Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

February 11, 1981

25 METER MILLIMETER WAVE TELESCOPE
MEMO No. 140

To: W. G. Horne

From: M. A. Gordon

Subject: Wind Measurements on Mauna Kea

My conversation with you, together with the very thorough memorandum of January 30 written by Sebastian, has cleared my concerns regarding wind measurements on Mauna Kea. Here's how I understand the situation

1. Jesse Davis.

   Jesse Davis has searched for commercially-available anemometers and masts. He will prepare a purchase order for the lower cost tower using guy wires. He will also approach Weathertronics to ask about programming their recorder to record wind velocity at 30-sec intervals for a small fraction of each hour, say 5 minutes. This small duty cycle is necessary to avoid changing the recorder more than once a day. I presume that such sampling should not hurt us very much.

2. Tom Krieger.

   Because of the sensitive problems involved with erecting structures in the summit area of Mauna Kea, Tom has agreed to erect our masts as part of his duties as director of Mauna Kea Support Services of the University of Hawaii. As I understand it, the tower base must be fabricated to appear portable. Permanent installations on Mauna Kea are prohibited without specific authorization from the Department of Land and Natural Resources. Tom will bill us for services rendered.

3. David Crawford.

   As astronomer in charge of KPNO's program to measure atmospheric conditions at Mauna Kea, Dave has kindly agreed to service the recorder in place at our site on Mauna Kea. In return, KPNO will have complete access to all of our results.

Attachments: Memo by W.G. Horne 3/9/81
Memo by S. von Hoerner 1/30/81
Memo by M. Gordon 1/13/81
Memo by Jesse Davis 9/26/80

4. Bill Horne

Because of your role as Project Manager, this entire plan is subject to your approval. Please let me know if these arrangements are acceptable to you.

c: David Crawford
Jesse Davis
Thomas Krieger
Gilbert Peery
Sebastian von Hoerner
Woon Yin Wong

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March 9, 1981

To: Mark Gordon
Jesse Davis

From: W. G. Horne

Subject: Wind Instruments and Tower for Mauna Kea

I have read the proposals for wind and temperature recording instruments submitted by Weathertronics and Climatronics and as Jesse recommends it seems that the Weathertronics data gathering system is best suited for our purpose. I am not sure that I fully understand how the data handling system works, but as I understand it the data acquisition system could be programmed to output to the cassette at intervals of one hour the one hour average of the data collected (temp., wind speed, wind direction) as well as the peak occuring during that period. If my understanding is correct and the cassette has the capability of recording this amount of data for a reasonable period of time then this system will be quite adequate. If however the operation is as indicated in Mark Gordon's memo of February 11 in which it appears that wind velocity will only be measured and recorded for 5 minutes out of each hour then I'm afraid that a lot of significant data will be missed and the usefulness of the data is questionable.

I agree that a time constant of 1 minute is probably satisfactory though I am not sure that since the scan time of the weathertronics sensor is one minute that is the time constant of the sensor. It might be smaller. Incidentally what is meant by "distance constant" equal to 14 feet shwon in the specifications for the "Stratavane" wind sensor? I think this really determines the time constant of integration in the sensor and if so the time constant for this instrument is around 20 seconds.

I looked over the proposals for supporting towers and am not impressed by the tower proposals from any of the firms. I don't think any of them really did any engineering analysis based on the parameters that Jesse set forth. Jesse very clearly states that the location is 14,000 feet high, wind velocity is 125 MPH and that an ice build-up of 2 foot thickness on corners and slender columns can occur. I note that Rohn quoted a tower designed for 125 MPH winds with 2" of radial ice per EIA RS-222C and that Tri-Ex doesn't state their design conditions. I think both companies just plain ignored Jesse's specifications.

I did my own rough analysis for the towers proposed by the two companies and none of them are satisfactory for the conditions set forth. I am sending Jesse a copy of my analysis but he must be warned that this is not a complete design or analysis by any means. It just answers the questions as to whether the proposed towers are strong enough, what size and shape of guyed towed would be approximately adequate, and could we get away with a temporary foundation if we guy the tower.

