SAFETY AND THE AMERICAN SPACE PROGRAM

TALK GIVEN AT USAFAC

William E. Thornton, M.D.

Some ten years age, and probably even now, spaceflight was considered to be one of the more hazardous endeavors man could engage in.

A very persuasive insurance salesman sold my entire graduating Air ROTC class an insurance policy with an aviation rider; i.e., no payment for aircraft accidents. Several months later I was not only on flying status but had been equipped with a jump chute. There were unkind thoughts about such salesmen, but later in medical school he managed to sell me a large cheap policy without any riders. On selection to the astronaut program he sent me one of the funniest letters I have ever seen trying to talk me out of that policy. Apparently his superiors thought even less of insurance salesmen who sold insurance to astronauts than I thought of him for selling policies with aviation riders. To this day I remain unmolested by insurance salesmen. NASA takes a little different view in that they sell all government employees the same policy. Some place in between probably lies the truth.

There is no question that spaceflight is potentially hazardous. When it began about ten years ago, 18,000 miles per hour for orbital insertion was almost an astronomical figure. Obviously, to reach these speeds in a reasonable time, fairly large accelerations are required. To return to earth this energy must be dissipated with the heating effect of deceleration, and great stresses on the spacecraft. Look at the propulsion system; rockets for a very good reason were not noted for their reliability. There were structural vibration problems, and anyone who has ever designed an instrument will find incredible the accuracy that is required of the guidance and navigation. For example, if you listen to the transcription of Pete Conrad on lunar descent, "hey there it (the landing site) is! Look at that, right where they said it would be, there's the landing site!" It's easy to understand how Pete ~~feels~~ felt because after traveling a quarter of a million miles to come right down initial on a selected site on another body still leaves one a bit incredulous. Then there is the great complexity; we're all well aware of the long chain of events, any one of which can wreck the mission. Millions of parts are involved here, and I could go on and on about the difficulties of completion of such a mission.

Add the human factor and you've added another order of magnitude of difficulty. This is certainly one of the most hostile environments man has explored, the absolute vacuum--you can alternately freeze or fry, depending on the configuration you place the vehicle or suit in--the radiation problem, not only particle radiation and so-called solar storms and Van Allen belts, but also the visible band and near visible radiation from the sun: ultraviolet, infrared. The problems of weightlessness with the peculiar problems of meteorites have been added.

In addition to the real problems there were many theoretical ones. In the 18th century some very learned men were writing about the dangers of riding in railroad trains and of how your "breath could be taken away" at high speeds of 30 miles per hour. There was a striking parallel to some of the theoretical things that were put forth prior to spaceflights. I listened to one very erudite paper that showed how a person on EVA would wind himself around the umbilicals and end up in a hopeless disoriented tangle. Others were concerned about eating problems, various problems of digestion under zero-g, and the psychologists had a field day with such things as the "break-away" phenomena. Much research time was spent placing people in conditions in which they were almost totally deprived of sensory inputs! I never could quite understand how that parallels space-flights, but there were many and serious concerns voiced.

Now let's look at the population who have flown spacecraft. So far those who have flown have been military test pilots for the most part. As you are well aware these people bring their own viewpoint. They have to have their own viewpoint when they fly such vehicles as test aircraft. It's a little different from the individual that has a 9 to 5 job; his off-duty activities and his general approach to life is a little different even from people that fly airliners. Most of the astronauts have ground vehicles in which they are capable of demolishing themselves, either over-blown motorcycles, muscle cars, sports cars, this sort of thing/as well as other sometimes vigorous avocations. I can say here, with no fear of contradiction, these are the most skilled pilots that you will ever find. The average age of the population is about 39 years with a range from 32 to 48 years. You can say that they are in above average physical condition. Most of this population pays a good deal of attention to this.

