The Space Congress® Proceedings

2000 (37th) Space Means Business in the 21st Century

May 2nd, 1:00 PM

# Paper Session I-B - Young NASA Personnel Performing Hands-on Operations on Flight Hardware - A History of Experiment Integration

Michael E. Haddad
*NASA Kennedy Space Center*

## Scholarly Commons Citation

Haddad, Michael E., "Paper Session I-B - Young NASA Personnel Performing Hands-on Operations on Flight Hardware - A History of Experiment Integration" (2000). *The Space Congress® Proceedings*. 12.
https://commons.erau.edu/space-congress-proceedings/proceedings-2000-37th/May-2-2000/12

37th Space Congress
May 1 - May 5, 2000

# Young NASA Personnel Performing Hands-On Operations on Flight Hardware – A History of Experiment Integration

By

**Michael E. Haddad**
**NASA**
**Kennedy Space Center**

## Abstract:

In the early 1980's, NASA was preparing to launch the first Space Shuttle to begin a new era in USA Spaceflight. At the same time new hardware called "Payloads", that would be taken into space aboard the Shuttle, were being developed. These Payloads contained a multitude of science experiments from all over the world. Many would be contained in a laboratory called "Spacelab", which was being developed by NASA and the European Space Agency. How would these Payloads be prepared for launch? A concept of allowing NASA personnel to perform the job, that normally a contractor would perform, was reintroduced. Instead of overseeing a contractor, NASA would perform the engineering function him/herself and get his/her own hands dirty. So was created the "Level IV – Experiment Integration" organization at Kennedy Space Center. Many young NASA personnel, most of them right out of college, would be responsible for preparing domestic and foreign multi-million-dollar experiments for space flight. This paper tells the story of that unique group, how it was a major player in the success of the Spacelab and Science programs, where some of those people are today, and how knowledge gained by that group of people is being used for current & future space flight activities.

## Introduction

In the early 1980's, NASA was preparing to launch the first Space Shuttle as part of the new, reusable Space Transportation System (STS). STS would carry a variety of new hardware into low earth orbit in either its large Payload Bay or the "Middeck" area inside the Orbiter. Most of this new hardware, officially called “Payloads”, was being developed at the same time as the Space Shuttle. These Payloads contained a multitude of science experiments from all over the world. Many would be housed in a research laboratory called "Spacelab", which was being developed jointly by NASA and the European Space Agency (ESA).

ESA is a consortium of countries that comprise Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Switzerland and the United Kingdom. These countries, along with the United States, would work together to design, build and test the basic structures that made-up Spacelab which contained the payloads and supported the many thousands of experiments planned for launch on the Space Shuttle.

The basic Spacelab structures were Racks, Modules and Pallets. Each rack (built in Italy) could contain one or more experiments. Two kinds of Racks were used; single racks (based on a standard 19-inch laboratory equipment rack) and double racks (twice the width of a single rack). Single and double racks would be placed together to make up an experiment rack train, Figure 1 (Partial Rack Train). The Spacelab Module (also developed by Italy) was a pressurized cylindrical compartment where Astronauts could work in a “shirt-sleeve” environment. The modules shown in Figure 1, are the main pressured shell that would contain the racks that housed many experiments Astronauts would operate during a Spacelab Mission. Pallets (developed in the United Kingdom) were large “U” shaped structures designed to support hardware that was exposed to the vacuum of space, Figure 1.

