CHAPTER V

ESTIMATES OF COST

1. Fabrication and Erection Costs

In making cost estimates for the telescope, the whole project has been subdivided into elements; these have been chosen to reflect the most likely way in which the various parts would in fact be procured. For example, the structural steel which goes into the entire tower and reflector structure is one element of the whole telescope, since it would be procured either by a single contract or by separate fabrication and erection contracts. The main mechanical parts, such as the azimuth trucks, azimuth and elevation bearings and bearing mounts, azimuth motors and gear reducers, elevation drive mount and its associated motors and reducer units, elevation gear rack and similar items have been treated in the estimate as separate procurement items. In this paragraph we will note how the estimates for these various parts of the work have been obtained, and then tabulate the estimated costs in Table 25.

(a) Fabrication of the tower and reflector structure and erection of the telescope. Fabrication estimates have been made separately and independently by the NRAO engineering staff and also by a contractor experienced in antenna construction. The methods of estimating used by both groups have been very similar. The fabrication tasks have been broken down into the various stages, material procurement, cutting to length, preparation of ends, cost of waste material, lengths and complexities of welds required and so on. Unit prices for these various operations have been chosen, based on the best possible information available from companies or individuals with experience. These unit costs were in costs per pound weight (for material) or cost per linear foot of welds. Thus the total fabrication cost of the structure was developed. The estimates prepared within the NRAO and by the firm of LTV Electrosystems agreed well. Although it is not possible to be precise about the location of either the fabricator or of the exact site of the telescope, shipping costs for all fabricated materials from a location near Dallas, Texas to a point near Tucson, Arizona were included in this fabrication estimate. The figure adopted in the estimate is shown in Table 25.

Before the erection cost was estimated, it was necessary to adopt an erection plan. Accordingly, Mr. A. A. Kester worked as a consultant for the design group and developed the step-by-step procedure for erecting the whole telescope. Mr. Kester has had long experience in erecting antennas; his plan showed the method of erection and the on-site requirements for buildings, cranes, equipment and men through the erection phase. His work was quite detailed and thus the cost of erection was developed by him from his basic estimates of man-hours, rental terms or purchase costs for machinery, expendable materials and similar items. The result of his work again has been compared with estimates made independently within NRAO, and the final figure adopted is in Table 25.

It should be noted that in all the figures adopted in the cost estimates, suitable figures for general and administrative expenses (G&A), fee or profit, burdens on wage or salary rates and insurance have been included as well as they can be estimated.

It will be noted that there is an intermediate structure between the 60 homology points of the dish structure and the surface plates of the reflecting surface. This intermediate structure effects the transition between the widely spaced homology points and the necessarily small surface plates and consists of a space frame structure composed of small diameter tubular members. The cost of this intermediate structure was estimated on a per pound basis by the NRAO engineering staff based on costs secured for space frame structures of small diameter tubes from two antenna manufacturers for the original 300-foot homology design.

Since the elements of this intermediate structure are quite large (approximately 28 feet x 36 feet x 8 feet deep), the final assembly will be made at the erection site in an assembly building whose cost has been included in the erection cost. This assembly building is also required to assemble on site those telescope members whose length preclude shipment in the final length.

(b) <u>The surface plates</u>. The total area to be covered by the surface plates is 38,258 sq. feet, and, as Table 5 shows, there are a total of 2912 plates used. Two designs of surface plate have been shown to be satisfactory; for the cost estimate we have chosen to use the machined-contour surface plate, since the means of manufacture of this plate can be stated with some certainty. The estimate of cost is derived from the Philco-Ford report, and includes all costs up to the mounting of the plates on the telescope. The cost of the final adjustment of the surface has been estimated on the basis of using the Zeiss pentaprism system and the total cost thus arrived at is included in Table 25.

(c) <u>Azimuth trucks and drive motors, pintle bearing, elevation bearings, elevation gear and drive motors</u>. The estimates for these items have been derived from quotations received from various possible suppliers (SDL Report H-10 contains some details). The estimates cover fabrication and delivery to the site. The cost of erection of these and of other subsidiary components of the telescope is included in the erection cost estimate already described in (a) above.