Since I'm being disagreeable I might as well point out that in my analysis I have not agreed with the Design Guide Lines set forth for the Mauna Kea Science Reserve either and have used my own. For example the guide lines state that the ice build-up has occasionally reached a thickness of 2 feet on corners and slender columns. This is a rather vague statement since it doesn't make clear whether this is the thickness of the ice coating the column or the thickness of the coated column. For a pipe column 3 inches in diameter this could mean the difference between a coated column 2 feet in diameter and one 4.25 feet in diameter. I have chosen to use 6 inch radial thickness of ice in my analysis.

The guide lines also state that wind velocity used should be 125 MPH with a wind pressure of 55 psf which might be alright for sea level but certainly not for an elevation of 14,000 feet. The dynamic wind pressure used in analysis is a function of air density and velocity and is expressed as $q = \rho \frac{V^2}{2}$ where ρ = density lb/ft^3
V=Velocity fps, with the density at sea level, 70^{o}F and 760mm mercury = .07651 lb/ft. 3, converting the density to mass density and velocity to MPH gives the usual expression for dynamic pressure $q = 0.00256V^2$ which must be multiplied by a shape factor (or drag coeff.) to arrive at the design pressure used. At 14,000 feet elev. however the density of the air has gone down to 0.04973 #/ft.^{3} at 70^{o}F and when one corrects for a temperature of 0^{o}F (estimated) we arrive at a density of 0.0573.

Then $q = \frac{.0573}{32.2} \times 1/2 \times \left(\frac{5280}{3600}\right)^2 = .001914\ (125^2) = 30.25\ \#/\text{ft.}^2$
using a shape factor (or drag coeff) of 1.3 makes pressure = 39.3 #/ft.^{3}.

Based on the Design Guide Lines which I consider as logical and practical I think a Tri-Ex T-26-25 tower using 2 lengths of 20 ft. each plus 1 length of 10 feet with 2" dia. pipe of 0.250 inch wall thickness guyed at the top would meet our requirements. This gives a maximum bending stress in the tower of 36,000 psi which slightly exceeds the allowable stress one would normally use for steel but since the case of maximum ice build-up coinciding with 125 MPH wind is somewhat remote I would use this tower for a non-permanent installation. A rather sketchy foundation analysis shows that a steel grillage foundation could be used which would avoid hauling concrete to the top of the mountain and complies with the temporary requirement. Guy anchors could be buried steel fabrication also.

cc: G. M. Peery

NATIONAL RADIO ASTRONOMY OBSERVATORY

Green Bank, West Virginia

January 30, 1981

TO: M. Gordon and J. Davis

FROM: S. von Hoerner

SUBJECT: WIND MEASUREMENTS ON MAUNA KEA

Thanks for Marc Gordon's Memo of Jan. 31, and Jesse Davis' Report of Sept. 26, raising the questions: Is wind gusting important, should we measure fast gusts? Is the suggested instrumentation adequate? Further comments? After several discussions with Woon-Yin Wong, the following remarks were derived.

WIND GUSTS are more important for a completely exposed telescope. In this case, the measurements should include gusts down to the dynamical frequency of the telescope structure; thus, we measured 12 years ago with a hot-wire anemometer with a time constant of $\tau = 0.5$ sec (Report 23, March 1, 1969).

In our present case, the outside wind (velocity v) enters the open door and creates inside mainly a circular motion (velocity $v_o = qv$) with a "mixing time" of $\tau = \pi D/v_o$, with D = diameter = 25 m. We do not know the windshield factor q which Woon-Yin Wong will measure at Kitt Peak; for the time being, my rather uncertain guess is, say, $q \approx 1/3$ for bad wind directions, and less in the average. Using q = 1/3, we get about

$$\tau(\text{sec}) = 540/v(\text{mph})$$

or $\tau = 30$ sec for v = 18 mph (maximum wind velocity including gusts, for precision operation, according to VLA specifications and also used in our 25-m Proposal where 30 km/h = 18.75 mph). Thus, we should measure the wind with a time constant of about $\tau = 30$ sec.

