25-METER MILLIMETER TELESCOPE MEMO NO. 69

NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

January 17, 1977

To: Working Group, 25-Meter Project

From: C. M. Wade

Subj: Report on the Site Search

I. Introduction

The present report is an account of the work done during the past six months toward finding the most suitable site for the 25-meter telescope. It does not recommend a site; instead, its purpose is to provide the information which the Working Group needs in order to make a recommendation. There is no discussion here of cost figures, since other reports have dealt with them.

The criteria which we have thought to be most important in the site selection are reviewed in Section II. The plan of work is discussed in Section III. This section also reviews the sites which were considered, however briefly, and subsequently rejected as unsuitable for our purposes. We feel that only two sites really merit serious consideration. These, Mauna Kea and Kitt Peak, are dealt with in detail in Section IV. The particular advantages and disadvantages of these very dissimilar sites are contrasted in Section V.

II. Site Selection Criteria

The criteria which define a good site fall into two general categories. The first and more fundamental includes the things which directly bear on the kind and quality of the astronomical observations which can be made. The most important factors in this group are the atmospheric transparency at millimeter wavelengths and the amount of the sky which is accessible to observation. The second cateory includes those factors which bear on the efficiency with which a visitor-oriented observatory can be operated. Necessarily, a great variety of factors enter into this group. Among the most

important are the ease of attracting and keeping a first-class resident staff, the accessibility of the site, and the availability of necessary support services.

No site will satisfy all reasonable criteria to perfection. People will differ in their views of how the various criteria should be weighted. No matter what our recommendation finally is, it will receive quite rational criticism from someone.

A. Atmospheric Transparency

The sources of atmospheric absorption at millimeter wavelengths are molecular oxygen (O_2), water vapor, and condensed water (clouds not composed of ice). The first two have been discussed thoroughly in Memo No. 64, "Review of Atmospheric Transmission at Millimeter Wavelengths," where it is shown that water vapor absorbs much less strongly than we thought when the 25-meter proposal was written. Therefore we now see it as a less severe restraint on the site choice, although it remains very important at the shorter wavelengths. The absorption by oxygen is generally insignificant except near the O_2 resonance lines.

We know from experience that the condensed water in clouds has a disastrous effect on observations at millimeter wavelengths, particularly in the continuum. Ice clouds (e.g., cirrus) have little effect because of the low dielectric constant of ice. Observations suffer badly if there is any visible non-ice cloud in the beam.* A very important site requirement therefore is that the frequency of water cloudiness be low. We believe that a high incidence of cloud-free weather is as important a consideration as low water vapor levels.

B. Available Sky

The closer one is to the equator, the more of the sky one can see. Assume that observations will not be made below some limiting altitude h_{lim}; then the most southerly declination that can be reached from latitude ϕ is

*The fluctuating atmospheric noise due to thin clouds moving through the beam, and the implied tolerances for continuum work, are not well understood. Beam-switching helps, but observations still suffer appreciably.

APPENDIX 1
to
25-METER MILLIMETER TELESCOPE MEMO NO. 69

Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY
TUCSON, ARIZONA

To: M. A. Gordon May 20, 1976

From: D. A. Webb

Subject: My Opinions on Hilo and Waimea as a Possible Telescope Site

Judy and I visited Hilo first and we were there for five days. It is a very lush, green town, and the weather was very beautiful for three out of the five days. We had the opportunity to look the town over very well and my opinions are as follows:

The University of Hawaii is a very struggling Kitt Peak type of operation. Kitt Peak has done well in obtaining the necessary type of equipment, manpower and dollars to make a thriving astronomical community. The University of Hawaii has spent many years developing an astronomy program and few years in developing an astronomy site. I believe that we would find it necessary to be virtually self supporting on the Mauna Kea site. The few pieces of equipment which are possessed by the University of Hawaii are surplus, not very efficient, and in most cases, in need of repair. The expenses involved in obtaining the proper consulting firms to obtain approval for a Mauna Kea telescope and the time that is required, I estimate at being approximately one year and many thousands of dollars.

The community leaders in Hilo are not anxious to see additional telescopes. The state leaders who actually make the decisions are. However, they are too politically motivated and the opinions which I received from Dr. Jefferies, his assistant, Ginger, and the consulting engineers with whom I spoke, form a consensus that it woult take at least one year after approval by our staff that Mauna Kea was the site, in order to obtain approval to build a telescope wn Mauna Kea. There would be many restrictions within that approval. For example, the citizens would be very much up-in-arms if the telescope were within line of site of Hilo or the surrounding community. This would mean that it would have to be at a lower level in order to be approved reasonably rapidly or at least within that one year time frame. It would take many trips and many dollars just to obtain the local approval. Since the master plan has now been changed in order to obtain approval by

the community, it would require that we maintain absolute minimum facilities at the mid-level and that we make our headquarters in Hilo or Waimea. The U H and the Canadian France telescopes are both strongly considering these possibilities since they too have been limited from having expanded facilities at Hale Pohaku. The master plan calls only for sleeping and cafeteria facilities along with absolute minimum lab space at the mid-point. The reason which they put forth in the master plan for dormitories is the need for acclimatization of the astronomers and employees to be able to sleep at 9,000 feet and work effectively at 13,000 or more. In our operation I feel that it would be essential to at least have our astronomers sleeping at the site of the telescope. I also feel that we would need to have some quarters and work space with a pressurized system at the top of the mountain. Our operators could work on a 4 day on, 4 day off shift, just as the employees of the University of Hawaii do. The University of Hawaii is now in the throes of changing work schedules for their day crews and will soon request that all employees of day crews, research assistants, etc., work 4 days on and 4 days off, with the 4 days on sleeping at the mid-point. They anticipate paying all costs for this and pro rating the cost of U of H employees to the visiting astonomers such that at the current rate, the meal and lodging charges are $30 per day for visiting astonomers in comparison with our existing $9 (approximately) per day for meals and lodging for visiting astronomers. The employees at the University of Hawaii Institute did not appear to have major problems working under non pressurized conditions. I suspect, however, that visiting astronomers who would be there for a minimum of 2 and a maximum of 4 days, would have severe difficulty unless they were sleeping within a pressurized system. This, in my opinion, is going to be very expensive and some figures will be provided in the cost consideration reports.

As for living conditions in Hilo and Waimea, my opinion of Hilo is this. It seems to be a nice clean town, very similar in many ways to Eastern communities, except our indoor house plants grow outdoors over there. The

strong influence of Oriental culture was prevalent everywhere. The school systems are, in the opinion of several people whom I talked to, very adequate. They provide the facilities for the students who are interested in learning. In the opinion of at least one person who has a child in school, the schools are not demanding of their students and do not push hard for motivation or striving for better grades, etc. Tom Kreiger, who is the mountain superintendent for the Institute of Astronomy is now in the process of moving his family from Honolulu to Hilo. His oldest boy who attends high school is understandably not enthused about moving to Hilo, however, he feels that at this time he will obtain a suitable education. The schools are generally quite old and while clean, they do not present an enticing appearance. There will soon be a new high school in Hilo which will be built in the newer residential area. The intermediate and elementary schools are scattered throughout the city, and again, appear to be quite nice. There do not seem to be any more than the normal problems in terms of drugs, etc., within the schools. Our observations of the number of children who we met on the street, at the hotel, and in the shopping centers was that the children do not have a very good command of English and did not seem to be interested in any more than the present circumstance in which they were in. This may not be much different than another visitor coming to Tucson or any Mainland city and seeing our children within a shopping center; however, it appears to be different and certainly the command of English and the manner in which the children acted was much different.

The wages for lower paid employees at the university working in Hilo are not much different from the wages for the lower paid employees within our organization in Tucson. The higher paid employees, it appears, average approximately 25% more at the university than they do at our organization in Tucson. Their benefit program is not comparable in my first glance opinion and in my discussion with the personnel administrator at the University of Hawaii. Our benefits are superior, and their salary administration techniques are totally different.

Food costs appears to be quite comparable as you will see from the accompanying charts. The clothing costs, again, are quite comparable in the

sense that somewhat less clothing would be required there than would be required in the Eastern states, although approximately the same type of clothing would be required there as what is required in Tucson. The cost of clothing is higher and my estimate is approximately 25% higher than it is in Tucson. Judy and I went shopping at the Hilo Shopping Center, Penney's store and neighborhood shops as well as the shops in the motel areas. The local neighborhood shops, in which I assume and it appeared, that most of the people went shopping at, had shirts on sale for $9.00, which normally would be about $6.00 in Tucson. A large percentage of people wore sandals as normal, everyday dress and they were less expensive than in Tucson. The regular shoes were about the same as Tucson. Most of the women in the stores were wearing "moo-moos" and in each of the stores, they started at approximately $20. So, clothing in general would be higher than here.

The real cost differential is going to be in the area of housing. It is my opinion that we will have to provide either a housing cost differential or significantly higher salaries in order to attract personnel to that area. The minimum, in my opinion, 1250 square foot house (new) sells for $58,000. This is in a subdivision atmosphere, certainly not a high class one. A 1500 or 1600 square foot home starts at $65,000. That's again, for a new house and all extras are on top of that. Nice homes with ocean views start at $100,000 and go up from there significantly. I looked at one home in Hilo which was approximately 2000 square feet on the lower and upper level and built completely out of cedar. That house, including lot, sold for $77,000. Ocean front properties are generally held by Hawaiians and must be leased on 55-year leases, renewable for lease rental purposes at 5 and 15 year increments. This land leases for approximately 4% of the appraised value and typically runs from $200 to $300 per month and up, for rental of the land. Housing cost of $30 to $35 per square feet, depending upon the interior design, whether it has carpeting, etc., is common. The rule-of-thumb which the real estate people seem to agree on was that housing and building in general costs about $10 per square foot more at Hilo than it does in the Mainland and that land costs are a minimum of $20,000 per lot for normal lots and more for view lots and nicer subdivision areas. In Waimea, most

of the land that is for sale is currently owned by the Parker Ranch. They are in the process, or will be in the process for several years, of selling off those parcels of land which are not now productive for cattle raising. Land cost here is somewhat higher than it is in Hilo, however, building costs appear to be about equal. The contracting people come generally from the Kona area and most of the materials would come to the Kailua harbor. My personal opinion is that the Waimea area would be most preferable; however, that is just my personal opinion. It is an open space area. The schools through intermediate school are public schools; however, they are now opening two private schools for elementary and intermediate grades, which will have a cost of approximately $1000 per student per year for tuition. That is local tuition, not including room and board or anything of that nature. High school students in the Waimea area are bussed approximately 15 miles to the Honokaa High School and those students who can afford to do so, attend the Hawaiian Prep Academy which is located within the Waimea area and it appears to be a beautiful facility. Building cost for an office building of 10,000 to 12,000 square feet in Waimea probably has to be handled through the Parker Ranch business manager, although there are now 2 office and shopping centers in the process of planning for the Waimea area. The Kona and Waimea areas appear to be growing at a much more rapid rate than the Hilo area. According to the Research and Development department manager, within the Hilo county government, Mr. Clarence Garcia, the population of Hawaii is increasing and it is primarily increasing over on the Kona side versus the Hilo side. Many different parcels of land could be obtained for a downtown building in the Waimea area - again, chiefly from the Parker ranch. In the Hilo area it would be required that we locate within the industrial park. All other land which is zoned appropriately is already filled with an existing building. There is no land available on the saddle road to Mauna Kea, so it would mean that employees would have to go through the town of Hilo on their way to the mountain road each day if they were to go from the office downtown, and if that office were at the industrial park.

In talking with 3 astronomers who were on observing runs at Mauna Kea, it was evident that all 3 felt that the night time observing capabilities

at the telescopes on Mauna Kea were absolutely superior to anything which they had experienced, including Chili, Kitt Peak, and other sites. They felt that the facility needed to be expanded very greatly as there is not adequate room for working on the equipment at the present time. They, or at least 2 of them, appeared to be disenchanted with the progress which has currently been made in expanding Mauna Kea as an astronomy site. One of the astronomers indicated that daytime astronomy for infrared type work was limited to about 3 hours of good astronomy time and felt that the night time observing made up for the lack of good day time observing.

The cost figures which I had for recurring costs were reviewed with Dr. Jefferies. He felt that with the exception of telephone costs, they appeared to be reasonable as recurring type costs which they now incur. He felt that FTS facilities would be available as a result of the NASA telescope, and would cut down, probably by $25,000, the cost which I had originally estimated. The University of Hawaii is operating on a very tight budget and it appears that we would be charged dearly for every service we had them perform. For example, in electricity, they would hope to generate all electricity from generators and charge us for the total costs, including depreciation and amortization of equipment, maintenance, maintenance personnel, diesel fuel, etc. They would charge us one-fourth if there were 4 different organizations. In the case of road grading capabilities, they would charge us one-fourth if there were 4 organizations of the costs contracted. If they were to do it themselves, we would again pay amortization, wages, time and materials. So, in general we would be paying for the use of equipment, personnel, and the normal costs involved in maintaining equipment, etc. We have fortunately been spared this cost of equipment charge from Kitt Peak. I feel that it is extremely difficult to accurately project the special costs which would be involved in setting a telescope on that mountain. For example, if we needed an emergency catapillar, it would cost $900 to have it brought over from Hilo, or at least that's what the University of Hawaii paid last year. Large cranes would have to be brought over from Honolulu. Most special projects would be very expensive. For example - cement per cubic yard delivered in small quantities runs approximately $300 per cubic yard. This is in comparison to $45 per cubic yard at Kitt Pear or Mt. Lemmon. Many of these costs I feel are very difficult at this time to project accurately.

After seeing the actual costs which relocated employees would be likely to incur, I do believe that at least an optional salary adjustment will be required in order to obtain top notch qualified personnel at a Hawaii site. In the words of Dr. Jefferies, there is a very definite economic shock when going to the islands. On the other hand, there are many people who do live there who feel it is worth economic sacrifices to live there. There appears to be a fairly good selection of radio technicians and typical Navy radio repair type personnel. There was also interest expressed by several employees at the university in our operation and what type of people we would be hiring. I was not able to determine exactly the kinds of skills that are available on the island. My feeling is that much of the management and top technical expertise would have to be imported. The costs of building a telescope on Mauna Kea are going to be significantly greater than on the Mt. Lemmon site; If for no other reason than that cement is much more expensive, and the volcanic cinder base requires a significantly larger foundation for construction. Many of the trades such as steel workers, etc. would have to be brought in from the island of Oahu and I can visualize a very expensive project, possibly much beyond that which I have estimated in the site cost comparison reports. Again, in the opinion of Dr. Jefferies and yourself as you have indicated before, these costs must be weighed in accordance with the amount of astronomy which can be obtained per hour, and per year at that particular site.

HAWAII TRIP REPORT - FACTS, FIGURES, AND OPINIONS

It is May 10, 1976, and this is a recording of a trip to Honolulu on the island of Oahu and eventually to Hilo on the island of Hawaii. The flight across from Los Angeles to Hawaii was on a DC 10 - nice and smooth. We couldn't see much ocean because we were way above the clouds and it was cloudy most of the time. As we approached Honolulu, we could see the city - a lot of hi-rise buildings in a densely populated area and quite scenic; however, today there were dark clouds hanging over the city.

