CAN REMOTE OBSERVING BE GOOD OBSERVING?

REFLECTIONS ON PROCRUSTES AND ANTAEUS [1]

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ABSTRACT

Remote observing seeks to simulate the presence of the astronomer at the telescope. While this is useful and necessary in some circumstances, the simulation is not the same as the reality. The drive to abstract the astronomer from the instrument can have unpleasant consequences, some of which are prefigured in the ancient tales of Procrustes and Antaeus. This article considers some of the human factors involved in remote observing and suggests that our aim be to enhance rather than supplant the astronomer at the telescope.

1. Introduction: Why Are We Here?

> "...we need to be reminded of the distinctions between the extraordinary power of science and the fallibility of those who practice it." – *A. Kornberg (1992)*[1]

Most of this meeting has dealt with the interesting problems that arise when we choose to operate a telescope remotely rather than be there in person. Of course, all space observatories must be run remotely, and they have been reasonably successful, but only at a cost that is appalling by terrestrial standards. If we decide to support remote observing at our ground-based telescopes because it is *good* rather than because it is *necessary*, we find ourselves asking questions like: What is good observing? What is the output of a successful observing run? What is meant by "high quality data"? and so on. To complicate matters, the increasing automation of observatory functions suggests to some that the local/remote distinction is unimportant – both observers sit in front of a computer and communicate through it. Can there any difference at all?

Let me approach the answers to these difficult and provocative questions by posing yet another: why we are here? That is, why are we here in person? Why have so many of us faced the perils of airline food and maniacal baggage handlers to sit in a room and hear each other talk? Human speech has such a low data rate that it can be carried comfortably over mere telephone lines, with ample room for transparencies. From the simple Nyquist criterion (the usual arbiter of issues in communications), our gathering together here is exceedingly strange. Why didn't we meet remotely? Is there some spooky advantage to proximity over distance?

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At NRAO we are building the Green Bank Telescope, which will be operated as a visitor oriented facility and will support remote as well as local observers. We are supporting remote observing because some of our users think that it will be a good feature, and because as of now it seems quite inexpensive. But we're not doing it because it will produce better astronomy or better astronomers. No one knows. And no one knows if, in the long run, it will be a blessing or a curse.

To some, perhaps at older observatories, who routinely struggle with balky, uncontrollable equipment in the depths of longjohn winter nights, the notion that automation could be overdone may seem ludicrous. Even modern telescopes frequently suffer from computer systems that are a hopeless clutter of ad hoc languages and machines communicating with each other poorly, and with the hapless astronomer, barely at all. It might not seem credible that astronomy could be done without an astronomer nearby. But the trends to automation and abstraction are firmly in place, and we need to decide how to use these tools before the decision is made, by default, for us.

The "reflections" that follow are my unsystematic comments on these issues. The view is from the human, rather than from the technical perspective, so I will not discuss what we *can* do, but rather what we *should* do with our limited resources and time. There is probably no observatory that couldn't perform better if it had more money for instrumentation. Should these dollars be spent instead on remote observing? I believe that many of my comments are widely felt but rarely articulated. Some have already been expressed at this meeting, while others come from the vast literature of applied psychology, a literature which includes many ancient fables, for the interaction of people with their creations has always aroused curiosity and passion.

2. Telescopes Produce Responsibility and Skills (and Data)

We want our telescopes to produce good science, and good data is a part, but only a part, of good science.

2.1 Responsibility

> **Responsible**. *adj.* **1**. Legally or ethically accountable for the care or welfare of another. **2**. Involving personal accountability or ability to act without guidance or superior authority. ... **4**. Capable of making moral or rational decisions on one's own, and therefore answerable for one's behavior. **5**. Able to be trusted or depended upon. – *American Heritage Dictionary*[2]

Observational astronomy does more than just pluck numbers from the sky; it also assigns a reliability to those numbers. When scientists present the results of an experiment, they take responsibility for those results by attaching to them the most precious coin of the scientific realm: the individual scientist's desire to speak the truth.

The definitions of the word "responsible" given on this page make it clear that responsibility is something particular to humans. It makes no sense to say that a computer is accountable for its own behavior, or that it is capable of acting without superior authority. In society, responsibility is so important that we do not even credit it to every person – a child or adolescent, no matter how intelligent, no matter how talented or athletically able, may still not be trusted to act responsibly in some circumstances.

