National Radio Astronomy Observatory
Charlottesville, Virginia

9 Nov. 1984

To: VLBA Project

From: R. C. Walker

Subject: Visit to Hawaii

At the request of project management, I attended the Mauna Kea Users Group meeting in Kona on Nov. 1, 1984. While in Hawaii, I visited some of the sites that have been discussed for the Hawaii element of the VLBA. This memo outlines some of the facts and impressions obtained during the trip that might be of interest to the VLBA project. The first 20 items are from my notes on the meeting. The rest are impressions gained from the site visits and conversations with various people. During and since the trip, my opinion of what we should do jelled considerably. My conclusions are presented at the end of this memo.

1. Dr. Laird Thompson is doing the Mauna Kea Observatory site survey and is likely to be a good source of information about possible sites.

2. The value of astronomy is now appreciated in the state - the level of opposition to astronomy development is now relatively small. The county mayor is very supportive.

3. A new airfreight service may be established at Hilo for heavy freight - the kind that would normally travel by truck or train on the continent.

4. Mauna Kea is clearly an outstanding site for optical work. Sub-arcsecond seeing is the norm (at least that is the impression I got) and half arcsecond seeing is not uncommon. Lelievre of the CFHT thinks that 0.2 arcsecond seeing might be achieved with a serious effort to improve dome seeing (effects caused by the dome) and through the use of addaptive optics. A serious effort at improving the resolution of images taken on Mauna Kea is in progress.

5. UKIRT supports remote observing from England through telephone digital links. They use a dedicated link from the mountain to lower level support facilities and standard commercial network services (Telenet?) to England.

6. The Caltech mm telescope's foundation is in place on the mountain. The dome is being assembled in Pasadena and the mount is being made at Owens Valley. They intend to move the structures to the mountain early in 1985 and receive first light (heat?) in early 1986. They expect that the surface will be good enough to allow observations at 300 microns. Perfectionists that they are, they are considering replacing the surface after about three years.

7. The UK/NL mm telescope's building (it looks more like a hat box than a dome) has been erected on the mountain near the NRAO 25 Meter telescope site. The antenna is being fabricated in Holland and is expected to be delivered in Hilo in July 1985. The telescope should be commissioned in 1986. I detect something of a race in progress between Caltech and UK/NL.

8. Dr. Richard Hills at the Cavindish Lab has the weather data that has been collected over the last year on a mast at the UK/NL site. Of special interest to us would be the wind records that would give an indication of what the statistics of observing conditions in the "mm valley" would be like. Unfortunately, the records of extreme conditions are not likely to be of much help because last winter was very mild.

9. The Japanese plan to build a telescope "with an aperture larger than 5 m" on Mauna Kea as a national facility (the Japanese National Large Telescope or JNLT). The preliminary concept is a 7.5 m telescope. Funding could begin in April 1986 at the earliest, followed by two years of preparatory work, five years of construction and two years of system adjustment.

10. The technical demonstration phase of the California 10 meter telescope project (TMT) is effectively done and a design report is being prepared. A dome and attached building have been designed. Negociations for funding are still in progress with the private foundation that is providing about $36 million and with Caltech and the state. The TMT representatives at the meeting seemed optimistic that the project will go ahead.

11. Detailed site testing is in progress on the mountain with microturbulence measuring towers and other instruments. The prime site for the TMT is being tested with an echosounding device. I'm not sure how much of the information being collected is of use to us. The optical astronomers are mostly worried about small scale phenomina near the ground near the summit. We are worried about the large scale distribution and fluctuations of water vapor as a function of site elevation and know that the water vapor is very low at the summit. Our concerns at the summit have more to do with the amount of time that will have sufficient winds to degrade pointing and the likelihood of conditions that could damage our telescope.

12. A telephone system (microwave) for the mid-level facilities at Hale Pohaku (which, by the way, are very nice) will go out for bid soon. There is some concern that the cost may be high.

