Preface

For any researcher the history of the American Space Shuttle program is both complex and extensive. It is therefore difficult to condense almost fifty years of development and operations into a single book, or even to a series of volumes. A more suitable aim for a single volume is to provide an in-depth account on a specific topic, a single flight, or a series of related missions. Even then, it is a challenge to condense the voluminous data into a single volume and still present a worthy account. This was the challenge I faced when commencing the research into how the Space Shuttle program was organized and operated to support the delivery, assembly, and resupply of the large structure in Earth orbit that we now know as the International Space Station.

Central to this story were the missions themselves, but the planning which went into each flight, the support provided by numerous ground facilities and teams of engineers, controllers and managers, plus the selection and training of the astronauts that flew the missions were also stories worth investigation. Trying to understand how each Shuttle stack arrived at the launch pad highlighted the extensive and interwoven preparations undertaken at the Kennedy Space Center in Florida, and this prompted further research into the process of integrating the hardware, experiments, and payloads, in addition to the facilities that supported the processing prior to launch. Next I came to the research for the various phases of a mission: the launch, the period of rendezvous and docking, the activities of the Shuttle crews at the station, the transfer of the payloads externally using the Canadian-built Remote Manipulator System, or internally by crewmembers manhandling the supplies into the station and the trash back out. Then there were the spacewalks conducted to support the external assembly and relocation of hardware at the station. Finally, there were the undocking and fly-around phases prior to returning to Earth.

For BIS publications, I had already briefly reviewed the series of Shuttle-Mir flights and the first four years of Shuttle-ISS operations spanning STS-88 to STS-113. For this project, I decided I would bring the story up to date, through to the completion of ISS assembly and the termination of the Space Shuttle program. I included the 1994 flight of the first Russian cosmonaut aboard an American mission (STS-60) that initiated the Shuttle-Mir program. These activities involved forty-eight flights of the Shuttle spread

across seventeen years, encompassing one rendezvous and nine dockings with Mir and an impressive thirty-seven missions to the International Space Station. Having briefly covered each of these missions in the two editions of the *Manned Space Flight Log* by Springer-Praxis in 2007 and 2013, I did not wish merely to repeat the flight activities recorded in therein. Equally, the constraints of the original single volume would not allow me to delve as deeply into each mission as I would have liked. I also couldn't merely update the articles in the BIS publications. Hence this project started out as a different approach to recording the extensive program.

From the start, it became apparent that a distinct profile was flown by each Shuttle mission to a space station. Of course a 'typical mission' never really existed, as each flight was unique in its own right. Nevertheless, I have reviewed a number of generic processes and sequences that can be considered to be common ground for each of the missions flown. What was also evident, was the clear division between the story prior to commencing the assembly of the ISS and the period after construction commenced. In researching for this project, I found that the desire to send a Shuttle to a station was almost as old as the program itself, and was one of the original reasons for developing what became the Space Transportation System (STS) concept in the first place.

In fact, the background to blending the Shuttle system with a space station program, and the other way around, was over twenty years in the making. From early conceptual studies for the Space Shuttle through to the dockings of the Orbiter at the Russian Mir space station in the 1990s was a long journey of design, development, cancelation, and eventual success. And this was before a single element of the ISS was launched. After discussing the scope of my research with Springer, they decided that rather than cover the entire story in a single huge volume, I should write two separate books.

In *Linking the Space Shuttle and Space Stations: Early Docking Technologies from Concept to Implementation*, I wound the clock back to the start of the Space Shuttle era and the ambitions to use that system to create and supply a scientific research station in Earth orbit, the background story to the proposed 1981 Shuttle-Salyut docking mission, as well as a simultaneous study by NASA into using the Shuttle to return to the Skylab orbital workshop and restore it to use. The narrative continues with the plans to use the Shuttle to assemble Space Station Freedom, before this morphed into the International Space Station with the inclusion of the Russians enabling NASA to gain much-needed experience of operating the Shuttle in concert with a large space facility by performing the series of Shuttle-Mir docking missions prior to initiating ISS operations. This first volume explains the background to key milestones required to 'link' the Shuttle to the space station, the development of a successful rendezvous and docking system, and an effective method of carrying and transferring tons of hardware to and fro between the two vehicles. The nine dockings by Shuttles at Mir between 1995 and 1998 provided a 'proof of concept' for more extensive operations planned at the ISS.

This second book takes up the story from the end of Shuttle-Mir, at the point where there was some concern that the start of the ISS assembly might be delayed once again due to the unavailability of Russian hardware to initiate assembly. The second chapter briefly reviews the three dozen Shuttle flights between starting to assemble the ISS in December 1998 and the retirement of the Shuttle in July 2011. The third chapter steps away from flight operations to review the fascinating and often complicated world of how crews are

assigned. The how and why of a particular astronaut's assignment to a given flight remain a largely mysterious process, a closely guarded secret confined to higher NASA management. Even those in the Astronaut Office who actually flew the missions sometimes have no idea why they were chosen over their colleagues.

