NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
ORAL HISTORY TRANSCRIPT

LOUIS LEOPOLD
INTERVIEWED BY REBECCA WRIGHT
HOUSTON, TEXAS – NOVEMBER 8, 2007

The questions in this transcript were asked during an oral history session with Louis Leopold. The answers have been amended for clarification purposes. As a result, this transcript does not exactly match the audio recording.

WRIGHT: Today is November 8th, 2007. This oral history is being conducted with Louis Leopold in Houston, Texas as part of the NASA Johnson Space Center Oral History Project. Interviewer is Rebecca Wright assisted by Sandra Johnson. Thanks again for allowing us to come to your home today and visit with you for this project. We appreciate your hospitality. We know that you became a member of the Space Task Group in 1959. Can you share with us how you learned of this opportunity and how your involvement with the space agency began?

LEOPOLD: I had been working for Motorola, Incorporated, and had been working with them for a number of years, and wanted to start a program there and recommended this, and the chief engineers of radar and communication, two of them, thought it was a good idea.

I had an interest in medical electronics. I had several relatives who were very close to me who were doctors, and they were psychoanalysts as well, in New England. I thought I saw applications of electrical engineering to medicine that had been neglected or never had been introduced. I had started to do some of this work on the graduate level at University of Michigan [Ann Arbor, Michigan] and University of Chicago [Pritzker School of Medicine, Chicago Illinois] medical schools.

I had been offered a position of instructorship at the University of Chicago, but I was surprised, and this may sound strange, but I turned it down, because the salary was so low. They offered me $5,000 a year, and I felt this wasn't very much money. But then they told me that the undergraduate teachers were earning $3,500 a year. At the time I knew that truck drivers, those who were going long distance, were earning $8,000 a year. So I thought to myself working at the fine school of the University of Chicago and only earning $5,000 a year didn't strike me as worth it for the work I'm combining, engineering and medicine.

The man who offered me this position was a top man in medicine, and in those days the University of Chicago probably had a faculty man in the medical school on the cover of Time magazine very often, like maybe once a month. Dr. [Nathaniel] Kleitman [pioneer in sleep research and co-discoverer of REM sleep] and Dr. Ralph Gerard, the one who offered me this position in physiology. He was the one who brought in—if you're familiar with medicine—the opposite of the sympathetic nervous system, call it the parasympathetic. Parasympathetic is the opposite of the sympathetic in the various nerve functions.

Dr. Gerard had an interest in me. I had taken the graduate record examination at the University of Chicago that they give to all graduate students. I may not have done very well in physiology, which is his field, but they had a section of this exam on engineering, and I happened to have aced that. That's what he wanted. He wanted an engineer in electronics to work with him, because he had had one, and this fellow had left. But the thing that discouraged me was the low salary.

I had felt, as I studied the first two years of medical school, that not very much in medicine had been developed having to do with mechanics and mechanical engineering, [such as] the movement of the arm and the movement of the body and the legs and of the people.

Doctors were informed about the heart, how the heart contracted, how it's shaped, what happens when it goes into oscillation. All of this description was presented of the outside of the heart.

Now, one of the reasons I was interested in electronics was that when I was about five years of age I was introduced to electronics. My father had a friend who was a radio ham [operator] and an electronics bug, and he worked with me with crystal sets. I liked him very much. So I used to build crystal radios. I would put on earphones and I would listen to the wrestling matches and broadcast them with my radio that I built. It was small, it was handmade, but that was electricity, that was electronics, that was propagation. This field came to me when I was a very young lad and I always liked it as a hobby.

During World War II, I was a civilian and then an officer at schools called Harvard [University, Cambridge, Massachusetts] and MIT [Massachusetts Institute of Technology, Cambridge, Massachusetts]. What did I study there? Electronics. They were teaching radar and microwave engineering for the first time at Harvard, given by the top professors in the land in this field. I was fortunate enough to be accepted there, and so I learned material that was very advanced.

All that started with a crystal radio set when I was five and six years of age. I guess so now the reason I bring this in is going back to the medical school again. Most of the discussions by the teachers were the mechanics of the heart, lungs and on and on—based on what they saw in the movement. I kept asking myself this question. Why don't they talk about the inside of the heart? What about the electrical phenomena? What about the microwave frequencies? What frequencies are these currents going? There are things—and this spread not only from the heart but to diseases like Alzheimer's and Parkinson's and others.