The airport is large, and very metropolis like, and appeared to be very busy. After leaving the airplane, we got on a "wikki-wikki" car. This is a small bus-train with one bus in front and with two busses behind being towed by the first bus.It's warm and humid - I noticed that immediately when they closed the bus up and we rode for the next block or so into the next airport terminal to get the baggage.

As we went toward the city, we passed many, many piers and ship-yard facilities. There are plenty of cranes available in this town for anything that we would want to do - very, very tall ones - they're building a lot of hi-rise buildings and so there are all kinds of construction equip-ment available. Also, a lot of heavy machinery, heavy backhoes and dozers, etc. We saw most of the familiar stores that you see in Tucson - Sears, Woolworths, Safeway. All the shopping centers are very similar to what there are in Tucson, except that they are much closer together. As we approached the center of the city, there were many tourist areas and the streets were just lined with tourists, shops, and people on the sidewalks selling their wares. They have one very large open shop which is called the International Market, and you can walk for two hours if you just wanted

to walk past all the shops. If you wanted to go in them, you could probably spend more than that. There is another one called King's Alley which is also very similar - many, many little shops clustered together in an open air atmosphere, with singers out singing and playing their ukeleles. It's very tourist attraction oriented. As we went down further past the Waikiki beach, we saw a few people surfing, swimming and boating in long canoe type boats like you see on Hawaii Five 0. We stayed at the Kaimana Hotel on the sixth floor. As we stood on the balcony, we overlooked the palm trees which were even with the sixth floor. The palm trees are very tall and I wondered how they stand up because the trunks are very thin compared with the trees we see in Tucson. After dark it is humid, but very cool and pleasant. There is a breeze coming in off the ocean, and we went up town and looked at all the shops that I mentioned. They were very nice and as I said, tourist oriented. Well, that's May 10th.

It's now Tuesday, the 11th. This morning I started out for the Institute of Astronomy at the university. The clouds were hanging over the mountains and apparently that's the way they always are in the city. The Institute for Astronomy is approximately four miles from the hotel where I an staying, and the hotel annually receives about 14 inches of rainfall, while the Institute for Astronomy annually receives approximately 200 inches of rainfall. It is into the mountains and not directly on the university campus. I first went to the university campus and looked through there. It is very old, but a lot of new construction going on, and generally quite a nice campus. The streets throughout Honolulu are quite narrow. Most of the cars, or a very large percentage of the cars are very small cars, and even I was driving a little Datsun, in which I had claustrophobia all the way; however, it was easy to manipulate and get around traffic and

narrow streets which are just about wide enough for small cars. I did not see many large cars, however, although most of the taxicabs are either Cadillacs or Lincolns, and they say they charge the same price as any place on the Mainland.

I did find the Institute for Astronomy which is back in a small valley named Manoa Valley. I met initially with Ginger Plaush, who is the assistant to the director. She gave much information in regards to the telescope installation, relations with the people at the University of Hawaii and the people on the island of Hawaii, and I'll essentially repeat these things right at this point. First of all, they did not see any objection to our providing our own small sleeping facility at the top of the mountain as they felt that driving down at night might be a problem, and they prefer to minimize that if at all possible. The land at the top of Mauna Kea is leased to the university until the year 2033. There is a fairly lengthy process to get approval for a telescope on Mauna Kea. One of the things which must be done is to obtain a conservation district use permit. The whole area is controlled by the State Board of Land and Natural Resources. We would have to arrange for a sublease through the university. In order to obtain this, we must obtain a state environmental impact statement. This is a very specific description of the facility, and they recommend that we get a local consultant to help in writing this. The reason is that if we should in the future decide, for example, to add a slab, a shed, workshop, another building, or whatever, it must be covered in the environmental impact statement initially, or we have to apply for another environmental impact statement. So, the object of course, is to get it as broad as possible to cover as many future uses as you would want, and yet at the same time, be as specific as possible so that we can get

approval for it. The path that this statement follows I have on a separate chart; however, it must be approved by the governor as to whether it is specific enough. Then it has to be approved and go through the Board of Land and Natural Resources. There are six people on the Board of Land and Natural Resources. It is an independent body and one of the people on the board is appointed by the governor and is the Hawaii party representative. If he says yes to something, then it is likely to be approved, because he is the Hawaii island representative. The politics of the situation for additional telescopes on the island of Hawaii is this. There are two major environmental groups, the hunters and the bird lovers. The bird lovers are seeking to protect a certain species of birds which live in a certain kind of a tree. The hunters are seeking to protect various animals, including a type of sheep, which when it roams in flocks, attacks this particular tree. Then the trees die and the birds go away. So, it started as somewhat of a hassle between the two of them when the University of Hawaii wanted to set up a telescope site on the top of the mountain. Most of the trees do not grow past 11,000 feet. So, the site that would be looked at for a telescope site really has no environmental impact on either the bird lovers or the hunters; however, they have joined together as a common cause to protect the total Mauna Kea mountain. This Thursday there will be a public hearing in Hilo on the Mauna Kea master plan. This master plan has been developed over the last two years or so. Originally, Dr. Jefferies had approval for building a complex at the mid-point at 9,000 feet known as Hale Pohaku. He did not approve of the architectural plan and then went ahead and sent it back, at which time because of the delay in the building plan, the environmentalists got into the picture and have postponed it

even further.

The governor is in favor of developing the telescope site on the top of Mauna Kea, and has been receptive to well planned proposals for additional telescopes. The county mayor has backed the environmentalists and is asking for a five-year moratorium on building additional telescopes on Mauna Kea. He is coming up for re-election and he believes that he will get the votes if he backs the environmentalists. Also, while he is a growth proponent for the city of Hilo, he also knows that the state does, in fact, have the final approval and that if there is a good telescope complex coming in, for example, if NRAO were to present a good proposal, and it would be approved by the state, then in both ways, he wins - a better community in terms of resources and more money, and also he's won his votes.

From the time that you submit your request for the conservation use approval, it takes approximately 180 days. Then of course, your county construction permits, etc.

I then met with Dr. Jefferies. He indicated first that many changes had been made in their philosophy during this past year. Their original concern and thoughts were to have a mid-level facility where most of the work was done, large machine shops, laboratories, dormitories, eating areas, cafeterias, etc. would be available, and employees would then drive from Hilo or from the town of their choice and proceed to the mountain. This year, because of the problem with the environmentalists, they have agreed and written the master plan to include the concept of having as little as possible at the mid-level facility and having as much as possible in terms of support in Hilo. The Canadian French people are now looking at having

their offices in Hilo or Waimea, rather than Honolulu as the University of Hawaii does. The Institute for Astronomy is now obtaining approval to have a mid-level facility that would sleep and feed approximately 50 people, plus have two, two bedroom complexes for each telescope. They would be used for those people who were chief telescope operators, or whatever you want to call the people in charge of each particular telescope. They plan to include a reading room and minimum laboratory space of approximately 800 square feet per telescope. The University of Hawaii is planning to have their day crews drive to the mid-point facility on their own time and they leave from there on company time for the top of the mountain. They expect them to work four days on and four days off, and a ten-hour day so that all of the day crew would effectively be gone from their homes for four days at a time, and sleeping at the mid-level facility. The same will be true with night assistants and generally other employees. In talking with some other people, including the business manager, he has indicated that in fact, he does not expect a lot of electronics work to be done at the mid-level, even though many astronomers feel that that is the way it should be. In fact, the electronics people leave from Hilo and go to the telescope and very seldom, if ever, want to work at the mid-level site. The British telescope is going to be very large and have a large working facility there. Dr. Jefferies felt that it was best for his employees to commute to the summit from the mid-point on a four day schedule rather than commute from Hilo to the summit daily as they have been doing. He has felt that driving from Hilo daily reduces efficiency to some extent in terms of their acclimatization and he feels that it also causes a considerable morale problem, although at this time morale problems are at a minimum. The other

reason, of course, for having minimum facilities at the mid-level as that they feel it is very difficult for them to get approval from the environmentalists and other people for a larger, more complete mid-level facility.

Dr. Jefferies felt that the university would provide water to us and we would pay for the gas, driver, and some amount of depreciation in the equipment. In each case, it appears in talking with Dr. Jefferies, and with the business manager, that they are just now forming a policy on how they will handle new telescopes. Robert Le Port, business manager for the University of Hawaii, has indicated they have different contractural agreements with the current telescopes that are on the mountain or that are planned for the mountain. For example, in one telescope contract, they did not have any amortization of equipment or facilities charged to the telescope users or tenants, whereas in the later contracts, they are charging tenants for depreciation, amortization, etc. This has a very considerable impact on our costs and we should, therefore, plan on paying the amortization costs on any major capital equipment which they would put in, or else we should just do it ourselves so that it would be ours. They have no ambulance or fire truck at the summit, mid-level or anywhere else, and currently have no plans for that type of equipment. They have no backhoes. They do have two graders and one snow blower and blade with which they plan to maintain the road and take care of snow removal. This past year the cost was $15,000 for snow removal, and they expect that normally it would be only about $2,000 per tenant for this service, unless we were significantly away from the optical telescope site in which case we may pay a larger share. The road maintenance he anticipates would be approximately $10,000 annually for the NRAO. Again, however, if we were away from the normal site, it would be

likely to increase, and we would also have to do significant upgrading on the road to the other site. The state has estimated that the total road maintenance costs from the mid-point up would be about $55,000 annually, and below the 9200 altitude site, the state would maintain the road. It also sounds as though they would like to have a complete maintenance staff, including plumbers, electricians, carpenters, etc., but they do not at this point have firm plans to do that and my assumption in talking with Dr. Jefferies and Mr. La Port is that they expect at this point to maintain only roads and the cafeteria and dormitory facilities, although they would like to be able to support other activities as well. The only equipment which they do have and could provide a service to us with is a fork lift at the summit, and they have one 1½ ton state truck which they can use to carry some items up. They also have a tanker for carrying water, and they generally carry very little water to the summit and drop most of it off at mid-point. They are undercontract with a local trucking concern to haul their water tank. Their water tank alone costs $15,000 and they had it made on the island of Hilo. If we are to need as much as 10,000 gallons of water per month at the summit, there is a good possibility that we would have to provide our own tank and hauling. Dr. Jefferies indicated that money is available for overhead power lines and that the cost of burying power lines to the summit would be approximately $8,000,000 underground versus $1,000,000 on poles. They have the money for running electricity on poles; however, they do not have approval for that. At this point they are in the process of purchasing four generators with a total capacity of 650 KW. They are purchasing these for the NASA program and NASA telescope. The university would prefer that we purchase our power from them.

So far, no one has been able to tell me exactly what the cost of power is, or will be. I hope to find out more about this when I talk with Tom Kreiger, who is their observatory superintendent. The University of Hawaii would require that we take the power from their central distribution point and run it underground and pay for all costs for that. Depending on our site, that could be a very expensive undertaking. I hope to have that information after a tour of the site, next Thursday. I could not get concurrence on telephone facilities. Dr. Jefferies felt there were twelve lines, initially, then he claimed it was only eight. The business manager, Bob La Port, thought there was only eight and they wereall used, or all but two used. Dr. Jefferies felt that they were all used. It is a microwave length to the mountain and he has promised to clarify the issue as to whether we would have to run telephone lines. I did review a letter in which the last four microwave lines to the mountain were installed at a cost of $18,000. So, that looked like a starting point. I also reviewed the salaries of the various personnel and have that information on a separate page.

Again, Dr. Jefferies felt, and I relate his feelings, that all development of electronics and administrative support must be at the sea level in which ever town we would choose, preferably, Hilo. Apparently, the city of Hilo and the leaders in Hilo are very growth oriented and anxious for expansion. This has been a favorable climate to build buildings and people are very helpful if they feel that you are going to do something good for the city. Again, on vehicles, the university has two Broncos, two Blazers, two nine-passenger four-wheel drive Chevy suburbans, and one two-wheel drive pickup truck and one flat bed. They pay from $150 to $200 per month on a three-year lease arrangement, which doesn't include service. They found

that vehicles simply do not last going up that mountain. Apparently, they develop transmission problems because of the altitude and they have had significant transmission problems,both there and at Maoui where they operate another telescope. I think I mentioned this before,however, they are paying $125 per trailer load (6000 gallons) of water to haul to the mid-point and the summit. If we use 10,000 gallons per month, built our own trailer, we would anticipate considerable cost in water. The water is city water which they use and get at their Hilo office. Their dormitory and cooking facilities are at the mid-point called Hale Pohaku. They charge $30 per day. This includes the sleeping room, hot supper, bag lunch at night and breakfast which individual astronomers prepare,and lunch which they individually prepare, or occasionally have the cook take care of. They have one full time cook and one part time cook. Their night assistants do not pay for their own meals, however, they feel the astronomer comes to the site and purchases in effect, the assistants' or the night assistants', and therefore, the $30 is intended to cover part of the costs of dormitory and cafeteria privileges for the night assistant. That is something that I think we should certainly look at if we are to go to this site. At the present time, the mid-level facility has no regular phones and must rely on a single mobile phone. It is not efficient and has been a problem for them. I was not able this afternoon to contact Jim Wood, who is the person in charge of costing the NASA telescope, as he was out on emergency leave for the day. I have a meeting with him tomorrow and will review all facts and figures for the latest cost estimate on that program. Late this afternoon I did tour the city and looked at some of the cost of housing in the Honolulu area. It is astounding! The houses excluding land cost approximately the same as what they do in Tucson including land. $25 per

square foot is an average number; however, land costs anywhere from $10 to $12 per square foot. They actually sell it by the square foot. The typical lot of 7500 square feet sells for $80,000 approximately. If you have a nice lot overlooking the bay, etc., it could run considerably more than that. Many of the homes are built on land which they lease, and it is leased typically at a cost of 4% of the appraised evaluation per year. If you have a lot which is appraised at $80,000 the true market value might be $100,000; however, it would lease at $3,200. on a 55-year lease arrangement with provisions for re-appraisal every five to fifteen years. Architecture here is much different from Tucson. Most of the houses are on very, very small lots and have beautiful shrubbery and trees surrounding them, to the point that they are totally enclosed. The typical house plants which you would find in Tucson are grown here as outdoor plants - split leaf philodendron, croton, spider plants - are outdoor trim plants. Many of the houses are made of wood and typically they are squarish in design, although there are many different styles of architecture here. A large percentage of the population live in town houses, which are essentially tall apartment buildings, and appear to be in very crowded conditions. Even some of the nice ones, for example, had clothes lines hanging across the back porches.

