COM CON KEYNOTE ADDRESS

DR. LYNN CONWAY

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Thank you very much its a great pleasure to be here with you today and an honor to present this keynote talk at this Spring IEEE ComCon talk. It is this talk today I would like to expand a bit on the theme of this conference, the theme of Intellectual Leverage In An information society. I think we are all seeing advances in computer-ated design in manufacturing and networking in environments and applications that make it possible for individuals and especially for small groups of people and for communities of people to accomplish things that were difficult, if not impossible, in the past. Taken together a lot of these advances can be seen as intellectual multipliers or levers that is as tools enhance our leverage and in leverage our analytical abilities are creative abilities and our ability to communicate with each other. Whats interesting I think is computer scientist and engineers as the creators of this new technology were among the first to be fully immersed in it, to really fully experience it, so maybe we have an added opportunity here. Perhaps we can reflect on, and share some of our experiences we can understand better how to create and to apply this intellectual leverage.

During the talk I'd like to surface and kind of brain storm a bit about the following questions. Where is this leverage coming from what does it consist and not just for the individual but for groups and communities as a whole. I also wonder if we can find ways to

better explain it to other folks, perhaps some stories, some metaphors that we find that get at some of the key ideas. I'd like try to raise some stories like that, to tell you some. I'd also wonder when as find the insights like that and find ways to explain these things to each other how can we create more leverage, what methods can we use to make more of then and finally how much more can we create that might be the limits to all this. Lets take this first question. Where is the leverage coming form? I think it's now pretty easy and almost intuitive for us to see how a technology leverages our individual abilities. We can actually go out and just measure how our machinery, how our software systems can let us analyze something, create something, or communicate things and some larger scale than we could before. We can see this all around us, we are used to using our machines at work, using electronic mail, maybe working in group projects in the networks, that sort of thing, so we can simply measure how much faster we can do things. This is individual leverage and I think it has taken some time for collective intuition to develop about all that and when those ideas were first articulated, for example, by Doug Engelbart back during his work at SRI, I think a lot of folks found that sort of way of thinking about our machines a bit hard to catch hold of. But now we look around us and I think most of us can just in just every day activities accept this idea of individual leverage. But we also see something else when we look around and that is some really giant social changes being caused by our technology. Effecting us, effecting the we work, the way we play, but, it is also effecting everyone else throughout our society. I

wonder if we can explain those rapid social changes by just adding up the effects of a lot of individuals getting a little bit of individual

leverage so that each do their thing just a little bit better. Is that all it is, is it just some sort of added in thing, or is it something larger and deeper going on? Well lets get to rounder questions like how does our culture change anyway, what is that when we look out in the world makes tomorrow different from today. How can we think about that, what I think about that question I sort of think in the following way, If we each just did the same mix of things from day to day then the world then the world we interact with would stay the same for most of us. We would see everyone else doing the same things over and over. But we don't do that our culture isn't that type of stable force, instead we each gradually change a little bit the mixture of things we do each day, but we just rotated those things around among us things still might be stable. But, we don't do that, we do more than that. Occasionally we innovate some new artifact, some new behavior and some of those innovations propagate through the culture and I guess you can see that it must be that the weights of innovation and the weights of propagation are large, then a world might change quite a bit, maybe not day-to-day but certainly year-to-year.

Now we've already visualized our technology can give us a little added power, give each of us some extra abilities be didn't have before. Now that might give us a chance to do something we couldn't do before, to produce some innovation. But the thing I want to focus on and wonder about a little bit is I wonder if we've noticed

how our technology gives us each that chance to innovate but also gives us a better chance a much better chance to propagate the innovations that we do make. Provides better paths for observing and communicating things, maybe thats where some of these social effects are coming from. The sort of thing I like to think about, and I wonder if perhaps somehow in the _____ of the situation, in the accumulative effects of advances in technology we might have some added group leverage or the genesis* and diffusion of innovations in social communities. This is the main area I would like to get into in this talk.

What I would like to do now is tell a short series of stories that I found really interesting and that gained some personal insights from and think you might find these stories interesting and maybe you can see some things in them that I haven't seen. I think they are just intriguing stories that get out this point, well what is an innovation anyway, and what does it consist and how do innovations diffuse around? What do we develop our intuitions about these things? And a little bit later after I go through these stories I'd like to tell you a few more about how some of us have been trying to acquire what we've learned from these stories to doing some things better ourselves.

Theres a fascinating story that I first heard in an anthropology class at Columbia, this was more than twenty years ago I guess, twenty-two, twenty-three years ago and I guess that was about ten or twelve years after the story had first been told. This story has helped me look for more things like it so I can share it with you. This is a sketch from Bonner's book on the Evolutional Culture In

Animals and the start is kind of a good icon for the story, a visual symbol for it, maybe something used to remember it. In the late forties some British bird watchers noticed members of a particular small species of bird opening milk bottles and drinking the cream. Sort of an interesting thing to notice, kind of a quaint kind of behavior, while this phenomenon attracted curiosity, the news about it spread among the bird watchers and a lot of folks began to look for it and the people were looking for it all over and they noticed that it was occurring only in one small area. They only saw these Blue ~~Tipped~~ Tit-Birds, as they were called, in just one little region opening milk bottles but then suddenly this behavior spread, really over a period of months, it began to spread rapidly, much like an epidemic. I've just sketched a sketch of the British Isles that shows some profiles where you can imagine people looking for how far something has spread as a function of time, or perhaps their measuring density of behavior. The idea is that this behavior of these birds spread very rapidly and diffused into places where it hadn't been seen before. Then we think about whats going on here, if you study birds a little bit you'll find that bird has an instinct for contact switching when they see another bird feeding. If a bird of a species sees another of its species members pecking away at the ground or pecking something thats close to them, and it notices the behavior a lot, its going to start doing that, its going to start pecking also so you see some possibilities here. Lets think of how this might have happened, maybe there was an open milk bottle somewhere and one of the birds just accidently happened to poke around in it and got some cream and that was great and so it kept drinking.

