Modelling the ISS

By Keith McNeill

STS-133 at the International Space Station with Japan's HTV cargo vessel. *Keith McNeill*

The International Space Station, or ISS, is the largest structure to have ever been placed in orbit, and over a thirteen year period grew from small beginnings into the large structure we have today. Originally approved as Space Station Freedom by President Reagan in 1984 and to be a US only programme, the station evolved into the ISS. Due to financial constraints and the results of the end of the Cold War, it became a collaborative venture between the US, Russia, Europe, Canada and Japan. It is permanently manned ranging from three to six occupants at any one time.

Back in 1998 when the first components were launched by the US Space Shuttle and the Russian Proton rocket, a model company by the name of Inter Mountain Railways released a 1/144 scale kit, followed by Revell in 2000 (more of that later). I decided that I would construct the model in parallel with that of the real station and match it with building the kit in (almost) real time. When I started I did not realise it would take thirteen years to complete though!

There were a couple of reasons for my decision not to just build it in one go – the main one being that you cannot rely on pre-flight artwork or even mock-ups to show what it will eventually look like on orbit. All spacecraft look different by the time they are launched due to thermal blankets, foil coverings and numerous antennae etc. not shown on artwork or mock-ups. Therefore if I wanted to have an accurate and realistic looking model, I needed to wait until I saw images of the elements on orbit.

The other reason being that I suspected with the complexity of the ISS, the eventual launch sequence of the various modules etc. would not match the original design the US and its partners had in mind when they first conceived of the ISS. I was proven to be correct in both assumptions over the years – more so than I ever expected.

The first element of the ISS to be launched was the Zarya Module. Built in Russia with US funds, it was launched aboard a Proton launcher. The second module was the Unity Node Module, launched aboard the shuttle and equipped with two Pressurised Mating Adapters, one of which would be used for shuttle dockings. The US hopes to continue ISS operations until 2028, although the Russians are currently not enthusiastic to go beyond 2020.

Starting the Model

The first thing I should say about modelling the ISS and describing "how to" in an article of this kind, is that I will have to deviate from my normal method of describing the build, as to do so, would fill a book. Although I did not actually take thirteen years of continual modelling, a substantial period over the years mounted up. I usually did a couple of upgrades a year depending on how many elements were launched, so probably spent a couple of months every year – at least – working on it - apart from three years when the Shuttle was grounded after the Columbia disaster in 2003. Also the level of detail which was incorporated into the model as astronauts added cabling, antennae, experiments etc. can only be gleaned from on orbit NASA photography.

Additionally, during the build NASA had a habit of moving some of the elements and modules around, requiring me to break things off and relocate them. NASA certainly didn't take us modellers into consideration by doing that! There is also the matter of several visiting vehicles which periodically service the ISS (more of these later). I should also say that it is probably one subject which can never be truly 100% accurate.

Due to the myriad of detail and of the scale I would suggest it is downright impossible to capture all the detail. Added to which the ISS never stays the same for any length of time before experiments or other equipment are added, removed or relocated. A veritable moving feast! You therefore have to choose a moment in time in which to model the ISS and I decided to complete it as it was at the

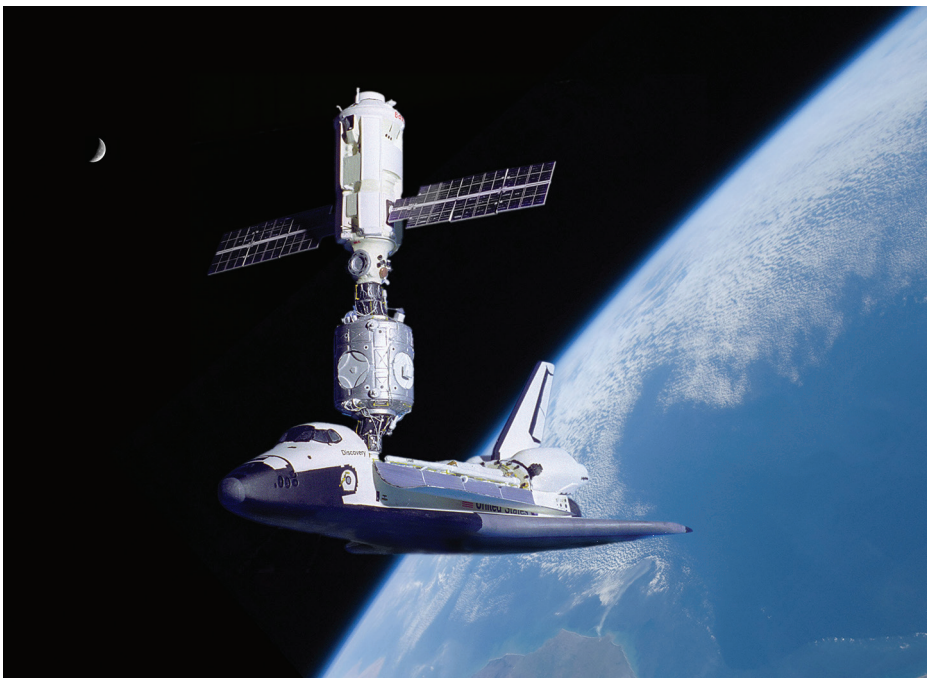
time of the last space shuttle mission, STS-135 Atlantis in July 2011.

