U.S. NAVY MEDICAL DEPARTMENT ORAL HISTORY PROGRAM

ORAL HISTORY WITH CAPT (ret.) JOSEPH P. KERWIN, MC, USN

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Interview with CAPT Joseph P. Kerwin, MC, USN, NASA astronaut and first American physician in space.

Before it plunged to earth in a shower of flaming pieces in the summer of 1979, the Skylab spacecraft served as home, workshop, and orbiting laboratory for three U.S. crews. The 118-foot-long, 100-ton vehicle contained 13,000 cubic feet of living and working space, about the same interior living space as a three-bedroom house. There were private sleeping compartments for the crew, a dining table, shower, toilet, and an 18-inch porthole for viewing the Earth and stars. One ton of food and 720 gallons of drinking water provided nourishment for three missions.

When it was launched in May 1973, Skylab was slated to perform many missions. Its sophisticated telescopes, cameras, and sensors would study the sun, stars, and the Earth below. From the Earth data alone, scientists hoped to find ways to monitor and later develop the planet's vast resources. Most importantly, Skylab would test man's ability to live and work for extended periods in a zero-gravity environment. With this last goal in mind, NASA chose a Navy physician, CDR Joseph P. Kerwin to be a member of the first crew. As scientist-astronaut, he would monitor the crew's health and conduct a series of medical experiments to determine:

--the effects of weightlessness on man's ability to perform mechanical tasks.

--assess the effects of long exposure to zero gravity on the cardiovascular system.

--determine whether normal sleep rhythms such as sleep and wakefulness are influenced by zero gravity and a rapid day-night cycle, and

--study nutritional requirements.

The mission plan was to launch the Skylab into a 270-mile-high orbit and get it functioning smoothly. A day later, the astronaut crew of Charles "Pete" Conrad, Joseph Kerwin, and Paul Weitz would be launched, and after rendezvous and docking would enter the space station to begin their 28-day mission.

Disaster threatened from the beginning. During launch and orbital insertion, the Skylab suffered serious damage. A shield designed to protect the crew from meteoroids and the sun's heat tore loose. Equally threatening was the loss of one of two solar panel arrays. The remaining panel had refused to deploy fully, providing the space station with but a fraction of its energy requirements.

NASA delayed the astronaut launch for 10 days as scientists and engineers at NASA facilities in Houston, Huntsville, AL, and the Kennedy Space Center in Florida worked feverishly and around the clock to save the stricken Skylab.

When Conrad, Kerwin, and Weitz finally blasted off on 25 May 1973, they carried with them the simplest yet the best tools American imagination and ingenuity could devise. After deploying an umbrella-like sunshade and freeing the stuck solar array with a hair-raising extravehicular space walk, the elated astronauts had the Skylab mission back on track.

Before being selected as a scientist-astronaut in 1965 Dr. Kerwin, an Oak Park, IL, native, was flight surgeon with a Marine air group and a naval aviator. He earned a reputation among his NASA colleagues as the most widely read of the astronauts. During his 28-day in Skylab, he relaxed in his off hours by listening to classical music and reading books on his favorite subject--science fiction.

Jan K. Herman: Were you, in fact, the first physician in space?

No. I was the first American physician in space. The Russians launched a physician way back in the mid 1960's. His name was Boris Yegaroff. he was up for a whole 24 hours but something went wrong with the spacecraft. It sounded like a flight that was supposed to last considerably longer than 1 day but they brought it back early. Boris never flew again. One of my colleagues met him several years later over in Russia and described him as a Soviet version of a hippie. He was the sport-shirted, free spirit--probably a little bit on the outs with the establishment already. I think they have flown a physician subsequently, although not in a medical capacity.

You must have some strong feelings about being the first.

It's a lot of fun to do something first. But I must say that space flight is so impressive an experience, that it's worth doing whether you are the first or not. Being on the first Skylab flight was a good feeling, even though the flights were equally challenging; in fact, all the skylab flights were almost carbon copies of each other. It was fun to be on that first flight. When the Skylab was damaged on the way to orbit, we had to throw the whole flight plan into the wastebasket and in 10 days design a new one and go out and "save the program." That might sound unpleasant, but in fact, it was just the opposite. We were faced with a challenge. We had a bunch of rather crude tools to go up there and do a job with. If we succeeded, it was a big deal and if we didn't, at least we tried hard anyway.

When they initially found that things were not going well with the spacecraft, you didn't have much time to prepare.

Very little. In my 15 years at NASA, there are two episodes that stand out as evidence of a bureaucratic organization functioning superbly. One was Apollo 13 which was the mission on which the oxygen tank blew up and the command module lost all power. The crew had to crawl into the lunar module and somehow get back home. The other was this Skylab rescue mission. I'm not talking about the inflight portion of it. I'm talking about the 10-day period that began with the first sign on telemetry during launch that something was wrong with Skylab.