The suggested INSTRUMENT, the propellor anemometer of Weathertronics, has a scan time of 60 sec, which I understand as the duration of shortest averaging and recording (please correct me if that is wrong); this would then be its time constant. It is twice as long as the one wanted, but I think this will not make more difference than a few percent, and I would call it adequate. I would not go to hot-wire instruments.

Regarding EVALUATION, I would suggest to record the data in blocks, one every hour. We then have 60 scans per block, enough for statistics, and we have 24 blocks per day, enough points for plotting time curves.

For each block, we record wind speed average, standard deviation from average, maximum and minimum speed. Further: date, time of block middle; and average temperature if this can also be measured. Do not record the single scans. My suggestions here are about the same as those in your Report; also, the suggested procedures look all OK to me.

The manufacturer gives -25°C as the lower limit. Question: how frequently is it colder on Mauna Kea? And could we use some better lubricant?

Regarding the TOWER, I do not understand the comparison and selection. If I read it right, there is a low-cost tower with guy-wires up to 110 mph, from Weathertronics, which looks perfectly OK to me. Why should we go to the high-cost free-standing tower from Rohn, up to 125 mph? For any desired wind velocity, free-standing will always and necessarily be a good deal more expensive than guyed; and the pull at the guy ropes will always be considerably smaller than the pull at the free-standing windward tower leg (in proportion to the height/base ratio), regarding the needed stiffness of foundations. (I agree that we should not take the guyed tower from Tri-Ex, up to only 50 mph.)

SvH/s

cc: W. G. Horne
H. Hvatum
W. Y. Wong

Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

January 13, 1981

To: S. von Hoerner

From: M. A. Gordon

Subject: Wind Measurements on Mauna Kea

Sometime ago, I called you to discuss what kind of wind measurements, if any, would be desirable on Mauna Kea. Kitt Peak National Observatory has recently received a grant to study weather and astronomical conditions on that mountain. These studies are related to the Next Generation Telescope project. Because this grant will pay for two technicians to service mountain instruments on a daily basis, KPNO has kindly offered to service a wind instrument for the NRAO. Thus it will be possible for us to obtain weather data from Mauna Kea easily.

I need to know whether you are interested in wind gusting, that is, the spectrum of the wind pulsations at our proposed site. Or, perhaps you would prefer longer term averages. In any case, the lead time for procuring recording apparatus can be considerable. I need to know very soon whether you would like this weather information and if so, what kind.

A month or so ago I believe, I sent a report prepared by Jesse Davis describing one type of automatic recording apparatus. Is this instrument suitable? Would you prefer a hot wire device to measure micropulsations? Or, is this data simply superfluous?

Please let me know as soon as possible.

cc: W. G. Horne
H. Hvatum
W-Y Wong

Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

September 26, 1980

To: M. A. Gordon

From: Jesse Davis

Subject: Mauna Kea Wind Measurements

I have undertaken an investigation of commercially available weather monitoring systems suitable for installation at the proposed 25 meter site on Mauna Kea. The purpose of this system is to collect meteorological data over a period of one year as an aid in the engineering design of the 25-meter telescope and dome. The requested system performance is as follows:

1) Wind speed and direction is to be determined at a height of 15 meters above the ground. In addition wind speed is to be determined at a point intermediate between ground and 15 meters.

2) The air temperature is to be determined at a height of 15 meters above the ground.

3) The data should be logged approximately once every five minutes. Data processing may be used to reduce the number of data points.

4) The unit must be capable of unattended operations for a period of several days. Local personnel will be available to periodically service the unit and collect the data.

5) Unit to be battery powered.

6) The tower should be erected by local personnel and should be of a temporary nature.