That seemed an appropriate point at which to stop building the model. As of January 2015 there were plans to relocate several US modules in order to free up docking ports for use by future crew and cargo spacecraft, and the Russians plan on launching at least one other module too, so you really need to consult the latest information for the current configuration.

I was lucky, in that when I started this project, I was able to obtain mission photography via the NASA Media Center (now closed) after each mission (now they are all available on the Internet) and there was not only good photography showing the construction tasks performed by each mission, but NASA often released fly around imagery taken by the shuttle after undocking, specifically designed to document the construction phase.

So it became a matter of poring over these photos at every building session to add as much detail as I could see onto the 1/144 scale model. I must admit that I never found out what some of the detail actually was, but if it was there I tried to make sure it was replicated, so a quite a lot of scratch building was required.

The only advice I can give to any budding modeller is, collect every photo you can find from the various shuttle missions visiting the ISS, making sure you get them in chronological order, and just do your research. Sometimes I think it was a long winded way for me to build in real time, but equally building it now when it is completed would be a very large task indeed.



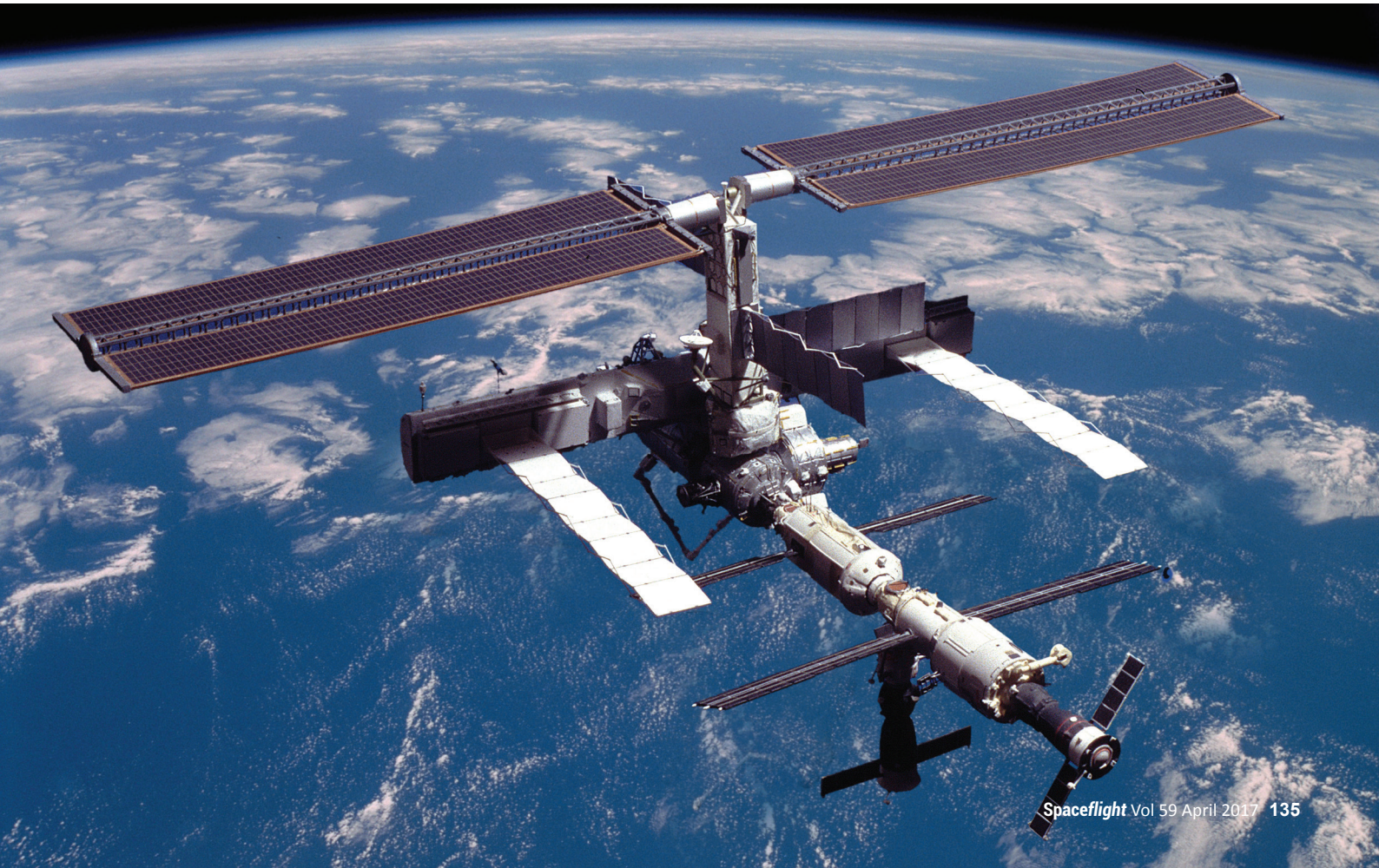
Zarya and Unity with a Pressurized Mating Adapter at each end and Shuttle Discovery on STS-96 in May 1999. *Keith McNeill*