Wednesday Evening, May 12th - First thing this morning I drove out to the Institute for Astronomy in Manoa Valley and found it very easily this time. I met at 8:00 with Jim Wood, the engineer in charge of the NASA program for design of the program. He, very kindly, had a complete listing of the infrared telescope project and the estimated budget prices which he feels will be effective in 1977. They are primarily based on prices which he has received in talking with the contractors and prices which he

has upgraded, partially from published information. They went out for bids on the original design of the infrared NASA telescope and because it was decided in Washington that the mount system was not proper, they decided to re-define this and have since redesigned the whole project and the entire telescope. I won't at this time go into all the numbers. Essentially, he feels that one of the most important things is to eliminate mountain labor to the greatest possible extent. For example, they originally had a lot of concrete work, structural and poured in place concrete, and felt when they were redesigning the telescope it was more practical to have structural steel and, in fact, have structural steel which could be done on the Mainland, tested, put together and assembled, and them disassembled and brought to the island. There are only three large buildings on Oahu which are built of structural steel. They do steel work, metal buildings and that kind of thing; however, they do not have good knowledge of heavy structural steel working and although there are competent contractors, this is not what they have normally done. Most of the buildings on Oahu and Hilo and most of the islands are built out of native stone or concrete. As a result, John recommends highly that panels, structural steel and everything, be made on the Mainland and then transported in the largest possible pieces to the island and assembled there. Most of the contractors require a guarantee of 10 hours per day, 5 days a week. In other words, 11 hours of pay per day. The steel workers, particularly try to arrange overtime during the summertime and it is subject to negotiation, but it generally works out that they end up working 6 days a week, or in some cases, 7 days a week. Most of these people are brought over from Oahu and they prefer to naturally make as much money as they can, do it fast, and it turns out for most projects the most cost effective way to do it is 6 or 7 days a week, despite the fact that they are working 10 hours a day for 11 hours pay and time and a half for Saturday and double time Sunday. So, structural

steel work is very expensive. Concrete will be batched, they hope, at the 12,000 foot level and they will have a batching plant. At that plant they hope to have concrete at $230 per cubic yard. That's not placing the concrete, or finishing the concrete, or form work or any of that. That's just buying the concrete delivered per cubic yard and batched at the 12,000 foot level. To buy concrete on a normal basis, not as a part of a major construction project, they want $296 per cubic yard and that was 1976 prices and concrete companies really don't want to deliver it because they are afraid of truck breakdowns, etc., and they will usually deliver up to only 5 yards. So; 5 yards of concrete costs $1000. Another consideration in terms of assembly on the Mainland; they try to make structures in the largest possible pieees, yet by the same token it's very important to get everything shipped from the Mainland into 8 X 8 X 24 foot containers. The reason for using that size container is so that everything can go from the Mainland to Honolulu, stay on the same ship and go on to Hilo. Larger containers requires that it be off loaded in Honolulu, placed on a separate barge to Hilo, and frequently they are damaged and very expensive to try to off load and ship over to Hilo in larger than 24 foot containers. At any rate, Jim Wood went on to say some other things that are very important to us in designing structure. First of all, the maximum bearing pressure for the ground is approximately 4,000 pounds per square foot and that's without safety factor, which means that typically they design for 2500 pounds per square foot. This requires a very significant amount of concrete for any foundation type work. If we plan on doing any work outside of the main new construction, we should try to minimize the concrete work because it takes

almost one day for a truckload of concrete to get up there and we will run into significant problems. There are not many trucks on Hilo to carry concrete up. Some other factors we should be aware of - earthquake loading, the seismic force horizontal which you have to be designing for: For building and components is .13 times the weight and telescope peers .3 times the weight. Wind loading is 125 mph and one of the other major factors is ice shielding. It is generally vertical ice shielding and as a result, the ice will build up to two feet thick on vertical surfaces, which is something we have to design for, making sure that when the ice does fall off, it will come off onto something that is strong enough to support it. The cost of the infrared telescope for the building shell, not including the telescope, the dome, the drive control, software, management or computers, is anticipated to be $153 per square foot. That does include a 10% contingency; however, it is felt that it is quite close in terms of overall costs. I had many other figures, but will put them in a separate report.

I then talked with Al Grey, who is the engineer and Chuck Fankenboner, who is the contracts manager. Nearly all of their parts are purchased from the Mainland. They maintain a large supply of IC's, resistors, switches, and general electronic components. Even in Honolulu, most of the electronic shops are radio, TV type shops and they pay 80¢ for a 28¢ IC. They purchase large quantities of each item at the same dealers and companies which we deal with in Tucson. There is now a Digital Equipment rep and they do provide service to Honolulu. The institute has purchased PDP 145 equipment and has it on Oahu now, but plans to put it on the mountain soon. They also plan to have their own campus machine shop moved to the Institute for Astronomy in the near future. It is a small machine shop; however, it has three machinists. One other point that Al Grey made was that they definitely need UPS systems

and I noticed that they did have an LGAR UPS in their computer room. It was a bit larger than our UPS. It was a 15 KW unit. Currently, they are generating approximately 80 KVA output from their 150 KVA generator. Their typical useage for diesel fuel is 10 gallons per hour. This has proved to be very expensive. At this point, there is only one tractor in Hilo that will take diesel fuel to Mauna Kea. No one has the exact figures on that and I hope to have that in tomorrow morning's meeting. It appears that we should plan on approximately $2500 per line for six additional telephone lines to the mountain. One other strong word of caution - don't buy any vacuum system computer components, such as the RKO 5 disk or tape systems, unless we go into a pressurized system and a humidified area. At this point, for the infrared telescope, they will be adding humidity; however, they do not plan to add any pressurization and so they have had to purchase different equipment for disks and tapes as each of those and the card reader need approximately 20% relative humidity, and of course, vacuum systems do not work. Another word of caution was cabling. All cabling should be of a neoprene sheet type, otherwise the normal PVC dries out. Another fact of interest is the shipping cost incurred in taking things from Honolulu to Hilo. For example, recently they shipped a grader over to Hilo from Honolulu. The freight was $900. Another fact that we should consider is air conditioning for computer equipment. In addition to needing humidification, as I mentioned earlier, air conditioning on Mauna Kea is only about 60% efficient so additional equipment must be installed because of this inefficiency. Further, in talking to the engineer, Al Grey, I found that there are on the island of Oahu, companies which can calibrate and repair equipment. Hewlett Packard has a repair center, and

Tektronix is subcontracted to EMC corporation for repair of equipment. EMC Corporation does have a calibration and maintenance operation here primarily for radios and navigation equipment, etc., but can handle much of our type equipment. Digital Equipment Corporation may set up a repair center on Hawaii Island, if they get enough additional systems there. Another point which Jim Wood came back to me with was to be concerned with the telescope line of sight to Hilo and Kamuela, that the environmentalists will be very concerned in making sure that you cannot see our telescope from those two cities.

I then talked to Susan Crookshank in the personnel department and obtained brochures and information in regards to personnel practices, fringe benefits, salaries, etc. I also obtained yellow pages, etc. for review and looking at various companies, etc. that would be available on the island of Oahu. I then also received what data Al Grey had on field strength measurements and various equipment that has been tested on the island around the tip of Mauna Kea, and have copies of all that. In addition, Jim Wood gave me copies of the NASA telescope plans and summit plans as they stand today. Business was completed on the island of Oahu and all questions seemed to be answered, so we left early for Hilo. We did stop to see the USS Arizona, which is located very close to the airport at Pearl Harbor, and took the boat ride out to the monument. We went to the airport and caught the early flight to Hilo. As we came in towards the island of Hawaii I took pictures of the top of Mauna Kea, which at this time is still snow covered, and was well above the clouds. As you go below the cloud cover, the island is totally green and beautiful. There were hugh waterfalls coming off of the green lush land and down into the ocean. It was very cloudy and raining when we got off the plane.

Thursday, May 13th - This morning I met with Tom Kreiger who is the superintendent for the Institute for Astronomy. He picked me up in a four-wheel drive vehicle, and we went up the Mauna Kea summit. The first 8 miles of road out of the city of Hilo was fairly good road, and then for about 8 miles there were very choppy, short turns. The road is narrow, in fact it was originally a one-lane road that was converted into a two-lane road by widening each of the sides. The original story goes that the Army camp which is up in the valley between Mauna Kea and Mauna Loa was a training base during the war and originally the road was built up in there with all of the curves so that in case the Japanese army was bombing them or strafing them with bullets, they wouldn't have a nice straight line to attack. Other people say it's curvy because that's the way the trail went and the road followed the trail. At any rate, it is a curvy road and there is about 8 miles of very slow bumpy driving. They have had several accidents on the road in which people have been killed because the road is so narrow and people try to pass if someone is going slow. After that, the road is quite good until the mid-point facility, which is commonly known as Hale Pohaku. We stopped at the mid-point facility for approximately 20 minutes as that is the custom. Most of the people that drive up from Hilo, drive to the mid-point and at 9,000 feet, have coffee and relax for 15 minutes or so to get acclimatized and then go on to the top of the summit. At this point it should be noted that two of the day crew live in Kono or Kamuela and drive their own vehicles to that point. The other five employees that live in Hilo drive a University of Hawaii vehicle and they leave downtown Hilo at 7:30 and get to the mid-point level at 8:30. Then they have their coffee and proceed to the top which takes another half hour. So altogether

the entire trip is approximately one hour and 45 minutes. The five employees who drive from Hilo switch off each day so that they each end up having approximately 3½ hours that they are driving a company vehicle. Then they come down from the summit and get back to Hilo at 5:00, so as a result, they work 36½ hours and the 3½ hours which they spend driving to the mountain and driving down once a week makes up that equivalent so that they end up working 40 hours. There is no overtime paid to those employees who drive the government vehicle, because they in fact make that time up driving. One of the other things about the road going to Hale Pohaku from Hilo is that there is a fairly significant amount of traffic on the road. We saw two large 4 x 4 army trucks go down the road and they go fast and don't move over much. We had a 4-wheel drive and moved over to a considerable extent to the right side and that is the point where they have had some problems. From the mid-point to the top, the road has recently been paved, in fact, finished last November; however, that road is in very bad condition most of the way and the reason is because the Canadian-France-Hawaii telescope is being built and there has been an awfully lot of heavy construction, plus the winter took its toll and there are now deep holes - I would say up to 6 inches deep on the road. In a way, it was almost as bad as the dirt road. In fact, on the way back we took the old dirt road which was in better shape than the paved one. In the winter they have up to 12 to 13 feet of snow covering the road and while they do have a Navy track vehicle, or what they call a cat vehicle that will hold 12 to 15 people, they cannot use it until the road is at least partially clear. The reason is that it's very difficult to see the side of the road as the snow goes

straight against the mountain and fills in the road so that it looks like a solid sheet of snow right down the highway and until they get a snow plow up there, they can't get it clean. This year the contractors lost approximately 14 work days and the observatories lost approximately 5 work days. The reason for it was several snow storms in which they had to have snow plows come up from Hilo to plow off the main road. The observatory does not have equipment suitable for pushing snow any major distance. I talked with Tom in regards to the diesel fuel. The cost of fuel for 6000 gallons is approximately $200. They are paying approximately 32 to 33¢ per gallon. In addition, the hauling charge from Hilo to the mid-point is $150, and approximately $250 to the summit. Normally they pay $200 hauling charge as half of the fuel is dropped off at the mid-point because there they are running the dormitory, cooking facilities, etc., and the rest is going up to the top. One interesting fact is that at about 12,000 foot, there is a glacier ocean bottom rock which came up from the sea when the mountain was founded, and there have not been any eruptions on Mauna Kea since its founding as far as anyone knows. Most of the terrain is cinder and lava; however, there is this one section in there that has very hard rock. We were able to observe some small caves where it is reported that ancient warriors went to dig the rock and quarry it and made tools and weapons from this very hard ocean floor rock. At approximately 12,000 feet there is a concrete batching site which is now being set up for the Canadian France telescope and it is just a large flat area which is quite firm.

I had the opportunity today to meet two engineers from a local consulting firm who are working on the Canadian France project. They have

done much of the work on the mountain in preparing the political documents necessary, obtaining soil samples and working in foundation structural engineering for the mountain. Because of the cinder there is significantly different structural weights required up there, rather than building it, for example, on granite. The politics and environmentalists are really strong in this area and so it was suggested by Dr. Jefferies and confirmed by these two people, naturally, that we have some assistance from a qualified person in preparing these documents. I met all of the day workers at the top of the mountain, observed the various telescope sites and took pictures of many of the possible sites and all of the telescopes on the mountain. Most of the workers seemed to enjoy what they are doing and I did not notice that they had any ill effects from the high altitude. One of the employees was standing on a platform 8 feet up in the air without a guard rail, and it didn't seem to phase him. It did phase me, however, and I felt faint and a bit dizzy at first. One of the things that Tom indicated was that he had and still does have, a fairly severe loss of memory of things that happen above the 9,000 foot level. I don't know whether I noticed that particularly because he mentioned it to be beforehand; however, I did make very specific notes of trying to write down what each photo was at the time I took it, and in a couple of cases, I took 5 photos and couldn't remember which one I took in order. Very unusual situation, because I've done that before and didn't have any problems. I did feel short of breath when I stood up and felt a lot better when I sat down or when I leaned against the side of a wall. Today there were several people from the Bureau of Land and Natural Resources looking at the land and

preparing themselves for a meeting tonight. I noticed that three of them sat in the car and did not get out and the two that did get out of the car felt very weak and dizzy when they entered the 88 inch telescope. One of them was over 40 years old and the other one was much younger, probably 30, and both of them felt severe dizziness and when Tom asked them if they wanted oxygen they both immediately said yes. I though I would try it and took a whiff for a minute or so but didn't notice any significant effects one way or another, although I think it did relieve a bit of the faintness for a couple of minutes, I'm not sure. They do have a small machine shop in the 88 inch telescope. I think its comprised of two lathes, a band saw, and a couple of drill presses - no metal working equipment such as brakes or shears at this point; however, they would like to obtain them. The university does not have any type of equipment such as small cranes or backhoes or tractors. I feel that if we locate here, we would want to have this equipment at our disposal. They do have a crane inside on their 88 inch telescope and I feel that we would also need to have a crane as part of our telescope design.

We came down the mountain and had a good discussion on the way down in regards to the local lore and scenery and I received the opinions of Tom in regards to living in Hilo. He was a Honolulu resident for the last 9 years, retired from the Navy, and joined the Institute for Astronomy. He has been living here on the island of Hawaii since November and is planning to move his family over in June as soon as his kids are out of school. He has been renting a small apartment and is moving into a little larger one until June and they plan then to purchase a home. His feeling on the school system was that it was generally a good one and that he has a boy who is

graduating next year from high school. His boy was not happy to come over because he had many friends at Honolulu, and did not like spending his last year away from his friends. However, Tom felt that he would adjust without any problem. He felt that the school system in Hilo had its share of problems - some marijuana and that kind of thing; however, certainly not any more than any other United States school and he feels that the situation will improve considerably next year because there will be a second high school built in Hilo. Right now there is one high school servicing the whole community. The community is about 30,000 people and the Island of Hawaii has approximately 70,000, so almost half on the island of Hawaii live in the Hilo area. He generally seemed pleased here. Some of the things we noticed while riding down were the orchids growing wild and there are many beautiful flowers as you are driving along. The town of Hilo is just about continuously covered with clouds and during the day there will be about 3 hours of sunshine at various times throughout the day. Otherwise, it's cloudy and rainy much of the time. The houses all have tin roofs, metal roofs with no wood in them except for the beam which the metal roofing are nailed on to. The reason for metal roofs is that wood and composition roofs tend to get water logged, soaked, and grow moss and eventually just rot away, so most buildings including the new expensive houses, etc. have metal roofs. There are some exceptions - there are some tile roofs and some special composition roofs on some of the buildings. There are no wild snakes on the island of Hawaii at all. In fact, there are only two snakes. They are both in a museum and one is sick as of today, but no other snakes are allowed, even as pets on this island. They feel that it is a Polynesian

paradise and they do not want any snakes around. They have some scorpions, but no deadly ones, only the kind that get you sick if they bit you. There are centipedes which do the same thing. Two of their biggest problems are cock roaches and termites. The have the dry wood eating type and they have the wet type which goes down and buries into the ground underneath the building, comes up through and leaves no residue as it is eating. There are not telltale signs of sawdust, it just eats the wood and one day you'll pound a nail in the wall to hang a picture and the whole wall will collapse. For cock roaches, they paint the cupboards in the kitchen and the woodwork and the corners and all areas around food with the No Roach made by Johnson's and put on no-bug paper on the cupboards and very seldom have any cock roaches in the kitchen area; however, despite all efforts throughout the house, they will occasionally have cock roaches in other portions of the house. They get into the furniture and into the carpeting and around the corners, etc. He does not feel that it is a troublesome problem, just one that you get used to. We then went to his office and went over some facts and figures and he then introduced me to the Chamber of Commerce man, Mr. George Abe, and I talked with him for a while. He suggested a number of people I should contact tomorrow in pricing of land, houses, square footage costs for buildings, etc., so that is my schedule for tomorrow.