Now what are their duties? The first potentially hazardous duty is flying because the T-38 is still used for rapid transportation as well as maintaining pilots' proficiency. The average is around 20 to 30 hours per month in this aircraft-usually less in mission training. You're probably familiar with the characteristics of it. It's an unusually good plane, although a bit short-legged, so you have to watch fuel. It's not the best weatherbird; ours have been modified with heavier windscreens, with added navigational and backup communications equipment as well as attempts to improve icing performance.

The real responsibility of the astronaut starts when he has to prepare himself for the mission. This begins some eighteen months to two years before the mission. He does a great deal of sitting, listening at conferences, and takes an active part in the design and preparation of the craft. One of the major stresses is the constant travel and rush--one side of the country one morning and the other side the next morning, getting there in between and the psychological stresses are fairly large. Demands on personal time are great. The training, needless to say, is rigorous as can be and made as realistic. The lunar simulators for example include an earth-bound rocket vehicle that allows a pretty exact duplication of the descent and ascent. More conventional simulators are used for the abort modes and every other aspect of flight. Tremendous amounts of time are spent on the emergency situations and these contingency situations are planned insofar as possible to the nth degree. Probably far more time is spent planning contingencies than in actual flight.

Now, with the benefit of ten years of hindsight, I would like to look at ~~the population who have flown spacecraft.~~ actual results. Let's come to the side of the picture that many of you have to view; that is, the failure side of what has happened--and there have been failures. There have been three aircraft losses, a bird collision, a control problem and a weather landing problem with theloss of four people. One was lost in an automobile accident. You all are aware of the three that were lost on the pad in the Apollo 4 fire. These are the fatalities. The potentially fatal accidents included one recent bailout with material failure in weather. There was also a bailout at the lunar landing simulator, and two spacecraft problems. You probably remember Armstrong with the reaction control system that went out and was spinning the vehicle up, and the thermostat that failed and caused the explosion in Apollo 13. These two were both material failures.

Now what's the nature of these failures? To me it's very significant that they weren't caused by meteorite damage, or break-away phenomena. They weren't suit failures, they weren't structural failures. They have all been what might be called ordinary earth failures. The sort of things you people deal with every day. Automobile accidents, weather problems, instrument problems and of course the largest, material failure. This says several things to me. It says that an extraordinary job was done in terms of knowledge that has been generated in the past that would allow such a mission to proceed without running into unusual failures. The fact that these are the same old things says a great deal about the state of knowledge, the ground work that people such as yourselves have done, that allowed the planning and execution of these missions.

Let's say a bit more about the failures. As you know, NASA has the most elaborate quality assurance program, the most safety oriented program that the world has ever seen. In spite of this, material failures have still slipped through. Where have these come from? They haven't been at the upper levels, they've been down at what I call the work level. For this reason I still consider the individual that may be wiping the windscreen on my aircraft, the one servicing it, the individual that's putting rivets in the spacecraft, that's inspecting the thermostat, making electrical connections--I still consider his role in safety as equal in importance to the managers. This may come as a shock to some of the managers. True, the ultimate responsibility is on their shoulders, but the same varied accidents that would most likely kill an individual ~~is~~ are the result of some physical act done by some supposedly low-level individual. Safety has to cut across the whole program itself to literally the last man in the link. It's the same old problems that keep coming up again and again. So much for the failures.

Now let's look at the successes in the American space program. Tens of thousands of aircraft hours flown since the last fatality. There have been a total of about 8500 spacecraft hours flown without fatalities, men have walked on an object other than the earth for the first time as a result of an incredibly complex program. There are too many firsts to even begin to list them. There have been 137 hours of EVA activity and no suit failures or any of the other things we worried so much about. I think people such as yourselves can take a great deal of consolation from this. It is an incredible success story because all of your are familiar with the failure rate that is likely to be incurred in the testing of a new aircraft type, but here we have not one, but three entirely different and new spacecraft series and not one lost during the actual flying.

