<u>"Space Shuttle/Spacelab-1 Research on Space Motion Sickness"</u>

C.M. Oman talk to AIAA New England Section, Avco Everett Researrch Laboratory, March 1884

I had almost forgotten till tonight that I had my first engineering job here at AVCO during the summer of '62. Haven't set foot in the building since. Good to be back.

As Jim Draper knows, both Larry Young and I came out of the Instrumentation programs in what was Doc Draper's Aero Department at MIT. So it was only natural that we looked at the inner ear as just a biological inerial guidance system.

Well, fulfilling predictions which some of us had made earlier, it has turned out that almost half of the crewmembers on the Shuttle have suffered symptoms of nausea, vomiting, fatigue and other symptoms strongly remeniscent of the various forms of motion sickness which almost all of us have experienced here on earth at one time or another.

Larry spoke to you last year about his involvement in a bi-national experiment on Spacelab-1 to study inner ear function and motion sickness, involving Larry and myself from MIT, Professor Doug Watt from McGill, and Dr. Ken Money, who works at a Canadian government lab in Toronto. Doug is a physician and physiologist, who is particularly interested in how the ear bone is connected to the leg bones - how we stand up and how we fall. Ken is a physiologist and reserve pilot who, incidentally, is among the six people just chosen to go into training to be the first Canadian payload specialists - Canukonauts, I think they're called - on a mission tentatively planned for the 1986 timeframe. Each one of us is responsible for one or more of the seven component experiments in our package.

Since Larry spoke with you, three significant things have happened in the space sickness area:

First, since nobody at NASA is happy with the idea of sick astronauts, the Office of Acronyms and Euphamisms has come up with an instant cure: space sickness has been renamed "space adaptation syndrome". This clearly shows that not all of NASA's problems require scientific and technological solutions.

Second, NASA Life Science managers, at least, havent been fooled by this flummery, and have carved out an additional 4-6 million dollars from their budget to develop additional experiments in this area, many of which will may fly on non-Spacelab missions.

Third, we finally flew Spacelab-1. And although all the results aren't in - some of the data hasn't even reached MIT - and obviously none of the papers are written, it is safe to say that we learned a great deal about the space sickness problem, far more than on earlier missions.

Since many of you may have missed Larry's talk, I won't bore you with any of the details. Let me just say that:

Some people, both in the Soviet Union and also within NASA, had hypothesized that the shift in fluid between the lower extremities and the upper body which occurs in weightlessness, and which produces puffy faces, stuffy noses, and spindly legs might also be responsible for the nausea, via some direct effect on the brain or the inner ear.

Spacelab-1 produced absolutely no evidence supporting this hypothesis. Instead, the crew - and we - are convinced that space sickness is caused by the same sort of mechanisms which produce motion sickness on earth, and which involve the vestibular portions of the body's neural movement control circuitry. Symptom onset was clearly related to crew head movements, and certain head movements were demonstrated to be more provocative than others. Those of you who do remember Larry's talk will be interested to know that we did see some indication of an increased dependence on visual cues for spatial orientation, particularly early in the mission. However, by day 4 or 5, the brain clearly has learned the new rules which govern the behavior of the inner ear organs in weightlessness, and the space sickness subsides.

We met the crew at Edwards just after the landing, and they stayed with us for five days of intense postflight testing. We - and they - were fascinated by the period of readaptation which goes on for 2-3 days in the body's movement control and spatial orientation mechanisms. Eg: after landing, when you turn your head, the orbiter seems to move; if you do a deep knee bend, even after a day or two back on the ground, the floor seems to move up and down !

As a result of all this, I think we- and NASA - will have a much better idea of which lines of research to stress as we move along attacking various aspects of this problem. This is a continuing effort for all of us: I flew some symptom monitoring hardware this past summer on STS-7 and 8, and plan to do so again later this year. The entire bi-national experiment is planned for flight on two more Spacelab missions; D-1 a German mission late this year or early next year, and the Spacelab 4 mission in 1985. This keeps us all really hopping; Like some of you, I'm kind of getting used to living on airplanes. I spent most of the fall in Houston and California. It has been fun to get to know my family again.

