Roundtable Discussion

Telesurgery and Robotics

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Charles R. Doarn: Thanks, everyone, for participating in our discussion today. I’m Chuck Doarn at the University of Cincinnati. We do a fair amount of work with DoD and NASA in the area of telesurgery. One of my colleagues, Dr. Tim Broderick, who is an avid telesurgeon, couldn’t be with us today. He sends his regards and has a lot of discussion points for our conference today.

Thomas Low: This is Tom Low from SRI International in Menlo Park where I’m director of the Medical Systems and Robotics Program. SRI has been involved in telesurgery from the early ‘80s, with very early work funded by NIH and Dartmouth. I was part of the original team that developed the early systems behind the Intuitive da Vinci as well as the current system called the M-7.

Kevin Hufford: I’m Kevin Hufford, a research engineer at SRI, where I worked on developing the M-7 robot into a deployable system that could be set up in a short period of time and helped harden it for working in an extreme environment.

Blake Hannaford: This is Blake Hannaford at the University of Washington. We work on robotics applied to surgery and have developed a system we call the Raven, which is also a portable telesurgery system. We have also looked at the characterization of surgery in order to drive requirements for surgical robotics, such as network characterization, and how Internet properties affect performance of telesurgery. Our surgeons here at The University of Washington work closely with us in the areas of surgical skill assessment, surgical training, and simulation.

Jacob Rosen: I’m Jacob Rosen, working with Blake on all of the above.

Charles R. Doarn: What I thought we would do is kind of use Tim’s outline that he sent the other day, along with a couple of other items that I actually brought up. I’m looking at this purely from a business perspective rather than a science, engineering, or even a medical perspective. Some topics for us today are the issues of latency, business models, quality of service, cost and potential future reimbursement, infrastructure to support such activity, bandwidth issues, and the general scope of telesurgery.

I started writing a manuscript with Tim Broderick, Gerry Moses, and others looking at telesurgery from a historical perspective. It has been said that telemedicine and telesurgery

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were, in fact, first used on Early Bird in 1964, one of the United States’ first successful launches of a communications satellite. I have often heard Dr. Michael DeBakey say he allowed people in Geneva, Switzerland, to observe an open-heart surgery case he was doing at Methodist Hospital in Houston. Clearly, the concept of linking two remote sites via a telecommunication link can be portrayed as telemedicine or telesurgery. In essence, however, it is really just television.

This prompts the question, what is telesurgery? Panel members, what is your definition and concept of telesurgery?

**Thomas Low:** For anything to be considered telesurgery, one would actually have to do a manipulation, rather than simply an observation or mentoring, which is a different sort of telemedicine.

**Blake Hannaford:** Certainly, that’s an important difference. Of course, it’s not enough to just provide manipulation. Surgery is a highly skilled manipulation and so the technology has to support that. It must allow the surgeon to do all the things done in a normal surgery, if not more. It has to give the surgeon confidence that the procedure is safe for the patient. This means paying a lot of attention to the quality of surgeon feedback, video quality, and latency.

**Charles R. Doarn:** Robotic surgery is really the foundation of interventional telemedicine. Some people in radiology and pathology might differ with our definition. The original intent of robotic surgery development—both with Computer Motion’s, Zeus platform, and SRI’s work to develop the da Vinci (Intuitive)—led us to believe that we could manipulate a device from a distant site, perhaps in the same room.

I know that Dr. Mehran Anvari and Professor Jacques Marescaux actually took that to a completely new level by taking the Zeus robot controls and moving them several thousand miles away. They were very successful in doing some of those kinds of activities. Do any of you have comments on this from your own unique perspectives?

**Jacob Rosen:** We should defer to the classical terminology of telemanipulation, namely, master and slave. The surgical console is the master and the surgical robot is the slave. As long as you have a master and slave with distance and a video link between them, then the definition of telesurgery is met.

**Blake Hannaford:** I would just add that the goal is to reproduce the capabilities of the human hand at a remote site. That’s another way to look at it, sometimes with the added benefit of miniaturization. The ideal system would be something able to reproduce the human hand at small scales at a distance. Of course, the human hand is incredibly versatile and it can do many, many things. This suggests that telesurgery is a foundation for lots and lots of different types of procedures and interventions.

Another way to look at it is that, if the task involves manipulation, the best user interface is clearly the surgeon’s hands. The surgeon’s input from the hands and feedback to the hands could be connected to a little miniature reproduction of the hand, but it could also be connected to a steerable catheter, laser, or some kind of other interventional device. A key proportion of telesurgery is the user interface to and from the surgeon’s hand. Obviously, this is a critical part to any kind of interventional telemedicine.