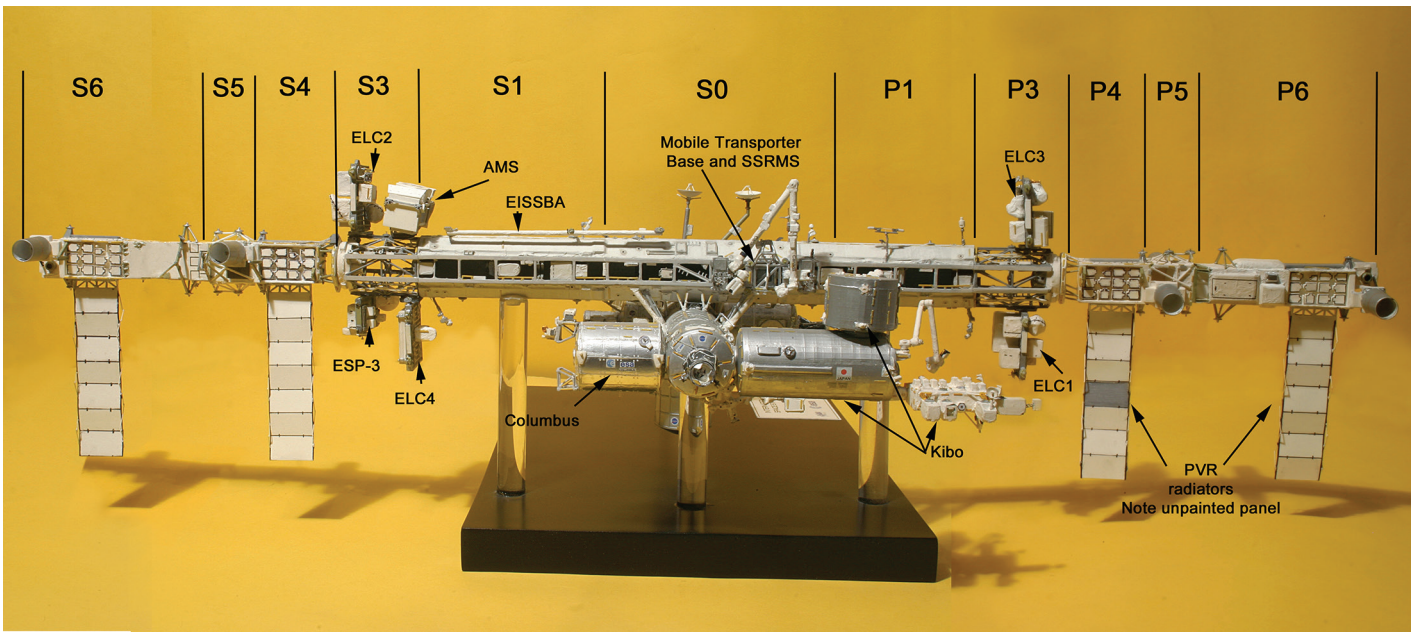
As I progressed I found the Inter Mountain Railway kit was remarkably accurate and often had items I simply did not think they would know about. The fit of the parts was so good it was almost too good with a dry fitting sometimes difficult to prise apart – which required a bit of filing or sanding to loosen the parts a bit to apply the glue.

Detailing

One aspect which relates back to what I said earlier regarding pre-flight illustrations, was

The ISS configuration with Truss segments S0, S1 and P1 installed during STS-113 in November 2002. *Keith McNeill*





The solar arrays and the large radiators have been omitted for clarity in this display of ISS elements providing a clear identification for port and starboard truss assemblies. *Keith McNeill*

the lack of Micrometeoroid and Orbital Debris Protection panelling (MMOD) on most of the kit modules. The US modules had panelling on all exterior faces and this had to be made from panels of 10-thou plasticard (a commercial product), cut to shape. The bulkheads had pie shaped panels in three layers of ever decreasing sizes. As you can imagine this was one of the more time consuming tasks. The two Kibo modules (Kibo was Japan's contribution of the ISS Program and consisted of two pressurised Modules – the Experiments Logistics Module, the Laboratory Module - and the Exposed Facility) had a different type of detailing displaying subdued raised panel lines. I solved that by scoring 10-thou plasticard with the pattern of lines and then flipped the card over and wrapped it around each module with the scored lines facing outwards – instant raised panel lines!

Located atop the Unity Module is the Z1 truss section (not part of the Integrated Truss Structure described below). It carries the four Control Moment Gyros and the large Ku-band parabolic antenna (later a second was added as a backup). Interestingly, the gyros were covered with a thermal material with a slight sheen which I found to be a perfect match to the plastic material used in Tesco bags, so that turned out easy enough to reproduce!

Then came the detailing of the modules with items such as the Trunnion Pin Attachment points, which were situated around the exterior (four per module) and formed the hard contact points for holding the module in the Shuttle payload bay and grapple fixtures for the Shuttle's Remote Manipulator to grasp the module.