Maybe it went back the next day and the milk bottle was sealed but it just started doing the same thing and so it got the reward, gradually other birds of the same kind started imitating this behavior. You don't really have to hypothotize* that these animals are conscious, you can see some possibilities for simple explanations but how the group acquired this behavior. But in your ____ once the innovation was made it would have been threshold if diffused rapidly, once it started there were enough of a density of birds perhaps and this was easy enough for them to imitate that it spread very rapidly and became a staple for it and people from the British Isles tell me that to this day they hadn't known where this come from but to this day in some areas, people still take counter measures against this phenomenon. Basically if milk is delivered in milk bottles they put little caps over the milk bottles otherwise once in awhile these birds will break the milk bottles open. They wonder in what does this innovation consist and I tend to think of it as something that you get enough speculating these birds being even conscious really somehow it consists of its behavioral feasibility for one thing. In its imitateability* by other species members and by the fact and measures of its behavior production over space and time, thats what the innovation is, its a form of behavior that the group has acquired. But I wonder thinking about this what might have gone differently, I wonder why it might have diffused faster in one direction than another, what if the birds themselves had had a slightly smaller feeding range, if they had only fallen around their local block instead of for the adjacent three or four blocks would this phenomenon have somehow started to really propagate, maybe it would have been below threshold. So perhaps

the innovation might have gone in one local area or just lost altogether. Now the biologists are not interventionists* like computer engineers and computer scientists are and they might not think along this next following line, but, I started thinking stories like this, what if you had a few birds that you had raised that were members of a species like this and you could train them to do some interesting thing, like open milk bottles. You wonder what processes could you use to perhaps propagate this out into a natural population, I mean, if you had enough of them that you sort of wondered how would you space them around so that the phenomenon might go above threshold. How could you cause a thing like that to happen. Well anyway this story about the the birds was itself so noticeable and memorable and so easy to retell that it propagated very rapidly and widely among human biologists. They started noticing this same kind of thing going on in all kinds of other animals, as it turns out, and just in the decade following the propogation* of this story some of the most interesting observations were made by Japanese biologists of innovations made by wild Japanese ~~macaw~~ Macaques's, small little monkeys, on a remote island off shore of Japan. This is a photo of Becks' Animal Tool Behavior" that shows ~~why~~ Macaws Macaques washing food in the ocean ~~and~~ its a good icon for this story.

It turn out that when the biologists began to observe this particular group of monkeys on the this island the, they were to stabilize their food supply, maybe there were other reasons like making it easier to watch them. They intervened to the extent of placing food on the beaches, in particular, sweet potatoes. One day a young female monkey was observed taking the potatoes and dipping

them in the water to wash off the sand, none of the other two members were doing that, and the biologists noticed over the next few weeks they noticed that other troop members were observing and imitating this behavior and gradually it diffused through the troop of monkeys they had just all habituated* to that, they took the sweet potatoes they took them down to the water washed them off and then ate them.

Now a little bit later on, and this is the part of this story that I find pretty intriguing, is the biologists added wheat to this monkeys diet by piling it up on the beaches and this exact same monkey genius, her name was ~~Imo~~ "Imo", thats the name they gave her, discovered that by dropping it on the water that that was a good way to make it taste better, to get rid of the sand of whatever, who knows what this monkey was thinking about or how they did visualize what was going on but the monkey did something with the wheat like what they had been doing to the sweet potatoes and it worked. Now this is a fairly complex innovation but it also eventually diffused throughout the troop.

Although their was an interesting measurements these folks made of the _____ diffusion of that innovation and ~~we~~ They found that it diffused more rapidly among the young than among the older animals. The young seemed to have a, provide a little more adaptive edge of the troop in a playful way trying out new and strange things, whereas, the older animals seemed to be the conservators of the accumulated innovations of the troop.

These kind of stories really intrigue me and they help you if nothing else build some intuitions and also lead to further questions

in our minds. You might think that somehow its fact is like the noticeability, imitateability* maybe the the association with food or reward, frequency or density of occurance that mediates the diffusion process, the acquisition of a group of an innovation like that.

The other thing about the story about ~~EMOE~~ Imo that I wonder is, would ~~EMOE~~ Imo have invented this weak placer* mining thing, if she hadn't first invented the potato washing. Maybe there is a possibility of seeing an accumulation there, anyway, what about more complicated situations. I wonder do innovations propagate in some similar ways in human groups? This is a topic of considerable interest in anthropology, and some of the recent work is revealing, interesting. This is a figure ~~form~~ from Cavelli-~~Sportus~~ Sforza and ~~Spellmans~~ Feldman's book ~~on~~ "Cultural Transmission and Evolution", and it show the diffusion of across ancient Europe of complex of food production innovations. As early farming displaced the age old hunter collector methods a quantitative models are being developed for processes like this as data is being accumulated the models are being tested against further accumulated data. I we can all afford to some deeper insights about these things in a picture as people do additional research on this. But just observations of the work is interesting, I think you will notice that this agriculture wave was pretty slow paced. It moved a lot more slowly through Europe than the milk bottle opening process moved through England. If you look at the chart, I don't think you can see the numbers on this, but it moved a thousand miles every two thousand years. When we think about this particular innovation it was a large complex of things somehow it had to drift together, there are all kinds of processes that must have analiated* that. But the big one

(p 43)

dimension, one thing I've thought about it is just in one narrow dimension, that somehow it was inexorable once started because among other things it enabled must greater population density than it did food collection. So large numbers of human culture carriers, the carriers of the new form kept filling in behind this moving wave front, as it moved there was a denser population on the other side in some sense keeping up pressure of on that way front. Those are the kind of things you might think about in _____this sort of process. But any way once the food production wave had passed through, we go down centuries and centuries and start looking for other innovations in this food producing community. We find that some things later spread extremely rapidly, for example the use of copper.

