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Preparing to fly

Today, the [training] facility computers and equipment are out of date and obsolete. Plans exist to update the equipment [but] over a 10-year period and are minimal.
Robert K. Holkan, Chief,
DG6 JSC Training Division.
From a memo dated April 11, 1986.

Despite years of planning and 60 months of flight operations, the comment above illustrates the frustration that was being felt in preparing Shuttle crews for space flight using equipment which should have been state of the art, but was instead already falling behind the requirements for a rapidly expanding program.

Training for space flight always presents a challenge for those who undertake the program and those who prepare and supervise their courses. Schedules were always tight during the Mercury, Gemini and Apollo programs, even when there were relatively few active astronauts vying for "sim time." By 1986, almost two decades later, it was becoming even more of a challenge during the early years of the Shuttle program to ensure that several multi-person crews remained at the peak of performance and ready to fly, while simultaneously implementing refinements to the system based on debriefings of recently-returned crews, initiating new training programs for future crews, and always pushing for new equipment and software programs within a limited budget.

Between 1959 and 1969, NASA had chosen 73 men in seven small groups of between six and 19 members. This cadre trained for or supported 37 missions across a 22-year period under the Mercury, Gemini, Apollo (including Skylab and the Apollo-Soyuz Test Project – ASTP), a number of ground and airborne

D. J. Shayler, C. Burgess, *NASA's First Space Shuttle Astronaut Selection*, Springer Praxis Books, https://doi.org/10.1007/978-3-030-45742-6_8

simulation, and the early Shuttle Approach and Landing Test (ALT) and Orbital Flight Test (OFT) programs.

In contrast, 84 men and women had been chosen in just four new astronauts groups in the seven years between 1978 and 1985. There were plans for more to arrive at regular intervals to meet the expected Shuttle flight rate (at least 26 missions a year from two different launch sites), crewing requirements of up to seven persons on one mission, and natural attrition rates. Clearly, the training program for such an influx of crews and missions would be put to the test, but it was a problem which NASA had addressed, or so they thought given the headline above, long before any astronauts were chosen to train for Shuttle missions or new astronaut groups were specifically selected for that program.

A NEW TRAINING PROTOCOL

Twenty years after NASA had chosen its first seven astronauts to train for the one-man Project Mercury missions of up to 24 hours in Earth orbit, the agency was faced with a group five times as large for flights on the multi-seated Space Shuttle, on Earth orbital missions of between seven to ten days. As NASA's programs progressed from Mercury to the two-man Gemini and then to the three-man Apollo spacecraft, the training syllabus had focused on a small crew mastering the workings of their spacecraft, acquiring the techniques of rendezvous and docking, and gaining new experiences in walking in space, lunar geology and space navigation, with a little science thrown in[1]. For those who had not previously qualified as a jet pilot in the U.S. armed forces (the civilian members of the 1965 and 1967 Scientist-Astronaut selections), there was also the rather daunting challenge of a 53-week U.S. Air Force (USAF) military jet pilot training course to graduate from, prior to tackling the astronaut basic, survival and academic training program.

A change in direction

Having moved on from the one-shot ballistic spacecraft that had featured in the 1960s and 1970s, the Space Shuttle necessitated a whole new approach to training for space flight, and the 35 members of NASA's latest group of astronauts would be the first to experience this transition. The era of 'hot-shot' test pilots with what became known as the "*Right Stuff*" aura and a 'can-do' attitude was over, to be

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[1] Significantly more scientific research was conducted by the three Skylab crews during their 28, 59 and 84-day missions in 1973/4. This included extensive studies in astrophysics, solar physics, Earth observations and resources, materials science and space manufacturing, engineering and technology, life sciences, and student experiments and science demonstrations.

replaced by astronauts with more academic and engineering skills rather than test flying credentials.

Early 1970s documentation researched by the authors from the NASA archives helps to explain the protocol in developing this new training program. While the experience of past programs would be useful, far more aspects would be radically new. At this point, there was no presidential decree to achieve new objectives (such as a space station) "within a decade," but there was a desire to push rapidly and safely towards the first orbital test flights of the Shuttle system, qualifying the design and format for much more ambitious missions in content and frequency. By the mid-1980s, the program had evolved to achieve 24 relatively successful Shuttle missions, but it was a system already under stress as a production line procession of crews and missions rotated through the program. A 'routine' process was emerging, not with the Shuttle missions themselves, but in assigning crews to train and fly those missions. But that process came to an abrupt halt on a cold January day in 1986, when *Challenger* and her crew of seven, including four members of the 1978 astronaut selection, were lost just seconds after leaving the launch pad, in full view of the gathered officials, family members and onlookers, and the world's media.

Reviewing Shuttle crew training 1986

The subsequent post-*Challenger* inquiry and recovery program would see the Shuttle return to flight in 1988, with a very different emphasis to its mandate. Before that, however, the causes and roots of the *Challenger* accident had to be scrutinized by a Presidential Commission, which turned the American space agency upside down as it examined all aspects of preparing for and flying the Shuttle in detail. Part of this in-depth assessment included the normally restricted process of training the crews, trying to uncover any issues which may have contributed to the loss of the astronauts and the vehicle.

Though training did not directly contribute to the tragedy, the 1986 *Report of the Presidential Commission on the Space Shuttle* Challenger *Accident* stated: "An assessment of the system's overall performance is best made by studying the process at the end of the production chain: crew training. Analysis of training schedules for previous flights and projected training schedules for flights in the spring and summer of 1986 reveal a clear trend: less and less time was going to be available for crew members to accomplish their required training." **[1]**

A number of issues were highlighted which directly or indirectly affected crew training, pressurizing the training process. These were summarized as late changes in the manifest from hardware problems, customer requests, operational constraints and external factors. In its recommendations, the Commission noted (Item 8) that reliance on the Shuttle as the nation's principle space launch capability created pressure on NASA to increase the flight rate. **[2]** In the future, NASA was advised to set a flight rate that was consistent with its resources, including establishing a firm payload assignment policy for more rigorous control of cargo manifest changes, to "limit the pressures such changes exert on schedules and crew training."

By late 1985, the system in place for producing crew training materials was struggling to keep up with the increasing and changing flight rate. The number of training simulators was another limiting factor, and the capacity of the two available simulators could not sustain training more than 12–15 crews each year (which the program had yet to attain, but which was planned for the next few years). Another limiting factor was when flights followed each other in rapid succession, where critical anomalies occurring on one mission could not be fully identified and corrected before the next mission flew. As Group 7 astronaut Henry Hartsfield testified, "Had we not had the accident, we were going to be up against a wall. STS-61H… would have to average 31 hours in the simulator to accomplish their required training, and STS-61K would have to average 33 hours… That's ridiculous. For the first time, somebody was going to have to stand up and say we have got to slip the launch because we are not going to have the crew trained." **[3]**

Clearly, the loss of the *Challenger* and her crew brought to the fore issues which had been getting worse for some time, as reflected in the statement at the start of this chapter. To enable the Shuttle to resume flying, these and many other recommendations, findings and issues had to be addressed.

The documentation released on Shuttle crew training, as part of the investigation into the loss of *Challenger*, provided a rare insight into how crews were trained for Shuttle flights in the 1980s, at the height of the active involvement of the 'Thirty-Five New Guys' (TFNG) in the program. Using this information as the basis for this chapter, and following a review of crew positions below, we present an overview of the Space Shuttle crew training process circa 1980s, which all of the TFNG completed on the path to their first space flights.

SPACE SHUTTLE CREWING NOMENCLATURE

Before reviewing the training program that all members of the Class of 1978 passed through as either a Shuttle Pilot (PLT) or Mission Specialist (MS)[2], it is useful to review the different positions to which a crewmember on the Shuttle could be assigned.

[2] The Ascan training program instigated in 1978 continued, with a few refinements, through to the Class of 2004 (Group 19 "The Peacocks"), who were the final group to receive Shuttle mission training. From the Class of 2009 (Class 20 "The Chumps"), the emphasis shifted to the ISS and future space exploration programs.

Prime Crew: The group of astronauts who fly the mission, which for Space Shuttle missions was as little as two and occasionally as many as eight. The Shuttle did have the capacity to fly ten crew members in an emergency situation, but this was never called upon operationally.

Back-up Crew: During the Mercury, Gemini and Apollo era, in the event of injury or illness during training, NASA assigned a team of astronauts to 'back-up' the prime crew. By shadowing their training program, the back-up team could step in at short notice to replace part or all of the prime crew, allowing the mission to proceed with little delay.

Though this system worked well and was utilized on some of those pioneering missions, it was not fully adopted for the Shuttle program after the OFT missions were completed, because it was felt that there would be an adequate pool of suitably prepared crewmembers capable of stepping in should the need arise. It was also thought that adding a second 'crew' to each flight would simply clog up the training syllabus and simulator time, which was already tight. However, there were a few occasions – mostly later in the program – where a sole NASA astronaut was assigned as back-up to a crew for a specific time or purpose. In general, from STS-5 in 1982 to the end of the program 30 years later, relatively few 'official' back-up NASA crewmembers were assigned other than for most of the Payload Specialist (PS) positions.

The system that had been in place between 1965 and 1972 (during Gemini and Apollo), in which a complete back-up crew could expect to skip the next two flights and be prime crew on the third to utilize their training to the maximum, was no longer viable for the expected frequent flights and rapid turnaround of the Shuttle program. The "back-up one mission, skip two, fly the third" system had been created in the early 1960s by former Mercury astronaut and Director of the Flight Operations Directorate, Deke Slayton, and worked extremely well. However, where the Gemini or Apollo flight profiles and objectives were relatively similar within the two programs, the expected frequency of the Shuttle missions and the multiplicity of operations on orbit between the ascent and entry phases meant that specific mission training for more than one crew per mission would have been difficult. As virtually no mission would be a duplicate of the previous flight, creating an on-going repetitive system from one mission to the next would have been almost impossible, and that was without considering hardware delays and changes to the launch manifest.

While no formal back-up system was adopted for the Shuttle's operational missions, some crews during the period 1982–83 were prepared to 'support' a mission with a similar payload, such as a Tracking and Data Relay Satellite (TDRS) deployment crew supporting an earlier TDRS flight, or a commercial satellite deployment crew supported by another team preparing for a similar mission themselves a few months down the line. Though not officially a 'back-up' team, this capability was available if required (which it was not) to replace a crewmember or even a whole crew. It offered additional and early standalone training in the Shuttle Mission Simulators (SMS) for the later crew and useful support for the earlier flight crew, until the astronaut pool included several flown Shuttle PLT and MS. The original assignments (prior to 1983 problems with the Inertial Upper Stage – IUS – deploying TDRS satellites) were:

- STS-5 crew (Comsat deployment mission) – supported by the STS-7 crew
- STS-6 crew (TDRS deployment mission) – supported by the STS-8 crew
- STS-7 crew (Comsat deployment mission) – supported by the STS-11 crew
- STS-8 crew (TDRS deployment mission) – supported by the STS-12 crew

In 2019, Steve Hawley explained the philosophy of these 'support' assignments: "There were often more simulations for training the control center than the crew might be able to support given their other obligations, and so what we could do in order to support the training and the Flight Directors and the control center people would be to use another crew further down the line that had a similar payload – it would still be good training for them, not negative training – and they would support what we would call the integrated sims if the prime crew wasn't available. We did that more commonly earlier in the program than we did later." Hawley could not remember when this was stopped, but by 1984 the manifest and payloads began to change more frequently, making it difficult to match crews with similar payloads in 'support' roles for simulations.

THE ASTRONAUT ROLES ON A SHUTTLE CREW

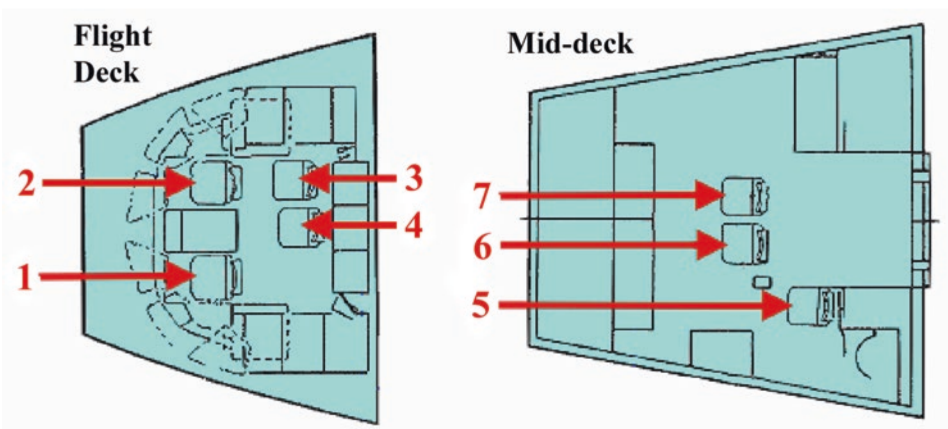

Fig. 8.1: A plan view showing the Space Shuttle Flight Deck (left) and Mid-deck (right) seating (Image courtesy of Joachim Becker, SpaceFacts.de).

The specific crew roles were defined as:

Commander: (CDR – Seat 1, the left-side front position on the flight deck). Each CDR was responsible for the vehicle in which they were flying, their crew, the success of the mission and overall safety. The position was analogous to the duties of a ship's captain.

Pilot: (PLT – Seat 2, right-side front position on the flight deck). Each PLT assisted their CDR and was formally second in command. Their primary responsibilities included operating and flying the Orbiter. During the orbital phase of the mission, both the CDR and the PLT assisted the rest of the crew in aspects of the flight, notably the deployment or retrieval of payloads, operation of the robotic arm, or in support of scientific objectives.

Mission Specialist: (MS#). According to NASA documentation, future MS were: "required to have a detailed knowledge of the Shuttle systems and operational characteristics, mission requirements and objectivities, and supporting systems for each of the experiments to be conducted on the assigned mission. By working closely with the Commander and Pilot, the MS are also responsible for the coordination of onboard operations involving crew activity planning, the use and monitoring of onboard consumables (fuel, food, water etc.), and for conducting experiments and payload activities. MS also perform experiments, spacewalks [Extra-Vehicular Activity, or EVA] and payload handling functions involving the [Remote Manipulator System] RMS arm."

The MS were not required to 'fly' the vehicle or land it, which established two paths of mission training for the NASA crew – one for the flight deck crew (CDR and PLT) and one for the MS – that could be merged when required. Each took on specific but mostly interchangeable responsibilities as a crewmember. The number of MS assigned to a flight crew depended upon on the mission flown.