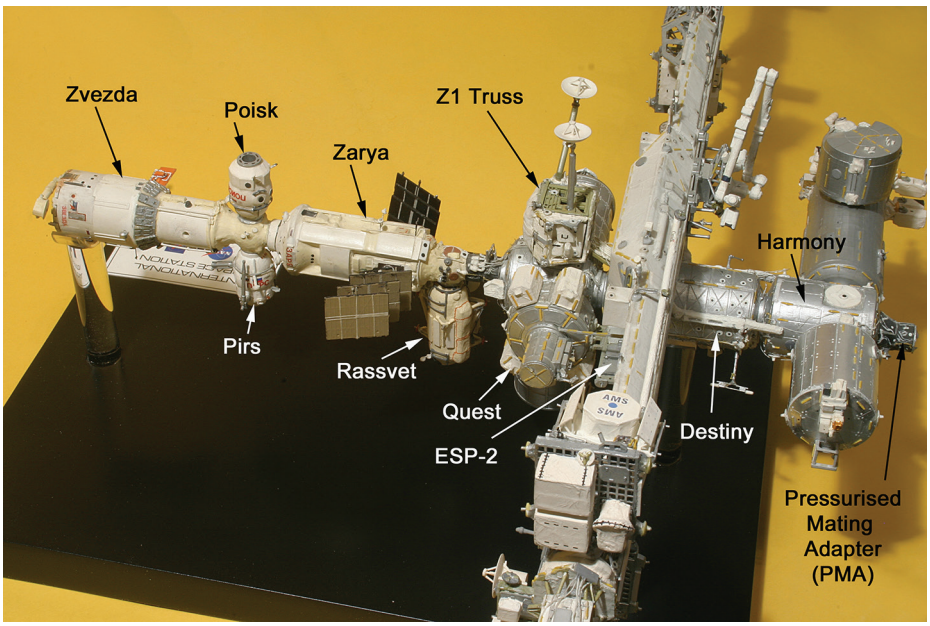
By this time Heller had also released a kit of a partial build station (based I think on a mock up at Toulouse). This was of no use as a model (the modules weren't even in the right configuration, had extra modules which were cancelled and no solar arrays) and of a scale of 1/125, it did have lots of these Trunnion Pins, which as it turned out, were under scale for 1/125 but quite near 1/144. There were so many of these pins required I ended up purchasing two of these kits as it would have been a pain to scratch build so many.

More details such as cabling, which was added by astronauts on EVA, was required to be added. These cables usually ran along the outside of the US modules and spanned over to others and only became evident on later photos as and when they were added, so that was something else I had to keep an eye out for – items added a lot later than the modules were. I used fine fishing line which isn't the easiest material to work with, due to the nylon it is made of and the fact it retains a memory.

Also requiring to be added was the addition of TV camera and light stanchions, experiment platforms and other miscellaneous detail. I initially used etched brass ship handrails for the handrails on the station, but over the years changed to making them from the finest Evergreen plastic strip. The reason being that during construction over the period, the model was handled a lot and anything fragile either pinged off across the room, never to be seen again or got crushed in situ.

Handling was a pre requisite of course at

The ISS as it appeared during the flight of STS-118 in August 2007. *Keith McNeill*



With solar arrays and radiators removed for clarity, another view of the fully completed ISS configuration with the Alpha Magnetic Spectrometer installed outboard of ESP-2. *Keith McNeill*

every update, and it became increasingly difficult due to the complexity and accumulated fine detail, to hold the model without breaking parts off. Even more so when I needed to relocate modules I had glued on in all faith they would never be moved, some force was required to break off said modules. And of course after every update I needed to hang it up for the photography. To be honest I'm surprised it has lasted this long! On another note, I should say that because of the ever changing configuration and moving Centre of Gravity, I kept having to make new stands for it. I believe I ended up having four different ones.

One module I did have to scratch build, even though it was included in both kits, was the US Quest Airlock. Oddly both kits did not get the correct shape, so not sure if the flight hardware design was changed somewhere along the line. Consisting of a large stubby cylinder and a small tube it was surrounded by nitrogen and oxygen tanks similar in shape to cartoon doghouses. I detailed it with some etched brass details I had lying handy.

Concurrently with the addition of modules the Shuttle periodically launched sections of the Integrated Truss Structure which forms the backbone of the station and which lies at 90 degrees to the line of modules and holds the large US solar arrays and radiators. The central section, the S0 truss, is bolted to the top of the Destiny Lab module, with sections spanning both starboard and port (note S2 and P2 sections were omitted from the original design, so there are S1, S3, S4, S5 and S6 only – and the equivalent on the port side).

The P6 truss section was initially attached to the Z1 truss to provide power to the US segment of the station in the early stages of construction and it was relocated to the outermost end of the port side late in the construction phase of the ITS, the final section being the S6 truss. Because of the excellent fit of the IMR kit I was able to attach the P6 to the Z1 truss without the need for glue so that when the time came I just needed to pull them apart. It did however necessitate rebuilding struts at the top of the Z1 at that point.