13. A semi-permanent construction camp will probably be established near, but detached from, the mid-level facilities.

14. The Management Plan, a part of the Complex Development Plan, is almost done. All public meetings have taken place and the comments received are being incorporated. The major public concerns seem to be related to access. The current plan is to limit the vehicular access by limiting the number of parking spaces to about 150 and to

accomodate larger numbers of visitors with a shuttle bus. It is clear that the skiers, hunters etc. do not want their access limited.

15. The power line design should be ready by March 1985. The overhead portion below Hale Pohaku and the underground section from there to the summit are being treated separately. It appears that service should be available in early 1987. The cost is expected to be about $5.5 million.

16. The road will be paved (20 ft. roadbed with 4 ft. swales on either side for a clear width of 28 ft.). Construction will start in May 1986. The cost of the power line plus the road is more than is available so road construction will start at the top of the mountain and proceed downward until funds run out. It is expected that some portion between Hale Pohaku and about 12,000 ft. will remain unpaved for some time and, therefore, 4 wheel drive vehicles only will be allowed above Hale Pohaku.

17. There is serious consideration of laying fiber optic cable along with the power line. This would allow telephone and data communication links with the summit without the use of microwave links. Normal telephone wires cannot be used in the same conduit as the power line because of inductive problems but this is not a problem for fiber optics. Removal of all microwave equipment related to the observatory will put the observatory in a stronger political position to try to limit the use of the mountain for other relay and transmission systems - a goal that should be close to our hearts.

18. There is a public fear (especially among Ham operators) that, if radio astronomy facilities are built, a radio quiet zone will be established that will limit their activities. It seems that the quiet zone arround Green Bank is well known and not very popular.

19. A committee will be established to work with the local communities to head off the light pollution problems that are causing problems at other observatories. The Californians are especially concerned about this because of the TMT and their problems at Lick, Wilson, and Palomar. They feel that working with the communities before there is a problem (eg. encourage less harmfull forms of lighting, etc) would be a much more productive approach than reacting to problems after the cost of alterations is high. The committee will be formed by the University of Hawaii so that it will have the political advantage of being local.

20. There are rumors of mm radars at the military camp in the saddle between Mauna Kea and Mauna Loa.

So much for the meeting, now for other impressions.

1. I was unable to get any sort of firm estimate of the cost to a user such as us of the power line and road paving if we use a Mauna Kea site. It seems that there is a complicated, time variable, and secret formula used in setting the tax. I did obtain a rough estimate of $500K for the charge to the Caltech mm facility. They have a

similar investment on the mountain as we would have but have more users. I would make a wild guess that our share of the cost would be about $500K or somewhat more, but less than $1 million.

2. The military camp mentioned in point 20 may be a serious problem. It appears to be very active with large numbers of jeeps, trucks (some with artillary), helecopters etc. moving about in training exercizes. Dave Hogg reported that the camp is something of a user facility in that it is used primarily for training of troops that are normally based elsewhere. The likely implication of that is that it would be very hard to keep track of, let alone influence, any sources of interference that might exist at the site. Most of the equipment will belong to the units being trained and will change frequently. I saw at least one radar (portable, I think) and assume that there are many more, especially since there is an Army Air Station at the site. My conclusion is that it is important not to be within line-of-sight, or close to, the facility.

3. I drove to the site near the Mauna Loa Observatory (NOAA) on Mauna Loa that was found by Wade and Hogg. It is at 11,000 ft. and has power and a paved road. Since the political problems are likely to be much milder there, it is a very attractive site. However, there are problems which are discussed in the next few points.

4. The Mauna Loa site is on the north side of Mauna Loa and so has a restricted southern horizen. The terrain is essentially a tilted plane with the angle of tilt being about 9 degrees (my estimate from the topographic map - Wade measured something like 14 degrees maximum blockage) with the line of levels running about east-west. The Hawaii site is farther south than any of the other VLBA sites so sources at transit will have higher elevations - in fact any source that can be seen from the other sites could be observed easily at transit from the Mauna Loa site. Note that in the configuration studies, we have generally assumed that the elevation limit at each site is 10 degrees, although the antenna will go to near 0 degrees. The Hawaii site is much farther west than the other sites so it will often be observing sources near rise. The high southern horizen will delay the rise of southerly sources as seen from the site but the effect will not be large in most cases. For example I calculate from the topo map a blockage of 6 deg. in the direction of rise of a -30 degree dec source. The effect gets worse for lower declination sources where the VLBA does not perform well. However observations with the Australians might be hampered.