Since I've been back, my colleagues have generally asked me three kinds of questions:

How did it go ? What did you learn ? And most importantly, was it all worth it? Which roughly translates into: " do you think that I ought to get involved"?

I think people are interested particularly because as of today we are at a new watershed point, the official beginning of what we hope will be the era of space station. Let me briefly give you some of my answers to these, particularly with respect to the issues, agonies, and ecstacies involving the Spacelab program as a whole. Spacelab-1 was the development phase for the Spacelab program, and after this, the whole operation will be alot more mature and run more smoothly. But perhaps some of the lessons we learned will surely apply to the Space Station development effort.

We started putting Spacelab-1 together back in 1976, and although we had a technical and scientific legacy from Skylab, both the scientists and the people at NASA were pretty naive about how to approach it at first.

Remember that Spacelab as a concept was spawned from the early efforts around 1970 to define "RAMs" - Research and Applications Modules - pressurized cans and pallets to carry experiments. When the station was shelved, ESA - then ESRO - decided to build a RAM to fly on the shuttle in sortie mode. The technical job fit - they thought - the amount of money they had to spend, and NASA was happy because there were no secret technologies involved.

Spacelab 1 was to be essentially a flight test and technology and science demonstration mission. 80 Experiments got selected in 1976, and in a disciplinary sense, it was a bit of a menagerie. The can and the pallet were built by ERNO in Germany. The computer was designed by CII in Paris, but I think in the end most of us felt that maybe the French should have provided the food, instead. ESA provided the entire Spacelab in return for half of the Spacelab-1 mission and the promise that NASA would buy at least one more set of hardware. Some people have said that ESA got a raw deal on this; maybe so, but they obviously didn't have very good bargainers. You can be sure they will be a little more shrewd in negotiating their participation in Space Station !

Since Spacelab wasn't yet an ongoing program, many of the experiments were only at the conceptual stage, and as the hardware got firmed up in '78 and '79 we discovered that the whole thing was overweight, and used too much power and crewtime. When the word got around Headquarters that there was so much stuff on spacelab, they couldn't close the door, the obvious solution was to pitch some of it overboard. Once again the NASA OAE came to our rescue by inventing the term "descoped" to describe what happened to many of the experiments. The three teams of vestibular investigators on the mission took a particularly big hit: in order to save weight, ESA decided not to fly the Space Sled, a seat which was to be used to run test subjects back and forth in the middle of the Spacelab module in order to test their vestibular reflexes. This was really significant for us; we were allowed to restructure our experiments, but what we came up with was nowhere near as good as what we had planned originally. At the time, ESA and NASA promised we'd all get a reflight with the sled, and to their credit, they have by and large made good on this one, for us at least. The Sled is scheduled to fly for the first time on the D-1 mission.

All the scientists were shocked by how rigid the system could be once the engineering design for experiments was frozen. In retrospect, this was a natural reflection of the scientist's urge to be sure his experiment will run right by repeated reoptimization of the hardware design, and the engineer's natural instincts to want to freeze a design and build something.

Other experiments encountered problems too. People with experiments mounted on the pallet viewing the earth, the atmosphere, and the stars found that the shuttle environment wasn't all that "clean": the shuttle offgasses and exhausts water vapor. It even glows in the dark ! And I remember vividly one day at an Investigators Working Group meeting back in '77 when it somehow fell to me to explain to the group of crystal growing Materials Scientists that when you have a 200 pound man moving around inside a 200,000 pound spacecraft, the advertised "micro-g" environment just wouldn't exist. "Milli-g" or "tens of milli-gs" was inevitable.