They have in the body what they call dendrites and axons and synapses. This is nothing but the electrical engineering in the wall here [pointing to house wall], except this is 60 cycles and that's the frequency generated by man. It may be a lower frequency, but I don't think anybody has ever recorded what frequencies the synapses, dendrites, axons that go to the brain and in Alzheimer's, what frequencies they are.

Now why would they want to know this? If they knew this and there was a difference in frequency between people who were Alzheimer's or Parkinson's or dementia cases and normal people, one could do something about changing the frequency and seeing what would happen. Very much like something that's occurred recently. A doctor out east found a spot on the brain where if anyone had Parkinson's disease and he had trouble moving his hands and so on, he could stimulate that and stop the movement of the hands so that they could act normally when he stimulated that brain in that portion. I said terrific, because the main part of Parkinson's is the lack of control of the arms and the hands and the movement and the shaking. So I said, except that what he's doing is creating surgery and then stimulating it.

I have a better idea. Cut the person open, put in a receiver, a little receiver, attach it to that spot, sew him up, let him walk around, be normal. Now when he has this attack of these Parkinson's diseases, let him just press a button, and that button is the transmitter that he can carry in his pocket, wallet, or his jacket, press it, stimulate the receiver. That receiver now puts a little energy in that part of the brain that this surgeon did—this doctor did when he opened the person's brain and stimulated it, and cut out the Parkinson's. I'm told that the chief problem with Parkinson's is the lack of movement. This gets rid of that, while you're stimulating. So to me, one could use microwave transmission to help many parts of the body, but this is just one.

Now one of the reasons I've had a little bit of experience of this nature was that we used amateur radio frequencies to stimulate a receiver in a body of a dog, and the dog had a receiver, and it stimulated his vagus nerve, and this was done by professors, not by me, but I helped, I was his engineer. The department of surgery wanted to know, when they operated, what muscles are affected when they do surgery, how can they control these muscles in the body, and they're talking about the surgery of the digestive system. It turns out that if you stimulate the vagus nerve, that can affect the body, and you can now learn something about the effects of it. But they didn't want to do this by cutting a person open and stimulating the vagus, because they don't know if it's the stimulation of the vagus that's affecting the muscles that they want to track, or the fact that he has shock because he's been cut open, so it's a part of surgery.

But if you put it in an animal, and you sew him up, and it's there, and he doesn't know it's there, and he walks around same as normal. When you zap him, you know it's the effect of the transmission that's stimulating the vagus nerve that's hitting the muscle. This was the sum and substance of that, the reason for the stimulation.

WRIGHT: Let me ask, how did you learn about the opportunity to go to the Space Task Group?

LEOPOLD: I worked for Motorola, and I worked for Motorola because I liked them, they were a fine company, and they were in the area of electronics, which I was interested in. But they knew of my interest in medical electronics, and so the chiefs of engineering and communications said that I would be a top man, top engineer, if they picked up medical electronics. About a month later after our meeting, possibly longer, on the headlines of the newspapers, Motorola had spent $5 million buying out a hearing aid company as the entry to the field of medical electronics. But

this was done without my knowledge. This was done without the position that I was supposed to have with respect to it. So now I went back to see the chiefs. I said, "What happened here?"

They said we have to apologize but this is what happened. We talked with you about it. We were sincere about it. We presented it to the board of directors and they told us to forget it, they were going to handle it. The board of directors was going to do this work, and they told these engineers that whatever they did is not what they were going to do with medical electronics.

So they evidently liked the field and they spent five million dollars buying out a hearing aid company in Minnesota, and they bought it out based on the fact that Sears Roebuck had made a contract with them to sell the hearing aids in their stores. So Motorola thought this would be a reliable company. Well, when I heard of all of this, I decided I wasn't going to stay there, because I had been promised a certain position, and so now I started to look for work probably on the west coast. It turns out that everywhere I applied for work I was given an offer.

But there was one position on the east coast that intrigued me, and this was NASA. I was in Chicago where Motorola was located and NASA was interested in me for my knowledge, but they were out east. [JPL (Jet Propulsion Laboratory, Pasadena, California] was among the companies on the west coast who interviewed me and made me an offer.] But the reason I chose NASA east coast [Langley Research Center, Hampton, Virginia], the Space Task Group, was because it was to put a man in space. I felt that was more valuable and interesting for me than robots or unmanned versions at JPL.