**Chuck R. Doarn:** One of the issues we always struggle with in the realm of telemedicine is the ability to project expertise to a distant site, whether it’s on the battlefield, Mountain Everest, in space exploration, or underwater. The individual providing medical or surgical care should have a basic understanding or knowledge of that. In these environments, being able to project this expertise virtually or naturally has huge benefit. We’ve been able to demonstrate this a number of times over the last couple of years with our various experiments.

I guess the question that comes up is, “If one assumes you have a fairly robust robotic system, what about the communication infrastructure that needs to support it?” Oftentimes, people ask me, “Well, what if the Internet goes down or the computer stops working?” There are always questions of latency and reliability.
in the infrastructure itself. What kind of infrastructure do you think really needs to be in place to make this a reliable effort?

**Blake Hannaford:** The Internet is becoming more and more the fiber of our society. Like electricity, we are depending on it more and more for all kinds of things. A hundred years ago, it was just a given that electricity would go out now and then—you couldn’t count on it. Today, it’s a big problem if the electricity goes off and we don’t have ways to back it up.

The Internet is turning communication into a utility that, more and more, we can count on. That doesn’t mean we can just sort of plug in and forget about reliability. But, at the same time, there’s a whole industry that’s working to bring it more and more into the direction we need. For each specific situation such as a battlefield, remote site, or a clinic in Alaska, there’s going to be different ways to provide the safety and reliability guarantees that are obviously necessary.

In a remote clinic, for example, you can have somebody present who may not be fully capable of doing the procedure, but is fully trained to take over and stabilize the patient in the event of communication loss.

**Jacob Rosen:** Another aspect of that is redundancy. There is an inherent redundancy in the Internet. If one of the servers can’t transmit the communication, there are others. But, as far as the endpoints, we need to build redundancy in order to increase reliability. This can take the form of two computers where, if one fails, the other one would kick in; or a UAV network working together where, if one is damaged, the other can facilitate a transmission. Redundancy is used in nature quite frequently. While it is already inherent in the Internet, we need to build it into the two endpoints.

**Kevin Hufford:** When reliability is an issue, there are some easy and more involved things that we can do on the remote side even if it is still a telemanipulation case. This may mean passively just holding this data until the connection’s re-established. If the robot understands something about the procedure being performed, it could be moved to a safer state at some point in the procedure. I think there are some relatively easy things that can be done on the remote side to make it safe, if there is an unreliable section, etc. Blake is right; reliability is only going to increase.

**Charles R. Doarn:** The second item on Tim’s list is telecommunication requirements for telemedicine versus telesurgery. Two large events have occurred in the last five or six years. One is Operation Lindbergh that Professor Marescaux did between New York and Strasbourg, France. The other is Dr. Anvari’s work in Canada. In both of these events, the networks were fairly large and fairly robust. At both sites, however, there are always teams of medical and surgical personnel who can support the surgery. If the robot or communications fails, these teams can take over the surgical procedure.

As we go through the next period of time, telecommunication can only get better and more reliable than it already is. We are also at the stage where, eventually, these systems may have some intelligence, where they could perhaps carry on in a steady state some activities that you were doing until you re-establish the connection. One day, they could be smart enough to do the entire procedure. This is certainly something that Dr. Rick Satava has presented at many, many meetings since I’ve known him for almost seventeen years now. Clearly, the telecommunications needed to do telesurgery is far superior than it is for telemedicine. Telesurgery is just an opportunity for telemedicine to expand.

We worked on the HAPsMRT Program with UW and HaiVision and Aero Environment out in California last year. We actually used an unmanned airborne vehicle (UAV) that was far easier to use and with less latency than perhaps using a low Earth-orbit satellite or geostationary satellite, because you don’t have that time delay. Did you guys at UW want to talk a little bit about some of that experience from a communication perspective?

**Blake Hannaford:** Time delay comes from different sources, and one of them is just the speed of light being an ultimate limit and communi-
cation satellites are 22,000 miles above the Earth, and so there’s, fundamentally, about a quarter of a second speed of light delay to get up there and back down. And, often, you have four of those links in a complete loop, so you may have up to a second of delay there. And so the other techniques,—like the airborne, unmanned aerial vehicle that carries a communication node—it can really eliminate that source of delay.

And we’ve been working pretty hard to really study where the delays are coming in practical implementations of this system, including using global Internet links, terrestrial Internet links. And an interesting finding that’s coming up is that the Internet continues to get faster. The delays that we’re measuring among different sites—to different sites in the planet, really—have dropped over the last few years, as you might expect.