What actually had gone wrong with the vehicle?

Around the workshop was wrapped a sheet of aluminum that covered the whole circumference with spring-loaded levers underneath. The idea was that once you achieved orbit, you would release these springs and they would pop the whole thing out. It would act as a thermos bottle, reflecting the Sun's heat. When the shield got hot, the interior would remain cool.

As the vehicle went supersonic 1 minute after launch, a bit of air got under the leading edge and ripped it clean off in a tenth of a second, taking with it one of the solar panels at the shoulder and dumping it into the Atlantic Ocean. It ripped around until it got to the other panel and, fortunately, instead of taking that panel off, the shield just ripped and left a fragment of itself under this panel which remained in place. Scraps of aluminum from the ripped shield wrapped themselves over the top of the solar panel and riveted themselves into it, preventing it from deploying.

Once in orbit, the temperatures began to climb and when the controllers commanded the panels to deploy, they got no response at all from the right panel which was no longer there. From the left panel they got a signal that it was unlocked. It opened about a foot and they got just a trickle of voltage from the solar panels, just a small portion of which were exposed.

In short, we had a vehicle that was extremely warm with just a trickle of electrical power. We had a third set of panels that did deploy normally.

For 10 days the controllers played a game with Skylab, turning its nose to the Sun in order to cool the surface. But when it was nose to the Sun, the solar panels didn't see the Sun and we lost all power. The goal was to find a compromise attitude that would keep it cool enough yet would still give it enough power to keep it alive so it could be controlled.

Meanwhile on the ground, they began to think of ways to free the solar panel but, even more importantly, something to put over the top of the workshop to reflect the Sun. We came up with a parasol and a sail. We had three different concepts. All three were invented, designed, built, tested, packaged, and shipped to the Cape in 10 days. On launch morning, we walked up the gantry into the command module and there was this big, brown blanket right under the seats with all these lumps and bumps inside of it--all this equipment, half of which we had never even seen in our lives and a little checklist that said what to do with it.

Did you ever get a chance to test any of it?

Some of the equipment we got to evaluate in the development stage. One of the first things we did was to fly back to Houston from the Cape. We split up the crew. One guy took this concept, one guy took that concept, and we worked the crew interface. How are we going to use this thing?

I got back to Marshall Space flight Center, broke my quarantine, and went in the water tank in the space suit and started evaluating means of going EVA (extravehicular activity) and deployed a sail. I worked with that for 2 or 3 days and then one of the backup crew boys took over and we went back to the Cape and regrouped as a crew.

Did you actually get to work with the parasol concept?

I wasn't working with the parasol. I worked with what they called the Marshall Sail. Of the three concepts, we used two. The second day in orbit, we deployed the parasol which was an umbrella-like thing we pushed through an airlock in the wall of the workshop. We didn't have to go EVA to deploy that. It was four fishing poles on a rod collapsed together like an umbrella with the material all folded in around it. You just pushed it out. As soon as the poles were free of the workshop walls, they were spring-loaded to come out flat, like an umbrella. We raised it and lowered it and jiggled it to make the folds and wrinkles come out and rotated it until it covered as much of the workshop as it could be made to cover. That worked satisfactorily and we brought the temperatures down from 130 degrees [F] inside to about 85 degrees [F]. From there, they varied as a function of Sun time.

When the second crew went up they took the Marshall Sail which was a sturdier, larger device that had to be taken out by two suited crewmen and deployed. We could have done that on the first flight. In fact, we kept asking for it because it was so much fun to go EVA. But they decided we had done enough. The second crew would do that.

When you went out on your first EVA, it was to get the aluminum scrap jamming the solar panel.

The first thing we did was deploy the parasol. Then we worked in the Skylab as long as we could. We then had about 12 days to do as much of the flight plan as we could, eating the food cold, turning lights out whenever we exited a compartment--saving power. We could do the medical experiments because they were low power users. We could do some of the solar physics work, as long as we didn't power up too many experiments at a time. We couldn't do the Earth resources photography at all. We tried it once and red lights went on and all the batteries lost their charge. It was a disaster. We did the best we could for about 2 weeks.

Meanwhile, the guys on the ground, using our reports, began evaluating the situation. We had firsthand damage surveys. The first thing we did when we got to Skylab was to fly around it in the command module and take a lot of TV. We also described exactly what the situation was. Knowing what tools we had on board in part of this sea of brown rope that we had in the command module, was a batch of tools that we had randomly selected from a large table about 5 days before launch. They had gotten together every tool they could think of, mostly from the local Bell Telephone company. We had a cable cutter that's remotely actuated by pulling on ropes. We had five or six 5-foot sections of aluminum pole. we had shepherd's crooks and saws--whatever we might need to go out there and do the job.