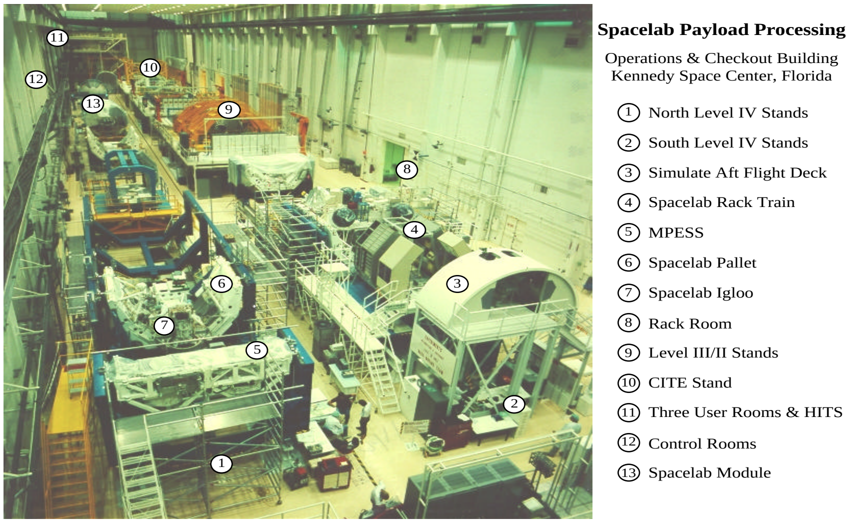

Figure 1, Hardware at Kennedy Space Center

The Spacelab program also encompassed several other hardware elements, Figure 1: the Igloo (built in Belgium), housed the on-orbit Spacelab computers and communications equipment; the Instrument Pointing System (IPS - built in Germany) provided a stable platform for precise pointing of telescopes; and the Mission Peculiar Experiment Support Structure (MPESS – built in the United States)

A Spacelab mission could be configured using any combination of this hardware. For example, Spacelab 1 used a module and pallet combination, Spacelab 2 used three pallets, and Spacelab 3 used a module with an MPESS. This hardware was reusable so after each mission the experiments would be removed and new experiments installed as the new mission dictated. Pallets and MPESS’s were also used for non-Spacelab missions like the Space Radar Lab (a pallet and MPESS) and Larger Format Camera/Orbital Refueling System (LFC/ORS) mission (single MPESS).

The capability of Spacelab and the possibilities for performing virtually any kind of science research in space was very exciting. But in what location would the assembly, integration, servicing and testing of the payloads containing the experiment hardware take place, and who would be responsible for preparing them for a Shuttle mission? It was decided to perform most of this work at the Kennedy Space Center

(KSC) in Florida and to reintroduce the unique concept of using NASA personnel to perform the “Hands-on” work usually performed by contractors. “Hands-on” meaning that NASA personnel would perform the engineering function and many times turn the bolts, fill the fluid tanks, push the buttons and command the experiments. The concept would cut costs by having only one person performing the work instead of two (a contractor performing the work with NASA oversight). It would also attract young professionals and provide a training ground for young NASA engineers. NASA engineers would work side-by-side with contractor technicians, supported by NASA quality & safety personnel. So was created the “Level IV” organization at KSC.

The term “Level IV” refers to the different levels of operational activities that were required to process a Spacelab mission. Level IV was the starting point where most to all of the experiment hardware was assembled and tested beginning with individual pieces. Level III/II was the integration of the experiment systems with the basic Spacelab module shell/Igloo and subsystems. Level I meant operating the hardware with the real Shuttle Orbiter flight software at the Cargo Integration Test Equipment (CITE) area. All three of these levels were located in the Operations and Checkout (O&C) building at KSC, Figure 1. Level I also included all activities that occurred after the hardware left the O&C, like at the Orbiter Processing Facility (OPF), launch pads, or at the landing sites. Because the same personnel followed the hardware through each level and also because these same people worked other missions besides Spacelab, the term “Level IV” was later changed to “Experiment Integration” (EI)

## Level IV – Experiment Integration Background

It was a risky idea to entrust young NASA personnel, many right out of college, with unique one-of-a-kind multi-million dollar flight hardware and to ask them to perform "hands on" activities that had never been done before. But they rose to the challenge. Working with domestic and international universities, private companies, government organizations, and other space related centers at locations all over the world, this was truly the first international effort in support of the new Space Shuttle Program. EI at KSC started, quite literally in most cases, with the basic nuts and bolts of what would later be a large payload containing ten of thousands of parts, miles of wire and weighing over 10 tons. I know, because I was hired into Level IV as a Mechanical Engineer in 1982, near the beginning of the Spacelab program, and worked there for seven years. The following will describe just how successful this risky concept was over the course of almost two decades.