But there’s actually another very significant source of delay, which is the compression equipment that’s used to compress the video and decompress the video at the other side. And that—those delays are now bigger than the Internet delays, even using very advanced, expensive custom video CODEC equipment, which is very nice, but often not designed to really minimize latency. We’re starting to work with experts on video compression and multimedia networking to see if we can’t figure out the absolute best way to minimize those delays.

**Jacob Rosen:** The difficulties that the video and the command to the robot have, are that both have two fraudulent delays. So the way the human is coping with that is just to move and wait, so they move and wait to see if the end effector actually moved. And so synchronizing between them in a certain way might accelerate the operation.

Another thing that you mentioned is autonomous operation. Right now, the systems are really straightforward in the sense that you move the tool and the tool moves in the same way. You can eliminate tremor and you can scale it up and down. But, as you mentioned—and Rick is always talking about this—autonomous operation can overcome time delays and it would put the surgeon in a high level of control, so the surgeon can’t point to a different anatomical location and ask the robot to perform the surgery autonomously.

So this is one of the routes to overcome time delays before the technology is actually available to give us the fast-time response that we expect.

**Charles R. Doarn:** In 1993, I was at a meeting in Montreal and this was the first time I met Rick Satava, who was talking about tele-surgery. This was before anybody had actually deployed a robotic system or the FDA had approved the use of any kind of—robotic surgery. And I remember him talking about this, and there was another gentleman there who was from the Air Force, Dr. El al-Said [?], and he—we were—the three of us were talking about this and I kind of was the nay sayer, being the non-clinician that I am, and I said, “If you are doing a surgery and you are in a particular body cavity and when you go to pull something and you cut something by mistake, you can certainly repair some things, obviously, like a blood vessel, for instance, if it’s not too large.” But the way in which the latency was played out at that time was that there was no way you could have a surgeon remotely do this task because the body would be reacting so rapidly that the robotic system couldn’t compensate for it because of this latency.

And so, from what I’ve seen in the last fifteen years or so is that latency is still an issue, but I think we’ve been able to overcome some of that by design. And I think, Jacob, you make a very good point about autonomous functions. If you make a mistake, you have to consider not only the delay response to repair it, but the body has moved ahead into a different state. But when we use the da Vinci, if you’re in the middle of doing something and you take your head out of the—the monitoring, the workstation—the system stops and for good reason. If you design into the system some of those features, I think you add a lot of usability.

**Kevin Hufford:** I think there’s also another interesting point that we noted with autonomy in NEEMO 12, when we were doing the autonomous needle insertion. The robot was able to insert the needle perfectly along the needle axis with no deviation from the needle axis, so
there was no bending of the needle or no interaction with tissue—unwanted interaction with tissue. And that’s something that would be more difficult to do in a telemanipulation case.

So, for us, seeing the sort of supervised autonomy in NEEMO 12 was very rewarding, so it’s not only just a compensation for latency, but the robot can do some certain specified tasks better than the surgeon could remotely. Even in a low-latency situation.

Charles R. Doarn: The other thing that always comes to mind when we talk about remote manipulation are the two robots—Spirit and Opportunity—that are on the surface of Mars. Now, realize that the communication delay between the surface of Mars and the Earth can be upward 22 of 28 minutes, one way. So, by sending commands to they then do exactly what they’re commanded to do. As we go down this path of robotic surgery or systems that can do robotic telesurgery, they can be programmed to do certain things.

I think the Trauma Pod project has some of those attributes to it—both SRI and UW can certainly talk a lot more about that than me. But I wanted to just go back real quick and talk about telesurgery as it was originally intended or as it was originally developed, based on the trauma surgery program that ended up being then developed into the da Vinci robot. I don’t know, Kevin, if you want to talk a little bit about how that all came about.

The next item is talking about the historical perspective, the recent advances, and the extreme environment challenges that we’ve worked on. And so there’s certainly a long list of the things that we, as a team, have been working on. I know that the whole concept of taking commercially available systems and pushing them together oftentimes leads to new devices and new ways of doing things.

I know in Operation Lindbergh, that that proof of concept that was done it was the most missed story of 2001, because of course, as we know, it had been done just a few days before September 11th and the tragedy of that day. But, again, this was one of those systems with a completely dedicated communications link.