(d) The foundation and track. This estimate includes all the foundation work needed for the telescope, including that for the azimuth rail track and pintle bearing. The erection plan includes temporary foundations needed for a derrick and false-work towers and the costs of these are included in the erection figure. The estimate is based on work by NRAO engineers and is for the foundation design already described. Final design must await the choice of a specific site, but the present foundation design is likely to be adequate for almost any reasonable choice of site.

(e) Feed support, subreflector and observing cabins. The cost of the steel feed legs, the framework of the observing rooms at the prime and secondary focal points, the cabins themselves with the machinery for rotation and the Cassegrain subreflector and its focussing and adjusting mount are all included in this estimate.

(f) The position reference system. The cost estimate for this system has been derived from costs of the component parts of the system. The first main component is the stable reference platform, which includes the torque motors, precise digital encoders, tachometers and the seven-sided mirror, all in a temperature controlled enclosure. Another main item is the seven 2-axis autocollimators, each of which has an associated tilt sensor. The coarse position encoders and a considerable amount of servo electronics all come into this estimate. The estimates for all the principal items come from possible suppliers, and the cost of engineering and integrating the whole system is included.

(g) The servo drive and control system. The main components here are the azimuth and elevation drive servo motors, servo amplifiers, tachometers and the electronics required for the various functions pictured in Figure 25. The costs have been estimated by the servo designer; again the costs of engineering and integrating the system have been included.

(h) The telescope computer. A typical present-day computer has been used to give the hardware cost, although it is likely that further advances in computer technique will allow of a different choice later. A liberal estimate of the cost of preparing the computer programs is also included in this estimate.

(i) The remaining items. Most of the remaining items in Table 25 are self-explanatory. The costs of preparing the site are included in the table, and are covered in more detail in the following paragraph. Project management and engineering covers the cost which would be expend by NRAO during the final engineering and construction phase of the work. It should be pointed out that while the present status of the design reflects a considerable amount of design effort in critical areas beyond that normally done in a feasibility study, NRAO plans to perform, by contract, a detailed design of all elements of the antenna prior to entering the fabrication and erection phase of the work. Staff already at NRAO will also be used in this work; their cost is not included.

2. Site Development Costs

Although no specific site has yet been chosen for the telescope, it is desirable to show what the development of a site would cost. To do this, we have assumed that the telescope is to be built on the VLA site Y-15 (see Chapter IV, Section 3d). We have also assumed that no site development for the VLA has taken place, so that the 65-meter telescope must carry with itself all site costs.

Table 26 shows the estimated site development costs. The items are largely self-explanatory. The standby generator is larger than is essential, but extra capacity is valuable and not too costly. The telescope service tower (to allow of work and installation at the prime focus) is an integral part of the control building, located on the north side of the telescope.

The erection plan for the telescope includes in its cost the provision on the site of a 160x60 feet building where the large members can be welded together. (They must be shipped in lengths of 40 feet or less.) This building would be retained and adapted to a shop, garage and storage building. The cost for this adaptation is shown in Table 26.

Of course, if it turns out that the VLA and the 65-meter telescope can share the same site (which seems quite possible scientifically), then a number of items in Table 26 would already be provided for the VLA. The site development cost has not been worked out for this situation, but would be significantly less than the $634,000 in Table 26.

3. Operating Manpower and Costs

Table 27 lists the staff who would be needed at the site to operate, maintain and manage the telescope. It also shows the estimated costs of this staff and of the materials, services and supplies needed each year.

We have not included in Table 27 the cost of services which the telescope would need but which would be supplied from the NRAO fiscal, personnel, purchasing and similar divisions. How the telescope would fit into the general Observatory management structure is too detailed for consideration here, but should present no difficulties.

