This is Steve Dick interviewing Lynn Harper on May 13, 1997 in her office, Building 239 NASA Ames Research Center, Moffet Field, CA

SD I usually start with a few background questions. Your full name, do you have a middle name?

LH Well I use my maiden name as my middle name so it's Lynn Dobieski Harper.

SD Alright, and date of birth and place of birth?

LH I was born June 10, 1952 in Bridgeport Connecticut.

SD Ok, and a little bit about you educational background.

LH I started out as the theater arts major in a local state school and was bored to tears with that, and ended up at University of Bridgeport in the science program, loved it, and I stayed with it and had an opportunity to work as a graduate student at Brookhaven National Lab in marine oceanography and at Stanford University in recombinant DNA in the early 70's. And that's what I did my thesis in. Not at Stanford; I did the work at Stanford, but I got the degree from UB.

SD What is the degree in?

LH Cell and molecular biology. Then after that, I was also going for my physics degree, bachelors degree at night while working as an engineer, believe it or not at a lamp factory at Voltarc Tubes, Inc. in Fairfield, Connecticut. And in the interval between research at Stanford and going for my Bachelors at night in physics, I worked briefly for the Boy Scouts of America (BSA), which is how I got into NASA.

SD How?

LH Well I was looking for a job, and they (BSA) were looking for an Exploring executive for science and business. And I was between jobs at that point and took it and I was on the job about a week when there was a notice in the Explorer magazine that said, "Explorers can propose experiments for the space shuttle," and I organized a series of posts and worked with the kids, and when they did the nationwide competition they were ten experiments selected from 100 nationwide, and five of them were from Fairfield County, which is from my kids. And that leveraged me into NASA when I had always wanted to work for the space program.

SD So what year did you actually come to NASA then?

LH '82, and I worked as a contractor. I called up NASA Headquarters in Washington at 4:30 in the afternoon, not knowing that the secretaries are gone by then, and the person that answered the phone was the director of life sciences, Gerry Soffen.

SD Oh!

LH And I told him it had been the dream of my life to work for NASA, and he asked me if I could write, and what my background was, and by then we were developing the five experiments for the space shuttle, which was fairly unusual, and I had a life sciences background, had a physics background, and had an engineering background, so all of that secured me the job, not because they were so impressed with those credentials, but because I told them I could write. And they were looking for a technical writer. And so I started with the Bionetics Corporation, which supported the NASA Life Sciences Division, and that's how I met Don DeVincenzi, working on the exobiology program plan. And with Tom Perry in the gravitational biology and biomedical flight programs. And what happened was I was to write a brochure for the Spacelab 4 mission, which was the first life sciences mission. In the process of doing that, I discovered a glitch in one piece of the equipment. And here I was, Joe kid from nowhere, and went in to the chief of flight programs at Life Sciences and says, "I think your equipment is going to fail when it gets to space," and bless his heart, Tom Perry was one of the best, he says, "what makes you think so?" And I sat down and said that they're trying to maintain a negative pressure, and as it turns out I had just got through developing high intensity lamps and special purpose lamps like for *Star Wars*, for the *Star Wars* movie we did some special effects stuff, and I worked a lot with vacuum systems. And I said the strategy is when you change out the waste trays in the research animal holding facility this was supposed to go on Spacelab 3, you're pulling it out against a negative pressure, and it's just not enough of a negative pressure to maintain the integrity of the system when the trays are pulled out. And so they went through it, and they said sure enough that's what would happen, and Tom said what's your background, we went all through that, and he said how would you like to be a program analyst, flight program analyst, and that was probably the most fun I ever had, and through that medium, I was sent out to SETI to raid them for money, because the flight program was in trouble.

SD A favorite past time at NASA Headquarters I understand.

LH Oh, it was, I was to go on the raiding expedition. And the flight program was in desperate need of money, and I went out. Tom Perry [NASA LIfe Sciences Chief of Flight Programs], Don Devincenzi, and Ron White are three of my heroes, and Tom said, "you know, Don's got this program, Search for Extraterrestrial Intelligence, and I'll tell ya, if it was anyone but Devincenzi I would have written it off a long time ago," he goes, "but the guy intimidates me, go find out what's really going on there." So I got the royal treatment from Barney Oliver, Tom Pierson, John Billingham, Vera Buescher, and I came back and I said they have to have more money Tom. It was the most incredible mind blowing set of presentations and experience that there was 1000 solar type stars within 100 light years of Earth. I've never been the same since finding out that fact. And that we had a reasonable way of detecting signals for me, it was just an incredible revelation.

SD So you came out to Ames for that series of briefings?

LH No, I came out to raid them and to review the programs, they just coopted me. But yes, that's what I had come out there for. And maybe I was doing some other stuff as

well because one of the things that Tom was going to offer them was after he was picking their pocket with one hand he was going to dangle some bait with the other, and offer the opportunity to develop an exobiology flight program, consistent with embryonic plans for space station, increased shuttle involvement, future planetary missions. Because at that time, Viking had been the only flight element, and that had been done prior to (I think it was prior to) the coalescence of all of the life sciences programs in one organization. So he had persuaded Gerry Soffen, I believe, who was the director of life sciences at that time, that exobiology should have an active flight component, and this was to begin setting the stage for that. So everything was happening around that particular time - '82 to '85. And it was it was in December of '86 that I was hired by NASA to be the program manager for advanced missions and special projects, which at that time would include SETI, the exobiology flight program which was receiving it's first funding that year, the controlled ecological life support system where I had carved out about 50K to get that started. I also was the manager of the Space Life Sciences Training Program at the Cape.

SD So at some point then you took over from Devincenzi, is that right?

LH It was in '86. That's right. Between '82 and '86 we started the exobiology flight program, I guess I could tell you how it happened; largely through arguments about creating a pot of money to make investments in technologies that would be uniquely supportive of exobiology interests. There was the PIDEP program, the Planetary Instrument Development Program, I think is what the acronym stands for, that was funded out of the Planetary Sciences Division, at that time run by Geoff Briggs. There was the astrophysics program managed by Charlie Pellerin with the Great Observatories suite. But there was nothing in Life Sciences that was the equivalent of advanced development, advanced technologies program. And after reading some of the source material that Billingham was in the process of developing at that time - that would be the cosmic history of the biogenic elements of compounds, the search for the universal ancestor, the ECHO report, Evolution of Complex and Higher Organisms, and I guess the last one is SETI. Or is it COMPLEX? I'm not sure which one it is, but the last in the series, some of the questions they were going for either could benefit from investigations in space or would require data from space in order to answer, and they were not being addressed anywhere else in the agency. So that formed the nucleus of the first advocacy of the exobiology flight program.

Then what happened was the space station began development, and Devincenzi was asked to participate along with Ron Greeley, who was chairing it at that time, in the uses of Space Station for planetary science, but they included exobiology as part of that package. And one of the primary meetings was going to be a kickoff at Flagstaff, Arizona. In preparation and concurrent with all this Don had as program manager for exobiology had asked Chuck Klein, former director of Space here at Ames, to chair an exobiology in low orbit series of workshops. One of the questions that was a seminal question in there is what is the role of organic material in the evolution of planets, leading to the evolution of life. What role did the organics play? And the physical scientists at that time thought none, or it didn't matter, it's all gravitationally based. But at that time the polycyclic aromatic hydrocarbons were starting to be discovered in planetary nebulae. And one of the characteristics is that they are sticky with an affinity

for carbonates and silicates. And there was at least the suggestion - never got as far as hypothesis - but at least the suggestion that these organics which were very tarry and sticky would allow the accretion of the planetesimals to the point that it could skew the development enough, so the gravitational influences would take over. So it might accelerate or act as a catalyst in it. And then the more daring among the crowd would suggest that perhaps they're actually necessary. Otherwise you just had dispersed, disparate pieces, and you don't get enough mass accumulation to allow the planetary system to form. And by the way, this debate is going on to this day.

But one of the ways they thought they might be able to resolve that was to do some high fidelity modelling studies in low Earth orbit. We'd build an acoustic chamber, suspend gases and grains in as close an approximation to interstellar medium or planetary nebular environment as we could get within the confines of the spacecraft, and see whether or not the organics play a role in accretion. Now a lot of these studies had been done on Earth, but the problem with them is that gravity immediately puts everything in proximity to each other and you always end up with basically slush. The problem with doing the simulation modeling on Earth is that everything settles out. And if you try to keep it suspended in order to get any kind of chemical dynamics, the amount of acoustic energy you would have to put in to keep it suspended is so powerful that you would overwhelm some of the subtleties of the reaction.

So from this, one of the campaigns I was on with Don Devincenzi was, "you know I think we could do a gas grain simulation facility in space on a station that would allow us to reduce by several orders of magnitude the amount of input energy and get at some of these answers more definitively." So Don goes, "well it's interesting you say that, there's going to be a meeting next week at Flagstaff," and he says, "what I'd like you to do is present this exobiology flight program for space station." I said, "we don't have one," and he says, "well you've got a week!" And so I got on the phone with Glen Carle, and Glen and I sat down with the gas grain facility, and flushed it out, did a conceptual design, discussed the parameters that we would be able to accommodate within the constraints of the space station as we understood it at that time, and I proposed it at Flagstaff the following week in one of my first professional presentations, scared half out of my wits. And for some reason, it just resonated with the crowd. The atmospheric chemists liked it because it allowed them to study some aerosol formation questions that they had been having, some of the microbiologists liked it because they'd been wanting to examine the survivability of microbes in various environments.