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Anything like that could have occurred in the earlier food collection era, maybe those things helped the copper use spread so fast.

In thinking about stories like this I wonder what really determines how really fast one set of innovations diffuses and displaces another. How can we visualize what the mediating in the structure is those structures and processes that effect or determine such things.

Now some stories from more recent history that I found interesting and I think that they helped reveal a bit what the infrastructure* is, by showing the dramatic effects that occur when you change it. It seems like a circular process, but bear with me. If can just tell the story which shows a a dramatic change, and in

the story I think we can surface a visualization of what it is thats causing such rapid change.

When I talk about change here, one thing I want to point out is that whether its the replacement or displacement or propagation of food production versus food collection. Or something recent like steamship technology replacing sailing ships. I'm thinking in terms of measurable things like the number of people that do the thing, or the number of carriers that form or members of that clan. Or else the number of artifacts of their behavior, their productions, things that we can count. Rather than placing any value judgments or trying to specifically described that particular form other than to contrast it from another.

Now there is an interesting way of researching history a school of thought pioneered by Bordell that focuses on this demographic the way you view of things and instead of studying the historical details the fine structure at the top of civilizations. People in this school of history studied widespread, deeply embedded structures of everyday life in the mass of the population. Trying the changes in these over periods of time, its amazing how stable these structures have been over time. Of course if we think about it basic subsistence agriculture has agriculture has been much of the pattern for the mass of people over time. So again at that level things change very slowly even as wars raged and empires rose and fell on top of all that, so that idea of cultural inertia kind of marks that school of history. And Rodell* himself becomes fascinated with the question of what are the limits of the possible? Seeing that things are more stable and harder to change than most people might realize. And by limits of

possible, I mean how fast can you cause actual change to occur, we can all sense what might be possible but it can be hard to make it happen or to cause it to happen.

Well anyway there is a similar work, a work based on a similar way of doing history that documents something very different than this view of stability in the sort of underlying mass of the population, and that is Weber's fascinating history of the very dramatic rapid modernization of rural France over a short span of about forty years from the period of about 1870 to just before the first World War. This war contains many many lessons and I want to paraphrase and this is really a paraphrase. Of just one short story from it, sort of a quarter of a page from this book, kind of hint at the things its looking for and to share some of the insights we find in work like this. This is the story about a rural rural village in France, a rather isolated clan of peasant farmers they have a very unique local culture small group and their culture has drifted a bit from all the other local clans, they don't interact with them very much and so they have their own strains. Little dialect, patterns of things that they do from year to year and so forth and it turned out, one of the things that effected them is that they had limited energy resources in this region and in this clan their innovation to cope with that problem was that in the winter time all the villagers would huddle together in one house at night and once it got cold they would pick a house and thats where they would all go and huddle together around one fire and then maybe after a week or two after they demolished that place they would move on to the next house and this process went on through the winter where they all huddled together. Now its

interesting to think about that because thats just an innovation and you could measure it in terms of energy, savings, but, there is something else going on there and that is as a side effect more than a side effect maybe its a central phenomenon here this was a novel element in their communications intrastructure. It mediated the formation and propagation of th their stories their oral traditions, these were illiterate peasants and it was through this gathering together all in one place every night, in the winter that they propagated forward in space and time. Their relatively stable isolated little cultural form was relatively stable from what little outside influence there was at that time. One year, and I think the cover of this books suggests this, although, in this case its a railroad rather than a road, but one year a roadway was suddenly cut through the woods right by the village, cut through the fields right by the village and a year later lots of strangers began passing by the village, the villagers began forms of trading with them. Trading they had not done before, turned out for various reasons the economic efficiency was increased they had some things that were worth in some distant places, than perhaps they had realized, and the young in the village gradually began to travel off to some of these distant places. A few folks that were literate happened into the village, maybe they would stay there for awhile and they would read letters that they received from folks in distant cities and stories about the life those cities reached these villagers. Gradually, because of the increased economic efficiency there wasn't a need for them to huddle together anymore and so that started to decline and so instead of just interacting with their own clan each villager

gradually began to interact with the outside world. That local culture faded away and a new form had appeared.

Now thats just one little local village with its own unique culture, but, the point of the story and the thing I find sort of sudden visualization thats really amazing is that, you read this book you realize this exact same thing was going on simultaneously all over France. Right at the same time railroads, roadways, telegraph lines, postal system, schools being dropped down everywhere, teaching the modern French language, all of that was going in at once and as this transportation/communication system was laid down all the thousands of local peasant cultures drifted in form from their unique forms and converged around this new intrastructure. And new forms propagated through that intrastructure of communications and transportations and so forth. A lot of them more intentionally propagated from Paris and the urban centers. So thousands of local folk innovations disappeared, but, the door was open further and more deeply extending the new domain and innovation of that time, industrialization.