The backup crew on the ground went into the water tank, mocked up what the problem was, selected tools, and designed an EVA for us. We rehearsed that on the 13th day inside. We cut the ropes, put the poles together, and practiced what we would do. On the 14th day we went out and did it. I figured when we went out that we had a 50-50 chance. The problem was that the damage was down in an area of the workshop where there were no handholds, no footholds, no rails, no way to get there, and no way to stabilize our bodies while we were working. But we got around that by hanging on to each other's legs; we had a lot of fun up there.

Your heartbeat went up to 150 at one point.

It was the frustration of holding those 25-foot poles with the cable cutter on the end, with no stabilization and trying to get those jaws hooked onto the scrap of aluminum. Once we got it hooked, we could use the pole as a handrail and get down there and do our business. We finally figured out how to stabilize ourselves. There was a little eyelet at the base of one of the antennas just about in the right place. We took a rope of the right length, hooked it

to my suit, down through the eyelet, back up, and hooked it again on the suit. Then all I had to do was stand up against it. It was short enough to give me a third foot. Suddenly, I was stable and not floating anymore, as long as I kept my legs taut. Clunk, out she went. We tightened the jaws down, crawled out there, fastened some ropes to the solar panel, then finished cutting through the last scrap. Once that was loose, the thing was ready to come up. But the hydraulic mechanism was frozen. We took the rope we had fastened to it and both of us just got between the rope and the surface of the workshop, and stood up, thus putting tension on the rope. We stood up and pulled and pushed, and bang, it came free.

Did it pop out suddenly?

It suddenly popped and came loose. Both of us went flying in different directions--on our tethers of course. By the time we both got stabilized and turned around, there she was, fully up, and the panels were slowly beginning to come out. It took them about 4 hours to come out all the way. By that afternoon, we were wallowing in electrons.

What did you find when you got on board?

Before we got there, the ground remotely commanded the opening of a dump valve and dumped all the air out of Skylab. They then closed the valve and backfilled it again with oxygen and nitrogen one time. That's all the oxygen we could spare. They still weren't sure that it was safe. We carried up samplers, space versions of the old mining sniff tube--just a glass tube with a chemical indicator. You pull air through it with a pump and watch for a color change. We tested the air in the workshop before opening the door. We did it through a little vent valve on the hatch. The test turned out negative so in we went. The air had a smell to it--a burn smell from the excessive heat which I'll never forget.

How hot was it?

About 130 degrees [F] that first day, about like the engine room on a ship. You'd go down into the workshop, work for 15 or 20 minutes, and then come back to the north end of the vehicle near where the command module was docked. Actually, it was quite cool down there.

What other things did you find wrong when you got aboard? You obviously had the heat problem and there was some fear that the film may have been damaged or ruined.

The heat hadn't damaged the film. Later in the mission the radiation began to fog the film, even though it was stored in a heavy

aluminum and lead film box, one of the heaviest things in the Skylab.

Some of the food had been ruined by the heat. Amazingly, the frozen food hadn't. There was enough power to keep the freezer going. Some of the food such as the catsup, which was stored in those little plastic pouches they have in restaurants, was all smelly and runny. At 130 degrees it just went bad.

Some of the batteries and battery chargers had failed. That was about it.

There was some concern that some of the vitamin content of the food had been destroyed by the heat. We took some food samples back with us but I don't think the assays were good enough to determine the vitamin content. I suspect that we were a little short on vitamins and that was one of the reasons why we had some blood loss and some skin changes--very mild--but things that the other crews didn't have. In fact, they sent them up with big bottles of vitamins and they popped them every day just to make sure.

Back in the 60's, there were some ideas about what effect prolonged weightlessness would have as far as loss in bone density, red cell loss, etc. The cosmonauts were known to have experienced some ill effects. Did your mission or any of those subsequent to it demonstrate any of this?

Oh yes. I think we have a very accurate description of the syndrome now. We aren't sure about the treatment but we can describe very accurately what happens to an adult, male human being who spends one three-hundredths of a lifetime in weightlessness. Some of the changes are profound, considering the maturity of the organism. There is an immediate shift of blood and interstitial fluid from the lower to the upper half of the body, a growth of an inch to an inch and half in size, just due to the unloading of the vertebrae. There is a dumping of fluid. When this fluid shifts, fluid that's normally trapped in the legs by gravity enters the circulation, increases the central venous pressure, dilutes the blood, and is excess baggage in weightlessness. You diurese or perspire it out and within 48 to 72 hours the body has lost 3 or 4 pounds of weight--totally fluid. The venous and pressure dynamics of the body have now returned to something approaching normal. But the blood is now concentrated. The hemoglobin is a few grams higher than normal. The bone marrow, now being hemoconcentrated, quits making red cells. We don't know what the signal pathway is. The body then becomes anemic. Red cells are not being destroyed abnormally but normal destruction is reducing the red cell count until, after 3, 4, or 5 weeks, the concentration in weightlessness is normal again. Red cell production then begins at a lower rate and maintains "normal" concentration.