At any rate, what happened was that this was baselined at that meeting, a formal change order was put into the space station to accommodate it, and the exobiology flight program was born. And the other technology that we were investigating, or technologies that we were investigating that formed another component of the exobiology flight program was a collection of cosmic dust -- intact capture. And at that time we were investing in two concepts: one was aerogel, which is the component of the Stardust mission now, and it was the first time that aerogel was being proposed to collect intact fragments of cosmic dust. Again with a lot of scientific skepticism, and we were able to demonstrate - mainly Peter Tsou at JPL - that using the air guns built here and in France that the geometry of the aerogel is such that it will allow fragmentation of a cosmic dust particle, but intact fragmentation so that it's not volatilizing the organics; they'd be trapped and imbedded

within the particles. And so that would allow us to do some definitive chemistry on both interplanetary as well as interstellar, that's the big prize, interstellar cosmic dust particles. And that's part of the subject of the Stardust mission, and as they fly through the comet's tail that's what they'll use to capture it.

SD Now this was happening while Devincenzi was still at Headquarters?

LH He was still at Headquarters, we were just forming it, and I got the first money walking in the door as the program manager to advanced missions and special projects. We had been able to advocate successfully for seed money, I think it was 100k for exobiology flight, it was one and half million for SETI, and it was 50k for the controlled ecological life support system, because I was also interested in human exploration of the Moon and Mars, and was on some of the study teams for that as well.

SD Now how is your job different from Devincenzi's?

LH Don originally did research projects, technical development and mission development. I took over "prjects", some technological development and all mission development. John Rummel took over the science.

SD So when you say a million and a half for SETI, were you involved in getting that money?

LH No, the money I was involved in getting was the full up money, the ten million dollars per year. We did the advocacy in order to get Congressional line item funding for that, and I was one of the architects of the strategy for that.

SD Yeah, now that I'd like to hear more about.

LH Ok. It started in '85 when by this time I was heavily involved as a flight program analyst, working for Don, working for Tom Perry in in Tom Perry's chief of flight programs, he was flying the Spacelab missions. So I was working with him in developing more life sciences missions, I was working with Don in developing the exobiology flight program, and also SETI. And I fell in love with the SETI project, SETI was my love child, and after talking extensively with the SETI people it became clear that at a million and a half dollars they could develop this from now til doomsday, they would never achieve sufficient critical mass to ever get out in the field. And at that time we were concerned about the microwave window closing. So at that particular time there was the proliferation of satellites and the closing of the microwave window and we were starting to be serious about time.

SD Yeah. SETI?

LH Oh, the main thing that became clear that what they needed to do, the technological challenge that was involved, we weren't going to be able to creep up on it any time soon. And we were faced with probably four problems. Problem number one is that SETI was in a quasi mode of acceptability - not really within the science community but within the science decision making community; Congress, the public, the NASA management

chain, it was a challenging concept, and it was almost a touchstone with how bureaucratically courageous somebody was, whether they were comfortable defending SETI or not. Regardless of their private view, would they acknowledge this in public? And many wouldn't. The ones that were very supportive would raise the objection that SETI was a ground based effort, and so probably more appropriately done by NSF. Another factor was everybody was scrambling for money, and it is a highly competitive environment, and it was enough money to be serious money, but not enough money to attract the level of support that some of the things like a space probe will do. And there was a fairly narrow community. So that was the milieu that we were operating within. On the other hand, it was starting to become clear that small increments of money we would never ever get there. And so we needed to have an injection of millions, roughly ten million a year, in order to get all of the equipment operating at once.

SD Now was this Billingham coming to Headquarters to argue this to you, or were you convinced by this time and you were arguing it to other people?

LH Both, except it wasn't Billingham. Billingham was always eloquent in the defense of SETI, but here was the problem. The amount of money we're talking about required us going public, and required us to stand up and make it obvious that the search for extraterrestrial intelligence was being actively pursued by NASA, with all that that would imply, and to go public in the press. This was not long after the Golden Fleece Award when Senator Proxmire shut it down, so JB wanted to give it some more time. Barney Oliver was convinced that we just were not spending the money we got well enough for him to be comfortable and that it needed an infusion of new funds. Getting those new funds required going public, and that's where we sort of went back and forth on it. The last year Don was at Headquarters we began the first formal process

SD That would have been '86.

LH That would have been '85. '85/'86 time frame, yeah. We began the formal process of seeking new funds by going through a new initiative process. And what we did at that point was we used the bureaucracy to work for us. One of the things that NASA had set up was the mechanism for proposing extraordinary ideas, developing them. And what it generally goes with is something called the new initiative questionnaire, a non-advocate review, and a budget scrub. And we went all through that for the first year, developed a SETI program plan which lays out everything you're gonna do, your science requirements, your technical approach, and that becomes the foundational document that a group of people who are non-advocates - neither adversaries nor advocates - come in and do a fair broker assessment of your project. We didn't make it through the first year. And as a result of that they will write a letter of recommendation to the Associate Administrator that says, "yes, this is important work, the approach has a high probability of success, these people understand the technologies well enough that there are no technological barriers to overcome, and they know what they're doing well enough to cost it out within a reasonable ten percent plus or minus costing approach." You almost never make it through the first time, and we didn't, but we learned a lot of important lessons, and the result of that was in that year, SETI went from one and a half million to 2.1. And then it began an incremental growth from there based on I guess you would call it technology packages that we were doing. For example, we decided to accumulate the

money and blow through the chip design. Because the MCSA [Multi-channel spectrum analyzer] was a technological showstopper; we had to demonstrate that we could get the speed of the system sufficient to be able to maintain a lock on a star, and receive the signal, process the signal in a reasonable time period to allow the resolution to make a reasonable case at that point. In '85 we had not done the chip. And the chip was really the pacing item at that point.

In '86, we concentrated the resources there and at least got through the first VLSI chip. And it was the first, it was the fastest digital signal processing chip going, and two other things happened. One, I woke up in the middle of the night and had a brainstorm that when I looked at the project charts that we had produced - at this point I'm probably program manager, there was a continuum really, so it's not that clear when something happened - but when I looked on the project charts it dawned on me that the first deployment we'd proposed was in October of '92, and it was the 500th anniversary of Columbus's discovery of America, and I said, "oh I wonder if we can make it," and I called up Barney. Oh the other thing we lacked is a sense of urgency. There was no driver to go this year versus next year. I called up Barney, I said, "Barney, you think we could be there? If we got the money could you be there October 12, 1992?" And he said, "well I think so, why?" And I said, "what about if we have the SETI initiation of the search on the 500th anniversary of Columbus?" And that was a galvanizing force. At that point we rebaselined everything to get out there on that day, the symbolism was working for us. Spielberg had just released *ET* on video, and they had made more money in one month selling the movie than we were asking for the entire 10 year project, and we used that! We used that argument effectively, and by this time we had the chip in hand. So when we went for the next non-advocate review, which we did in '87,, we passed. And it may have been '86, I have to tell you, I'm a little vague on what happened in '86. No, it was FY '87 that we were in.

SD But '86 was the year that you became program manager?

LH It was, December of '86 I became program manager.

SD At that point Don came out here to Ames.

LH Don came out to Ames, right. And it was, I guess it was right in that first year, could we have done it that soon? It was probably FY '88 now that I think it through. It was probably FY '88 that we passed the non-advocate review. No, it was '87, because we got our first big funding in '89, so it was '87, had to be. Because it's a two year - you know the budget cycle? So we got the first big funding in '89, we must have passed the non-advocate review in '87. So it was '87 that we passed the non-advocate review. And that was a wild experience, because we had a number of challenges, and we had one person on the review board who was not hostile, but he did not want a ten million dollar SETI program to appear.

SD Is it confidential who those people were?

LH The chair of the committee was Jeff Rosendahl, who was the Chief Scientist of the Office of Space Sciences and Applications at the time.

SD He's at NASA now.

LH Yes. One of the members was the deputy chief scientist of NASA, his name was Joe Alexander. You know I don't remember everybody's name, I would have to look up in the records. Joe Alexander was the one that was recommending that we drop the JPL portion, and that if we agreed to do that then he would support it. And we said no. And then he raised a series of objections, we were able to answer those objections, we were running around the clock for days, doing nothing else but organizing the technical arguments against what was being said, and when we got through, Rosendahl said it was ready to go, and nothing would be gained by delaying it. And those were magic words. So he put that in front of the NASA administrator, in the meantime we'd been organizing an education program through Congress to let them know what the real story was. Because there was so much about SETI from the outside that was apocryphal, and hype and lunatic fringe, that it was important that the decision makers throughout this process were aware of what the program really was. And so Jill Tarter and Tom Pierson and Barney Oliver and JB [Billingham], Frank Drake, Carl Sagan, many many people went to the Hill and said here's what the program is, here's what the proposed costs are, and you will see it proposed by NASA. And so they did their homework, and we made it through with Congressionally protected funding.