I'm sure that we can find lots of stories like that now the effects of the the industrial revolution are occurring in many other countries, maybe not as suddenly and dramaticly and with such a sudden crystalization* and in such a directed manor as it happen in France, but, I think we can see that the, somehow, the form and the parameters of this transportation and communications system determine the rate of the resulting changes by resetting the limits of what was possible at the time.

Now these perspectives from the historical stories as I think about them, they make me wonder, wonder if there isn't a similar

thing going on in our own time. It's an information technology playing a similar role right now, because it seems to me that the central position of the now stable industrial intrastructure, the centrality* of all that is being displaced by the new information intrastructure which is sort of independently lacing in everywhere. Going in and among and around all of that existing stuff and it just seems to be happening all around us. I think we all know a lot about that, but, we can also see it in our mass media, but, without the perspective of the these past stories I wonder if we might really realize the dramatic possibilities, what lies ahead.

There was a recent National Geographic issue, some of you may seen, speaking of mass media, it had a long picture story about chips in the valley and various aspects of computing. There were a couple of pictures in it that struck me as rather touching reflections on what seems to be happening right now. ____ Even if we see a course that now familiar course of child at play, intensely involved in interactions with a computer game playing, but also becoming a person in the world ahead. And we also see a picture of a Nebraska farm family as it turns out interacting through their machine, with a whole network of software applications and activities and friends and businesses in the mid-west. So I think here we see something of what reminds us of what happened in France that somehow people all over the place are finding new ways to intermediate actions with other people, with the world. New ways to conduct their lives, they are changing what they do with their time through the machines and the networks and the software that we are creating.

So whether we like it or not we are agents of change in the world, thats what we do and our technology has already had a huge effect on things. We are working on the second derivitive*, we produce things that other people use to change their lives. Now if you think for a moment we are also able to use that new technology to help us in our work and I think it's amazing that we can continue to apply in past innovations, to help produce innovations but, we can use our technology to propagate our innovations. So I think we have finally got quite a bit of leverage, both individually but especially collectively. So that what we have seen so far is just the beginning.

I'd like to tell you a story about some of the work that I've been involved in, in my own group we have brain stormed a bit about how to improve our methods, and how to use our information technology to help us innovate and propagate things. How we have applied some of the insights gained from things like the biology and anthropology and history stories that I have told. I'm sure that we have just scratched the surface in this and there are a lot more things that we could discover in this area. I think it would be interesting if we perhaps could allow ourselves to share stories like this, see what more we can learn.

This is a story about the design and propagation of _____design methods, and here is an icon for the story, I think there are a number of lessons to learn in this and many of them are straight forward. It does take some innovation to make complicated things simple, so you might look for that as something to try to do, something new to do. To make things simple because what we have learned is that when you can make things simple they propagate more

easily, and there must be some thresholds in all that. Also it seems that things are more likely to propagate if they are noticeable. If you can't see them and observe them and kind of think about them they may not propagate, but if you put them in a form where those things happen they might propagate better that they would otherwise. Also they propagate if they look like they are fun to do, and if doing them proves to be fun that really also seems to help. Also if the doing of the thing thats fun to do produces artifacts that you can go show your friends thats also something that might further the progation. But I think the story reveals to me more subtle things and complex things, things that I am really just now coming to grips with and getting a better feeling for.

And that is that the production of a piece new of technology, some new knowledge of one form or another isn't just a thing in itself it doesn't get out there, it doesn't become a real thing, it isn't in a sense an innovation, if it doesn't also generate around it its users, and all the cultural forms of its use. So that is something to look for in this story that somehow technology and its use is jointly involved but it also I'll point out along the way ways we used our computers and communications environment to help us do some of this.

In the mid-seventies I and my group at ~~Park~~ Xerox PARC began collaborating ~~Carber~~ Carver Mead and his ~~in this~~ group at Cal Tech in an effort to create simplified microsystem design methods. What we are really hoping for is to be able to produce methods that system designers could use to create systems in silicon as easy as could in TTL. And we had some successes in that early work, I won't go into the details of it, its talked about in this book. But we begin a document these methods and

create some examples of their usage. In 1978 I traveled to MIT to teach an experimental course, basicly to run an experiment to see if students could learn and apply these methods to do successful design. So this was an experiment. We are also working on refining the preliminary text. In a one semester course there the students learned the basics of design and then did some design projects. I'm going to quickly go through a sequence of slides to suggest what I mean by a design project. (Slide presentation)

So I might have an architectural idea they want to do some image processing thing like mirror and rotate that map data. They might have an idea on how to block out the physical architecture of the structure of the hardware and subsystems and from what they learn in the course they can create register transfer levels cells that when replicated could implement those subsystems. They learn how to ~~way~~ lay out cells and silicon. Use some tools that would generate code that described their design and could use that code to run a check plotter for example, to take a look at that design, ~~their~~ there are about twenty projects in that course, and these seem really exciting for the students to do. I think a lot of the students feel at that time experience something. I remember back many years before the excitement when compilers for the languages first coming around. Chips at this time were something that students hadn't been doing, or compilers were amazing to do. So it was the sort of thing that if the students wanted to do this, the doing of it was tremendously exciting, they got very wrapped up in it, so it was fun to do or stimulating to do. Well after this course was over I transmitted these files over Arpa net

