July 27th, 1946
212 W. Seminary Ave.
Wheaton, Illinois

Dr. Harlow Shapley
Harvard College Observatory
Cambridge 38, Mass.

Dear Dr. Shapley:

My letter of the 11th indicated that I would work up a tentative program for a full fledged investigation of cosmic static. This has been somewhat delayed because I have taken advantage of the interest shown by our mutual friend Dr. Otto Struve.

We have had considerable correspondence and a couple of conferences. The outcome of this consultation is embodied in the accompanying rather long monograph. While I believe everything has been considered you may find something omitted or some points not clear; in which case I will be pleased to elucidate further on the particular matter.

For your convenience I am attaching a summary giving the pertinent financial considerations on one sheet.

If possible I would like to set the whole program in motion as soon as possible so that all equipment may be removed from Wheaton before cold weather sets in.

Sincerely yours,

Grote Reber

Financial Summary

At the present time the writer has on hand at Wheaton, Illinois capital equipment for cosmic static investigation and development representing a cash outlay of approximately $11,473. Substantial engineering and labor has been applied to this equipment to bring it to its present state of usefulness. If the project were to start today and all labor to be paid for to produce equivalent apparatus the estimated financial outlay would be $15,278. About two years would be necessary to complete the work already done.

The attached program envisions two years continuous operation and development. The financial budget is as follows.

Capital Cost

Building	$2500
Equipment foundations	500
Equipment transportation	1200
Disassemble equipment	350
Assemble equipment	1000
Additional instruments	3000
Truck or station wagon	1500
Fence and roadwork	500
Total	$9450

Yearly Operation Expense

Salary of man in charge	$5000
Salary of helper	3000
Material expense	1000
Total	$9000

Total budget for two years work $36,450

July 27th, 1946 Grote Reber

PROGRAM FOR THE INVESTIGATION OF COSMIC STATIC

by

Grote Reber

Introduction

From an astronomical point of view the greatest need in this cosmic static investigation is increased resolving power. Such may be achieved by using higher frequency electronic equipment or a larger mirror or both alternatives.

At the present time 480mc is quite far into the region of diminishing returns for the electronic equipment. By continuation and refinement of the present techniques it may be possible to go up another octave. This development would take perhaps two years to arrive at apparatus of useable sensitivity. Beyond that will require something new and yet unknown in the electronic art. The expense of these electronic development programs is quite substantial when probing into unknown fields.

Consequently the best and most certain road to success in securing greater resolving power is by means of a larger mirror, say 300 feet in diameter costing on the order of $100,000. For the time being such large capital investment appears to be out of the question.

At the present time the only available equipment for cosmic static investigation work is owned by the writer. It is now situated in a very urban location and its operation greatly handicaped by man made disturbances. Only about five hours or less of each day are useful for operation. Up to the present time this work has been carried on as a spare time activity or hobby. Greatly increased results could be secured by removal of the apparatus to a better location and prosecution of the work on

a full time basis. The following program describes how this may be accomplished.

Astronomical Work

The details of the astronomical studies must be left to persons skilled in these matters. In general the program will consist of making thoro surveys of the source of this radiation and measuring its intensity at a variety of frequencies. A second problem which can be attacked is the spectral distribution, if any, from given directions with the aid of radio frequency spectrometers (wave analysers). The design and construction of such apparatus falls in part IV below. It is for these spectroscopic investigations that an equitorial motion of the mirror is absolutely necessary to counteract the effect of the rotation of the earth. This is part V of the program and is discussed under Drive below.

Theoretical work may be carried out at any observatory or university where such skilled scientists are now located. Data may best be accumulated and stored at one location however and not necessarily the place of observation. The theoretical men should be in close touch with observers so that maximum observational results may be secured.

Location of the Observatory

The mirror should be located at a southern latitude and in the country far away from man made electrical noises. Of all these noise sources, auto ignition systems are by far the worst. Natural static is very weak and uncommon at these frequencies, even in the tropics.

A southern latitude is necessary because the structure will stand out of doors with no protection from the weather. Snow and ice will cause serious unbalance. One accident has already been

had due to this cause (see Ap.J., Nov. 1944, page 284, next to last paragraph).