This evening we went to the meeting of the Bureau of Land and Natural Resources. It was an interesting meeting in a room designed for approximately 50 or 60 people and there were 80 or 90 people there, many of them standing in the hall. The only people who were allowed to speak were those that disagreed with the advisory committee or the staff recommendation on the Mauna Kea master plan. Each of the people that spoke took exception to the

fact that they did not want to have a case by case consideration on new telescopes. They wanted a moratorium on new telescopes of at least five years, or an absolute maximum number of six telescopes on the mountain. They also wanted no facilities, or in a couple of cases, very minimal facilities at the Hale Pohaku mid-point level. From thereon they wanted other things such as eradicating or fencing types of sheep that eat certain types of trees that allows certain types of birds to become extinct. Others wanted to be able to hunt anything, so it was a hunting versus game protecting type of discussion. Others were interested in the skiing facilities at the top of the mountain, etc. We left before the meeting was totally over; however, we talked with Dr. Jefferies and he indicated that there would be no final determination made tonight and there was not much point in staying around. One other point that I didn't mention earlier, and that I did mention to Dr. Jefferies for clarification was that a long narrow area of approximately three miles by 1/2 mile wide on the summit was allocated for radio telescopes and a number of people objected to that being there and the explanation was that at the time that allocation was made it was made because there was a proposal from a group for a series of interferometer type telescopes and some more questions were raised and it was explained that each dish would only be 20 feet in diameter and that there would be five and they would be on a "T" shaped or cross-shaped form with four dishes at the central part of the cross and one at the bottom. But, they would cover three miles, so of course, all that anyone heard was that they were going to cover three miles and there were five big telescopes covering three miles of territory. Dr. Jefferies indicated that he would clarify that point - that a radio telescope does not necessarily have to do

that, that it could be a more conventional dome shaped facility such as an optical telescope.

Friday, May 14th. First thing this morning I revisited Mr. George Abe of the Chamber of Commerce and discussed with him briefly some realtors and asked him to set up an appointment with the mayor for me. He did for 10:30. I then went to the Hilo Iron Works which, according to Tom at the Institute of Astronomy, has done much of the work for the C & F project and has done some work for the Institure of Astonomy. The Hawaii Institute of Astronomy has their own machine shop in Oahu and has most of their major things done there; however, they have used the Hilo Iron Works and they have also used the A & A machine shop. The very precision work they have had done at their own shop. In talking with the production manager, Mr. Matt Mathiew at the Hilo Iron Works, he indicated that they have structural steel capability, large welding facilities, fabrication facilities, and also have a complete machine shop with vertical and horizontal mills, lathes, grinders, etc. They do not do any engraving, however. Their major type of work is maintaining all of the steam turbines for the island and they do much close tolerance machining for that type of thing. They have also done all of the finish machining on the dome rollers for the C F & H telescope. They do not have any heliarc welding facilities; however, he indicated that another small shop in Hilo does have heliarc welding facilities. He did not seem receptive to showing me the plant, although I could see some of it and it is a very large building.

I then went to the Hilo Community College which is a fairly small college in the number of students - they have 1668 students at this time;however, the physical plant covers a lot of territory and they do have many different

trades there. They have an electrical building, probably about 40 X 80 for electronics, they have a large building for auto mechanics, a large building for machinists and machine tools, and another for diesel and heavy equipment manufacturing. They have an electrical trades type building and then they have a series of other buildings which were in behind. I did not get a chance to look at them, but I suspect all of the general arts type buildings. It is quite a large facility, particularly for such a small number of students.

I then went to the department of Planning and Zoning to determine which areas would be useable for a down town facility. I did introduce myself, but did not say the company name because of the political problems going on in Hilo in regards to the telescopes. As I asked for information on the Planning and Zoning maps, she looked strangely at me as though, who are you and why do you want these, so I did say who I was and where I was from, and she had a great big grin on her face and said just a moment, at which time she brought over a young gentleman from the Planning Commission. I told him I was looking for the maps which would show likely places for erecting a downtown facility of approximately 10,000 square feet to be used as office, engineering, laboratory and storage space, preferably on the road to Mauna Kea. He then showed me the zoning map and showed me very clearly that there definitely is no land available between the downtown area and Mauna Kea. I did receive the zoning codes as to where we could build a facility. After a bit of discussion on the subject, he indicated finally that about the only place that would be feasible would be out towards the new industrial park in the Hilo airport area; however, he was not at all aware of the cost of land or whether the land was even available and if it was available, how one would go about getting it, and at that point seemed to be not very helpful. I then went to talk with Mr. Clarence Garcia, the

Director of Economic Development and Research, and he was not in so I did leave my name and said that I would contact him later.

At that time I then went to see the Hawaii mayor, Mr. Herbert Matayoshi. As I introduced myself I indicated to him that I was from the National Radio Astronomy Observatory, and that I was here on a business trip to determine the cost of building a telescope on Mauna Kea. I said that since I was talking with some of the people that worked for him, I did want him to at least meet me and me to have a chance to meet him and explain to him that we were very interested in Mauna Kea as an astronomical site, since it is by far the best site in the United States from an astronomy standpoint. He thanked me for my courtesy in coming to see him and letting him know what my intentions were, and then proceeded to describe to me his Mauna Kea philosophy. That being, that he is not in favor of any additional telescopes on the mountain, and of course, I knew that before I went there, but on Dr. Jefferies advice, did go to see him anyway. His feeling was that the mountain meant an awfully lot to him and that he did not want it desecrated in any way, shape or form, and that when he gets up in the morning he can look out his living room window and see the mountain, and now all he sees are telescopes and he doesn't want to see any more telescopes. He feels the same as many of the other residents of the area,that they do not want to see telescopes on their very beautiful mountain. He then went on to say that he realized that there must be some balance between the economic factors, meaning that there would be additional jobs and additional money put into Hilo because of this, the Chamber of Commerce's point of view, the hunter's point of view, the bird lover's point of view, and so on, and

that a balance must be met and he understood that; however, from his standpoint, he was not in favor of it. He was also not in favor of the Canada France telescope, bu that one was approved, and thus he does not have any say as to whether this one would be approved as that is up to the Board of Land and Natural Resources. I also indicated to him that our intention was to have a building in downtown Hilo which would be a lab, and that we would also have our main facilities as part of our telescope on the top of the mountain and would not be particularly interested, as we see it at this point, in having a very expanded mid-level facility. The reason being, that our astronomers do not spend long periods of time as optical astronomers do and they would not need to stay acclimated, we would probably have to pressurize our facility so that they could withstand a very short time period on Mauna Kea and be back down again. I also indicated to him that the meeting last night in regards to radio telescopes had presented a somewhat misleading picture in the sense that they had been discussing interferometer type telescopes which would cover three miles of land and have five dishes and that our telescope proposal would be more in line with the optical type telescopes which had a large dish with a dome over it. I did not give him details in regards to that. I thanked him for the opportunity to talk with him and he thanked me for meeting with him and I left and went back and bought a Hawaiian shirt so that I would look like a Hawaiian and not a foreigner as Ginger Plasch from the Hawaii Institute told me last night. I had been wearing an Indian bolo tie and she said I looked like a foreigner, so I got dressed up in a Hawaiian shirt and went then to meet with Dr. Jefferies and Ginger and a man named Fred from the Neighbor Island Consultants, who was completing a meeting this morning on the

Canadian France Hawaiian telescope and trying to get approval through the county board for putting the cement plant at the mid-level. In the meantime this morning, I did purchase a local newspaper. I have found two articles, including one front page article which referred to our considering a telescope here. I did meet with Dr. Jefferies and the group for lunch, and Judy also attended. We had a very interesting conversation. The general feeling on behalf of those three was that the total Mauna Kea site plan would probably not be approved in the very near future; however, if there are serious proposals for a telescope on Mauna Kea, they would be dealt with individually, as the plan states. He felt that the governor and the president of the University of Hawaii would make the decision as to whether or not there would be additional development on Mauna Kea, and those people are in favor of astronomical research and development of the Mauna Kea facilities. So, we should proceed on that basis. After lunch, I reviewed with Dr. Jefferies, the cost comparison that we have for recurring costs, and he felt that the telephone bill might be excessive, however, he then agreed as he stood there and added it up. (They use all commercial rather than any FTS because the University of Hawaii is not allowed to use FTS). He felt that there would be FTS facilities on Hilo when the NASA telescope is complete, so part of that bill could be chopped down because of the inter-island calling charge that I had included. He also felt that otherwise the statistics and costs appeared to be reasonable from what he could see. His point was that the astronomy per hour was one other factor that has to be weighed in any kind of cost comparison.

I then talked with the RSM Realty, Inc. Jack Sims, who is the sales director for that realty company. He showed me the types of houses which are

available in the Hilo area.There are houses one can purchase on leased land and some which can be purchased with the land. He gave me directions to many of them and I have pictures of some of the new ones,since that is the easiest type of comparison. A house with approximately 1200 square feet sells for approximately $55,000 to $65,000. That's on a fairly small lot and a subdivision type atmosphere. The houses are constructed primarily by 2 X 4's, 2 X 6's, and plywood for the floors. The roof has galvanized metal put right over the 2 x 4 ceiling joists. They claim that by putting plywood on as a strengthener, it would rot and they would have considerable troubles. So, they put the metal on and apparently do not have many problems with leaks. If they do, they go up and put some tar on it and that seems to satisfy the situation. The houses with the composition type roof were considerably more expensive. They went up to $65,000 and I have a picture of one of those. I asked one person who was having a house built, and he declined to tell me what his house cost, but gave me the prices of each of the houses next door. I then looked into the possibility with Mr. Sims, of buying land near the airport. He indicated that all of the land in the airport area is land that is owned by the Hawaiians, or in some cases, the state. In order for us to consider land there, we would have to lease it rather than purchase it. One acre of land on a lease of 55 years, with 15-year increments for rent adjustment would run approximately $2500 - $5000 per year. It could run more than that, depending on the particular parcel of land. We would then build our own facility on the leased land. The Planning and Zoning Commission had indicated earlier one industrial area that would be the prime area on which we would be able to put a building. I then looked around at some additional houses that were for sale and the additional areas in which houses are for sale. There are some houses on the saddle road heading towards Mauna Kea,

and there you can buy fairly large homes on the order of 1600 square feet for $55,000 to $65,000. There is one for sale in the same area with a pool and nice landscaping, that runs $78,000. There were four houses for sale in that area. I saw pictures of them; however, they are in the area which receives the most rainfall of any area around Hilo. As a result, the subdivisions were started, but not very popular. The area in which houses were from 1800 to 2000 square feet, and in which the school was a good one, ran about $83,000 on up. They are homes that vary in age from 3 to 25 years old.

Today was quite a nice day in Hilo. The sun did shine for the first time since we've been here. Yesterday and before, the sun did not shine for more than an hour at a time, nor more than 2½ hours during the day in Hilo; however, it was absolutely beautiful on the top of Mauna Kea, because the sky was blue and we were well above the clouds.

Saturday, May 15th - This morning we left for the Kamuela or Waimea site to take a look at things over there. From Hilo going towards Waimea along the ocean side, we passed through many, many towns, most of which are sugar farms and plantations. Both sides of the street down to the ocean are covered with sugar cane. There are 3 sugar cane processing refineries between Hilo and Paauhau in which you turn off to go to Waimea. There are no particular tourist sites except for a state park at the site of Akaka falls. However, it is a very pretty drive on nice roads. We then went into Waimea to the Parker Ranch Shopping Center and met with Mr. Yoshio Kimura, who is the manager of the Kamuela branch of the Territorial Savings and Loan Association. The shopping center was open and Kamuela is the post office name for Waimea. Waimea is a term that means brown water. The reason is that most of the drinking water is from the rainwater, and it comes down on much of the green folage

which has brown ends on it, and when the water ends up in the pools or ponds,it is champagne colored and thus the name is Waimea,meaning brown water. There are towns named Waimea on 3 different islands in the Hawaiian island group, and in order to stop the confusion of mail, they have changed the name from Waimea to Kamuela. As you enter Waimea, and I will refer to it as that because that is how the people there refer to it, the homes look much like the Hilo homes.