## Level IV – Experiment Integration Activities

### Planning

Long before the hardware arrived at KSC, EI personnel were assigned an experiment (most of the time multiple experiments) for each payload. Starting approximately 2 years ahead of time, he/she would travel to locations all over the world to participate in the many design reviews, meetings, schedule reviews, preliminary testing and other events required to prepare the hardware for arrival at KSC. This included not only the flight hardware, but also the ground support equipment (GSE) that was required to support the flight hardware operations. In some cases, the experience of the EI engineers shaped how the flight and/or GSE hardware was designed and built

In addition to their experiment assignments, EI personnel were responsible for developing, operating, and maintaining much of the GSE, like the checkout systems which simulated the Spacelab and/or Orbiter subsystems during Level IV testing. These responsibilities required enormous amounts of time on the part of EI electrical and software engineers. Everyone in the branch had to wear at least “two hats” (i.e., they were responsible for some part of the checkout systems in addition to duties as experiment engineers or lead mission engineers). The Payload Checkout Unit (PCU), and High Rate Multiplexer Input/Output

Test System (HITS) folks received significant training from the vendors until they became experts in their own right. The Partial Payload Checkout Unit (PPCU) team actually participated in the original design and development of their system. It wasn't unusual to see engineers and co-op students crawling around under the floors with multi-meters and oscilloscopes, or spending weeks in front of a computer terminal developing code to provide a new capability. This daily interaction with the checkout systems resulted in the EI engineers becoming experts on the Spacelab and Shuttle avionics that their checkout systems simulated, which was an enormous advantage during experiment testing and mission operations. The mechanical and fluids engineers developed similar expertise with the mechanical GSE.

EI personnel were also responsible for reviewing and commenting on the experiment drawings. From a mechanical engineer's standpoint, this required many weeks of studying the drawings to become familiar with what the hardware should look like, once assembled. We had to figure out the best way to assemble these pieces together into the Spacelab racks or onto the pallets, which many times drove out errors in the drawings and overall design. The same was true for electrical schematics, wiring diagrams and electrical components. A great deal of time was required to understand the function of each electronics box, how it was suppose to "talk" to the other electronics in the Spacelab, the cabling in between, and software used to command the systems.

An overall time line had to be established for all activities that would need to be performed at KSC. Since the launch date was considered a "hard" or immovable date, the logic was to begin there and work backwards to determine the time required to complete all activities before launch. And of course, in the beginning all of these activities had never be done before so the only option was to guess how much time would be required to complete a test or assembly task. As more payloads flew and our experience increased, we became more accurate at estimating future timelines.

## Operational tasks

At the West End of the O&C, many payloads began to be assembled, integrated, serviced and tested on their journey to be launched into space. "Assembly" meant obtaining the parts necessary to put the experiment together. Depending on the mission, the parts could come from anywhere on Earth. "Integration" meant bringing together many different experiments and/or subsystems that would support the experiment(s). "Servicing" referred to supplying a certain commodity to an experiment/system such as, pressurizing a gaseous nitrogen bottle, loading freon into a cooling loop or supplying liquid helium to a storage system used to keep sensitive detectors healthy. "Testing" could mean powering up a device or flowing fluid through a system looking for leaks. All of these activities required procedures to be written and performed. Level IV personnel did both. Building on the reviews of the flight hardware drawings and documents, discussions with design organization and many many meetings during the planning and operational phase, procedures were created and performed to bring the experiments up to an operational state. Done for all levels of payload processing (Level IV through Level I), this included, pre-flight integration, and post-flight deintegration as well as support and direct input for on-orbit operations during the mission. Most of this work was performed side-by-side with the experiment's chief Scientist, called the Principle Investigator (PI). The PI's came from many disciplines and locations all over the world. Even though it was the EI personnel's responsibility to process the experiments, the PI's and their science & engineering teams were still intimately involved in all phases of pre-flight and post-flight operations.