And I recall, when we did some early telemedicine work in the late ‘80s and the early ‘90s, we again used commercially provided telecommunications, but it was dedicated. It wasn’t a shared sort of service. When we did our Intuitive Surgical robotic activity from the University of Cincinnati to Sunnyvale in March of 2005, we used the open Internet and, of course, we repeated that at the American Telemedicine Association in April, through the one that was in Denver. But that used the open Internet and I’m not so sure that you’d want to do surgery on the open Internet, because that—you know, people getting into a system and perhaps making—making problems with that.

But from a standpoint of a wide-scale telesurgery application, do you think that the biggest challenge for us out there is the communications and the problems that are caused by it—latency and quality of service? Or do you think it’s more of the design of the interface to replicate the surgeon’s hands?

Jacob Rosen: I would just like to conclude the previous issue with autonomous operation before we get to the new topic, by saying that you can operations in two different ways. You can automate the service to the robot and this is what Trauma Pod did, automating the entire tool, services and equipment, or disposable services. This is one aspect of automation.

The other aspect is automating the surgical task. The difficulty with automating the surgical task is, if you deal with bones, for example, where you have a fixed structure in space and you know exactly the dimension of the bone, you can drill it or mill it or do whatever you want with it. But you’re dealing with something that is unchanged as a function of time, if you fix it. If you deal with soft tissue, they are constantly changing.

So by the time you give a command to suture, then one lip of the tissue can change dramatically and—the only way to overcome it is by simulating soft tissue, and when you simulate, you can sort of predict how that soft tissue will change its size and shape. But soft tissue simulation is a huge problem, because it’s nonlinear, viscoelastic and—it’s an open issue right now. I don’t think there is a good simulation platform for soft tissue.

So when you deal with autonomous, I think
you—you can separate it into two things.

Simulation has a way to rack up delays, and autonomous operation is still an open issue with respect to soft tissue.

**Charles R. Doarn:** Okay. I think the concept of simulation is very, very important. We here at the University of Cincinnati, obviously, like most medical schools, are beginning to integrate a wide variety of simulation into the curriculum and I think that’s very important.

One of the things that we—Tim, actually, Tim Broderick—talked about at the ATA a few years ago was the whole concept of being able to do the driver’s education concept with the da Vinci robot, where you could actually sit and do the procedure on a simulated patient, perhaps the night before, so that, when you get in to the operating room, you’ve already done the procedure on that very patient, just in a simulated environment. And, of course, that takes a tremendous amount of computing power and storage and so forth.

So I think those are very, very useful tools, as we come into this next phase, if you will, of advancing medical care.

So we talked a little bit about, just before that, Jacob, a little bit about whether we thought it was the communications infrastructure and the nuances that go with that or if it was really the systems that are going to be the show-stoppers or at least—not show-stoppers, but the stumbling blocks, if you will, to make this a more comprehensive business model.

**Jacob Rosen:** Well, I think—I just want to refer to what Blake said about end effectors. What we are experiencing right now are—the first generation of end effectors, where they emulate or copy a manipulation of the human end effectors held by his or her hand. Our hand has a lot of other sensors, for instance, we can feel texture, we can feel temperature, we can feel pressure, and so the new generation of surgical tools would include sensors on top of just simple manipulation.

So there is definitely a lot to do as far as the tip of the instrument touching the tissue in conveying information back to the surgeon.

**Chuck R. Doarn:** Kevin, what do you guys think about it at SRI?

**Kevin Hufford:** Which is the bigger issue? I think the communications issues will probably go away. I think the video encoding issue clearly is a big one that, if it can be solved, would help a whole lot. I think Jacob’s right. The manipulation issue has been solved per se from a—say, for laparoscopic procedures, the intuitive da Vinci is a clear example of an interface that works well and is in 500 operating rooms worldwide. So it provides the necessary degrees of freedom and the interaction for the surgeon.

But I think, as far as feeding information back and the richness of that information feeding back, I think that’s clearly an issue to address. How do we make the surgeon feel as if he is doing the operation? For the richness of that user interface and his ability to move around seamlessly and not have the user interface or his interaction with the master console be something he has to keep in his mind, but that sort of goes away and he’s more consumed with just performing the procedure, I think that’s a—definitely something we need to work more and more on.

**Charles R. Doarn:** So we think about telecommunications as really the network or the roadway, if you will, of getting advanced healthcare into these remote environments, whether it be just strictly telemedicine or actually being able to operate on someone at a distant site in a disaster response, for instance, or, say, in the middle of Montana where a surgeon can’t make it or you can’t get to the surgeon for quite some time, but the systems can be deployed.

