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6. SPACELAB D-1 MISSION

Dr. Bonnie J. Dunbar
NASA/JSC, Astronaut

(Note: This paper has been reproduced from tapes.)

Thank you, and Bill, we did learn from the lessons of Skylab. There were several documents printed after those flights called Lessons Learned from Skylab. I've read them and found them very informational and I think you'll be pleased to know that I think the vacuum cleaner now works better. We did use it for some furnace cleaning and we do clean the filters out and we have improved the access. We have ensured that we don't have to take off all those bolts again.

What I would like to do today is talk about the D1 mission from a couple of perspectives. The first one, of course, is from the point of view of safety, materials handling, toxic materials, but the other is from the point of view of the laboratory and the equipment we used and some of the different philosophies utilized on this flight. My Ph.D. is in Biomedical Engineering but most of my professional life has been in materials and most of my laboratory experience has been with high-temperature furnaces and diagnostic devices and so forth. So I find that this is a very interesting part of the research that's occurring on Spacelab missions, on the middeck, and will occur on Space Station.

(First slide)

I will introduce the crew and background to you. This flight was called 61A in the NASA language. It actually had another name, D1 (Deutchland Eins) which was the first German-sponsored Spacelab flight. Germany, not ESA, but DFVLR in Germany, bought this flight, the launch for about 59M. They invested about 229M of their funds in the experimental hardware that went inside the lab flight. This was a first of a series of flights. D2 will occur in late 1991. Their stated intent is not only science but the development of hardware for Space Station. So, 1991 will see us with a couple of new furnaces that actually won't be heated up but will be tested for advanced technology and will eventually be used on the Station. The crew consisted of five NASA career astronauts. The commander, Hank Hartsfield with NASA, the pilot Steve Nagel from the Air Force with NASA, the Mission Specialists myself - MS1, MS2 Jim Buchli with NASA from the Marine Corps, MS3 Guy Bluford from the Air Force. Guy and I were assigned as the two people on board in charge of the Spacelab subsystems, much as Owen was on his flight and also assigned the task of training for the experiments. There were three Europeans on board. Professor Reinhard Furrer from Berlin, Dr. Wubbo Ockels from the Netherlands, who is an ESA astronaut and flew on this flight because about 30% of the hardware was ESA. It was part of the cooperative agreement ESA had with Germany. And then, Professor Ernst Messerschmid Stuttgart. The five of us then were called the payload crew. We then trained primarily in Europe starting about 19 months prior to the flight. We spent about 6 and 1/2 months in Europe and the rest of the time in Houston. Guy and I trained with the rest of the crew on the Shuttle and the Spacelab systems.

Just to review a little for you what Spacelab is, it is actually an in-the-bay laboratory connected to the middeck with a tunnel and it's a shirt-sleeve environment. There are two hatches that separate the lab from the middeck at launch, one here in the middeck and one about here at this area. Very often, we carry pallets behind the laboratory when we fly with other experiments and we did so on this flight. This is not our configuration. But we did carry a U.S. pallet in the back which contained the Materials Experiment Assembly which was an automated, high-temperature levitation furnace.

The experiments, as I said before, within the lab were primarily German. We did have a cooperative physiological experiment with MIT which was in here. And then, there were nine middeck lockers devoted to supporting the work in the laboratory. Just a note about air flow. The air flow in this system was such that the cabin air flowed this way through the tunnel into the middeck so that the laboratory environment was really quite clean. It was the cleanest part of the Shuttle. Air debris or environmental debris builds up over time, so by the seventh day all of that those flakes of skin, hair, paper, and food that might be out were really accumulating on the middeck. Filter cleaning was a routine and important part of our mission and every other mission as well. We have improved the access so we don't have to take off the panels with large amounts of screws.

Just a quick look at the lab as it is in MBB/ERNO. You can see the pressure holes on the end and then the experiment racks themselves. Each rack comes with a standard set of facilities. For instance, air handling tubes and electrical cables for data handling and for power.

And as it looked in the payload bay. This was from the middeck back at the lab and you can see the tunnel, the hand rails for the EVA access if we needed to go outside.