Again due to the one-of-a-kind nature of these payloads, problem solving was a major part of our job every day. Every new day was different from the previous day because new problems occurred or twists on old problems would challenge the ingenuity of the Level IV team. Also every payload complement was unique, so each payload (even reflights) was a new adventure. However, as more payloads were processed, our experience base grew and grew. This allowed us to "tap" knowledge obtained on one payload and apply it to the next. Most fixes had to be done immediately (or "real-time") because there was not enough extra time in the schedule to dwell on coming up with a solution or create a team to analyze the problem. Each problem would be documented on an individual Problem Report (PR) and it was the responsibility of the EI personnel to determine and carry out the solution to the problem. PR's for a single payload could total into the thousands, with one double rack logging more than 100 PR's before it was ready for flight. Some problems would be recorded as "Unexplained Anomalies (UA's)" because they occurred only one time, or could not be reliably repeated, and so a solution was never determined. As an example, on Spacelab D-1, an experiment would lock up for an unknown reason, that required a restart to "fix". EI personnel needed to weigh all the risks and make a tough engineering call on whether or not we, the scientists and the astronauts, could live with this condition, which we did. Other problems involved the GSE, some of it older than the persons operating it. In one case an old power supply built in 1964 caught fire in the O&C cleanroom area. No harm occurred to personnel or the flight hardware, but the company that built it no longer existed by the late 1980s. So, the EI personnel had to learn about the outdated power supplies to establish preventive maintenance for the rest of the equipment. EI engineers also had to keep track of each and every part, including those lost somewhere inside the Spacelab. One PR described finding a part that was not lost! An electrical clip was discovered in a pallet that should not be there, so it was recorded officially as "a found but not lost clip". EI work required making hundreds of decisions a day on how best to assemble, integrate, service and test the hardware.

The days were long as well, most being 12 hours and many extending to 16+ hours. Sometimes we would sleep at work instead of going home. Due to the high launch rate and limited number of personnel at the time, many experiments, payloads and missions were being worked on at the same time. I remember at the peak, working 3 different payloads at three different locations in the O&C building all at the same time on the same day. One electrical engineer, who worked on the International Microgravity Lab (IML-1), Spacelab J (Japanese Spacelab) and United Stated Microgravity Lab (USML-1) payloads simultaneously, remembers asking in a meeting, which module the team was talking about? Some jobs would require multiple technicians so the engineers quickly ran out of contractor technician support. The work could not stop, or the hectic schedule would not be met, so we were trained to perform the technician role, which I did many times. The Quality Assurance person would read the steps from my procedure and I would perform the work. Another engineer was the only person with small enough hands to access very tight areas. One mechanical engineer spent the 1984 Christmas Holiday installing electrical cables on Spacelab-2. It was a feverish pace, but most of us were young and could go flat out for months at a time because we lived and breathed the space program.

Assembly took a great deal of time because KSC was usually the first place the parts came together. Tasks that appeared simple on paper sometimes became very difficult once the actual assembly started. The challenge was staying on that estimated time line even though problems occurred and the hardware was not performing as designed on paper. These activities included major coordination with the design organizations to ensure timely hardware arrival dates to KSC and once at KSC, tight interaction to solve the problems that occurred. Hardware arrival delays would cause us to adjust our schedule; there was always other work that could be done in the meantime. We worked closely with personnel from all over the world. Sometimes in person or via phone, fax, or later, e-mail to the host country, say Italy for the Tethered Satellite System (TSS) or Germany for the Spacelab D-1 mission as needed to talk with the designers about a proposed fix to their hardware.

The Spacelab racks arrived at KSC just as basic, empty structures. For each mission the racks would be populated with hardware assigned to fly on that specific mission. Assembly and integration of the rack components took place in the Rack Room of the O&C, Figure 1. Initially this location was used just to assemble racks, but as more Spacelab missions flew, the room held over a dozen racks in some form of integrated or deintegrated configuration. Each Level IV engineer could be assigned multiple racks per mission, so one engineer could be assembling racks for a future mission and disassembling racks from a previous mission, all at the same time. The more complicated racks could take several months to almost a year to assemble and fit all the hardware as designed, including solving any problems that cropped up all along the way.  One general problem was that cables were often larger than shown on the drawings, which impacted other hardware in the rack and made routing the cables very difficult, which also impacted the installation of other hardware, and so on. We needed to be sure the fix for one piece of hardware did not cause other problems somewhere else in the rack. Once completed (and sometimes still uncompleted), each individual rack would be added to the rack train in preparation for integrated testing. Due to schedule conflicts, some rack integration would be completed after addition to the rack train. Some racks were tested individually before inclusion into the rack train.

