<u>SAND, SILVER, AND STARS</u>
Scenario and script by B. Franklyn Shinn
Winnipeg, March, 1974.

TITLES:
Sand, Silver & Stars — 1:25 Building
How he made his observatory — 1:45 Dome
Produced by B.F. Shinn
With Jack Newton's telescope.
Animation & artwork by Edward Barker

I

2:42 Jack Newton, President of the Winnipeg Centre RASC decided about 1969, the time had come to create his own observatory.

3:05 The amateur astronomer has two ways to get a telescope; he can buy it ready made or he can make it. Making a telescope will yield more telescope per dollar, so the choice depends on whether you prefer making telescopes or dollars. Supplies for mirror grinding are available quite readily, and all you need in addition is some time to read and place to work.

3:30

3:49 Of course there is something very satisfying in owning the professionalism of the ready made product, and you can always blame the manufacturer if it doesn't work up to your expectations. This is less satisfying if you yourself are the manufacturer.

4:05 Sir Isaac Newton dreamed up the idea of using a mirror to focus the light from a star, so I suppose we must blame him for the amateur telescope makers' embroilment. Anyway, Jack felt that what a 17th century Newton could start, a 20th century Newton could continue.

4:24 It is more usual to use two pieces of glass to grind a telescope, one becoming the concave mirror and the other a convex tool, but Jack had heard of using bathroom tile for the tool, supported on dental plaster. This would further improve the ration of telescope to dollar, so we started.

4:45

5:12 II He hadn't made a mirror before, so he decided to get me to mastermind the job. I am a firm believer that you should keep a log of everything you do when you're making a mirror, and of course who inherited the job of making out the log?

5:28 This is what he means by 'masterminding'?

5:44 Grinding is a matter of pushing the future mirror back and forth across the tool with abrasive between them. from time to time the abrasive wears down and must be renewed. Adding it by shaking it on this way could result in grinding down the edges and perhaps ought to be avoided. (6:04) We didn't make a practice of it, but we found that when the mirror was brought back across the coarse added abrasive it broke away from the tool revealing a very interesting pattern whose regularity gave us an indication of the evenness of contact.

6:24 As the abrasive wore down a mud accumulated on the mirror which had to be flushed off. (6:30).

6:35 III To shorten the telescope Jack wanted it made to the Cassegrain design, so we had to cut a hole in the primary mirror and make a convex secondary mirror. The hole was cut by a -- "cookie cutter", what else! It was a brass tube of the required diameter, with a notched end, used in a slow-running drillpress. (6:57).

7:17 A jig cut from plywood made sure we got the hole exactly in the centre. (7:22).

[There's a pause at this point in the voice recording].

7:35 A small dam of plasticine kept the abrasive mixture near the tool during cutting. The abrasive we used was No. 120 Carborundum. 7:45, 8:00. In all the grinding the abrasives are used in water which cools both glass and abrasive preventing them fusing into an almost unworkable mass. 8:10.

8:20 The .... is somewhat traumatic. From time to time we had to renew the water, and add abrasive. Releasing pressure on the cutting tool allows it to pick up a fresh charge. 8:40.

[Pause].

9:06 During this cutting operation the refraction intrigued us; it made the hole in the mirror look larger than the tool that was cutting it.

[Pause].

9:55 About two hours work and the hole was deep enough. We left an eighth of an inch of glass to be cut through after grinding was completed and the mirror polished. Leaving the plug in the hole prevented the edges from distorting in the subsequent operations.

10:15 IV With the hole cut we returned to fine grinding, and just to check that the surface was uniform we put a quick polish on it with honeycomb foundation. About five minutes polishing on this beeswax mat using Barnesite as a polishing agent was sufficient to flatten the peaks of the hills until a reflection of Ronchi lines could be checked for straightness.

Real polishing takes place on a pitch lap with grooves or lands. To form the grooves we placed a rubber mat on the surface of the well-cleaned mirror and poured the pitch over it.

10:57 Pitch comes in chunks. We used a -- mixture -- of brute force and kindness to break it up. Putting it in a plastic bag first, cuts down on the recollecting time.

A suitable ladle for melting pitch can easily be made from an old tin can.

11:27 At all stages of telescope making absolute, almost frenetic cleanliness is a must, but before pouring the lap I cleaned the tool with turpentine to make sure the pitch stuck to the tool and not to the mirror.

I always like to add beeswax to the pitch. It seems to temper it and produce a pitch that is more likely to have the right hardness over a wider range of workroom temperatures.

Barnesite as a polishing compound was reported to be very fast. That was for me! A mixture to the consistency of thin cream was brushed over the mirror surface to keep the pitch from sticking. 12:02.

12:29 The melted pitch was carefully strained through two thicknesses of nylon from a pair of hose -- with the leg removed. I consider this a must. Straining the pitch, that is! 12:40.