On all Shuttle flights between STS-5 in 1982 and the end of the program in 2011, MS were assigned to each flight crew. These could number as few as two or as many as five. With the inclusion of foreign nationals in the NASA astronaut training program from 1980, each new astronaut selection (though not all) after that date could include representatives from partner agencies in the Space Station Program who had completed the NASA MS training syllabus, (Canada, Europe, Japan, and even Russia from the early 1990s, whose cosmonauts needed to complete only an abbreviated MS training program due to their previous experience).

While this seemed outwardly sensible in a growing international program, these international crewmembers, as well as American or overseas PS and USAF Manned Spaceflight Engineer (MSE) candidates, took up some of the limited number of flight seats on a mission given their importance to that mission or payload, which in turn restricted the seats available to NASA's career astronauts and the frequency in which they flew. Outwardly, the inclusion of such non-NASA personnel into a crew never seemed to cause major crew integration problems, though there were some initial doubts and some adapted to their temporary astronaut role better than others. For today's International Space Station (ISS) Program, such multinational crewing or 'non-career' crewmembers are now familiar, but in the early 1980s this was still a relatively new phenomenon and in some cases took a while to get used to by the parties involved.

Which Mission Specialist does what?

Once assigned to a Shuttle crew, the MS received a numerical designation which did not necessarily reflect their previous medical or scientific, technical or engineering experience. Though taken into account on some missions, it often meant that an astronomer would not *always* fly on an astrophysical research flight, nor a doctor on a medically-orientated mission, or an engineer on a deployment mission.

In his NASA Oral History, Mike Mullane explained the differences in these roles: "At various times, different people – Judy [Resnik] and I, for example – [laid] out the roles and responsibilities for the [three] Mission Specialists, [such as] their roles and responsibilities, generically, so you don't have to reinvent a training program every time you name a crew[3]. So we came up with a scheme in which MS-1 had overall responsibility for payloads and experiments in orbit, and MS-2 had primary responsibility for flight engineering and helping the Pilot and Commander during ascent and entry, and back-up for payloads. MS-3 really had responsibilities for independent experiments and also an EVA responsibility. [4]

"So that's kind of the way we laid it out. MS-3 would be typically the most junior and the lowest training requirement but heavy on EVA. MS-1 would have the largest overall responsibility and, in principle, ought to be the most experienced member of the astronaut Mission Specialist crew. And MS-2 had the most simulation time, [spending] an enormous amount of time in the simulator… We split it that way in order to recognize the fact that the flight engineering role was the dominant training requirement for one of the Mission Specialists, and therefore that person shouldn't be burdened with overall responsibility for the satellites."

Mission Specialist 1: Usually occupied Flight Deck Seat 3 located behind the PLT. Normally 'ascent trained', their primary role was to assist the flight deck crew in operating Shuttle systems, by monitoring displays of checklists on the way to orbit. On some flights, MS-1 would swap places for the descent with another crewmember, usually MS-3 who had flown the ascent on the middeck.

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[3] Here, Mullane is referring to a nominal five-person Shuttle crew, consisting of CDR, PLT and three MS.

Mission Specialist 2: [see *Flight Engineer* below]

Mission Specialist 3: Normally occupied Seat 5 near the left-side hatch window on the middeck for launch. As they could be 'descent trained', they could swap with MS-1 in the Flight Deck Seat 3 seat position to assist the flight deck crew during the entry and landing phase. From 1988, in response to upgrades following the loss of *Challenger*, the MS-3 position was given added responsibility to activate the escape slide pole, designed for rapid crew exit from a stricken Orbiter. Fortunately, though they were well trained for this role, it was never called upon in a real emergency. From STS-26 in 1988, the MS-3 role also encompassed the responsibility of helping crewmembers get out of their launch-entry suits, as well as stowing the middeck MS seats and ensuring that equipment on the middeck was ready for orbital operations. At the end of a mission, MS-3 also led the crew's efforts to unpack the seats and assisted in donning launch-entry suits in preparation for landing. Often overlooked, this role could be quite involved and at times very busy.

Mission Specialist 4 and 5: Launched and landed on the middeck, taking Seats 6 and 7 facing the middeck lockers and having minimal roles during ascent or entry. During Shuttle-Mir and when returning ISS crewmembers, one or more of these seats would be reconfigured into a recumbent seating position, allowing the crewmember to lie prone on the middeck floor with their feet in vacant locker spaces to ease their adaptation back to Earth's gravity after a lengthy stay on a space station. Yet again a member of the TFNG, Shannon Lucid, pioneered this system when returning from her six-month Mir mission in 1996. It became the standard on Shuttle missions returning ISS resident crewmembers through to 2009.

Flight Engineer (FE): Always allocated to MS-2, occupying Flight Deck Seat 4 between and behind the CDR and PLT. This position was developed during STS-5 (by Class of 1967 astronauts William B. Lenoir during ascent and Joe Allen during descent) and evaluated on STS-6 (by Donald H. Peterson (class of 1969) for both the ascent and descent phases). The MS-2 role included the responsibility of assisting the flight deck crew during the ascent to orbit, for deorbit preparations, and during entry and landing, as well as sometimes assisting with complex orbital maneuvers of the Shuttle during science operations. They also monitored potential abort modes during ascent and contingency planning in the event of a mishap during landing, keeping track of real-time information via the Capcom and calling out milestones during the ascent and descent to the flight deck crew. Essentially, MS-2 was also a third set of eyes and ears on the flight deck during critical phases of the mission. For one member of the Class of '78, this proved very useful in his rise 'up the ranks' on the Shuttle flight deck.

As Steve Nagel, the Group 8 astronaut who flew initially as MS-2 (despite being selected as a pilot) before going on to fly as PLT and then commanding two subsequent missions[4], explained: "The MS-2 is like the Flight Engineer, so you learn all the same Shuttle systems that you'd have to learn as the Pilot or the Commander. So the switch from MS-2 seat to the Pilot seat wasn't that hard. It was just that I had all the head knowledge, and now I just had to be able to put it into practice. I had done a little bit of that, but at a certain point I had stopped training for the second flight [to fly his first mission], and then I got right back with it after the first flight. The missions were totally different, but what I had to learn for the Shuttle systems and all that was almost a one-to-one carryover, except for the Spacelab… The Spacelab was something totally different, and I had had some classes on it and learned some about it before the first flight, even. Then I had to stop [for the first flight], and [then] pick it up and really hit it hard before the second flight. So the Spacelab was a big difference."

Developing the roles on the mission was an on-going process as the program matured, as Steve Hawley explained in a 2019 interview. A professional astronomer by trade, Hawley was determined to master the new skills required for sitting in flight deck seat 4. "It was challenging, but it was awfully exciting, [and] one of the things that motivated me [was that] I really wanted to understand how everything worked. So I learned how the software worked and then I learned how the other systems worked. As a matter of fact, I think it was prior to 41D [in 1984], I wrote a little handbook that explained why the malfunction procedures for aborts were written the way they were, and I did it for the benefit of the others in training. I had a good time understanding why we do it, and a lot of the time I found out that people thought they knew why these steps were being done and they were wrong." **[5]**

Payload Commander (PC): This was announced as a new crew role by NASA in January 1990, with the change from commercial satellite deployment to more scientific payloads. It required a flight-experienced MS to be assigned but was not a dual role as with MS-2/FE. The PC was given additional responsibility for managing the major science or other payload assigned to the mission. The role was to provide long-range leadership in the development and planning of payload crew science activities. The PC had overall responsibility for the planning, integration and on-orbit coordination of payload/Shuttle activities on their assigned mission, while the mission CDR retained overall responsibility for crew and mission safety. The initial allocations of this role were made after the respective crewmembers had been assigned to their missions. Of the four initial PC assigned, three were from Group 8 (Norman Thagard on STS-42/IML-1, Kathy Sullivan on STS-45/

[4] Dave Griggs was another pilot candidate from the Class of 1978 who flew his first mission, STS-51D in 1985, as MS-2. At the time of his death in an off-duty plane crash in 1989, Griggs was in training as PLT for STS-33, which would have been his second space flight. It was widely expected that he would also have transitioned to the command seat on his third mission, had he lived.

Atlas 1, and Jeff Hoffman on STS-46/Eureka/TSS-1), reflecting the importance of this new position as the science became more complex on Shuttle missions. As with EVA crew assignments in the 1990s for complex spacewalking objectives requiring longer training time, subsequent PC assignments would be made in advance of the remainder of the flight crew in order to help identify and resolve training issues and operational constraints prior to crew training. In addition, it was envisaged that the role of PC would serve as a foundation for the development of the Space Station *Freedom*/ISS Increment Commander concept, another example of the significant role that members of Group 8 provided both in the development of Shuttle operations and also in planning and preparing the initial ISS crewing regimes.

In her 2009 Oral History, Kathy Sullivan explained that the role of PC had more than one element to it. **[6]** "Payload Commander was the NASA Mission Specialist who would oversee and organize typically two Mission Specialists and two Payload Specialists who work back-to-back shifts operating complex, multi-experiment Spacelab flights. I think several factors went into conceiving the Payload Commander role.

"One is [that] you've got a very complex Spacelab mission with a dozen, to three or four dozen experiments. The training time that the responsible Mission Specialist should put into that needs to be longer than the Pilot and Commander probably need to put into the basic orbital operations. So you're going to want to slot in Mission Specialists 18, maybe 24 or 36 months in advance so they can build the relationships that are necessary with the scientific team and the payload operations team, get out to the factories, laboratories, engineering facilities, and see the flight hardware [to ensure] that the mission simulations are going to represent those payloads. Sometimes it's built into the Shuttle Mission Simulator. Sometimes the preparation is done differently. The payload crew [played] a really substantial role in helping the simulation teams know how to model the payloads correctly."

Sullivan also explained the authority given to the PC in these more complex missions, "to provide a long lead time for the mission crew, to be sure that one of the NASA Mission Specialists is considered and recognized as authoritative in all those early planning decisions. You want that group to be able to make effective decisions and move the flight preparations forward, not have various people on the team saying someone doesn't have the authority to do this or [that] we need the [mission] Commander to make this final decision. Naming a Mission Specialist as Payload Commander gave that authority. You're also counting on that person to use smart judgment when different payload operating or crew issues do impinge on larger flight ops constraints that do eventually need concurrence by the Flight Director or by the Commander. You're not going to step in and overrule those or supplant those. You need someone who's representing CB [Astronaut Office] and JSC [Johnson Space Center, Houston, Texas] and able to keep the ball moving in those early lead phases. Helping the Payload Specialist folks, who sometimes have had prior flight experience – one of our Payload Specialists had flown before – but often this is their first time. Giving them some guidance about 'This is how it's going to get done,' or, 'This is the way things normally go.' Being that training voice about life aboard the Shuttle, with some authority backing that up.

"That was the whole idea. Later, closer to launch, when you combine the payload crew with the Shuttle crew, that balance shifts around. The Shuttle Commander is the Shuttle Commander, there's no two ways around that. You help the Commander in that sense, because you know the mission teams. You know the experiment teams. You have a little more insight about the personalities, cultures, backgrounds, mindsets that the payload team brings to bear and can help jump-start the overall crew's understanding of that by the time investment that you've made. That was the idea behind it."

Payload Specialist (PS): This position was created specifically for the Shuttle program. They were professionals in the physical or life sciences, or technicians trained in Shuttle-specific requirements or hardware. The PS were chosen by sponsoring organizations, customers, or investigator working groups approved by NASA. They could also be politicians with links to the space program or guest observers flying on behalf of major suppliers. Though not career astronauts, they had to meet NASA's health and fitness standards and pass security vetting, but they did not have to be U.S. citizens. In addition to preparations at a company facility, university or government agency, the PS also had to complete a comprehensive flight training program to become familiar with Shuttle systems, support equipment, crew operations, housekeeping duties and emergency procedures. This specific training at NASA centers usually took place as much as two years prior to a flight (sometimes a much shorter time period), though each mission required some individual adjustments to this schedule. Several Group 8 astronauts flew in a crew that included PS.

Manned Spaceflight Engineer (MSE): Despite the cancellation of the USAF Manned Orbiting Laboratory (MOL) program in 1969, without a single crewed mission flown, the USAF sought to be involved in the development of the Space Shuttle for military objectives, and were adamant that the size of the Orbiter's payload bay should fit their requirements for planned classified payload deployments, rather than NASAs smaller bay size for more scientific operations. At its creation in the late 1960s, the Shuttle was intended to have a 'launch-all' capability, handling not only civilian payloads but all of America's military and classified payloads as well. There were plans for the USAF to purchase up to three Shuttle Orbiters of its own (known as "Blue Shuttles") and associated hardware (engines/fuel tank/boosters, etc.) and operate them with all-military crews into strategically advantageous polar orbits from a specially converted facility, Space Launch

Complex 6 (known as 'Slick 6'), at Vandenberg Air Force Base (AFB) in California. Hoping for up to 12–14 Department of Defense (DOD) Shuttle missions each year, there were plans to create a classified Mission Control Center in Colorado, but USAF budget restrictions, problems in reaching the required annual Shuttle launch rate, hardware difficulties and the loss of *Challenger* contributed to the USAF pulling out of the Shuttle program after 1986.

The MSE designation was therefore created in the late 1970s to train and fly serving military personnel to accompany classified payloads on dedicated Shuttle missions. Though plans for its own fleet of Orbiters were eventually abandoned, the USAF still desired to have its own personnel on-hand for classified military payloads, and as a result chose a total of 32 military candidates in three groups (13 in 1979, 14 in 1982 and 5 in 1985) to train as MSE. While military observers and specialist crewmembers were trained and assigned to crews, in the end only two MSE flew, on two separate Shuttle DOD missions during 1985, the crews of which both included representatives from Group 8 (Shriver, Onizuka and Buchli (with Gary E. Payton, USAF) on STS-51C and Bob Stewart (with William A. "Bill" Pailes, USAF) on STS-51J). Following the loss of *Challenger* and subsequent grounding for nearly three years, the USAF budget restrictions and a move to expendable launch vehicles signaled the end of the MSE program by the late 1980s, with no further flights completed. A third military crewmember, Thomas Hennen, was not an MSE but flew on STS-44 in 1991 under the command of Group 8 astronaut Fred Gregory.

Crew responsibilities

With the crew assigned and 'seated', each crew member received specific crew responsibilities as well as key roles in preparing for their missions.

Key crew roles

RMS Operator: On most, but not all Shuttle flights, the Canadian-built RMS robotic arm was carried on the port longeron of the payload bay. The operation of the RMS, from the aft flight deck station, was normally undertaken by a specially trained MS, though some CDRs were also RMS qualified. As well as learning to lift, deploy, capture, maneuver and lower payloads around the payload bay safely and securely, RMS operators became an integral part of Shuttle EVA operations, relocating an EVA crewmember positioned on the end of the arm around the payload bay, or positioning equipment in support of their spacewalk.

