Question #1

- - Tell me briefly about your experience helping to create the
- original NSFNET backbone between the NSF supercomputer centers. How
- was this different from the Internet as it existed back then.

In the mid-1980s, before the NSFNET, access to the Internet was rather limited. At that time the Internet was basically authorized only to the US Department of Defense and its contractors. I remember being unofficially connected back then via such ARPA contractors, and when Bernie Galler at the University of Michigan called the ARPA office to legitimize my then dial-up Internet connection to the R&D Arpanet, it sure raised some eyebrows.

It really needs to be recognized that these ARPA pioneering projects laid the groundwork for the NSFNET, which then triggered the larger Internet.

The original 56 kilobits per second NSFNET backbone, using Fuzzball-based LSI11 nodes, became operational in mid-1986 between the five new NSF supercomputing centers and the National Center for Atmospheric Research. Those formally responsible got the links and equipment in place, but ran into difficulties making the system work. I stepped in and turned the backbone into a functional state, with access via NCAR's University Satellite Network project, and basically ran the backbone from then on, until the new T1 network came online in mid-1988. I remember that Dave Mills, principal author of the Fuzzball software, was of great help supporting the original backbone, and Scott Brim's group at Cornell University significantly contributed with statistics processing, and working on routing software.

The rather open-access nature of the NSFNET and new routing paradigms constituted a challenge for the Internet, which until then was basically a hierarchical structure centered around the Arpanet. With the NSFNET, there were suddenly multiple national backbones with very different administrations and modes of operation. In my opinion, the NSFNET activities most certainly propelled the Internet out of the US Department of Defense research context, and paved the way toward today's global and very broad cyberinfrastructure. In fact, the 1986 NSFNET had started at a time when using the Internet Protocol was frowned upon, due to a new mandate by the US government towards using OSI protocols instead

Question #2

- - Tell me briefly about your time with Merit, when the proposal to
- upgrade the NSFNET backbone to T1 was approved. The time between
- the award and when the backbone was up and running was pretty short.
- Did the team work long hours to get it done? What was it like working
- on the project?

I was the Co-Principal Investigator for the new NSFNET award to Merit at the University of Michigan. With Eric Aupperle as the Project Director having Merit commitments beyond the NSFNET project, responsibility to make the system and its architecture work was on my shoulders, with help from many people working on the components. I also had to spend lots of challenging time with the Internet community, trying to make them believe in our concepts, and that we would make things work.

We were working hard with Merit's dedicated staff, and our partners IBM and MCI, to make the project succeed. Lots was new ground to cover. The backbone nodes, which IBM built, were basically architected from scratch, and were really a distributed system of nine small computers, plus various other parts.

MCI thought we were pretty crazy, wanting unchanneled 1.5 megabits per second T1 links, instead of multiplexing them down to 56 kilobit per second voice-like circuits. When we told them that within a few years we need unchanneled 45 megabits per second DS3 links, they thought we are completely insane.

But, both IBM and MCI worked with us through all the issues, and we made it all work in time and within budget to the NSF, and they were generally excellent project partners and a real pleasure to work with. We worked a lot of long hours. We also got a lot of flak from people in the Internet community then, a number of whom could just not believe that we would be able to make it work at all.

Let us also not forget that an integral partner, as important as any other one on this project, was the National Science Foundation, as part of the NSFNET cooperative agreement. Steve Wolff and his staff were very involved, continually part of the decision making process, and extremely pleasant to work with. Beyond the award itself, the National Science Foundation most certainly deserves as much credit as anyone else for the success of the NSFNET.

Question #3

- - What was the impact of the NSFNET on the Internet after the T1
- backbone was implemented.

I think a lot of the initial Internet explosion was due to NSF's openness for usage of the NSFNET. Suddenly many more people, especially universities, came to the table. A meeting Scott Brim and I had with Pentagon officials resulted in opening up the Internet Engineering Task Force to the NSFNET and beyond. New routing complexities required innovative approaches, resulting in things like the creation of the still-in-use Border Gateway Protocol, to hold a meshed Internet of many autonomous constituents together. All this laid the ground work for industry to eventually step in, especially around the mid-1990s, to create an all but globally ubiquitous cyberinfrastructure that would change the world.

Question #4

- - Tell me how the partnership between a non-profit, academic
- institution like Merit at the University of Michigan, and private
- sector providers such as IBM and MCI worked, and who had what
- responsibilities?

All of us worked side by side, but all of us also played our roles. IBM delivered the backbone nodes, MCI provided the implementation of the T1 circuits, and Merit made it all work as a system. I was amazed and pleased by how well two very large U.S. companies were able to work with us in this loose federation Of very diverse constituents.

I guess a critical key to this was that we all really wanted to work together on the exciting NSFNET project, while having an opportunity to make a real difference.

By the time I left Merit and the University of Michigan near the beginning of 1991, to start at the San Diego Supercomputer Center, we had already made great progress towards upgrading the NSFNET backbone to a 45 megabit per second T3 capability and had demonstrated it in December 1990 to the NSFNET community: cross country and across several T3 nodes. Another clear success of the partnership.

Question #5

- - Did you have any idea the network would grow as fast as it did?
- How did you keep up?

We had no idea about how successful things would be, and how many people and projects would quickly come to depend on it. But those kind of things are still happening, as the Internet gets brought towards even more remote areas and to new uses. If the underlying concept is sound, like it is for the Internet, and it addresses a real need, it should come as no surprise to see heavy growth.

The issue with "keeping up" is to NOT view the Internet as a static "build it and they will come" environment. It is more like a living organism, that has to constantly evolve, build new components, replace or abandon old ones, and so on. Including always anticipating the need to accommodate new applications, new users, new environments, new technologies, and a seemingly inexhaustible hunger for ubiquity and performance.

Question #6

- - The NSFNET upgrade helped get the ball rolling toward the modern
- Internet we know today. Looking forward to the next twenty years,
- where do you see computer-aided communication going? If you were a
- young person just starting out in computer science today, what do
- you think are the next great challenges for their generation?

I could see people build beautiful virtual worlds in their computers, as a decentralized system, but networked with each other. I don't mean like today's often violent games, but environments, including graphical ones, that reflect the sense of what people would want to live in and work in and to communicate with each other, augmenting the real world. A person's part of that world may only exist in the local computer, under local control, but optionally connected and available to others. On the negative side, society would have to even deal more with computer addiction. How do you separate the real world from virtual worlds? Some of that is even hard today, where we already see the complexity of the real compute engine being the aggregation of computers via the Network.	In the next twenty years society will likely have to restructure eventually on various issues. Specifics, I don't know, but I doubt some of the current paradigms will be tenable in twenty years or so. For example the massive daily commutes people accept, to get to and from work, may not be realistic any more. But the compartmentalization of work and living areas make a change very difficult, and may possibly eventually be required very sudden. I suspect that during those times in the future, the network will have an even more significant impact on society than it does today, easing transitions, with telecommuting just being the beginning. Enabling cyberinfrastructure is, and will remain, one of the biggest assets society has to define its future and to evolve towards it.