The Parker Ranch was at one time the largest ranch in the United States. It has sold off some of the land and decreased some of the lease hold which it has had over a period of years. It is now, I am told, the second largest cattle ranch in the United States. They have approximately 350,000 acres, depending on who you talk to, (it want from 295,000 to 350,000 acres), of which approximately 100,000 acres are owned by the Parker family. The other land is leased from the state or federal government.If we build an office in Waimea, we would probably deal with the Parker Ranch people as they own much of the land in the area. They are now building a new 1.5 million dollar medical center in Waimea. Approximately 1/3 of the money was raised locally and the balance is state funds. The new medical center, they feel, will attract many new doctors and be the best facility in the surrounding area and that end of the island. They now have two optometrists, one dentist, and three doctors, however, there are other doctors that live in the area and practice their medicine In Honokaa. It is expected that they will eventually have 8 doctors' offices, plus the optometrists and dentists in that area. This town is very nice and clean, and right on the mid-point between the rainfall dividing section. On the one side toware Hilo they have more rain and it increases as you drive dowards Hilo. On the other side, going west towards Kona, the rainfall

decreases to approximately 30 inches per year. The town has one very nice shopping center and one much older shopping center, 2 regular banks - full service types. Right now they have two savings and loans and expect another one very soon. The coldest weather recorded is approximately 42 degrees and that's at about 5:00 A.M. and happens about two times a year. The daily winter temperature averages 60 to 70 degrees and the daily summer temperatures average 75 to 80 degrees. There are three public beaches within approximately ten miles and they are Hapuna Beach State Park, Puako Beach, and another beach within the same general area. Most of the town is dependent on cattle business; however, approximately 35% of the merchants depend on tourism and 65% of the merchant business is local trade. They have an elementary school and a junior high school which appear to be very nice facilities, and they have a small library with $600,000 appropriated for a larger one. The high school students go to Honokaa High School which is approximately 15 miles away. There are private busses which are under contract to the school systems and the Honokaa High School has approximately 700 to 800 students. A private school which is in Waimea has the 7th to 12th grade, and costs approximately $1000 to $1500 per year for local residents. Boarding students pay anywhere from $4000 to $5000 per year and it is the best, or one of the best, of the college preparatory schools in the Islands of Hawaii. Many, many students come from the other islands to attend this particular school. By next year, they anticipate that there will be 2 private elementary schools and one private intermediate school. At one time the high school which I just referred to, did take in elementary students, and then stopped and is now strictly junior and senior high. So, they are building two additional private schools which they expect to be fairly low in cost. Within the town there are three hardware

stores, one drug store, two grocery stores, two laundromate, three excellent dining facilities, two drive-ins, one theater. They have cable TV and they receive all of the Honolulu and Hilo radio stations. They have 24-hour police protection and have a 24-hour fire department which appeared to be very nice. They also have a community recreation center, tennis courts, and many of the finer amenities. They also have a baseball park which, in the Islands, seems to be the thing. For example, when we left Hilo this morning, they had baseball games, and the day before they had little league baseball games, right along the ocean front in Hilo. There is a nice baseball park in Waimea, also. They have a gynmasium for the people in Waimea. They have fairly strict building regulations in the sense that they do not allow anything over a 2-story building and that is, I think, as it should be, for all of the buildings are low and do give the appearance of a wide open feeling. In talking further with Mr. Kimura, he indicated that the community association has worked closely with the Planning Association in the county government and he felt that although Waimea did not receive its fair share of goodies from the government, that they did get along well, and they did not have any problems with the people in the county government. Within 10 miles from Waimea there are two beach hotels and soon there will be another one. This new one will be an international type sport hotel. There are two hotels within 15 miles. There are two golf courses close by, one of which looks green and very nice. I was told that houses are more expensive in Waimea than Hilo and I was also told that they are about the same. Houses were generally on much larger lots in Waimea than in Hilo. They do have a concrete plant which is just outside Waimea about three miles past the airport. They have a small airport which handles about one to two flights per day and it's about 35 miles to the Kona

airport which handles many more flights per day. Vegetables for most of the islands are grown in the Waimea area and generally vegetables are less expensive in the stores. Judy checked the prices in the stores and found that they were very similar to the ones in Tucson. In Hilo the prices had been just slightly higher. Vegetables, etc. were the same general prices. The reason that meat is approximately the same there, and slightly more expensive in other parts of the island is that even though it is grown on the island of Hawaii and right there on the Parker ranch, it has had to be fattened up on grain for the last few weeks, and the grain is all brought from the Mainland. The altitude of Waimea is approximately 2500 feet, As I mentioned earlier, it is the dividing point between the wet area and the drier area. To the west of Waimea, the grass turns brown after the summer and becomes more desert like. Right now, it's a beautiful green. We also saw Century plants and prickly pear cactus of various types to the west of Waimea. Most of the homes are heated by electricity. Mr. Kimura's house has a $65 electric bill every 2 months and he indicated that it was a nice, fairly large home with just 2 of them, and they were not at all cautious about leaving their electricity on and frequently left their TV on when they were not watching it, etc. We then went to see the Kona airport and on to look at the facilities and housing areas between Waimea and Kono to see where there would be a drier atmosphere. We looked at the airport and back along to the Hapuna Beach State Park and Mauna Kea Beach Golf Course area in Kawaihae, which is strictly a town that has a hugh chemical plant and a boat launching facility and one National Park monument. Then there was one very nice housing development area and I have a picture of it. It looked as though it was primarily retired people from the Mainland, judging by the people we saw standing around. But, it was done very

tastefully - both condominium and single family housing. From there we went back to Waimea through the back roads and the housing areas. There were very nice homes in this area. We saw the prep school, at which time my camera broke, and then we went from there across the saddle road back to Hilo.

Sunday, May 16th - We got up early to visit and take pictures of the recreational areas around Hilo. The first place we visited was the Black Sands swimming area which was the best swimming beach near the Hilo area. It was not as crowded as I expected and a drive of about 30 miles to get there. It is in an area that's on the absolute eastern tip of the island of Hawaii. There are several parks there - Lava Tree State Park, Mac Kenzie State Park, Kaimu Park, Harry K. Brown Beach Park, and Isaac Hale Beach Park. There were some people appearing to maybe be starting to surf, but we did not actually see anyone surfing there. The beach is fairly narrow, and it is in fact, black sand. It looks to be made of crushed lava as the lava flow comes down very, very close to there. Much of that tip of the island apparently does not have electricity, as we talked with one farmer there, a farmer, store type person, and he had his own diesel generator. We saw other generators out a little ways away from the beach. There were telephone lines in that area. On the way there, we saw a lot of wild orchids growing along the road and many little farms growing anthurium flowers which is a 3 - 4 inch across large red waxy type flower with a pink or yellow center stem. This is one of their other major crops that they export and sell locally from the island. There are many of these anthurium farms in the Hilo area. We also took pictures of the Papaya and banana trees. There are hugh orchards of Papaya. The major crop of the Island of Hawaii is sugar cane and that is apparent everywhere. There are just miles and miles of sugar cane. The second major crop is the cattle which is raised on the west and the north and west side up towards the Parker ranch

area. The papaya, flowers and vegetables are the other major crops grown here. Of course, tourism, is another major industry of the area. The local people that we did talk to claim that tourism is not as important; however, there were sure an awfully lot of tour busses and limousines traveling around this morning between the beaches and the Hawaii volcanoes around Hilo.

We then went to the Hawaii Volcano National Park and saw the Kilauea crater and and lava tube. They had a 12-minute movie showing the eruptions of the Kilauea crater and other volcanic actions in the last 15 years. It was quite interesting and it was also an area in which I certainly would not want to be near when they were erupting. The lava comes out at approximately 2000 degrees and erupts far below sea level first, and then, depending upon the amount of gas within the volcanic action, it flows. If it is a strong gaseous flame, then it creates the smooth flow lava called Pa Hoehoe which is the smooth lava that comes out and flows at approximately 20 miles per hour and flows like water. If there are interruptions in the gaseous flow, the it promotes the Aa Aa type of lava which moves much slower - as much as 100 feet in a day and these look much like big cinders. There are other areas which they call steam vents. One was not too far from Hilo - about 7 miles. There was steam coming out of it and it looked like a miniature volcano. The largest one we saw was not more than 10 feet across, but all of the rock was extremely hot with steam coming off of it. There were even ferns growing on the inside of this small crater. There were 5 other little ones which ranged from about 3 feet across and 3 feet deep to approximately 10 feet across.

It is now Monday, and the last day on the island of Hawaii. This morning, very early I called Clarence Garcia, who is manager of Research and Development for the county of Hawaii and set up an appointment for 9:30 A.M. I next went back to the Institute of Astronomy offices to verify some of the prices and

obtain their opinion on some of the prices which I received in the Waimea area from the banker. The banker over there had indicated that the houses there cost in the area of $10 per square foot more in Waimea than in Hilo which did not seem reasonable to me. I talked with Gail, the secretary for the Institute of Astronomy. She if a lifelong Hawaii resident. She did not feel that there should be such a difference either, although she did indicate that land in Waimea area would probably be slightly more expensive than most of the land in the Hilo area. She gave me the name of a real estate company whom she felt was much more reliable than the people I had originally talked to in Hilo, and I called him and I told him what I wanted and he arranged for a meeting this morning with myself, Mr. Elroy Osorio, who is a realtor with The Land Company, Mr. Russell Drummond who is manager of real estate development for The Land Company, Mr. Osorio is manager of the real estate area, and Dick White who is with the Bonneville Construction Company. I met with them and described to them the requirements that we would have of approximately a 10,000 or 12,000 square foot building and received what I feel after much discussion, was a very good cost estimate for a building in the Hilo area. He also indicated that the rent for leasing land in the industrial area is approximately $5,000 per year. Commercial land here leases from the Hawaiian owners at approximately $20,000 per year per acre, however, we would probably not need commercial type zoned land. We would be satisfied with the industrial type zoning area. Sewers and utilities are very inexpensive in the industrial area. The warehouse space would run on the order of about $25 per square foot. That would be what they call a split rock construction, similar to slump block in the Tucson area. The lab area they calculated at $45 per square foot, based on heavier air conditioning and electrical requirements. We probably

would want to add another $5 for electrical that we tend to want much more heavily than normal. The warehouse area of 3000 square feet would have minimum air conditioning and the office area would have minimum air conditioning as 72 degrees is close to the ambient temperature here and it would be primarily humidification relieval. Parking is approximately $1.50 per square foot. He also gave me prices for homes, indicating that either homes or a building would be comparable here with Waimea. He said that the materials go into the shipping port at Kailua which is near the Kono airport and that there are considerable construction crews over there, although his company would like to do the job and be considered in the future for any endeavors that we would have. Their office was in a brand new home which they are using for a model home. It was approximately 2000 square feet, completely made of cedar, indoors and outdoors, located very close to Hilo High School. The house sells today for $57,000, had 2 bedrooms downstairs, a living room area, a small dining area off the living room, and a small kitchen area off the dining room, all in an open air sort of way. It has a spiral staircase going to the second floor and a sitting room at the top floor and it's built in an A frame type fashion, such that when you are sitting on the second floor, you can look out the windows which go in the top of the A on the front. It was a very nice house. The land is $20,000, so that house sells for $77,000, not including landscaping, fencing, or anything of that nature. It would be, I would consider, a nice cedar type home. Most of the lots in the area sell for $20,000 and the real estate man felt that $20,000 would be a good normal price that you could figure on for housing lots, whether a 7500 square foot lot or 15,000 square foot lot in Hilo. If you want a view lot, then it would be $30,000 to $40,000, depending on a number of different items. A house of 2000 square

feet is approximately $30 per square feet on top of that. Again, he did not feel there would be much difference between Waimea and Hilo, although land might be more expensive in the Waimea area.

Prior to meeting with these people, I met with Mr. Clarence Garcia with the Research and Development group of the county of Hawaii. I indicated to them the scope of our project, the approximate time frame, and solicited his comments on whether Hilo or Waimea would be a more appropriate spot for a downtown office. I described to him our method of operation and the way I felt that we would operate with a downtown office and an office that had the pressurized sleeping facility at the top of the mountain. His first reaction was that he would like to see it either in Hilo or Waimea. He felt that Hilo was more convenient today, although Waimea or at least the Kono area, is expanding more than the Hilo area. As of this time, the population in the Hilo area has declined relative to the population on the Island of Hawaii. As of July, 1975, there were 72,400 people on the island of Hawaii and only 28,000 in the Hilo area. In the past, there were 30,000 in the Hilo area, and that has remained fairly constant for a number of years. Most of the growth in the area has been in the outlying regions, particularly in Kona. From his standpoint as head of the advisors to the mayor and/or the county of Hawaii, he felt that our main concerns were to be sure that the people were kept informed of the scope of our project and the status of our project and be sure that the public relations was done in an effective manner such that all people heard exactly the same thing and it was told the way it is, rather than telling one person something and the story being slightly different to the next person. This is a small community and everybody soon finds out and compares notes with regards to what you have said. The second comment was that we should be very sure that the telescope is not in line of sight to Hilo or the

other communities. This is one of the strong concerns that people have. His particular concern was that he did not want to see the mountain loaded with telescopes, because he felt that in the future there were other types of endeavors which were also of equal importance, such as, for example, radio astronomy or solar energy experiments that might as well utilize the top of the mountain. He lives in Honokaa, which is right over near the Waimea area. For him it is a 45 minute drive around the beach to Hilo each day. He lives there because the weather is cooler and drier and he just happens to like it better. In building his home 2 1/2 years ago, he found that there is a vast difference on the cost of a 1453 square foot house. He had prices quoted of $62,000 versus $36,000 plus land. There were very significant differences in the prices which are quoted by contractors. By the right amount of shopping and working, he feels that the islands can be very competitive. He did verify that land in the Waimea area would likely be a little more expensive and recommended that we deal with Jim Whitman, who is business manager for the Parker Ranch. He felt that if Waimea were the site that was chosen, the Parker Ranch would be very receptive to putting together a package type deal for a building and even some lots for construction of houses or whatever we would want to consider. His feeling again, was that ocean view land in the Hilo area was at least $5 per square foot or generally for a nice size lot, $40,000 to $50,000. For an average subdivision type lot, probably $20,000, so he confirmed what was later told to me by the real estate people.

LIST OF SOME OF THE PEOPLE THAT I TALKED WITH ON THE HAWAII COST STUDY

Ginger Plasch - Assistant to Director at Institute for Astronomy - University of Hawaii

Dr. John Jefferies - Director of Institute for Astronomy - University of Hawaii

Robert La Porte - Business Manager, IAUH

Charles Fankboner - Contracts Manager, IAUH

John Wood - Engineer for IAUH - NASA Project

Al Grey - Engineer in Electronics, IAUH

Susan Cruikshank - Personnel Administrator, IAUH

Tom Kreiger - Mountain Superintendent, IAUH

George Abe - Manager Hawaii Island Chamber of Commerce

James H. Pedesen - Planner for Neighbor Island Consultants

Steve Birge - Senior Engineer for Neighbor Island Consultants

Herbert Matayoshi - Mayor of Hawaii

Clarence Garcia - Director of Department of Research and Development, County of Hawaii

Yoshio Kimura - Assistant Vice President for Territorial Savings

Jack Sims - Realtor for RSM, Inc.