I decided of the companies that made the offer—there were about 10—that I wanted to go with NASA. So I started right near the beginning of the program. I joined the NASA Space

Task Group in September 1959 and was responsible for the communication systems onboard the Project Mercury capsules.

Incidentally, among the things I did at Motorola was a lot of communications electronics, solid state devices, transistors, antenna work. Antennas were a favorite hobby of mine, and so I did a lot of antenna work that they needed, and we would work on the roofs of the buildings and elsewhere around the country. So I had a pretty good background with antennas. It turned out to be very very valuable in the space program.

I was active on the Gemini Program and headed up the development and engineering of the Apollo antennas and microwave systems. My responsibility through the space program encompassed two lunar experiments, followed by designing microwave portions of new vehicles, the Solar-Powered Spacecraft and the Space Station.

I don't know if you have much information on the Solar-Powered Spacecraft. But I had introduced it, and it had been turned down in Washington [D.C.]. But the reason I liked it was that if it were to work, I think most of the power we'd use at home and in industry would come from the Sun by way of NASA. But somehow or another, the body of engineers in Washington turned it down. May have been too expensive for them. But it won't be as expensive as what they'll pay for oil.

I worked closely with the Mercury astronauts, particularly Gus [Virgil I.] Grissom and Deke [Donald K.] Slayton, and these fellows were all friends of mine. We used to have meals together and go out together, enjoy ourselves.

On the Shuttle Program, I worked engineering problems with Captain Robert [L.] Crippen, Mary [L.] Cleave, Shannon [W.] Lucid, Steve [Steven A.] Hawley, [Sherwood C.] Woody Spring, Bruce McCandless [II], and Owen [K.] Garriott.

I earned a bachelor of science in chemistry and sciences at the University of Michigan and have a BSEE [bachelor of science, electrical engineering] from Illinois Institute of Technology [Chicago, Illinois]. I am a graduate of the preradar and radar schools at Harvard University and Massachusetts Institute of Technology, and was a graduate student in electrophysiology, University of Chicago Medical School. I have presented or published approximately 35 technical articles, and am listed in *Who's Who in the South and Southwest*, *Who's Who in the Government*, and other directories.

I conducted a graduate study, which I did part-time, toward the MBA [master of business administration] degree at the Graduate School of Business University of Chicago, January 1958 to June 1959. I had taken—again this is while at Motorola—a one-year transistor course at Northwestern University [Evanston, Illinois], 1953 to 1954. Also, graduate study in medical sciences with emphasis on electrophysiology, Schools of Medicine University of Michigan and University of Chicago, 1949 to '51.

Okay, let me share some of my experiences. Starting in August 1959, I joined the National Aeronautics and Space Administration at Langley Field, Virginia, then moved to [Manned Spacecraft Center] Houston, Texas. In July of 1961, I became the group leader for the antenna and microwave group for the Apollo vehicles. My duties involved supervising the design and engineering of antennas, antenna systems, microwave equipment, multiplexers, diplexers, coaxial switches and transmission line systems. These systems are located in off-the-pad aborts. This included the drop vehicles, the Little Joe II vehicles, and SA-5 [first launch of the Block II Saturn I rocket] through SA-10 [A-105, third flight of an operational Saturn I].

I was responsible for radio frequency interference, radiation, and propagation tests and for the design and installation of three antenna ranges at the NASA site in Houston, and for the

design and installation of the anechoic chamber free space room of 100 megacycles through 60 kilomegacycles. That was my design. I had the University of Michigan radiation laboratory do the architectural work and build it. These are the antenna ranges and anechoic chamber in which Apollo and other space vehicles were checked out for electrical, electronic, and radiation characteristics. Beacons, telemetry transmitters, command receivers, antenna systems, electrical power systems, simulated flight missions were evaluated in these facilities. During this period I presented a number of papers on Project Mercury. These include: "A Review of the Characteristics and Development of the communications Equipment on Board the Mercury Spacecraft," October 27, 1961, and "Communications Systems of the Mercury and Apollo Research and Development Spacecraft," February 9, 1962.