What do you think are the challenges for us to get to that point where this could be—I realize that there’s only one commercial product in the market right now, at least in the United States, that being Intuitive Surgical’s da Vinci system—both the classic or the new S device. What do you think it’s going to take for this to become more widespread and, more importantly, more cost-effective for wider distribution?

**Jacob Rosen:** Typically, you’ll see two surgeons standing next to an operating table. So
two surgeons would have four hands and four eyes. So if you truly want to replicate it with a robotic system, you need four—at least four arms and at least two cameras to look at the surgical side from different perspectives.

From the surgical console, what we have done with surgical robotics is we changed the scene, because we put only one surgeon in control and all the rest are just floating around assisting him or her. There is a concept where we can develop multiple surgical consoles where two surgeons can work collaboratively, as they are used to—sharing some arms or even manipulating some arms individually.

So in deploying things in a complete vacuum where you don’t have any medical expertise around, the only way to do it is to incorporate into the remote side some intelligence so it can overcome time delays where you cannot really control it in a one-on-one fashion and you also—you also want to deploy enough manipulation capability so it can emulate two surgeons walking on one—one patient.

Charles R. Doarn: Okay. I think that, if we were to go to a venture capitalist and say to them, “We have a robust robotic system that is smaller than the current systems, very easy to use and can be connected just by plugging it into your WiFi or the wall—wired or unwired”—what do you think would be the kinds of issues that they might have as an investor into seeing this completely deployed as a useful tool in the practice of medicine?

Kevin Hufford: I think one of the issues—or one of the questions that might be raised is what—in the case of deploying into a disaster area—what capabilities does this robot and a surgeon dealing with the issues of latency and so on in remote sites, what can they provide over what the staff on-site can? And I think being able to demonstrate certain procedures that, say, may occur in a disaster area may help to motivate more—exploring the area more.

I think the real, thing is not only just the telementoring, but actually giving that remote surgeon the ability to put some hands on the patient, not just eyes and ears. I think that’s a real motivating thing for bringing in someone who has some expertise so you just have a general surgeon. You need to bring in a neurosurgeon or something like that. But I think that at least as far as the disaster area application, you need to explore what capabilities does the robot bring to the table?

Charles R. Doarn: Well, I know that in disaster response telemedicine has been a vitally important tool, as was demonstrated in the Spacebridge to Armenia—Operation Strong Angel—which was a demonstration project, in the sense that it was—there wasn’t a real disaster. But, certainly, one of the things that we learned from our UAV activity in Simi Valley was that you could deploy a relatively inexpensive communications tool, meaning this unmanned airborne vehicle, in an environment such as post-Katrina, where you could have a telecommunications link.

So if you have a robust telecommunication system that can link to remote sites or a surgeon in a surgical team with a surgical robot, I believe that you can do quite a lot of surgical intervention.

I think the challenge that lies before us is that the infrastructure, the cost, the quality of service, and the latency still remain significant—they’re not necessarily huge barriers to overcome, but they still remain challenging for us to take telesurgery to the next level and that’s a more wider distribution. Sometimes people ask, “Why would I want to have a robot do the procedure when there’s a surgeon standing right there that can do the same thing?” And I don’t think it’s a matter of “because, it’s the same thing with having the da Vinci in the operating room.” Someone is always going to ask the question, “Well, it’s great you have a robot, but what real value is it?”

And it’s not necessarily measured in the cost or the fact that you’re a university and you have this new technology. It’s more in the opportunity costs and the changing dynamics of healthcare where you have to look for value. If you can do a robotic surgery remotely and the patient doesn’t have as many incisions, takes fewer drugs after the procedure, loses less blood, and has less pain, then these are the measures of success.

But when you start to be able to manipulate systems from a distant site, now you can begin
to affect a greater population. And then you tie in the whole idea of teaching and curriculum development, where you now can teach people remotely how to do a procedure, whether it would be using an animate or inanimate model.

Charles R. Doarn: I was going to just touch on the use of these—Polycom versus HaiVision. And I’m not so concerned about those two particular companies but the whole idea of using a CODEC. What is the experience that both of your companies have had using these different kinds of codecs as far as the quality of the actual video image? How do you see those improving?

Thomas Low: The industry is obviously—in terms of videoconferencing—has been focusing more on bandwidth reduction and quality of image than they are on low latency, and that’s something that’s unique in our application. And it is something that obviously High Vision is interested in or has put some emphasis on, but with the MPEG-4 standards, you’re pretty much stuck with—what is it Kevin—90 milliseconds?

Kevin Hufford: I think with MPEG-2, they were demonstrated 90 milliseconds and MPEG-4, I think is in the 140–180 millisecond range.