Running most of the length of this structure is the Mobile Transporter Base which would help translate EVA astronauts along the length of the truss and also an attachment point for the Space Station Remote Manipulator System. The robotic arm is a larger version to the shuttle arm and like that, was built by Canada. From initial NASA illustrations the spine was going to be an open truss work, but the IMR kit parts were solid in nature. Thus when Revell released their kit with the open sections, most of us who had purchased the IMR kit went out and bought that with the intention of replacing the IMR parts.

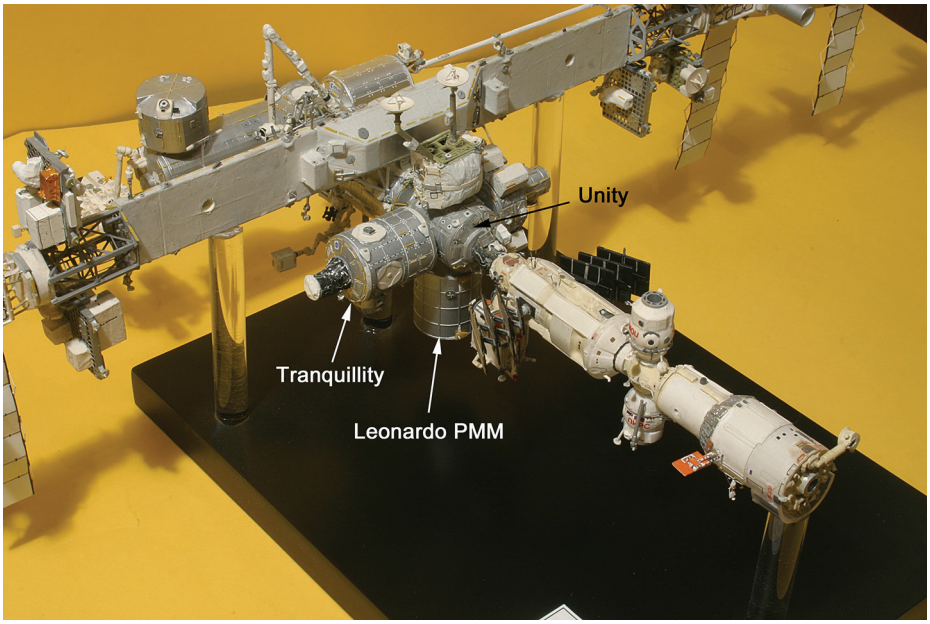
However as previously related, this was one area the illustrations got wrong and the truss was covered with thermal blankets on all but the facing side. So the IMR ones only needed the forward facing side removed. Only one section at either end of the truss is open – these being the P3 and S3 sections (port and starboard – see accompanying photo showing ISS layout) and these were constructed from Revell parts slimmed down, as the Revell truss is slightly over scale. The trick in building the length of truss and the rails which would carry the Mobile Transporter was complicated by the fact the truss took some three years to complete because of the downtime due to the Columbia accident. I was pleasantly surprised that when I had finally completed the truss sections everything lined up, allowing the Mobile Base to move freely along the length of the truss.

I also required the outboard truss segments (P4/S4) to rotate as these hold the large solar arrays which track the sun, and I needed them to be moveable for the photography. Also in case I ever transported the model to shows I had these outer sections removable. As it transpired the model is too delicate to leave the house.

Solar Array Problem

Now to one of the biggest problems with this model, or indeed any spacecraft with solar arrays. Despite a modeller's best efforts we

With radiators installed but no solar arrays, the Russian segment is clearly seen in this view looking forward. *Keith McNeill*



Keith set up this arrangement as though the aborted fly around by a Soyuz spacecraft during STS-133 had actually taken place. Note the fine work on simulated black tiles on the orbiter Discovery. *Keith McNeill*

have to contend with gravity which the real thing does not. The real arrays are very fine – and long – and trying to scale these are impossible. I went through about four iterations. I ignored the printed card kit ones and drew up artwork to replicate the array pattern – front and back – printed them out and glued them to 20-thou plastic card.

The truss work which lies between each double array is supplied in both the IMR and Revell kits as a single length of solid plastic with raised detailing to mimic the girder work. Whilst relatively effective viewed from a distance it does not add to a particularly realistic model. Initially I built these from long EMA ladders which were better than the kit parts, but luckily after-market parts became available in nickel silver etch from Realspace Models (see contact details at the end of this article). These greatly added to the realism of the model.

Despite only attaching the arrays for photography I found they just would not stay flat, so I tried another tack by making them a lot thicker with lengths of brass for strengthening the edges but that didn't work either. I should say at this point that I didn't need to do all sixteen arrays as like the rest of the truss the full complement hadn't been launched yet.

To cut a long story short I ended up with a design which still droops, but is somewhere between the thick and thin versions. Still way out of scale, but have to live with it. I have to tilt the arrays for the photography such that the gravity vector is going through them edge on. When not being displayed or photographed they are removed. By the time all arrays had been launched, I had arrived at my final solution and could complete the remainder to the new specification.