Who takes responsibility for data gathered remotely? Who speaks for its correctness? Take the case of the Westerbork radio telescope. Authors of a successful proposal to use this instrument are often not even notified that the observations are being made. Instead, they receive in the mail, sometime later, a fully calibrated map of their field. Who is responsible for the correctness of these data? Who knows how to interpret the lowest contour? Who should respond to a referee's comments? In this example, can the remote astronomer be expected to vouch for the data quality? But if not the astronomer, then who?

This is an extreme example of a split between the astronomer who ends up with the data, and an observing specialist who is responsible for what happens at the telescope. Perhaps use of astronomical archives is also in this category. The split is created naturally in most remote observing schemes. I do not want to imply that an astronomer present at the telescope automatically produces correct or responsible data, or that the remote, but attentive astronomer must be utterly irresponsible. No, divided responsibility can exist even in locally operated systems, and to some extent is an inevitable outcome of the complexity of modern observatories. But since much observing is done under less than perfect conditions, being in proximity to the telescope increases the likelihood that variables of that particular day and time will be scrutinized, that the weather will be noticed if it is unusual, and so on. The more opportunities there are to interact with every part of the telescope system, in some literal sense the closer one is to the telescope, the easier it is to be responsible for what occurs there.

2.2 Skills

Everyone knows that there are good observers and bad observers. I believe that it is important to give our telescope users the opportunity to become good observers. Someone who actively plays with the equipment, tries out various combinations of things, and constantly iterates on technique, not only gets data and a sense of its correctness, but also develops skills which can make the next data better. The way to become a skilled observer is to participate in the observations as completely as possibly, to seek active control or understanding of every phase of the process; to try to recognize the difference between the basic limitations of an instrument and those limitations which are rooted in style or tradition. It is hard to see how the "consumer" of Westerbork data described above can even be called an observer, much less a skilled one. And I find it difficult to believe that observing skills can be acquired more easily at a distance (if at all) than in close proximity to the telescope.

The drive for new instrumentation and new techniques usually comes from the most skilled observers, for they are not only technically competent, but motivated by specific but varying astronomical interests. They provide new ideas and the impetus to keep our telescopes at the state of the art. We need skilled astronomers, not just observing specialists, and we need to help more astronomers become skilled. Students especially have to learn in depth about the instruments, and not just about the control systems that are abstract representations of them.

2.3 Data

Quite often the details really don't matter – the routine data acquired from a telescope without special effort are good enough. The measurement of a high signal-to-noise spectrum, say, or of the flux density of an object, might require no subtlety at all, and might as well be done in a batch process as by a skilled observer (provided that the sky is clear, etc.). But I suspect that it takes considerable experience to be able to decide that an observation will be routine, and it may take several trips to the telescope, by someone, to set up and debug even a "routine" observing procedure.

3. Astronomers and Their Hammers

> "If you give a child a hammer, it will treat everything as if it were a nail."
>
> – *attributed to Abraham Maslow (1908-1970)*

3.1 Hammers Don't Gossip

The Law of the Hammer, as stated by the great child psychologist Maslow, has general truth. We tend to define the possibilities for action by the tools we have at hand. We tend to define our choices by the options we are given.

A relevant example is a menu-driven observing program. It is a blessing for the novice who immediately has a list of all possible choices and (via a click on a mouse) a way to effect a choice. Menus are good organizational tools, they enhance efficiency and reduce errors. But they are also dangerous for several reasons, and one is that they don't create, repeat or even understand gossip.

The menu choices at an observatory pertain to real physical devices, observing techniques, and so on. But most front-line observatories are constantly improving all equipment and increasing the understanding and development of new techniques. Also, things break. While it may be possible in theory to keep a telescope control program always totally up-to-date, in practice it is rarely worth while to do so. Instead, most observatories implicitly rely on local "experts" to communicate the latest information. Often, the best expert is the person who worked the previous shift.

As an example, consider the VLA, which is so highly automated that it is run by batch processes almost all the time. It is, however, in such a natural state of flux that inside information is frequently essential to get the best data. Visitors are assigned a local expert who advises on the most recent state of equipment, observing strategies, and data reduction schemes. Even so, a VLA observing run is apt to start with the telescope operator's announcing that an antenna or two have been having some difficulties, and have been offline for the last few hours.