The operation of a new, large millimeter-wave telescope would, of course, also add burdens to the electronics, computer and engineering divisions of the NRAO. These burdens are estimated in the long-term plans for the growth of NRAO insofar as the manpower needs are concerned. There would be a need for increases in the annual amounts spent in electronics, particularly in "other observing equipment" and in "test and repair equipment" which would probably average about $0.25 million per year. This additional funding would have to start at about the same time as the approval of the telescope construction to give adequate lead-time for equipment development.

4. Final Engineering and Construction

The design work described has brought the project to the stage where it is ready for final engineering, to be followed by construction. The final engineering will result in the complete drawings, design information, fabrication, erection and test specifications needed for construction to start. The amount of work in this phase is large and quite costly; it should only be undertaken when it seems clear that the telescope will be built.

Two ways are possible by which the project could proceed:

(a) Engineering, fabrication and erection under one prime contract. This route implies that a prime contractor is selected on the basis of proposals solicited and received to carry out the complete work, but in two main phases:

Phase 1: Prepare the final engineering design. This phase would only be satisfactorily concluded when NRAO has approved all the engineering work.

Phase 2: After approval of Phase 1, proceed with fabrication and erection on the site.

(b) Separate final engineering from fabrication and erection. This route separates Phases 1 and 2 above. The engineering in Phase 1 is carried out by a contractor selected on the basis of proposals solicited and received. On the satisfactory completion of his work, which includes material needed for solicitation of bids, a prime contractor is selected to fabricate and erect the telescope after a further bidding process.

We need not discuss here the possible advantages and disadvantages of these two possible routes. Whichever is followed, it is possible to show a time and cost schedule of how the work would go. Route (b) would be a few months longer than (a) on account of the second solicitation of proposals, so in Figure 30 we show an approximate time and cost schedule for following (b). There would not be any great difference in overall cost whichever route we followed.