Large radiator panels were deployed from the truss facing towards the rear of the station, with a set of three heat rejection system (HRS) radiators on both port and starboard sides. In addition there are four smaller photovoltaic radiator (PVR) assemblies which were deployed from the P/S4 and P/S6 trusses. At first only the central HRS panels were deployed and only later the remaining panels (see below). For all radiators I removed the moulded-in deployment scissor mechanism and made new ones from plastic strip.

With regards the PVR radiators, it is interesting to note that one individual panel on the P4 truss radiator is unpainted. Initially I thought from studying the photos that it was the sun reflecting from the panel, but all photos seemed to show the same abnormality on that particular panel so I checked with Lockheed who manufactured the radiators and after they contacted Boeing (lead contractor for the ISS) and the Johnson Space Center. I was informed that paint refused to adhere to that particular panel and they received a waiver to fly in that condition.

The solar arrays on the Russian Zvezda and Zarya modules were replaced with the equivalent arrays from the Revell kit. These have nicely raised detail on both faces and I added extra ribbed detail on both front and rear with white self-adhesive Letraline. The Zarya arrays required to be retracted to allow clearance for the deployment of the HRS radiators, but remained in a partially deployed state which formed a concertina shape. At that point in the construction I had to cut the arrays into the separate panels and reattach them in this new partially retracted configuration.

Scratch building

In addition to the modules which came with the kit, the US launched the Tranquillity module, the Harmony node module and left in place a Permanent Multi-Purpose Logistics Module. The standard MPLM was used to ferry supplies and equipment to and from the ISS in the shuttle payload bay. Three were built by the

Italian Space Agency and named Leonardo, Raffaello and Donatello, the Leonardo MPLM became the Permanent Multi-Purpose Module (PMM) and docked to the station to serve as extra storage space. The Russians also launched the Poisk Docking Module which was a duplicate of the Pirs Docking Module, both of which were heavily modified from kit parts, and the Mini Research Module - Rassvet - which had to be built from scratch.

The European Space Agency's contribution was the Columbus Laboratory Module and this was scratch built using a spare Revell US module. The exterior of Columbus is relatively devoid of obvious MMOD panelling but is covered with a chrome finish. For that I used Bare Metal Foil. The detail of white lining and dots was replicated with white Letraset.

The Shuttle also delivered External Stowage Platforms (ESP) which were basic open lattice work platforms which spanned the payload bay and were used as platforms for stowing large external spare parts for the station (three of them). Similar Express Logistic Carriers were also attached to the station truss. There are four of these. I used some fine cross hatched etched brass to build the platforms and just had enough to complete the complement.

Also attached to the spine was the Alpha Magnetic Spectrometer experiment. Almost as large as one of the ELC stowage platforms this was a late addition to the station before the Shuttle ceased flying (flown on STS-134) and as such couldn't be expected to be kitted, so again more scratch building. It is mounted on the S3 truss segment.

Following the Columbia accident, additional safety protocols were added to the shuttle mission profile – one being the rendezvous pitch manoeuvre or backflip which the Shuttle performed below the ISS prior to docking so that the station crew could inspect and photograph the underside tiles. The Shuttle crew also used a 15.4 m long Orbiter Boom Sensor System to conduct a highly detailed view of all tiles after launch and prior to re-entry. At the far end of the boom was an instrumentation package of cameras and lasers used to scan the leading edges of the wings, the nose cap, and the crew compartment.

The OBSS was attached to the end of the Remote Manipulator System to extend the reach of the RMS. This configuration had also been used to allow an astronaut to reach the furthest outboard solar array to fix a problem, so NASA decided it might be of use in the future and on the penultimate shuttle mission, the shuttle crew left the OBSS (now renamed as the Enhanced International Space Station Boom Assembly) attached to the starboard truss section. This was simply replicated with a length of plastic tubing of the correct diameter.

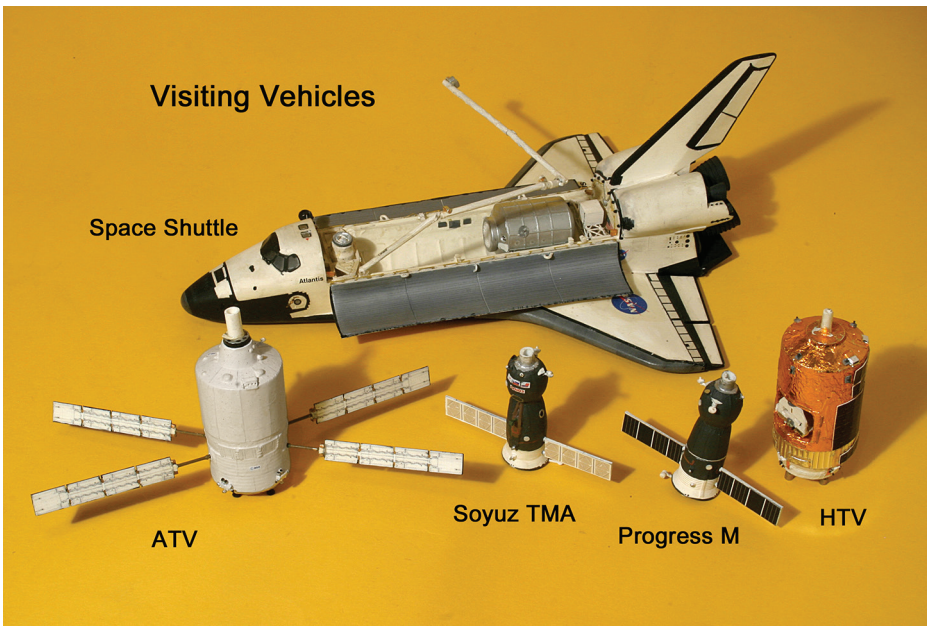
Talking of robotic arms, the kit comes with an articulated station RMS. Similar to the shuttle RMS, the SSRMS is longer at 17.1 m and has seven joints. The kit parts do need further enhancements to make it accurate. Likewise, the Special Purpose Dextrous Manipulator (SPDM) or Dextre as it is known, is a two armed robot which is part of the Mobile Servicing System on the station which requires modifications. It also has attachment points on the US Destiny laboratory where I usually parked it as I had positioned the SSRMS on the Mobile Transporter Base (though neither are attached permanently as I needed to be able to move them around for photography). The kit also comes with an articulated Japanese Kibo arm which is attached to the exterior of the Kibo laboratory module.