Likewise a larger part of the celestial sphere is available for measurement at a southern latitude. To this end the mirror should be located on a cliff which drops abruptly to the south with a long level plain stretching from the base of the cliff to the southern horizon. The reason for this is as follows. When the acceptance pattern (single lobed) of the mirror is pointed horizontally, ground reflections break the single lobe up into a diffraction pattern. The angle which the lowest lobe of this pattern makes with the horizon is inversely proportional to the height of the mirror in wavelengths above the reflecting plane. This difficulty will be mitigated by mounting on a cliff which overlooks a plain to the south; as it is in this direction that the lowest angle to the horizon will be desired. Terrain in other directions is not important provided large obstructions such as mountains are not close by.

Clear weather is desirable but not of primary importance because haze and light clouds have small effect upon these wavelengths. A wide variety of such locations is available at no expense in south west Texas. McDonald observatory would be a suitable base of operation to provide living quarters etc.

Mirror

The only presently available mirror is of transit telescope design. Since motion in declination only is provided it is necessary to rely upon the rotation of the earth to sweep out a band in the sky. Only one sweep can be made in each day. At least two charts must be made at each declination for confirmatory purposes. Thus a great many days will be required to cover the sky using such a

system. Even with the present 31 foot mirror at 180mc it consumed the better part of a year to secure the information presented in figure 4, page 385 of the Nov. 1944 Ap. J. New apparatus is now functioning at 480mc with this same mirror. Something over two years will be required to make a comprehensive study using these slow and laborious methods.

Mounting

The obvious solution to the above difficulty is to provide the mirror with an equitorial mounting. The present mirror is not of a suitable mechanical design for an equitorial mounting. However a turntable is available which will then give the mirror an altiazimuth mounting. By making sweeps around the azimuth, the sky may be covered just as effectively as with an equitorial mounting. The only complication involved is in reduction of the data. This difficulty may be mitigated by the use of suitable nomograms.

Dive

A suitable alternative to an equitorial mounting may be had in an altiazimuth mounting with proper drive. This drive must so control two motions (altitude and azimuth) that one effective motion (right ascension) is produced.

Such can be accomplished by a suitable control box. This box will consist of one motor driving an equitorially mounted shaft at a speed equal to the desired rate of rotation of the mirror. By a combination of cams and levers this equitorial motion will be transformed into two separate motions (altitude and azimuth). The separate motions will operate separate selsyn generators. These in turn will control an amplidyne drive which will supply power to the main driving motors of the mirror mounting. Thus complete and instantaneous control may be had over the main

mirror mounting at all times from the control box at a remote location.

Provision must be made for locking or braking. Such mechanism should be push button operated from the same control box and supplied with suitable electrical interlocks to prevent power being applied to the drive motors when brakes are on. Since the mirror will stand outside with no dome for shelter, a braking mechanism is absolutely necessary to prevent damage from the wind.

A remotely controlled drive of this type would be impossible to build for use with a conventional telescope where the angular accuracy desired may be on the order of a second of arc. However for the present mirror the accuracy desired need only be on the order of a few minutes of arc and therefore it enters the realm of practicability. The design of such a drive comes under part IV below.

Order and Operation of the Program

The operations of this program will concern themselves with matters closely associated with the art of radio communication as well as with the science of astronomy. Tentatively this program may be divided into five parts.

I. Make astronomical investigations at 480mc using present mirror until a larger one becomes available.

II. Design of electronic equipment for use at frequencies above 480mc.

III. Improve the sensitivity of lower frequency apparatus.

IV. Design wave analysers.

V. Design of the altiazimuth to equitorial control.

Upon setting up the equipment at a good location, part I of the program should be immediately put into operation using the turntable and taking data by sweeping around the azimuth at frequent intervals. When that is going well part II should next

be attacked. On parts II and III cooperation may be secured from M.I.T. Reasearch Laboratory of Electronics (see pages 81 & 83, Feb. 1946, Rev. Sci. Inst.).

Capital Cost

Most all the capital equipment for this program has already been accumulated. It is enumerated in a later section. At present it is in partial operation or stored at Wheaton, Illinois. To put the program in motion, funds will be needed as follows.

