A TELESCOPE IN 700 DAYS

Building the 300-foot

By John W. Findlay

Introduction.

This paper is derived from a talk given at the symposium on the 300-foot telescope, held in Green Bank on September 25 and 26, 1987, to celebrate the first 25 years (or 9131 meridian crossings) of observations made with the telescope. A program of the various talks is given as Appendix 1, and it will be seen that the main facts of the history of the telescope and of some of the science which has been done with it were described. The audience was made up of users of the telescope and many of those who have operated, maintained and improved it over the years. All speakers tried to tell the truth as they saw it about the telescope and its work. I have transcribed the words I spoke without making any more alterations than seemed necessary to me to keep the text readable without losing the feeling of pleasure that I got in giving the talk to an excellent and friendly audience.

The Talk.

Just about everything I say in this talk will be recollections of what happened, looked at through my own eyes. This is the only way I can do it. I have checked facts fairly well, but the feelings and opinions that I had at the time may well appear every now and again. To start I should like to go back in history to before AUI was invented and recall that I was associated with some of the inventors. In the years 1936 and 1937 Norman Ramsey and I were students together in Part II of the Natural Sciences Tripos in Cambridge; we worked together for two years attending the same lectures and going to the same supervisor. For our final year that supervisor was Maurice Goldhaber, later to become the Director of Brookhaven. He taught both of us nuclear physics, and by the end of the year and the onset of the examinations, we knew it. The other man whom I must mention, although others of you have already done so, is Lloyd Berkner. All I need say, because you already all know it, is that the Observatory would not be here now if were not for him and his work.

Now, how did we come to the 300-foot telescope? We were trying to get the Observatory working as quickly as possible, and by 1960 I believe many of us often felt angry and frustrated because the 140-foot, the "off-the shelf" telescope, was flat on the ground. It really was not there at all and the only thing being built was the foundation. And there was Gart Westerhout with his cigar in his mouth, working away at the 85-foot telescope. He has been for many years one of our most consistent users. But in those days we didn't really have a telescope

worthy of him, or many other users, and certainly not in the least worthy of the plans, money and effort going to make up a National Observatory. Fred Haddock had a telescope as big as ours, so also did Ed McClain (and he was shortly to add a second), and Bernard Lovell had brought the Jodrell Bank 250-foot into use in late 1957. We had built a lot of buildings at Green Bank, the staff had grown to more than 60, and the annual operating budget was more than half-a-million dollars. And we had persuaded Otto Struve to become our first director. We were frustrated.

So we searched for ways to get some observing done with a large but easy to build telescope. At the time, I called it the search for a "quick and dirty" telescope, and I still stick to this description, though it irritated some people. (Isidore Rabi was one; he did not like it at all and he told me that the U.S.A. does not build cheap and dirty instruments.) We tried several ways to go and tested two before making a choice. I looked back over the suggestions, and one we did not follow up came from Frank Drake, who suggested using a zone plate. A zone plate does, of course, bring a plane wave to a focus (actually to several foci) but the focal length is wavelength dependent. We did in fact ask Neil Stafford of the Stanford Research Institute (SRI) to try an alt-azimuth design with a very low elevation axis, so as to lower the cost at the expense of giving only sky cover near the zenith. SRI had built several, quite simple 150-foot telescopes--one on the Stanford campus and at least one for air defense on the coast of Scotland. Stafford came up with what you might call a "stubby" alt-az design, which might be built for a few hundred thousand dollars. The other design to consider was obviously a small edition of Arecibo, which was then being designed. We actually considered using the top end of Hospital Run as a site; it was not a hole-in-the-ground, but it was a trench and I thought cables could be put across it, and we could build a 430-foot spherical antenna like Arecibo for about this $300,000 we were talking about. So, before I reached the first day of my 700 days, I went up to Ithaca and talked with Bill Gordon and then at some length with Marshall Cohen. As many of you know, Marshall is clever, and he described the Arecibo feed design. After about an hour I said, "You may be able to do it Marshall, but I am sure I can't; it's too difficult for me." And I was right; wasn't I? For a long time it was too difficult for them. It was the feed difficulties which turned me away from the spherical reflector. In addition I could not see how frequencies could be switched for different programs as quickly as we felt would be needed. In this I was probably too cautious.