EVA Crew: For safety reasons and to achieve mission objectives, at least two astronauts in each crew were trained as EVA crewmembers, using the designations EV1 and EV2 (plus EV3 or EV4 etc., as required), with suit identification marks distinguishing each astronaut out on EVA. All EVA teams featured a lead crewmember (usually EV1). As the Shuttle program developed, more extensive EVA programs were devised in preparation for assembling the space station and for servicing large payloads. Several members of the Class of 1978 were instrumental in developing the Shuttle EVA system that was so critical to the success of missions such as servicing the Hubble Space Telescope (HST) and much later during the assembly of the ISS. When multiple EVAs were planned, a gap day was normally inserted into the flight plan between the EVA days to allow the EVA crew to rest, clean and prepare their equipment for the next sojourn and to review plans for the next spacewalk. Another crewmember (normally the PLT) was assigned to the EVA 'crew' as an Intra-vehicular crewmember (or IV1), to help the EVA crew put on and remove their pressure suits and associated equipment. Usually, an EVA-trained crewmember also acted as chorographer for the spacewalk taking place by observing and directing from the flight deck windows, while other members of the crew controlled the Orbiter or took still photography and film during the spacewalk. Shuttle-based EVAs, like RMS operations and subsequent rendezvous, docking and logistics transfers to space stations, required a team effort that often lasted several days.

Rendezvous and Proximity Operations: Rendezvous with another large object and keeping the Shuttle in close proximity (Prox Ops) only became a major crew objective of several missions towards the end of the Group 8 era. The techniques were pioneered during the early Shuttle missions, with Group 8 astronauts heavily involved during retrieval missions such as Solar Max, Westar, Palapa and Leasat, but with the advent of HST servicing missions and docking to Mir and ISS, it became even more important to practice and master these skills, as no American astronaut had rendezvoused and docked with a second object since the mid-1970s. During the mission, the CDR and PLT handled maneuvering the Orbiter, while the MS handled the RMS, performed visual cueing roles, operated the laser ranging equipment and conducted photo documentation. The key was to have as many eyes as possible on this tricky and intensive operation.

Docking/Space Station Operations/Logistics Transfer. Unfortunately, despite being part of the original planning, the use of the Shuttle with a space station did not reach flight stage until the mid-1990s. By then, most of the TFNG had relinquished their active flight status to seek new goals. As a result, only three members of the selection (Gibson, Lucid and Thagard) visited a space station, the Russian Mir. In 1995, Hoot Gibson performed the first docking between two spacecraft by an American astronaut since Tom Stafford had linked his Apollo spacecraft with Aleksey Leonov's Soyuz in 1975. Already on Mir and scheduled to come home with Gibson and his crew on *Atlantis* was fellow Group 8 astronaut Norman Thagard, who had become the first American to live and work on a space station since Skylab over 20 years before. The following year, Shannon Lucid lived aboard

Mir for six months, initiating a continual presence on the aging Russian station by a series of five American astronauts (working rotational residencies over the next three years) in advance of ISS assembly. These missions to Mir spearheaded a cooperative program with the Russians that resulted in the creation of the ISS, which is still in orbit and operating over 20 years after its assembly began.

Science support: With no space station to build or visit, the early Shuttle missions between 1983 and 1995 (the period in which many of the TFNG completed their missions) had the primary objectives of satellite deployment, retrieval and repair, or science-focused missions using research payloads in the cargo bay. On these missions, many MS worked as part of the 'science' crew supporting the collection of data, while the 'Orbiter' crew (the CDR, PLT and MS-2/FE) looked after the vehicle's systems and maneuvers, as well as sometimes participating in certain biomedical experiments, albeit reluctantly in some cases. During this period, the PC role was created, which would in turn evolve into the Science Officer position assigned to early NASA ISS resident crew members.

TRAINING THE SHUTTLE ASTRONAUTS

The following are summaries of Shuttle mission training programs gleaned from NASA documents from two periods. [7]

The first selection is from 1980, at the very start of the TFNG assignments following Ascan training and the year prior to the Shuttle reaching orbit. The second selection originated from documents made available during the 1986 *Challenger* enquiries, investigating the roles and depth of NASA astronaut participation in the Shuttle program at that time. This was after all 35 of the Group 8 astronauts had flown at least one Shuttle mission each, and while the Shuttle training program evolved over the ensuing years, these documents offer a good representation of the type of training conducted in the mid- to late-1980s when most of the group were active.

NOVEMBER 1980 TRAINING STATUS

In 1980, Shuttle *mission* training was categorized in four areas:

- *Basic training:* This was generic in nature and aimed mostly at recently selected astronauts. It was designed to familiarize them with the NASA infrastructure and the Space Transportation System (STS) program, and to prepare them for further training in more individual roles.
- *Advanced training:* Under this phase, the individual gained the generic knowledge and skills necessary to perform STS operations at a proficiency level required by the position (PLT/MS) for a "typical" flight.

- *Flight-Specific Training:* Based around recurring simulator training, this phase provided the individual with the knowledge and necessary skills unique to their flight. It also included practicing generic STS operations in a flight-specific environment to prepare them for a mission.
- *Recurring training:* This phase was used to maintain the proficiency of experienced astronauts in critical areas of STS operations which were seldom used, as well as incorporating any new information and techniques to a particular field.

In summary, new astronauts would undergo the 'basic training' program as part of the Ascan phase, prior to moving on to advanced training as qualified astronauts who could be included in the 'pilot pool' of available personnel. Potential flight crew members would be selected from this pool to receive flight-specific training, to a level that would deem them to be 'flight ready' and able to perform their assigned mission. After their flight and any post-mission requirements and recovery, the crew would be broken up and returned to the pool of available personnel, where they would occasionally complete any recurring training required prior to their next flight assignment, be reassigned to administrative roles, or eventually step down as an active astronaut.

At the time (1980), this was all theoretical of course, as the Shuttle had yet to fly. However, with a new group of 19 Ascans joining the team (Group 9), plus the 35 Group 8 astronauts and over 20 members of the earlier groups still active, an effective system had to be devised to balance those in training preparing for missions alongside post-mission activity, support roles, natural attrition, medical illness and vacations. It must be remembered that though astronaut training is always intense and involved due to the requirements of the role, the members of the astronaut team (as with flight controllers, trainers, managers and workers) male or female, could become ill, take vacations, travel on official business and request more family time away from constant assignments. Also to be taken into consideration were their responsibilities outside of NASA (especially with serving military astronauts), and times when members of the office were preparing to leave and their absence had to be covered. Just one year before Shuttle started flying, as the 1980 document underlined, the training program was still immature. In the late 1970s, to help develop the Shuttle training program at a quicker pace, it had been decided that the first six flights of the Shuttle (all originally part of the OFT program, subsequently cut to just four missions) would have members of earlier selection groups assigned to the crews. The same 1980 document also revealed that "new Pilots and Mission Specialists [from Group 8 initially] would be assigned to flights beginning with STS-7," which is exactly the way it transpired.

Projection (1980)

As mentioned, by the time the first members of Group 8 began flying in 1983, it had already been decided that no back-up crews would be assigned after the OFT series had been completed. Instead, crewmembers with suitable skills and/or similar flight experience would be available to fulfill a given role as required, or could be assigned to a crew to replace an ill or removed crewmember.

In attempting to make future projections, certain assumptions clearly had to be made. As a guide, the 1980 document focused upon the pilots rather than the MS, suggesting that the re-fly rate for pilots could be an average of three flights per year. Training would be as a crew rather than individual simulator time, and with several 'older astronauts' passing the age of 50 by 1983, the attrition from the office was expected to be heavy during the early operational years; therefore a lower average re-fly rate would be acceptable during those initial years (Financial Year (FY) 1985 and earlier) in order to allow more pilots to be trained "as insurance against attrition losses." Another interesting point made in this 1980 document was the recognition that the serving military astronauts from the Class of 1978, who were just two years into their assignment at NASA and recently out of Ascan training, were scheduled to return to the DOD by 1985/1986, suggesting that the Flight Operations Directorate at JSC was already considering looking for replacements

The 1980 projections suggested that each crew would be spending at least 25 hours per week in training by the flight of STS-7, with an average of 16 hours spent in the simulators by crews training across a 50-hour working week. The unknown variables at the time were the 'classified' developments in the DOD Shuttle Operations and Planning Center (SOPC) objectives, especially as all crew training was planned and agreed to occur at JSC. Some of the basic requirements to schedule these classified objectives remained secret to all but a small group.

Five months prior to the first Shuttle flight, sufficient development had been made to the training program to be able to propose some forward planning as the new group of astronauts were completing their basic training and beginning to receive mission support assignments, pending allocation to their first flights.

In 1980, the main objective of this early Shuttle training program was to develop a list of minimum requirements for a small number of *pilots*. After two years of experience from the STS-1 training flow, significant progress had been made in the simulation of a Shuttle mission model. Based upon the experience of STS-1, a refinement of these definitions followed, and in some cases they were redefined, to take full advantage of the cheaper part-task facilities available within the training program to make the best use of this resource on a restricted budget.

The predictions in 1980 suggested that standardization of the ascent and entry phases would be possible as early as STS-10, or possibly sooner. Repetition was felt to be key at this time, with a program of "standard orbit training" being introduced after two or three missions had flown similar profiles (which would later be defined as TDRS or Comsat deployments, as well as payload bay science missions such as Space Radar Laboratory). Part of this prediction was to factor in the possibility of pilots flying an average of three missions per year. This did not fully come to fruition, although it was evaluated several times by flying the same astronaut on a second mission a few months after his previous flight. This included: Bob Crippen commanding STS-41C in April 1984 and STS-41G six months later in October; Karol Bobko commanding STS-51D in April 1985 and STS-51J that October; and TFNG Steve Nagel flying as MS on STS-51G in June 1985 and, after a record four-month turnaround, returning to space as PLT on STS-61A that October.

Another factor which had to be taken into consideration was the size of the Orbiter 'fleet.' At the start of the program, only a small fleet of Orbiters had been formally authorized, limiting flight seats even further and, as a result, requiring crew performance standards to be maintained at a high level for longer periods between flights. By early 1980, only the first operational orbiter, OV-102 *Columbia*, had been delivered to the Cape and it would not be ready to fly on a mission for a further year. After flying for a fifth time, *Columbia* would be taken 'offline' to undergo a period of upgrades before returning to fly the program's ninth mission. The second Orbiter manifested to fly in space was the former Structural Test Article (STA-099). This had been converted into the operational Orbiter OV-099 *Challenger* and followed *Columbia* into orbit, on the sixth mission in 1983. The other Orbiter, OV-101 *Enterprise* used in the 1977 ALT program, was to have joined them, but it was deemed too costly to convert the atmospheric test vehicle to orbital standards, so *Enterprise* was relegated to further ground testing and destined never to fly into space. At this time, there were just *two* authorized vehicles left in the Rockwell production flow at Palmdale, OV-103 *Discovery* and OV-104 *Atlantis*. They would not be operationally ready until 1984 and 1985 respectively, so *Columbia* and *Challenger* would bear the brunt of missions between 1981 and 1984. While Shuttle missions had been planned to last for 7–10 days each, it still required a considerable effort to maintain and process each vehicle for flight, a factor which had not been fully appreciated in the early projections that described a larger fleet of Orbiters flying one mission a week. Each of the Orbiter vehicles also required occasional down time for maintenance, effectively taking them out of the flight schedule for critical servicing and upgrades throughout their operational life. Taking just one Orbiter out of the schedule for a short period was a serious detriment to mission planning. Actually losing one to accident or permanent grounding was unthinkable.

There was also the question of OV-105. In the early 1980s, the oft-proposed fifth Orbiter was not intended to be a flight vehicle, but merely authorized for fabrication as a set of structural spares in the event of the loss or severe damage of one of the other Orbiters. As for further vehicles joining the fleet, any prospect of an OV-106 or OV-107 and beyond never progressed further than initial discussions.

As the program matured, factors affecting the training focused upon simplifying the flight software and creating workaround and waiver options. Critical to all of this was the availability of the SMS, which the 1980 report noted was the "single most critical element of the training program." The SMS was already overloaded, and was projected to be even more so by 1984. Even this early in the program, it was already deemed inefficient to conduct part-task Guidance and Navigation (G&N) training in the SMS, warranting a separate (and costly) simulator for that role. The document indicated that the Shuttle program was "currently too immature to commit to a more extensive trainer [i.e. a third SMS]", but if the Guidance and Navigation Simulator (GNS) could "grow gracefully toward a third SMS capability" it would be beneficial. As Carl Shelly noted in his presentation, "[The] GNS is deliverable earlier than a third SMS station. We need it now for its part-task training application, but not later than one year preceding a flight rate of 22−25 flights per year to relieve SMS training load (currently early 1984)."

Locating the GNS in Building 35 at JSC provided a level of redundancy in the training capacity, in the event of the SMS being lost due to hurricane damage, flooding or accident. Consideration was also being given to moving the SMS up one floor to reduce this risk.

A different approach

The change from Apollo era training to the Shuttle was significant. There were some similarities, such as in crew performance standards and crew training for nominal, abnormal (e.g. aborts) and malfunction situations, but the differences between the programs were notable.

Generic training for Shuttle focused more upon operational procedures (or "how to work it"), as opposed to understanding the technology *plus* operational procedures (or "how it works, plus how to work it") as it had been in past programs. Standard procedures and tasks were now listed in a Flight Data File (FDF), with approximately 80 percent of the program classed as 'generic'. Flight-specific training had been reduced substantially by limiting recurring rehearsals of specific plans or procedures, while part-task trainers saw greater use. For example, the Orbiter Single System Trainer (SST) saved 63 hours of SMS time per crewmember, while the Orbiter GNS was expected to save a further 113 crew hours in the SMS once implemented. Though the use of computers was expanding, in 1980 it was still expected that Shuttle crews would spend a significant amount of time utilizing self-study workbooks (then termed "paper training"). Overall, Shuttle training offered a far more structured program based upon formal task analyses of the onboard job.

FLIGHT CREW TASKS CIRCA 1980

In the 1980 document, STS-1 PLT Robert Crippen listed the tasks the flight crew were expected to handle during a nominal Shuttle mission:

Monitor/mode vehicle

For this function, the flight deck astronauts monitored the dynamics of the vehicle by observing both the ascent and entry trajectories, essentially serving as a back-up to the vehicle's computers and being ready to take over manual control in the event of contingency or off-nominal situations. They were trained to monitor the sequence of automatic events, including the separation of the twin Solid Rocket Boosters (SRB) and the External Tank (ET), the cut-off of the three main engines and activation of the vehicle's cooling system. They would also monitor Main Propulsion System (MPS) propellant dumps during nominal and abort modes.

