NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

DRAFT

July 8, 1997

MEMORANDUM

To: R. Brown

From: J. M. Payne JP

Subject: Preliminary Cost Estimates for MMA Receiver Work in Tucson

We have not been able to discuss my memo of June 13, 1997, but I have decided to put out this very preliminary cost estimate and to combine discussion on both memos in a phone meeting fairly soon. Another document that is relevant is my memo to Bob Brown of January 23, 1997 in which I summarized a meeting with Darrel involving a basic plan for the construction of all the MMA receivers. This present memo addresses only the development phase and assumes that in two years from now we will wish to equip two prototype antennas with the basic receivers described here. The following assumptions are made:

1) The cost estimate should include any incremental manpower or services required to do the work. I assume that NRAO machine shop services will not be available to us.

2) The cost of test equipment is covered only for the prototype work. The submillimeter development will require an additional investment.

3) The cost of extra office space is included.

4) The cost of development work to be done in Tucson that will almost certainly only be relevant to the final array is included. The laser local oscillator system and the final receiver packaging development are covered here.

5) The cryogenic development work is not included as I understand that is being estimated by Larry.

6) The cost of the device development and fabrication is not covered.

Each item is broken into four categories:

1) Costs of materials. In some cases, this is a good estimate resulting from several days work; in other cases, it is more or less an intuitive guess.

2) Engineering time

3) Technician time

4) Machine shop time

At the end of the memo, the incremental cost in engineering and technician manpower is estimated and all the machine shop time is priced at $50 per hour.

I must emphasize that this is a preliminary estimate that will require considerable refinement.

ESTIMATES

1) Holography Receiver

Although LES-8 is no longer operational, LES-9 is still available for radio astronomy support.

This estimate assumes the use of LES-9 at a signal frequency of 36.84 GHz. The component cost is accurate; the rest are best estimates.

Component costs	55k
Electrical engineer time (EE)	12 man-months
Technician time (T)	10 man months
Software development(P)	4 mm
Mechanical engineer time(ME)	4 mm
Machine shop (MS)	4 mm

2) Nutating Subreflector

As outlined in the June 13 memo, there are many questions to be answered here. The estimate here makes the following assumptions:

A) The geometry is as described in MMA Memo #163.

B) The switching rate is low - around 5 Hz.

C) There is a simple calibration source in the center of the subreflector but for 3 mm only.

D) The subreflector is fabricated from aluminum with a tolerance of 10 microns.

E) There is subreflector positioning in axial, elevation and azimuth directions.

F) We do use a compensating mass to eliminate reaction forces on the structure.

G) We only switch in azimuth - up to ± 3 beamwidths at a wavelength of 3 mm.

H) Both prototype antennas are equipped with nutating subreflectors.

DRAFT

The estimate comes out as follows (per antenna):

Component cost	50k
EE time	6 mm
P time	1 mm
ME time	8 mm
MS time	6 mm
T time	6 mm

3) The Receivers

All the remarks made in the June 13 memo still apply and the cost estimates made here make some sweeping assumptions. There are bound to be disagreements with these assumptions, but I feel that it is important to make a start. It must also be appreciated that time is very short indeed, and I feel that a conservative approach is the correct one. The remarks made in the June 13 memo will not be repeated here. The assumptions are as follows:

A) The prototype receivers will be housed in one dewar.

B) The minimum frequency coverage will be 90-115 GHz and 200-300 GHz.

C) If time permits, additional bands will be added: one in the 30-40 GHz range, the other a HEMT in the 70-90 GHz range.

D) All bands will be dual polarization.

E) The IF will be 1.5 GHz and the BW 600 MHz. I understand that this may not be acceptable for the interferometer tests as the backend will expect an IF in the 4 GHz range. However, any change in the IF frequency will have to be handled by the device makers. The 1.5 GHz, 600 MHz BW will be satisfactory for evaluating the antenna performance.

F) The 90-115 GHz and 200-300 GHz receivers will be double sideband.

G) Receiver selection will be made by pointing changes.

H) The cryogenics should be estimated in two ways: the first on what we have, the second on the purchase of a 4 K Gifford-Mcmahon refrigerator.