This is in German so don't worry about reading the print at the top. It's only one side of the lab but I wanted to briefly explain the disciplines we had to deal with. Thirty percent of this flight was devoted to materials science. Everything from high-temperature processing of metal alloys and semiconductor material such as gallium-antimonide to looking at basic science using laser interferometry to study Marangoni Flow, for instance, and inter-diffusion of melts. The way the flight was organized was that each rack had a discipline so there was not a mix of disciplines within racks and those racks were integrated at a subcontractor before they went to Bremen for a test within the lab floor. The blue rack is a subsystem rack in the Spacelab that had the data or high-data rate recorder, the computer interface here for the subsystems, also the black boxes, for instance, inverters and computers within it. The red racks represented one side of the experiment racks. There was a large materials science double rack. MSDR flew for the first time on Spacelab 1 and this was its second flight. So, those problems that they had encountered on the first flight in 1983 they attempted to fix on this flight in October of 1985. Next to that was a stowage rack. There's also a rack called process commer. This was the rack which contained the small lasers. And, then, next to that a stowage rack with equipment for this vestibular sled. Vestibular science is comprised of about another 30% of the flight. On the other side, not shown, was another large double rack of material science that was called MADEA. There was also a glovebox, a biological glovebox, and you will see that in a moment. In the back you do see the Materials Experiment Assembly here and then three GAS cans, communications experiments flown by the Germans.

Like most Spacelab flights, the scientists on these flights are tied in directly to the crew. We don't have this capability right now for middeck experiments but it is a particularly nice feature of Spacelab flights in that the scientists on the ground can interact with the crew on board and it is something that we do encourage. However, what was unique about this flight is that the scientists were not at Marshall or a U.S. remote POCC. They were all at a POCC, or Payload Operations Control Center, within Germany at Oberfafenhoven. This is what our communications looked like. Here's the Shuttle. We communicated to the TDRSS satellite down to White Sands. This went to a domestic satellite signal relayed to Goddard to JSC. The experimental data, because the Germans are interested in Spacelab subsystem data, they are using their POCC to develop a Space Station capability. They asked that some of that be shipped over as well so we sent that to Intelsat 5, which is a commercial satellite over Germany that went down to northern Germany and then by land line to Oberfafenhoven near Munich. There's a picture out of their control center. It's the same facility that has controlled their satellites. They're using it for their Spacelab missions and they will probably use it to interface with their Space Station operations as well. They do have one feature we don't have and that's color CRTs at their control sites.

On board, you see one of the two shifts working. This is myself and Reinhard and Ernst working in parallel to a flight plan that's been developed over time in 5-minute increments because time is money with a certain amount of time padded in each day for contingencies because there is no perfect world. In-flight maintenance is an important part of every lab whether it be on the ground or on board. In this photo, I have some tools on my leg. You always carry scissors and pencils and other tools around. I'm checking some data in an incubator. Reinhard's at the materials science double rack and Ernst is at the rear probably looking at some vestibular science hardware.

This is glovebox that we carried on board developed by ESA. In this facility, the whole rack contained two incubators, a freezer, a cooler, and the glovebox. This facility was flawless - first flight. It contained over 80 different boxes, which I'll show in this next photo, containing a number of experiments. This is one of the incubators. Each of these little cigarette-shaped boxes contained an experiment. Some were sort of autonomous in that you would rotate the sample from a freezer to a cooler, then maybe to an incubator, and then back into a freezer. Others were actually plugged into little chips at the end of this box and then the data went to the CRT display who would either initiate the experiment, monitor it, or it would let us know when it was finished.

Here's a closer look at the box. This is built by Dornier who built all the boxes and then all the experimenter had to provide was generally the interior. This provided one level of containment. Inside might be something like this. Inside this little box were maize seeds and there were two plungers at the end. One of the plungers provided the water to germinate the seeds and the other one may have been the fixative which we later plunged down and fixed the samples. When we worked with these samples (took them in and out of the box), the glovebox itself was considered one level of containment and that's something to remember when designing experiments. We have a triple containment rule but there are ways of providing that rather than putting everything into three boxes and then not leaving access to them.

On the other side of the lab you see myself and Wubbo working. I'm in front of the MDEA facility which included a gradient heating furnace and a mirror heating furnace. The samples, as you can see here, are all outside the furnace and they are exchanged. This was routine for all five high-temperature furnaces we carried. I think it is important to remember that the materials that we carried, such as gallium-antimonide, are only toxic at temperature, not at ambient conditions, as long as they don't have a high vapor pressure and you are not actually touching the surface. So, in a lot of cases such as this one, that sample has a glass tube around it but you might say that is single level of containment. But once I put it in the furnace and close the door and there is an interlock there that as soon as I start heating it up will prevent me from ever opening that door again until it is back at temperature. We operate in a safe environment. There are a lot of interlocks and safety features built onto this furnace. I consider this the most sophisticated rack facility we have probably ever flown. It has microprocessors which plug under the front which contain the thermal processing curves. There are codes built into the samples themselves that go out and fetch the processing curves. It protects proprietary data and yet it is safe.