Elroy T. Osorio - Realtor the The Land Company

Mat Mathiew - Production Manager Hilo Iron Works

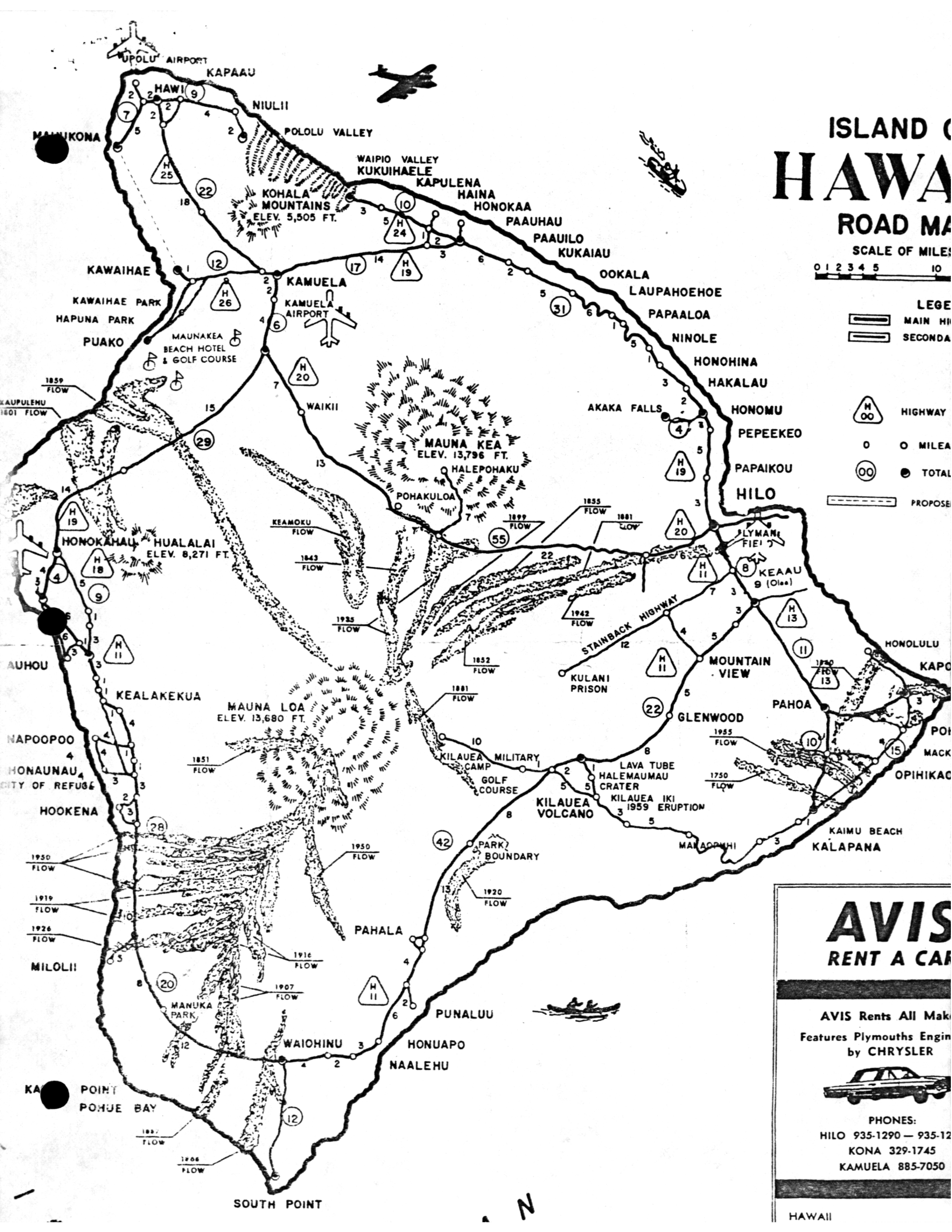
Dick White - Estimator and contractor for Bonneville Construction Company

Russel Drummond - Land sales for the Land Company

ANNUAL SALARY AVERAGES - INSTITUTE FOR ASTRONOMY

HIGH GRADE LEVEL TECHNICIAN	$16,000
LOW GRADE LEVEL TECHNICIAN	13,200
FRESH OUT OF TECH SCHOOL 20 YRS. OLD	12,000
HIGH QUALITY MACHINIST	15,000
NEW BSEE ENGINEER - 22 YRS. OLD	16,000
EXPERIENCED ENGINEER	19 - 25K
SENIOR ENGINEERS	25 - 35K
NEW PHD	16,000
PROGRAMMERS	15 - 19K
HIGH QUALITY SECRETARY	10,000
GENERAL TYPISTS	6 - 7 K
ACCOUNTING CLERKS	7 - 10K

NOTE - These are pre July 1976 salaries.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HAINA
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PAAUHAU
PAAUILO
KUKAIAU
OOKALA
LAUPAHOEHOE
PAPAALOA
NINOLE
HONOHINA
HAKALAU
AKAKA FALLS
HONOMU
PEPEEKEO
PAPAIKOU
HILO
KOHALA MOUNTAINS
ELEV. 5,505 FT.
KAWAIHAE
KAWAIHAE PARK
HAPUNA PARK
PUAKO
MAUNAKEA BEACH HOTEL & GOLF COURSE
KAMUELA
KAMUELA AIRPORT
WAIKII
MAUNA KEA
ELEV. 13,796 FT.
HALEPOHAKU
POHAKULOA
KAUPULEHU
1801 FLOW
1859 FLOW
KEAMOKU FLOW
1843 FLOW
1935 FLOW
1855 FLOW
1881 FLOW
1899 FLOW
HONOKAHAU
HUALALAI
ELEV. 8,271 FT.
KEAAU
9 (Olaa)
LYMAN FIELD
STAINBACK HIGHWAY
1942 FLOW
1852 FLOW
KULANI PRISON
MOUNTAIN VIEW
HONOLULU
KAPO
1750 FLOW
PAHOA
GLENWOOD
KEALAKEKUA
MAUNA LOA
ELEV. 13,680 FT.
1881 FLOW
1955 FLOW
1851 FLOW
KILAUEA MILITARY CAMP
GOLF COURSE
LAVA TUBE
HALEMAUMAU CRATER
KILAUEA IKI 1959 ERUPTION
KILAUEA VOLCANO
1750 FLOW
OPIHIKAO
NAPOOPOO
HONAUNAU
CITY OF REFUGE
HOOKENA
KAIMU BEACH
KALAPANA
MAILAPUHI
PARK BOUNDARY
1950 FLOW
1920 FLOW
1919 FLOW
1926 FLOW
PAHALA
MILOLII
1916 FLOW
1907 FLOW
MANUKA PARK
PUNALUU
WAIOHINU
HONUAPO
NAALEHU
KA POINT
POHUE BAY
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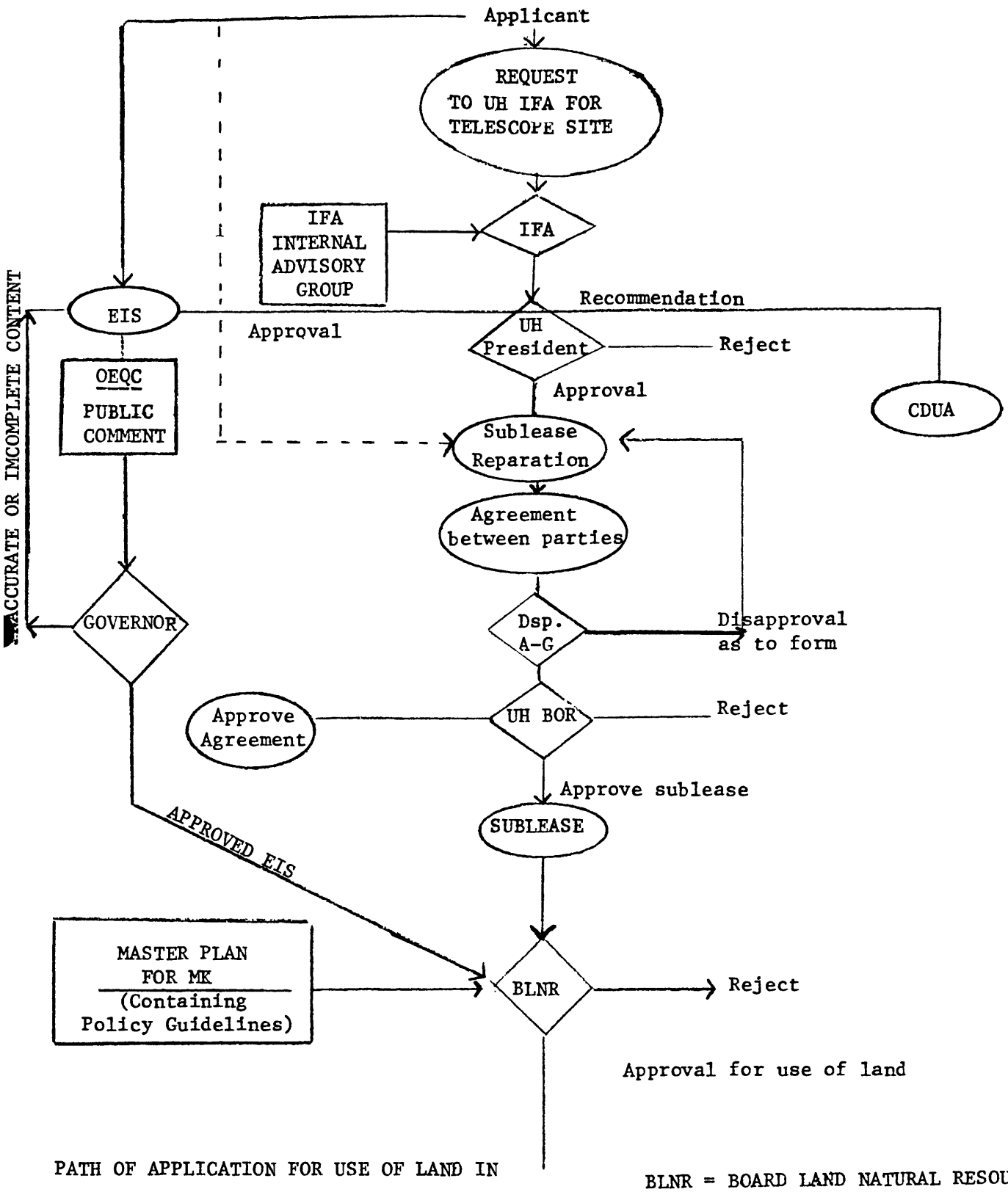
HILO 935-1290 — 935-12
KONA 329-1745
KAMUELA 885-7050
HAWAII



PATH OF APPLICATION FOR USE OF LAND IN THE MAUNA KEA SCIENCE RESERVE AREA

BLNR = BOARD LAND NATURAL RESOURCES
OEQC = OFFICE ENVIRONMENTAL QUALITY CONTROI
EIS = ENVIRONMENTAL IMPACT STATEMENT
CDUA=CONSERVATION DISTRICT USE AUTHORIZATIC

$$\delta_{lim} = h_{lim} + \phi - 90°.$$

The fraction of the sky which transits at altitudes $h \geq h_{lim}$ is

$$\Omega/4\pi = (1 - \sin \delta_{lim})/2$$

$$= [1 + \cos (h_{lim} + \phi)]/2$$

provided $\phi \geq h_{lim}$. The time which an object at declination δ spends above $h = h_{lim}$ is

$$T = 2 \arccos \left[\frac{\sin h_{lim} - \sin \phi \sin \delta}{\cos \phi \cos \delta} \right] .$$

Since it is reasonable to expect that much of the work to be done with the 25-meter telescope will involve objects near the galactic plane, it is useful to know how many degrees of the galactic equator rise above $h = h_{lim}$. This is given by

$$\Delta \ell = 2 \arccos [-\cos (h_{lim} + \phi)/\cos \delta_p]$$

where $\delta_p = 27\overset{\circ}{.}4$ in the declination of the north galactic pole.

We shall use the above formulae in Section V when comparing the sky coverage at Mauna Kea with that at Kitt Peak.

C. Logistic Factors

Atmospheric transparency and latitude directly influence the kind of astronomy that can be done. They are absolutes which cannot be improved by human effort. The quality of the astronomical work at a given site depends, however, on the efficiency with which the instrument is maintained and

operated. This in turn depends on what we call "logistic factors". The costs of construction and operation are other relevant logistic factors.

Unlike transparency and latitude, the logistic factors are a heterogeneous mix of practical matters which must be evaluated more by common sense than by "scientific" analysis. Taken together, they are nearly as important to the success of the instrument as the more objective site characteristics. They are a vital part of the body of factors which must be considered in making a balanced choice of site.

The most important of the logistic factors are the following:

(1) Accessibility.* A number of things fell in this category. First, a road to the telescope is necessary. The road must allow the passage of large trucks; it must be easy to maintain, particularly if snow is expected to occur frequently; and it must permit safe and fairly rapid travel. It would be most helpful if the site already has a reasonable road; otherwise we must supply one, which is likely to be a very large cost item.

Second, we do not expect the site staff to live next to the telescope. We intend to have offices and laboratories in a community where the staff could have their homes, as for our present Tucson facility. People will have to travel daily from this community to the telescope, and some unfortunates will be called out at odd hours to make emergency repairs. Thus the travel time from the community to the telescope must not be excessive. We regard 1-1/2 hours as a practical maximum.

Finally, the community itself should be reasonably accessible from the outside world. It is most desirable that it have regularly scheduled air service, including air freight.

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* We considered the possibility of easing the access problem by use of a television-telephone link from the telescope to the "downtown office". The idea was that such a link might make it unnecessary for the observer to be physically at the telescope, and that many service calls might be avoided by having an engineer instruct the telescope operator. It appears that, with the backups a fully reliable system would require, the link would be quite expensive. Since frequent trips would have to be made anyway, we feel that the link is not justified.

(2) Ease of staffing. Effective operation of the telescope requires a first-class resident engineering and technical staff. It will be hard to get and keep such people if they do not find the headquarters community an attractive place to live. Thus we must consider the availability of suitable housing (or building sites), the quality of schools and medical services, employment opportunities for spouses, the cost of living, and the cultural and recreational offerings of the community.

(3) Support services. There are a great many services that are needed for efficient operation which we would prefer to buy rather than provide ourselves. Examples are machine shops, electronic and electrical supply houses, computer maintenance, etc. It would be very helpful if they were available within a convenient distance. It would also be very helpful during the construction phase if certain contracting services (e.g., concrete batch plant, hauling firms, earth movers, crane rental) were available nearby.

(4) Electric power. We need a large amount of electric power, well regulated and with a high level of continuity. Since power lines are expensive, it will be a costly matter for us if we have to go a great distance to pick up adequate electrical service.

III. The Search for Sites

Since July 1976, we have reviewed the entire site question from scratch. The work done prior to the 25-meter proposal had concentrated on White Mountain in California, Mauna Kea in Hawaii, Mount Lemmon in Arizona, and the Pikes Peak area in Colorado. Except for Pikes Peak, we were guided largely by the infrared site search of Westphal (1974). We had made no attempt to identify and evaluate every possible site. And we still regarded low water vapor as much the most important site criterion.

Early in the present work, we assembled an extensive list of possible sites in the Southwest, which then were filtered with the following criteria:

(a) Latitude $\lesssim$ 37° N. This limit is arbitrary, but reasonable in view of the increasing difficulty of observing southern objects from more northerly latitudes. The mean level of cloudiness also tends to increase appreciably to the north of this limit (see Fig. 1).

(b) Longitude $\gtrsim$ 111° W. Again, this limit is somewhat arbitrary; it is the longitude of Tucson. It was regarded as reasonable because incursions of wet air from the Gulf of Mexico are quite frequent as far west as Tucson, but only rarely proceed west of the Colorado River (information from Dr. W. D. Sellers, climatologist at the University of Arizona, and from the Weather Bureau at the Tucson airport).

(c) Elevation $\geq$ 9000 feet. Sites below 9000 feet would be unlikely to have significantly better water vapor levels than Kitt Peak.

(d) Within 50 miles of a town of at least 5000 people. The travel time has to be excessive if this condition is not met.

(e) In the United States. Why go international if we don't have to?

In addition to the places admitted by these criteria, we retained White Mountain, Mount Lemmon, Cerro Gordo, and Kitt Peak as possible sites.

We believe that the choice for the 25-meter site lies between Mauna Kea and Kitt Peak. There are some very strong points in favor of each. These sites will be discussed in detail in Sections IV and V. In comparison with them, the other possible sites seem distinctly inferior when all of the relevant factors are considered. The remainder of the present section will describe the sites which were looked into and rejected.

Several of the localities which fit the criteria listed above are quite difficult of access, and for this reason were not given serious consideration. They include:

(a) The two highest points in the Sheep Range, some 30 miles north of Las Vegas. They are Hayford Peak (36° 39' N, 115° 12' W,

el. 9912 ft.) and Sheep Mountain (36° 35' N, 115° 15' W, el. 9720 ft.). These lie within the Desert National Wildlife Range, and the Forest Service told us that it would be very difficult to get permission to build a road, much less a telescope.

(b) Telescope Peak (36° 10' N, 117° 05' W, el. 11049 ft.) Within the Death Valley National Monument. It is 50 air miles from China Lake, and technically just meets the distance-to-civilization criterion. In fact it is quite inaccessible.