1. Purchase a three car garage with concrete floor to house the apparatus. It should be divided by partitions and interconnecting doors into three separate rooms. Overhead car doors will then open up one side of each room to facilitate entry and removal of equipment. These rooms will provide space for respectively the library and study at north side, shop in center and power plant and storage at south side. Some plumbing and wash facilities will be necessary. Cost about $3500
2. Concrete foundations for outdoor part of power plant and azimuth turntable of mirror. Cost about $500
3. Transportation of equipment from Wheaton, Illinois to location in Texas. This will require about six truckloads as follows. One of structural steel, mostly turn table; one of power plant, mostly lead acid batteries; three of parts of disassembled mirror; one of library and instruments. Each load about 200 dollars or total $1200.
4. Cost to disassemble mirror and pack up library and instruments about $250.
5. Cost to assemble turntable, mirror and power supply about $1000
6. Fund for purchase of additional instruments; namely High Frequency "Q" machine, Vacuum tube transconductance and plate

resistance tester and a small bench mill. Cost about $2000

7. Small truck or station wagon for hauling material and equipment, most of which is large and heavy. Cost about $1500

8. Road work and fence to prevent damage to apparatus from cattle, about $500.

The above eight items total $9450 and represent the capital investment necessary to put the program on a going basis.

Operations Cost

Personnel salaries will be needed on a yearly basis as follows.

Man in charge	$5000
Helper	$2500
Labor charges	$7500

Further operating expenses will be encountered in this work if sections II, III & IV are to be prosecuted with vigor. This will involve the purchase of various electronic components such as tubes, condensers, resistors, etc. Further, considerable raw material will be expended in the form of copper and brass tube, rod, sheet, wire, nuts, bolts and gasoline for truck. Estimated annual expense from these sources $1000. Total annual operations expense $8500.

Recommendation

It is recommended that provision be made for two years work. Thus a grand total of $26,450 will be required to carry out such an investigation of cosmic static for a period of two years at a suitable location and under favorable circumstances.

Equipment on Hand

The writer has on hand the following apparatus. Considerable effort has been expended in going over all the bills to properly allot charges. Approximate cash expenditure is given. Cost of reproducing today is quoted in parenthesis.

One mirror 61.4 feet in diameter, 20 feet focal length on a transit mounting, complete and assembled. Also various structural steel parts for reinforcing and a new track to be added when reassembled. The materials cost about $1600. Several months of labor were supplied by the writer who fabricated most of the parts and erected the structure himself. If it were to be reproduced today and labor included the cost would probably be ($3500).

One steel turntable with track 30 feet in diameter and electric drive to give the above mirror an alt-azimuth mounting complete but disassembled. Cost $2100. Todays figure probably ($2500). However, this like a lot of other material would be quite difficult to get and considerable delay would be encountered in procuring now.

One new heavy duty wind driven 3.5KW 110v D.C. power plant with 60 cells of 615AH farm lighting battery. Generator driven by three bladed self feathering vanes 16 feet indiameter on 80 foot self supporting tower. Complete but disassembled. Cost $1800. ($2000)

One set of recorder apparatus complete and assembled. This consists of an Esterline Angus recorder and General Radio D.C. Amplifier assembled with associated apparatus in a steel cabinet on dolly. Parts cost about $800. Labor supplied by writer. Todays figure including labor about($1200). About 50 rolls of chart paper and assorted pens, ink, spare tubes,etc. are included in above.

One set of electronic apparatus for use at 160mc complete but disassembled. This consists of antenna equipment which is aluminum

drum 5 feet long and 4 feet in diameter with internal cones and assorted baffles and mounting; 180mc high frequency amplifier using five stages of 954 tubes; and regulated power supply for amplifier. The cost of this kind of equipment is quite difficult to guage. The final product is the result of a lot of experimental work. While not all the material went into the final product about $1100 worth of material was expended in the development. Labor and engineering was all supplied by the writer which under the original development was considerable and extended over two years. If the apparatus was to be reproduced today on the basis of todays knowledge, which was not available at the time, and labor costs included; probably ($1500) would suffice.

One set of electronic apparatus for use at 480mc complete and assembled. The situation here is similar to the development of 180mc apparatus. Separate engineering developments were carried out on the antenna equipment involving the construction and test of several designs; the high frequency amplifier involving two complete designs; and two power supplies. Engineering charges and labor to carry out this development would have been very great if paid for as this apparatus represents about the limit of what can be achieved at the present state of the art. Further improvements are still in progress. About $1500 of material has been consumed in the development. To construct the latest version using todays accumulated experience would cost about ($1500) including labor.

One set of machine tools consisting of South Bend bench lathe and assorted tools and fittings $320 or ($350); one Dunlap drill press with sets of drills, reamers,etc. $65 or ($85); one grinder $15 or ($20). Also new Thor electric hand drill ($23) or $23; and a large variety of accessories and hand tools estimated $150 or ($150).