WRIGHT: Would you share with us your thoughts about those first days when you arrived at the Manned Spacecraft Center. Who talked to you about the job?

LEOPOLD: What happened was that I was interviewed in Chicago, and I received an offer to work for them, and that was as a GS-14 [General Schedule, pay scale], which was supposed to be a pretty good rank.

WRIGHT: Was that better than that University of Chicago professor job?

LEOPOLD: It was. It was better. What shocked me was the University of Chicago had a fine reputation, but to offer me that small an amount of money. Now maybe the professor who offered it to me wondered why I turned it down, but I felt that wasn't enough money to satisfy

anything. I've talked with doctors since, and they said it's true, the salaries for teachers at medical schools in those days were very low, but they've gone up and up and up since then. So they're probably very high now. But at that time, that's what it was. That was the reason I said no. But I felt NASA was just as interesting.

WRIGHT: Did you move right away from Chicago to the Hampton [Virginia] area when you got the offer?

LEOPOLD: Yes. When I got the offer, I moved from Chicago to Newport News [Virginia]. I stayed in Newport News for, it seems to me, a long time. Yes, until we moved to Houston. This area [reference to home address], first of all, is very close to Telephone Road. Telephone Road was where NASA engineering first started.

WRIGHT: Before you moved to Houston, did you spend a lot of hours working at Langley when you first started?

LEOPOLD: I had been assigned positions representing Langley at McDonnell Aircraft and then at Downey [California]. That was at St. Louis, [Missouri], McDonnell, and then I think I spent a year there, and then I spent a year or two at Downey on the Apollo Program. But at the same time I was living—part of the time I was at Langley, my home base in Newport News, and then part of the time we'd moved and I was here in Houston, when I think I went to Downey.

Originally, I am from Boston.

WRIGHT: Well, that was nice for you to be able to go to Harvard, because you were close to home.

LEOPOLD: That's right, that's right. But I didn't live at home, though, because I lived too far away. My family's home was too far from Cambridge, so I would live where the other students lived, in rooming houses in Cambridge. Meantime I had cousins who worked in Newton. They had their offices there, and they were practicing medicine.

WRIGHT: Do you want to talk at length about working with McDonnell in St. Louis?

LEOPOLD: Now the one who knew this material was Scotty [Scott H.] Simpkinson. Scotty and I were very close, and he brought me in on problems on Mercury and then later on. He was very close to the Director of NASA. It was through him that I started to fly around the country representing NASA at these companies.

I just want to mention quickly that before I even did any work in St. Louis, there was a visitor to our facility on Telephone Road and that was the John F. Kennedy, President of the United States. There's a building that used to manufacture hats that's on the corner of Telephone Road and Westover Street. So [NASA] took it over, and we were there for about a year or two, and I think we may have been there a year at the time when we had the visit from the President. He wanted to see how this was going. So we were honored. We thought it was great that he was looking in on us. He was on a quick mission. He visited several places here. But ours was one of them.

WRIGHT: Did you know he was coming?

LEOPOLD: Yes, I knew in advance he was coming. Coming to visit us and see what we were doing, what progress we were making. This [building] was converted from a hat factory, and we hadn't built anything at the Johnson Space Center [then Manned Spacecraft Center]. As a matter of fact, when I first arrived in Houston I took a drive over to the site for the Center and I saw—God, I don't know what you call this man, a shepherd or something, he was with sheep and with animals on this area. That's what you saw there. It was a blank area near a lake.

WRIGHT: Let me ask you a question about the hat factory. How much were you able to develop in that facility before you moved down to the Manned Spacecraft Center? What were you working on there at the time?

LEOPOLD: At the time? I was working on communications material. But we gave contracts to McDonnell, and McDonnell became the prime contractor, and they'd give subcontracts to communications companies and others. I would spend my time looking over the results, and the tests that were done, and what they did.

Now, there was one other little thing that I had that fortunately the Space Task Group had done. They had a set of advisers and they were at MIT Lincoln Laboratories. They were advisers to us, and that's where I used them.

But let me go on with my story. Now when we moved to Langley I was reading charts and graphs, spent my time just putting my feet on the desk and just reading them. I read the results of tests that were done in laboratories. Now Collins Radio was a radio company that was

doing work in communications for McDonnell in St. Louis. I read something that bothered me.