What about the future? You've all heard about Skylab. This is to be our first temporary space laboratory. Medicine is going to play a large role in this one. A lot of the medical experiments will also be astronautical experiments, a whole series of others will be working with new technology, working with high temperatures, and with new techniques inside the craft. The craft itself is a modified Saturn 4B fuel tank, 68 feet long, 28 feet in diameter, and it's had solar panels and telescopes added and an adapter section such that the standard Apollo command service module can dock with it and undock. The first of three missions is to begin approximately six months from today; the first will be a three-man--two pilots and a physician/pilot--28 days, primarily medically oriented. This will be followed by two 56-day missions; again one scientist, two pilots in each of these. This is a limited life vehicle, and at that time we will go out of space until the Shuttle comes along.

Just running briefly through the medical experiments, there are some fairly elaborate vestibular and sense of orientation experiments, and a very elaborate metabolic calcium balance study, elaborate even by ground-based standards. Every gram of food is to be accounted for, all of the waste materials, samples are to be brought back. I might add that some of the major difficulties are encountered in the waste collection system. Some of us consider this waste collection system one of the more hazardous aspects of spaceflights after living with it for 56 days. We have a bicycle ergometer on board to allow exercises and maintenance of condition, we have lower body negative pressure apparatus to put on known stresses and follow the man's deconditioning if such occurs.

As for the safety aspects of it, the atmosphere itself is 5 PSI, 70% oxygen, 30% nitrogen with little higher than average $CO_2$ content of probably 5 mm of mercury. Again we've lived in the atmosphere for 56 days and it presented no problems. We had a mockup of the craft itself; as a matter of fact it was smaller, and that also presented no problem. The water will all be carried up on launch. There is a microbiological control of one part per million iodine, minimum, which will be measured and checked before usage. Assuming the investigators get a couple of dietary questions worked out and provide enough food, there'll be no food problems. Major medical experiments all have elaborate safety measures including shock protection. For example, there is extensive monitoring of subjects that are grounded, so a good deal of design effort has gone into this aspect of it. As for the more conventional safety aspects, there is a scatter shield since this vehicle presents a rather large target for micrometeorites. There are pressure and gas sensors. The planned mode here in the event some opening should occur, is that individuals will have time to go to the command service module and use this as a life boat to get back. The large volume should preclude any castrophic decompression. Radiation is not anticipated to be much of a problem. We're deep enough into the magnetic field so that we don't worry about solar flares, and we are below the Van Allen belts. There is some rather nominal radiation monitor equipment on board, badges, and some ionization warning devices and survey meters. A big hazard, I suppose the one that most people are concerned with, is fire. This danger was unfortunately demonstrated with the same atmosphere in a chamber at the School of Aerospace Medicine shortly after the Apollo fire. This is still a hazardous atmosphere. I am afraid some people are lulled by the idea that there is nitrogen present, but things burn very briskly with 70% oxygen. A water hose system is aboard which an individual can if necessary fight his way through a fire with; there are foam bottles on board; there are U.V. sensors in all the critical areas as well as overall surveillance with sensors. Very elaborate precautions have been taken on this aspect of things. I don't know how many of you are familiar with the precautions that are taken but every bit of flammable material is either covered or protected in the spacecraft. Fundamentals of this program is the quality assurance that I mentioned earlier and NASA has the most elaborate the world has ever seen. Any item that goes aboard of any size, for example, an experiment package, has a documentation package for this. We use the rule of thumb of about one hundred thousand dollars just to make sure that such a thing is primarily safe and will also perform its job.

There is one advantage not previously available in that it will be possible to effect rescue. It will be a bird on the pad; should anything happen, there will be the possibility of going up, docking with the two-man crew and bringing the three-man crew home after a reasonable opportunity to turn around. So these are the major safety aspects of the SKYLAB program.