Cost Estimate per Receiver (This assumes the two basic bands as above)

Component costs(per receiver)	220k

(Note: The use of the G-M 4 K system will save 6 mm of T time per receiver, but will cost about $20k more. This estimate is for the G-M machine.)

EE time	20 mm
ME time	8 mm
T time	20 mm

MS time	24 mm
P time	6 mm

4) Test Equipment

We have done a fairly comprehensive list of test equipment and ,of course, it reflects the low level of funding for test equipment in the millimeter/ submillimeter frequency range in recent years. This list does not include several items:

A) An antenna range for the mm/sub-mm wavelengths. We will need one and it would seem sensible to invest in a range that can be shared by all the NRAO sites. Green Bank now has a magnificent indoor test range and maybe this should be instrumented for the higher frequencies.

B) Test equipment required for the laser LO development. This is included separately in the estimate for that development.

C) The equipment required for the submillimeter bands.

Cost Estimate

General Test Equipment	290k

5) Increase in Space

The cost of additional space is $70k per year.

6) Laser LO development

This development is a two-year program that will hopefully culminate in the demonstration of a low-noise LO suitable for the MMA. Details of the program and its cost are being worked on at present and the costs presented here are preliminary. The project will be split between Tucson and Charlottesville. The phase locking of two 1550 micron lasers will be done in Tucson as will the demonstration of adequate polarization purity over Km of fiber. The evaluation of the mm-wave photo-mixer being produced by UCLA will be done in Charlottesville, mainly by Tony Kerr.

Components	75k
Test Equipment	25k
UCLA contract	264k
EE	18 mm
MS	3 mm

DRAFT

SUMMARY

Direct costs (NRAO labor not included):

ITEM	QUANTITY	COMPONENT COST ($k)	MACHINE SHOP (man-months)
Holography receiver	1	55	4
Nutating subreflector	2	100	16
Receivers	2	440	48
Test Equipment	1	290	-
Laser LO	1	360	3
TOTAL		1,245	71

Seventy-one (71) man-months of machine shop time at the University of Arizona translates into approximately $600k.

So total direct costs are $1,245 + $600 or $1,845k.

OTHER COSTS

In addition, we should include incremental costs as follows: (Dale and Darrel will have additional inputs, I'm sure).

1) Increased support

When we take the estimates of the NRAO people needed to build the prototype receivers, we come up with something like the following additional effort. For this estimate, I have assumed that in order to build two items that the effort scales are:

EE	1.5
ME	1.5
T	2.0
P	1.0

In terms of man-months, this give the following effort spread over the two years:

EE	69 mm
T	62 mm
ME	28 mm
P	11 mm

So the conclusion here is that in order to build the bare minimum to support the first two antennas, we will need:

EE	3.5
T	3
ME	1.5
P	0.5

When Harry Fagg from CSIRO joins us, we will have the following staff available:

EE	7
T	5
ME	1
P	2

The most glaring deficiency here is the ME. We have only one at present - Jeff Kingsley - and he will be fully occupied on the antenna design. The other staff members have to keep the 12 Meter antenna operational and it is hard to see how, at the present staffing levels, that we can do the MMA prototype development and maintain the 12 Meter. In addition, the above estimate does not include any provision for the development of the final receivers which must be a parallel development effort .

FINAL RECEIVER DEVELOPMENT

The exact nature of this development work is not clear at present as the device availability is uncertain as is the status of the LO development. The first stage will almost certainly be the development of the final receiver package with the associated optics, IR filters and electronic interfaces.

My tentative estimate for this work during the next couple of years is as follows:

Components and machine shop time	400k
One full-time EE	
One full-time T	
One full-time ME	

SUMMARY

Equipment needed for evaluation of two initial antennas and photonic LO development:

Components, machine shop and test equipment	1,845k
Extra people required: one EE, one T, one ME	

DRAFT

Final Receiver Development

Components and machine shop	400k
Extra people required: one EE, one T, one ME	

Miscellaneous

Extra space	140k
Extra travel	50k

GRAND SUMMARY	
DIRECT COSTS	**$2,435k**
NEW HIRES	**2 Electrical engineers** **2 Technicians** **2 Mechanical designers**

c: D. Emerson
A. R. Kerr
P. Napier
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