When you return to earth after 4 weeks, you have lost plasma volume, interstitial volume, and red blood cells. You come back to gravity and immediately all this fluid is again trapped in the legs and the body is now in mild shock. You're low a few pints of blood. This accounts for the orthostatic intolerance, and explains why men returning from space traditionally have been a little unsteady on their feet. They are also unable to exercise very well, have a tendency to have an increased heart rate, and a lower blood pressure in the upright position; they can't tolerate standing very well initially.

But all this is physiological. It's adaptive rather than pathological. Within 48 hours on the ground, the fluid volume is back to normal; thirst takes care of that. The red cell production is much slower to come back to normal and the body is slightly anemic for the first 4 or 5 weeks, but not noticeably.

The interesting thing about all these cardiovascular changes is that they are rapid, relatively profound, and very noticeable. But they are time limited. They go so far and no further. They are not a concern for long duration space flight. The same thing is true with changes in the vestibular system and the balance mechanisms. You get profound subjective changes in the way that apparatus works. It has to adapt to a whole new environment. It causes motion sickness on some of the crew early in the flight. But that's all over and done with in a week or 10 days.

What is the relationship between weightlessness and the loss of body calcium?

The bones do, in fact, begin to go negative in calcium balance after a week or two of weightlessness. The body loses a small fraction--a few hundred milligrams a day of calcium. The crew on the 3-month mission had an average loss of about 6 percent of their total body calcium. It's a straight line function. We don't see any tendency for that to level out but I think that is because we haven't flown long enough yet. The turnover of calcium from the bone pool to the body pool is a very slow thing. I suspect that when we've flown 6 months, we'll see people stabilize at 10 or 15 percent less body calcium.

The Soviets, then, haven't given us any calcium data from their long duration flights?

No. We'll get that information in dribs and drabs over a period of 3, 4, or 5 years--when they figure we're about to find out ourselves. In the meantime, we get generalities from them. The two communities do talk to each other but we never get as much as we'd like to.

Calcium balance is touted by some people as a potentially serious problem for a Mars missions and truly long duration flights of a year or more.

My personal guess is that it's not going to be a problem. It too will find an equilibrium. But we will have to fly for a year before we know that.

Once you return to earth, is there a problem in replacing calcium loss?

Let me make one overall statement about the way we've conducted medical research up till now. We have not attempted significant countermeasures to things like calcium loss because we wanted to find out what the natural body does in adapting to weightlessness. The only compromise we made was in the field of exercise. Muscles you don't use atrophy rather rapidly. I'm talking about the leg muscles and the back muscles--the big weight-bearing, gravity-fighting muscles of the body. Our 28-day crew exercised daily on a bicycle, strapped to the pedals so we wouldn't float away. But we didn't exercise hard--15 or 20 minutes a day. We found that we could ride the bike but that was about all we could do. We'd lost waking, climbing, running muscles. Our calves and thighs were very much smaller in circumference, from 4 to 5 centimeters. We were pretty weak and unsteady when we got back for a few days. At that point, we decided to increase the dietary allowance of the crew in flight because we'd been on a constant calory diet for purposes of our intake and output study. We had been kept to this rather low-calory diet. After the first flight, we decided to give the crews more to eat and make them exercise harder to keep those muscles in shape. We devised other means of exercising besides the bicycle which stressed the right muscles in the right way.

The third crew, which stayed up three times a long as we did, had less weight loss and more muscle strength than the first 28-day crew. Exercise worked.

How did the regimen change?

They used the bicycle twice as much as we did. But they also added two things. One was an "Exergym," one of those small, personal exercise devices that consists of a cylinder and some ropes and hooks, You essentially pull and push against resistance--isotonic exercises. We bought a couple of those and shipped them up with the second crew. They used them but they didn't help enough. So one of our resident geniuses invented a poor man's treadmill. What you really need, he thought, was the weightless equivalent of jogging.

You need to get compression forces on the long bones and exercise the extensor muscles of the legs in a way that a bicycle doesn't. He built a strip of slippery teflon about 3 by 2 feet. The men would remove their shoes and use the device with just their socks on. It had bungies and a waist belt. They put on the waist belt, fastened the spring bungies to holes in the floor, which compressed their feet down against the teflon with 150 pounds of force. They would lean at a 30-degree angle, grab a handle so they wouldn't fall down, and then jog. Their feet would slip over the teflon. It was similar to running on a daily basis for 10 to 15 minutes in addition to the bicycle and the isotonics and they came back stronger in some extremities than before they were launched.

Exercise is definitely the answer to muscle atrophy, but as to what's a good countermeasure to calcium deficiency, we don't know yet because we haven't tried. We could alter the amount of calcium in the diet, or alter the calcium to phosphorous ratio. You could add vitamin D, use parathyroid hormones gingerly--we're a little cautious about fooling around with hormone balance--but there are things that can be used as countermeasures as the flights get longer.