13:03 Lower the tool onto the top, and -- "squoosh" it down. 13:17.

13:41 About half an hour after we had poured the pitch we turned the whole assembly over getting the mirror on top. Through it we could see the surface of the lap. We were to see this sight for the next fifteen or twenty hours. 13:56.

14:18 V Getting a mirror to slide the first inch can sometimes be quite difficult, and this one was no exception. Persistence, kindness, and a certain amount of stubborn brute force finally started it. 14:33. Once they begin to move the resistance of mirrors soon falls off.

14:40Once we had the mirror off the lap, we could tear out the rubber mat, leaving the grooves and squares. 14:56.

15:07The polishing stroke is like the grinding stroke, travelling back-and-forth about four inches, 1/3 of the diameter of the mirror. Some variation in path was introduced by making the stroke take a small "w".

The French physician Foucault worked out a way in which a mirror could be tested for accuracy. The light from a star comes in parallel beams which the mirror must bring to a point. The light from a lamp inside a sphere would be reflected back into the lamp. 15:45. A telescope mirror begins as part of a sphere. If the lamp is moved a bit to one side the returning rays will move to the other side and we can observe them. If the rays do not all return to one point a knife edge inserted at that point will cut those in focus at that point but the other rays will bypass the knife edge. The eye sees parts of the mirror reflected rays to the knife edge focus go dark; it looks like a shadow crossing the mirror.

In this Foucault apparatus the lamphouse is at the left; the light issues through a slit visible in the prism in the centre of this picture. The prims turns the beams toward the mirror. To the right of the prism is the knife-edge which can be moved in and out of the reflected beam by this screw. 16:36.

16:56 The knife-edge can be moved forward and back and the reflected beams can be observed either with an eyepiece to see that knife-edge and slit are actually parallel; or directly by eye so that we can look for the shadows on the mirror. 17:24. The screw that moves the knife-edge back and forth can have a micrometer measured on a scale, the Barr scale, which has an inch divided into 10th both vertically and horizontally. The opposite points are joined by diagonal lines and the travel of an index across this enables the position of the knife-edge to be read easily to a hundredth of an inch, and estimated to much smaller intervals. 17:57.

18:12 The mirror was set up on a test stand that allowed it to be tilted and adjusted until the reflected beams encountered the knife-edge. The distance from he knife edge to the mirror is of course the radius of curvature of the mirror, twice its effective focal length.

18:12 VI Bringing our eye down behind the knife edge we began to look for the shadows as they crossed the mirror. If the knife edge was between the mirror and the focal point the shadows crossed in the same direction as the knife edge. If the knife-edge was beyond the focus, where the rays had crossed, the reflected shadow crossed in the reverse direction.

19:09To reflect parallel beams from a star accurately the mirror must be a little flatter at the edges so that its shadowgram is that of a doughnut, but the shadows are so delicate they are extremely difficult to photograph.

19:29A somewhat different form of the test was invented by Ronchi, when he substituted a series of parallel wires for the knife-edge. Under this the mirror shows a pattern of lines whose curvature of straightness is a development of the curvature of the surface of the mirror. As a Ronchi screen is brought back beyond focus the curves reverse. A spherical mirror would show straight lines, but it would reflect parallel beams from stars to slightly different points from the edges and from the centre. It must be corrected to a parabola in order that all the beams will be brought to a common point. This means that the centre of the mirror must have a deeper curve than the edge. 20:12. I like to parabolize by overhanging the polishing lap so that more polishing takes place in the centre than at the edges. The amount of change is measured by locating the centre of curvature of each area by the knife-edge position.

[Pause].

20:43The knife-edge shift to create a parabola from a sphere is given by r^2/R; r^2 over R. In this formula small r is the radius of the mirror zone wherever you're measuring it, and the large R is Radius of Curvature of the whole mirror. 21:05.

[Pause].

21:11 This we calculated for several different radii of the mirror, and masks were arranged so that the shadows could be observed at each. The shift of the knife-edge necessary to create shadows at that point was measured, and polishing was adjusted to centre on the various high points until they polished out to the right depth. The amount of glass to be moved is only measurable in millionths of an inch.

21:48 Particular interest was paid to the 70% zone where the knife-edge ought to lie exactly half-way between its position for the centre and it position for the edge. The position was of course observed on the Barr scale. 22:04. 22:31: Jack's mirror went through several interesting patterns before it finally became a smooth curve from edge to centre.

22:48 VII After the primary was finished we had to turn our attention to the secondary. This was a small mirror which felt like a toy after the 12½ inch one. It was too small to use tile, so I used two pieces of glass, Pyrex blanks 4¼ inches in diameter, one of which would be cut to the required 3 inches for the finished secondary. We required a convex mirror this time, so that would be the lower of the pair we ground.