This happens to be a drawer full of spare lamps. We were also able to exchange lamps. They are, again, glass lamps or glass bulbs. I don't know if you can see them on the end there, but they are carried up in plastic and foam and then exchanged on orbit.

In the gradient heating furnace we carried very benign metal alloys and the alloy samples themselves are a little over 1 foot. That's the end of the sample which also happens to be a door of the furnace and in that door of the furnace which screws in is a cable that plugs into the front of the panel which then goes to the PROM and fetches all of the necessary information to process or gives the necessary information to process that sample. We did have one problem with the gradient heating furnace sample. One of them, there are thermocouples inside these samples, and, for some unknown reason, one of them broke in the furnace and I pulled it out and recognized that we had less than a full sample down there. We knew it was a non-toxic material. I used a flashlight to look down into the bowl of the furnace and saw the rest of the sample down there. We had long forceps. We retrieved the rest of the sample and there was some debris in there. We put the vacuum cleaner over the front of the furnace and sucked out the debris. We took a bottle brush, cleaned out any powder that might have been in there, and then continued processing the rest of the flight. Now I should add that was not an "on-the-wing" procedure. Preflight, we had tried to provide for all these contingencies and that was a planned operation in case we had any problem with these materials.

A closer look at the materials science double rack. You will see some of this in the short film that I am going to show from the flight. It was called the fluid physics module. We also had a cryostat device for growing protein crystals. We had an isothermal heating furnace, a gradient heating furnace, and then the power boards and so forth.

This is the mirror heating furnace in which we did some of the single crystal silicon and some of the other semiconductors. In this case, the crewman here has it open and is actually cleaning it out. This was one problem we did have on flight and there are probably several reasons this happened. We think that there are two possible things that happened. We know a sample overheated. We think that one plausible reason is that the sample that was provided to us late was not the one that was coded in the computer or documented. In order to start this furnace you have to go up to another minicomputer, you type in a code, and it echos back to you. It is an "arm and fire" situation. You read that code, you press an ENTER, and that puts in the proper thermal profile. In looking back through the data, we think that a slightly different composition sample was provided late by the experimenter and we are trying to tighten up that safety loop to make sure we fly what we think we are flying and that we have the proper procedures to respond to it on board. There are other details to this that I can discuss off-line but that was probably one of the things that caught our attention is that we had something there we didn't know we had.

We can do a lot of things on board now that require small, painstaking actions. Here Ernst is taking small plant roots and cutting them with a razor blade. We are doing more laboratory operations, we are still remaining safe. Everything has a tether on it -- every scissor, every forcep, every razor blade has a tether and velcro because we can't afford to let it loose. We can't afford to let it be a hazard to the rest of the crew. We know it is there but someone else may not.

And the fluid physics module, the question came up about cleaning up fluids. We worry about fluids getting loose that may not be toxic to you and me in a 1-g environment, but in the eye or other membranes can be toxic, and this case is silicon oil. It has a tendency to wet everything once it gets loose. Towels help to some extent but the real action one must take is to prevent it, to contain it, to ensure that the surfaces being used are not wetted by it unless that is part of the experiment and it is contained. On the first flight of this rack some silicon oil inadvertently was let loose. The crew thought they had cleaned it up, the rack was sent back to Germany to DFVLR. It had crawled back behind the rack along every piece of cable back there to the underneath portion of the Spacelab floor and it took them nine months to clean up that hardware.

I mentioned in-flight maintenance. The Space Shuttle has its own IFM tool set, the Spacelab has its own IFM tool set,and sometimes experiments provide their own. We do encourage it. We have a group in the astronaut office called the Science Support Group and we start working with experimenters early trying to pass our lessons learned in experiment operations and how to design them and how to provide access. One of the things we do encourage is it may break. We would all like to think our stuff doesn't break. It may break, it may provide a hazard. So show us how to get in to it, provide us the opportunity for access, and make sure we have the tools on board to do it.