(c) Two mountains near Flagstaff, Arizona: Humphreys Peak (35° 21' N, 111° 41' W, el. 12633 ft.) and Kendrick Peak (35° 25' N, 111° 51' W, el. 10418 ft.). These get a lot of snow, and are distinctly more cloudy than most of the area under consideration (see Fig. 1). A shoulder of Humphreys Peak called Mount Agassiz was examined carefully by Kuiper (1970) as a possible infrared site.

(d) A number of peaks in the mountain ranges just north of the Los Angeles-Pomona-San Bernardino megalopolis. The likelihood of severe earthquakes is very high, since these mountains are bounded by the San Andreas Fault and other active fault lines. The peaks over 9000 feet are:

1. Sugarloaf Mtn. (34° 12' N, 116° 48' W, el. 9952 ft.).
2. (unnamed on our maps) (34° 12' N, 116° 43' W, el. 9113 ft.).
3. Mt. San Antonio (34° 18' N, 117° 39' W, el. 10064 ft.).
4. Mt. Baden-Powell (34° 22' N, 117° 46' W, el. 9399 ft.).
5. Two peaks in the San Gorgonio Wilderness Area, and hence off-limits anyway: San Gorgonio Mtn. (34° 06' N, 116° 50' W, el. 11502 ft.) and Anderson Peak (34° 08' N, 116° 55' W, el. 10864 ft.).

Bill Williams Mountain (35° 12' N, 112° 12' W, el. 9256 ft.) is about 30 miles west of Flagstaff, and there is a nice road right to the top--

because there is a fine collection of transmitters up there. It also is in a relatively cloudy area.

San Jacinto Mountain (33° 48' N, 116° 41 W, el. 10831 ft.) is an isolated peak 8 miles west of Palm Springs, California. There is a tramway to the summit area from a terminal a few miles north of Palm Springs. The high ground, however, is taken already by a State Park and two Wilderness areas. The seismic hazard in this area is high.

The sites discussed so far were dropped without much pain. We turn now to sites which were examined much more carefully before they were rejected.

White Mountain was considered thoroughly in the earlier work. We dropped it because of seemingly insurmountable problems of access. After the submission of the 25-meter proposal, Dave Cudaback of Berkeley made an heroic effort to find a new route to the top from the Bishop area which would afford the speed and reliability we require. He found one that he regards as hopeful. Several of us looked it over in July, and we found ourselves unable to share Cudaback's optimism, in regard to either the all-weather serviceability of the route or its cost. In order to get an engineer's opinion, Bill Horne was asked to examine the route. He believes that development of Cudaback's route would cost upward of $1M, and that further study would likely show the route to be impractical anyway because much of it lies on loose slopes which are highly susceptible to rock slides. There still seems to be no practicable way to make White Mountain suitable for our requirements at a reasonable cost.

Mount Lemmon (32° 27' N, 110° 47' W, el. 9157 ft.) is a very enticing site because it offers easy logistics and, apparently, quite good sky conditions. The problem is the forest of radio transmitters on Radio Ridge, just outside the astronomical area at the summit. Measurements show (Memo No. 54) that these transmitters would not seriously affect receivers of the kind now being used on the 36-foot telescope. Unfortunately, we could not control the facilities which might be added to Radio Ridge in the future, and

we don't know what kind of receivers might be required a few years from now. Moreover, there certainly will be loud political repercussions from some of our colleagues if we put the instrument in such a "rich" radio-frequency environment. It might be possible to soften the flap if we could find a reasonable spot on the mountain where intervening terrain provides shielding from the transmitters. We did in fact find several such places above the 9000-foot level. Unfortunately, only one of these has any chance of being accepted by the Forest Service (they all lie outside the area which has been reserved for astronomical facilities), because the others are important recreational areas for Tucson. It is on the north side of the summit where the mountain would block the lower 20° of the southern quarter of the sky. This is unacceptable on astronomical grounds. There simply is no good way to keep Mount Lemmon in the list.

The only really interesting new possibility which was turned up by the map search described earlier is the Charleston Peak area in the Spring Mountains, about 30 miles west of Las Vegas. Charleston Peak (11918 ft.) is the highest point on a horseshoe-shaped ridge which extends for some miles. Most of the ridge is above 10000 ft., and it exceeds 11000 ft. in several places. All of the high ground is within the Toiyabe National Forest. Two of us visited it in September. We learned from the Forest Service that all of the high ground except the southernmost part is being run as a Wilderness Area (although for administrative reasons it has not officially been designated as such). The only area where they might possibly accept a proposal for telescope construction is on Harris Mountain (36°10' N, 115° 37' W, el. 10018 ft.). The accessibility of this, and indeed of the entire summit ridge, is poor. There is a one-lane dirt road which ends half a mile from the summit of Harris Mountain, and 1600 feet below it. The mountain is steep from the road terminus upward, and the surface is very loose and prone to sliding. We found it hard to traverse even on foot. It would be expensive and probably difficult to upgrade the existing road and extend it to the summit. There is no alternative route, owing to the topography. Access would be a

major problem in developing this site, and it is principally for this reason that we dropped it. Another point against it is its direct line of sight to a large Air Force radar base on Angel Peak, less than 6 miles to the north.

We gave careful attention to another site which seemed quite promising. This is Cerro Gordo (36° 32' N, 117° 47' W, el. 9180 ft.). Cerro Gordo is the most accessible high point in the Inyo Mountain chain. It is near the southern end of the range, a few miles east of Owens Lake, in the "darkest" part of the rain shadow of the Sierra Nevada mountains to the west The Aerospace Corporation owns over 200 acres of ground near the summit. They have made infrared hygrometer measurements which indicate that the water vapor level is low.* There is very little cloud, because of the shielding by the Sierra Nevada range. Although the data are sparse, there is every reason to believe that it is an exceptionally dry and clear site. There are really three separate peaks. Cerro Gordo proper is a narrow, rocky ridge which doesn't look very enticing as a building site. Half a mile south there is a nice round hill, of about the same height as Cerro Gordo, which has a radio repeater used by the Inyo County sheriff's department. Because of this, there is a passable and reasonably well maintained road. A third peak of about the same elevation, 1-1/2 miles to the northwest, might be the best potential site of them all. It, too, has a road to the top because the Air Force operated a radar on it until a few years ago. Despite the good qualities of Cerro Gordo, however, we do not feel that it is likely to be greatly superior to Kitt Peak since its better atmosphere would be bought at the price of 4-1/2 degrees of latitude. Its astronomical merits are not enough to compensate for its remoteness from any support facilities and from a community which could readily accommodate our staff. It is about 80 miles from the Ridgecrest-China Lake area to the south or the Bishop-Big Pine area to the north.

Various people have suggested that we consider Sacramento Peak (32° 47' N, 105° 49' W, el. 9222 ft.) or South Baldy (33° 59' N, 107° 11' W, el. 10783 ft.). These are in New Mexico, and South Baldy lies between Socorro

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* The measurements give a mean W_V of 2.2 mm for the non-summer months, which is comparable with Mauna Kea (private communication from Eugene Epstein). The mean summer value is 8.0 mm.

and the VLA. All of New Mexico, however, is subject to frequent incursions of wet air from the Gulf of Mexico, especially during the spring and summer months (Gringorten et al. 1966). Water vapor levels will be higher on the average than for comparable sites farther to the west. The cloud frequency, on the other hand, probably is not greatly different from that at Kitt Peak (see Fig. 1 and Beckers 1976).

IV. The Serious Contenders

We believe that the only really serious candidates for the 25-meter telescope site are Mauna Kea and Kitt Peak. We shall discuss Mauna Kea in considerably more detail than Kitt Peak, since Kitt Peak is already well known to all of the Working Group.

A. Mauna Kea

The excellence of the night sky above Mauna Kea and its remoteness from city lights and industrial pollution make it a superb site for an optical observatory. The Institute for Astronomy of the University of Hawaii has operated an 88-inch telescope for Mauna Kea since 1970. There are also two 24-inch telescopes. The 140-inch Canada-France-Hawaii telescope is nearing completion. Construction has started on two large infrared telescopes: the NASA 120-inch and the United Kingdom 155-inch. Mauna Kea is becoming a major international astronomical center.

Mauna Kea is the highest of the five large volcanoes which have coalesced to form the island of Hawaii. It is dormant, and perhaps extinct; the geological evidence indicates that the last eruption took place between 2000 and 4000 years ago (Macdonald and Abbott 1970). As for the other volcanoes, Kohala has long been extinct, Hualalai last erupted in 1801, while Mauna Loa and Kilauea have erupted frequently since 1800.

Some of the relevant features of the island of Hawaii are shown in Fig. 2. The positions and elevations of the volcanoes are indicated. The locations of major towns and the principal roads are shown also. To the northwest are part of the island of Maui and the uninhabited island of Kahoolawe. Red Hill on Maui is a good transmitter location for the pattern range discussed in Memo No. 42.

Figure 3 shows the south slope of Mauna Kea from the Humuula Saddle (where it meets the north slope of Mauna Loa) to the summit. The Saddle Road connects Hilo and Waimea. The road distances from the Mauna Kea turnoff are 28 miles to Hilo and 32 miles to Waimea. The distances from the turnoff to Hale Pohaku and to the proposed site for the 25-meter telescope are respectively 6 and 14 miles. Hale Pohaku, originally a ranger station, is a modest collection of mostly temporary buildings which serve as a mid-level base for the observatories and for the contractors working at the summit. The present facilities are minimal. The summit area, including all of the ground above 12000 feet, is in a dedicated "Science Reserve" administered by the University of Hawaii under a long-term lease from the State. The road up the mountain is quite good. It is paved as far as Hale Pohaku. It is in effect graded cinder from there to the top, since the light paving put down early last year soon broke up under the heavy truck traffic.

The summit is shown in Fig. 4, which includes an area of about 4 square miles. A circled cross marks what we believe to be the best location for the 25-meter telescope. The optical telescopes are all on the crescent-shaped summit ridge, which consists of several coalesced cinder cones. To the left is Puu Poliahu, which we earlier had thought to be a good place for the telescope. The road to its top was made for Kuiper's original site tests in 1963. The beautifully symmetrical cone at the bottom of the map is Puu Hau Kea (also called Goodrich Cone), which is off limits for development.

The site we have chosen as best for the 25-meter telescope lies on the 13400 ft. contour. Its geographic coordinates are:

latitude: 19 ° 49' 37" N

longitude: 155° 28' 48" W

The primary reason for this location is that the summit ridge gives it considerable protection from the prevailing tradewinds, which come from northeast to east. This should allow more observing time with the dome open. The location has important subsidiary advantages as well:

(1) The dome should be invisible from every inhabited part of island. The importance of this is discussed later.

(2) There is no serious sky blockage by the terrain. The highest horizon, at elevation 9°, is to the northeast. Puu Poliahu to the

(2) There is no serious sky blockage by the terrain. The highest horizon, at elevation 9°, is to the northeast. Puu Poliahu to the southwest rises less than 8°. The southern horizon is perfectly clear (the site is about level with the top of Puu Hau Kea).

(3) An existing road, which would need little improvement, passes within 300 feet.

(4) Although the ground is covered by loose cinder, it probably is underlain at shallow depth by the massive lava flows which outcrop nearby. Test boring will show whether this is the case, and if so whether the lava has sufficient thickness and strength to carry the foundations. The foundations otherwise must be designed to "float" in the cinder, like those for the optical telescopes.

(5) The site is well removed from other activity on the mountain, existing or proposed.

(6) There is a clear line of sight to Red Hill on Maui, 128 km away (see Memo No. 42, dealing with the pattern range).

(7) There is no need for a steep stretch in the access road, as there would be were we to put the telescope on Puu Poliahu or the summit ridge. Thus the access is less subject to interference from snow. The summit ridge is unreachable for several days each winter because of heavy snow on the steep final section of the road.

The Director of the Institute for Astronomy, John Jefferies, has assured us verbally that this location would be acceptable to the University of Hawaii.

The cloud cover on Mauna Kea has a dominant diurnal component and a much weaker seasonal component. We are concerned with water clouds, not cirrus. This is helpful, since over half of the time lost to clouds by optical and infrared observers on Mauna Kea is due to cirrus. The most serious cloud problem for us is the regular afternoon buildup. To quote from Morrison et al. (1973):

> Mauna Kea rises well above the normal tradewind inversion layer, which is at about 2500 m altitude. This inversion usually breaks up in late morning, and approximately two-

> thirds of all afternoons are cloudy, largely as a result of orographic buildup. Near sunset rapid cooling generates strong downslope winds that move the clouds and moist air down the mountainside, maintaining dry, cool air over the summit until late morning, when the upslope winds begin again.

Most afternoons therefore will be of little use for millimeter observations.

The night-time cloudiness is a quite different matter. Through the courtesy of John Jefferies, we have been given copies of the monthly time-lost reports for 31 consecutive months (March 1974 through September 1976). These show that night-time observers lost an average of 41 hours per month (out of an average of 360 scheduled) to cirrus, and 30 hours per month to other clouds or fog. The latter component shows an appreciable seasonal variation--an average of 16 hours per month during May to October, and an average of 46 hours per month during November to April.

It appears therefore that while most afternoons would be lost to us, clear weather could be expected for about 90 percent of the remaining time since night sky conditions tend to persist until late morning.

The precipitable water vapor above Mauna Kea certainly is low, as one would expect for such a high site. Just how low, unfortunately, is rather uncertain. On the basis of mean radiosonde data, Kuiper (1970) estimated values of the 5 and 50 percentile levels of W_v for a large number of places, including Mauna Kea and Kitt Peak. For Mauna Kea, the median value through the year (there is little seasonal difference) is 1.9 mm*. Daytime

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* Kuiper's figures are based on data from Gringorten et al. (1966), which in turn rests on radiosonde measurements during 1962-1966 inclusive. We have analyzed monthly mean radiosonde data from Hilo for the 1966-1971 period. We find a 12-month mean value of 2.2 mm for W_v at the level of Mauna Kea. This is perfectly consistent with Kuiper's median of 1.9 mm. We also agree with Kuiper that there is little seasonal variation of W_v.

measurements with Westphal's infrared hygrometer during the year ending 1 July 1972 gave a median of 1.2 mm and a 25th percentile of 0.7 mm (corrected to ambient pressure).* Night-time 8-25 micron spectral measurements of the moon and Mars, during July to September 1971, are best matched by synthetic spectra calculated for W_v = 0.5 mm (see Morrison et al. 1973). Dyck and Simon (1975) measured an average W_v of 0.5 mm at 33 microns, and they state that a lower value would be expected on about 25 percent of the photometrically clear nights. There is of course a tendency for all of these values except Kuiper's to be biased toward better than average conditions because they follow from measurements which necessarily were made in good weather.

There are two communities where we might reasonably put the observatory offices and laboratory. The most obvious is Hilo, the largest city on the island (population 26353 in the 1970 census). Hilo has direct air service from the mainland as well as Honolulu and other places in the islands. It has most of the "urban amenities" to be found on the island. It is one of the two places with port facilities (the other is Kawaihae, on the west side of the island). It probably could absorb 35 new families without great strain. Unfortunately, it has a very wet climate (average annual rainfall is 137 inches) which few mainlanders would like.