Instead of walking around the table as we had with the big one I put this one on a turntable. 22:39. I cut out the mirror with a cookie cutter, and to true up the edges fastened it on a block of wood with pitch, chucked the block in a small lathe, and spun the edge against an iron band with the usual water and abrasive. It took about half an hour. 23:57.

24:47All that masterminding wore me down, so I sat this one out! By this time of course the small convex mirror was smaller than the tool on which I had ground it, so to prevent this causing problems I made the lap on dental plaster the same diameter as the mirror. 25:15. The same process again; the rubber mat, melted pitch strained through two thicknesses of nylon, lubricate the mirror, etc. This time I used cerium oxide instead of Barnesite for polishing since I was more familiar with it, and as perhaps it is a little slower I preferred it for the delicate surface of the small convex mirror. 25:43.

[Fill].

26:35 VIII Convexity was the big problem. Being convex it wouldn't bring the light to a real focus. I tried testing it through a lens of shorter focus than the theoretical negative value of the secondary, but the only result was some of the most fascinating Foucault pictures I have ever seen. These patterns of not-quite-concentric rings were quite uncooperative, they would not smooth out. Eventually I realized that they rotated if I rotated the lens, but not if I rotated the mirror; they were in the lens system, not on the mirror surface!

27:15The classical way of figuring the Cassegrain secondary is to set the system up facing into a flat, but we didn't know anyone with a flat and we didn't feel like making one, especially as you can't make one, you have to make three!

How to test that secondary? Eventually I worked out another way to do it; I set up my own Shinn/Newtonian with the pinhole at its focal point and directed the beams into the Newton/Shinnegrain, -- oh, I beg your pardon, the Newton Cassegrain. Then we could figure as if we were figuring on a star.

27:53Of course when we had finished all that figuring what we had fabricated was only the support surface. Grains of sand melted and fused into the finest glass, ground and polished by the most fastidious loving hands, can reflect only a tiny portion of the starlight that falls on them. They must be given a silver coat to lift our gaze from he stuff of this planet to the kingdom of the stars..

28:21 IX Silver tarnishes, so to-day's telescope maker coats his mirrors with aluminum. Neither Jack nor I had facilities to do this, so we took the mirror to the laboratory of Rene Lamontagne, another member of the Winnipeg Centre RASC.

We found Rene about to re-aluminize the mirror from his son Kenneth's 6-inch. Since this would be under a glass belljar where we could spay on the inner workings, we talked Kenneth into allowing us to photograph the process, even if our distraction might result in his dad having to do the job over.

Again, as we have mentioned, absolute cleanliness is a sine-qua-non of successful telescope making. In no stage of the work is this more true than in aluminizing. It begins with a thorough washing in nitric acid, whose corrosive properties and asphyxiating fumes should be well known. After a rinse the mirror is put aside to dry, and the belljar and interior of the chamber are thoroughly cleaned with caustic soda or caustic potash, NaOH or KOH.

Merely drying the mirror is not enough; a small amount of phosphorous pentoxide is placed in a mesh-covered container within the chamber to act as a desiccant during pumping down.

29:35 Rene hung strips of pure aluminum foil along a tungsten filament that would be inside the belljar with the mirror. (30 secs).

30:05 Pumping down is done by two pumps; a mechanical pump backing up a diffusion pump. Pressure remaining in the chamber is indicated by the glow around electrodes at a potential of 1000 volts, and pumping continues until there aren't enough molecules left to ionize and the glow stops. Then air is bled into the chamber to restore the glow for a minute or so, a process called ion bombardment which dislodges and clinging water molecules from the surface of the glass.

When the glow stopped again, Rene turned on the filament current and watched it heat. Aluminum foil hung over it melted "wetting" the filament. He increased the current and aluminizing began, and finished almost before we realized it had begun. Out came the new Kenneth Lamontagne Astronomical Pride and Joy! 30:54.

31:41 Finally Jack could assemble and try his telescope. He had constructed a very rigid mount and observatory while the mirror was in production. The design resulted from years of experience with less-than-rigid mounts. His new one had a concrete pier and very heavy bearings and was housed in an observatory building.

Jack had come up with an ingenious secondary support which he could turn over, replacing the convex mirror with the usual Newtonian diagonal, so his telescope could function in either mode. 32:17.

32:27 There are always some last minute adjustments. They take quit a bit of time, but at least this postpones the fateful moment when the decision has to be made to look through the system and subject it to the Moment of Truth test! Jack's rigid mount contributed much to the rather pleasing results we were to find. 32:47.

33:26 The supreme moment; the first look!

33: Jack, as always the astrophoto-phobe, found that his movie camera would work through his telescope. Not only that, but his zoom lens gave him variable power in telescope-camera combination.

34:13 XII Varying the power in this way produces the most convincing demonstration of what happens when you spread light out by increasing magnification. Notice how, as the image size is increased, the illumination drops.

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35:33 And -- that's how he built his observatory!

35:42 Bird flies.

35:48 Fadeout.