The Spacelab pallets were used to support either Spacelab missions, like the double pallet Astro-1 mission, or non-Spacelab missions, like the single pallet LIDAR In-Space Technology Experiment (LITE-1) payload. The basic structure remained the same but what was mounted to the pallet changed from mission to mission. Honeycomb-shaped support structures, cables, fluid lines and electronic boxes covered the surface of most pallets, as on the Shuttle Imaging Radar (SIR-B) antenna, Figure 2 and some using the IPS, which held one or multiple telescopes like on Astro-1.

Figure 2, EI Mechanical Engineer Luis Moctozuma , right with beard, performing Shuttle Imaging Radar -B Antenna operations on Spacelab pallet in Level IV area at KSC,  Mission SIR-B.

Integration operations ranged from installing multiple small experiments into one rack, to integrating multiple telescopes on a pointing control system as in Astro-2 mission.

Another major activity, and sometimes a very hazardous operation, was servicing experiments and payloads with fluids and/or gases.  Freon and water were some of the room temperature fluids employed, but we also dealt with cryogenic fluids like extremely cold superfluid Helium (–458ºF) on United States Microgravity Payload (USMP-1) Lambda Point Experiment. Gases ranged from standard Nitrogen and Helium to the complicated gas mixture required for Cosmic Ray Nuclei experiment on Spacelab-2. Servicing could be required periodically for a payload during its entire time on Earth before launch and after landing. EI personnel required special training to be able to use some of these commodities.

Once assembled, integrated and serviced, payloads were tested to assure proper function before launch. Nobody wanted the Astronauts to take up valuable science-gathering time fixing problems that could have been detected and fixed on the ground. The tests could range from powering up small individual experiments like a single middeck experiment, to operating large payloads containing 70+ international experiments like Spacelab 1. The EI engineer often knew more about the operation of their individual experiment than the PI him/herself, because the EI engineer understood how it worked within the Spacelab environment. The PI knew how to run it on the bench back in the design lab, but that didn't always involve an adequate simulation of the Spacelab Command and Data Management System (CDMS) avionics, flight software, power systems, and other systems in which the EI engineer was an expert, Figure 3. Another benefit provided by the EI engineer was his or her knowledge of KSC operations amid the multitude of organizations and paperwork

Figure 3, EI Engineer Sue Sitko, standing, discussing software problems with test engineer, software designer and foreign PI's in KSC User Room,  Spacelab D-2 systems. The EI engineer (with the help of the various resident offices) served as liaison between the PI and the rest of KSC. The EI engineer knew where to go to find things, who to talk to, and how to ask. The EI engineers would guide the PI teams thru the often confusing processing flow, so in the end PI teams would have learned how to interact in the Spacelab/Shuttle world (something that would prove invaluable during mission operations). So in a way, we helped train the PIs.

Testing was done in phases; starting at the assembly level and going up to major integrating testing with the Orbiter at the OPF or launch pad and involving hundreds of personnel. As an example, for Module missions, the rack trains were tested in the Level IV area to drive out any problems between racks and simulated Spacelab subsystems. The rack train then would be placed into the flight Spacelab module (Level III/II), and tested against the flight Spacelab subsystems to assure a whole healthy payload before proceeding to Level I, CITE and/or the Shuttle Orbiter. Once the payload was installed into the Orbiter, it would be tested for the last time before launch. This scenario would change depending on if the mission was a Spacelab module mission, Spacelab pallets and/or MPESS mission or other non-Spacelab missions using Spacelab hardware.

Experiment assembly, integration, servicing and testing would take place mostly in the O&C building but EI personnel would perform any ground tasks stated above, during OPF operations, Pad Operations, and Landing operations at KSC, Edwards Airforce Base, or White Sands Landing Facility.

Pre-flight OPF operations started with installation of payload into the Orbiter payload bay and then testing only the specific interfaces between the Orbiter and payload. Other flight preparation operations included placing barriers over sensitive instruments, servicing payloads, and final flight closeouts. Once the EI engineers performed a complete mission turnaround in the OPF for the MSL-1 missions. Normally after a Spacelab mission the hardware returned to the O&C for deintegration, but due to the shortened first Microgravity Science Lab (MSL-1) mission (due to an orbiter problem) the payload remained in the orbiter for all re-flight preparations; a task never performed before in the history of the Shuttle program. EI contributed to the successful re-flight only 3 months later.