and here you can see a use of communications intrastructure. We transmitted the design files to the West Coast where folks in my group merged them together in a one giant chip type. And fabricated the chips. Heres a slide that is just sketches that process of taking the code and merging projects together, making mass, making wafers and packaged chips. Heres a map of the overall project chip with all those projects packed together. In a photo of the resulting project chip, and I think if you look at this, in the upper right hand corner you will see printed in silicon the same thing we saw printed that had been printed on a check blotter before, on paper. Also turns out since all the students got lots of pictures and chips and so forth there were a lot of artifacts started to go in circulation that let people realize that this thing was happening. I seem to see at the time how noticeable these artifacts were, so we made up lots of them and gave them to people. Well anyway a number of these projects worked and it looked like we had something really interesting here. And this course produced kind of a noticeable result, as the next school year approached we were working on completing the book and preparing it for publication and I was wondering what could we do next. I had already gotten some leverage by using the ---net, heres a map of the net. Just to send projects across the country and I used the net quite a bit for electronic messages with folks around the university community, but I wondered what if we found a way to provide mass implementation of silicon chips. A whole bunch of universities for students all over the place, that might attract a lot more folks to try out our methods to see if they work. It would also help us further test the methods to see if people could use them and

the stuff would work. So I got the idea of creating an automated server, software system that could interface the net with a lot of scale up for interaction with lots of people so instead of us having interact with people out there all over the place, we would have a server do this for us. Handle the electronic message and the design fall transfer from remote users. So I ___repeat of that slide I did before added one step something that mediates the remote interaction one step.

Now the summer of 1979 we worked on this software system and we announced out over the network that if folks would send us their design files by a certain date at the end of the courses, we would implement chips for them and we would implement them for free. We got a huge response over the network, people that noticed the MIT course running people thought "Lets try that out, lets get involved" well we sent out instructional materials, we ran some instructors courses. We also sent out over the network detailed instructional messages on how to organize the project labs, how to get involved in this whole thing. What protocols to use to interact with us, Xerox Park. We sent library cells out over the network that people could use to start doing their design. So we were using this network to help initiate project activities, so that folks could imitate the MIT type of course. An while that was going on during the fall Alan Bell over at Park pioneered architecture and design of thing we have come to call the implementation system. It was a software system that would interact with users messages, help us build up the data base of design files that were being accumulated to be fabricated. And then after the design deadline we could sever our connections with the n

network and use the system to organize these projects into multiple project chips and convert those files for mass making. Well during that fall, courses ran at about a dozen universities with a tremendous amount of competition and collaboration going on. People were sharing design tools among the schools; they could ship them around over the network and that sort of thing. But as people noticed the activity at other schools, that would kind of crank up their activity. Instructors really tried to see if they could get a good course going. It was really a tremendous excitement that was generated as this happened and especially as the design deadline neared. There was a great rush of activity all around the network as this deadline approached on December 4. Then the deadline passed and here is a picture of ~~Allen~~ Alan Bell at Park using one of the Park machines to interact with the implementation system to merge the resulting projects. So this just stands for the capturing of all of these design files. ~~Well the~~ The masks were mass ~~work~~ then made, wafers fabricated, project chips, wire separated and bonded and packaged. All totaled I guess there were over 80 projects from about 120 designers from all these different schools and these slides suggest the scale of the activity. This shows the idea of having one kind of wafer that's got multiple kinds of chip types in it. And in each type has multiple projects. And then finally, a student would get wire-bonded, one or two or three chips with just their project bonded out. Here's a little closer picture of that where you can see the final artifact the students got is one of these package chips shown at the bottom. Well these all went out about 4 weeks after the deadline--went out to all the students. They all got them back about the same time. As a really vast collection of

artifacts that we sent out, these now went into circulation. It was a lot of fun for everyone. We also sent out a little flyer where students could order further pictures of their chips that they could send off to Melgar// photographers down in the valley and so students were getting more and more pictures and those all went into circulation. Some of these students took their project pretty seriously and tested them. There was some interesting designs. Examples are, on the one hand, some full die sized designs like this list microprocessor that was done by researchers at MIT's artificial intelligence lab. This was an iteration of an architecture that was done the year before when I taught the course there.

There are many other innovative designs. One set of projects that was interesting was a set from Stanford University which was included in this adventure. This includes the first prototype of Jim Clarks ~~VOSI~~ VLSI geometry entry. It is the project down in the lower right hand corner. As many of you know, Jim's architectural innovations in that work have been the basis for an exciting new venture startup silicon graphics in the valley here. A venture that's trying to seize a commercial opportunity opened up by this particular innovation. There are innovations like that all through the project set so we sort of provided a canvas that people could paint on and a lot of people then came and learned and did their thing; learned things from it.

Anyway the large scale and many individual successes, projects, and tools from this effort helped us really de-bug our design methods and helped a lot of other folks debug the associated design tools that people were building.

But perhaps the most importantly the result went above thresholds in terms of artifact production, tool production and the provision of a sort of widely known about scripts for all the various parts of the action; the things that people did using theses kinds of methods and implementing projects that way. Enough people seem to find out about how to do it and find _____ that it went above threshold so it now seemed to imbed itself into the technical culture. We followed this process in some detail during just that couple of year period from MIT course through these adventures. For example, tracking by tabulating by school the evolution of their design environments; the kinds of tools they were using; the number of projects they were doing; what machines they were doing them on--that sort of thing.

We interacted over the network in message traffic to accumulate the information like this so that we could get some sense of what was going and understand where the successes were occurring and why; which tools were working and people found useful; and therefore, helped them get their projects done.

Let's reflect just a moment now on this story and a bit on the methods that we used just to summarize those methods.