The last resort would be artificial gravity. We could build the long duration spacecraft like a dumbbell with the living quarters at both ends and the skinny corridor in between. We could then twirl it like a baton and create centrifugal force or artificial gravity in the living quarters. We don't really want to do it because it's a complex system to engineer and really why bother? Weightlessness is one of the priceless commodities for experiments and you hate to ruin it by rotating the whole spacecraft. You have certain disadvantages. You can't pour milk from a bottle into a glass and drink it; you have to squeeze it from a bag. But this is a minor thing. You can learn to housekeep at zero G with a few day's or a week's experience. Then it's so much fun to float around like Peter Pan in space. And it's very convenient. If this room were at zero G, we could put two more people in it because we could put a desk up there and a desk up there on the ceiling and use the volume. That's the way we designed Skylab. We had work stations all over the place. You'd be working here and your buddy, who was upside down, would be working up there.

What were the Series 70 experiments?

This included the intake and output study--the calcium, nitrogen, electrolyte, and caloric balance. We measured everything that went in and came out. The losses of electrolytes are not disturbing and are simply proportional to weight loss. There are still some unexplained hormonal changes that indicate kidney

function is in some way altered. We don't know whether it's altered because of pressure relationships in the arterial and venous blood or for some other reason. We don't know if there is such a thing as "stress" that is in fact releasing adrenal hormones which cause aldosterone, renin, and all those things to change. Again, I'm not concerned because there were no clinical effects.

We had several cardiovascular experiments. One used lower body negative pressure. This was a simple way of simulating gravity as far as the heart and blood vessels are concerned. You take a garbage can with a hole at the top, slide into it feet first until you're in it up to the waist. You then wrap a rubber seal around your waist and attach a vacuum line to the garbage can and remove the air. The negative pressure on the lower half of the body pulls and pools blood in the body's lower half as it does when you're standing upright in normal gravity. The heart now has less blood to work with so it must work harder. What you are stimulating is the physiologic state of the individual after reentry. By varying the amount of negative pressure by the amount of air you pump out of the garbage can, you can simulate the effect of gravity. You measure the amount of pooling you get by very accurately measuring the increase in the circumference of the legs and then you look at the physiological response. How high does the heart rate go, what happens to blood pressure, does anybody pass out? That test was one way of simulating the readaptability to gravity. The first few tests concerned us because we were getting a much more dramatic response than we got on the ground. The effect of losing the blood was very obvious. But we found out from this test that this doesn't change over a period of time. As I say, that's a quick adapting mechanism. You lose so much and you don't lose any more. That gave us confidence that on long missions we would be able to bring the crew back without any problem.

We also did metabolic rate testing on the bicycle. We measured not only heart rate and blood pressure but also oxygen consumption and carbon dioxide production.

We also discovered that one's ability to exercise was unimpaired as long as you didn't allow the muscles to atrophy. This gives us confidence that crews can do heavy work at zero G. They can go EVA and construct space platforms or solar-powered stations, etc. Just keep them working, give them enough to eat, and they will be fine.

These were relatively crude experiments and the changes, I think, were profound considering the short period we were up there, and the maturity of the organisms. I think the next step is to begin to look at the details in animals. Take mammals--mice, rats, guinea pigs, animals with short reproductive spans--and observe whole

generations born, raised, reproducing, and dying in weightlessness. I think we'll see changes in mammalian physiology that will make our eyes pop. I think we'll learn a lot about how embryonic maturation is affected by gravity. The bones may never calcify at all. The shapes, the muscle patterns, the nervous system responses, the balance mechanisms, and muscular reflexes may be totally different. We may, of course, be raising animals that are incapable of living in normal gravity. I'm not sure we'd ever want to do that with humans. But as a fundamental experiment in how living matter operates, there are a lot of opportunities. This, no doubt, is one of the directions we will be going in the next 10 or 15 years. Besides that, we will be preparing to do bigger and better things in space with humans such as construction of space stations and eventually interplanetary travel. All this implies that clinical medicine in weightlessness will have to be developed. We will have to learn to build dispensaries and hospitals, how to operate them in a weightless environment. But this may be primarily an engineering problem.

Speaking of the clinical aspects of space flight, what did you run into during your Skylab mission?

We were very fortunate. We had very few injuries and illnesses. It's a very healthy environment. I was prepared to totally manage minor injuries and illnesses and stabilize major problems. I had intravenous fluids, drugs, a minor surgery kit for suturing, hemostasis, and I had a fundamental lab capability. I could even do cardiopulmonary resuscitation if it were necessary. That part of the kit was never used. We had a few headaches, one case of fluid in the middle ear due to pressure change, a foreign body in the eye, and a dislocated finger which popped itself right back in, and that was it.

You were looking at the effects of orbital frequency on sleep patterns. Was this an experiment?