Thomas Low: So that’s sort of a fundamental bifurcation, if you will, in terms of how it has been looking. Whether or not ultimately it will be worth the bandwidth to have a low-latency solution is yet to be seen.

Charles R. Doarn: The experience that we had with the Polycom versus the HaiVision when we did the da Vinci test between the University of Cincinnati and Sunnyvale—we knew, when we put the High Vision in, it was a much better quality, but I would state that the CODECs that are out there today—and Tom, you made this comment very well a moment ago—are those codecs predominantly made for videoconferencing? And do the videoconferencing companies predominantly make systems for videoconferencing, not telemedicine necessarily, and certainly not for surgery.

I know that Patrick had led a SBIR out last year for a number of companies to look at the next version of the CODEC. But I’m just wondering whether we’re going to need, from a telesurgery perspective, something completely different or if we can piggyback on current developments for the traditional videoconference world.

Thomas Low: Well, even in videoconferencing, latency is an issue. It’s just not such a critical one and not such a limiting one. But, as Jacob said earlier, as the bandwidth becomes more and more predominant, I see the need for compression and, with it, the inevitable latency becoming less and less. So it may be that CODECs eventually become things that are sort of unnecessary when it comes to telesurgery and that we essentially just use the broadband.
Charles R. Doarn: When we talk about latency and the possibility of it maybe going away with, obviously, a lot of bandwidth, what about the whole concept of automation? Does that require a significant—significantly more bandwidth to remotely control something, or can you space it out and just take some more time?

Thomas Low: Well, there are two elements—two elements that contribute to the latency. Obviously, there’s the actual compression and decompression time, which is predominant in when you’re traveling a relatively short distance.

As soon as you start talking about significant distances—now, I’m talking about satellite bouncing, I’m talking about communications to the moon and beyond—then the predominant contributor to latency becomes the actual time of transmission of a signal. And that is, obviously, unavoidable.

And as those become predominant, it doesn’t matter how much bandwidth you have, you’re going to be forced to move into a mode in which greater amounts of autonomy are provided on the remote side, so that more complex procedures can be performed without the operator’s continual intervention. And it’s really not about the need for the bandwidth as much as it’s about the ability of a system, remotely, to be able to react immediately to changes in the environment through local sensing, where, with a human in the loop remotely, that would be impossible.

Charles R. Doarn: Good comment. Jacob, want to follow up on that comment at all?

Jacob Rosen: So, if you look at surgical robotics as a field, the systems that are out there, it’s clear to the community that’s version 1.0. And the early adaptors bought them, but the surgeons are looking for things that they cannot do with their own hands, whether they can go into small spaces or tele-operate with some autonomous operation. So before we will see these capabilities in new systems, I don’t think some dramatic change would happen in the field.

As far as overcoming a time delay with simulation, what I was trying to say by saying “simulation,” is that the robot has a certain understanding of the surgical side or sort of has a template or intelligence built into it. So you as a surgeon or an operator, you’ll give high-level commands, like, “Suture from point A to point B,” and then there would be a simulator running while the robot is running. So if the tissue would change, then the robot either will see it or will be able to accommodate that change due to the effect that there is a simulator running in parallel.

What you really want to do is put the surgeon in a different position. You don’t want him or her to move tools left and right. You want the human in the loop to have high-level command over the operation. And you cannot expect a company to get to that level. That would be a very intensive research effort made by many, contributors to get to that stage.

Charles R. Doarn: Okay. Let’s see. When we’ve talked about—well, I guess, I’m thinking of a few things, and then we’re probably going to need to wrap up here in a few minutes—because I know each of you has some other things that you need to get to. We’re going be doing a series of experiments on the DC-9 this coming Fall and in the past we’ve done stuff on NEEMO 9 and NEEMO 12, with both robots. When I say “both robots,” meaning the RAVEN, University of Washington, and, of course, the SRI M-7.

When we look at putting telesurgery in extreme environments, from the standpoint of a technology demonstration or evaluation, what do you see as the biggest challenge, aside from the financial aspects of it? What do you see as the most technically challenging activity of getting things deployed in these environments and actually doing this work?

Jacob Rosen: Let me start with that. I think we have already demonstrated that technologically, and it’s not a problem. You can do it. The problem that we are facing is to cast the science into this effort. And what we have proposed is to use a standard platform such as the FLS to standardize the manipulation tasks. And we are facing a difficulty to publish these results, because the scientific community is not interested in these adventures and demonstration
of capability. They are interested in the science behind it.