On orbit, at the beginning and end of orbital operations, the CDR, PLT and FE (MS-2) astronauts would be busy. For a nominal mission, the astronauts would become familiar with activation and deactivation of the heaters, the Auxiliary Power Unit (APU) and hydraulics; MPS idling and re-pressurization; reconfiguring the Reaction Control Systems (RCS) and Orbital Maneuvering Systems (OMS); closing the ET door on the belly of the Orbiter and reconfiguring the Data Processing Software (DPS). They would initiate opening and closing the payload bay doors and vent doors, deploying and stowing the radiators, and reconfiguring the vehicle's electrical systems, the Environmental Control and Life Support System (ECLSS), and the Guidance, Navigation and Control (GN&C) subsystems.

On orbit, they would perform maneuvers by adjusting the attitude of the vehicle and initiating orbit adjustment burns as required. They were also required to update the vehicle's attitude and the state of the navigation platform by performing alignments of the Inertial Measuring Unit (IMU), monitoring the star tracking acquisitions and maintaining the correct navigation state.

Malfunction safing/reconfiguration

A major element of Ascan training was learning how to cope with and overcome system failures or problems. The future astronauts were trained during simulations to respond to various malfunction subsystems and, where possible, reconfigure the vehicle accordingly to address issues by means of prescribed actions.

For problems with the MPS, training addressed the failure of one or more of the Space Shuttle Main Engines (SSME), problems with the flow of data or communication with the MPS, leaks of the He (Helium), high LO_2/LH_2 (Liquid Oxygen/Liquid Hydrogen) pressure, and low LH_2 ullage pressure.

The Ascans trained in responsive actions to signals of over speed or under speed of the APUs and hydraulics, excess Exhaust Gas Temperature (EGT) and oil temperatures, leaking APUs, and leaking or low pressure hydraulics. For problems encountered with the communications systems, the astronauts were trained to be ready to reconfigure the system and manage the back-up antennas.

For the ECLSS, they simulated sealing cryogenics leakages and reconfiguring the system, including the fans, the cabin pressure system, the flash evaporator, the H_2O (water) and Freon loops, and the heaters.

With problems in the OMS or RCS, they were taught how to identity and isolate a leak and reconfigure the systems around the problem. If a thruster failed again, the astronauts were instructed how to isolate the faulty jet and reconfigure the remaining thrusters to compensate for the loss. They also learnt how to regulate and manage the propellant valves.

For GN&C issues, the crews were instructed how to manage the flight control system channel, the failure of aero surfaces, and controls to isolate IMU failures and TACAN (TACtical Air Navigation) failures.

The DPS training included identifying component failures, corrective actions and reconfiguration, as well as the interaction of the system with the GN&C components and increased task complexity. For electrical problems, instruction was given on AC Bus and invertor management, and DC Bus and fuel cell management.

Crew system operations

Training was given on how to use, clean and maintain the waste management system (the Shuttle toilet), the food system (including selecting their own meals from the available menu and tasting samples of the selection to help them choose). This training also included operation, maintenance and housekeeping of the onboard galley. They were instructed on the range of cameras carried in the crew compartment (TV, still and movie) and in the stowage onboard the vehicle. Medical emergency training was included, as were familiarization sessions for the range of crewmembers' personal equipment, the Earth terrain maps, navigation devices, stowing and setting up the middeck seats, and various escape procedures.

As it took about a year to train a Shuttle crew, depending on the mission objectives and the past experience of the assigned crew, the total training hours required for all these tasks varied mission by mission.

EVA operations

The MS (and some pilots) were instructed and qualified for the Extravehicular Mobility Unit (EMU) EVA suit, operating the airlock, and a number of contingency EVA tasks such as closing the payload bay doors, stowing a failed Ku-band antenna, possible thermal protection system tile repairs, lowering the payload support platforms and so on. This took place initially in bench tests of equipment, followed by unsuited and suited training in 1*g* simulations, in aircraft flying multiple parabolic curves to give up to 30-seconds of 'weightlessness' on each parabola, and finally over many hours spent suited in the huge water tanks at JSC and the Marshall Space Flight Center (MSFC), Huntsville, Alabama.

FLIGHT DATA FILE

The FDF featured volumes of *paper* checklists that were either flight-specific or generic, carried on board for reference. It covered ascent, entry, post-insertion and de-orbit preparation for both nominal and contingency situations; EVA; the Crew Activity Plan/Flight Plan; orbital operations, Payload Deployment and Retrieval Subsystem (PDRS); photo/TV; and rendezvous.

In the days prior to laptops and personal computers, there were also smaller pocket checklists for ascent, orbit, and entry, as well as an Orbiter systems data book, a DPS dictionary, malfunction procedures books, orbit operations schedules, crew systems checklist, photo/TV checklist, medical checklist, EVA checklist, egress procedures for both nominal and contingency situations, and an ever-changing 'updates' book. As up-to-date as the Shuttle was, it still required a veritable library of documents to back-up the onboard computers, as well as teams of controllers in Launch and Mission Control, scores of contractors located across the country, hundreds of hours of training, and the capabilities of the astronauts to retain the information presented.

CREW RESPONSIBILITIES

Once a crew was assigned, the enormity of what lay before them became evident. There was so much to prepare for and keep track of, and with seemingly very little time to do so. With no formal back-up or support crews as in the Apollo days, the flight crew was entrusted with deciding which of the team would be responsible for what. Therefore, in addition to understanding the major elements of the mission, there was a division of labor to enable the crew to follow and report on developments (or in some cases the lack of developments) in key areas, and for each to be the crewmember responsible for certain items (primary) or to support (back-up) a fellow crewmember in other areas. Such specialization changed flight to flight depending on how the CDR and his crew split up the list, but could typically include:

- For the CDR, PLT and MS-2: The DPS, the MPS (SSME/ET/SRB), OMS and RCS; the APU and hydraulics; the Electrical Power Distribution System (EPDS); and the ECLSS.

- For the MS: Responsibilities included supporting the flight deck crew with some of their tasks; communications and instrumentation; opening and closing the payload bay doors; the photo, TV and cam recorder equipment; serving as crew medic; crew personal equipment; keeping the FDF up to date; in-flight maintenance checks; being aware of changes to the Flight Rules; the Text And Graphics Systems (TAGS) on the early flights; primary and secondary payload hardware and systems; scientific experiments and investigations; Detailed Test Objectives (DTO), Detailed Supplementary Objectives (DSO) and the RMS; Earth observation objectives including geography, meteorology and oceanography; middeck and student experiments; the EVA/EMU and associated equipment; and even inviting guests to the launch, designing the crew T-shirts, and the occasional comic crew photo. All this had to be scheduled, assigned and completed before launch, keeping the crew training diary very busy as the clock ticked down towards lift-off.

THE TRAINING DIVISION (1986)

At the time of the *Challenger* accident in 1986, at least 25 'crews' had progressed through the Shuttle mission training flow to flight status, with a further ten complete crews (over 60 crew seats), including about 20 Group 8 astronauts, in various stages of training for missions in the remaining months of that year.

The "just to be sure" syndrome

During the investigation into the *Challenger* accident, part of the Presidential Commission's remit was to evaluate the training that the STS-51L crew had received and to determine whether this had any bearing on the accident. Two main points were discussed in detail: their workload in the weeks leading up to the accent; and their workload and frequency of use of the training facilities.

By 1986, the Shuttle had been flying for five years, but crews had been 'in training' for almost a decade, including the crews who flew the ALT series of flights in 1977, those who had supported the original OFT program, the first operational mission, and the maiden launch of *Challenger*, the second Orbiter. Members of the 1978 group had been in various stages of preparation for crew assignments or specific mission assignments for seven years, and three more astronaut selections had followed in 1980, 1984 and 1985. The training methodology would evolve following the *Challenger* accident as the program moved into the 1990s, but by then most of the 1978 class had moved on from active flight training to managerial roles or had left the program. At the time of STS-51L, all 35 members of the 1978 group had flown into space at least once, with several having logged two missions. Therefore, reviewing the 1986 accounts of Shuttle crew training is relevant both to the peak of Group 8 participation and to the level of Shuttle mission training in the mid-1980s.

In his memo to the Commission, Robert Holkan, Chief of the JSC Training Division, wrote: "Training workload generally peaks in the last 10 weeks before flight due to the arrival of the specific software products used during the flight. These products are installed in the simulators and the final training is conducted. However, late delivery of these products can cause training compression and increase the crew workload." It was also pointed out in the memo that there was a certain amount of self-generated loading on each crew: "This load comes from the legitimate concerns felt by each crew that they need just one more simulator run or just one more meeting with the checklist people, or some similar group, before the flight 'just to be sure'."

According to Holkan, the SMS, the main training facility, "has been a constant source of problems through the entire program." He cited that it had been less than capable since the start, and that the system had provided adequate training only through the constant efforts of the personnel utilizing it. "It is basically not a good teaching environment," Holkan continued, underlining, just five years into the flight program, that "the facility computers and equipment are out of date and obsolete." On a brighter note, he observed that there were plans to update the equipment with the aim of increasing the capabilities of the SMS as "an effective teaching machine", but added that "the funds for those modifications are programmed out over a 10-year period and are minimal."

Shuttle Training Division

From the late 1970s, a number of the veteran astronauts were pathfinders for the new Shuttle training regime, eventually providing the crewing for ALT program and the first six operational missions. Their experience proved useful in defining the techniques, equipment and procedures, but it was the TFNG who were the first large group to progress through this training cycle with no previous space flight experience and only a few years' experience of working at NASA. It is worth exploring the training division circa 1986, as a background to the processes that each of these 35 astronauts – and many that followed them – experienced prior to taking their first flight into space.

During the mid-1980s, at the peak of Group 8 involvement in Shuttle flight operations, the JSC Training Division had a staff of 270 who were responsible for training both the flight crews and the flight controllers. Within this group were approximately 150 instructors who specialized in the various media, with a further 70 who were more computer orientated and who were dedicated to programming and developing the training facility, adding new lessons into the syllabus.

The Training Division was responsible for developing training plans and maintaining a training calendar, which included standalone sessions, integrated simulations, joint simulations, and simulator and trainer requirements. This covered the ascent and reentry phase including various abort modes (Return To Launch Site (RTLS), Transoceanic Abort Landing (TAL), Abort To Orbit (ATO), Abort Once

Around (AOA)), the orbital phase including systems operations, payload deployment, and rendezvous and proximity operations (there was no docking training at this stage). Science and EVA training were not mentioned, while space station training was limited to concepts, requirements and facilities.

The 'charter' for the Training Division was to "provide [a] training program for flight crews and flight controllers." To meet this objective, the functions of the Training Division were listed as: To define training requirements; formulate a training plan; develop a training course, material and scripts; conduct training sessions; integrate, schedule and record training programs; define the required training facilities; negotiate user agreements for outside facilities; develop and operate selected training facilities; and provide real-time support for EVA and crew systems. To achieve this, in the days before laptops and digital programs, the Training Division generated a significant amount of printed products, including training catalogs, training plans and schedules; Shuttle Flight Operations Manuals (SFOM); workbooks; training lessons; and scripts and training records to provide a historical database of how each 'crew' progressed through the training cycle.

Training Hierarchy

Preparing a crew for a flight on the Shuttle relied upon a range of techniques, which included (but was not limited to):

- Paper media workbooks, training manuals and briefing notes.
- Computer-aided instruction which, in the 1980s, came from "Regency" small computers that provided a number of lessons to the student crewmember/controller on how particular instruments worked[5].
- Single System Trainer (SST). This was a medium-complexity machine that allowed the student to learn about one system of the Shuttle in depth, such as the electrical system, prior to moving on to another system.
- Water Emersion Training Facility (WETF), the water tank used to train EVA crews for spacewalking using neutral buoyancy. At this time, the former centrifuge building (Bldg. 29) had been adopted post-Apollo to provide a large water tank on site at JSC. While the WETF was capable of supporting water egress training for Shuttle crews, it was unsuitable for supporting EVA training to service larger payloads such as HST and Solar Max. Since the late 1970s, the larger Neutral Buoyancy Simulator (NBS) 'pool' at MSFC had been used for EVA and RMS crew training, but in 1997 a new, much larger Neutral Buoyancy Laboratory (NBL) was completed at the Sonny Carter Training Facility near to JSC. This was used for Hubble servicing training and for developing and practicing ISS assembly tasks. **[8]**

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[5] Regency provided a programmable 64 x 64 spot touch screen that displayed switches and indicators, and component schematics. Using this, the trainers could communicate with the teaching software by touching the screen in the appropriate place.

- Shuttle Mission Simulator. This complex machine was able to duplicate all phases of a Shuttle flight profile, with simulated views out of the windows, motions, and working cockpit instruments.

A building block approach was followed for Shuttle training, in the three distinct phases of basic training, advanced training and finally flight-specific training prior to launch.

Self-study formed part of the basic training phase, with workbooks, texts and videotapes supplementing the training before the students progressed to the advanced phase that incorporated computer-aided instruction. The advanced training also incorporated one-to-one instruction, using flight hardware trainers and SST to focus upon the avionics system, Orbiter systems, crew systems, and payload and carriers.

As the advance training progressed, it inevitably increased in both complexity and overall cost. Once flight-specific training came to the fore, the team instruction became more involved, with advanced and flight-specific training requiring more use of the SMS, together with phase training for ascent and aborts, orbital operations, entry and landing, rendezvous, payload deployments, Prox Ops and EVA (there was still no reference to docking at this stage of the Shuttle program). Integrated simulations developed communications skills, trained the flight controllers, crew and payload customer, and verified procedures.

PLANNING A TRAINING CYCLE (Circa 1986)

With 25 crews successfully progressing through the training cycle and several more in various stages of preparation for their missions, the assigned 'training-flow' appeared to be working, for the time being. In developing the training plan system, the team had factored in a smooth flow for new crew assignments as the flight rate increased. That helped reduce the workload on the training management. Parts of this system had been automated, but there were always unforeseen incidents requiring a short-term change to the plan, and such incidents, as well as changes in the manifests, triggered the *unplanned requirements cycle*. If a manifest change impacted crew assignments, the extra work this entailed was amplified. Any change in the manifest usually resulted in unutilized training, but this was not always the case. The crew of STS-51D had received rendezvous proximity training as part of an early manifest, but when that manifest changed it appeared their training would be wasted. On their flight, however, during the attempt to rendezvous with and activate the stranded Leasat satellite, this early training came in handy, even though they had not planned to use it on their flown mission. The rule to remember in planning a training cycle was that "schedule slips cause inefficiency."