SD And what amount was that then?

LH It as I think it was 12 million. It was the full hundred million dollar program, and that was what we went for, and the first year's money was 12 we were requesting in order to make that '92 date. And in Life Sciences where Arnold Nicogossian now is the Division Director for Life Sciences increased the funding in anticipation of getting that money to six or seven million in '88, and then in '89 we received the first full funding. And I had come out here on a tour of duty as deputy project manager for SETI for a six month period of time, and sharing an office with David Harper. And one thing led to another, we got married, it was a clear conflict of interest and then we continue. And I left Headquarters and I came out here, and I've been here ever since.

SD So SETI is important to you for more reasons than one.

LH Absolutely, I've got three kids as a result of SETI. And married to the most wonderful man.

SD Now how long were you at Headquarters for then?

LH I was at Headquarters from 1982 to 1989, officially there was a six month period in '88/'89 when I was here.

SD And why did you leave in '89 then to come out here?

LH Oh, there were two reasons, one of them personal, one of them professional. The personal reason was six members of my family had died over a six month period and I was pretty shell-shocked and Headquarters is a pretty stressful environment. I was also

getting divorced. So there were just one too many things in that mix. And so I really came out here to make a change. But also I had never worked at a NASA Center. I had hands on experience as an engineer, but I'd never done the engineering management in the formal sense which is necessary for NASA career development. So I was always going to do it at some point in my career, and when SETI made it through the gate - and also incidentally I was able to get the CELLS flight program congressionally funded as well, with congressional approval for the development of the CELLS test facility for space station and the gas-grain facility and the cosmic dust collection. I was pretty much at a jump off point; I could stay and manage it out of Headquarters, but the enabling work had been done, it was a good time to pick it up on the other side with some hands on experience with the project development and learning the technical side of SETI and technology development. Which was a fabulous experience. And so that's what happened.

SD Just to close out on the SETI story then, of course in '93 Congress cancelled the whole thing. Do you know any of the inside story of that aside from Senator Bryan.

LH I don't think there is much of a secret story. I was not at Headquarters at the time, the people to talk with would be Gary Coulter, who took over for me, and John Rummel, who is there. There were bad times for the agency at that time. There were bad times. And we had lost the space exploration initiative, space station was floundering. Goldin had just walked in the door, so there'd been a change of command, there'd been a change of administration, and everything was a mess. And I'm not sure that the challenges that had been successfully resisted in previous years - either that people weren't at the right place at the right time who were advocates within Congress, or that Senator Bryan sort of pulled the fast trick, which was he proposed his bill after hours. And the people that we would normally have had there, in the voting mass who were familiar with the truth of the project were not there to refute it. Plus Bryan - he and the senator from New York, he died, I don't remember his name. But in the previous year they had recommended cancelling the SETI project on the basis of false information. So that was easy to fight, we just put the truth out.

SD What did they claim the false information was?

LH Check this one, I think they claimed that we were signalling. That we were attempting to signal to somebody who wasn't there. I think that was what they, you see I was out of the project by then.

SD And who was saying that?

LH Bryan and the senator from New York.

SD Oh Bryan already was saying that before?

LH Yes, Bryan was two years. And anyway they were able to stop that just by telling the truth. And so he looked very foolish. And so the next year he used a different tact, and a much harder tact. The tact he used was there are many worthy projects, I'm not sure we can afford this one. Well that's a good tact because there are always many

worthy projects and you're not sure you can afford any of them, and this was as I said at a time when the whole line up of supporters for SETI had changed, and we didn't have time to get back in there and recreate enough of the critical mass to support the project.

SD But his press release that he put out was maddening, I don't know if you remember if you saw it or not,

LH Oh yes.

SD You know about the little green men and Martians and all this.

LH Yes, and that was just something he did for political reasons back home, but he didn't use that in Congress. He used the much harder tact of saying many worthy efforts and this is solid science, we're not saying it's not solid science. Oh that's what it was, he had said everybody knows this is not real science, well of course the National Academy had endorsed it, and the National Academy made no bones about the fact that yes, this was real science and Bryan didn't know what he was talking about, and that was effective. Next year he did know what he was talking about, and used a more effective argument.

SD Ok, were there other issues in exobiology during the years you were program manager? Straightforward what you usually think of as exobiology, you know the experiments under prebiotic conditions and all of that.

LH Were there issues?

SD You talked mainly about SETI and the flight activities. But there's another component to exobiology.

LH Which is the ground-based.

SD Yeah, all that's going on.

LH Was there any fight for funding for that? Or that just sort of was going along?

SD Not seriously. One of the policies I've always made as a manager in any capacity is I will not grow on your failure. If it's new and it's good enough to do, I'll go get new money for it; there's always money. And there really is always money. NASA had a 13 billion dollar budget, ten percent of that is in play - all the time. And that's money that isn't costed, committed, obligated, planned for somebody else's project. It takes work to find it, but it's worth it. Now if I'm going to go for really big money, I'll go through Congress and make the case. And so it wasn't an issue because I didn't make it an issue. If I had tryed to close down somebody else's project in order to fund mine, yes of course there would have been issues. But it was not necessary to do, I've never found it necessary to do.

SD Do you remember what the funding was for exobiology at that time?

LH Six million roughly, and I think one and a half was SETI. And I think Burt Edelson who was the OSSA associate administrator at that time, put in an additional roughly million, I think. Or 800k to a million.

SD So when SETI went up to ten million it was actually getting more than the other exobiology.

LH Yes. Well, major projects usually do. It was at that point in a small flight project category. And that was the tact we took in developing it. That this was essentially the flight equivalent for an exobiology mission in the arena in exobiology at that time; it had five basic RTOP categories, that paralleled those workshop developments - origin and evolution of the biogenic elements and compounds all the way through, those were really the RTOP categories and there was one - the evolution of advanced life - of which SETI was the primary component of that particular element. And certainly the level of scrutiny we received for SETI was unusually high for a project that was essentially by NASA terms fairly small. And so we were righteous, we had been looked at in every possible way by every possible group and many many challengers. So that was it's initial success, and quite honestly that's still why it's able to succeed on private donations because it's a solid case, and they're doing a solid job.

SD Ok, well lets move on from Headquarters then; you came out here to Ames in what position?

LH Well, no position really. I was picked up on a good faith basis by Joel Spearans in the Space Project group here at Ames. And my first interview he said, "I figure you'll figure out something to do after you've been here for a while." So the next thing that happened was I heard about the 90 day study and the potential to go back to the Moon and Mars. And I called up Bill Berry, who had been the chief of flight programs here, when I was doing work with the gravitational biology flight programs, as a program analyst. And I called him up, I said, "Bill, I wanted to toss my hat in the ring to be a part of the 90 day study." Dave and I had just got married, 90 day study came up, and I was on a plane out to Houston for 90 days working on the development of Moon and Mars. And the process of doing that is all of the background and enabling science, but it's also where the traditional space science, planetary science, and the human sciences intersect. And I have always enjoyed that. And of course my background with life support, exobiology, gravitational biology all work together, and that started that out.

When I came back I told Bill that one of the big holes in the program that you could drive a truck through was the life support systems that were being looked at at that time were about ten years old. And that there was no development program after Phil Quattrone (of Ames) died here to do that. So what happened was Bill and I formed the advanced life support division, he was chief I was deputy, and that's what I did for about a five year period of time. And then Bill went back to Headquarters, the red team white papers started, and it was recommending basically that Ames be almost shut down. And that the space sciences at Ames be piecemealed out and thrown away. And the biggest criticism we were undergoing at that time was that the Ames program was too fragmented, we were doing this Earth sciences stuff, and this life sciences stuff, and this grav-bio stuff, and this exobiology stuff, and it was just diffuse. And I said, "no it's not a bug, it's a

feature! This is a strength, this is multidisciplinary, it's why we can do all the things that we could do." And using John Billingham's life in the universe concept, we put together a life in the universe counter proposal to closing this down. And it was presented by Bill Berry, and I have a copy of the original thing, by Bill Berry to Wes Huntress, who was the AA, Harry Holloway who was the Associate Administrator for Life Sciences at that time. And actually I knew Harry because I had been executive secretary of the life sciences advisory subcommittee at the NASA advisory council while I was at Headquarters as well, and Harry was the chair. And I think Townsend from Earth sciences, and the chancellors of Stanford and UC and Frances Cordova. And Bill presented "Life in the Universe", and Wes Huntress said, "that's it! But I don't like this life in the universe, we'll call it astrobiology.

SD So this was what, a couple of years ago?

LH This was '95, March of '95.

END SIDE A

SD So, let's talk about astrobiology then, keep going.