I have just a few concluding remarks. Safety, I think, is the bottom line of any laboratory operations. Not just the Station or the Shuttle but any lab and I've worked in a number of them. I remember some very drastic procedures that were imposed at the University of Washington while I was a graduate student after two very fatal accidents. One where a student walked between two large capacitors and died. Another in which a student froze a fixative in the chemistry department. The refrigerator exploded and he died. So it is not just a Station, it is not just a Shuttle matter, laboratory safety is important to all of us.

Because of that, I was sort of interested in what was happening in laboratory safety and I recently found that the NRC was too. They just put out a new book called Prudent Practices for Handling Hazardous Chemicals in Laboratories. The first thing it says you have to do is develop a philosophy. I would like to encourage us today to talk about what that philosophy is, not just for the U.S. Lab, not just for U.S. hardware, but remember that we are connected to two other national laboratories and that we have to have an international safety policy and words to the effect that we are going to do closed-hatch operations are not acceptable. We cannot leave people alone in an environment in which they may not be safe. We have a common environment. We do not have enclosed life support systems. The air that I breathe is the same air that someone on the other side of the Station may breathe. And so, we would like to pass that on. To recommend a uniform safety policy for the international lab. We don't think the full burden should be on the experimenter, but also on the systems. I think that's happening. In other words, the Spacelab comes with scrubbers and so forth. Not every experiment is expected to do its own scrubbing and provide all the levels of containment. If we did that we'd have no science on board. Nobody could afford it. But we need to have clearly articulated requirements for what the experimenter is supposed to do in proving three levels of containment for instance. We need a reliable contaminant detection, as was mentioned before. I know there are a lot of efforts on mass spectrometers. We don't need them for Station, we need them now. We need to have the various groups working together on it. We need them now because we have a CDSF, Commercially Developed Space Processing Facility, or the Industrial Space Facility that's going to come on board that we are going to revisit. We have to know what the environment is like before we enter. Just for a comparison, when we enter the lab and we know we have scrubbed it before we go up, we look at some parameters on the onboard displays before we ever open the hatch. We look first of all at pressure. We look at pressure over time, the PDT, to make sure we don't have a leak. We look at PPO_2 - partial pressure of oxygen - and CO_2. Then we try to get a look with the cameras. There are cameras hooked up inside to ensure that we don't have anything else rattling around there such as glass shards or other debris that could be a hazard to the crew. So, we do need reliable contaminant detection and we need to have it real time and as soon as possible and we'd like to test it on the Shuttle before we put it on the Station.

Some of the lessons learned in developing experiments. This is maybe not a safety point but something that I would like to pass on. You can't automate what you don't know. If you could automate early on in the process or the experimental development you would not need graduate students. In all the years I spent in the lab before I came to

NASA, I found that when you are trying to develop an experiment or a piece of hardware, you need to tweak it, you need to change process variables, and so forth. We are trying to encourage people to use the human element when it is practical, automate where it is necessary, and come to the best medium of both worlds. Now, some of those experiments will eventually be totally automated, they may even be outside of Space Station. They may be material processing facilities that float out there and we just recover samples ever so often. In the area of life sciences, they may never leave the Station. They may just mature but still remain inside the environment.

Spacelab, Space Station, is a laboratory. It's also unique. It is, in itself, in a hazardous environment and we cannot escape. I am very gratified that this conference is occurring because it will allow us to discuss what we can do to enhance our scientific return at the same time as being safe. The experiences of Skylab, Shuttle, and Spacelab will hopefully lay a foundation for what we have done and how we can build upon it. I think that we need to work very vigorously in this area. My personal opinion was after having flown this flight that Germany had a more aggressive plan in how they were going to utilize their flights to develop Station hardware and I certainly would encourage you, if you are developing hardware, to think about prototypes being flown on Spacelab flights. Maybe not the final version. For instance, on D-2 we will see two new facilities. One is called Rotex. It is an automated furnace facility but it is being flown first inside the lab to ensure that it works because it uses an uplink command capability from Germany. Germany will command across the ocean to JSC and uplink through to JSC and shuttle these commands to operate this furnace. Perhaps something that will go on a free flyer eventually. Also, there is a new furnace on board in the materials science double rack. It is called Isothermal Heating Furnace-T. The T is turbine blade. They have a lot of interest from their power plant companies in Germany on single-crystal turbine blades. I do not know the details of this. It may or may not heat up, but I think it will be a high-temperature furnace and a developmental furnace. And if you read all of their charts they state as a Spacelab goal development for Space Station.

In any case, welcome, and thank you for affording me the opportunity to pass these comments on.