The other possibility is Waimea (also called Kamuela), in the saddle between Mauna Kea and Kohala. It is a small community of a few hundred people. The headquarters of the Parker Ranch, which owns much of the northern part of the island, are located here. We understand that the headquarters of the Canada-France-Hawaii telescope will probably be put in Waimea. Waimea is 2700 feet above sea level and has a much less rainy climate than Hilo. The surrounding country is rolling grassland with plenty of big trees, reminiscent of parts of northern Arizona. It is about 15 miles by road to the

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* These numbers are taken from Morrison et al. (1973), who give a detailed histogram of the values of W_v measured by Westphal (1974). Using the data from the same Westphal report, we get a much broader histogram and a corrected median W_v of 2.6 mm. We have no explanation for the discrepancy.

Kona coast, where the island's best beaches are. Inter-island air service is available at Kamuela airport, about 2 miles south of town. Waimea may not be "urban" enough, however, to suit the majority of our staff. It is 60 miles by road to Hilo, where the main shopping and medical facilities* on the island are located. It is nearly 40 miles to Kailua, which probably will rival Hilo in a few years. Not many houses are available, although plenty of homesites are to be had.

The travel time to the Mauna Kea summit is about 1-1/2 hours from either Waimea or Hilo in good weather, if no acclimatization stop is made at Hale Pohaku.

Dale Webb and his wife visited the island last year. His informal report of the trip is appended as Attachment 1. It covers many of the human factors to be considered in the site selection, and it shows pretty well how a typical mainland employee is likely to react to what he finds in Hawaii.

There has been a great deal of vociferous opposition by island residents to further development on Mauna Kea. It has been loudest from two parties: the local chapter of the Audubon Society and the sheep hunters. Both groups are small but vocal. Both claim to be concerned about the "environment", although one might doubt that they agree on what is meant by the term. They have had some support from a larger body of people who are uneasy about further development for more diffuse reasons. Many, for example, are understandably disturbed by the high visibility of the domes on Mauna Kea. We certainly are heading off a lot of opposition by putting our instrument where it cannot be seen from below. There are other people who are uneasy about change in general--anything new is suspect, especially if it is imported from the mainland. The main tangible result of the opposition, and it is an important one, is that a Master Plan is being developed by the State which will define the course of future development on Mauna Kea. This has been in

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* The general hospital nearest to Waimea is in Honokaa, about 15 miles away. There is a new medical center with several physicians in Waimea.

the making for nearly three years. The hope is that it will be adopted in final form by the end of January, 1977. We do not yet know what it will have to say about future development. The opponents hope it will end development; the Institute for Astronomy hopes that it will only require that new instruments be strongly justified, without a precise numerical limit. At this writing, it is quite possible that the Master Plan will prevent our going to Mauna Kea. In such a case it makes the site decision for us.

Two of us (Gordon and Wade) went to Hawaii in December. We talked to a great many people, including some who strongly oppose new development on Mauna Kea. We found that there are also a lot of people who might welcome our coming. We were careful to make sure that everyone heard exactly the same story from us. The main points we made are these:

(a) We have not selected a site yet, but the particular advantages of Mauna Kea make it a strong contender among the several sites under consideration.

(b) Our instrument will be invisible from Hilo and the heavily populated coastal area north to Honokaa, and probably from all other inhabited parts of the island as well.

(c) The project is not yet funded, and probably it will not be before 1980.

(d) The capital cost will be $18M - $20M, and construction will take about a year.

(e) The annual operating budget is expected to be about $1.8M. About half of this would be spent on the island.

(f) Most of the resident staff of about 35 will have to be imported from the mainland. There will not be many jobs for present residents of the island.

(g) The headquarters for our operation will be on the island, not in Honolulu.

By emphasizing these points, we hoped to discourage unrealistic fears or hopes about what our telescope would mean to the island. We came away with the impression that our instrument could be put on Mauna Kea without serious public opposition if we handle our public relations wisely. In making clear the points listed above, we have taken the first step toward gaining public acceptance.

B. Kitt Peak

The discussion of Kitt Peak will be short, since it is well known to all of the Working Group.

The preferred location for the 25-meter telescope is the present picnic area near the 36-foot telescope. It is easily accessible, and there is enough relatively flat ground. The elevation and geographic coordinates are very nearly those of the 36-footer (6300 ft.; 31° 57' 11" N, 111° 36' 51" W). Other usable locations may exist, but we have made no effort to find them.

In our experience with the 36-footer, rather little time has been lost to clouds. The tabulation below gives the average time lost because of clouds during 1970-75:

January	45^h	July	54^h
February	39^h	August	(shut down)
March	87^h	September	66^h
April	24^h	October	75^h
May	9^h	November	21^h
June	12^h	December	42^h

The average is 43 hours per month. Assuming that 700 hours per month are scheduled, this implies a loss of about 6 percent to clouds (ignoring the worst month, August, which is devoted to the annual maintenance shutdown). Such a low rate, taken at face value, would indicate that clouds are a negligible problem at Kitt Peak. This is not a safe conclusion. The above tabulation includes only the times when conditions were so bad that the observer

gave up and suspended observing. Furthermore, most of the time during 1970-75 was devoted to spectral line work, which is less sensitive to clouds than continuum observations. Therefore the cloud problem must in fact be worse at Kitt Peak than the tabulation suggests, but how much worse we cannot say. It seems reasonable to assume that conditions are good for about 85 to 90 percent of the time (excluding August).

We have two sources of information on the amount of water vapor over Kitt Peak. Both refer to the summit, which is about 600 feet higher than the 36-foot telescope. Kuiper (1970), using five-year mean radiosonde data, finds a median value of 5.1 mm for W_v during the 9 best months (September to May inclusive). Direct measurements with an infrared hygrometer during October 1971 to May 1972 (Westphal 1974) give a median W_v = 3.0 mm (corrected to ambient pressure).

The discrepancy between Kuiper and Westphal is about the same for Kitt Peak as for Mauna Kea. There are three possible causes which together might account for the difference:

(1) Radiosondes do not respond to humidities under 10 to 25 percent, depending on temperature. When the humidity was below the detection limit, it was supplied by assumption; specifically, it was assumed to be at the detection threshold when in fact it could equally well have any lower value. This would result in a systematic over-estimate of W_v by Kuiper.

(2) Westphal's data were gathered only in clear weather, which would bias his median W_v toward artificially low values.

(3) It is possible that the Westphal measurements were made during a dryer than average year. The Kuiper values are 5-year averages which should be less susceptible to the peculiarities of particular years.

These remarks apply equally to the data for Kitt Peak and Mauna Kea. The conservative approach is to use the Kuiper values in comparing these two sites,

even though they may tend to overstate the amount of water vapor. One would like to do better, but it is not clear how one can, given the data we have. At least the Kuiper material should have similar deficiencies for both sites, and to this extent provide a valid basis for comparison. We have not felt, however, that the data warrant correcting Kuiper's summit values of W_v to the 6300 foot elevation of the 36-foot telescope. This would mean increasing them by about 10 percent, which probably is well within the noise.

V. Discussion: Comparison of Mauna Kea and Kitt Peak

As stated earlier, we believe that the site choice lies between Kitt Peak and Mauna Kea. Each offers notable advantages, but in very different ways--Mauna Kea is superior on purely astronomical grounds, while on Kitt Peak we could operate more easily and probably more efficiently. The question is simply: Are the astronomical advantages of Mauna Kea worth the greater expense and difficulty of operating there?

Table 1 lists a number of latitude-dependent geometrical quantities for Kitt Peak and Mauna Kea. They are computed from the formulae given in Section II.B. It assumed that observations are restricted to altitudes above 15°, which corresponds to a signal path of about 4 air masses in the atmosphere. The 12°.2 latitude advantage of Mauna Kea translates directly into a 12°.2 more southerly limiting declination. The solid angle about the south pole which is unobservable is nearly twice as great at Kitt Peak as at Mauna Kea. The galactic center spends 27 percent more time above 15° at Mauna Kea than at Kitt Peak*. The unobservable portion of the Milky Way is 80° at Kitt Peak, 45° at Mauna Kea. Centaurus A, the nearest "radio galaxy", is above 15° for nearly 6 hours each day, while it is never above 15° at Kitt Peak. In general, Mauna Kea is advantageous for observing objects south of the equator, since they spend more time above the limiting elevation and culminate nearer the

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* Mauna Kea has the further advantage that the galactic center transits at night during the most cloud-free months of the year. The opposite is true at Kitt Peak.

zenith. There is little net difference between the sites for objects in the northern half of the sky.

Kitt Peak is probably superior insofar as the incidence of water clouds is concerned. Assuming that 6 hours are lost every afternoon at Mauna Kea, with 90 percent of the remaining hours clear, one can estimate that there should be about 5900 hours of clear weather each year. At Kitt Peak, if 85 to 90 percent of all time is clear except for August, which is lost entirely, we should expect to have about 6800 to 7200 hours clear each year. Roughly 400 hours per year would be lost at Kitt Peak for routine weekly maintenance, whereas on Mauna Kea one would schedule maintenance in the afternoon hours which are lost to observing anyway. Even so, we can expect to have appreciably more service out of the telescope, in terms of observing hours free of water clouds, on Kitt Peak than on Mauna Kea.

Consider now the transparency of the atmosphere during clear weather, which depends mainly on the precipitable water vapor. In this discussion, we shall use the median values from Kuiper's (1970) report: W_v = 1.9 mm for Mauna Kea, W_v = 5.1 mm for Kitt Peak. We note in passing that the 5-percentile value for Kitt Peak, 1.9 mm, is the same as the median for Mauna Kea. The median optical depths at the zenith are given in Table 2, for the six windows of interest. They have been computed with the formulae and numerical coefficients given in Memo No. 64. The reader may find it helpful to refer to the graphs in that report. The absorption by molecular oxygen has been included. One can see that the median optical depths are 2 to 3 times greater at Kitt Peak than at Mauna Kea. The optical depths from Table 2 have been used to calculate the median transmission of the atmosphere at the zenith and at elevations of 30° and 15°. The results are given in Tables 3, 4, and 5.

At frequencies below 100 GHz, the transparency is high at both sites and Kitt Peak suffers little in comparison with Mauna Kea. At 150 GHz Mauna Kea is noticeably better than Kitt Peak, particularly at low elevations.

Mauna Kea is distinctly superior at 230 GHz. Under median conditions, observations at 345 GHz would suffer so severely at Kitt Peak as to be almost useless, whereas they would be quite feasible at Mauna Kea. This brings up a question which needs thorough discussion: How much emphasis should we place on observing at 345 GHz, a frequency above the design limit of the telescope? If we think it is not very important, then the superiority of the transparency at Mauna Kea is fairly moderate in terms of practical observing. If we believe that observations at 345 GHz are likely to be of great scientific value despite the limitations of the telescope, the superiority of Mauna Kea is crucial.

We turn now to the logistical side of the problem. Mauna Kea and Kitt Peak both meet our requirements in a number of important ways, although not always equally well:

(1) There are adequate roads to both sites. In the case of Kitt Peak, the roads are excellent.

(2) The travel time is acceptable. In the case of Kitt Peak, it is very good, only one hour being needed to drive from our Tucson office to the telescope. The driving time to Mauna Kea from either Hilo or Waimea is 1-1/2 hours in good weather, without an acclimatization stop of 20 to 30 minutes at Hale Pohaku (which the Institute for Astronomy people feel is important). Most of the route is not safe for high-speed travel, especially at night.

(3) Adequate electric power is available at Kitt Peak, and soon will be at Mauna Kea.

(4) Either site would be shared with other major observatories. This can be helpful in areas where cooperation is feasible: transportation, libraries, road maintenance, some shop facilities, etc. The help we receive on Kitt Peak, however, is much superior to what can be foreseen on Mauna Kea. KPNO is so well equipped and staffed that they would be hard to match in these areas.

(5) Each is in an area set aside for astronomy, which provides some protection against unwelcome activities nearby.

We know that Tucson is an excellent base for operation. It has most of the services we need, it has a fine climate, it satisfies most of our staff as a place to live. Hawaii compares rather unfavorably with Tucson in several ways:

(1) The remoteness of the island from the rest of the country will cause problems, simply because of the time and expense required for travel and the delivery of needed items. It probably will force our operation to be quite a bit more self-contained than it would be on the mainland. The isolation might also be an important source of employee discontent.

(2) It will be necessary to go to Honolulu, 200 miles away, for many of the industrial and supply services that are readily available in Tucson.

(3) Tucson has a much larger pool of highly qualified technical people to draw on when new hiring is to be done. Most of the people in the State of Hawaii whom we might consider hiring are in the Honolulu area, not the island of Hawaii.

We expect that it will be harder to assemble and keep a first-class engineering and technical staff in Hawaii than in Tucson. Among the reasons are:

(1) The island cannot compete with Tucson in the range of medical services, the quality of housing at a given price, the cost of living, or employment opportunities for spouses.

(2) The island schools probably are not as good as those of Tucson, although the people we talked to differ widely in their opinion of Hawaiian public schools. There are excellent private schools.

(3) Families coming from the mainland may have difficulty adjusting to the predominantly oriental culture of the island.

(4) Many people may find island life painfully confining.

We will need some pretty creative personnel policies if we are to keep a good staff in Hawaii. Certainly the idea of moving to Hawaii is not popular with our present Tucson staff.

Two other points should be noted, although they are not critical to the choice of site:

(1) Because of the high altitude, it will probably be necessary to pressurize some or all of the working spaces on Mauna Kea.

(2) Kitt Peak is tectonically stable, and it is solid granite. Hence foundation design will be simpler than for Mauna Kea, which is subject to moderate earthquakes, and where the foundations would rest on cinder and/or lava sheets.

Before making the final choice of site, we should get the response of prospective users of the telescope to the following questions:

(1) How important is the better coverage of the southern sky at Mauna Kea?

(2) How important is it to be able to observe regularly at 345 GHz?

There is no consensus among our own staff on these matters. We expect none among the outside users either, but their remarks should be illuminating.

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Table 1 - Latitude-Dependent Geometrical Parameters*

Quantity	Kitt Peak	Mauna Kea
Limiting declination, δ_{lim}	-43°.2	-55°.2
Fraction of sky, $\Omega/4\pi$	0.84	0.91
Obs. time for galactic center, T	$6^h.2$	$7^h.9$
Obs. time for Centaurus A, T	0	$5^h.9$
Range of galactic equator, $\Delta\ell$	280°	315°

* Computed for a minimum observing altitude $h_{lim} = 15°$

Table 2 - Median Optical Depth at the Zenith

Frequency	Kitt Peak	Mauna Kea
22.2 GHz	0.040	0.017
31.4 "	0.027	0.015
90.0 "	0.088	0.041
150 "	0.173	0.066
230 "	0.342	0.127
345 "	1.020	0.380

Table 3 - Median Transmission at the Zenith

Frequency	Kitt Peak	Mauna Kea
22.2 GHz	96%	98%
31.4 "	97	99
90.0 "	92	96
150 "	84	94
230 "	71	88
345 "	36	68

Table 4 - Median Transmission at h = 30°

Frequency	Kitt Peak	Mauna Kea
22.2 GHz	92%	97%
31.4 "	95	97
90.0 "	84	92
150 "	71	88
230 "	50	78
345 "	13	47

Table 5 - Median Transmission at h = 15°

Frequency	Kitt Peak	Mauna Kea
22.2 GHz	86%	94%
31.4 "	90	94
90.0 "	71	85
150 "	51	77
230 "	27	61
345 "	2	23