Most of us have a natural reluctance to commit opinions to writing or to a computer help file unless they have been checked out and confirmed. But often such raw hunches, rumors and gossip ("Receiver B seemed flaky to me. I couldn't pin it down, and it looks ok now, but you may want to watch it.") are the most important bits of information an observer can get. In automating telescopes, we often try to remove the need for gossip because it is viewed as unnecessary, or even as evidence of a flaw in our system. But let us face the fact that active telescope systems use gossip and inside information to function efficiently, and that gossip evolves as the natural response to the need for extremely current though low-grade news. Of course we want to purge obsolete information from our systems, but why not also accept the role of gossip and plan to use it efficiently? If there is somewhere a general-purpose telescope whose online documentation reflects the current status of the instrument, it is probably a sign that that observatory has spent too much money on software and not enough on new instrumentation.

3.2 But I Thought It Was a Nail!

A more pernicious effect of the problem revealed by Maslow's Law of the Hammer is that, over time, observers will stop trying to do things that are not listed in the menu. Menu-driven observing encourages menu-driven thinking. I am not talking about intimidation here as much as laziness and ignorance, and the pressure is never overt, but subtle and persistent, very persistent. We need to create a climate in which astronomers imagine new uses of the instrument, combine existing functions in new ways, and tailor the equipment to the task, rather than the other way around. The imagination of an astronomer on-site is often stimulated by seeing the telescope and its equipment and recognizing that the current configuration is just one solution to a problem. We must encourage remote (as well as local) observers to break free of the menus.

Maslow's Law reminds us of another interesting factor: astronomers may use the available tools in ways that were not originally intended or foreseen. We will always be surprised, perhaps pleasantly, perhaps not, by the consequences of human creativity and stubbornness.

3.3 Well, You <u>Should</u> Have Wanted a Hammer.

If remote observing comes to constitute a large fraction of the use of a telescope, I think that there will be a subtle, but tremendous, almost irresistible pressure to discourage equipment and observing methods that don't easily lend themselves to control from a distance. An example which is not as silly as it sounds is that there can never be an instrument on the Hubble Space Telescope that requires frequent tweaking by some technician with a screwdriver. Of course not: the HST has to run remotely. But is it good to be so restricted on our terrestrial telescopes? That is, is it more important that a new device be totally debugged, reliable, and integrated with the system before it gets on the telescope, or that it gets into use, producing results, as quickly as possible? I vote for speed. If we don't pay special attention, we may not even notice that we've created a restriction, a bed of Procrustes (see §11), on which the unusual experiment won't fit, until all the creative users are gone.

4. The Mongoose and the Cobra (Science is Subtle)

> "...though Rikki-tikki had never met a live cobra before, his mother had fed him dead ones, and he knew that all a grown mongoose's business in life was to fight and eat snakes." – *Rudyard Kipling (1893)*[3]

> "In the vicissitudes of human experience and development, conflict is an unfailing attribute." – *Jacob Arlow (1985)*[4]

There is a fundamental tension in scientific activities that was alluded to in previous sections but here will be faced head on. Simply put, the culture of science and the culture of management/administration are not compatible. Like the mongoose, who just can't abide the cobra, and the cobra, whose feelings are reciprocal, the tension is irreconcilable.

A manager has to function smoothly and be reliable. That is the nature of the job. Schedules must be kept, payrolls met, the rent and electricity bill paid. Major random events are definitely not welcome. Scientists, on the other hand, like change. Even though they need to be methodical and plan experiments well in advance, scientists still like change a lot. They rarely do the same experiment over and over. Asked "what equipment will you need for your research next year?" they want to answer "I can't tell. It depends on what happens next month." Managers, understandably enough, find this attitude less than helpful. But if an organization is run for the ease of managers, science dies. We've all heard about the U.S. Government agency that recently asked its scientists to write a report giving their research plans for the next year *including detailed information on all discoveries that would be made.* But on the other hand, I'm not sure that anyone past adolescence would want to work for an organization that refused to act in a fairly predictable fashion.

The point is that science is subtle. There are few reliable ways (other than benign neglect) to encourage it, but many ways to stifle it. Our carefully developed hardware and software tools, intended to enhance scientific productivity, can easily turn into a hammer thrust into the hands of a scientist who needs a screwdriver. In particular, we at this meeting are potentially very dangerous to science, for as scientists who are involved in the way observatories are run, we can be both mongoose and cobra. We have the ability to force our particular scientific style on our institutions, for better or worse, and may even do so unconsciously.