The best way to serve our funding sources is to extract the science out of these efforts and, if you’ll ask Blake, he would say, “Well, we can extract the science in the lab. We don’t need to do that anymore.” But my position on that is, I think, we still need to do the science in this environment, because this environment would generate constraints that we cannot generate in the lab and, every time, it’s something different.

But we need to pay attention to the—to collect the appropriate information and to be able to report it scientifically.

**Thomas Low**: Both the M-7 and the Raven are very sophisticated instruments. And it certainly was a challenge in NEEMO 9 for SRI to re-engineer that system to a point where the layman could deploy it. And that would be robust enough to withstand the rigors of deployment into that kind of environment.

The DC-9 is going to be sort of a similar situation. The master controller that SRI developed many years ago is an area where I think significant advances can be made before tele-manipulation or telesurgery is widespread—an area where the costs and accessibility of such systems need to improve. And that’s one of the areas where we are planning on focusing some effort in coming months—and this is something that I think UW has already done, to some degree—is the making the master controller a more accessible piece of hardware than the remote side, the slave system.

There is still room for improvement in terms of the robustness of our systems. I know we breathe a sigh of relief when we get through one of these extreme environment missions with our robots still perfectly functioning and there obviously needs to be more engineering effort put forward before these systems can really see widespread practical application.

**Jacob Rosen**: Yes, and compared to other lab experiments, I think both systems are built to a more industrial standard and we benefit from it significantly as we try to deploy them in these environments, but I think we are building more mature versions and understanding the difficulty of laymen operating them. It’s definitely the step that both of us would take.

Standardizing the console—the master console, as Tom mentioned—is a key thing, because then we have a standard, not just the master, but also a protocol where we can manipulate different end effectors or slave systems.

**Thomas Low**: And I guess it probably would make sense to just briefly discuss the work that is ongoing to develop such protocols. Blake and I have been in communication and have developed a draft protocol to allow eventual interoperation of SRI’s and UW’s robots and with, we hope, eventually being able to expand that protocol to permit anyone who’s interested in developing robotic instruments to have it share that interface standard.

**Jacob Rosen**: One more comment, not related to that, but even when Intuitive started selling their systems, they would have an engineer or a technician on site every time the system would run. And, here, we had a person for almost two years standing next to the robot all the time. The systems are definitely maturing, so I don’t think we are in a difficult position, but we—as we do this more and more—we understand the difficulties in trying to re-engineer our systems.

**Charles R. Doarn**: One of the biggest challenges is building the systems and making them robust and connecting them. From the user perspective, the biggest challenge is usage. If it is just used in the OR and not for telesurgery, where it takes a huge effort to turn it on or a huge effort to deploy it, then it may not get a lot of use.

And I know Dr. Ron Merrell made this comment to me many, many years ago. He was talking about how surgeons sew—how they suture, how they suture a wound, for instance, or do an anastomosis—in that, when Singer developed his sewing machine, the way the sewing machine works is nowhere near what you do when you use your hands.

So the concept of surgery—manipulating what your hands do—we’re still stuck in the—
I don’t meant 20th century mindset, because we’ve been doing surgery like this for many, many centuries. But perhaps the next generation of robotic systems that can be manipulated from a distant site will be completely different.

**Thomas Low:** Oh, I agree completely, Chuck. And, again, this is one of the basic tenets of our future work in Trauma Pod as well as our own internally funded work. And that is to look at techniques in which the brand-new brands emphasize and take advantage of the capabilities of a robot and how those are better than what a surgeon does. So really trying not to mimic a one-to-one the way that things are done conventionally today, but to look at areas in which the robot can excel.

And one example is the ability to compensate for vehicle motion, if you have a device like this mounted into an ambulance or evacuation vehicle of some sort or perhaps on a transport aircraft, evacuating soldiers—being able to accommodate unexpected accelerations of the vehicle from rough road or from air turbulence and to provide some degree of autonomy, if you will, in the slave manipulator to adjust to those external forces.

**Charles R. Doarn:** Every once in a while, when I give a presentation about advancing medical care or robotics or whatever it might be, I always use this picture—and you may have seen it before. It’s from the Rand Corporation and it shows this older gentleman standing in front of a very large bank of what looks like monitoring devices—you know, straight out of a mission control for NASA—and there’s a big steering wheel. And the thing at the bottom says, “This is a home computer. Everyone will have one in the future.” And this was in 1955.

And when computers first started coming out in a PC format back in the early '80s, there were a lot of people that thought that this would never be of value and no one would ever really use them and they still needed the big IBM computers for data manipulation, and yet today we all carry these cell phones and iPods and all that with memory and all these capabilities.

