INTERVIEW OF

DR. RONALD TURNER

ANALYTIC SERVICES, INC.

Conducted by Troy Cline

P R O C E E D I N G S

MR. CLINE: All right. Well, Ron, thank you so much for your time today. It's exciting to be here and to already be talking with you about some of your interests and research. Could you tell us exactly who you are and what you do now and your interest in space weather?

DR. TURNER: Okay. I'm Ron Turner. I'm officially designated a Fellow of Analytic Services, or ANSER, a not-for-profit company in the Washington, D.C. area. So we provide support to the government on a variety of issues, and I've been with this company for about 28 years. And a good chunk of that time has been spent in the area of space weather, actually. I primarily work lately in the area of risk management strategies for astronauts that are exposed to the space radiation environment. So that's the main area that I focus on.

In the last several years, I've started to get interested in the broader topic of severe space weather and the impact that it might have on the nation and the nation's infrastructure. You've probably heard that a severe space weather event could potentially knock the power grid off, and it could be down for anywhere from weeks to months, and that, of course, would sort of ruin your day.

Our company does a lot of work in homeland security, and so I've got some training in things like national response policy and stuff. And so in the last few years, I've applied my understanding of how we -- how the nation responds to significant events to how the nation would respond to a significant space weather event. So it sort of grew out of risk management -- you know, a very narrow topic, which is risk management strategies for astronauts, to a broader topic, which is how the nation responds to severe space weather events.

MR. CLINE: Now, that basically answers the question of what is your primary research interest, or is there more to what you'd like to say about that particular …

DR. TURNER: No, I think that's basically my research interest.

MR. CLINE: And I'm very interested in

hearing more about, when you're talking about risk management for astronauts in space, because many people have asked questions about with our future of going into space, potentially going back to the moon, potentially going to Mars and beyond. Right now, most of our understandings that people have been telling me is that we don't really have the ability to go for six, seven, eight, nine months or a few years in space without lethal doses of radiation. Is that true, and how could we protect ourselves?

DR. TURNER: Okay. Well, yeah, radiation is one of the key issues for a long-duration space flight. It's long been recognized by NASA that countering this radiation threat's going to be critical to doing any long-duration space mission, whether you're going to Mars, which might take up to two to three years, or if you're even going out to some -- any deep space location, on the moon, maybe, even, for six to nine months or a year. So you've got to -- you definitely need to worry about the space radiation impacts on the astronaut.

There's two broad things that space

radiation can do to astronauts, and they're from two distinct sources. You've got the really major events, like a space weather storm, a solar storm that creates a solar particle event, and then you have several days, maybe, of really intense radiation that an astronaut could potentially be exposed to.

Then you also have the steady background drizzle of space radiation called the galactic cosmic radiation. Now, the galactic cosmic radiation is there all the time, but at lower doses. The difference between -- another key difference between the two is the GCR is really highly penetrating, so there's not very much you can do to shield against it, and it builds up over time throughout the mission.

The solar storms, if the space weather community comes through with what it needs to do, which is to provide adequate warning that a solar storm is either imminent or one is ongoing and has the potential to last for a long time, that space weather warning goes to the operators. The operators get the astronauts into shelter, and solar storms can be shielded with relatively modest equipment --

relatively modest habitats. You can shield a space radiation event with relatively modest shielding.

And so it's really difficult for one of these space weather storms to actually be lethal, okay, or even reach the point of causing space weather sickness if you've got a system in place for warning the astronaut that the event is underway. They have one to three hours, even, to get under shelter and still not get a critical acute dose. So as long as the space weather community is involved in the planning of these missions, then that's a manageable issue.

The other extreme, which causes more consternation for the mission planners for these long-duration missions, especially a mission to Mars, is the GCR.

MR. CLINE: And GCR stands for …

DR. TURNER: Galactic cosmic radiation. Galactic cosmic ray, radiation. The GCR is the component that I was talking about that's highly penetrating, but a very low -- very, very low dose rate (ph). It just builds up over time.

So with nominal shielding on a habitat or a spacecraft, you can provide some level of protection to the astronaut inside that vehicle, doubling the shielding, which more than doubles, say, the mass of this vehicle, which is prohibitive from a system architecture point of view, only reduces that dose by about maybe 20 percent. So adding mass, adding shielding is not an effective way to mitigate the GCR threat.