LH My background was eclectic enough that one of the things that I was able to do was to add value, not because I was necessarily a deep expert, but because I could bring tools and techniques from a different discipline and apply it to this discipline. So from life sciences to exobiology or to astronomy or planetary sciences or vice versa. And I discovered that disciplines tend to enclose themselves, and they build up a tradition in both thought and techniques, and the rigors of those developments are so strong that they don't generally jump to a very different subject. Like a physicist may wander into chemistry and the chemist may wonder into physics, but a physicist doesn't generally jump into biology. And exobiology was the first place where that really started. But the exobiology community tended to focus more on the non-human aspects of development. With the exception of SETI in terms of the advanced intelligence. Pretty much the program focused on everything up to the first billion years of life on Earth, and then the problem got radically different and was mostly the purview of an NSF evolutionary biology approach. And because of the NASA way of organizing things, manned space flight was just not even in the equation, and in terms of being a strong supporting element or an element for study. And Earth sciences had collaborations with exobiology and planetary atmospheres and so forth, but what we did in astrobiology is to say this is the continuum, there is no reason to stop of the borders of disciplines.

And our hypothesis was that if you were to take the great challenges in each one of the subdisciplines of Earth sciences, life sciences, and space sciences and synthesize them, the resultant would be a new set of questions that were so significant in their own right, that they'd become grand challenges themselves. That was the hypothesis, and we test it, is that true? Yes it is. When we started this in '95, and it was confirmed very rapidly through the Ames science advisory council, where the leading scientists from around the center are asked to serve as a science advisory body. And we took a look at whether or not the synergies that we thought we saw happened mostly ad hoc by one scientist happening to be in relative proximity of another scientist, and they do a collaboration

across discipline lines, whether or not there was more than there than what would happen just by happenstance. And so the science advisory council took a look at it, and they were able to generate a series of grand challenges for each discipline, and then a synthesis of those that formed the basis of the first conceptual content of astrobiology. Then we sat there and we thought some more, and one of the things that we packaged, collected up and researched is the progress that has occurred in the past ten to fifteen years in the questions of the living universe and what we now know, and what we can do. Couple that with the extraordinary explosion of electronic technology over the past five years alone, and all of a sudden we had a formidable new base, a much higher spot on the ladder, to start, and an array of tools that were breathtaking. And now some of the old questions that we couldn't even think about attacking before, once we got out of the boxes of the disciplines, and just jettison them, all of the sudden now we could really come up with some extraordinary advances towards answering these questions as well as posing some new ones. And the advances are how do habitable worlds form? How frequent are they? Nobody's even asking the question any more, is there any other habitable planet?

SD Not after the last year and a half.

LH And even with all of the facts related to the Mars rock, just in finding more planets outside the solar system than within, filled in the Drake equation to such a significant degree, that now you start looking for frequency.

SD Although there's still an inference there because you're only finding giant gas planets.

LH True, true, but it's at the detection limits of, but it's everywhere. I mean basically it's everywhere we look on the main sequence within the habitable range, we're finding something, and we're certainly seeing so many pieces of evidence of developing planetary systems. And that's the second part of it. The Hubble Space Telescope was an amazing contribution, because what became apparent just day after day as one dazzling picture after another started coming in with some other fantastic element of the universe, was that the processes of cosmic evolution seem to be in different stages at different locales throughout the universe. So you should be able to actually see them, and link together and pose those questions and do a comparison, and determine the roles of various constituents within these environments. The level of sophistication in sensitivity of the equipment was so much better than it had ever been that now you can do an unbroken link, and that's what we're starting to do. An unbroken chain of events, going from the big bang forward, and into not only the origin and evolution of life, and those extraterrestrial events or cosmic events that affect the evolution of life on Earth, but we were now able to pose a new question. We had been flying for ten years in space on the space shuttle, with Mir and on biosatellites, in a very organized and coherent way in the life sciences programs. We found a number of physiological changes that occur as a result of space flight, but no barriers. And so we were able to pose the question meaningfully for the first time, is there an evolutionary destiny for terrestrial life beyond Earth? And begin to answer that question. And in so doing, we start to redraw humanity's portrait, in that we are capable of engineering long-term habitable zones beyond Earth. In that when you look at issues of cosmic evolution, we need to look at

ourselves as a species that evolved from the planet that has the capability of leaving the planet, and establishing settlements on other worlds. Terraforming in fact other worlds. With all of that capability implies. And it's time to confront that part of the question because it's clear that it's within our technological grasp. It's also clear that within our technological grasp is an understanding of global ecosystem processes in a way that would allow you to manage them. And that management of such things may be a necessity. Certainly if our children are going to enjoy a nurturing, healthy ecosystem environment, we are much too powerful as a species to be ignorant of the effects of our rate of change.

SD So from what you've been saying then, astrobiology seems to be broader than exobiology but not quite as broad as the Origins program?

LH Probably broader than Origins.

SD Broader than Origins?

LH Broader than Origins in the sense of the breadth of life. Origins may be broader in the sense of the magnitude of the origins of galaxies. But this is the life chain and it goes through the current time, now looks at us as a contemporary species that is one of the most if not the most evolutionary force on it's planet that can design new species, and introduce them into the environment. That can rescue species from the brink of extinction, that causes the extinction of species. That can do all of this and take it to another world. That becoming the origin of life on that world, and establishing an evolutionary destiny, either through the natural adaptive characteristics of terrestrial life or through engineering them to be more successful in those novel environments. And we can do these things, and what effect does all of this have on the cultural evolution that is part of the intent process of technology and futures. So we're looking at futures and we're acquiring the tools to be able to predict when able aspects of change, that have evolutionary echoes that are profound.

While this is going on we are accessing environments beyond Earth that are just breathtaking. From my computer in a couple of minutes, I can get a picture of the universe as it looked 12 billion years ago. I can do this from my desktop! And I'm not the only one, a school kid that gets into the NASA homepage can do that. That is an extraordinary capability. We have a global village, the internet is so responsive or is so appropriate to the human condition that we consider it now any kid that is growing up that can't handle the internet is at a disadvantage in their future life, it is embedded in the culture. And we're cloning, we are genetically engineering organisms. In fact the thing that started me on the train of cultural evolution and in some of the studying humanity as a species of profound evolutionary importance, not only to this world but to others was I went to Las Vegas with my husband. They have white tigers here, they have elephants here, there is not one thing that as far as the eye can see in Las Vegas that's natural to this environment; this is a terraformed environment. And it is a challenging environment to enable the comfortable, even luxurious living of so many many people. And they handle influxes and outflows, and every one engineering job was probably handleable, but if you were to ever try to do that, the sheer magnitude of what was accomplished in that environment was awesome. They changed the course of rivers, they blew through

mountains, they created these oases in the desert and that's when it occurred to me, there is absolutely no reason that we cannot establish an evolutionary potential beyond Earth. And you can go through the philosophical debates of why would you and why could you, but I think we're rapidly approaching the time that we're saying because these have always been life sustaining, progress sustaining, quality of life sustaining enterprises and so they will be in the future. There's not a manifest destiny imperative, it may be just a sound genetic physiological recognition that the access to new terrains has always paid off all through history. So we're coming to the maturing of our species, and as we approach the new millennium in terms of what we can do and what we think we should do.

SD So all of this idea about astrobiology started a few years ago with a threat to shut down Ames?

LH It started with the threat to shut down Ames because it was too diffuse. It was saying pick one and stay with it, don't do all of these things. And we looked at that and we said no, and everybody said no. Even those who were in the best position to defend themselves said no. And that's a remarkable thing, in a territorial environment where my program is good and yours is well not as good as it could be. And certainly if it's a toss up, yours goes before mine does. That's not what happened here, and it was a very honest assessment and a very remarkable technical assessment, enabled by enough cross linkages among people and scientists that we had examples of the success of interdisciplinary collaborations. We had enough of them to make the case. And then we started taking a look at what it meant to access environments beyond Earth. What it would mean to start finding life in abundance. We had to start confronting the idea of life in abundance once we started detecting planetary systems and recognizing it's just a matter of time and technology before we can resolve planetary atmospheres and determine bio-signs within those atmospheres and in fact there's a whole plan on that, the pale blue dot workshop report put together by Desmarais, and Carl Sagan attended and a lot of leaders of we can image these things, we can do this. At the same time, we take a look at Mars. The trial by fire and Mir was one of the best defenses for the continuation of human space flight, these guys are up there with a quarter of an inch of metal separating them from vacuum, with a fire. The life support system went down, the CO2 removal system went down, the oxygen system went down, and they were able to pull it off; that's a very robust capability. And that's a primitive device, that's a primitive system. We never lost the focus of going back to the planets in person. There is a technical reason for doing that, there is a symbolic reason for doing that, and it's just the right time to go do that. And they can be the moon, Mars, or both, but we have never been better at designing robotic vehicles. The questions of the Martian history is one that will probably only be answered or can only be answered either by human missions over the next 30 years, or lots and lots and lots and lots of robotic missions over the next 100.

SD So where does this stand now? As far as, I mean you have to advocate this program to somebody?

LH I'm not sure how much of an advocacy it was, Wes Huntress was the one that put in the word "astrobiology", and when we discussed the content of the program, this is where we start. What we're saying is that here are the big events in the evolution of life: the big

bang, the origin of life, multicellular organisms, and what it is in the future. The Origins program goes through the origin of life but it doesn't really go through the origin of intelligence and other things. Although it does discuss them.

SD That always seemed to me to be an artificial stopping point.

LH It's completely arbitrary.

SD Because of Congress, right?