Software encapsulates the philosophies of its builders. We need to remember that good science requires extreme flexibility of individual and institution, and we need to value and reward change as much as we do order and efficiency. We have to develop a culture of change in which we become suspicious, and begin to worry, when things remain fixed for too long a time.

Which brings me to the question of how to measure the success of an observatory, or the quality of science that it is doing. This problem is so knotty that most everyone dodges it and concentrates on the more easily quantifiable: papers published, visitors serviced, or even more primitive issues like observing efficiency. I will not argue that telescope systems should be less than maximally efficient, but efficiency itself is not a very selective criterion, for it says nothing about the quality of the data that are being gathered so efficiently, or the worth of the experiments themselves. A skilled observer puttering around a telescope, trying out various schemes and just doing things differently, may discover that the previous dozen observers who gathered their data with high efficiency were getting the wrong numbers. One characteristic of a good observatory may be that it lets its users do *exactly* what they want for the largest possible fraction of the time, even if what they want to do seems horribly wrong or utterly worthless!

5. The Importance of Screwing Up

> *Another occult belief is that of being always right. Never to err is only possible when insignificant questions are involved. Those who attempt to achieve infallibility consistently will instead achieve essentially nothing at all. In fact they should be reminded of the old wisdom that "who does not know that he is a fool half of the time, is most certainly a fool all of the time". –Fritz Zwicky (1957)*[5]

It is important that the observer be able to make mistakes and to screw up an observation, whether remotely or locally. The feedback makes observers more skilled. Also, it may reveal interesting features or possibilities of our systems that were not previously known. But there is no need to belabor the point. Anyone who has ever worked as a scientist knows the basic truth of Zwicky's comments.

We can permit astronomers to blunder around in our observatories, and to screw up in various ways, only if we feel that they have some degree of responsibility. I was very impressed on a visit to Yerkes Observatory to find that there never has been an interlock or limit switch that prevents an observer from driving the movable floor into the back of the great 40-inch refractor. As explained by my host, Lew Hobbs, the knowledge that such a catastrophe could occur through careless use of the controls they hold in their hands, has made the generations of astronomers (and graduate students) who have worked at Yerkes more reliable than any mechanical device could be. While I, personally, would nonetheless install a limit switch, the general lesson is clear. The good use of an instrument requires some responsibility on the part of the user. The best way that I know to encourage that responsibility is by the feedback that comes with proximity. The feel of the Yerkes floor rising up, or the wry look on the telescope operator's face when asking an observer "Do you really want to point at the ground?" all heighten the observing experience, enhance observing skills, and contribute to general attention to detail. At the telescope, an error can produce more than a "invalid operation" return code on a TV screen. The feedback is immediate and possibly profound. Steel moves across the sky. Alarms may sound. Someone at this meeting said that a good remote observing system should allow observers to break the equipment, and I agree, but only if they understand at all times that they have that power, and will be able to *feel* the consequences.

6. The Telescope Operator – Just Another Human

> "In spite of decades of effort and a huge investment of resources, modern computers do not see very well. In any ordinary sense of the word, they don't "see" at all. ... This blindness to ordinary environments contrasts sharply with the success of machine recognition in artificial domains. Computers have long been able to recognize the magnetic letters stamped on checks; modern scanning systems can even "read" (i.e. identify the words in) printed text. It's only the real world that gives them trouble." – *Ulric Neisser (1992)*[6]

The principals in an observing session are usually the operator, whose main responsibility is to the telescope, and the observer, whose responsibility is to the data. With some exceptions, the primary characteristic of both observer and operator is that they are human beings. Humans do certain things very poorly, like stare at a control panel waiting for something to happen, and other things very well, like respond creatively to unfamiliar situations. The issues of remote observing are not too far removed from those of remote operation, as both place distance between man and machine. Much has been written about remote operations in various industrial settings, for in some circumstances lives hang in the balance.