Now, what is the GCR threat? Well, the GCR threat -- one of the known things that the GCR can do to the astronaut, that deep space radiation can do to the astronaut, is increase the probability that sometime in life, they will develop cancer. Okay? So it's not an immediate mission threat, it's a lifetime threat to the astronaut, which, in many ways, is just as important as the mission itself, because you don't want to put the astronaut out there in harm's way with all the mission-level risks, which are already high, get the astronaut safely back to Earth, only to have him or her undergo, you know, severe health problems for the rest of their life. So you still want to minimize the long-term health effects to these astronauts.

Where we might have some room in helping the mission planners is it's not likely that the GCR dose would ever be lethal during the course of a mission. In fact, NASA's current permissible exposure levels limit the astronauts to a risk that's no more than 3 percent excess probability of getting cancer in their lifetime. The catch is that the NASA limit is at the 95 percent confidence interval; that is, there's a 95 percent chance that the exposure that they get will not cause their risk of cancer to be 3 percent for the rest of -- an additional 3 percent for the rest of their life.

And that uncertainty, the 95 percent uncertainty, keeping the limit inside that 95 percent uncertainty, that's what limits the days in deep space to 150 to maybe 220 days. It's -- it depends on the astronaut's age, it depends on the astronaut's gender. So, you know, female astronauts are more susceptible to deep space radiation than male astronauts. So there's a -- and younger astronauts are more susceptible because they have a longer lifetime ahead of them for the cancer to develop. Okay? So if you want to keep the astronaut risk at 3 percent at the 95 percent confidence, then you have to severely limit their time in deep space.

So the question is are those the right guidelines? You know, is that really the right level of protection that we need to impose on the mission planners? Is an additional 3 percent risk of cancer the right number, given all the other risks that the astronauts were already posed -- already faced with? Is the 95 percent confidence interval overly conservative? Can we, you know, reduce that confidence interval?

Those questions, actually, are being addressed by a National Academy committee under the Institute of Medicine, and I am on that committee, so I, you know -- that report is due out in the March timeframe, and we're going to be going back to NASA with some recommendations on the framework that they could use to understand what level of risk is appropriate for health risks that are -- that have a large degree of uncertainty, and the committee's responsibility is to look at more than just the radiation risk, because there's a lot of health risks that we don't understand all the impacts on that the astronauts are going to be exposed to when they go on these deep space missions.

MR. CLINE: You know, what's very interesting, I just conducted an interview with astronaut Dr. Phillips, who had been at the International Space Station for about six months, and he said he received -- of course, when he came back, they do the testing to find out how much radiation you've been exposed to and so forth.

And he said he was at a particular level that wasn't alarming, but it was still something he wanted to pay attention to, but he said what's interesting is over half -- or about half of the dosage of radiation that he received wasn't in space, it was during the testing phases of getting ready --

DR. TURNER: That's right.

MR. CLINE: -- to go.

DR. TURNER: That's right. There's a --

there -- when they -- when NASA looks at the radiation exposure to an astronaut to determine whether they can fly the next mission, for example, they don't just look at the dosimeter that the astronaut wore on the last space flight and the one before that. They do look at the medical exams he's been under, he or she's had. They look at their -- the -- all the radiation history that they have access to, which is quite a bit.

So, yeah, and we're reaching a point where the 3 percent limit, even though you -- even though no astronaut has come close to the 3 percent limit on an International Space Station mission and is -- they're not likely to under any one space mission, they're reaching the point where, as they look at longer stays on the space station, there are some astronauts that come close to those limits, and so they're not -- you know, they're sort of precluded from being selected for those missions.

So that gets the astronauts' attention a lot -- the Astronaut Office attention quite a bit, when they realize that some of their members may be not permitted to do a mission that they would love to train for because they're potentially up against these radiation limits. So it's a very serious issue, even in the era of space station, and it's going to be even more important when we start doing these deep space missions, or if we choose to go back to the moon someday.

MR. CLINE: Now, what is also interesting for listeners to understand and hear about again is the reason that, on Earth, we are relatively safe from most of these radiations that we're talking about right now. It's because of our magnetic field and atmosphere?

DR. TURNER: And atmosphere. The atmosphere's a big chunk of it -- is a big part of it. The magnetic field goes a long way toward mitigating the galactic cosmic rays. The atmosphere finishes it off, finishes off that protection.

So we have, in the -- I'm trying to -- trying to come up with numbers that -- that -- that mean more than a thousand grams per cubic centimeter. Say a water equivalent thickness of protection would be about -- I don't know. I've got to convert a thousand --

MR. CLINE: Uh-huh.