First, we used the now familiar basic method of experimental computer science; generate and test. Do you have an idea; build a prototype of it, run it and try it out. We applied this simple experimental method to all the different things that we were trying to evolve. Things like the design methods, or the book, or how to run a course, or how to create a design tool. In each of those things had to go through some successive stages in its evolution from just

the first feasibility test of something; for example, the early notions of do we have methods that work down to the extended field trials of a development prototype. For example, running the adventure for lots of universities.

I think you'll notice that there were a large cluster of systems in this case that we were jointly evolving. All the things from the design methodology thru courses and projects and so forth. And then it was the doing of the projects that closed the experimental feedback loops on all of that.

Now I think you can see how the intrastructure we had access to--the computers and the communications--would let us get intellectual leverage as a social community, as a whole group of people. Not just the few of us at ~~Park~~ PARC or people at Cal Tech and so forth, but all of the people who were participating in this out at the universities. It was a very diffuse and distributed activity thru our computers our communications and also through the methods we were using that we were able leverage our intellectual capabilities and run this evolutionary process fairly rapidly.

I hope that by sharing and studying stories like this we can perhaps further improve our methods so that as this suggests our methods and our use of technology might make a real difference in whether an innovation can take hold or not. For example, you might have a situation as on the left here where there is an interesting innovation that may have some real promise; might improve some activity and it may start to seed but then go back _____ threshold and just fade away and disappear or merge into a much longer flow of the evolution of technology. Or, you might, as it is

suggested on the right, find a way to have methods that would let you rapidly exploit an innovation; propagate it if it works.

I think there is one other thing about this story I would like to leave with you is that ~~our~~ of feeling that when you create technology, when you create design tools, methods of doing things, intrastructure for getting chips quickly implemented, that kind of thing, you have to at the same time create the social rolls that people are going to play in all that. You have to provide names for these new rolls they are going to play. There is an implementation service. There is a fast turnaround remote implementation. There's all those kinds of things. Multi-project chips. Invented terms and invented rolls for people to play. You have to in a sense, somehow design and create a prototype and propagate the cultural form that surrounds the technology. As a community we need to be able to do that. A way I think about that is--think about a road; just a road off through some fields somewhere. And you wonder, what is a road? It's a piece of technology. It's hardware. It's a change in the physical material world. That's one way of looking at it. I think we often look at technology that way. But a road really isn't that. A road, in fact, in order to stay being a road, in order to propagate forward in time as a road, it has to be on the maps. It has to be in people's minds. It has to have people who think about using it each day. People that pay taxes to keep it maintained and the maintainers. All of that is what keeps the thing being a road. Otherwise, it will stop being a road. So creating a road means somehow the community, the technologists*, the group has to create that cultural form also.

I would now like to, as a final topic, speculate a little bit about the future and think about what are the limits to what we can create. Given the successes of our field so far, you might wonder what are the limits. As innovations accumulate we keep resetting the limits that are possible in terms of how fast and to what extent we can propagate changes; propagate innovations. It is clear that cultural inertia constrains those processes. Right now, given the technology we have there is still cultural inertia. That's a good thing. It provides some stability. But the inertia keeps declining as new technology appears that makes it easier for people. Increasingly independently of location so things don't just diffuse laterally basically, they can diffuse in much more complicated ways. For people to notice and observe those things, to interact with things remotely, to imitate them, to playfully try them out, then to start collaborating with other folks or competing with them to do the things and become skilled at doing these new things, our technology can help all of that happen faster.

So we have perhaps in our remaining lifetimes a chance to see a lot further into the future than what might otherwise been the case. We'll get a chance to see a lot of this running by us faster. Looking further into the future and experiencing more of the future possibilities. But forgetting those rates for a moment, what about the content of these coming changes. Are we really going to like these things or not? Well there are so many possibilities that I'm sure that as far as content of change what's technologically possible we can all brainstorm and there is a line in science fiction we could draw on where people thought about what it might be possible to do. But I

would like to sketch two different areas of technology that's kind of just now coming in. And, these are different enough that I think that they suggest the amazing the space of possibilities.

In talking about these things, I'd like to also have us now think, we're now looking ahead. But what if we were involved in either one of these--these very different things--how could we use our technology, how could we use the insights and the stories that we heard and that we might read and think about, how can we use that to make either of these go faster or go further or take form in some interesting and some rapid way.

The first of the technologies that I would like to talk about is one that is aimed at enhancing our own human visual and tactile and interactions with remote events, remote phenomenon. I think it is something that many of you have probably noticed already. Maybe some of you here are even involved in this technology. And that's the amazing things that are coming from the convergence of the television medium--especially video disk technology--convergence of that with computing technology. The convergence of interactive computing and imagegraphics* image generation with the sort of interactive real world like visual television images that we can get on interactive video disks systems. This promises to open up a whole new kind of dimension for human experience, for sort of seeing and interacting remotely.

There was a wonderful demo (end of tape--side 3)

both a metaphor for the idea and also in a way a propagation method for it. Just seeing it once you really catch the idea.