I have investigated several possible commercial suppliers of equipment which will meet the above requirements.

I contacted several manufacturers of weather instrumentation. Of these, three manufacturers made equipment appropriate to the task. This is by no means an exhaustive survey of all manufacturers, but rather is intended to be representative of what is available. Each company offers a slightly different product from the others and therefore direct comparison is not possible, however, I have attempted to pick a system which is as close to the requirement as is possible.

Weathertronics, Inc. of West Sacramento, California offers what I believe to be the most cost effective. Weathertronics offers its model 1151 microprocessor based system. This system is designed for remote installation.

The system accepts signals from the various sensors, processes and stores the data on a standard Phillips cassette according to a user-supplied program which is stored in the micro-processor memory. In addition to the basic data-logging operation described the microprocessor will provide for engineering unit conversion and linearization of the data in addition to a rudimentary statistical program package which will perform real time data analysis, greatly reducing the number of data points which must be recorded and thereby extending the period between field servicing. The basic sensor scan rate of the unit is once per minute. The data may be recorded frequently as once per minute or once per day. A 60 minute tape cassette will store approximately 6000 data point. For recording intervals greater than one minute the one minute sensor scans may be averaged. The statistical package will provide the standard deviation of the data from the average value, the minimum and the maximum values of the data during the period. Up to nine sensors can be accommodated by the data logger. A total of 36 data analysis operations may be performed. In addition to the sensor data the Julian date and time are recorded. The data are recorded on the cassette via audio frequency shift keying at a 300 baud rate. The data logger together with its cassette recorder and battery pack is contained in a weather-proof housing which mounts to the base of the tower. The battery life is estimated to be greater than 4 months.

Wind speed and direction is measured by a Weathertronics Stratavane wind sensor. This sensor combines wind speed and wind direction measurements in one unit. Wind speed is measured by a machined aluminum four blade propeller rotating at a speed proportional to the velocity of the wind. The propeller drives an AC generator. The propeller type, rather than the cup type, of anemometer is chosen because of its superior performance under conditions of icing. Wind direction is measured by a vane driven potentiometer. Air temperature is measured by a wind aspirated linear thermistor. (Note that soil temperature could also be measured.) Data sheets have been included for each of these items.

I foresee several possible problems with the Weathertronics unit. The data taking routines and the data processing routines are stored in the microprocessor memory. This memory is volatile. A loss of power would result in the complete loss of the program. All data taking would cease pending the re-entry of the program by the operator. Program entry is relatively straight forward and may be accomplished by untrained personnel. A simple dual battery system will allow the operator to replace the data logger batteries periodically without losing the program. It is recommended that this course be adopted to reduce the possiblity of an error occurring on program re-entry. A related problem is that of lightning strikes. The tower is a likely target for a lightning hit. The tower must be thoroughly earthed and each of the signal lines must be provided with lightning protection. Weathertronics has indicated that when the proper lightning protection precautions are taken that the unit has proved reliable. Even though the unit may not be damaged by a lightning hit it is likely that the program memory may be altered. In this event the data will likely be lost. It is therefore recommended that the microprocessor memory contents be checked periodically, especially after periods of electrical storm activity.

A second possible problem involves the ambient temperature. The unit is guaranteed to operate between temperature limits of -25°C to 50°C. If the temperature falls below -25°C it is likely that the lubrication in the tape transport will freeze preventing the recording of the data. If this is felt to be a problem, auxiliary heaters must be installed to keep the recorder temperature above -25°C. During periods of freezing rain or snow it is possible that the wind speed and direction sensors may ice to the point where operation ceases. Should this occur, all data will be lost until the ice is removed. One final consideration regarding temperature effects is that of battery types. It is recommended that alkaline-manganese dioxide cells be used because of their excellent low temperature performance.