And so it’s clear to me that the way we develop surgical tools will continue to evolve and that the ability to link them at distant sites, regardless of wherever we are—one could assume that, if you had a disaster, for instance, and you wanted to deploy a robotic, a surgical robotic system, to this disaster zone, that would have to be ready and packaged and ready to deploy at a moment’s notice and I’m not sure we’re quite there yet. But it can’t be this huge da Vinci robot.

**Thomas Low:** It can’t be these big—I mean, I’ve seen both the RAVEN and the M-7—they take a little bit to put together. But once they are together, they’re fairly easy to use, although I don’t know what it would be like to actually do surgery on a human from a distant site with such a system, but that’s clearly something on the horizon that we need to focus on.

**Charles R. Doarn:** Right. A lot of the technologies coming out of home healthcare and telemedicine really lend well to changing these paradigms. I think it was in *Wired* magazine that was showed the M-7 being carried into someone’s house. I’m not sure, but I got that picture, I guess, from Tim. But it clearly illustrates that perhaps one day you could do surgery at home.

**Charles R. Doarn:** Well, I’m not so sure that’s the case, but, with all the technology that’s coming out and the way in which technology continues to evolve, there’s no doubt in my mind that this is not that far off in the future.

**Charles R. Doarn:** Well, what I thought I would do, in sort of closing, and we may need to have another phone call just to further discuss some things. But what I thought we would do is have everyone make a summary statement, if you would.

So, Tom, would you want to make some closing comments?
Thomas Low: Yes, certainly. So the key players in this emerging area are still a small team; it’s a small pond. And I think that what makes a lot of sense is for us to continue to work closely together in a collaborative mode. The funding is obviously still somewhat limited and we need to be approaching this in a strategic manner where we identify—really develop a road map, if you will—that we collectively pursue as opposed to each doing our individual, pursuing our individual interests. And I think that’s the way that we are going to make the most progress and use the limited funding that is available in this field most productively.

Jacob Rosen: I just want to cite Rick when he refers to a surgical robot as an information system. And I think we need to remove ourselves from the mechanism and look at these systems in a more global way, if you want.

So it’s clear that we are dealing with the first generation. The question is, “What’s next?” So adding intelligence to these systems, you know, creating a marriage between imaging modalities and robotic systems and giving, essentially, the surgeons a tool that they can do things that they cannot do right now with their hands and with the current system. This is probably what we are trying to—will try to do in the future.

Charles R. Doarn: In closing, I’d like to thank everyone for participating. We look forward to further discussion. The future is very bright in this area of the integration of telemedicine, telecommunications, surgical care, and robotics. I believe that these are very useful tools, not only from a research perspective and, of course, we’ve done a of lot of really cool demonstrations. But I think it’s more that these tasks that we’ve done are necessary steps to get us to the next level, not only from an education perspective, educating us as researchers, but also providing a platform to develop new education tools. So to become a surgeon doesn’t take seven to fifteen years. Even today in the New York Times, there’s an article about a shortage of cardiothoracic surgeons, that the average surgeon, by the time they are out practicing, they’re 35 years old and have $200,000 or more in debt. Certainly robotics and simulation systems can help—we hope—help alleviate some of that.

I think telerobotic surgery is a natural extension of the surgeon’s hands and is a very useful tool, as has been shown in numerous examples. And I think that this leads then to a paradigm shift in the way in which we practice surgery and the way we teach—always coming back to that concept of education.

I think telesurgery is no longer a novelty. It’s not ready for prime time, of course, but it’s certainly a very interesting field. It has a huge potential and has many applications and I think the barriers that we discussed earlier—and those barriers and characteristics are similar for telemedicine—also are impacting telesurgery. But, as I’ve watched over the last fifteen to twenty years, these barriers continue to ebb away and, I think that they’ll ebb away faster now because the computer systems are far better than they were fifteen years ago—telecommunications gets better almost on a daily basis.
ROUDTABLE DISCUSSION

AU1
Please provide degrees for Hufford and Low.

AU2
Wording approved here?

AU3
Please confirm spelling.

AU4
Not clear—addition OK? or reword?

AU5
Something missing here? Another speaker?

AU6
Sentence OK?

AU7
Please id Trample [?]?

AU8
Correct person here?

AU9
OK? sense? “is always going to”

AU10
Same person here?

AU11
Is wording correct here?

AU12
Reword “it’s a constant wait”?

AU13
Half [?] Smart OK?