DR. TURNER: -- in realtime, a thousand grams per centimeter squared into a distance, which is, I guess, about ten meters --

MR. CLINE: Uh-huh.

DR. TURNER: -- of thickness. So we've got the equivalent of ten meters -- I'll check this number, but I think we've got the equivalent of ten meter water thickness, you know, protecting us from the galactic cosmic rays. You're not going to put a ten meter wall around the astronauts all the time. Even that seems a little short. It may be even thicker than that, a thousand grams per centimeter squared of water -- of thickness between us and the (inaudible).

MR. CLINE: So essentially making a spacecraft out of water in a way to --

DR. TURNER: Well, out of material, lossy (ph) material that's very, very thick. And, actually, even the thickness of the atmosphere doesn't count, because that's the narrow -- that's straight up. Okay? We actually get protection, you know, both from the ground below us and all the thicker angles that the radiation has to come through from -- you know, oblique angles from outside space.

So we've got a -- the short answer is we've got a tremendous amount of shielding above us right now, and we still get radiation. The background radiation, there is still a significant component of our natural background radiation that comes from cosmic rays. Okay? Our day-to-day life, we still get a significant amount of background -- a significant fraction of our daily background radiation comes from cosmic rays, even with all that shielding. So take away that shielding, and now the astronauts' exposure goes way up.

MR. CLINE: Now, in your experience -- I've heard many people talk about the Apollo missions that have gone to the moon before and that we were very fortunate when those missions launched. There was some information, of course, and knowledge about space weather at that point, not like we have now, but that we actually, at times, went up between storms and the -- had the astronauts been in space during a powerful storm, that could have been a different story.

DR. TURNER: All right. We had -- we had a double challenge in the -- in the Apollo era that we got lucky. One was we didn't go during a major storm, like you just said. In fact, between two Apollo missions, one of the -- there was one of the most severe space weather events that we have on record.

An August 1972 event is one of the ones that we still measure other storms against in terms of severity. So one of the biggest storms we -- radiation storms that we've had occurred between two Apollo missions.

So the other challenge that increased the risk was the actual lander -- the Apollo lunar lander had a very thin shield, a very thin -- very thin walls, the lunar lander, very -- you know, not a whole lot more than what you would get from a spacesuit anyway. And so had that storm happened while the astronauts were on the lunar surface, especially if they had been off some distance from the Lunar Module, so they had to get back to the module and then get back and rendezvous with the Command/Service Module before they could, you know, really get safe.

The Command/Service Module had a fairly robust amount of shielding associated -- well, the one -- the piece that was in orbit around the moon and the piece that they came back in had a lot of shielding from radiation storms, but the lunar lander, you know, had very thin walls and would have been very susceptible to a solar storm.

And so in a way, we got lucky, but, you know, you can still play the odds. A storm is about two -- the severe part of a storm is probably two days, at worst, a week, and so you put that one week against all the one-week landing opportunities in one year, and the odds still go down. So it wasn't that miraculous that we got lucky -- that we, you know, survived, but it still was a -- it still was a threat that -- and one of the chances that we took.

(Off the record.)

MR. CLINE: Can you tell us a little bit more about with what and when you were involved in space weather research?

DR. TURNER: Okay, sure. Well, I got my PhD in physics in 1984, Ohio State University, in nuclear and particle physics, not at all space weather. Okay? Of course, I grew up in Florida in the Space Coast, where my father actually was a technician associated with the Apollo missions.

So every day at dinner, he'd come home, and he'd tell us, you know, these stories about this, that, and the other that just happened, you know, when he was working on the Apollo -- working with the Apollo Command Module that day. Okay. So it was cool. Okay? It was awesomely cool growing up, you know, with the space program evolving and having a personal connection to it.

So I was -- even though my academic interest at the time, even as a kid, started to go into the area of physics and nuclear and particle physics, because that was exotic, cool stuff too, okay, I still carried with me this fascination with the Human Space program.

Okay. So fast-forward to about 1984, when I get my PhD, and I start working for this company, ANSER, Analytic Services, and Analytic Services is supporting the Air Force with a whole variety of space programs, and I get -- I am, fortunately to me, assigned to support the Air Force weather satellite program, which is a low-altitude weather satellite that helps the -- that would help the Defense Department with Air Force operations.

Well, the weather satellite carried space weather instruments on it, and being a physicist and liking the space program, I taught myself about what these space weather instruments were doing and what they were -- you know, what -- you know, why they kept these space weather -- so-called space weather instruments on their satellite that was supposed to be looking at terrestrial weather, you know?