To me, the data I was looking at would not work. It just was something that showed a discontinuity, and I knew if I were building an antenna and designing one, the antenna wouldn't work with the data I had in front of me. So I reported to my supervisor, who happened to be a mechanical engineer. I told him that it wasn't going to work, and he said to me as a word of caution that these two were very large companies, McDonnell and Collins, and they wouldn't let anything like that go by that wouldn't work. He said I'd be taking them on.

I told him that I had worked for Motorola, and Motorola would not accept that. So he said okay, prove it. So now I called MIT, told them what I had found, they agreed with me. MIT Lincoln Labs set up a meeting in Cedar Rapids, Iowa, where this test was done, and may I read part of what I've written?

WRIGHT: Please.

LEOPOLD: I read charts and graphs which showed the results of tests. One was in the laboratory at Collins Radio. These showed the operation of the disk-cone antenna. That was the name of the antenna in the Mercury vehicle. It had a disk and it had cones. This was an omnidirectional one, so no matter how the spacecraft turned you'd get communication out of it. It could go in all directions. It could receive from Houston as well as transmit in any direction the spacecraft was. So it was called the disk-cone antenna. This is the main antenna for communication from and to the Earth.

I saw what appeared to be a breakdown in the operation of the big antenna on the Mercury spacecraft. I told my supervisor branch chief about this breakdown. He reminded me

that these companies were two of the largest in the United States and would not allow this to happen. I pointed out that Motorola, meaning myself, would not accept this.

At this period of time, MIT Lincoln Labs were technical advisers to the Space Task Group. I talked to them about my conclusion. They wanted to see the lab tests for themselves. We arranged a visit to Collins Radio in Cedar Rapids, Iowa. MIT, NASA, McDonnell Aircraft, and Collins supervisors witnessed these tests. As the vacuum test—now what this was was a big vacuum jar, and in the middle of the vacuum jar was a Mercury model. So it was a small one, of the Mercury Program and the antenna in it. Everything was the same except very small. So they would make the vacuum in this vacuum chamber.

As the vacuum tests of the Mercury vehicle and antenna were all witnessed, a complete breakdown of the antenna and communications at certain specific altitudes. Now when the breakdown occurred, everything was perfectly clear. The spacecraft, the antenna was working, transmitting and receiving, and we were changing the vacuum—the greater the vacuum the higher the altitude. So as a spacecraft goes up high enough, it's pure vacuum, and that's what we were doing. We were going from room temperature room atmosphere to the vacuum in outer space.

As we did this, suddenly you saw all kinds of particles in the vacuum chamber. They were metallic and debris and they were floating around, and there were thousands of these little things inside this vacuum. We looked at it and I guess we were all shocked. This was a breakdown of the antenna system and the communication. Now our conclusions were that this couldn't happen. If this were flown, you'd get nowhere. There'd be a breakdown in communication, and the spacecraft might have been blown up or something.

The MIT Lincoln Lab engineers went back to Cambridge, Massachusetts, and after a study they stated the Mercury Program could not survive lack of communications, as we all realized. The MIT people recommended the disk-cone antenna, which had parked at certain vacuum levels, be encompassed in a container which would house the antenna in a vacuum on the ground and throughout the mission. In other words, we'd put it in a vacuum-enclosed container on the ground so that now it was operating in a vacuum completely, no steps in between. It was encompassed so that when it went up to fly it kept the same vacuum.

The antenna was kept in a vacuum from the start of the mission until the end. It was sealed in with no changes in vacuum. It flew successfully.

I flew to McDonnell Corporation to investigate a noise problem. Have you ever heard of the noise problem on spacecraft? Now the one who was there with me was Scott Simpkinson. But I flew on that particular problem. In the spacecraft, you have all sorts of equipment going on chattering, making noises, either transmitting or switches are going on, people are talking from the ground up to the spacecraft and back. But the noise in the background was almost intolerable. They had real trouble hearing.

So I flew to McDonnell Corporation to investigate the noise problem. During the Mercury flight, the astronauts could not communicate with the ground and with each other because of the electronic noise in their voice system. As I heard about the tremendous noise interferences in the background of the communications system, I remembered a similar problem we had encountered at Motorola.