Then we come to the future. The thing that NASA has its hopes riding on is a combined airplane/spacecraft, if you will, the Shuttle. This is going, in some ways, to move back toward more conventional techniques over part of the mission in that probably a high degree of piloting skill will be required. There isn't going to be much go around capacity in this vehicle for coming back. The speeds and sink rates will be high. ~~This sort of thing is going to be considerable on it.~~ Now this is still in the design definition phase and so I can't say a great deal about safety, but I will say one thing and that is, we're going to have to use the lessions learned on the previous programs and make the safety program more efficient and more cost effective. I mention this fiture of one hundred thousand dollars. This vehicle, the Shuttle vehicle with all the payloads--you're not going to be able to spend that kind of money, so you've got to become more efficient in the safety aspects. Hopefully the day will come when individuals such as yourselves, individual researchers in colleges and such will be able to put together a reasonable package, one that does not require a documentation package this high, then go along with the package, spend days, weeks with it in space, perform the investigation, and be brought back home. We have simply got to cut things a bit more closely without sacrificing any aspect of the safety.

Finally, if you will bear with me for an amateur's plea to the experts--these are a few pet observations from having been around the Air Force, airplanes and having been, shall we say, an interested observer in the space program. When you design safety programs, make allowance for the human being. As a human being, as all of you know, you have good days and you have bad days. Now I am not going to apologize for the human being because on the lunar landing for example, it was the computer that became confused when overloaded and quit. The human being pressed on and landed; but again, I would urge you to make allowance for the human factors. Make allowance for errors. They're going to occur. The important thing is to keep the bigger or the fatal errors out and if some errors occur, leave enough room, leave enough leeway to get out of fatal situations. Then, let's get to Safety itself. It means a great deal to me. It's not the frosting on a cake; I think this is lost sight of too frequently. It's one of the most fundamental human emotions, and that of simple self preservation. Now lest this word emotion bothers someone, it is the driving force behind the whole flying and space operation. People too often approach a safety program as something that is routine, something that can be accomplished by slogan, by elaborate charts, by generation of programs at a high level. It takes more than that to make it work. You've got to get all the way down to the individual crimping a connector on a wire. Let's face it, it takes a few extra minutes to look up a hydraulic leak to see where it's coming from rather than wiping it off. This time could be more enjoyably spent. We can be wise in hindsight, and say for example that on Apollo 4, similar fires have always occurred when high $O_2$ pressure has been used. The Navy is very familiar with this thing. It would be easy to take this view, but remember, it always takes an ignition source. Some place along the way there was a wire too small, a breaker that didn't function, or a connector that wasn't properly put on. So remember the little man and the last detail.

Now for safety programs, I can remember being discouraged and disappointed about a safety program the Air Force once had. This was in the McNamara days when everything was going to be reduced to cost accounting. They had gone to a great deal of trouble, and had a famous test pilot who was a general going around making a canned pitch. The pitch was that being unsafe was not cost effective. Well, I thought it took a good deal of courage to read this to a bunch of people which included pilots. I tell you, though, as brave as this man was, he would not have had courage enough to have taken that approach to anyone on one of those days that a group of people file quietly into a chapel, smell the stink of funeral flowers, watch some poor kid, some poor wife, the chaplain trying to say some words that mean something to her, or to the people that have to go out to see the hole in the formation that goes over--you're not talking about cost effectiveness--you're talking about fundamental emotions--life and home itself.

You're not talking about the spilling of red ink. You're talking about the spilling of blood. When you think about safety--like it or not--no matter how detached a scientist or administrator you are, if you try to put it on any other basis than this, you are making a mistake. Thank goodness, it usually is on basis of a deep dedication--not on just another program basis.

Finally, I'd like to say thank you. You, and people like you in the past, people that have made it possible for an old man like me to realize a lifelong ambition. I didn't begin to fly jets, I didn't begin to fly anything until the age I would have been taken off flying high performance aircraft a few years ago. It has given me a great deal of pleasure since then. Every time I strap on a chute and sit down in an ejection seat and live on the instruments in a bad weather situation, I say thank you very much for all that.

Finally, for the future, I have two kids that I hope will be able to enjoy the same sort of things. I hope they will be able to go a lot further than I will--the moon and beyond. How successfully, how safely they do this lies in your hands. And so my last admonition is simply to keep up the good work.