LH No! Scientists stop themselves, it's because of management lines. In other words, if I'm in one division and this goes over to your division, you and I may never make that connection, we may never make that hand shake.

SD But aside from that you are forbidden to follow up SETI these days, by Congress.

LH Ah, no you can talk about it, you can't pay for it. No, freedom of speech is still alive, guaranteed by the constitution, you just can't pay any money on it.

SD Right.

LH What we did in astrobiology is says it's all important. Now, how do you make a program of that? You don't say, "wow, everything in the universe related to life is ours in astrobiology." We said no. What we're going to do is determine what the key questions are. In the '96 NASA strategic plan we won. And that was the first time astrobiology is mentioned, it's defined as the study of the living universe, it's said that it provides the scientific foundation for the biological investigations within NASA, of the origin and distribution of life in the universe, gravity in living systems, and the study of Earth's atmospheres and ecosystems. These three are existing programs. What does astrobiology do? It goes beyond those, and it asks the questions that require the linkages of those or the sharing of knowledge and resources and talents from these and it goes into some new directions, some of which are partially being addressed by new programs, many of which are not. And that's what astrobiology should do - start filling in the holes.

SD By the way the word astrobiology was used back in the 50's already.

LH Yes. Yes it was. And this was our operating hypothesis, was that our integration of knowledge from these endeavors when you couple it with the suite of discovery and tools that are available to us today, allows us to address questions about the living universe that were not possible until now. So what are these recent discoveries? And recent is a big word. In relation to the frequency of life, the discovery of 11 extra-solar planets, possible life on Mars, certainly a warmer weather Mars, suggestion of a possible life site under Europa's ocean - or ice mantle rather, discovery of the material exchange - the magnitude of material exchange between planets. That has become extremely interesting . . . the Mars rock did that for us. All of the sudden we're looking at the possibilities of the exchange of viable organisms.

SD Panspermia again.

LH Absolutely. And if that wasn't doing it, we're doing it when we go out into space and we dump wastes outside the spacecraft into the interplanetary medium. Most of its going to burn up, come back in, some of it's not. And there were organisms that were found on the Moon after several months that were still viable, and so the survivability . . . oh and LDEF [Long Duration Exposure Facility] came through, showing the survivability of organisms in interplanetary space is far greater than the biologists have predicted. And the tomato seeds were a great example, they were there for seven years. And they grew.

SD It's all part of the life in extreme environments, you know, inside rocks and thermophiles and all that.

LH Exactly. That's right, and the envelope of acceptable life sites has grown to be so great, what would you eliminate? Boiling hot environments? Freezing cold environments? No! So the habitable environments have become much better defined, and have increased dramatically from our earlier thoughts. The discovery of the probable site of the Cretaceous-Tertiary boundary, now we all know that now, but at the time that was big debate element, and that's a recent confirmation of the Alvarez hypothesis on the survival potential. The early dating of life on Earth, how fast it started, the life in extreme environments.

SD By the way I talked to Desmarais, and he said that he thinks the life on Mars issue is about the same place the 3.8 is, in other words the 3.8 billion years ago for origin of life is still pretty uncertain, the 3.5 is certain, but 3.8 is about as uncertain as the Mars rock, is his opinion.

LH Right. And I go along with it, but it's certainly clear that it happened relatively fast because at 3.5 you have thriving microbial mat communities, and those are not, those would have taken some time to develop. The genetic engineering, molecular evolution in the test tube as we get closer and closer to the synthesis of an artificial cell, humanity is the most powerful and deliberate. The idea of an evolutionary event with intent is a new way of viewing at least our own role in terrestrial development - extraterrestrial development in terms of where our sphere of influence goes. Cloning, ozone hole, the release of increasing numbers of genetically engineered products, we can occupy space explore other worlds, establish settlements. The changes in global culture made possible probably by the space program. In talking with a lot of the reporters, and since I've gotten interested in cultural evolution I've tried not to miss an opportunity to talk to them about it. But the idea when people saw the Earth against the array of space, when we were able to see that from the moon, that it really did cause a rethinking planetwide. What was Asimov's line? Saying that Russia has pollution problems is like saying your side of the boat is leaking.

And just that thin band of atmosphere that's all that's separating us from a non-living world. And the space program - computers and communication. I really think we're seeing a profound change because of those three things, because of global access and communication. It is very difficult, and I think the Vietnam war showed that it is very difficult to watch a war, and to have it drag on for a long time, and to knowingly participate in bringing that much misery. That's not the image we have of ourselves,

thank goodness. It was gratifying to discover, we don't consider this to be an admirable trait of humanity. And when we could watch it occur, when we could see famine we can coordinate and mount relief efforts on an immense scale that just was not possible. The change of life brought about by nothing else but weather satellites so you can evacuate areas, and the saving of life that is the resulted I from that has been by itself an enormous change.

So there has occurred a change in our view of us versus them that has extended far beyond the boundaries of any one nation. More even than the melting pot characteristics of the United States. And with enough technology, wisdom and knowledge, we can direct the future of evolution of Earth and other planets. It would be a conscious intent, it may have to be a conscious intent. So then you put in the tools, this is not as grammatically presented, but the extraordinary computing power, not just the memory size, but the ability to do multi-variant, data driven model sets with increasing fidelity, increasing accurate in their portrayal of real world events. World Wide Web in terms of the communication tool between geographically dispersed groups so you don't have to move somebody from Massachusetts to here to collaborate, you can do it over the web. Permanent space laboratories, we've been in a campaign mode, I don' t know how much any field of science would progress if we only got to view and experiment for a week once every few years, which is the prior mode even with the shuttle. But once you get a permanent space laboratory up and you can continually change out experiments, do new stuff, take advantage of opportunities without delay, you're about to go to a step function increase in terms of the returns from those missions. The tools in molecular biology and genetic engineering, not only are they fields in themselves, but those tools when applied to questions of the living universe will allow us a lot better fidelity in answering questions about the origin of life, it's potential elsewhere, it's destiny elsewhere.

Nanotechnology just brings in a whole new realm of accessibility or sophistication, size of new types of instruments for studying planets. Global remote sensing is obvious, the ability to observe and model the globe, and to verify the accuracy of those, and to have it accessible by so many people, that was the other thing, you want to see anything in the world, there's a web site there that you can basically view any part of the world that you want to through the emerging frequent access to space, not just orbital space but deep space through the millennium spacecraft planetary missions. The Discovery missions, Goldin's new NASA "better, faster, cheaper" has actually happened, and it's an extraordinary improvement; this is a better NASA than it was when I came here in '86. The presence in robotics, when we started looking at establishing manned Mars mission that were self-sufficient for the mission duration, we were going nuts with the resupply and life support, you know it's 11 metric tons per person per year in an open loop life supply system, and that's a big amount of stuff. But you can recycle it, the problem is that you'd like to live off the land as much as possible. So we had some conflicts for in situ research utilization, but we positively strained ourselves trying to come up with robots that would tend this stuff, and you're going well you know, it's not like a plant moves all that fast, we can tele-operate it, and we can. And so will it be tedious? Sure. But it's a heck of a lot cheaper than trying to have a robot that's that smart, and of course eventually we'll get there anyway.

And the frequent access to the planets - ok, you put it all together, what can you do? So you can determine by what properties do matter and systems self organize and develop into increasingly complex systems. How do living systems emerge from molecular chaos? That's the real question. And the answers are probably scattered all over - you can do it in the test tube, you can observe them occurring in the interstellar medium, in the developing planetary systems you're starting to see structure emerge out of that molecular chaos, I mean it's doing this spontaneously; it's a very fundamental property of matter. How frequent in occurrence is life? How do we habitable worlds form? In fact of the biogenic elements upon which life requires to evolve, are they necessary for the formation of planets on which life can evolve? Can you have planets in the absence of them? We don't know of any cases that there is. We only know our solar system right now, but we do see the biogenic elements scattered throughout. Is that only because it's a happenstance of this solar system? Are there other solar systems out there that don't have those, or one of those is missing, can it still be habitable? So maybe there is a way of detecting the potential for habitability, and we've just started asking that question. Hubble is giving us some access, Great Observatories are, there are new technologies that would be required to trace that through. How do you maintain a habitable world? Did Mars have life and lose it? Does Mars still have life somewhere in an aquifer or deep setting? How do you maintain them? Are cometary impacts necessary, detrimental, does it matter? How do life and the environment change each other? What is that relationship? Is it organism to organism, species within species, niches, physical, chemical, and biological and start taking a look at how those changes persist. And one of the places that you can examine that is in space. Because you're taking everything with you, you're changing one variable - gravity, and you can examine that whole engineered environment, it's a natural ecotron, and we're doing it all the time. But by the way they never looked at that. No one has looked at using the spacecraft itself as an experiment in ecosystem development. Because the Earth sciences guys and the human exploration of space guys, they don't intersect that often. And in fact it was one of the space sciences people that said why don't you use the spacecraft as the examination of artificial ecosystems? You know what you put in it. It's one of the most documented environments that's ever been created, it's isolated from absolutely every other input that you can think of, you can see that change over time if you start looking for it. And that would be an emerging new area, is every time a spacecraft goes up with biological inhabitants including the biosatellites, we'd not only need to look at the individual investigations that are under way, but the environment itself, and start refining our knowledge of ecosystem development.