5. The Mauna Loa site is in direct line-of-sight to the entire military reservation with no possible way to hide from it. In my mind, this is the most serious, and perhaps fatal, flaw for this site.

6. The Mauna Loa site is on an active volcano. In fact I see this problem, which caused us not to even look at Mauna Loa at all until now, as being relatively minor. The location found by Wade and Hogg has not had a lava flow for more than a hundred years according to the maps (probably much longer) and is not threatened by any known rift zones or the summit caldera with its current configuration. I would

estimate that literally billions of dollars are invested on the Island of Hawaii in facilities in more threatened locations (including the city of Hilo).

7. Clouds will be a serious problem for any site below the inversion (about 11,000 ft.). Any site on the eastern side of the island will be covered a large fraction of the time. Sites on the western side are typically clear overhead, but their eastern horizens are blocked by clouds over and near the mountains. Since the Hawaii antenna will be observing in the east much of the time, this is not good.

8. It is often assumed that we will have less wind at a low site. My great statistical sample of two days shows that this assumption may be false. The winds in the area just south of Waimea were stronger than those high on Mauna Kea on both days. I suspect, but cannot prove, that air trying to get arround the mountain was creating high winds at its base. Recall that winds are often much more severe arround the bases of tall buildings than elsewhere - could this be the same effect? On at least one of the days, the weather conditions were described as "trades" in radio reports and, by all apparent criteria, matched the "typical" conditions that I have read about in reports on Hawaii meteorlogical conditions. In the summit area, the winds varied from calm in sheltered areas to mild on the ridges. It is clear that local topography is very important. For this reason, it is important for us to get wind data for as close as possible to our specific site before building in Hawaii. The UK/NL data for their site would probably apply to the "mm valley" area and would be a good place to start.

9. Sites can be found on Mauna Kea that are at roughly 11,000 ft., are out of sight of the road, and are out of sight of Hilo (the last two criteria seem to be important to some local interests). However these sites are outside the region in which telescopes are to be built according to the plan for the development of Mauna Kea. If we choose such a site, we must be careful to be well out of the line-of-sight to the military reservation.

10. The planning process in Hawaii is very serious. If we want to do anything outside the Mauna Kea plan, we will have severe political problems, first with the Institute for Astronomy, and then with the public (the latter is the cause of the former). Unfortunately the plan was formulated just before we contacted the Institute about our desires so the possibility of a telescope well below the summit is not included. Because the plan is very new and was arrived at after great effort, any attempt to change it now would not be welcome (although not totally impossible).

11. It is possible that we might be able to change the criterion that the telescope must be out of sight of the road. This is a conclusion that I have reached after having walked arround the area looking at sites and thinking about what I would prefer if I were an ardent conservationist (which I am). Given the choice of constructing in an unspoiled area such as any of the out-or-sight locations, or next to the road where there is already strong evidence of man's presence, I

would choose next to the road and save the other areas. Of course, the third option of not building in the vicinity at all might be chosen by some.

12. Cost of access is an important factor if we choose a site that is not next to the road. The paved road and buried power line are going to cost about $1 million per mile each. Using this cost, our access would cost about $1 million per half mile and could not be shared with other users. I expect a half mile is about the minimum access distence that would be needed for a site that is out of sight of the road. For a site at 11,000 ft, we would probable be charged about half as much for the main road and power line as the summit users. Therefore, using the very rough estimate of our share of the road and power line costs given above for a site on the summit, access will only be cheaper at 11,000 ft if the distance from the road is less than 1/4 mile.

13. Of the sites on Mauna Kea, the summit would be the easiest politically. However we have concerns about the survival of our antenna on the summit. Also there are concerns about the fraction of the time during which observating conditions will be good. More data on weather is needed to properly address these concerns. Note that use of a radome would eliminate both concerns. If the UK/NL data show that the winds are not a problem for observing, could some sort of shelter that is only in place during storms be used?