> **FIGHTING BOREDOM**
> FIGHTER PILOTS have G-LOC and transport pilots have B-LOC – boredom-induced loss of consciousness. A Douglas Aircraft Co. test pilot says designers are contemplating installation of a beeper that would sound in the cockpit occasionally. If the crew does not respond by pressing a button or talking, an alarm would sound to rouse them. –*Aviation Week and Space Technology (1991)*[7]

At NRAO we have telescope operators because they improve overall observing efficiency. One could always design a fully-automated system that responded to problems by going through an orderly shutdown and calling for help. The Hubble Space Telescope does this all the time. But more observing gets done if there is someone on the spot to diagnose and perhaps repair routine problems, to help the observer if possible, to take over certain operations so that the observer can get some sleep, and to provide a high level of monitor and control of the entire telescope and its surroundings. Tom Ingerson, in his talk, noted that having a person as part of the telescope system can make a tremendous improvement in the operation of an observatory. Human operators can be the best solution to the problem of how to operate a telescope, but only if we do not expect them to act like machines.

The airline industry has run into this issue with a vengeance. They joke that the aircraft cockpit of the future will have only two occupants – a pilot and a large dog. The dog is there to bite the pilot if he tries to touch any of the airplane's controls. And the pilot's job? To feed the dog[8]. A similar message is given by the "B-LOC" article reproduced above. The essence of the airline's problem is that computers can fly commercial airplanes better than humans *provided that no unanticipated events occur.* So the aviation companies face the dilemma of having to keep an aircraft crew ready to intervene, at a moment's notice, with their highest level of skill and concentration, in an environment which is mortally boring. Airbus Industrie, purveyors of perhaps the most automated commercial aircraft, holds "overconfidence prevention classes" to remind its pilots that even if the computers say that everything is A-OK, the airplane may not be[8].

Many observatories are coming dangerously close to this state right now, and more will be so in the future. The problem is not one that can be cured easily by motivational sessions with the telescope operator. Automation tends to reduce a person's sense of responsibility because the computer appears to have been given charge of the situation. At NRAO we recently debated whether there might be advantages to remote *operations* of the Green Bank Telescope, i.e., to having the telescope operator located in the main lab building rather than at the telescope several miles away. After much thought, I am convinced that this would be a grave error. How can we ask someone to be responsible for a telescope and then place him miles away where he cannot perceive it directly?

"I am what I am and that's all what I am ." – *Popeye the Sailor Man*

There are at least two problems with remote operations which also apply in some ways to remote observing. The first is reflected in the adage: out of sight, out of mind. We really do forget about those things that do not frequently intrude on our consciousness. I was struck by Mel Wright's comment that he has found it necessary to cycle staff from the Berkeley Campus to the Observatory at Hat Creek because people get disconnected from what is going on if they are away from the telescope too long. A telescope operator who communicates with the telescope only through a computer terminal is being taught an unconscious lesson every minute – that his main responsibility is to what is on the terminal – that the real telescope off yonder is secondary, someone else's problem, or worse: an abstraction. This is another manifestation of Maslow's Law of the Hammer. The human tendency to put the "out of sight out of mind" should not be seen as a problem to be overcome by education or training, for more like our inability to perceive x-rays than my inability to read Chinese, it is our natural way of dealing with the immense flood of information presented by the senses. We block out what is not immediately important.

The second problem is that we make poor use of peoples' talents if we restrict their information to what comes over computer terminals, video cameras, microphones, etc., unless it is absolutely necessary. There is no adequate substitute for human beings and their senses when it comes to perception and creativity. While it may seem that remotely controlled devices can convey information that is almost as good as one gets by being there in person, serious efforts in this area have in practice been marked more by failure than by success[6]. The video camera, e.g., is not a good substitute for the eye. [3] For one thing, our eyes are constantly in motion,

[3] Again, I am aware that remote sensing is necessary in hostile environments like the core of a nuclear reactor or the vacuum of space. But I am concerned here with situations in which we have a choice, and the environment of most of our terrestrial telescopes is not especially forbidding.

driven by a creativity and perception that cannot be replicated by machines. If a telescope operator hears a peculiar noise, he may want to touch a device, or smell it, or look around behind it, all without thinking especially hard or logically about the "search pattern" he is going through. It is not the same as peering through a fixed monocular video camera. Our creative tendencies make it difficult for a machine to simulate a person.