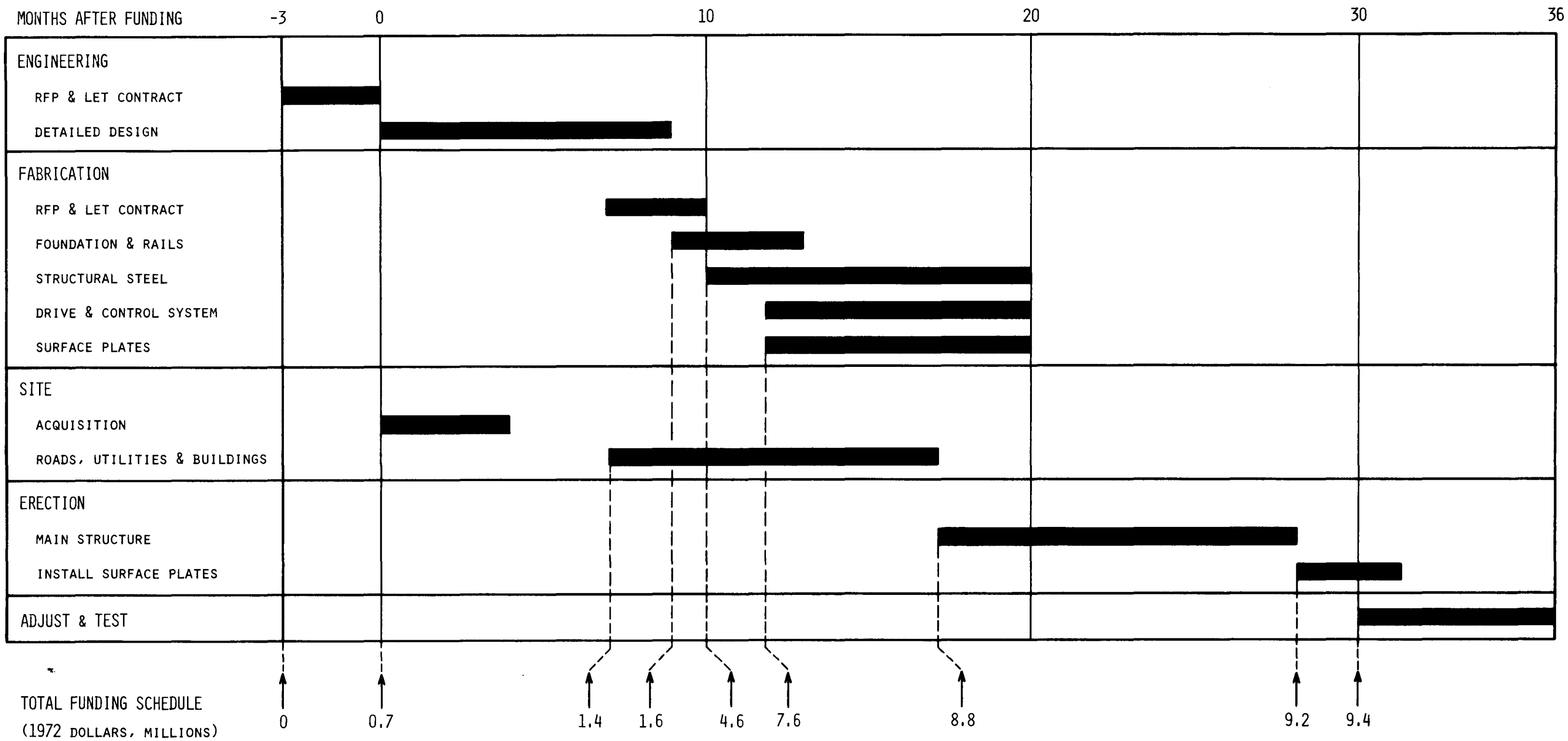

Figure 30. Work and cost schedule.

5. Cost Escalation

All the above cost estimates have been prepared on the basis of costs in January 1972. For the first time in many years, wage and price controls are in effect; it is difficult therefore to predict how costs will escalate over the coming years. It seems reasonable to adopt a 6 percent per year escalation of all costs, both for materials and labor.

Table 25. 65-Meter Telescope Cost Estimate (1972 dollars)

		Thousands of $
Fabrication of reflector and tower structure, including counterweight		1,475
Fabrication of intermediate structure		441
Erection of complete telescope		1,080
Surface plates, installation and adjustment		1,540
Azimuth trucks, gear boxes and motors		340
Pintle bearing		50
Elevation bearings		95
Elevation gear, gear boxes, drive motors		190
Foundation and track		146
Feed and subreflector supports, subreflector instrument cabins		250
Optical position reference system		460
Servo control system		500
Telescope control computer, including software		200
Ladders, walkways, hoists, cable trays		42
Telescope cabling		100
Painting, start-up and test		200
Site preparation		634
Project management and engineering		450
		8,193
Add 15% contingency	Total	9,422

Table 26. 65-meter Telescope

Site preparation estimates (in 1972 dollars) for placing the 65-meter telescope on the VLA site Y15 (Plains of San Augustin). These estimates assume that no site development for the VLA would have taken place.

	Thousands of $
Site acquisition	5
Grading and draining	40
Roads	10
Water system	52
Sewage system	12
Electric power distribution	35
Stand-by generator (500 kW)	80
Control building (3300 sq. ft.)	140
Dormitory building	115
Shop and garage	35
Telescope service tower (on control building)	110
Total	634

Table 27. 65-meter Telescope--Operating Cost Estimate

On-site Personnel	Totals	
Site manager, administrative assistant, clerk, secretary	4	49k
Electronic engineer (3) and electrical/mechanical	4	60k
Technicians, electronic (3) and computer (1)	4	40k
Telescope operators	6	60k
Telescope mechanics	2	20k
Programmer	1	15k
Laborers/handymen/driver	2	12k
Guards (night only)	2	12k
Housekeeper/cook	1	5k
Part-time, temporary, overtime -- 10 percent	-	27k
Totals	26	300k

Salaries of on-site personnel	300k
Benefits, 15 percent	45k
Travel	15k
Utilities--telephone 5k; power 15k	20k
Materials, services and supplies	100k
One-third cost of painting telescope (paint every three years)	32k
Total Annual Operating	512k