The start of the process generated a training calendar listing requirements vs. tasks, a flight manifest that included the flight-specific requirements of that mission, and the training records from previous crews. This provided a summary of crew training requirements for that mission around the time the flight crew was named. From this, a crew training guide was produced listing the training sessions to be completed and the time before launch to complete them. Typically, as many as *ten* crews could be in training at this point. Unassigned crews in the pilot pool received about 16 hours per week of generic training, but only after prime crews had been scheduled, taking advantage of schedule inefficiency at this time. A series of training interfaces and reviews usually began prior to Launch [L]-40 weeks, with the crew being named and their tasks defined at L-38 weeks. A cargo review was completed at L-36 weeks, followed by a training guide review at L-32 weeks. The first training status report was issued around L-29 weeks, with flight-specific training commencing at L-27 weeks. The training team met to review the training (termed Team Tag Up or TTU) on weeks L-20, L-16, L-12, L-10, L-8, L-6, and L-4, with the second status report reviewed during L-14 and the third and final report during L-4. About two weeks after launch, a post-flight training report was completed and published.

Cataloguing the training

Having recognized the need to establish a database of training experiences since before the first Shuttle flight, the JSC Training Division had maintained a training catalog, which detailed exactly what training each crew person required for a specific flight. In 1985, a similar catalog recorded the training of Shuttle flight controllers. Any changes to the training flow were instigated by the Training Division Office, with the cooperation and input from the Astronaut Office as the system developed.

Standalone training flows

Standalone training began in 1979 and was completed in the SMS. For this simulation, the instructors acted as the Capcom and in all positions of Mission Control. Initially, the crews were instructed and tested on their actions and procedures in nominal situations. Once they had demonstrated their ability to do this, the training teams introduced malfunctions to tax them and teach them the correct responses. Some limited contingency training was also completed, but it did include near-catastrophic situations. This type of training evolved over the ensuing years, resulting in fewer training hours across all areas. All changes were recorded in the training catalog.

The original training flows for Shuttle OFT crews were developed in 1978, based upon experiences from earlier programs and “guesswork” about the Shuttle. Each of the four OFT crews followed this flow during their training and each pair commented upon it afterward. This was all collated and led to the first major revisions for the STS-5 crew (1982). Logically, the experience base would grow as more missions were flown, enabling further refinements to the training flow. Over time, lessons were added, some removed, and the content or sequence was changed, with successive reviews further defining the amount and type of training required to prepare a crew to fly the Space Shuttle. By 1986, the training team felt that the Orbiter part of the training catalog was very mature and required minimal changes. However, further refinement was necessary regarding payloads, RMS operations, and rendezvous and Prox Ops (see Table 8.1).

TABLE 8.1: SHUTTLE TRAINING CATALOG REQUIRED TRAINING HOURS

Training Area	Nov 1982	Sep 1984	Jan 1986
Ascent	97	91	89
Orbit	129	93	89
DPS	61	43	43
GNC	86	104	98
Support Sys	89	126	126
Crew Sys	76	79	88
EVA	133	154	152
Deorbit/Entry	183	140	141
PDRS	146	141	143
Prox Ops	71	65	63
PAM	47	48	51
Spacelab	179	146	146
IUS	40	63	58
Total	***1317***	***1293***	***1287***

Adapted from the Transmittal of Official STS-51L Training Presentation [& attachments], compiled by Frank E. Hughes, Training Group Lead, Mission Planning and Operations Team (DG6), NASA JSC, Houston, Texas, dated April 11, 1986, Ref DG6-86-107. Presented to the Presidential Commission on the STS-51L accident, at JSC on Tuesday April 1, 1986. Copy on file AIS Archive.

In the three years between STS-5 and STS-51L, Shuttle training hours had reduced from 129 hours in November 1982, to 93 hours by September 1984, and to 89 hours by January 1986. Several factors led to the reduction between 1982 and 1984, most notably that the CDR was recently flown and therefore did not require advanced training. Several of the lessons were combined to make better use of the simulator time. As Part-Task Trainers (PTT) developed, some lessons were dropped because the material was covered in new lessons developed for the PTT. Dedicated lessons for the MS were combined with the same lessons taught to the CDR and PLT. Timeline and Crew Activity Plan (CAP) lessons were dropped as the material was being duplicated in new payload-specific lessons. As the training flow evolved, new Flight Procedure Handbooks were introduced.

Interestingly, the refinements introduced between 1984 and 1986 included a change in the philosophy regarding the CDR taking advanced lessons. Such advanced sessions now became a requirement for the CDR, based on when they had last flown. Several of the Flight Procedure Handbooks were deleted and new Handbooks introduced into the system, while Shuttle Portable Onboard Computer lessons were introduced. Orbit Skills and Orbit Timeline lessons (totaling eight hours) were dropped, as these were now covered in the payload lessons.

Integrated Training

These sessions were designed to develop coordination between the flight crew and Mission Control teams. For these sessions, the Flight Director (FD) and his team were located in Mission Control, while the crew entered the SMS. Radio links between the two were simulated using data and phone links. The integrated training process featured a script that the training team followed, which detailed exactly what malfunctions were to be used and when in the session they were to be implemented. The responses from the crew and controllers were monitored and any incorrect actions were discussed and rectified after the session. In reality, the integrated sessions probably trained the flight controllers more than the flight crew, but the development of a coordinated crew/controller team was paramount. A schematic of integrated and joint integrated sessions involving the Payload Operations Center is shown in Fig. 8.2.

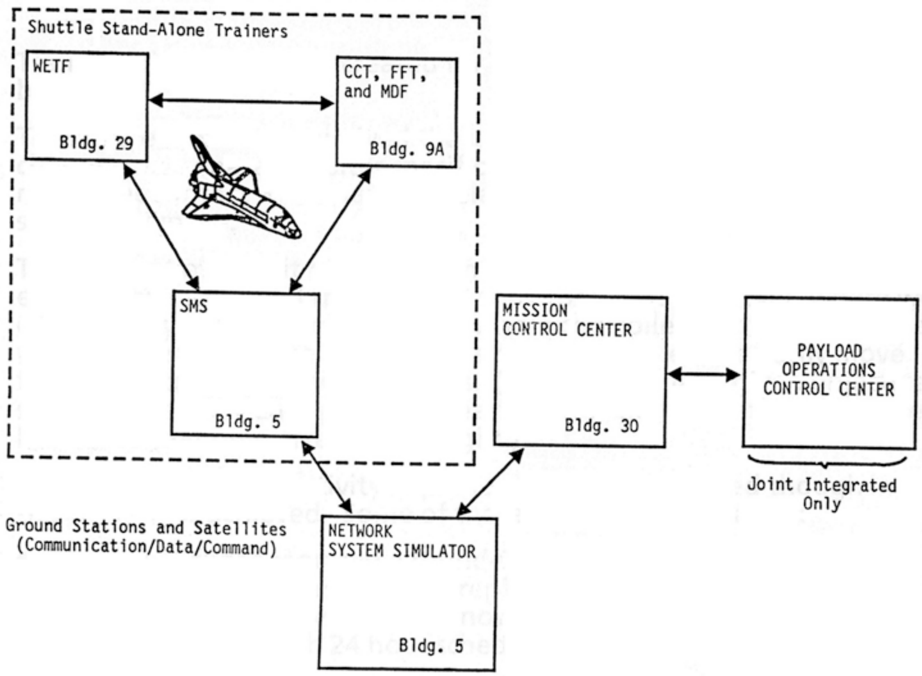

Fig. 8.2: The Integrated and Joint Integrated Simulation Network circa 1986. Taken from the Official STS-51L Training Presentation, April 1, 1986.

Towards the 1990s

As previously mentioned, during the review into the STS-51L accident the JSC training department acknowledged that the Shuttle crew training facilities were out of date or obsolete. As concerning as this was, just five years into the operational program, there were plans to address this situation. Reading between the lines, it appears that long-requested funds would be channeled directly into upgrading the trainers, as the scope of the program had already exceeded the capabilities of the trainers as constructed in the late 1970s. These upgrades included improved fidelity displays for the MPS, and visuals out of the windows. There was also a desire to provide a GNC trainer to support the training flow of pilots at an improved rate. Additionally, there had been issues with the delivery of software upgrades, which had caused compression in the training program. Changes to the manifest led to challenges in delivering new upgrades in a timely way, and as a result, the end-of-the-line training loads were delivered later than desired. The best-case scenario was to have a stabilized manifest cycle, but this became an ongoing issue through the Shuttle era and affected a variety of support areas across the program. It was also found that increasing the crew workloads quite naturally created a situation in which the crews requested more time with the final flight software product, to ensure that everything worked as expected before they needed to use them during the mission.

The loss of the training skill base, from the retirement of experienced astronauts but also from the pool of crew trainers or flight controllers, also affected the smooth training flow, as any new person joining the team required 6–12 months to train up, although new methods were always being sought to improve each training position. Even by 1986, the Shuttle training program was still being described as "evolutionary." However, the new format of not assigning dedicated back-up crews, with replacement crewmembers available as required from a pilot pool, was working well. Recent studies into re-flying a CDR and crew had also suggested major benefits. Still requiring further work was the amount and timing of Ascent Integrated Training for each flight, and there was an urgent need to upgrade the RMS and Prox Ops training philosophy.

Looking back almost 40 years, the participation of the TFNG in supporting the earlier veteran astronauts helped to create the Shuttle training program which, with regular upgrades and refinements, operated successfully for three decades. As a group, they were instrumental in ensuring the smooth transition from the earlier one-shot missions of the Mercury-Gemini-Apollo era to the more routine operations of the Shuttle. The legacy to this has been in supporting the assembly and resupply of the ISS, although most of the TFNG had long since retired by then. Forty years after the selection of the eighth astronaut group, as NASA once again prepares for a new generation of human spacecraft to replace the Space Shuttle, its current astronaut team, like the TFNG before them, provide the vanguard of crews as America embarks into its next era of human space flight.

SHUTTLE CREW TRAINING CYCLE

All of the above resulted in a definitive program to prepare selected crewmembers for their flights on the Shuttle system, the contingency procedures they hoped they would never need, and the specific mission they had been selected for. A detailed account of crew training is beyond the scope of this book, but for the 1978 selection, a summary of the Shuttle training flow is presented here for the reader's reference.

Upon selection to a crew, their training became a priority, and as the earlier flights progressed so their training moved toward the top of the queue for simulator time. Flight-specific training generally consisted of the following:

- The CDR and PLT logged flying hours in the Shuttle Training Aircraft (STA), practicing the approach and landing profiles until just a few days before launch. They also maintained their flight proficiency level by flying their T-38 jets.
- The whole crew participated in the crew systems refresher course, whether they were rookies on their first mission or space flight veterans, as these systems were constantly updated and changed as the program matured.
- Refresher courses and flight-specific profiles were included in Flight Operations training.
- The flight-specific training changed depending on the missions, but could encompass some of the following
    - PDRS, which included RMS training, the various deployment systems for different payloads and any retrieval operations specific to their mission.
    - Carriers, which were a range of hardware devised for the STS system and designed to 'carry' various payloads, experiments and hardware. They were interchangeable between missions as required. These included: the European-built Spacelab pressurized long module and unpressurized pallets, instrument pointing system and Igloo system unit; the Payload Assist Module (PAM), which was phased out by the 1990s; the IUS; the Centaur upper stage, which was deleted from the manifest after the loss of *Challenger*; and, from 1990, the pressurized SpaceHab augmentation module.
    - Attached payloads that could be coupled, which included the Get Away Special (GAS) experiment canisters, the Hitchhiker payload attachment devices and any mission-specific packages
    - Middeck experiments, which included small experiments that could fit in or on the front of middeck lockers, such as the educational student experiments and flight-specific experiments such as the SAREX Ham radio or IMAX camera.
    - Prox Ops/Rendezvous, which included any joint operations with specific communication satellites, the Shuttle free-flying Pallet Satellite (SPAS), larger science satellites such as Solar Max, the Long Duration Exposure Facility (LDEF) and HST, and, from 1995, rendezvous and docking training for the Russian Mir space station[6].

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[6] By the fall of 1998 and the start of ISS assembly, none of the remaining TFNG in the Astronaut Office were directly involved as crewmembers in assembly mission training.

- EVA training, which included familiarization with the associated EVA hardware (pressure suit, tools, tethers, restraints) and procedures (donning and doffing, pre-breathing, airlock operations); contingency operations and scenarios; and planned EVAs for specific missions (such as Solar Max retrieval and repair, or HST servicing).
- Manned Maneuvering Units (MMU) until the mid-1980s, and the smaller SAFER rescue unit from the early 1990s.
- Virtual Reality (VR) training was just coming into the mainstream at JSC as the STS-61 crew was preparing for the first Hubble servicing mission. Now commonplace for ISS EVA training, this was a new tool in the EVA training portfolio in the early 1990s.
- Space station construction techniques and simulations (none of the TFNG were assigned to the ISS assembly missions).
- DTO, DSO and Risk Mitigation Experiments (RME), which consisted of a variety of new investigations aimed at evaluating procedures, hardware and systems that may or may not be used operationally on future missions. They could be investigations on the characteristics of space flight, the operation of the Orbiter, the environment the Shuttle was flying in, or research into reducing potential risks. The DTO were usually more engineering based, the DSO were experiment based, and the RME were risk based.

Crew training could vary from printed workbooks and classroom studies, to bench reviews, 1*g* simulations, reduced gravity simulations, and visits to contractors or other NASA field centers, such as KSC for launch training. There were also programs of public affairs duties, such as interviews with the media and press conferences, as well as specific tasks such as designing the mission logo and choosing the food to be included in the mission menu. A variety of training devices were developed to support such pre-flight crew preparations.

SPACE SHUTTLE FLIGHT CREW TRAINING FACILITIES

The facilities for training Shuttle crews were far more extensive and widespread than were available during the Mercury, Gemini and Apollo eras, but still limited in comparison those for the current ISS resident crew training. Below is just a brief summary of the different facilities and locations used by the TFNG in their preparations for the various missions they were assigned to or flew.

Johnson Space Center, Houston, Texas

Building 1: Headquarters Administration Building

Center Management and support administration offices

Building 2: Public Affairs Office
Includes the media briefing room for press conferences, and interview rooms

Building 4 (North (the original Astronaut Office location) and South): Mission Operations Support Offices
Incudes the Astronaut Office and the Mission Control Center (MCC) FD Offices. Over the years, Building 4 also housed a number of smaller training devices and aids, including:

- Single System Trainer for the Orbiter and Spacelab science lab
- Crew Software Trainer (CST) part of the SST system
- Part Task Trainers also linked to the SST
- Shuttle Procedures Simulator (SPS) [also known as the 'Spare Parts Simulator']. In the early days of the program, parts from this trainer were often cannibalized to get the more critical SMS working. By the early 1980s, the SPS was scrapped and a GNS was constructed for part-task training from the remaining parts.