Instead of replacing the human, perhaps we should replace the machine. Human beings are designed to be good at creative perception and decision making on the fly, so why waste that ability by restricting an operator to a desk behind a computer several miles away from the action if he could be on the spot? I suggest that our goal should be to use remote sensing to supplement human perception, not to supplant it.

I do not know how to reconcile the desire for increased automation, and thus increased reliability and control, with the need to keep the operator fully involved with the telescope. The same considerations apply to the observer. Perhaps we should not automate a task unless it produces an **overall** improvement in the telescope system, including in the functioning of operator and observer. This approach would deliberately leave certain jobs to people. Perhaps we should give the operator other duties, such as telescope maintenance, that fill the time and keep him fully in touch with the instrument. We must face the fact that our observatories are run by and for human beings, and focus our efforts on enhancing human abilities rather than attempting to simulate them.

7. TV is Only TV

> *March 28:* "... we all landed safe & sound, one of our servants (Margaret's maid) excepted, who was very ill on the voyage & is not expected to live ..."
> *June 2:* "Rode over to the observatory in the dark to dinner and got beset by Van Renen's Dogs, a hungry savage pack of 5 or 6 large hounds & curs of low degree, who had all but eaten me & my horse too ..."
> *July 30:* "Rode over to Observatory Botanising & shooting by the way. Shot a large Gull – The Splendor of the flowers in the flats about the Camp Ground is amazing. Swept [the sky] till 3 AM." – *John Herschel (1834)*[9]

Astronomical expeditions of the past were heroic affairs, as much a physical as a mental challenge. At many observatories observing is still strenuous, though we are trying to change this. But is it really wise to seek to turn experimental astronomy into an activity that is indistinguishable from watching TV?

Every once in a while it is good to remember that watching TV occupies a very small part of the spectrum of human activities, and, to first order, that the content of the TV show is not important. In other words, it does not matter if we are watching a computer display or a 1970's sitcom; while watching TV we are essentially at rest, using only our eyes and ears, focusing on a small part of our surroundings. The flickering display induces a metabolic state that has been measured as less energetic than sleep.

To second order, there are differences in muscular activity between using a computer and watching a TV show. The flick of the remote channel changer requires less coordination than light typing on a keyboard. But the difference is still small on the scale of human activity.

To third order, there is a qualitative difference in content of a TV screen and a computer screen, and perhaps this is what distinguishes us from the majority of the U.S. population who spend a comparable amount of time staring at a tube. Much creativity can occur in the interaction between programmer and computer, and I doubt that people go into computer science because they like being paid to watch TV. But that is what they end up doing, and forcing others to do. Perhaps it is not a good idea to make astronomers and telescope operators dependent on such a narrow information channel. I find it difficult to believe that human beings are designed to function well in so stupefying an environment without major damage to the body or mind.

8. I Want to be Left Alone

> "An observatory is stocked with human beings, after all, and the isolation that dark, clear skies require is always a potential stress factor. Some adapt, some crack, others just get grouchy." – *Evens and Mulholland (1986)*[10]

The astronomer at the telescope is blessedly free of most of life's distractions. Usually, the phone does not ring constantly, few passers-by disrupt a contemplative moment, and even the choices for lunch are limited. Observatories give one the ability to concentrate on observing. This ability cannot be taken for granted for remote observers, many of whom choose remote observing precisely because it allows them to do other things simultaneously. For this reason alone, it is unlikely that the quality of remote observing can ever be as high as that of local observing. There is no way to guarantee the attention and involvement of a remote observer. In contrast, presence at the telescope encourages a high degree of involvement, especially if the astronomer has had to come some distance or does not use the instrument regularly.

At this meeting there have been several discussions of remote observing centers: communication and control facilities situated some distance from the telescope, to which an astronomer would travel to observe. These could give one isolation and focus, and also the context of gossip, and it seems possible that with the proper design and feedback, such centers could promote some responsibility for data and instrument. What they do not give is familiarity with the instrument or more knowledge of it or ability to manipulate it than was anticipated by those who wrote the communications programs. Moreover, even at a remote observing center, can an astronomer who is unfamiliar with the telescope ever really *know* what is happening with it?