So we were left essentially with the idea of a simple transit telescope. For this we already had Bob Hall, who was the designer for Blaw Knox of the 85-foot telescopes. Blaw Knox had supplied one to Fred Haddock, two to JPL and of course, one to us. The design was fairly simple, and I remember one day

sketching a transit telescope on the blackboard with Dave Heeschen and saying, "This is easy; we just have to tilt it." And so I went up to see Bob Hall to talk to him about the design; that day was the first of my 700 days and it was November 7th, 1960. He met me at the airport; he was of course at that time working for Blaw Knox, and his first words were, "Well, I'm fired." This was something of an overly dramatic statement. Bob had already decided to join the Rohr Corporation in Chula Vista, and so he told Blaw Knox that he planned to leave them in two or three months. The reply he got was that he might just as well leave at once, and so he did. It turned out that he did not have to arrive in Chula Vista for about six weeks, and Bob told me that, in that time, he could set down the overall design of a transit telescope which would meet our plans. And in fact, this is what he did. He set up drafting tables in the basement of his house, and I hired (following his advice) five engineers who were in fact on the Blaw Knox payroll) and in six weeks these, with Bob, working at nights and week-ends, produced enough drawings to set the design of the telescope. They didn't get it quite right, but never mind. At the end of the six weeks I had enough drawings to make it possible to go out for bids on the steel structure in the February of 1961.

In the interval it was necessary to increase the number of drawings and to have an engineering office devoted to the telescope, and I asked the advice of Max Small at Brookhaven. He proposed Ed Faelten, who had a small engineering firm in Buffalo, and who was well known to Max from their work in the shipyards of WW II building Liberty ships for the German submarines to try to sink in the battle of the Atlantic. Incidentally, earlier in the 300-foot story I had asked both Max and Bob for a rough estimate for the cost of the structural steel erected and both had said that, if it were kept simple, it might be bought for about fifty cents a pound, or $1000 a ton, which I felt was really quite cheap and we already had NSF approval to spend $300,000.

So, as I said, by February we had about 30 Faelten drawings of the steel and adequate foundation designs, and so we were able to ask for bids on the telescope and its foundations. In those happy days we got ten bidders for the steel. We bid it separately, to fabricate the steel and to erect the steel; the erection, however, had to include also the placement of the main bearings, the drive package and the chain. These items, as well as the foundation work, were designed and bid separately.

During the bidding process I got what I think was the only pressure which might have been intended to affect the contract award. This came about because Blaw Knox complained about the use of Hall and the engineers used in the early design. I felt that Bob Hall was a free agent, but looking back I am not so sure that I was quite correct in using the five engineers. But nothing came of this difficulty; I, of course, visited Blaw Knox

and explained what had been done, and the bidding resulted in a contract for fabrication and erection being let to Bristol Steel and Iron of Bristol, Virginia. Many will know Bristol as the city where the Virginia-Tennessee state line runs along the center of Main Street. The foundation work went to B.F. Parrott (who had already built the Works Area building), the drive package and drive chain was done by Link Belt and the bearing mounts were from Lake Erie Engineering.

Let me show here a photograph (Plate 1) of the telescope as it was after completion. It was changed quite a lot in later years, as some of the following speakers may wish to describe. We held a ground-breaking ceremony on April 27th, 1961; Plate 2 shows Otto Struve with the spade and Plate 3 is a group of the men from Bristol, Ed Faelten, the author and Otto. Fabrication of steel started in April 1961; by that time work on digging the square excavations, which went down to a layer of rather fragmented rock, had also been started. Foundations were also prepared for the drive package, which was to be below ground level, and for the two temporary erection towers. A fairly novel method for transporting the mixed concrete from the batch plant to the excavations was used--a pump sent the material through a pipe from the plant to the hole to be filled. This was quicker than wheel-barrows, at least until there was a pump failure, when the workers were presented with a long six-inch pipe filled with rapidly-setting concrete. Nevertheless, we did get the foundations successfully in place without too much trouble.