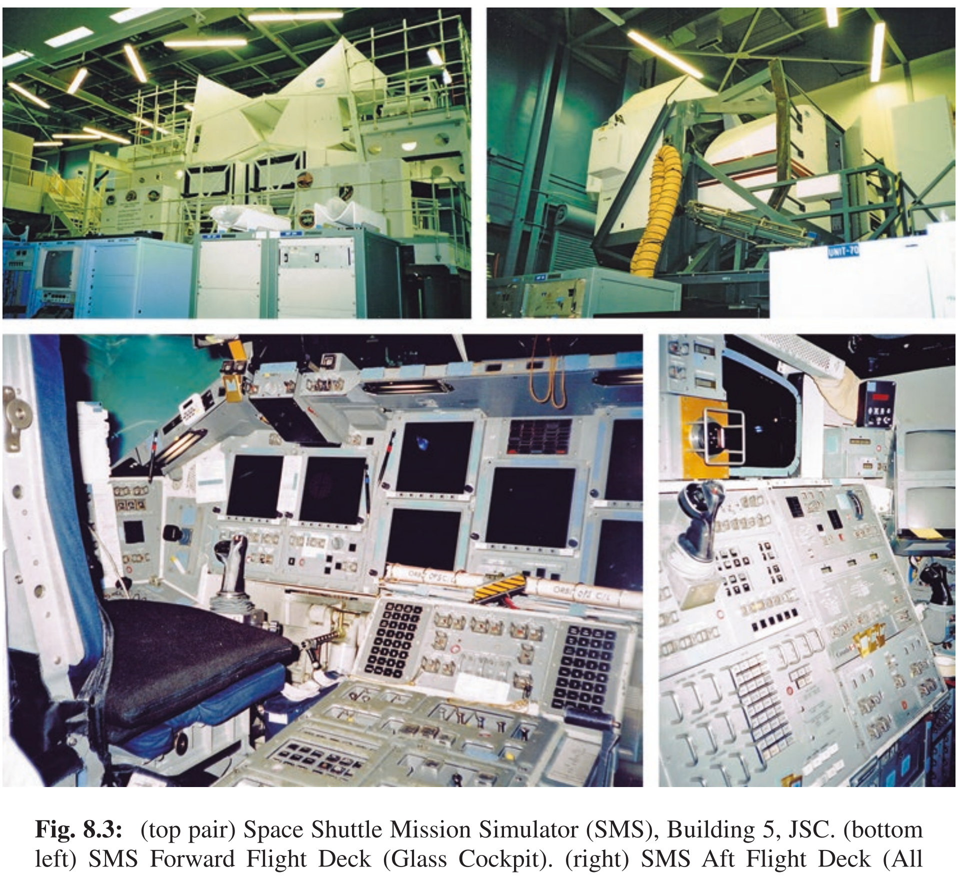

Fig. 8.3: (top pair) Space Shuttle Mission Simulator (SMS), Building 5, JSC. (bottom left) SMS Forward Flight Deck (Glass Cockpit). (right) SMS Aft Flight Deck (All images from the AIS archive).

Building 5: Space Mission Simulation Facility (now the Jake Garn Mission Simulation and Training Facility)

Used in series of simulations (or "sims") during training. Integrated simulations were linked to MCC but standalone simulations were not. The Joint Integration Sims saw the crew in the simulation patched into MCC and MSFC, the NBL, or Goddard Space Flight Center (GSFC, Greenbelt, Maryland). These simulations were conducted at varying levels of intensity, with the less complex ones staffed by simulator instructors or members of the training staff standing in for flight controllers (and throwing in unexpected failures and contingencies to push the crew responses and experience). More complex sims with MCC involvement required a dedicated console in MCC called the Simulated Control Area.

- *Shuttle Mission Simulator-Fixed Base (SMS-FB)*
  This simulator included high-fidelity mock-ups of the Orbiter flight deck and a low-fidelity mock-up of the middeck. Computer-generated realistic views were provided out of the forward, aft and overhead windows.
- *Shuttle Mission Simulator-Motion Base (SMS-MB)*
  This comprised the forward part of the flight deck of the Orbiter, using a six-axis hexapod motion system with additional extended pitch axis to generate motion cuing for all phases of the flight. This simulation only gave the crews accurate visual scenes outside the forward compartment windows.

Building 7 Crew and Thermal Systems Division

- *EVA Mobility Unit Malfunction Simulator (EMU MALF SIM)*
  Familiarized an EVA crewmember with the various potential failures while wearing the EMU.
- *Caution and Warning Simulator (CWS)*
  Similar training sessions about the various cautions and warnings generated from the EMU.
- *EVA Vacuum Chamber (EVA VC)*
  Pressurized simulations wearing the Shuttle EVA suit

In addition to training sessions, the vacuum chambers were used to qualify the suits prior to the first Shuttle missions. One of George 'Pinky' Nelson's first technical assignments was to support the development of the Shuttle EMU prior to STS-1. "I sought that out, actually, because it really looked like fun to be able to work in the suit, [to] go outside," he recalled in 2004. **[9]** "Story Musgrave at the time was the EMU person. So I started working with Story, and he helped check me out in the suit. There were three or four of us who were working EVA-related issues. Anna Fisher and Jim Buchli were working EVA issues, closing the payload bay doors and tools and things like that, and I was working the suit side of things, so we overlapped quite a bit. Story was a fabulous mentor in terms of just physically learning how to use the suit. His depth of knowledge of the suit and the way he operated in terms of really digging in and getting to the bottom of every system, really knowing everything inside out, was a great example of how to work, so I learned a lot from just being around Story and watching him work, and then getting checked out in the A7LBs, in the Apollo suit. [We] Had this little water tank in Houston and I did some work in the tank at Marshall [MSFC], in Huntsville [Alabama].

"I spent a lot of time going to design reviews and some trips up to Hamilton Standard [Inc.], where the suit was being designed. I don't think I ever went to [International Latex Corp. in] Dover [Delaware] during that time. I might have once to see where the fabric part of the suit was being put together. But the suit was one of the long poles in getting the Shuttle ready to fly. The folks in Houston who were in charge of it, [Walter W.] Guy and his group, were really working hard, and it was a difficult task to get it pulled together. The suit actually blew up shortly before STS-1. I was home working in my garden. I was playing hooky one afternoon, and I got a call from George Abbey. He said, 'Where the hell are you?' [I replied] 'Well, I'm home working in the garden'. He said, 'Okay. Get in here. We just had an accident with the spacesuit'. They [the technicians] were doing some testing in one of the vacuum chambers in Building 7, and… they had the suit unmanned, pressurized, in the vacuum chamber. They were going to do some tests and they were going through the procedures of donning the suit and flipping all the switches in the right order and going through the checklist.

"There's a point, when you get in the suit, that you move a valve. There's a slider valve on the front of the suit, and you move this slider valve over, and it pushes a lever inside a regulator, and opens up a line that brings the high-pressure emergency [oxygen] tanks on line. You do that just before you go outside. You don't need them when you're in the cabin, because you can always repressurize the airlock. When you're going to go outside, you need these high-pressure tanks. They're two little stainless-steel tanks about six inches in diameter, maybe seven. And it turned out that when this technician did that, he threw that switch and the suit basically blew up. I mean not just pneumatically, but burst into flames, [and he] got severely burned. It was pure oxygen in there. The backpack is made basically out of a big block of aluminum, and aluminum is flammable in pure oxygen. So this thing just went up in smoke. And they reacted very well. So then I was put on the Investigation Board for that, and spent a couple of months at least just focusing on what had caused this and [whether we could] identify it and fix it and get it ready before STS-1. So I learned even more about the design and manufacturing and materials and all of that in the suit during that process. It was fascinating. The [NASA] system for handling that kind of an incident really is very good. We've seen it with the big accidents we've had. They really can get to the bottom of a problem very well."

Building 9 Space Vehicle Mock-up Facility (SVMF)

This facility developed, operated and maintained the various mock-ups and training facilities to support crew training and engineering activities.

- *Crew Compartment Trainer (CCT)*
  This was a high-fidelity replica of the Orbiter crew station and was used for crew training and engineering evaluations of on-orbit procedures. The astronauts followed over 20 different classes to learn how to operate all the Orbiter subsystems. Capable of tilting to nose up configuration, the CCT permitted training in pre-launch activities at JSC in advance of progressing to the Cape, thus saving the crew travelling time and training time in Florida. The crew module was an accurate representation of the flight deck and middeck but with non-functioning switches, connections, guards and protection devices. It did have exactly the same physical characteristics and movement as the real vehicle. The fabrication closely replicated the actual vehicle and included fully functional flight-like CCTV systems.
- *Forward Fuselage Trainer (FFT)*
  This was a full-scale mock-up of the Shuttle Orbiter, minus its wings. It was used as a test-bed for various upgrades to the fleet, for astronaut training such as a 1*g* walkthrough of EVA airlock and payload bay operations (including lighting and CCTV systems), and for emergency egress by means of a Sky Genie™ from the crew overhead windows or via a functional (inflatable aircraft-like) escape slide from the side hatch when platforms and ladders were not available. Fabricated at JSC in the 1970s, this was the oldest mockup in the SMVF.

On May 3, 1993, Rhea Seddon, in training as PC/MS-1 for STS-58/Spacelab 2, was participating in a simulated emergency evacuation of the Orbiter in Building 9, wearing the heavy and bulky orange launch and entry suit. **[10]** The crewmembers seated on the middeck successfully evacuated the Orbiter from the side hatch using the inflatable escape slide. However, Seddon and her colleagues on the flight deck had to unstrap, carefully descend the ladder to the middeck and then exit from the side hatch. This was not as easy as it might sound, as with the faceplate of the suit closed their vision was impaired, and getting entangled in the leads and cables was common in such tests. As MS-1, seated behind the PLT on the right of the flight deck, it was Seddon's responsibility to be the 'spotter' for the CDR, MS-2 and PLT, ensuring they exited their seats before leaving the flight deck herself as the last crewmember to vacate the vehicle.

As she wrote in 2015 "I kept my spot behind Rick [Searfoss, the PLT] and pulled all their straps and lines clear as they left the flight deck. Then I huffed and puffed my way across Bill's (McArthur, MS-2) seat and down the ladder. 'I hate this stuff. I hate this stuff,' I panted under the cumbersome load [of the launch and entry suit]." Having managed to get downstairs to the middeck, she sat on the edge of the hatch and prepared to go down the inflatable slide, thinking "this is the easy part." The slide traverse was fine until she neared the bottom, when she felt "a horrendous pain in my left foot. Trying to stand up at the bottom of the slide, my left

Fig. 8.4: [top left] Space Vehicle Mock-up Facility, Building 9, JSC. [top right] Crew Compartment Trainer. [bottom left] Forward Fuselage Trainer, [bottom right] 1G Full Fuselage Trainer (All images from the AIS archive).

foot collapsed under me." Sprawled on the floor with trainers and medics around her, she was shouting "left foot, left foot," but with the faceplate closed no one could hear her. It was not until she opened the visor that she could shout where the pain was coming from. After she was painfully extracted from the boot and then the flight suit, she was examined. "After a brief discussion [with the duty flight surgeon in the Flight Medical Clinic at JSC] and even briefer exam of my foot and ankle, he assured me it was a sprain, but we'd take an x-ray. As he turned to leave

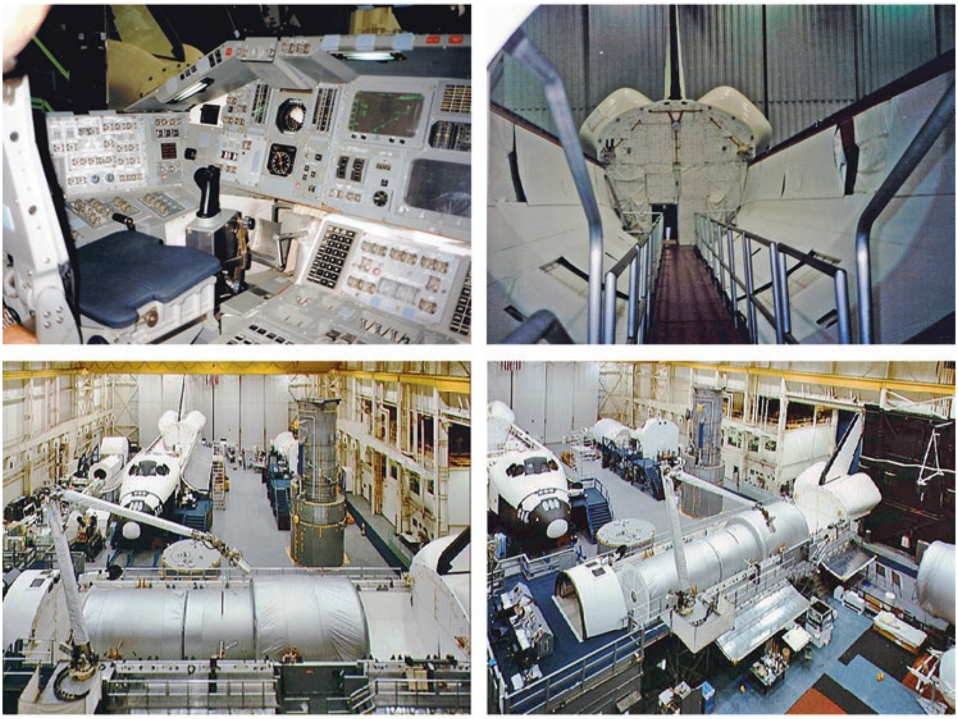

Fig. 8.5: [top left] 1G Flight Deck Commander Seat. [top right] 1G Payload Bay Trainer. [bottom pair] PDRS (RMS) Trainer (All images from the AIS archive).

the room I glared at his departing back, thinking 'I'm a doctor, you turkey, and something is BROKEN'!"