No it wasn't. We had so many variables already that we didn't want to vary the sleep-wake cycle of the crew additionally and throw all our other hormone measurements off. So we decided that we would get up at 6:00 in the morning Houston time and go to bed at 10:00 at night Houston time regardless of whether it was light or dark outside. We ignored the 90-minute day-night cycle that you get in a low earth orbit. We essentially stayed on a 24-hour Houston work-rest cycle and eliminated that as a variable.

How did you find sleeping in space? Could you get along with less sleep?

The average duration of sleep is about a half hour less than on the ground. Subjectively, I would say that sleep is lighter and that you are more easily wakened and disturbed. The electroencephalogram showed that our percentages of time spent in the various stages of sleep including deep sleep was about the same. The pattern varied somewhat, but on average it was about the same as it was on the ground. I think the reason we woke up more often was just the strangeness of the environment and the fact that any little noise is a different noise and tends to wake you up.

On your Skylab mission, did low humidity lead to any dermatological problems?

Yes. We had a very dry spacecraft. It was, of course, much warmer than it was designed to be. The air circulation went from a fan through the cabin where it picked up moisture from perspiration and carbon dioxide, then passed through a cooling system which condensed out that moisture. So the air was constantly being dried as it passed through the environmental control system. We had a very clean spacecraft with no bacterial or mold growth anywhere. As for personal bacterial growth or dermatological problems, we did have a few cases of dry skin and flaking. Some crewmembers developed a few boils, but nothing serious enough to require treatment. And that was it.

We did bacteriological studies pre-flight, inflight, and post-flight. We took swab samples from the throat, various points on the skin, etc. and characterized the bacterial flora of each individual. How many species did he carry up with him, how many did he carry back? We found what had been predicted that some of the species we had on launch weren't there after reentry. Presumably, these species are not hardy enough to remain in being on or in the body without being refreshed from the ambient air or soil, etc. There were fewer bacterial species but certain species overgrew. Staph was the number one example. We also noticed that bacteria found pre-flight on one individual might be found post-flight on all three. In the very long run this could spell trouble. You might find bacteria that were essential parts of your flora--certainly intestinal bacteria--which are required, might die out and the individual might run into a dysentery problem. We might also find that in the absence of normal species on the skin and the throat that abnormal species like staph might overgrow and begin to cause clinically significant problems on very long duration flights. It's been suggested that on such flights you would carry along a supply of bacteria and that every now and then you would pop a capsule containing lactobacillus or smear the skin with something containing

normal soil type aerobes that are part of your normal floral population.

You mentioned earlier that radiation had begun to fog your film after several weeks. How did radiation, in general, affect the crew?

Radiation didn't affect the crew at all. The largest radiation dose which the third crew sustained was between two and three rems, and considering that that's the dose you get from a series of GI x-rays, it's not a great deal. The film is more sensitive in that respect than human beings are. Some of our high speed films began to get a little background fog.

Even through the lead shielding of the film vault?

Yes. Our rule was that even the cameras we used for out the window or interior pictures had to go back in the film vault every night to protect the film. But there were no human effects. On long duration missions cumulative radiation might become a problem and in particular on missions to the Moon we had a problem with acute high doses of radiation due to solar flares. In low earth orbit you are protected by the Earth's magnetic field. The high energy particles are mostly diverted into the Van Allen belts. When you are outside the magnetic field of the Earth, such as the surface of the Moon, you are subject to 100, 150, or 200 rems of radiation within several hours, especially if a really massive solar flare spits a lot of particles toward the Earth. In the Apollo days we had quite a worldwide network of astronomers who were looking at the Sun and looking for changes and trying to give us several hours lead time on the major flares so we could hustle the crew off the Moon's surface and back into the command module which was heavily shielded in time. It was a risk to go to the Moon. In fact, we never had a big flare during a lunar mission.

Are you subject to great risk just passing through the Van Allen belts?

Yes, but you go through them so fast and you're inside a spacecraft so that the dose rates are but a fraction of a rem.

One type of mission we are thinking about flying is a geosynchronous mission. You would need to service those spacecraft or build solar power stations to convert sunlight into electrical power and beam it down to Earth. This, by the way, is a project we're very excited about. The logical place to have spacecraft like that is in geosynchronous orbit because you will have one ground receiving station and you'll want the satellite to be overhead. This means a lot of manned work in construction, maintenance, refurbishment,

and repair in geosynchronous orbit. Unfortunately, this type of orbit happens to be right in the middle of the outer Van Allen belt. It's a high radiation environment, but it is low energy radiation, electrons that are low velocity and not very penetrating. It doesn't take much shielding in the spacecraft to keep the crew safe. Even using the thin-walled Skylab, you would have a safe 90-day stay time in synchronous orbit before you reached your dose limit and had to return to Earth. But if you go EVA in a spacesuit, you could reach the limit in as little as 12 hours. This tells us we can't do EVA in synchronous orbit the way we've been doing it in the past. We will probably have to design a little scooter with remote manipulator arms but which itself would shield the crew and allow the astronauts to do their work remotely. The only other option would be to build a shielded suit and I'm not sure this could be done while preserving the requisite mobility.