14. It will be very important that the Hawaii antenna be capable of making high quality observations at high zenith angles to the east. That is where sources being observed with the rest of the array will usually be. The specific site chosen will make a big difference here. The important factors are that the eastern and south eastern horizens not be seriously blocked and that observing conditions not be poor when the secant z term is large. Both of these factors favor a high site. For a further discussion of low elevation observing, see the appendix.

15. Much of the "mm valley" on the summit of Mauna Kea has restricted horizens. If we choose to use a summit site, we need to be careful to find a specific site with good horizens. See the Appendix below for a discussion of the effects of horizens. I will try to investigate this further from the maps but a site visit would be needed eventually. Note that use of a radome would eliminate the need for the shelter of the "mm valley" - a more exposed site could be used. Sites in the summit area are well shielded from the military reservation.

16. There will be several high quality mm telescopes on the summit of Mauna Kea. Having our VLB equipment there too will allow VLBI using those telescopes without major logistical problems. Note that we are also near mm telescopes at Owens Valley, Kitt Peak, and maybe in Texas and Mass. depending on site choices. Also mm VLBI using the above sites and Nobeyama will be possible.

17. If we make a special effort to make the Hawaii antenna the best of the array, it may be possible to do useful 3 or 4 mm single dish observations during the times when the VLBI sources are too low to be seen. I would estimate that a few hours a day (2 to 4?) would be available for such use.

In summary, I have just about convinced myself that we should put the Hawaii antenna of the VLBA on the summit of Mauna Kea, inside a radome. We should see Dave Hogg's water vapor measurements before making a decision and we should explore the options at 11,000 ft. further to see if a site with reasonable access cost and political feasibility can be found. We should also consider whether we are morally justified in taking one of the total of 13 telescopes that are allowed in the Mauna Kea plan by the year 2000. However the Hawaii antenna is probably the most important of the VLBA because it provides the highest resolutions. It has the greatest need for good observing conditions both because it will often be observing at low elevation angles and because the correlated flux density on long baselines is typically lower than on short baselines. There are no short baselines connecting it to other sites. Also the weather in Hawaii will not be correlated with that at the other sites (There will be considerable correlation of the weather at least at the western sites) so insuring a high probability of good conditions will be important to having good conditions at all stations simultaneously reasonably often. In the end, I think that we will be able to justify the high cost of using a summit site. In any case, we probably should not go below 11,000 ft.