9. Why We Should Implement Remote Observing Anyway:

1. It gives us the ability to do short observing projects. There are worthwhile, straightforward experiments that require use of a telescope for only a few hours, or, in some cases, a few minutes. Requiring the astronomer to travel to the telescope produces a threshold for proposal submissions that is unlikely to be crossed for a brief observation. I believe that many more short projects would be proposed if astronomers could be guaranteed a reasonable chance at getting good data without having to travel hours for just a few minutes on the telescope. Remote observing may even open up novel uses of telescopes, e.g., the monitoring of an object for just a few moments every evening.

2. It increases the efficiency of telescope use. If some fraction of all proposals can be run remotely, telescope schedulers will be able to take advantage of particular weather conditions or vagaries of the instrument. At the Green Bank Telescope, where some experiments will require a clear dry atmosphere while others will do quite well in a steady rain, remote observing will allow us to match the program to the contingencies of the weather.

3. It promotes new kinds of collaboration. At this meeting we have heard some amusing stories of remote observers "peering over the shoulder" of a collaborator who is at the telescope. There are also other ways in which collaborations could evolve. Imagine consulting a skilled specialist half way around the world for an opinion, or running several experiments simultaneously on geographically separated instruments. This latter feat is now done routinely in Very Long Baseline Interferometry, but not without considerable help and coordination at each telescope, and with little real-time feedback. We can do better.

4. It will open our instruments to more users. The discipline required to produce a remotely operable telescope system is liable to make that system more friendly and powerful for all users. It may open up a telescope for use beyond the circle of insiders who know the location of the unlabeled switch that turns on the receiver.

5. It may save money? There has been a strong sense at this meeting that implementing a remote observing capability will not save an observatory any money. This may be true if the telescope continues to be scheduled as it was before remote observing was possible. If, however, as I suggest above, new observing forms evolve to take advantage of the new capabilities, then the answer may be different. One reason why large observing collaborations or short projects are not supported now is because they are too expensive if everyone must come to the site.

6. It is always worthwhile to add another tool to the toolbox. There is a problem only if, like Maslow's child with a hammer, we mistake the tool for the task.

10. Why We Are Here

By now, the analogy between our travel here to Tucson for this meeting and an observer's travel to a telescope should be clear. A meeting is much more than the presentations. Creative speculation, gossip, rumors and uncensored opinions occupy the spaces between and around items in the formal agenda. Vital information is transferred in casual comments over coffee, comments that might never be made in an open forum. In many cases we arrive at our personal evaluation of the formal presentations from informal discussions about them. People who are separated from these interactions miss much of the meeting, even if they absorb the complete agenda.

At this meeting we also have great freedom of action, which would not be the case if we were joined electronically. If we wish, we can look not at the speaker, but at our neighbor who may be frowning or laughing. We are free to poke around the back of a computer, or to leave the room for a private conference with one or two others. This goes on all the time. In *The Wizard of Oz*, the rapscallious Wizard shouts, "Pay no attention to the man behind the curtain" as his fraud is revealed by the dog who is not content with what is presented to him. While we are at this meeting, we can to some extent manage the flow of information on our own terms. We can see for ourselves. We are not bound by the menu.

More subtle, but possibly more important in the long run, is that at this *meeting* we are *meeting* people. In normal contact we quickly develop a "feel" for the other person, find out whether communication is easy or difficult, establish a level of trust or skepticism. At a good meeting, quite often a shared vocabulary is developed. We come to understand the meaning of certain words by their context and by watching the group react to their use. Words, phrases, metaphors are created and spread throughout the community from the interactions at meetings. A good meeting conveys the same richness of experience as a good party, but usually with fewer morning-after regrets.

There is also the matter of civility. People linked electronically don't behave very well. Anyone who has ever participated in a "phone" meeting, in which several groups communicate only by voice, knows the poverty of these sessions and appreciates the value of proximity. I have been in many phone meetings and have often watched local folk read a newspaper, engage in a secondary conversation, or make faces or gestures when a remote party has the "floor" – all deadly insults if done in person and all expressing a kind of hostility that I believe is encouraged by the physical absence, the abstraction, of our colleagues. In my experience, phone meetings dehumanize interactions and, though often seemingly necessary and convenient, need to be supplemented by frequent personal contact to avoid creating major rifts in an organization. A similar situation can arise in e-mail. Some colleagues whom I know to be warm, gentle and reasonably open-minded sound aggressive to the point of violence, wild, irresponsible and outright bigoted in their e-mail missives.