Most of the modules have national flags, space agency logos and names on the exterior as does the SSRMS, and these were custom made decals from my Epson printer.

Visiting Vehicles

Known in NASA parlance as Visiting Vehicles, this covers all additional spacecraft which launch crew and supplies to the station. These include the Space Shuttle, Russian Soyuz

Soyuz TMA shown docking with the ISS. The model from which this came was out of scale, reduced in size by Keith in Photoshop. *Keith McNeill*



The array of Visiting Vehicles depicted here show the various spacecraft and modules in scale, this assembly of vehicles being before the Dragon and Cygnus commercial resupply flights. Keith McNeill

crew vehicles, Russian Progress resupply and fuelling craft, the European Automated Transfer Vehicle (ATV) and the Japanese H-II Transfer Vehicle (HTV). Currently it also includes Cygnus and Dragon resupply spacecraft, but these are outside the scope of this article as they only just started operations to the ISS, several years after I completed this project.

The Soyuz spacecraft was used to ferry cosmonauts (and some "Spaceflight Participants" – paying guests) to and from the ISS, but following the retirement of the Space Shuttle in July 2011, the Soyuz is currently the only means for crews from all nations to be launched to the station. The Soyuz remains docked to the station during the crew's visit and acts as a lifeboat in the event of an evacuation. It has an on-orbit lifetime of six months, thereafter it must be replaced. This often results in the ISS crew reduced from six to three crew members for a limited time until the replacement crew is launched. The current version of the Soyuz is the Soyuz TMA-M. The Progress spacecraft has also gone through a number of iterations and the current Progress craft is the Progress M-M.

Starting with the Space Shuttle, I favour the standard Revell shuttle kit with a few modifications. The entire payload bay had to be rebuilt, although it is slightly under scale compared to the ISS kit as the modules will not fit in the bay. However it is close enough, so all the payload bay detail such as thermal blankets, Ku-band antenna, the Orbiter Docking System (which comes with the IMR kit – but I hadn't noticed and built my own), RMS arm and OBSS were scratch built, as was the under tail compartment holding the parachute installed post-Challenger.

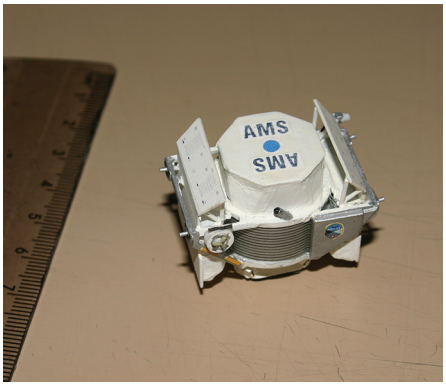
The real let down with the Revell kit are the Space Shuttle Main Engines (SSME). There is no detail, just large stepped rings. The Airfix SSMEs are vastly superior so the Revell ones were binned and were replaced with Airfix ones.

Initially I painted the underside matt black, but when docked to the ISS model, this lack of detail detracted from the photography. The tiles get worn by multiple re-entries and are shades of grey and show streaking and plenty of detail. I eventually decided to rectify this, by utilising the photos of the underside of the orbiter which had been taken by the ISS crews and map the resulting montage of photos to the underside of the Shuttle model and made decals which covered the underside. These decals certainly improved the look of the model in the photos.

I used the IMR Soyuz and Progress kit parts as these were closer to the correct shape than the Revell ones were. Split into three parts, each craft consists of (from front to rear) an Orbital Module, Descent Module (in Progress this is the fluids storage tanks) and the Propulsion Module. The most obvious external difference between the two is the "neck" between the Orbital Module and Descent Module/Storage Module which is thicker on the Progress. I scratch built all the various antennae, periscope and various other details including custom made decals. Again I dispensed with the printed IMR solar arrays and used the detailed Revell plastic kit parts.

The Alpha Magnetic Spectrometer was scratch-built to scale for attachment to the ISS.