I understand that you are very involved on the Space Shuttle project. Exactly what are you working on?

We are working on an interesting problem with the Shuttle. How do you go EVA without getting the bends? We have a different vehicle with a different atmosphere and a potentially serious bends problem.

What's the atmosphere in the Shuttle?

It's sea level air. In Skylab we flew one-third of an atmosphere--70 percent oxygen and 30 percent nitrogen. The pressure was low and you could put your suit on and go out without even worrying about it. In the Shuttle that's not true. It's like popping from sea level up to 30,000 feet just like that when you go outside. We have to develop procedures to wash the nitrogen from the system or possibly reduce the pressure of the whole vehicle for several hours before a planned EVA to allow the crew to get the nitrogen out of their blood and joints.

What else have you been involved with on the Space Shuttle program?

One of the nice things about being on Skylab is that until we get more flights under our belts, we are the latest guys that have flight experience. Inhabitability, sleep station design, EVA procedures, controls and displays, computer techniques, etc. are some of the areas in Shuttle design and operation where we can be of help.

Our particular job right now is not to work on the Shuttle systems themselves. We have another large group getting ready for the first flight. Our job is to work with all the payloads, all the

things the Shuttle will carry up with it once we get the test program over with and to work with all those designers to make the thing operable. Synchronous orbit satellites are some of the items we're working with. We will carry the upper stage rocket with the attached satellite in the payload bay. The Shuttle will go into lower Earth orbit, deploy the satellite and booster, and then back away and let it fire the satellite into a higher synchronous orbit.

We also have attached payloads; some are man-operated, some are not. We'll have flights of 7 to 10 days duration doing medical experiments, scientists doing astronomy and atmospheric physics, etc. The design of the instruments with the capabilities of the Shuttle in mind, putting together flight plans and check lists, the design of software and hardware interfaces with the crew--all need crew input.

So, that's what we're doing. We have a list of 30 or 40 payloads to work with.

Then, there are the medically involved problems--motion sickness, the problem of acceleration on reentry, and the bends problem I've already mentioned. These are the only three medical problems we have right now. The bends is a matter of the Shuttle being a sea level air vehicle and EVA being a suit environment of 4 psi instead of 14.7 psi.

The problem of motion sickness, which is not a serious one for long duration flights, is a serious efficiency problem for short duration flights. If you fly with a crew of six and you have 50 experiments and 7 days to do them in, it means everyone's got to hit the deck running when you get to orbit and work like hell for a week to get that flight accomplished. If half the crew is seasick and begins to feel better at day 5, you've got a serious problem. It's expensive to operate like that. We are working to try to solve motion sickness in three ways. How, for example, do you predict from some kind of test you can do on the ground who's going to get sick? We can't do that yet. We just don't know enough. The correlation in past flights between guys with good tolerance to motion sickness in airplanes, boats, cars, and rotating chairs has not been good. The most lead-headed crewmen have gotten sick in space. We're devising batteries of tests to try and find one that will predict accurately.

The second thing is to habituate. Once you find out who is susceptible, perhaps you design some exercises or evolutions for them to go through on the ground, whether it be aerobatics in an airplane, some form of SCUBA diving, three-dimensional rotators, take them to the amusement park and put them through all the rides, or something that will make them more resistant to motion sickness.

The third thing is to develop better drugs to prevent the

symptoms from incapacitating them in orbit.

Have you come up with such a drug?

Yes, and it's still the best drug there is for motion sickness and it was invented by the Navy. It's a combination of two relatively common drugs--Scopolamine and Dextroamphetamine. When Dr. Graybiel [Ashton Graybiel of the Naval Aerospace Medical Research Laboratory] worked on this problem 10 years ago, his researchers did an exhaustive review of the literature and they noticed that way back around World War I, when there had been a great deal of work done on seasickness, an investigator had reported that Scopolamine appeared to be effective. Somehow it had gotten lost. They began doing tests at Pensacola using Scopolamine and found that it was effective but made people drowsy. What would counteract the drowsiness? Amphetamine was the logical choice. They tried Dexedrine and found, much to their surprise, that it potentiated the motion sickness-preventing effect of Scopolamine. The two drugs together were more than twice as good as either one alone. And it makes sense. You have a sympathomimetic drug and a parasympatholytic drug operating together suppressing what must be parasympathetic mediated vomiting effects from the stimulus. Scopedex is, therefore, our first line drug.

Is it on the market under another name?

No. Both drugs, particularly Dexedrine, are subject to abuse and most drug companies are very hesitant to market it for this indication.