On subsequent examination, it was discovered that Seddon had broken four metatarsal bones in her left foot. After further consultation she was advised to have surgery to align the bones with screws that could be removed later, which would mean she had to be in a cast for six weeks after surgery and a walking boot for a further six weeks. An investigation into the incident determined that the slide had slightly deflated each time a crewmember descended, and buckled a little when Seddon made her ride down, causing her left foot to catch at the bottom and twist backwards. It was also determined that she had inadvertently pointed her toes to the left, so future crews were reminded to ensure their toes pointed up before descending the slide. Fortunately, her flight was delayed for a couple of months for other reasons, which gave her more time to recover and continue training. To her surprise, Seddon was able to fly the mission **[11]**

- *One-g trainer for the Orbiter cabin (01G-CAB)*
  Flight Deck: This trainer included Orbiter displays and controls, representative of the flight article, which were limited in use or, like the hand controller, functional for positional adjustment only. The four flight deck seats replicated the flight vehicle, and the Sky Genie™ device was used for emergency crew egress training. The CCTV systems supported systems training and featured two 10-inch color monitors, allowing the crew to view live video from any of the CCTV around the FFT payload bay.
  Middeck: Up to three MS and one instructor could be seated in this area and there was capacity for additional seats, a treadmill and biomedical attachments if required. The switches on the middeck were replicas of those in the flight vehicles, and the middeck could be fitted with an airlock featuring working hatches and systems, the post-*Challenger* crew escape system (slide-pole), a functional side hatch, middeck accommodation rack (the galley), and stowage for TV equipment, locker trays, cameras, etc. Three or four sleep stations could also be fitted, but the Waste Management Compartment (WMC) included was not a functional model. Middeck lockers were configured according to the mission in the forward and aft positions, with fully operable doors, latches, hinges, and trays and padding cushions, giving the crew an accurate representation of the locker layout and content they would find on orbit. It also gave an accurate representation of the locker numbering systems used on the vehicle to locate specific items from the crew manifest documents. **[12]**
- *One-g trainer for payload (01G-PLB)*
  Payload Bay: This was used for fit checks and orientation simulations of specific payload configurations. With flight-like thermal blankets, a mock-up winch and lighting, it could also be used for crew familiarization. A non-functional RMS was mounted on the port side, while the airlock could be mounted externally in the payload bay and interfaced with tunnel adapters. Other mock-ups that could be fitted into the payload bay simulator included the SpaceHab or Spacelab pressurized modules, unpressurized pallets and, from the mid-1990s, the Orbiter Docking System (ODS)
- *Precision Air-Bearing Floor (PABF)*
  Replicating EVA on Earth is impossible without assistance. A number of simulators have been developed over the years to facilitate this. The PABF provided a two-dimensional simulation (and three degrees of freedom) of a microgravity environment. A polished metal surface measuring 32 x 24 ft. (10 x 7 m) was used to teach and develop mass handing techniques by using a thin cushion of air, similar to an air-hockey table, to ‘float’ heavy objects over its polished surface.

- *Partial Gravity Simulator (PGS, also known as POGO)*
  This simulation combined servos, air-bearing and gimbals to simulate a reduction in gravity and was used by the astronauts to evaluate their ability to overcome tasks in simulated partial or microgravity conditions.
- *PDRS Deployment/Berthing Trainer (RMS TRNR)*
  Working from a mockup of the Aft Flight Deck and RMS work station, crews could simulate using the RMS to move objects (including air-filled balloon mock-ups of payload) around the payload bay to rehearse the deployment or retrieval of payloads.
- *Spacelab Simulator (SLS)*
  Functional mock-ups of the Spacelab pressurized laboratory module.

Building 16 (and 16A) Shuttle Avionics Integration Laboratory

- *Shuttle Avionics Laboratory (SAIL)*
  This was the only facility in which actual Orbiter hardware and flight software could be integrated and tested in a simulated flight environment. The set up consisted of an avionics mock-up, designated OV-095, contained within a basic skeleton shape of a real Orbiter. However, its electronics were identical to the flight vehicles, so it was sometimes preferred to the dedicated training simulator as a training device. Operated for the whole of the Shuttle program up to 2011, many of the 1978 astronauts were the first to work in this facility, both prior to STS-1 and in support of other missions.
- *Shuttle Engineering Simulator (SES, now Systems Engineering Simulator)*
  The SES has been in continuous operation since it was installed in 1968 and supported real-time man-in-the-loop simulations for Shuttle for many years. The Orbiter forward cockpit mock-up was located in East High Bay of Building 16 and was used for the two main areas of operation entry and on-orbit simulation, using a range of digital computers. The other mock-ups in this area included an Orbiter aft section and an MMU station. On-orbit operation could support station docking and berthing, payload handling and deployment, MMU operations and several other devices. Accurate representations out of the window, thanks to ever-improving computer programs and graphics, linked the SES to SAIL.
- *Orbiter Guidance and Navigation Simulator (GNS)*
  This was linked to the fixed- and motion-base simulators in Building 5. Originally, this was to be used for guidance and navigation issues, but following the 1986 Rodgers commission enquiry into the *Challenger* accident, the GNS was upgraded to a fully-fixed-base simulator as a part-task trainer to assist pilots in mastering the navigation training or flight techniques as required.

Building 17 Space Food Systems Laboratory

- *Selection and preparation of food for the crew menus.*
  Inside this simulator is a test kitchen, a food processing laboratory, a food packing laboratory and an analytical laboratory. In this building, a dietitian and nutrition team helped the astronauts to select items from the menu, which utilized eight types of food processing techniques: rehydration, thermo stabilization, irradiation, intermediate moisture, natural form, fresh, refrigerated and frozen.

Building 29 Weightless Environment Training Facility

- Originally called the Neutral Buoyancy Trainer (NBT, later WETF), this included mock-ups of the Orbiter middeck crew compartments, an EVA airlock, the scientific airlock (Spacelab), Instrument Pointing Systems, IUS tilt cradle, and mock-up payload bay doors and Ku band antenna. The round portion of this building was used for centrifuge training for Gemini and Apollo crews. The WETF was superseded by the much larger NBL at the Sonny Carter facility just north and offsite of JSC.

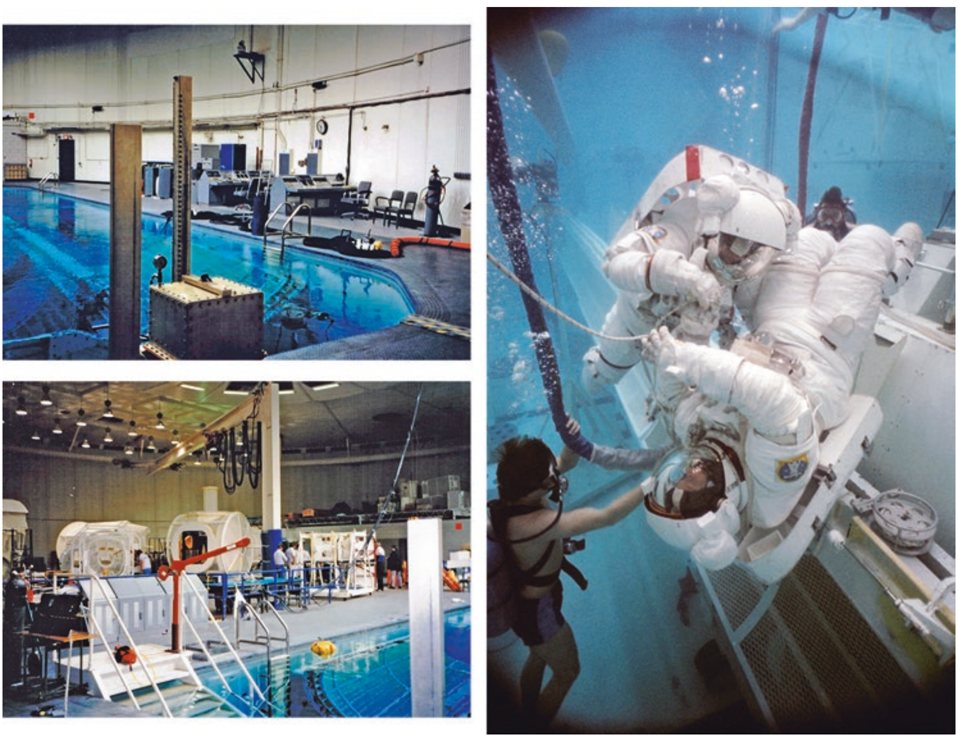

Fig. 8.6: [left images] WETF, Building 29, JSC (Image from the AIS archive). [right] STS-41D EVA crew and TFNG Mike Mullane (EV1, red stripes on suit) and Steve Hawley (EV2, no stripes) conducting contingency EVA training in the WETF assisted by support divers.

Building 30 Mission Control Center Houston

- *Mission Control Center (MCC)*
  Created in 1965, this facility became famous through its radio callsign of 'Houston', although that city is about 30 miles (48 km) north of the JSC site where MCC is located. The original Mission Operations Control Rooms (MOCR, pronounced "mohker") used during the Gemini and Apollo era were renamed Flight Control Rooms (FCR, pronounced "flicker") for the Shuttle program. FCR-1 was used for the first Shuttle missions, while FCR-2 was used during classified DOD Shuttle missions. From the mid-1990s, a new five-story extension was built, with two new control rooms ("White" and "Blue") developed for the space station made operational. The older FCR-2 was used in tandem with the White control room until 1996 and then the "White" control room was used by itself until the end of the Shuttle program. Teams of controllers manned the consoles around the clock during each Shuttle mission and one of the assignments for both new and veteran astronauts was to man the famous Capcom console, talking directly to the flight crew. Capcoms were assigned to an FD team for Ascent/Entry/Orbit 1, 2, 3 or Orbit 4 (the planning shifts). Capcoms from the 1978 selection on console during key events in the program included: Dan Brandenstein (1981 launch Capcom, STS-1 *Columbia*); Dick Covey (1986 launch Capcom, STS-51L *Challenger*); and Shannon Lucid (2011 Lead Capcom Planning Shift STS-135 (*Atlantis*), the final mission in the program).

- *Payload Operations Control Center (POCC (Spacelab) until 1990 when it moved to MSFC)*
  The POCC was operated by flight controllers and researchers during Spacelab missions (except for Spacelab-D1 in 1985, see below), where they received and analyzed data from the experiments onboard the Orbiter, directed the science operations during the mission, and liaised with controllers in the adjacent MCC. From 1990, this facility was moved to MSFC, in Huntsville, Alabama.

Building 33 Space Environment Simulation Test Facility

- *ECLSS Test Article, JSC.*
  This facility provided a real-time, crew-in-the-loop engineering simulator. It was used to test changes with existing systems and for engineering analysis, in this case for the ECLSS of the Shuttle Orbiter.

Building 35 Guidance and Navigation Simulation Facility

- *Orbiter Guidance and Navigation Simulator (GNS)*
  Believed to have housed a fixed-base crew station of the SMS.

Building 45 Project Engineering

- *Virtual Reality*
  An immersive environment facility that provides real-time, integrated EVA/robotics procedures and development training. This was just coming online during the training for the STS-61 crew, including TFNG Jeff Hoffman, but grew in importance as the assembly of the ISS approached.

Building 259 Astronaut Selection and Isolation Quarters

In 1967, this building located at the rear of JSC was used as a warehouse, but was modified in the 1980s to support the Shuttle program. Many astronauts looked upon this inconspicuous building, separated from the more well-known buildings on the site, as a very special place in which they shared many unforgettable moments together as a crew, including sharing a dinner with their spouses prior to departing to KSC for the launch. History may have echoed around the halls and rooms in Building 259, including its use as the selection office that processed their applications to join the program, but time caught up with the aging building and a new facility (Building 27) was constructed in 2004.

OTHER NASA LOCATIONS

Not all the Shuttle training could be accomplished on site at JSC, requiring the astronauts and crew to travel to other NASA field centers or to locations across the United States.

Ellington Field, Houston

- *KC-135.* This military version of the Boeing 707 was NASA's reduced gravity aircraft (known as the "Vomit Comet") from 1973. There were two stationed at Ellington Field (N930NA and N931NA), both of which were retired in 2004.
- *T-38.* Since the 1960s, NASA has operated a fleet of (updated) T-38s, which are used for astronaut transport between sites, as a proficiency trainer, and as chase aircraft.

NASA Forward Operating Location, El Paso, Texas

- *Gulfstream II Shuttle Training Aircraft (STA).* Four of these modified aircraft were used to duplicate the Shuttle's approach profile and handling qualities, giving Shuttle pilots accurate simulations of the Orbiter's descent prior to attempting the task on a live mission. Operations were completed at White Sands Space Harbor, New Mexico and at the Shuttle Landing Facility

(SLF) at KSC in Florida. These aircraft (tail numbers N944NA (s/n 144), N945NA (s/n 118), N946NA (s/n 146), and N947NA (s/n 147) were also used to assess weather conditions prior to Shuttle launches and landings. All four aircraft were finally retired in August 2011.

Sonny Carter Training Facility (SCTF)

- Site of the Neutral Buoyancy Laboratory, featuring a 202 ft (62 m) long by 102 ft (31 m) wide and 40 ft 6 in (12.34 m) deep diving tank holding 6.2 million gallons (23.5 million liters) of water. This is large enough to contain full-sized replicas of the ISS modules, payload and visiting vehicles, but not the full-sized truss structure. When this facility was opened in 1995, the second Hubble Service Mission crew (STS-82), including TFNG Steve Hawley, were the last to train heavily in the water tank at MSFC and conducted their final sims in the new tank at the SCTF just north of JSC.

Goddard Space Flight Center (GSFC), Greenbelt, Maryland

- *Hubble servicing training (lead center)*
- *Spartan free flying platform (lead center).* The POCC at Goddard monitored all free-flying (satellite) systems delivered, retrieved or serviced by the Shuttle.
- *Compton Gamma Ray Observatory (lead center)*

Kennedy Space Flight Center (KSC), Florida

- *Operations and Checkout Building KSC* (O & C Building)
- *Launch Complex 39, KSC* (launch simulations, and escape and fire training)
- *Launch Pad 39A* (simulated pad ingress/egress training; simulated countdown)
- *Launch Pad 39B* (as above)
- *Shuttle Landing Facility (SLF)* From 1984, the SLF became the preferred and primary landing site for most (but not all) missions.

Marshall Space Flight Center (MSFC), Huntsville, Alabama

- *Neutral Buoyancy Simulator (NBS)* Constructed in 1968 in Building 4705, this 75 ft (22.86 m) diameter, 40 ft (12.19 m) deep water tank held 1.4 million gallons (5.2 million liters) of crystal clear water and was the primary training facility for large-scale EVA by engineers and astronauts until the Neutral Buoyancy Simulator (NBS) was opened at the Sonny Carter Training Facility near JSC in the mid 1990s.