The three year delay in the launch of the very first space shuttle also had a profound impact on the whole Spacelab program. NASA had a hard time learning that when delays are encountered, you just can't financially turn the key off on university research groups the way they are used to doing with contractors from industry. Most experimenters wound up significantly underfunded during this period, and as a result, academic institutions like MIT were forced to de-facto "buy in" by providing additional support. And alot of labs who were interested and involved in space research but did not happen to have an experiment on the mission got cut off completely. As a result, NASA alienated a significant fraction of their overall scientific user community. This came back to haunt them last year when they went back to the same group of people and said "ok, guys, at last we are ready to work with you. What would you like to do on a space station ?" It would not be an overstatement to say that the official response from the science community was guarded !

One very positive aspect of the program, though, during this period was the business of crew selection and training. An unstated but very major objective of the mission was to gain experience with the "Payload Specialist" and "Payload Crew/Flight Crew" concepts. Payload Specialists were people who were not professional astronauts and were to be selected by the Investigators themselves - this is very important - to fly on the mission. Two PSes were to be selected, one from the USA and one from Europe. They were teamed with two NASA Mission Specialists, professional astronauts who with the PSes were to operate Spacelab and its experiments. We wound up with an outstanding group of people to train. This was lucky, because our vestibular experiments by nature required extensive crew involvement as both subject and operator.

Larry and I were particularly pleased that a then-graduate-student and member of our laboratory, Byron Lichtenberg, was chosen as a crewmember. Byron did his PhD thesis with us, and also happened to be a seasoned USAF pilot, with 2 DFCs flying F-4s in Vietnam and Thailand. Byron's enthusiasm for the life sciences was infectious, and many of the crew became quite intellectually involved in our area. What with the three year launch slip, we had plenty of time to train the crew. I believe we used it very productively. And at times it was clear that when the crew showed up for training, it was not we that were training them, but the reverse. They all had come to know a great deal about the whole payload and taught us alot. All of us feel that the friendships which evolved among the crew and the investigators was a very positive aspect, both in a personal sense, and because it made communication between the ground and the Spacelab go much more fluidly during the actual mission:

An important part of the Spacelab concept is that experiments can be done interactively: linked up by real time TV and voice loops, the PI on the ground and and PS in the spacecraft can do an experiment together, if they need to. We all tried to design our experiments to operate as autonomously as we could, particularly in the areas of fluid physics and the life sciences, we knew there would be the need to talk back and forth frequently. Nothing like this had ever been done before, even on Skylab. And, honestly, nobody was sure how well it would work. One of the positive aspects of waiting around for the launch and doing alot of extra training and simulation, though, was that we all had plenty of time to practice. In the end, everyone in the JSC management admitted they were astonished how well it worked out.

By early last year, we were all ready to go, but waiting on the qualification of the 109% thrust engines we needed, and the availability of the two TDRSS data relay satellites in geostationary orbit. We designed all our experiments on Spacelab assuming two TDRSS would be available to handle all our communications including TV with the spacecraft, and to relay all our data to the ground. The main engine problems finally got fixed in the spring after a delay of several months, and then we all held our breath while NASA tried to get the first TDRSS up on station and operating. But as you all know, there were design problems with the IUS booster which made it lucky indeed that we'd even got one TDRSS up there, and NASA decided not to launch the second satellite until the IUS was revamped. Waiting a year or so for the second TDRSS just didn't make sense to anyone, so by summer it was clear: we would have to redesign the mission timeline assuming we had only one TDRSS. Fortunately, we were able to accomplish this late change without too much impact, since there was a high data rate recorder on board, and a human crew to change tapes out.