So I got fascinated with that. Well, we also -- our company also helped this thing called the space -- the Department of Defense Space Test Program, and the Space Test Program flew research missions that tried to get a better understanding of space weather.

The panel that would decide what instrument would fly next was usually made up of a bunch of colonels that were operators and weren't physicists, and so they didn't really understand the nuances of the research world when the researchers would come in, and they'd say, "I've got this experiment. It's looking at space weather. It's going to help you communicate better because we solved the communication problem." Okay? They all sounded the same to the colonel board.

So ANSER asked me to put together sort of an introduction briefing before they do their space weather briefs from the experimenters, just to give the panel an overview of what space weather is and what the different experiments were trying to accomplish and how the different experiments were actually different from one another, trying to accomplish different things; where there was overlap, where there wasn't.

And, of course, my job wasn't to try to tell them which ones were good or bad, it was just to tell them, you know, "This is a level playing field. This is what all these instruments do." And that was really cool because it gave me the chance to get to know the space weather researchers, especially on the DoD side. Okay?

So I got to know a lot of the scientists that were doing space weather for the Air Force and the Department of Defense, and I got to know a little bit about what they were trying to do, and I always had to keep an operational view on what they were doing.

So when they told me about all the cool stuff they were doing, I had to think, "Okay. That's all really cool. I'm a physicist. I think that's a lot of fun. But why is the Air Force going to care?" Okay? "What does this mean to them in an operational sense that would cause them to want to continue your funding?" So I had to -- even at the beginning, I had to keep this dual hat on, the research hat and the applications had, so I was the filter between the scientists and the operators giving these briefs.

Well, that was cool, but added to that was I still had this interest in the Human Space Flight program. So the whole time, I would think, "Is there anything I can do with this knowledge to start working for NASA in some way?" And in the early '90s, I did go over to NASA, literally knocking on doors, people I didn't know, just saying, "Hey, I have this fun interest in the radiation risk problem to astronauts. Do you care that I have this interest?"

And amazingly enough, I found somebody who said, "Yeah, we do care," and that was the Human Research Program that was studying the radiation risk to astronauts. Mostly they were looking at the biological side of the problem; you know, what does a certain level of radiation do to a cell that makes it eventually turn cancerous? Okay?

So they didn't have a lot of -- they had physicists on board. They had the physicists who were the accelerator people who knew transport of particles through matter, but they didn't have anybody in their little circle of researchers that was an expert on the space weather side.

So NASA had their space weather people over here, and they had their human effects people over here, and they had their operations people somewhere way over there. Okay? Not really talking to one another.

And I said, "Well, you know, I've already got this experience of trying to be the interface between the science community and the applications and the operations community. Maybe I can apply that same experience to you on the radiation risk problem and start looking at risk management strategies from a larger perspective."

And that's what caught NASA's eye, and lo and behold, they did, in fact, fund me to start working on that area, and that was thrilling for me. And I benefited a whole lot from being able to go to annual space weather conferences from the operational people and also going to science conferences that the National Science Foundation would fund.

So I'd go to talk to the scientists, and they would know nothing about the biological side, so they'd talk to me, and then I'd go to the biologists, and I'd talk to them about the space weather side. So I managed, you know, to be, again, just like I was for the Air Force, sort of an interface between these different communities, and that was really, really cool. So basically, I just kept adding to that, and that's how I -- you know, that's how I got really going in space weather.

Now, recently, I mentioned already that because my area of expertise became radiation risk management for astronauts, my company works in the area of homeland security, and so I did broaden that research area -- or that interest area into how one, you know, applies national risk management strategies against national effects of space weather. So that's another area of interest that I've developed, and that's slightly more recent.

MR. CLINE: When you talk about space weather effects nationally, you're talking about societal effects upon electrical grid systems, power …

DR. TURNER: Yeah. We've been lucky that we haven't had a -- sort of a super storm in space weather in the last 50 years or more. Okay? We've had severe storms, but we haven't had a super storm, super storms like what happened in the mid-18 -- in 1856, this thing called the Carrington Event, which was a really super storm.

Obviously, in the 1850s, we didn't have massive power grid problems, but we did have telegraph lines that went from one city to another city, and this storm, the Carrington Event storm, was so severe, it coupled into these long transmission lines that carried telegraph cables from one to another -- coupled into those lines and actually put enough energy into those lines that it caused the telegraph equipment to overheat and burn entire shacks down. I mean, that's how much energy got dumped into the system, and that's one, you know, very, you know, simple system that had a -- that one of these super storms interacted with.