We had placed a preamplifier just behind the microphone of the speaker, so when someone talked, the voice was amplified by a separate amplifier to make it pretty strong, instead of going into that massive noise. This amplified the voice so strongly it could be heard clearly

over the noise background in the system. Now the voice analyst could be heard distinctly over all sources of noise and interference.

I suggested the adaptation of a preamplifier to Scotty and the others, and I called Motorola. They said they'd send me a preamplifier, but it had not been cleared for space work. I said I wanted to use it on the ground. I wanted to prove a concept.

The result, they said, was complete silence from noise and interference throughout this comms [communications] system. Oh, it was complete silence. That was the word. I gave the preamp to the McDonnell people. They put it in the system. They ran it themselves. When the engineer came back to report, we said, well, how did you do with the preamp? He said everything was silent in the spacecraft. They had no problems at all with communication. So that solved that problem. I was told the McDonnell engineer used this technique to remove interference in their comms system.

I'd like to talk about a problem at the Goddard Space [Flight] Center [Greenbelt, Maryland]. This was probably two or three years later. They were having trouble with communications in their equipment. I had attended a meeting. It turns out that they wanted help from the other Centers. So I attended a meeting and when I heard of this problem, I remembered hearing someplace that Hughes [Aircraft] had had difficulty with some of their equipment. So I asked the people at Goddard whether this was Hughes circuitry. They said yes it was; it was supplied by Hughes. Now what had happened was that at Motorola, I had had literature and knew that if you used printed circuits, [and you use printed circuits generally with transistors, solid state devices,] and those printed circuits are near high voltages, let's say a cathode ray tube or a TV set or other units requiring high voltages, this affects the circuitry in the printed circuits so now you have problems. You interfere with the communications.

At the Goddard facility, the printed circuits were susceptible to high voltage, causing shorts. Hughes Aircraft has electronic printed circuits and their electronic printed circuits had broken down, so I notified Goddard. They heard this from me and they wanted written proof, and I sent them written proof showing that. This solved their problem. But it was a serious one for Goddard, because they had no idea it was Hughes equipment that was doing this. But Hughes had built these printed circuits in that way. Now another thing happened to me.

I was sent to Rockwell to assist Bill Gray, who was in charge of NASA's office at Rockwell at Downey. I was to follow and help correct electronics problems. I did this for a few months, and then an astronaut came to me and asked that I help him check out the new Shuttle vehicle. Now what would happen would be a vehicle would be built for a Shuttle for NASA by Rockwell. But before NASA would take it over, they would check it. So they put an astronaut at it to operate it, the controls. But he needed help. He needed someone to look over the electronics meters and readouts and all the systems in the spacecraft. That was me.

I would check and evaluate the readings on meters which indicated the successful operation of the new spacecraft. I said I would help him. I've never turned an astronaut down, so I said sure. So I worked with him on his spacecraft, and we checked it out. I noticed it was about 6:00 or 7:00 in the morning when we were through, instead of the night before. We would run into a number of problems on the spacecraft that we would have to correct. Finally we did it. We did it successfully.

A week or two later, a second astronaut came to me and asked for my help again. In other words, this was the beginning, and I didn't realize every time a spacecraft would be complete and an astronaut came, he'd pick me, ask me to help him. I don't say no to an astronaut. I think it's too important. Each time we would check out a vehicle, we finished about

4:00 or 5:00 a.m. Problems would come up, and Rockwell had to fix them. Thus the delays until early in the morning. I would go home in Downey to sleep and come to Bill Gray's office at 10:00 or 11:00 a.m.

Bill Gray talked to me, and he asked why am I not there at 8:00 in the morning. I said well, I'm sorry, but I was working with the astronaut, told him his name, that we finished an hour or two ago, and I had had to get some sleep. This went on for several weeks, and he said he couldn't do this. He said I'm supposed to work as his assistant starting at 8:00 in the morning and until 5:00 in the afternoon, and I'm not coming in at 8:00. At first I tried, but I averaged about two hours' sleep a night, and I couldn't do this. So I reported to my chief engineer. I told him about the difficulty with Bill Gray, and he said well you can't go on. You're in an impossible situation. So they pulled me back to Langley and sent somebody else or got somebody else for Bill Gray. But I worked with probably six or seven or eight astronauts in the meantime.

[End of interview]

For more information on Lou Leopold's work at NASA, read his document ***The History of the Anechoic Chamber Antenna Range and Laser Tunnel****.*