What hurt most, in the end, was the flurry of concern that arose after STS-8 that there was a problem with the ablative nozzle liners of the solid rocket boosters. This was a potentially serious problem, and we all accepted the month delay it cost us in October while the shuttle was rolled back in to the VAB and new SRB components were put in. But as a result the launch had to be delayed until November 28. And while this didn't hurt the life sciences much, it caused a big hit to the science in the other disciplines. Every backyard astronomer knows how important real darkness is to good viewing. Our astronomy, atmospheric and magnetospheric physics experiments really need darkness to operate properly. Unfortunately, launching on the new moon in the winter months into a 57 degree inclination orbit, and being forced as we were to launch around noon so as to assure daylight in th abort landing areas, you inevitably wind up in an orbit that places you continuously above the shadow of the earth for much of the mission. You are flying in continuous twilight. Sort of like trying to do astronomy while living above the artic circle in the summer time. This one really hurt. Overall, I'd guess that we lost maybe 20% of the potential mission science right there. But we all felt we should press on. Many experimenters like ourselves could not tolerate further delay in Spacelab-1: our equipment had to be committed to later missions already in the hardware integration stage. And ESA was completely out of money.

So when Spacelab-1 finally did lift off the pad on November 28th, you can understand that the mood of many of the investigators was not all that optimistic: we were tired of having to compromise and recompromise our experimental objectives, and we were all wondering what else could go wrong. Noone was as surprised as we were to see how well things actually went !

The launch was flawless, the orbit was perfect.
The crew, although sicker than we knew on the ground, pressed on with grit and determination that literally made you choke with pride in your friends up there. There were hardware failures, but in almost every case the crew and the ground came up with a work-around, or the crew fixed the problem outright: the high data rate recorder, so critical with only 1 TDRSS failed, but Bob Parker took it apart and fixed it. Ditto the big metric camera when the film jammed. he made a darkroom out of his bunk. When the 35 mm flash camera failed in our experiment, Byron pulled an special adapter out of him personal luggage, substituted the spacelab video camera and pressed on. He'd been thinking about the "what if's" on our experiment during the long months of the launch delay, and had quietly come prepared. There are lots of other examples.

The one TDRSS we did have gave us live TV and voice for a significant fraction of the mission, and this made a significant difference in a number of cases.

You can sit at your console and watch the crew do your experiment, and if you see something going wrong, you all know each other and the experiment so well that coaching them is a snap. If things go seriously wrong, you also really know in detail what happened, so that diagnosis and replanning is much easier. The voice and TV makes the people on the ground participants in the experiments in a very real sense.

Overall, for us, the first 8 days went far better than the simulations we had practiced, i.e. pretty much entirely according to plan. The cadre of controllers and planners in the Marshall Payload Operations Control center did and outstanding job the entire mission. When it was obvious that the mission was a success, and the orbiter had enough consumables, it was decided to stay up an extra day and just see what the crew and the Investigators could do with it. We'd gotten through all the pre-planned science that we could. So we started getting interesting calls like: " hey, looks like we've got a couple of hours of crewtime opening up this afternoon; why don't the vestibular and fluid physics guys get on the line and we'll cook up some follow up experiments". And we did, and it was very interesting. Looking ahead, this mode is probably the way a space station crew could operate part of the time.

NASA and particularly ESA had gone to great lengths to provide 24 hr a day 7 day a week video coverage of the mission, but I really don't think the press understood what was new and different about Spacelab. Also, scientists traditionally publish first in peer reviewed scientific journals. But since this was the first Spacelab, the press hadn't learned that most scientists are really reluctant to see the first release of their experimental findings be on the front page of the Huntsville Times. The press had alot of people waiting outside the doors of the Payload Operations Control Center, and grew suspicious when there weren't any scientists coming out the door to hype the significance of their new findings. The press assumed that things were not going well at first. I'm not sure the press ever really got the word out about how successful the spacelab mission -as flown - really was.

What did we really learn from all this ? Well, the scientific results will be out in the July 1st edition of SCIENCE. Beyond that, it is clear that Spacelab works, and is a reasonable place to do science. The human element can be enormously significant. When you are running a science factory, the ability to recognize and respond to the unanticipated result is of enormous importance, and the human presence on board contributes materially to that. The time required to put a Spacelab mission together and fly it must be cut significantly, but we have to recognize that the personal and professional relationships which develop between the payload crew and the investigators take time to develop, and are very important for mission success. NASA must recognize the importance of providing stable financial support for those scientists willing to take the professional risks of getting involved in space research.