Communication between people is never easy, even in person, where we have access to the full range of the senses and plentiful redundancies of speech and gesture. In the highly filtered world of telecommunications, it is all the more difficult. It seems that distance diminishes everything. That's why we're here.

11. Reflections on Procrustes and Antaeus.

> "Every time I come up with what seems like an original thought, it turns out that some damn Greek said it first." – *Anonymous*

Procrustes

"I cannot stop to tell you hardly any of the adventures that befell Theseus on the road to Athens. It is enough to say that he quite cleared that part of the country of the robbers, about whom King Pittheus had been so much alarmed. One of these bad people was named Procrustes; and he was indeed a terrible fellow, and had an ugly way of making fun of poor travelers who happened to fall into his clutches. In his cavern he had a bed, on which, with great pretense of hospitality, he invited his guests to lie down; but if they happened to be shorter than the bed, this wicked villain stretched them out by main force; or, if they were too tall, he lopped off their heads or feet, and laughed at what he had done, as an excellent joke. Thus, however weary a man might be, he never liked to lie in the bed of Procrustes." – *Nathanial Hawthorne (1851)*[11]

Antaeus

"There was one strange thing about Antaeus, of which I have not yet told you .... whenever this redoubtable Giant touched the ground, either with his hand, his foot, or any other part of his body, he grew stronger than ever he had been before. The Earth, you remember, was his mother, and was very fond of him, as being almost the biggest of her children; and so she took this method of keeping him always in full vigor. Some persons affirm that he grew ten times stronger at every touch; others say that it was only twice as strong. But think of it! Whenever Antaeus took a walk, supposing it were but ten miles, and that he stepped a hundred yards at a stride, you may try to cipher out how much mightier he was, on sitting down again, than when he first started." – *Nathanial Hawthorne (1851)*[11]

Astronomy

> "Such an attempt can take one of two antithetical forms: a search for purity or a search for self-enlargement. ... The desire to purify oneself is the desire to slim down, to peel away everything that is accidental, to will one thing, to intensify, to become a simpler and more transparent being. The desire to enlarge oneself is the desire to embrace more and more possibilities, to be constantly learning, to give oneself over entirely to curiosity, to end by having envisaged all the possibilities of the past and of the future." – *Richard Rorty (1986)*[12]

As individual scientists, we seek to reduce, isolate, extract the laws from the tumultuous phenomena. Our accomplishments are judged on the narrowest of grounds. But our scientific institutions, our observatories, even the way we approach our research, must be more expansive.

Several months ago the computer system that I had used for some years was shut down and a modern workstation “with 100 times the power” was placed on my desk. In one blow all my programs were rendered inoperable, though admittedly the new computer could do wondrous things such as chirp like a cuckoo clock, display the latest weather map of the South Pacific, and produce a running graph of the fraction of the CPU power being used (which is usually near zero since it does not know how to run any of my programs). I accept its power, efficiency, and ultimate utility. I'm learning C++. But when asked to “name” the machine so that it could be referenced over the network, my choice was obvious. It is called Procrustes.

Then there is Antaeus. For us, the most interesting part of the tale occurs at his death, when he fell in battle with Hercules, who quickly recognized that Antaeus, as the son the earth, drew his strength from frequent contact with it. Every time Hercules flung Antaeus down, he rose renewed and stronger.

We find ourselves doing astronomy from a variety of motives, but they are usually positive: we find it intellectually stimulating, we find it a fascinating way to lead a life, the challenges are not trivial. I know of no individuals who have ended up in astronomy because they could not succeed at the practice of law or have made a mess at real estate sales and so settled for second best: the life of a scientist. Observational astronomy has its own special attraction. It is a diverse activity which may involve elements of physics, photography, electronics, structural engineering, optics, mathematics, computer science, luck and the ability to work alone without sleep and to endure cold. Why would someone do such things?

Hercules defeated Antaeus by separating him from the source of his strength. He held Antaeus up in the air away from the ground, and Antaeus so removed was hardly Antaeus at all. His strength diminished with distance from the earth, he became too weak to fight, was crushed and flung aside.

We too can become intellectually weakened by distance, by separation, transformed into consumers of data, not experimental scientists or producers of it, and, like Antaeus, held at the end of a leased line away from the source of our strength, wither and fade. We are neither unprecedented nor unique in our situation, nor in the struggle to prevent our tools from diverting us from the reasons we made them in the first place.

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