What this demo showed was a story of a person riding around Aspen, Colorado. And it could have been anywhere; it could have been somewhere in Switzerland, for example. But the person wasn't actually riding around Aspen, Colorado. They were sitting at their work station which had an interactive video disk system and some computer controls. Someone else, before this was all happening, had actually ridden around Aspen, Colorado and taken every possible turn that you can make in the town from every possible direction and video taped that. OK? Then he put all these sequences on to a collection of video disks. Now we can take that and with some simple programming and a little imagination on how to design a fun thing to interact with, you can sit at a computer terminal and you can start down a street somewhere, in fact they have a map on the display also so you can find out where you are, you start down the street and as you are going along you can say, "Well, gee, I think I'm going to take a right turn here and see what's down this other street." And so they showed the person doing that and click, click, click you are suddenly going down that street. At the same time they might be able to turn their head and look to one side and see the stores that they were passing; the buildings they were passing. And they could stop the bicycle or the car or whatever it was they were in or on and if they wanted to in a few places the could actually "go into" those doors or buildings--look around inside. All this was stored in a frame sequence so that this idea has become to be know as surrogate travel and that's a good term for it and it really sounds like fun to do. There are a lot of places in the world I would like to see that I am not going to get a chance to see and if I could, each night or whatever, sit down and do roam around one of them, that would be a lot of fun.

Think about this. Just looking at this slide we might be passing a village and we stop on our bicycle and we are looking over there and so we come down to a turn in the road and we say, "OK, I think I want to go look at that village, that looks interesting." So I take a turn and that's all in the frame sequence. And then when you get down into the village we might stop somewhere and or take a look off to one side and look at the scenery; maybe notice some familiar landmarks for example.

But think what might happen next. Suppose now we're not in Aspen Colorado just using simple surrogate travel but we're riding our bicycle around Zermøt. OK? But it's not a bicycle in Zermøtt; it's our bicycle exercise machine. So what these folks have done in this new system is something interesting. They have gathered data on topography and so when we come to a hill, we really got to work to get up the hill! Everyone can coast down the other side. We might have races; see whose good at scoping out topograhy maps could figure out a route to get from one place to another quickly, so we could have games to see who could get from one place to another. Actually, this isn't too far fetched. Because I think they are really are some systems on the market right now for bicycle exercise machines are built right in some of these video disk things.

Well what may come after that? What else could you do with that? Well what about connecting up such things with the networks and let's suppose we each in a group of us--say we have a dozen people--we each have the riding around Zermot in our bicycle

exercise machines applications things sitting on our shelf, we all decide to get in that some evening and we're riding around. If you had enough activity going in the networks, you could keep track of where everybody was so if you pass somebody or if they were coming thru you could generate images for them.

So I think you can see how in some kind of network video game you could actually merge some of the image generation and cause all kinds of new games to become possible. Chasing, hide and seek, all that sort of thing. You could just end up with all kinds of new ways in interacting with people. But I think you can see that that kind of game that kind of remote experience thing is just a metaphor for a new intrastructure that's opening up that will let people do all kinds of things they couldn't do before and share experiences and interact with things remotely.

OK now another coming technology that I think is interesting it's maybe a little further out on the horizon but maybe it has some possibilities that I would like to talk about now. The technology of creating remote servers that practical human reasoning. The practical application of artificial intelligence methods are in expert systems. In this case, instead of bringing the world to you and seeing it and looking at it and so forth, the idea here is sort of the reverse of that. It's how to plant some of your intelligence out in a remote server that does things for you somewhere else in the world.

To suggest some of the possibilities, I'd like to tell you a story about some work we have going on in my new group at Park. Work that Mark ~~Steth~~Stefik---? and Danny ~~Bau~~Bobrow--? and Sandra ~~Mat~~Mathei--? have underway. In this I'm going to sort of suggest how we've been trying to struggle to figure out some way of making the ideas

of what the stuff is visible to people. I think the thing that was so wonderful about the surrogate travel demo is that it stands for what it is. It lets all of us quickly get the idea and want to get in and do the thing and understand what it is.

Coming to the expert's system story, the group has been trying to simplify and try out these simplifications and propagate the technology for building expert systems. That technology is presently in a really archaic form. It is kind of difficult to get into. There are only a few human carriers if you will. It has a sort of modest number of practitioners in the AI community. So we are wondering how shall we proceed.

First the move has been toward simplification and the group has created a software environment on top of interlist that we call loops--this is the icon for loops. This environment integrates together some simple and easy to learn versions of major programming _____ including object oriented programming, data oriented programming, and the _____ programming methods that are used in AI--all of the things that are needed for knowledge representation in expert systems. Now we have the systems now in a prototype form and we hypothesize that it does provide a thoroughly and easy environment in which to build expert systems. And one that could be evolved toward eventually use by non AI specialists.

Now following what now must be a familiar pattern, we're trying to use our information technology to boost the process of trying this environment out, of simplifying it further and of propagating it. And so we have begun offering some intensive courses where folks study the environment and then build a little modest rule-based system. These are short courses. The folks do this in a short period of three days. They learn how to do it and then they try to build a little miniature system. Now one of the ways we have used our machines to help that is by having the students get started fairly easily by instead of building something from scratch, they modify an existing mini-expert system. So they are modifying an existing one. Also, the one they are modifying they are trying to build one on top of deals with really familiar real-world practical knowledge. Things that we are all fairly familiar with in our everyday life. And it does it in a simulation game world. We're trying to make this fun to do. The students are motivated in these course by the challenge and the fun of having to face the competition on the last day in the course and this knowledge competition as we call it is a play off in the simulation game world among the expert systems that the folks have built on the previous two days. Now here some plots of some icons and artifacts of the simulation game world. I'll just tell you briefly just what this world is like. Each of the student's expert systems controls the movement and the buying and selling of commodities by an independent trucker in the simulation world. And the simulation is animated--if you look at the big plot on the lower left corner that's what you'd see on your display screen--the simulation is animated like a video game and when the game is running there are trucks going all back and forth, zooming in and out of these places where you

can buy and sell things going along those roads, trying to avoid bandits and hijackers, if they are carrying breakables* they have to be careful not to go in a place where there is rough roads. All of that kind of think. OK? So that's what you see when the game is running. But the idea here is that unlike a video game where you would grab the control of your truck and decide each move where you are going to go and what you are going to do and just make you go do it, here your expert system plays the game for you. OK? You have to imbed in the expert system you created all the practical knowledge that you can come up with that's going to work, that's going to help you survive and maybe help you do better at buying low and selling high without running out of gas. OK? So that at the end of the game you might end up the winner and have more money than anybody of the game and that's the goal of this particular game to make more money.