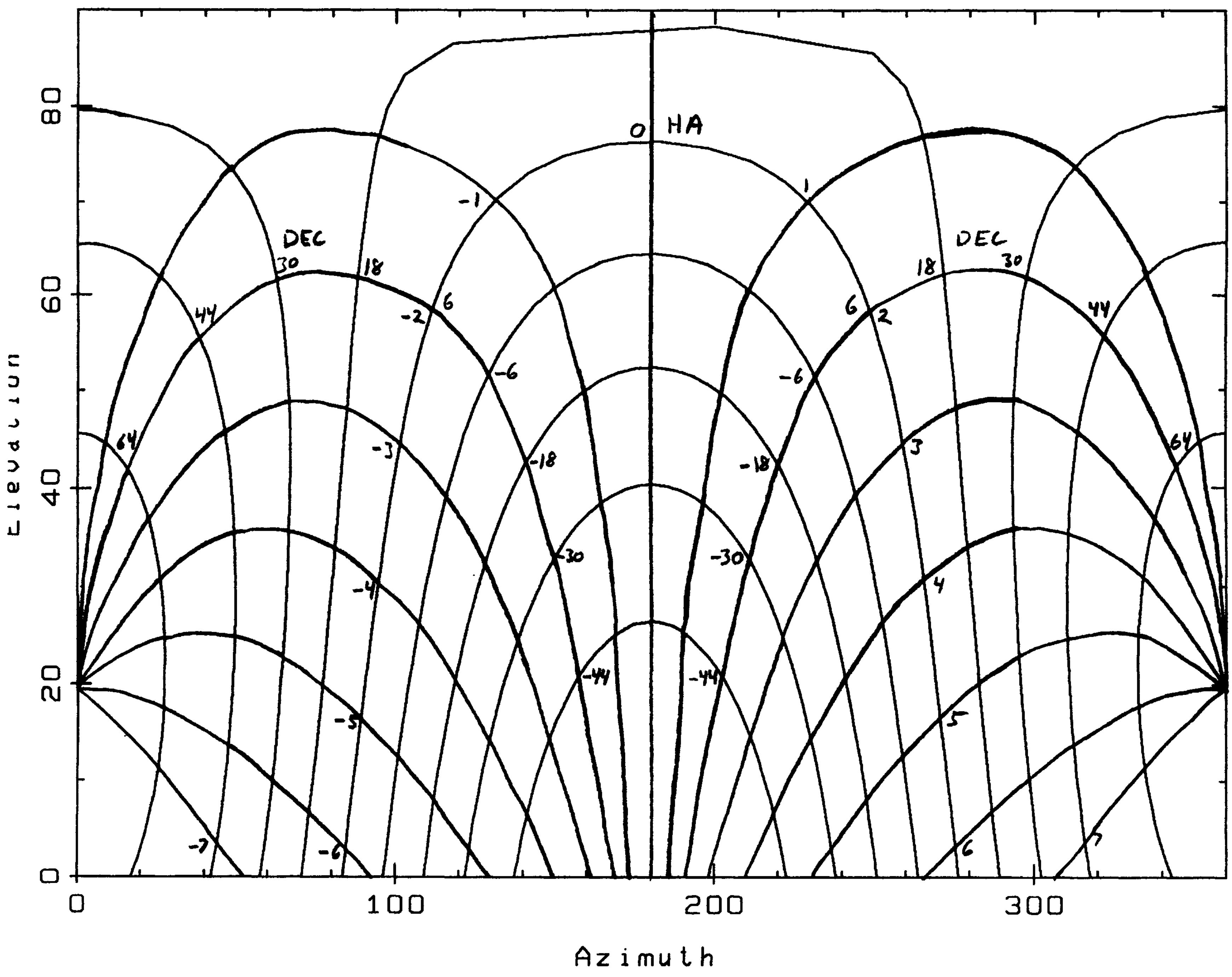
APPENDIX on Elevation Limits.

I have attached two figures that help show the effects of horizen blockage for the Hawaii site. The first shows the azimuth and elevation for sources as a function of hour angle (HA) and declination. Note that, with this low latitude station, the sources at all declinations of interest to the VLBA (although not necessarily to experiments with Australian telescopes) rise at a steep angle to the horizen and therefore do not spend long times at very low elevations. However, since the Hawaii site is much farther west than the other sites, the time of mutual visibility of sources is shortened. The period during which a source is at low elevation is a greater fraction of the total available observing time and is therefore of greater importance than for the continental sites.

The second figure shows the uv coverage of the array for three declinations (44, 6, and -30 degrees) with three different elevation limits in Hawaii (20, 10, and 3 degrees). The elevation limits at other stations are 10 degrees in all cases. The effects on the uv coverage are not especially large, although the 20 deg. case shows significant degradation so observations will generally be desired below that elevation. Note that the degradation is probably as bad for the northern sources where circumpolar observations are limited as they are for southern declinations.

I conclude from these plots that, while it is desirable to have low horizens, it is not as critical as some of us had been assuming. Specifically, I would be more comfortable with a site in the "mm valley" where there is blockage about 10 deg. in some directions than I was before. We should remember when choosing a site that the antenna may be used in experiments with Australia, Japan and any other Far Eastern telescopes that might be built, so we should not totally ignore the western horizens.

Az vs. El for Hawaii



Hawaii Elevation Limit

HAWAII	19.80	155.50
ARECIBO	18.34	66.75
HSTK	42.43	71.49
OROVILE	48.90	119.75
OVRO	37.05	118.28
FDVSNEW	30.47	103.95
KITT	31.96	111.60
LASL2	35.81	106.27
PIETOWN	34.33	108.14
IOWA	41.58	91.57

Scale in km
(kilometers x 10^3)

Full VLBA

Elevation Limit
All Except Hawaii
10°