So now we look at our society the way it is today, and we ask, well, we've got power grids that, you know -- that go across the country. We know that there have been storms that haven't been as severe as the Carrington Event, but they've been severe enough to cause electrical grid disruption, melting power transformers in Quebec and in South Africa, so it can happen. We've got in existence proof that it can happen.

The question is, you know, how likely is it? We don't know, because we don't know how often the events like the Carrington storm are. Are they one in 500 year events? Are they one in a hundred year events? We don't know. And we also don't know exactly how a storm like that would play out locally, you know, from the -- on the Earth on a local time scale. So there's a lot we don't know about the physics, but we're learning a lot. There's a lot of research going on to try to quantify those effects.

My side of the problem doesn't have anything to do with the physics, other than trying to keep up with what the research area is. Rather, because our company does a lot of homeland security work, I look at what the national policy framework is, and how would that national policy framework be invoked if we had one of these large events or thought one of these large events was pending? So that's been a really fun area -- well, interesting area for the last few years.

(Off the record.)

MR. CLINE: Can you tell us some of the key events or a turning point in space weather research in your experience?

DR. TURNER: Actually, that's an easy one for me, because I think that there's one very, very significant event that was a major milestone in making space weather what it is today as a discipline, and that was a number of years ago, when NASA first started making data from one of their satellites available in near realtime to the forecast community, and that was the WIND spacecraft.

The WIND spacecraft was out there trying to monitor, as the name implies, solar wind parameters, parameters of the solar wind, and it had a number of other observations that it made, but, again, mostly to characterize the solar wind.

The solar wind gives us the background that all the other space weather effects ride on top of, so you need to know the solar wind conditions are in order to estimate, you know, what the impacts might be into the Earth.

So when NASA started making this wind data available to the operational forecast community --

NOAA in Boulder has a group that does the -- even then did the routine national weather forecast. Well, it revolutionized their ability to do realtime forecasting, because they had a least a little bit of data that was not just, you know, based on secondary observations, but was one of the primary drivers.

They knew when the solar wind speed was increasing, when the magnetic fields were increasing, the interplanetary magnetic fields were increasing. They had direct measures, more -- sort of like us now not just, you know, wondering is the rain going to increase tomorrow, but actually knowing that a hundred miles away, a front is crossing, and then 50 miles away, when did that weather front, you know, get there so that now we could forecast when that weather forecast was going to get to us.

By having this realtime data available from WIND, we started to get a realtime sense of what the space weather environment was. That led NASA to expand that program because it was so effective. Now we have data -- more and more data started to become available in realtime to the operational community, including observations of the sun from the SOHO spacecraft, even more precise data and more regular data from the ACE spacecraft, and today we just rely on those things.

SOHO has been replaced in realtime by the Solar Dynamics Observatory, SDO, so there's still realtime data on watching the sun, WIND data, which, admittedly, even at the time, was spotty, because it wasn't always there. There were periods when the wind data -- when the WIND spacecraft wasn't where it needed to be to give realtime warning to Earth.

But now we have the ACE spacecraft that is in the right place to give the realtime warning. Of course, the ACE spacecraft has been up for a very long time, and we don't know how long it's going to last. You know, there's a new spacecraft being planned to take ACE's place, at least as an interim replacement, to make some of the ACE measurements.

So that really revolutionized, to me, the space weather community and being able to communicate effectively to the public that this space weather really is important. Look, this is the data that we just had.

The research community realized that there was a lot of advantages to having this realtime data stream available. It became a lot easier to get access to realtime data, even if you weren't the principal investigator of that instrument. So while there was always a lot of good sharing of space weather data, now the sharing was enhanced, was more realtime, and you could test your own theory -- before you went public, you know, you could -- back in your own lab, you could test, well, did that really work or not? It didn't work. Let's tweak the parameters. Ah, now it's starting to work a little bit.

Things like the Community Coordinated Modeling Center at Goddard were implemented to enhance this modeling community and what it did. So, really -- and I think a whole lot of that -- a lot of the impetus for that was when NASA started making realtime data available to the operational community.

(Whereupon, the interview of Dr. Ronald Turner was concluded.)

CERTIFICATE OF TRANSCRIPTION

I, MARY E. YOUNG, hereby certify that I am not the Court Reporter who reported the following proceeding and that I have typed the transcript of this proceeding using the Court Reporter's notes and recordings. The foregoing/attached transcript is a true, correct, and complete transcription of said proceeding.

_______________ ________________________

Date Mary E. Young

Transcriptionist