The performance of the system may be inferred from the output data. Many potential problems may be diagnosed and corrected by studying the output data. One of the DC input channels to the data logger may be used to monitor the battery voltage. An examination of the output data may be used to infer the proper operation of the wind speed and direction indicators. The proper operation of the microprocessor may be inferred from the data. It is recommended that the data be examined as soon as possible after the data tape is collected to avoid the unnecessary loss of data.

The data may be recovered from the cassette, using a standard tape player and a standard 300 baud modem of the type used for transmitting digital data over telephone lines. NRAO currently possesses in-house the equipment for doing this. It is not necessary to purchase the cassette tape reader offered by Weathertronics. The data may be recovered at the site for inspection. To accomplish this it is necessary to have a 30 character per second printer of the type found in most computer installations, and a modem or other decoder. The data is encoded on the tape in standard ASCII code and therefore it is necessary only to connect the modem directly to the printer. The data will be printed out in standard engineering units as specified by the data collection program.

Two additional companies, Climatronics Corp. of Bohemia, New York and Meteorology Research, Inc. of Alta Dena, California were investigated. Each of these companies provide a unit which is similar to the Weathertronics unit. These systems are more expensive than the Weathertronics system. Table 1 give a price comparison. The Weathertronics unit represents the most cost effective solution.

A tower will be required to support the instrumentation heads. I have contacted two tower manufacturers requesting engineering assistance and a quotation for a tower suitable for installation on Mauna Kea. I have included a copy of the request for quotation together with the responses. The harsh environmental conditions found on Maun Kea necessitate a very rugged tower. The tower would be a 15 meter self-supporting tower designed for 125-mile per hour winds with 2 inch radial ice load per EIA RS-222C. Both towers would require a concrete foundation. Neither company made a recommendation regarding the foundation design pending the results of a soil sample from the site. It is recommended that soil conditions be determined as soon as possible so the foundation design can be completed. Mark Gordon has suggested that it might be best to contract the tower installation, including foundation design, with the University of Hawaii. They have experience with conditions and operating considerations on Mauna Kea. The towers, excluding the foundation, may be installed by a crew of 3 to 4 men in approximately 7 days, including an allowance of operation at 14,000 ft. The tower design has been reviewed by the NRAO engineering staff. Preliminary analysis indicates that the Rohn Tower is the better choice. The Trie-Ex tower design is marginal. It is recommended that the tower manufacturer be required to provide detailed mechanical drawings of the proposed tower together with a bill of material for NRAO approval prior to delivery of the tower.

Delivery time for the system has not been quoted. It is expected that the tower may be a long lead item, and therefore it is recommended that the order be placed as soon as possible. It should be remembered that the time required for shipment from continental United States to Hawaii could be of the order of 4 to 6 weeks. It is recommended that orders be placed as soon as possible.

I have included the data sheets for each product examined. Also included is a section taken from the Weathertronics operators manual which describes a sample program. A listing of the available data processing programs is also included.

I would recommend the Weathertronics system outlined above.

Weather Instrumentation
Price Comparison

Meteorology Research, Inc.

	#	
Model 5000B "Weather Wizard"	(1)	$ 6170.00
Battery & Housing for same	(1)	285.00
Cables 10M	(2)	150.00
2nd Wind Speed & Direction Sensor	(1)	895.00
Tape Reader. Cassette to RS232C	(1)	3690.00
Minimum Cost		$ 11190.00

Climatronics

	#	
100782 Cassette Data Acquisition System	(1)	$ 3500.00
100108 Wind Speed/Wind Direction Sensor	(2)	950.00
100093 Temperature Sensor	(2)	170.00
100778 Wind Speed Translator	(2)	400.00
100779 Wind Direction Translator	(2)	400.00
100820 Temperature Translator	(1)	200.00
100949 Standard Deviation Computer	(1)	1000.00
Enclosure	(1)	200.00
Cables		150.00
Minimum Cost		$ 6970.00

Weathertronics

Sensors & Cables*	$ 2107.00
Remote Cassette Data Acquisition System	3396.00
	5503.00

*See attached quote for cost breakdown.