We're looking at better ways of administering it because one of the problems with orally administered drugs for motion sickness is that if you begin to get symptoms, your gastric motility ceases and the absorption of the drug will be very poor. You will eventually vomit most of it back up. Therefore, you must take it as a preventive and Dr. Graybiel is now looking at skin patches impregnated with Scopolamine and a vehicle, probably DMSO, for transdermal absorption of the drug--very steady, very low blood levels but insensitive to the effects of gastric absorption.

You said that susceptibility to motion sickness generally becomes less as flight duration increases. Is there any fear that an astronaut will become motion sick during an EVA?

Yes. In fact, on Apollo 9 we had the first serious case of motion sickness. Rusty [Russell L.] Schweikart was quite severely hampered by motion sickness. There was very serious concern. He was due to go EVA on day 5 and they nearly cancelled it because they thought of the danger of his throwing up in the suit. It could coat

his visor and he might end up aspirating it and really get into trouble. Fortunately he was feeling better by day 5 and they went ahead with the EVA.

So, essentially, there's really little defense against the possibility of motion sickness on an EVA.

That's right. If you have to go EVA on the first or second day of the mission that's something you have to think about. You really like to have at least one crewman who is a known insusceptible.

What other medical problems do you have to look forward to on the Space Shuttle project?

One short-term clinical problem is the problem of blackout. Will the pilot black out upon reentry? You look at the G profile and wonder how anyone could black out. They're only pulling 2 Gs. High performance fighters in dogfights and tight turns can pull 5, 6, and 7 Gs for short periods of time with G suits. But the difference is, we will be going into space for a week to a month and we will lose blood, the cardiovascular reflexes are down, plasma volume is down. We will be intolerant to gravity when we return from space. This reentry G, which is very gentle, is also of long duration. It's not like the average turn in a fighter which is 30 seconds to a minute. Shuttle reentry is about a 25-minute profile and the Gs last a long time. You don't want the pilot blacking out while he's manually flying this 1 billion dollar machine down to the runway. We are going to give the Shuttle crews G suits and we're in a bit of a controversy now as to how they will use them. Do they prophylactically inflate them every time they reenter before the onset of Gs or do they wait until they feel the suits are necessary? I suspect that on the short flights the crews won't need the G suits at all, but on longer flights they will.

The big event last summer was the death of Skylab. What were your feelings when it finally plunged back to Earth?

Relief. It would have been nice to have gotten a piece of it as a souvenir, but what the heck. We didn't design Skylab as a permanent vehicle. It was designed as a test bed for space station concepts. It was designed for a 1-year lifetime. The fact that it was still alive and commandable after 6 years was remarkable and surprising, particularly in view of all the problems we had with it the first week. We weren't sure it would last the month and here it was 6 years later still waking up and answering commands. I don't think it was a useful vehicle to us anymore had we been able to keep it up. It was just a great big piece of junk. There are some people

who won't agree but that's my opinion.

So we felt no emotional sorrow to see it go. We felt a great deal of apprehension that it would hit someone. We did, in fact, have a plan to go with the Shuttle and reboost it to a higher orbit. We were the victims of our own miscalculations.

The space program is still pretty new and our precise mathematical figures on the effects of drag on spacecraft at very high altitudes were off. We estimated a lifetime for Skylab until 1983 and it turned out to be 1979 instead. The orbit simply decayed sooner than we calculated.

The other miscalculation we made was how active the Sun was going to be in the next solar cycle. As it turns out, the Sun goes through these 11-year cycles and when solar activity increases, particles of radiation from the Sun hit the atmosphere and heat it, causing it to expand. This causes the density at very high altitudes to increase. Therefore, the more solar activity you get, the more drag you have on spacecraft in high orbits. We had a solar cycle that started out like gangbusters and was quite a bit higher than the average cycle on which we based our calculations.

We are also a year or more late in getting the Shuttle airborne. We did have a plan back in 1973 to go and reboost Skylab at that time. It was rather hastily thought out, would have been expensive, and would have meant another manned launch with a specially modified command module. The Administrator met with the forecasters and questioned the need for such a mission. They told him that Skylab would be pretty much in the same orbit in 1983, the Shuttle would be ready in 1979, and even if those calculations were wrong and Skylab did reenter early, the chances of it hitting anyone were very, very low. He decided to save 300 million dollars and take his chances. That decision, I'm sure, gave him some sleepless nights last spring, although that last prediction, fortunately, turned out to be true.

They tell me you're a great fan of science fiction and that you took a few books up with your for relaxation.

Yes, we had some books. One of the fun things we brought back was a photo of one of the rooms in the Skylab in which strapped to the wall was a copy of a Ray Bradbury novel. A few months ago we presented Ray with a copy of that picture showing that he had been read in space.

Are you going to get another chance to fly and if so will it be on a Space Shuttle mission?

The answer to the first part of that question is yes, and to the second, most probably. The delays in the program are not that

helpful to us older guys. We should have launched the first Shuttle by now and it's still probably a year away, but we are really looking forward to it.