made from gallium arsenide. Older spacecraft tended to be circular. Now a reaction wheel can be built inside the craft and it can spin inside, allowing the craft to be any shape that is required for the mission. Only professionally qualified people are allowed to do the soldering. Women are much more suited to this for some reason.

Communication with Earth is facilitated with dishes made from Titanium. Heat pipes are made from copper and filled with ammonia. Insulation, which is usually gold in appearance, is used to protect the craft from heat and radiation.

2. Surviving in space

Satellites are made on Earth, transported to the launch site and then launched.

There are many issues in preparing the craft so that it can survive in the environment of space. Stress corrosion tests are carried out to prevent failures. Copper wire can suffer damage due to “red plague corrosion”.

Conditions that the craft will encounter in space are replicated in the laboratory. Tests which simulate vibration movements at the equivalent of 7.5 on the Richter scale are carried out. LEAF (Large European Acoustic Facility) uses nitrogen-powered air horns to blast noise at the craft to test its ability to withstand noise pressure from the engines at launch. The Large Space Simulator, 10m in diameter, is used to replicate the temperatures expected to be encountered. Solar lamps are pointed at one side of the craft - in space one side will be hot and the other cold. A video of the preparations for the launch of Bepi Colombo was shown.

Satellites must be able to survive the temperatures and the vacuum of space. For telecommunications satellites 76,000 cycles are catered for. Alternations between hot and cold conditions are tested. Cadmium and zinc can boil in a vacuum at 100 degrees and so they are used in their pure form.

Ultra-violet radiation can cause white coatings to go brown or black, but if the coatings are already black they stay black. Satellites may have to cope with temperatures caused by the equivalent of 13 times the solar radiation experienced on Earth. Solar storms, such as the one that caused power failures in Canada in 1989, have to be prepared for.

Space debris is a hazard and it was made worse in 2007 when the Chinese blasted one of their own satellites, breaking it into 3,000 pieces. The crowded orbits include millions of dust particles, but it's the solid objects that are more concerning.

“Demisability”, or "what goes up must come down", must be catered for. Large pieces from satellites have landed back on Earth, including in Namibia and Texas. Sometimes pieces fall into the ocean. A large piece landed in India. Most pieces burn up in the atmosphere.

Material technology is a an important consideration. Playtex had the right machinery for designing spacesuits for lunar missions. Velcro and Teflon existed before NASA was created, but these materials were then adapted for use in space missions, and, as is often the case, these developments were then further adapted for use on Earth. Space missions are very good at taking old technology and adapting it for their own purposes. Water filters, CMOS sensors, cordless devices and cochlea implants were developments we make use of that were previously used in space programmes.

Some ideas used in the manufacture of spacecraft are new. The giant infra-red telescope on Herschel is new. It has the largest silicon carbide mirror ever developed for space.

The Solar Orbiter will experience temperatures of up to 520 degrees and has been manufactured to withstand thermal cycles, electron and proton radiation, UV radiation and 13 times solar constant radiation. To enable it to cope with high temperatures a surface treatrment technique called CoBlast is used to apply bone char, as used in cave paintings millennia ago, to the heat shield.

3. Future technology

3D printing is a major part of the future of space missions. We can print metals as well as plastics. We can take a part, put it in a computer model and then use a laser to create a layer, then another layer and thereby build up a part one layer at a time - the printer bed method.

The blown powder method of printing has become a useful procedure for ESA. Why use it for space? The part count is reduced. You can re-design the part and after that you can print what you want. You can save 60% in mass, 50% in cost and 97% in materials.

In metal powder printing spherical powder particles are melted by laser. Even lattice structures can be printed in this way. Printing itself is not the issue. The issue is how the created part will behave mechanically and whether it can be done in space. A metal printer is to be installed on the ISS soon. It will work in weightlessness, while powder printing will not because it would drift everywhere.

Bio-printing using bone or skin can be done on Earth now, but we might be able to do it on the way to Mars, enabling medical issues to be treated as necessary when they arise by printing the materials in situ.

We could even develop a lunar base by sending robots to collect regolith in the moon dust and use a printer to create a lunar village from it for astronauts to live in. This is science fiction at present, but it could perhaps be achieved in 10 years time.

This had been a fascinating and detailed talk delivered by a European Space Agency employee who really knows the technical necessities for complex and valuable scientiific missions to space. Those present thanked Andrew Norman in the usual manner.

Forthcoming meetings

January 15th 2020 Bob Turner F.R.A.S. – “Astronomical Things That Could Happen in the Next Few Years” + January Social evening with food and drink

February 19th 2020 William Joyce F.R.A.S. – “The Search for Life in the Solar System”

March 18th 2020 Steve Cross of the Gee-Archaeological Survey – “Pyramids, Temples and Sun Worship in Ancient Egypt”