One of the real treasures that the space-biology programs have brought back to Earth is a understanding of the incompleteness of our knowledge of life. If our models of living systems were 100 percent we would be able to predict what happened in space, and of course you can't do that. We've had many, many surprises in studying living systems in space. So it's telling us where those models are incomplete. Similarly, we can begin doing that with ecosystems.

What is the biology of exploration? Now this goes in and out of the view graphs, depending on how comfortable the presenter is with it. The idea - and I'll admit to introducing it - is what is the genetic basis of the exploration imperative? All through time we have found one excuse or another to go some place else, even when we didn't

have to. I mean there were vision quests. The guys that decided that they we're going to go to the south pole - now why do you have to go to the south pole? I mean at that particular time there was no driver whatsoever for anybody to go to the south pole. But as a result of taking that step, we've discovered the ozone hole now. It always pays off, we probably instinctively know that because not only do these explorations occur, but they tend to have the support of their government or their tribes or their cultures that says, "yes! Some subset of our population will go out to some bizarre, strange place, and if they come back, we'll know something important." And all through time when we start looking at it this has been codified in many cultures in many places. So when something is that widespread, I suspect genetics - that there is a genetic basis that says this is a good idea to do, and we are driven towards it. It's not just a matter of the "we ran out of room". Because frequently we didn't run out of room when we start these endeavors.

What's the potential for biological evolution beyond the planet of origin? Now this brings in a lot of questions: it's panspermia to start origin of life here, it is us starting, becoming the origin of life elsewhere, it is looking out our own evolutionary destiny and whether or not there is an evolutionary destiny for humanity in extraterrestrial environments. And it's all wrapped up in a question of how planet-bound is a living thing? How dependent on their initial environment? Creating and sustaining ecosystems obviously in order to sustain populations that expand, we're not dealing with the camping mode of life support, or even the field lab of a space station. We're dealing with an ecosystem that has to evolve in an alien place using indigenous resources, and our ability to engineer those environments has also taken a step function increase over the past ten years. So we have a reasonable expectation of success. This is another one that goes in and out of the viewgraphs depending on how comfortable the speaker is with it, how can we predict and manage evolution? The hypothesis of some of us - and I'm one - is that we are rapidly developing the computational tools and the scientific insight to create models that would predict evolution. There are others that believe that evolution is far too idiosyncratic, and dependent on chance, and there are too many variables to ever do this effectively. I'm not sure. Certainly those that made the argument, "oh, you're never going to see it, it doesn't matter because evolution occurs at such long time constants" are reevaluating that position in the light of the new information about just how fast speciation has occurred in the observable sense. And it goes back to what the role of intent, how did these change cultural evolution, how did cultural evolution change your ability to address or answer these.

SD So who do you present this to now?

LH Everybody.

SD Anybody who'll listen?

LH Yeah. One of the things, we don't have a group - we have all groups! And including sociology and historians, this is an active process of examining issues of life in the universe, and it's at the embryonic stage so we're not prepared to throw anything out yet. So we organized the astrobiology workshop that occurred in the fall, and we had members . . .

SD Yeah I think I got a copy of that, that was last September?

LH September. And that had a wide representation of the science community, and it was through that that we started asking questions that clearly had cultural . . . . the answers to many of these questions will impact society. And the web probably made us alert to the idea that this can be a participative endeavor, and maybe should be a participative endeavor. And so that's bringing us into contact with people who might have been isolated from this type of development as maybe to esoteric or nonrelevant. But of course the public likes it very much.

SD So who here at Ames has been most involved with astrobiology?

LH Dave Morrison, Scott Hubbard, Don Devincenzi, Jeff Cuzzi, Sherwood Chang, Bob McElroy, Emily Holpin, Mal Cohen, Charley Wade, Dave Peterson, Chris Potter, Kevin Zahnle, Lou Allomandola, Bill Boruki,

SD And how did this happen that all these people got involved? There must be somebody spearheading the whole thing, right? I mean how did this group pull together?

LH You're asking a great question, I'm not sure how to answer this. I've been intimately part of this since it began, literally since it began. Bill Berry was the director of the Space Directorate here at Ames. And we were, remember I told you about that meeting, it was on a Sunday. The AA's were going to show, Franz Cordova who was chief scientist, and either the provosts or chancellors of the UC and Stanford and the center director of Ames of course, were going to come in on a Sunday and basically decide our fate. And we had one pitch, and I remember this clearly because Wednesday before the pitch was to be made, Bill circulated the presentation he was going to give. And I read it and I was horrified, it just basically said, ok, kill us.

SD This is Bill . . .

LH Bill Berry. And that was what he had been given, and I said, "no!" And I called him up, because I had worked for him, he had been division chief, I was his deputy. I called him up and I said, "Bill, you can't do this," he said, "give me an alternative," he goes, "give me any better alternative and I'll take it," and so I said OK, and I came up with I think it was this pitch. And it was based on everything we had been doing at Ames but had never collected together to make the case for the power of multi-disciplinary work.

SD So what was the date of this then? Of that meeting?

LH This was like March 20, it was in March of '95. And this was it, it says reinventing Ames Space alternative concept is collaboration. And we started using NASA's own studies to talk about this.

SD But this was after . . .

LH The red team white paper, I can give you a copy of that too. These are some of the seminal documents . . .

SD I'm just trying to piece them all together.

LH Yeah, ok. And here was the problem statement that we were looking at. We were looking at significant budget and manpower decreases. And what all of the alternative strategies were being proposed were being proposed for consolidation on the idea that consolidation will get you more for less. So JSC was going to get all of manned space flight, JPL was going to get all of robotic planetary missions, Goddard was going to get all of Mission to Planet Earth. They say, oh good, we'll stratify the whole space program into armed camps, and what we said was, "no!" The other way of getting more for less is to collaborate, and to use the multidisciplinary nature to realize better products faster, cheaper, and all of these things. Is that possible? And this was the case was we made, that yes.

SD You know who else would be a fan of this?

LH What's that?

SD The Vice President.

LH Well as it turned out, he is.

SD I was at that meeting, have you heard about this meeting, December 11? He kept saying interdisciplinary, interdisciplinary, the great thing about this is all the people it brings together from so many disciplines, just what this does.

LH Well how widely are you going to circulate this information and how soon are you going to do it? Because there's stuff I tell you off the record that I certainly don't want me on the record . . .

SD All I'm doing now is just gathering information, there's not even any guarantee that this history will ever be written.

LH Ok. Well this next thing that I'm going to make is sensitive enough that you should know it because it's sort of the background real truth, but actually most people even here don't know it happened. We used the web, we used Keith Cowlings Rif Watch, you know Rif Watch?

SD Yeah.

LH We used Rif Watch first of all to protest the red team white paper, to disseminate the alternative, and to make the case for interdisciplinary work.

SD That's the astrobiology on the web, there's something like that . . .

LH Well yeah, but this was before that even existed. This was in '95 and we got it out to everybody. And I don't know whether that was the turning point, but we did discover all of the sudden everybody started talking about interdisciplinary, multidisciplinary. We

put together a bunch of arguments for it, what it will do for you, how you can handle it, how it's different from other approaches.

SD Sorry would you give that date again?

LH We received that red team white paper, I'm printing it out for you. It's right on the top of the page, because it's off of my email. By the way email was the vehicle for this. What would happen, oh it was bad. Something would be marked confidential and they would receive it from email, and they had it out to the world within hours. And people hated some of the things that were going on with the red team white papers so much, I mean I was getting calls from New York minutes after I had sent it to five people. It was amazing. Astrobiology is a program the web enabled. And it was a response to what was happening, and it the reinvention and it was an alternative, and bless Goldin's heart, he took that alternative, he accepted a good alternative.

SD February 2nd '95, now who wrote the white paper?

LH Well it was the red team at NASA headquarters. And I don't think we were ever able to find all of the names. We didn't try too hard, but I don't think we were able to find all of the names. Oh and here's the chronology of what happened, and what we did. I actually wrote the chronology down because there was a feeling at the time that everything was hopeless. And I tried to say we've already had an impact, we've been able to change this direction and I needed at one point when morale was particularly low to say that.

SD So then when was the decision made not to go with the red team recommendation and to go the astrobiology route?

LH 3/26 and 3/27 '95. ARC Space briefs Cordova AA's provost, turning point for ARC code as origin of mission lead in astrobiology. It was March 26, and the draft I showed you was dated and created March 23rd, that's how close we were to the line. And Jesus, does this bring back memories. And Goldin confirmed it on May 19th, and announced it at a press conference. The primary focus is information sciences leave for Ames and astrobiology lead for Ames. And the science would be an institute and the door was opened for further negotiations. In fact what you have there is the chronology for NASA reinvention. Not only what happened for us, but everybody else you'll talk to, there were major events that I've got listed here that were turning points in thought. So if you can get the source documents from each one of these things, you'll see the evolution of change, not only from our center, but from all the other NASA centers as well.

SD Oh, that's great.