- *Payload Operations Control Center (POCC).* Moved from JSC in 1990 and was renamed the Spacelab Mission Operations Center to control all Spacelab missions (Except Spacelab-D1 and D2 which used the Space Operations Center of the German Institute of Aviation and Spaceflight Research and Development (DFVLR), at Oberpfaffenhofen near Munich in Germany.
- *Shuttle ET; SSME, IUS payload and related crew training (lead center)*

Additional locations

- *Ellington AFB/KSC/Edwards AFB.* Shuttle Training Aircraft training locations.
- *Dryden Flight Research Center, Edwards AFB, California.* Primary landing facility for the early missions. From 1984, it became the primary alternate landing site in the event of a non-return to KSC.
- *White Sands Space Harbor, White Sands, New Mexico.* A back-up landing site, used only once in the program (STS-3, March 1982)
- *Martin Marietta Plant, Denver, Colorado.* Prime contractor for the MMU, where a simulator was provided for training on the MMU flying and operational techniques. Astronauts wearing the simulated MMU were able to 'fly missions' against a full-scale mock-up of a portion of the Orbiter, using controls similar to the flight MMUs to maneuver the unit in three straight-line directions and in pitch, yaw and roll.
- *Hamilton Sunstrand facilities, Nassau Bay near JSC*. Hamilton Sunstrand of Windsor Locke, Connecticut, were the prime contractor for the Shuttle spacesuit and PLSS. At this facility, Shuttle EMU units were stored, repaired, tested and prepared for flight.
- *SpaceHab Inc.*, *Webster, Clear Lake*. On Gemini Street, offsite but close to JSC. This provided a location to develop and produce the pressurized SpaceHab middeck augmentation module flown from 1993 (STS-57). A SpaceHab mock-up was also available at Ames Research Center.

DEPARTMENT OF DEFENSE (DOD)

The DOD originally intended to fly its own Shuttle missions from both KSC and Vandenberg AFB. The first DOD payload was carried on STS-4 in June 1982, the fourth and final OFT. Though many more were planned, in the end only ten dedicated DOD Shuttle missions were flown, all within the NASA STS program, between January 1985 and December 1992. The interesting point here is that at least one serving military member of the 1978 selection was assigned to each of the ten mostly classified missions, creating yet another unique fact in Space Shuttle history.

TABLE 8.2: GROUP 8 DOD SHUTTLE MISSION ASSIGNMENTS 1985-1992

Mission DOD	Mission STS	Year flown	Primary DoD payload	Commander	Pilot	Mission Specialists
1	51C	1985	Magnum (USA-8)		Shriver	Onizuka, Buchli
2	51J		2x DSCS III (USA-11 &-12)			Stewart
Planned	*62A*[1]	*1986*	*Teal Ruby*			*Mullane, Gardner, D.*
3	27	1988	Lacross/Onyx (USA-34)	Gibson, R.		Mullane
4	28	1989	SDS-2 (USA-40)	Shaw		
5	33		Magnum (USA-48)	Gregory, F.		
6	36	1990	Misty (USA-53/AFP-731)	Creighton		Mullane
7	38		SDS-2 (USA-67)	Covey		
8	39	1991	AFP-675 (various)	Coats		Bluford
9	44		DSP	Gregory, F.		
10	53	1992	SDS-2 (USA-89)	Walker, D.		Bluford

[1]STS-62A (planned July 1986 launch) was to be the first polar orbit Shuttle mission, and the maiden Shuttle launch from Space Launch Complex 6 (Slick 6), Vandenberg AFB. It was canceled in the wake of the *Challenger* accident earlier that year.

As all the crews for the Shuttle DOD missions comprised current or former members of the U.S. military, it is obvious that details of their assignments, missions and experiences have been limited over the years since they flew, and will probably remain so for some time to come. When the authors researched their previous volume of astronaut selections in 2015, which included the selections for the USAF MOL program, some details of that program, crew training and hardware had recently been declassified, 50 years after the program was terminated. Significant gaps still remain in the information about the MOL program, and primarily the activities of the astronauts assigned to it. **[13]** The same is true for the astronauts assigned to the ten DOD Shuttle missions and most of their activities on those flights.

From what the authors can determine, most of the Shuttle Orbiter training for the DOD missions was conducted at JSC, which is sensible since most of the training hardware and software was based there. However, there were other training sessions in 'other locations' around the country. There were also visits to the various payload manufacturers to become familiar with the hardware they were to carry, as well as training sessions with the flight controller teams at Sunnyvale as part of the classified preparations for each DOD mission.

- *SCF Satellite Control Facility (DOD missions), Sunnyvale, California* (USAF)
- *Defense Language Institute (DLI), Monterey, California (U.S. Army).* Russian language studies for training in Russia for Mir residency missions

Contractor locations for DOD shuttle training and familiarization included:

- *Lockheed Martin (Lacrosse or Onyx radar imaging satellite deployed from STS-27 and Misty recon satellite deployed during STS-36).*
- *TRW (contractor for Magnum SIGINT spy satellite launched on STS-51C and STS-33).*
- *General Electric/Hughes Aircraft Company [subsequently Lockheed Martin Space Systems]. Contractor for the Defense Satellite Communication Systems (DSCS III) 2 launched on STS-51J.*
- *Rockwell International Space Division (Teal Ruby, intended payload for STS-62A).*
- *Hughes Aircraft (contractor for second generation Satellite Data System (SDS) military comsats deployed from STS-28, 38 and 53).*
- *TRW/Northup Grumman Aerospace Systems (Defense Support Program recon satellite, deployed from STS-44)*
- *STS-39 carried a range of six payload 'packages' designated AFP-675, with instruments provide by the Phillips Laboratory; USN Research Laboratory; Los Alamos National Laboratory; and University of Florida*

FOREIGN LANDS

The members of the 1978 selection were as much pioneers of many of the astronaut roles and assignments as were their predecessors. In particular, they expanded the international astronaut training program, following on from the ground-breaking work done during ASTP in the early 1970s. ASTP was a single mission that involved the final Apollo spacecraft joining up in Earth orbit with cosmonauts of the Soviet Union flying a solo Soyuz, though many more joint missions were proposed and planned. The ASTP program was seen as a period of détente, but changes in the wider world away from the space programs of both nations put paid to follow up missions for two decades. Despite this, the premise of the Shuttle program and major cooperative ventures with Canada (the supplier of the RMS), Europe (ESA/Spacelab) and Japan (Spacelab J), together with their partnership within the *Freedom* (subsequently International) Space Station Program, meant that crews assigned to missions flying associated hardware would travel to foreign countries for at least some training and familiarization sessions. The inclusion of international PS, and later the inclusion of the new Russia that emerged from the breakup of the Soviet Union into the ISS program, expanded this activity globally. Today, many astronauts travel the world to train with colleagues across the globe.

Canada

- *Spar Aerospace Ltd., Weston, Ontario, Canada.* This was the primary location for early RMS training.

Europe

- *Bristol Aerospace Systems (BAe) Bristol, England.* Visited by the STS-61 crew for familiarization with the replacement Hubble solar arrays they were to fit on the first servicing mission.
- *European Astronaut Center, Cologne, Germany*. The mission management for the 1985 Spacelab D mission was handled by the Space Operations Center of the DFVLR, at Oberpfaffenhofen, near Munich, Germany (now the DLR Columbus control center).

Japan

The payload crew of Mark Lee (PC), Jan Davis and Mae Jemison visited Japan for STS-47/Spacelab J training multiple times over three years prior to the mission. The Orbiter crew of CDR Hoot Gibson, PLT Curt Brown and MS-2/FE Jay Apt were assigned to the flight about 12 months prior to launch and, as a result, "trained in Japan from May 2 to 11, 1992," as Gibson explained. "We trained in Tokyo and Tsukuba, but had some time for sightseeing. We rode the multiple trains that went to Mount Fuji and we rode the subways around Tokyo. There were also evening receptions because this was the first time the Japanese had met an orbiter crew (CDR/PLT/MS-2). [We] also debriefed in Japan after the mission during November 14 to 20, 1992, staying in Tokyo again and travelling on the Bullet Train to Kobe for the debriefing, before spending a few days relaxation prior to heading back home." **[14]**

Russia

- *Cosmonaut Training Center named for Yuri Gagarin (TsPK), Moscow.* This was used for Mir resident crew training and Shuttle visiting crew familiarization training. **[15]**

Contractors

In the course of their time with NASA, members of the 1978 class of astronauts followed the tradition of earlier groups in visiting major and smaller contractors across the United States. They met workers as representatives of the Astronaut Office and the "public face of the space program," or as members of a specific crew both during training and after the mission was completed, to offer a personal thank you to the workforce for their efforts and dedication.

Major Shuttle contractors visited included:

- Rockwell International, (now Boeing) Downey, California (Orbiter vehicle)
- Rocketdyne Division of Rockwell International, Canoga Park California (SSME)

- Martin Marietta Corp., Michoud Aerospace, New Orleans, Louisiana (ET)
- Morton Thiokol Chemical Corp., Brigham City, Utah (SRB)
- Spar Aerospace, Canada (RMS robotic arm)
- Hamilton Standard (now Hamilton Sundstrand), Windsor Locke, Connecticut (Shuttle EMU)
- Martin Marietta Denver plant, Denver, Colorado (prime contractor of the MMU).

This represents just a small selection of the dozens of contractors stretched across the United States, big and small, visited by members of the TFNG in their preparations for their missions on the Space Shuttle.

PUTTING THEORY INTO PRACTICE

So what did all this mean? To give just one early example of Group 8 mission training, we need only to turn to the STS-7 Post-Flight Training Report, which recorded the first four TFNG to go through the system and complete a mission. **[16]**

Standalone training was conducted in the SMS with the objective of supporting the earlier STS-5 integrated sims. "The CDR (Crippen) and PLT (Hauck) attended all non-payload related lessons and the majority of the payload lessons. MS-2 (Ride) functioned as the Flight Engineer and attended essentially all lessons. MS-1 (Fabian) and MS-3 (Thagard) attended only payload and orbit timeline lessons." Crew systems training began in July 1982 and was completed on June 8, 1983 (just ten days before launch). Contingency EVA training had to be adjusted halfway through the training program due to Norman Thagard joining the crew in December 1982 and replacing Robert Crippen as the original STS-7 EV1 crewmember. Thagard's preparation was the shortest EVA training time period (six months) of any crewmember at the time.

The STS-7 crew supported the STS-5 deployment integrated sims, allowing them to acquire additional knowledge about the PAM and Hughes satellite systems and operations. This meant that their training for STS-7 could be further developed and refined. The STS-7 crew were also the first to require Prox Ops training. Despite not having the luxury of previously developed on-orbit procedures, their training was a success, enabling advancements in generic Prox Ops training by using the STS-7 training as a guide in redesigning the program for future flights.

The crew was also the first to receive PDRS training. There were several problems with the training loads in the SMS for STS-7, due in part to the slip in the launch of STS-6. This necessitated a number of recommendations to correct the issue for future missions. In payload briefings, conducted together with Bob Crippen, Hauck, Ride and Fabian received four hours training each for PAM-D briefing, Palapa B1, Anik D, and OSTA 2, and two hours each for the Monodisperse

Latex Reactor (MLR) experiment and the seven GAS experiments, as well as 16 hours training each on CFES.

During their year of mission training, Rick Hauck would log 1,039 hours training for STS-7, Fabian accumulated 719 hours, and Ride 988 hours, with Thagard acquiring 334 hours in six months. A total of 162 hours for Hauck, 132 hours for Fabian, 154 hours for Ride and 97 hours for Thagard were logged in the series of Integrated Simulations (split into ascent aborts; orbit procedures Day 1, 2, 3, 4 and 5; de-orbit prep; entry; a 58-hour simulation; and a contingency orbit Day 6).

T- MINUS AND COUNTING

As shown in this chapter, the training for a Shuttle crew, especially in the early years when the first members of the 1978 group flew, was both challenging and demanding, from the time that they arrived at NASA, through the Ascan training program, the technical and support assignments, being assigned to a crew, and preparing and flying a mission. Of course, the work did not stop there, because invariably following the mission came the post-flight debriefings, medical examinations, press conferences, report writing, interviews, public tours, homecoming celebrations and finally, after all the dedication and intensity of preparing for and flying the mission in the media spotlight, the reality of returning to Earth and catching up on all the household chores that had remained untouched while the celebrated family member was 'out of town' for a while!

With their mission training behind them, it was at last time to put all the theory and practice into action and go fly the mission. It was time for the TFNG to earn their astronaut gold pins.

References

1. *Report of the Presidential Commission on the Space Shuttle Challenger Accident*, June 1986, p. 166.
2. Reference 1, p. 201.
3. Commission Work Session, Mission Planning and Operations Panel, JSC, April 1, 1986, p. 198.
4. Mike Mullane, NASA Oral History, January 24, 2003.
5. Steve Hawley interview with author David J. Shayler, October 2019.
6. Kathy Sullivan, NASA Oral History, May 28, 2009.
7. **Shuttle Flight Crew Training**, Carl B. Shelly, JSC Flight Operations, November 1980; also a Memo from Robert K. Holkan, Chief of Training Division (mail code DG6) to the Lead, Mission Planning and Operations Team/STS-51-L Data Design and Analysis Task Force, April 11, 1986 (initiated by Frank Hughes, DG6). Copies on file, AIS Archives.
8. **The Hubble Space Telescope: From Concept to Success**, David J. Shayler with David M. Harland, Springer-Praxis, 2016, pp. 213–224.
9. George Nelson, NASA Oral History May 6, 2004.

10. NASA News Release 93-032, May 4, 1993.
11. **Go for Orbit, One of America's First Women Astronauts Finds Her Space**, Rhea Seddon, Your Space Press, 2015, pp. 413–416.
12. For an explanation of the middeck locker numbering systems see **Linking the Space Shuttle and Space Station**, David J. Shayler, Springer-Praxis, 2017, pp. 176-181.
13. **Last of NASA's Original Pilot Astronauts: Expanding the Space Frontier in the Late Sixties**, David J. Shayler and Colin Burgess, Springer-Praxis, 2017.
14. Emails to David J. Shayler from Robert "Hoot" Gibson, August 20 and 22, 2019.
15. For details of on Mir training by NASA astronauts, see *Cosmonaut Training for Astronauts*, in **Russia's Cosmonauts: Inside the Yuri Gagarin Training Center**, Rex D. Hall, David J. Shayler and Bert Vis, Springer Praxis 2005 pp. 274–289; also for Shuttle-Mir docking missions, see **Linking the Space Shuttle and Space Stations: Early Docking Technologies from Concept to Implementation**, David J. Shayler, Springer-Praxis, 2017.
16. **STS-7 Post-Flight Training Report**, Mission Operations Directorate Training Division, TD225/A192, NASA LBJ Space Center, October 13, 1983. Copy in file AIS archives.