Some of the audience saw the less-than-perfect video tape last night which was recovered from a film made by a young English student, (George Gilbart-Smith, the son of a friend of mine) who spent the summer of 1961 at Green Bank. I had intended to try to do a time-lapse sequence of the telescope which, when speeded up, would show it growing like a flower. So George went every morning to the site, mounted a movie camera onto a fixed post, and shot some film with the camera always pointed in the same direction. Well, this was a stupid idea, but only recently Fred Crews recovered the film, and with the skilled help of Brookhaven, managed to put together the video that you saw.

So, during that summer, the telescope structure started to grow. It was a very simple structure; there were the two towers to carry the elevation bearings, two erection towers at the North and South corners, and another similar tower at the center to position the hub. The dish structure was built on these--the steel was bolted together using high-tensile bolts, and the inner and outer rib structure was added after pre-assembly on the ground. Plates 4,5 and 6 show various stages in the steel erection and the way two mobile cranes were used. During the bidding process Blaw Knox commented to me that they did not believe that the design was adequately strong. It had been done by the old-fashioned methods, and I had already made plans to

review the design work by making a computer check. So, as soon as Bob Hall got to Rohr, I gave him his design back and asked for an evaluation using a suitable computer program. He was able to do a stress and deflection analysis over the period when the bidding was in process and during the start of the steel fabrication. He made a number of design changes, and, if anyone looks at the structure now, it is possible to see a number of main members which are made up of small cross-section members backed up by bigger ones. It was these bigger ones which were added as a result of the Rohr analysis.

My dealings with the Virginia gentlemen (as I called them) during the summer of 1961 were thus punctuated by the arrival of changed drawings from Rohr while the first work of detailing and fabricating the steel was being done at Bristol. There is a considerable body of work needed to turn the design drawings into the detailed drawings needed for fabrication members, joints and sub-assemblies. All this work was done at Bristol and while it was in progress I, with Faelten, used to go to Bristol about once every ten days or so with about a page or page-and-a-half of member changes to be made. I used the name "Virginia Gentlemen" because a typical day in such a visit would start at eight in the morning at the plant. We would be greeted with "Tee-off time is 12:30, so let's get started." And we had to keep to this. I would hand over my list of changes, sometimes quite large amounts of steel, and after a period of study the conversation would go somewhat as follows:

Bristol: "This looks OK. We can do it."
JWF: "Good, what will it cost me?"
Bristol: "We will work it out and bill you."

It was quite an experience, but they really were gentlemen. The first time I went through this I asked how they would bill us and was told that, since the contract was in terms of the cost per unit weight of the steel for fabrication and erection, they would bill us at this rate for the steel which I wished to add. When I suggested that they might already have cut and punched steel which the changes would waste I was told, "Why don't you leave our business to us?" And this is the way it was worked. As we checked when the bills came in, we paid only for the added steel. And we always teed-off at 12:30. Throughout the course of the steel-work at Green Bank there was only one accident, which turned out not to be too serious. The dish structure outside the main square frame was erected one pre-assembled sector at a time using two cranes. When one such sector was bolted in place, a crane was unhooked too soon and the steel fell. One iron worker, who was on the falling steel, held on until the steel struck the ground in a crumpled mess; he then stepped off safely.

The work went ahead steadily at Green Bank, as the Plates 4, 5 and 6 show. Until by the beginning of December, the main structure was in place, and about 400 of my 700 days had been used up. We were very fortunate in not being stopped by weather, for it was important that the steel should be completed before winds became too strong. Through the winter, all we did was to measure the shape of the steel on which the surface was to be placed. I had not demanded any accuracy from the steel fabrication and erection, other than the steel as fabricated should fit together in erection. I had not decided exactly how to attach the surface mesh, since I did not know how closely the steel would lie to its desired position. Sidney Smith and John Ralston did the tape-and-transit survey of the steel and we found that the properly shaped surface could be fitted to lie within a few inches above the steel. ("A few" was in some cases as big as eight inches.) The surface which was to be made from sheets of 3/8th inch Squarex mesh, identical to that proposed for the 600-foot NRL telescope at Sugar Grove, could then be supported by Nelson studs the correct height above the steel. Nelson studs are lengths of threaded steel rod, which can be shot into the steel in a spot-welding operation. The plan was to set a nut onto each stud at the required elevation and to bolt the sheets of Squarex onto these nuts. (See Plates 8 and 9.)