Keith McNeill



The European ATV only flew five times but was the largest of the re-supply craft. It docked to the rear of the Russian segment and also supplied fuel, and as with the Progress craft, initiated regular re-boosts of the station. I used parts from the Revell kit and other spare parts to build this. The arrays were made from plastic card and the artwork for the arrays both back and front were custom made from decals of photos of the real arrays.

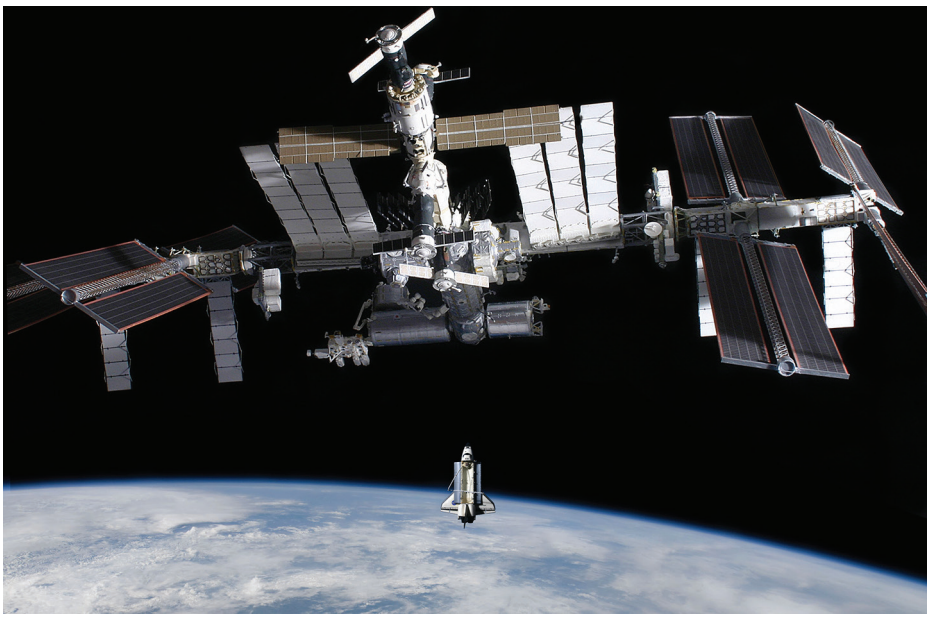
The Japanese HTV was also scratch built. I had already built the Aoshima kit which is advertised as 1/72, but is in fact 1/102. Not sure how they could get the scale so wrong, but that is another story. However all I did was scale down the parts and build a 1/144 version. Covered in gold foil and chrome Bare Metal foil, it is quite a nice looking spacecraft. Unlike the other re-supply craft, the HTV does not dock to the station. Instead it manoeuvres close to the ISS and the station's arm grapples it and berths it to one of the Common Berthing Mechanisms on the Harmony Node Module. Yet again custom made decals were used for the HTV solar panels, although in this case I just had to reduce the artwork which I had used for the larger scale kit.

During the STS-133 shuttle mission NASA had agreed with the Russian Space Agency Roscosmos, that a Soyuz would depart and photograph the station with all of the Visiting Vehicles docked (which didn't happen very often). However, unfortunately the departing Soyuz was a new version which had developed problems and the Russians declined to undertake complicated manoeuvres for a fly around so that opportunity was lost. I decided that I would duplicate the photography which would have taken place from the planned angles with the model. On the penultimate shuttle mission, STS-134, the photography finally took place but by that time the HTV had departed.

Looking at the photographs I have taken of the model over the years, when I started with only two modules some 120 mm in length to what it looks like now gives one a true sense of just how this remarkable spacecraft has evolved.

The two best publications which describe the individual ISS elements and detail the

International Space Station Size & Mass	
Module Length	51 metres
Truss Length	109 metres
Solar Array Length	73 metres
Mass	419,455 kilograms
Habitable Volume	388 cubic metres
Pressurized Volume	916 cubic metres
Power Generation	8 solar arrays = 84 kilowatts
Lines of Computer Code	approximately 2.3 million



A simulated view looking up at the USS with Shuttle Endeavour on STS130 bringing the Tranquillity module and the Cupola. *Keith McNeill*

construction phase are;
Reference Guide to the International Space Station edited by Gary Kitmacher
Haynes International Space Station Owners' Workshop Manual by Dr. David Baker

Realspace have the US solar array trusses for sale: http://www.realspacemodels.com/

NOTE about the photography:

Over the thirteen years I worked on the model, I have used print film, transparency film, which was scanned and converted to digital, and digital cameras of increasing resolution and the quality of the accompanying images reflect the changes in formats.

Spaceflight would like to thank the International Plastic Modellers Society (IPMS) for permission to reproduce this feature. Readers may like to know that there is an active space modelling section at the IPMS.

I decided to ask Keith McNeill to contribute his report on building the International Space Station because it represents a master-class in model making and associated photography. Launched in 1963, the IPMS can be contacted through their website – ipmsuk.org. Editor

Another view of the simulated fly around with a clear view of the workmanship that gives a remarkably realistic appearance both to the International Space Station and the Shuttle. *Keith McNeill*