At the launch pad, operations would range from: removing covers off experiments before launch, to rebuilding an experiment (as on USMP-1) only weeks before launch, to the first time ever loading of a science payload with very hazardous Hydrazine propellant as on the ORS payload. A very critical Pad activity dealt with placing perishable science samples into a vertical Spacelab Module very late in the launch countdown; about a day before launch. Access to the module was very complicated and required the use of the Module Vertical Access Kit (MVAK). MVAK was a systems of pulleys and motors which lowered a person on the end of a cable in a harness down into the module. This system was used many times to load time sensitive science samples, such as the primates and rodents for the Spacelab Life Science (SLS) missions. If there was a launch scrub, the activity would have to be repeated to remove the first set of samples and install fresh samples. Depending on mission requirements, EI personnel also sometimes supported launch countdown operations from the payload consoles in the Firing Rooms located in the Launch Control Center (LCC). There we monitored and commanded payloads systems, right up to launch.

Whether it was a dedicated Spacelab mission or not, EI personnel were responsible for installing and testing the middeck experiments that flew in the crew compartment of the Shuttle. Before the flight, we would prepare the middeck experiment as needed, transport it to launch pad, assist the Shuttle technicians with installation into the Orbiters middeck area, then perform a short Orbiter-to-experiment interface test. Many of these required installation the same day as launch. After landing, EI personnel would be at the landing site to assist with removal of the middeck experiment, shortly after the flight crew existed the Orbiter, then perform any post-flight operations. The EI team also successfully designed, built and processed the CHROMEX middeck experiment, which flew on multiple missions.

Figure 4, EI Mechanical Engineer Angel Otero, right, with Dr. Ulf Merbold, Spacelab-1 Payload Specialist (ESA), preparing to relay information to the on-orbit crew from the German Space Operation Center (GSOC) located in Oberpfaffenhofen West Germany , Spacelab D-1 mission

After developing an extensive background and knowledge of the hardware during all the months of pre-flight preparations, EI personnel supported on-orbit operations. This took place at the Payload Operations Control Centers (POCC's) located at either Johnson Space Center (JSC) in Houston Texan, Marshall Space Flight Center (MSFC) in Huntsville Alabama or German Space Operation Center (GSOC) located in Oberpfaffenhofen West Germany, Figure 4. Problems encountered on-orbit may mimic ground problems, which the EI engineer would recognize, and then relay the solution to the crew on-orbit. For any new on-orbit problems, the EI engineer could pull from past experience to help isolate the problem and suggest solutions. One EI person's experience was recognized by being selected by the Principal Investigators as an Alternate Payload Specialist for the Astro-2 mission. Another was chosen to be one of the main interfaces to the crew (a Crew Interface Coordinator) for the Space Radar Topography Mission (SRTM). Also, the Astronauts flying these missions would participate in many KSC EI activities. What better practice for the real thing than operating the flight hardware first on the ground before they see it in space? EI personnel, PI's and Astronauts often became co-workers and good friends over the many months & years needed to prepare payloads for a mission.