Chapter four recalls the myriad procedures, facilities and activities that were needed to get a Shuttle mission off the launch pad, and specifically those to the ISS. Details of the principal facilities at the Kennedy Space Center in Florida which supported Shuttle pre--launch and launch operations were covered in depth in the first volume, and so are only briefly recalled here. Instead, specific to the International Space Station program, is the description of the specialized building that was created in order to handle the vast amount of hardware and cargo that was assigned to the Shuttle missions to the ISS over a period of thirteen years. A 'flight' into space can be viewed as the sequence of events from a spectacular launch through to a safe landing, but a 'mission' often starts months or indeed years before anything reaches the pad, let alone leaves it, and it can continue for some time after landing. Each mission is inseparably linked to the activities on the ground needed to prepare, launch, and return an Orbiter and its payload (including the crew) to Earth…prior to starting the process all over again. It is a fascinating story of management, planning, dedication and sometimes compromise, while also keeping an eye on the weather, not just at the launch site but also at the various potential landing sites around the globe. In fact, Shuttle processing throughout the program, not merely for the missions to Mir and the ISS, deserves a dedicated book!

Chapter five returns to flight operations and the journey from the launch pad to the ISS and, after the loss of Columbia in 2003, the introduction in 2005 of an impressive 'back--flip' maneuver known as the Rendezvous Pitch Maneuver that was executed by each Orbiter to allow ISS crewmembers to conduct a detailed examination, especially of the thermal tiles on its underside. The chapter also recalls the docked phase, during which a visiting Shuttle crew would integrate with the long-duration station crew.

The following two chapters review how the tons of hardware and cargo destined for the space station was delivered and then either transferred inside or bolted on. Chapter six covers the transfer of large elements of hardware internally by the crew, physically moving equipment from the pressurized compartments of the Shuttle. This transfer was often through numerous hatches, tunnels, and crowded compartments into the modules of the space station. By a reverse route unwanted materials, samples from experiments, and trash were loaded aboard the Shuttle for the trip home. This chapter also reviews the various methods and items of crew apparatus that were available to carry logistics between vehicles, and the skills required by the 'loadmaster' to ensure that every item was positioned just where it ought to be. A series of procedures developed during the Shuttle-Mir missions were found to be very effective during the Shuttle-ISS assembly and resupply flights.

The seventh chapter explores, in some depth, the development of using the Shuttle Remote Manipulator System (RMS or Canadarm) in an extensive program of robotics at the expanding station. Operating the RMS was never a large part of Shuttle-Mir but with a wide range of experience from using the arm on several other projects, such as the Hubble servicing missions, NASA was confident it would function satisfactorily during the early stages of ISS assembly. As the station expanded, in 2002 the reach of the RMS on the Orbiter became a limiting factor in continued assembly, requiring the installation of a

robotic arm on the station (SSRMS, named Candarm2). Despite these restrictions, the RMS continued to be used on missions to the end of the program for examining the Orbiter, working jointly with the SSRMS, and in supporting teams of astronauts during EVAs. The history of the RMS also warrants a separate story to be written.

The series of EVAs at the ISS are explored over two chapters, and how after many years of study the myriad of tasks were approached, resulting in the highly successful series of spacewalks that supported the assembly and expansion of the facility. Here a more in--depth approach is presented in the build-up to space station EVA activities *by Shuttle flight crew members*, with those conducted by resident crews left to be covered elsewhere. The story begins with plans to use extensive EVA operations to support the assembly of Space Station Freedom and the enormous growth in the projected number of spacewalks that would be required not only to assemble that facility but to maintain it throughout its operational lifetime. It would have been difficult for the astronauts of visiting Shuttles to support station resident teams in a seemingly endless series of back to back EVAs during each year of operations.

The penultimate chapter continues the EVA story at the ISS and the preparations to scale what was known as the 'Wall of EVA' for assembling the ISS, and how, step by step the use of a larger neutral buoyancy training facility and a series of spacewalks to evaluate tools and techniques helped to create the baseline to support an extensive and highly successful series of EVAs at the ISS over the thirteen-year period of assembly. As with other aspects of the Shuttle and ISS programs, it is hoped a far more detailed history of EVA at space stations will appear in due course.

The closing chapter reviews the undocking from the station, fly-around inspection, and return of an Orbiter to Earth. It is remarkable how smoothly missions to Mir and the ISS were executed. Nevertheless there were always plans and procedures available to overcome a variety of potential problems. One of these 'what if' scenarios addressed the difficult situation of an Orbiter that had docked at the ISS and was unable to return safely to Earth. This chapter concludes by looking at how an unmanned Orbiter would be undocked and disposed of. This situation never occurred of course, but it is worth recording here in order to complete the story of the Shuttle activities at space stations.

In researching for my project about the Hubble service missions – which were also instrumental in developing techniques for Shuttle rendezvous and EVA operations at the ISS – I found so much more to study and record. The same is true for this current work, which has prompted more in-depth research into each Shuttle assembly mission and the people who prepared and flew them. There was simply not enough room even within two volumes to tell those stories in great detail, but this work continues…

David J. Shayler, FBIS
Council Member, British Interplanetary Society,
Director, Astro Info Service Ltd.,
www.astroinfoservice.co.uk
Halesowen, West Midlands, UK
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