LH Yeah. And I have all of the source documents, unfortunately, they're in there. I'm going to be moving.

SD Don't get rid of the documents.

LH No, but they're all in these boxes and I'll never find them until I actually unpack every single box. Ok. Oh and then we had a ball doing a lot of writing development and sharing ideas, and in fact here's the initial origin of astrobiology.

SD Now the idea of the institute ...

LH Ah, I can tell you where that is. We're looking at downsizing the staff. We're also looking at another problem that's peculiar to the civil service which is realigning skill mix to be responsive to new opportunities. Just because you have three botanists does not mean that you're going to be able to do an effective space mission without engineers, but there was going to be a hiring freeze. Obviously if we were going to be getting rid of people we weren't going to be hiring people, and there was no way of surgically getting rid of people in a bureaucracy. That's the bottom line, you do it by union rules and seniority, and that's not necessarily going to get you the best thing. So what can you do? Well we basically said, "why not work collaboratively?" This goes back to the solution to all problems is collaboration. Rather than do cut throat competition, let's start sharing resources under broad umbrellas. Like astrobiology, we'll pull together of team of two engineers, a computer scientist and a materials guy, and an Earth scientist and a space scientist and a life scientist and they'll form a team and they'll do an investigation of a Mars probe. Or they'll do an investigation of planetary atmospheres, or artificial ecosystems, or whatever. But instead of keeping the teams always established because you've hired them and now you have them forever, use an institute to bring together temporary teaming arrangements. If it turns out it's going to go ten years then you make a different arrangement. But most of these at least investigatory, speculative experiments, investigation experiments, maybe three years. And everybody's got day jobs that they're going to go back to, they're going to teach at universities or they're going to do the next level of work, and that once you complete a body of work, each individual member may want to take off on a different direction, there's no reason to keep them locked together either. Let the whole system evolve, that's the foundational strategy; let the system evolve with as much freedom as you can.

So the institutes were proposed as a way of enabling that. And what we were proposing initially, and I have the concept background on this one, is . . . we looked a few models. We looked, well I'm almost afraid to say institute, I've got a gizillion documents on them. Here's an institute white paper. This was April 29th, '97. So this was one month, this was our first concept for how we could do this not reduced role for Ames, we were proposing an expansion under the same budget constraints, and this was our idea on how to do this. And I was the source - Scott Hubbard, Kathleen Connell, Keith Cowling, although most people don't know he was involved, he was a pretty risky ally. But Keith Cowling was involved in this, and Kathleen Connell and Scott Hubbard and I wrote this, so this was our first concept on what the institute was, what it could do. And it was in the, this was our first attempt to model it, we addressed the issue of reinventing NASA, we hit hard the issue of multidisciplinary work, and this was the institute white paper, and it got pretty specific. We were able - I'll give you one other document because it was important, it was the analysis of Ames and multidisciplinary, what it could do. And we distributed it everywhere with every mechanism that we could find.

SD Yeah actually the origin of the term astrobiology, I remember reading on the web.

LH Yeah. Well Keith is somebody who is involved in this, in fact he is more involved in this than he may even know.

SD Where is he?

LH He is on Rif watch on the web.

SD Where is he physically located?

LH Reston.

SD Oh, that's a few miles from where I am.

LH I know. He is the manager of an element of the American Institute of Biological Sciences. He actually has a day job where he is employed by AIBS, but at night he is the webmaster of Rif Watch, and he is at www.reston.com, and just tell him that you and I spoke, and I told you that if you don't have Keith Cowling's part in all of this, you don't have the whole story. Oh there are people in the system who would kill me for making that statement. Have you seen rif watch?

SD Yeah, I've seen that. I've looked at it once or twice, but not lately.

LH Oh, some of his old stuff where he was really yanking Goldin around was powerful. And . . .

SD Do they read that at NASA?

LH Are you kidding me? He's the best source for space news anywhere! He's better than space news. He's more accurate, he's got the insider information from everybody, we all send information to Keith, he is NASA's underground. In fact Goldin when he started created the underground, it was the first time. And I remember talking to a guy that Goldin brought in I think from Los Alamos, his name was Joseph - I forget his last name - he was terrific. And he was saying that he and Dan were working on a strategy to give the asylum back to the inmates, and he succeeded marvelously. Goldin was proposing ideas that were so Draconian. And NASA still harbors a command and control mentality, for the most part it comes from a project discipline. Ames of course does not have a lot of that discipline, so we were probably some of the least affected. But the closer you were to Goldin, the more strict what you thought he wanted became. And it's not clear that what people thought he wanted was what he wanted because whenever we proposed an alternative that was truly a better idea, he just took it. I mean it was not a hard sell, in fact it was one of the easiest sells we've ever done. Again, I think what we're proposing is a right answer. I don't want to say we're the only ones doing multidisciplinary work - we're not, but NASA was becoming so compartmentalized both from it's discipline relationships as well as it's organizational structure, that we were in danger of just fragmenting the whole agency. And it would not have resulted in a better product, and it wasn't resulting in a better product.

SD But how about Origins, do you give Goldin credit for Origins which organized things systematically around a central theme?

LH Yes, I do. I give him credit for a couple of things. One is that he wanted bridging programs, and I don't know if our arguments were influential in that decision or whether others were, but it's certainly the right answer. What had happened was as you recall office of space sciences and application under Leonard Fiske used to contain Earth, space, life, and astrophysics as separate divisions but they came together at monthly meetings, so there was a lot of interchange among the groups. And Goldin came in and he created the office of Mission to Planet Earth, Human Exploration and Development of Space, Office of Life Sciences and Applications, and took exobiology out of Life Sciences and moved it into office of Space Science. All of the sudden we lost all those connections. Life Sciences when I was there had all of those programs. I don't know, did you know that? That life sciences division under Gerry Soffen had biomedical research, space medicine which was different, advanced life support, the CELLS program [controlled ecological life support program], biospherics or global biology program, because my first job there was to write the global biology program plan. Not write, but edit it as a technical writer. So I got all of the inputs and then had to organize it and make it a coherent story. And that was my first job there, so I worked on the global biology program. The next one was the exobiology, and at that time it was called space biology, which dealt with non-human biological aspects of space investigations. That persisted all the way through at least '92 because of SETI.

SD SETI was put under TOPS for a little while before it was completely chopped.

LH Right, that was about '91. Was that about '91?

SD It would have been.

LH Ok '91 and '92 exobiology and SETI went to Space Science, and that was the death knell. Life sciences was actually a better advocate.

SD I was going to say, what's the story behind that, why that was done. Was it just the new administration coming in.

LH I was out of it then. I don't know.

SD Do you think Life Sciences definitely though was a better advocate than Space Sciences for exobiology.

LH The exobiology program grew from 6 million to 16 million, and then it went from 16 million down to 6 million. It looks clear to me. And Nicogossian, who is eccentric even by NASA standards ... Nicogossian is an interesting character, and he's a real player in all of this. Nicogossian went to the mat for us in SETI, and we wouldn't have made it without him. And no one will give him credit for that, but nobody knows the inside story like I do in his role.

SD You mean at the point you were getting the 10 million?

LH Yes. It required the division chief to fall on the sword. And that's what it took, the Division Director of Life Sciences had to go up and defend this red-haired child to all of the people, and he had to stand there to somebody who says, "well I'm going to take it out of your hide, you're not going to get that increase in biomedical research, the astronauts are going to crash the space shuttle. You're supposed to take care of the astronauts up there." So he had to go make the case for this crazy program in Life Sciences, and how to handle the increased money and still meet his responsibilities in keeping the astronauts happy, and he did it. And he defended it in Congress, he used his advocacy routes, because as a Division Director he was responsible for briefing and educating Congress, he used those routes to tell the SETI story, to provide us with opportunities to tell the story, he provided us with seed money, he never raided the program other than the usual token raids that they all did - 10% rake off.

SD But then the whole thing was killed.

LH It was killed. And I think - I don't know for a fact but I think if it had remained under Nicogossian, also during that time Holloway was coming in. So it was a mess, that was a time period where you had a lot of new people coming in, so you lost your advocacy route. But anyway, exobiology was taken from Life Sciences and put into Space Sciences, in return microgravity sciences was brought into the Office of Life and Microgravity Sciences and Applications. Under the idea that these people use the same research environment, therefore . . . I don't know, benefits will accrue if they all sit in the same place. Which when it comes to living systems is not a real accurate thing.

But at any rate, global biology remained. Well global biology was actually transferred almost in total to Office of Mission to Planet Earth, at the same time, now that used to be in Life Sciences. What they retained was an absolutely amazing program that demonstrates multidisciplinary nature, and that is the medical ecology program or remote sensing and public health. And that's when they began to use remote sensing techniques to determine the vectors for malaria, and where they would be located so that nations who were plagued by these problems could go in and eradicate those swamps. And since we're talking about countries that are fairly poor, it had to be fairly surgical in order for the country to be able to afford the manpower to go in and take care of these areas. And here at Ames is where it was developed, and it was a union of medical issues and global remote sensing. And it was done in Nicogossian's program, he was one of the primary advocates of that. And you'll see where this is heading because Nicogossian is back in Life Sciences. And astrobiology is as much his creature as Billingham's in the way that he supported these unique multidisciplinary programs when nobody else would touch them. And he had the courage to do that. You really should meet him because when you do you're going to think I'm the world's worst liar. He will be weird, he will be vague, he will talk in a strong Armenian accent, which by the way gets worse depending on whether he actually wants you to know what he's saying or not. One of the smartest people in the world, but he will not act that way. But he's an experience, you should meet this one.