Now, this is an interesting sort of thing to think about because I think the game is starting to help us to tell people the story of what an expert system is. These programmed packages that the people create are not just lots of procedures that include algorithms on how to buy low and sell high given the mix of the game board because in fact there is a game master who each game generates a completely different game board. So there isn't a fixed game board. The world is different each play. Also if someone were to come up with a way to algorhythmically* nailing this game master is just going to introduce some new difficult to deal with phenomenon in the world that you hadn't thought about just like life does in the real world. So folks have to struggle to come up with rule sets of what to do in different situations in order to survive in this game.

They are programming these at the level of this sort of practical reasonings so that if they do get into trouble they can pull into a stop somewhere and get an update on their rules. Get some new news, some new ideas about how to operate in this world.

Well here's a little closer view of the game board and I think you can see that while the game is running there are some dials and gauges there. What people do in this course is create a lot of their own dials and gauges so that they can watch what's going on in their truck. They certainly want to watch their fuel, they want to watch how much money they have, and so forth. They can, by observing all this as the game runs, they are also watching the rules flash by as they are executed they can get an idea of why their trucker has just gotten into trouble or just won very well in some situation. So they can think about how they are going to improve the rules for the next game. The creation of the game world itself; the world that the student's encounter, involves the creation of a complex class and object world--here's an inherent _____ that shows the structure of one particular version of the game, of some of the commodities you could deal with in this world. And this is what you will encounter when you get into this game world.

This slide shows and expert system builder deep in thought building his game player and then finally here's a picture of a group of players standing around watching the playoff. Watching their expert systems compete against each other. That's Mark S_____ at the keyboard interacting with the game master to sort of host this set of playoffs.

Well I think that you can see that besides providing a teaching environment, we hope that this game might be an easy remember easy to tell story that stands for metaphor for the key idea. The expert systems could be positioned as intelligent agents and servers for you out in the networks doing your bidding for you. If they can explain why they just did something and explain it back in terms of the practical rules they just executed, the rules that you had put in them. The _____ as the world changes someway that you can't cope with, then they can be easily modified at that same level of practical knowledge. There might be all kinds of interesting side effects of possibilities if this kind of technology could be developed, if more people could get into it, and know how to do it, to understand how to do it. Things we've thought about are that there might be a possibility for more commonly shared literacy of the specifics of practical knowledge that people use in situations. You could really externalize* what that knowledge was. There would be a language, if you will. An environment for expressing and formally articulating that knowledge. There also might be a lot of interesting scaling effects as we can each in a sense replicate parts of our intelligent behavior that we might just want to can for awhile and let them go off and interact with the world while we go off and do other things. Maybe try to acquire some new innovative behavior.

But now these two things I just talked about seem very different one is the experiencing of remote things yourself, the other is imbedding out in remote machinery some of your own reasoning processes. Now let's think for a moment. There's always chances for convergence. There's always ways for things like this--no matter how far apart--to interact with each other.

Let's go for one more step in that. If we were riding around Zermot in our bicycle exercise machine, and we see someone coming down the street, or we interact with a generated image of someone that's going along with us, think now, that might be another person that's causing that image to move around. Someone else is just out there in the game like us riding their bicycle around Zermot. On the other hand, it might be an expert system. It might be a player that someone has cloned off and replicated and has running in a server. For example, we might want to have an expert tour guide for Zermot to follow us around and show us things as we wanted them to do.

Well anyway, I think these two examples sort of suggest the infinite dimensions along which we might leverage our technology. To further augment our information infrastructure. In the process, will undoubtedly open up new forms of human experience. There's just no doubt about that. New directions for cultural change. Who can say where that frontier is going to end or where its limits might be. What the limits might be to what we can eventually create.

To conclude, I think you can now see why I think the theme of intellectual leverage in an information society is a good one for us for the '80's. How it can provide a larger context for our thinking; a larger framework for interacting with each other about our work and about how each of the things we are individually involved in might be converged and interacted with things other folks are doing. I think that by exploring the sources and the effects of this kind of leverage, we can gain both a greater role in events and at the same time a greater understanding of our role in events. Those things kind of go together. And I think we can see our role in events maybe one of far more influence than that which is first obvious.

And from that I personally gain a real sense of appreciation of how fortunate we are to be in this field at this time. A real sense of anticipation and excitement about the future.

I hope the stories in this talk will help you see some familiar things from new perspectives. And perhaps also help to to propagate some of those perspectives so that, for example, when we we see our seemingly simply natural event, like a little bird opening a milk bottle, maybe we'll wonder where in the world did that innovation come from? Wonder whether it's spreading or not. And what things are mediating that process. And when we observe a person using a powerful personal computer, interface to a large network, instead of sitting there reclusive programmer or running an arcane program that would have been perhaps our view a few years ago, maybe now we'll wonder if this might be a creative individual using strong methods of leveraging their technology to participate in or perhaps even lead some great adventure out in the network.

Thank you.