## Lighter times

EI activities were very demanding mentally and physically, as well as time consuming, but there were a number of lighter times that would break the tension, keep people upbeat and overall keep the job fun and exciting. One US experiment used a microphone to listen to the internal motors and actuators inside its telescope but on one day of testing, EI personnel and the PI substituted the real noise with the noise of broken glass. The rest of the test team was startled, and initially concerned until the substitution was revealed, after which all had a good laugh. German engineers would bring German chocolates to the EI engineers and tell wonderful stories of Germany and Europe. Another round of testing ended with a party at which British guys were wearing black cowboy hats, and attempting southern accents. The SRL-2 mission had an orbital pass over KSC, during which the on-board SIR-C and X-SAR radar instruments imaged 30 Corner Reflectors that were previously set up on the grounds by 50 EI engineers to spell out the letters "KSC" over the distance of a mile. The image can be seen on the KSC web page at http://www.ksc.nasa.gov/shuttle/missions/sts-68/ksc-srl-image.html. Because we were so dedicated and the space program was our life, many of the people we worked with also became our closest friends, with a few couples even getting married. After a 12-hour day, 8 of us would go to dinner with the PI's, engineers, scientist and astronauts, and spend the next 4 hours talking about work and helping each other solve experiment problems. Many of us were certified scuba divers so we would plan diving trips to the Florida Keys. The fall brought the Payload Halloween Party that was attended by Astronauts, National News media personnel, foreign PI's (picture Japanese engineers in Mickey Mouse ears!) and KSC's center director. Started in early September, setup for the Halloween party entailed transforming a local home into a haunted house with a different theme each year, like transforming the garage into a swamp. EI personnel designed and built the automated special effects contained in the house. Also, I remember one fall, while working on Spacelab D-2, watching Monday night football with a German Ph.D. trying to explain how American football was different from his "football" sport, soccer. Snow skiing every winter became a weeklong EI social function. One year we had an Irish friend located in Italy fly all the way from Europe to join us for a ski trip in Colorado. In 1987, the Level IV softball team won the KSC B league championship. The list goes on and on.

## Personnel today

Today, with the completion of the Spacelab program, the Level IV - EI organization no longer exists but many of the EI personnel have remained at KSC. Many other EI personnel left KSC to go work at other NASA centers, where their KSC experience could contribute to the future success of NASA. One ex-EI person left KSC to go to work for another ex-EI person at Glenn Research Center (GRSC) with a major factor in his recruitment being EI experience at KSC. Some have left NASA all together and are working for private companies throughout the United States

## Knowledge transfer for today and the future

Many of those personnel that did stay at KSC are working on the International Space Station (ISS) program. Their experience is being applied to assembly, integration, and servicing of Space Station elements currently at KSC. A series of tests involving the Space Station Elements, call Multi-Element Integrated Testing (MEIT) is using many NASA ex-EI personnel in an EI type role. Their experience testing dozens of unique payloads will be applied to testing the one-of-a-kind Space Station elements, as well as spot potential problem areas early, to help assure successful operation on-orbit. Ex-EI personnel have already supported ISS missions 2A and 2A.1 for on-orbit operations from the KSC Engineer Support Room (ESR) and will support all future ISS missions. Also the KSC Utilization organization for ISS has a number of ex-EI personnel that to this day are performing Middeck payload work and future ISS experiment racks and payload work.

## Summary

Neurolab was the last Spacelab Module mission to fly on the Space Shuttle in April 1998. The Shuttle Radar Topography Mission (SRTM), as of this writing scheduled to launch early in the year 2000, is the last mission of the Spacelab Program. Pallets and MPESS's will continue to be used for ISS. From early 1981 until today, the following is a summary of EI accomplishments:

| Payload bay payloads: | Middeck payloads (Crew Compartment): | Overall: |
|---|---|---|
| 39+ Shuttle missions | 53+ Shuttle missions | 70+ Shuttle missions out of the 96 total Shuttle missions to date flying a combination of middecks and/or payload bay payloads, including, primates, 60+ rodents and 2400+ jellyfish. |
| 44+ Payloads | 150+ Payloads | |
| 600+ Experiments | 200+ Experiments | |

Countries interacted with included; Austria, Belgium, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, Spain, Switzerland and the United Kingdom. Contributions have been made in the following areas; Astronomy/Astrophysics, Atmospheric Sciences, Life Sciences (plant, animal, and human), Materials Sciences, Low-Temperature Physics, Earth Sciences, Remote Sensing, Solar Physics and Space Plasma Physics, Space Technology Demonstrations, Fluid Physics and Crystal Growth;

The EI role was a very exciting and rewarding time frame in the history of KSC. The payloads were challenging, but for most EI personnel the people we met and worked with were the best part of the job.

One EI Electrical Engineer summarized it the best, "Every time I saw a Spacelab mission lift off, I got a very special feeling inside that lasted about two weeks. The performance of the experiments and the Spacelab was an unqualified success on every mission, and it would be hard to be more proud of the work we did. The fact that we got to work with a bunch of great people from KSC, other NASA centers, and from around the world as well as work on a new complement of experiments every few months made it a fun, exciting, and interesting job that could easily be called a passion rather than work."