Purchased electronic measuring apparatus as follows. Measurements Corp. vacuum tube voltmeter $135 or ($135); RCA signal generator $350 or ($350); Lavoie frequency meter $175 or ($190); National type HRO communications receiver $190 or ($230); General Radio resistance boxes, output meter and variacs, also Triumph circuit analyser $280 or ($320).

The main piece of home made test equipment is a special high power signal generator. The equivalent cannot be purchased today. Cost of parts about $90 with labor by the writer. Cost to build today including labor ($250).

A large assortment of electronic components including special tubes, power supply parts and over fifty Weston type 301 meters of assorted ranges are on hand. Estimated $450 or ($500).

Considerable raw material in the form of copper, brass, bronze, mica, bakelite, etc. is also on hand. This might be assumed to be merely junk; however such a suitable collection is valuable if any construction work is to be undertaken. The very wide variety is difficult to estimate but probably cost about $150. Todays figure about ($300) plus a lot of procurement effort to get it together.

Also on hand are three rotary inverters from 110v DC to 110v 60cps AC of ratings 175, 150 and 500 watts. The first is completely assembled into a special sheild box with voltage regulator etc. It is particularly intended to drive the AC electronic and recording apparatus when cosmic static measurements are being conducted. Hence great care has been used to make it electrically quiet. The other two are for driving equipment on bench tests. This apparatus cost about $180 plus labor. To reproduce today plus labor ($275).

The above cash expenditures total about $11473. Untold hours of labor have been expended over about ten years collecting and building the above apparatus. In the aggregate it is eminently

suitable for this type of development investigation of cosmic static. Its main function and value is with such work. For other purposes its value would greatly decrease. Consequently for this reason, among others, the writer desires that it be kept together and put to the use for which it was collected. If the program were to start from scratch today about ($15278) would be necessary. At least two years continuous work would be necessary to carry the program to its present state.

Proposal

The writer proposes to donate the use of all the above equipment to the project and agrees not to remove any therefrom during the active life of the project. The title of ownership will remain with the writer however. After the initial period of two years has been completed the situation will be re-evalued.

If it is decided that important results have been secured and that the project will be continued on an expanded scale; then the writer proposes to donate the equipment outright in such fashion as he determines may be most advantageous for tax purposes. The project will then become the owner.

If, on the other hand, it is decided for any reason that the project is not to be continued; then the writer reserves the right to remove any and all of the above loaned equipment at his convenience.

If the program goes into operation, the writer desires to be appointed as the man in charge. He wishes this not only because of his great interest in the subject but also because he rather feels as god-father to the project and has a responsibility to see that the infant is brought up properly.

Library

The writer is also owner of a rather substantial electronic

library. This consists of a few of the later better books (approx. $50) on the subject but mainly extensive files (mostly unbound) of the leading journals as follows. The cost figures are given merely as the yearly subscription rates multiplied by the number of years. No present day cost is possible as most of the material is impossible to secure at any price.

Proc. IRE, 1928 to date complete plus some earlier $230
Bell Technical Journal 1925-date $30
Jnl. Franklin Inst. 1924-date $132
Jnl. Applied Physics, Complete-date $106
Electrical Engineering, 1930-date $160
Review of Sci. Inst., complete-date $85
R.C.A. Review, complete-date $14
Electrical Communications, 1924-date $35
Wireless Engineer, complete-date $150
Philips Technical Review, complete-prewar $15
Gneral Electric. Review, 1930-date $51
Jnl. I.E.E. (british), nearly complete 1930-date $102
Communications, 1935-1944 $20
Westinghouse Engineer, 1944-date $4
QST, 1927-1934, $20
Physics Abstracts A & B, 1945-date $12
Also a wide variety of bulletins, pamplets and monographs on electronic subjects, approximately $50.

The grand total of the above is $1266. For the time being the writer wishes to include his library with the above apparatus. However ownership is to remain with the writer. Quite likely at some time in the future it will become apparent that the library will be more useful elsewhere than at the scene of oberservations. At such time the writer reserves the right to remove the library at his wish.

Recapitulation

The above program can be put into operation quite readily. It is requested funds be made available for two years work. The writer hopes that all details can be ironed out promptly so that all material can be removed from Wheaton, Illinois before cold weather sets in. As soon as this program is well underway and substantial results are being secured, serious consideration should be given to acquiring a large mirror for an expanded program.

Grote Reber

July 25th, 1946 Grote Reber