Fred Hoyle had sent one of his graduate students, Miss Joan Crampin, to work at Green Bank and she accepted the task of planning and computing where all the studs should go and where the nuts should be set on them. She did this correctly, as can be seen from the fact that the telescope later worked adequately at 1400 MHz. The only other thing I remember about Joan Crampin was the skill and enthusiasm with which she danced the "twist" (a dance of the early sixties made famous by someone called Chubby Checker). We got the surface in place that winter, with only one problem caused by Union rules. I proposed to ask our own telescope mechanics to place the surface sheets, but was told by Darin and Armstrong, who were now on site working on the 140-foot foundation, that this was not correct and Union labor must be used. The Virginia Gentlemen came to my help and took the extra task of placing the surface, using of course their own erection crew.

The drive package and chain (Plate 7) were delivered and installed on the telescope in February 1962 . Cabling was begun at about the same time and by May 1962 we were faced with the fact that the instrument was ready to be tilted. I had been helped a lot by Spencer Greenwood, a top-level mechanic who had been a shipyard superintendent (in the same yard as Max Small) in WW II and who was working on the 140-foot. In fact, there is a story that he saved a major error when that telescope was being erected. One test which was made when the polar shaft and hydrostatic bearing were in place, was to pump the oil into the bearing for the first time. As it floated, the bearing was supposed to move very slightly down-hill. But Spencer, for some

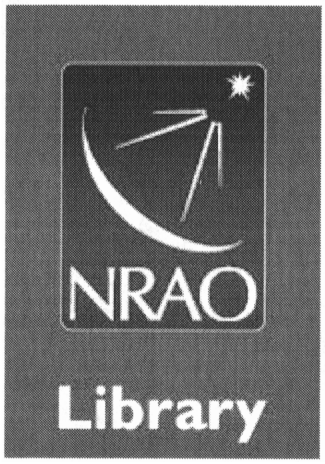
reason unknown to others, had welded a strong steel stop at the lower end of the shaft. When the oil was pumped in, the coefficient of friction at the sphere fell to zero--as it should. But the center of gravity of the sphere and shaft was so far below the sphere, that the sphere could ride up-hill out of the bearing pads as the geometry allowed the C of G to fall. And so it did, and the shaft did not hit the ground because of Greenwood's stop. John Ralston was standing with a millimeter scale to measure the shaft movement; in dead silence someone handed him a yard-stick. (Unfortunately, I was not present, and I cannot confirm this story.)

We tilted the telescope for the first time on May 4th, 1962, and, as Spencer Greenwood had helped a lot with the drive, I left it to him and Fred Crews to drive the instrument to its South and North limits. I was (as is not unusual at such times) quite uncertain whether everything would work, so I went away and sat in the field and watched the operation from a distance. All went well. I described the surface setting earlier, but we deferred the installation until the summer of 1962, since there was plenty to do with completing the control building and cabling the instrument, for all of which the summer work period was essential. I remember showing the incomplete surface to Joe Pawsey when he visited Green Bank in July 1962, shortly after he had accepted the directorship.

The final work to bring the telescope into use was shared among many, in Telecope Operations, Electronics and Site Maintenance. Frank Drake saw to the installation of 750 MHz and 1400 MHz continuum receivers, and by October 1st, 1962 observations had begun. I suppose the end of the project from my point of view was when the instrument was handed over to Fred Crews as head of Telescope Operations. I have no exact date for this, but I recall that I and a few others were sitting near the telescope one evening when Fred came past, entered the control room and tilted the telescope. As he came out I called to him, "OK Fred, it's yours." I have always remembered this as the hand-over.

Illustrations.

Plate 1. The 300-foot telescope in its original form.
" 2. Otto Struve at the ground-breaking April 27th, 1961.
" 3. April 27th, 1961. From left: M. Howell, BS&I Erection Manager; John Hawkins, BS&I VP for Sales; Jim Tilley, BS&I Executive VP; E.R. Faelten, Engineer; JWF; Otto Struve, Director NRAO; and Charlie Bush, BS&I Engineer.
" 4. The telescope on October 6th, 1961
" 5. " " " November 2nd, 1961
" 6. " " " December 1st, 1961.
" 7. The Drive.
" 8. Shooting Nelson Studs.
" 9. Placing surface August 17th, 1962..



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