SD So when exobiology was transferred from Life Sciences then, it came under . . . .

LH Huntress.

SD Huntress then.

LH Right, and global biology went under . . . it could be Shelby Tilford, but I think he got eliminated in the blood bath. After Len Fiske got fisked, I think Tilford was gone at that time too, and a new guy came in, maybe it was, I forget who it was, Thompson maybe? I'm not sure.

SD So where does astrobiology stand now then? I mean right now.

LH Who has it? Everybody has it.

SD But Ames hasn't been reorganized.

LH No, why would you? . . . reorganizing for a program that crosses the discipline boundaries. Basically we all still do work in each one of the contributing disciplines, it's just that the door's been opened to encourage new kinds of work, and new kinds of ways of doing work. And right now, yes Headquarters is having the challenge of trying to figure out how they're going to fund this puppy. Because how do you make a budget from these different funding threads from these different organizations. So we are challenging them with that and we're not helping them come up with the answers all that much, but again we're just starting. There are some activities under way already, and some of it was enabled by our center director and the other player in all of this is Harry McDonald.

SD Who is the center director now?

LH Harry McDonald. Ames has had a checkered history of center directors who I don't think realized what they had in this culture, and what to do with it. And McDonald is another thing, McDonald is the center director Ames always wanted. We love him.

SD What was his background?

LH Interesting. He is an aeronautics, he's got his doctorate in aeronautics but his holds a patent on a device for heart valves. His wife is a physician, and he's very comfortable in a multidisciplinary milieu. In fact he's very comfortable in it and we're very comfortable with him, he's been a breath of fresh air. And Morrison is great. First of all, Ames right now from the division level on up through the center has the most talented management lineup I have ever seen in my career at NASA. And that's a long time, it goes back to '82. And this is the most talented management team in that they are largely collaborative. And that is saying a lot.

SD You're optimistic about getting funding then?

LH Well we already have it. Wes Huntress has secured over $40 million this year from that President's summit meeting for the combination of astrobiology and origins, 10 million of which is - not this year but next year - 10 million of which is earmarked for

astrobiology right now. Life Sciences is also kicking something in. Earth sciences, we expect to develop, they're lagging a little bit just because we don't have an actual staff in astrobiology. I am the one full time no conflict astrobiology person here at the base. Everyone else is doing part of their work that they've been doing in their disciplines plus donating some of their time for astrobiology development, and that's where we are right now. Over time I would expect that would shift more and more, and more and more people will spend more and more time, of their professional time in the implementation, the actual hands on research in astrobiology.

SD If you're the one person now, how do you fit into the exobiology here in building 239?

LH Well this is the life support floor, ok? And on the next floor you've got Life Sciences and Earth Sciences and on the top floor you have space sciences, that makes it a perfect astrobiology building. I work for Don Devincenzi, I used to be the division chief of Advanced Life Support, I got out of management because I had a three year old at that time, and division level management in NASA is more than a full time job, and I didn't want to have to make the choice between my son and my work, and do a bad job at both. So I asked to get out of management, and went into the technical development of astrobiology. I worked for a while for . . .

SD Probably more interesting anyway.

LH It's great, oh yeah, I wouldn't go back for anything. Of course after the twins are born . . . clearly not going to go back. But yeah I worked for Center for Mars Exploration as well, that was a great time, with Geoff Briggs, and we worked on developing some of the Mars concepts. So that's what I did between the idea of astrobiology and the reality of astrobiology, which is just really coming into it's own right now, it's happening as we speak, it's the most exciting event, at least on a par with SETI, SETI was pretty exciting, and because it can encompass it. And in fact we have made the statement in at least one of the versions of one of the write ups that we've done that the search for extraterrestrial intelligence is valid and should be pursued. And so we will revisit that when there are people that want to devote the time to making that happen.

SD You think it's possible that NASA could once again sponsor SETI?

LH Sure, why not?

SD As long as Bryan is still in the Senate?

LH If we have a concept that is fundamentally new, or even proposing the next generation, and there are people that are willing to spend the time necessary to advocate this in recognition that it's a potentially at least hostile environment, the case for SETI has never been better. We have found planets, we're no longer even projecting that there might be planets which is where we were in '85. We had Beta Pictoris, I mean we made a lot out of Beta Pictoris, we used that picture everywhere.

SD It's in my book too.

LH Yes, yes. Ok, so that was '85. Just follow the Drake equation through, a computationally based system, look where we were in '85, we were producing some of the first VLSI chips, the digital signal processing engine that was the heart of the MCSA. We laugh at that now, we laugh at those clock speeds, this is an old system, so our ability to do these things has never been better. Hey if anybody said that I could put together a group of five of the caliber of the SETI people that we have, I'd go for it again, I'd do it. And we'd make it. It's the right thing to do. And I do believe that NASA when confronted by the fact - it can be influenced by facts - will do it.

SD NASA can, but will the Congress?

LH Yeah, I think we found that that was true, but you have to have so many. Each individual there is truly an individual, their vote does count, and there's 535 something like that, congressional members and any one of them can stop you. So usually you don't have the staff that is capable of covering 500 places, and as we saw, one guy could stop you if you got the wrong combination. Let's say you could only hit 100 with any kind of meaningful presentation. Just your statistics would tell you that at some point, a guy who hates you, five people who like you and 25 people who don't know you, are going to converge in some place in a decision time. And that's what I think happens, they couldn't win with the magnitude of the voting.

SD Well you've got Gore on your side, I can tell you that. Have you talked to anybody who was at that meeting? Like Chris McKay was there.

LH And Yvonne Pendleton, yes.

SD I mean he was obviously very excited about it, it went on for three hours and he was having fun.

LH It is fun. The fun is back in NASA. It is fun, this is the kind of thing that empowers us as a people, and are really no threatening parts of this. We are far more powerful in our non-space activities in terms of the impact that we can have. This puts us in context of something great. I noticed when you started your book, you raised the issue of little people confronting a big universe, and that can be frightening. And in fact that's my mother's view, she says, "are you really comfortable with all of this space stuff?" And I say, "yes!" and she says, "well I look at that and I feel so insignificant," and I said I look at that and I said, "I can understand that. And I feel enormous." And so it's how we're handling those things. Gore has clearly been an advocate for this. Whether he is convinced for astrobiology or he has his own interests that converges, this was the right program at the right time in the right environment, and I think for the right reasons.

SD I gave him a copy of my book, so maybe that helped out.

LH I bet it did.

SD I don't know if he actually read it or if his staff briefed him on it, but at the meeting he talked about it several times, so . . .

LH Did you ever read Gore's book on . . .

SD I have it, but I've only skimmed it, I've never really read it.

LH It's a brilliant, clear, it's clear that he understood the problem of bureaucracy. Where is your book? Is your book available in book stores or is it something you have to order?

SD It's Cambridge University Press, it costs $50 so a lot of bookstores don't have it. It's going to go into paperback probably early next year when it will be $15 so then they'll all get it. But right now . . .

LH Yeah, but I'll get the original version, this looks like something that my library can't be complete without. This is a major thing.

SD Yeah, I've got the whole history for the century in, so . . .

LH I definitely need to read it.

SD But this has been great, I mean, I didn't realize how much of this was going on in the astrobiology angle.

LH Oh, and there's so much more that, we're just . . . what I would love to do if I had known, there are things you should see at this center of what people are doing that were foundational for the concepts in astrobiology. What the Earth sciences people are able to do, using GOES data, triangulating, they're going to determine where the outbreak of a disease is in a city. And what they need to find are vegetation areas within a city that are no bigger than this room where there are the right combination of rainfall, dogs, and a certain vegetation kind that identifies that breeding site of this mosquito, in a city, because that's where an outbreak has occurred of this particular disease. And watching triangulate in on these conditions using those models. I mean it's just awesome. And in so doing you also get an appreciation of the resolving power of this equipment. And so you're seeing maps of cities with literally vegetation types identified and distinguished from another green plant, that's pretty amazing. I know with stuff like this, when we started doing the medical micro and the planetary atmospheres work that Pollack used to do with Brian Toon, and the ozone hole. The discovery of the ozone hole was partially an Ames phenomena, and in determining the characteristics and the causes Ames is heavily contributing to that. And that was the result of a collaboration between a space scientist Jim Pollack, and the Earth scientist Brian Toon, examining planetary atmospheres, comparative planetology of planetary atmospheres. And they were able to determine the mechanisms resulting from that collaboration. That was one of the really big multidisciplinary activities.

SD Well it's almost 5, can you suggest any other people I should talk to? I'll be here for a couple of days yet.

LH Will you? Sure. In fact, I'll take this, I'll write down the names of the sort of astrobiology brain trust. By the way, we're adding new members every day, but these are the ones who have been in from the beginning.