

June 27, 1956

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Dear Charles

On July 11th my wife and I are leaving Boston for Europe. This is going to make my attendance at the July 11th meeting difficult, not to mention the meeting the next day. I regret this very much and shall do my best to get to the Wednesday meeting, but it is all the more reason for my recording now, in response to your letter, some comments which I should want to make if I were there.

Turning first to the most pressing question before us, I do not share your doubt that A.U.I. can build and manage the facility in the way that it ought to be done. The Trustees of A.U.I. are not preoccupied with atomic energy problems as such. They may have been so occupied, to be sure, on occasions when major technical decisions and laboratory policy interacted. But I have had the clear impression that important scientific decisions at Brookhaven have been made by scientists close to the problem, whatever it may have been. The main job of the Trustees has been to see that a large scientific institution maintains its own internal vigor while properly serving as a laboratory for a broad scientific community. This Brookhaven does, and does well, judging from my own acquaintance with it and from the opinions of other physicists in Cambridge who have spent much time there. I don't know of any organization in the country that has had experience and success comparable to that of A.U.I. in this special sort of enterprise.

I am in no position to argue the political merit of the contention that it would be unwholesome to entrust the supervision of a national facility, located in West Virginia, to an Ivy League outfit. I would like to know how the radioastronomers at Ohio and Michigan feel about the substantive merit of this argument. Except for them, permitting our Washington friends to choose their own category, the area now served by Brookhaven is in actual fact going to provide most of the radioastronomers for the facility, in the beginning, at least.

There may be valid arguments of a different sort over creating a new organization and it is most desirable that every bona fide possibility be examined. My own opinion at this time is that A.U.I. is hard to beat.

This expression of confidence in A.U.I. does not mean that I agree with everything in the feasibility study. On some technical points I disagree and also, to some extent, on matters of emphasis. These objections will be explained presently. But I do feel that the A.U.I. group has done a very good job and that the whole project is much farther ahead than it would have been without their zealous work. We have a good site, we have reached substantial agreement on the first important instrument, and we certainly know a good deal more than before about the job of building the colossal telescope.

As concerns the design study for the 140 ft. dish I still suspect there has been a tendency to screw the tolerances too tight. It is very evident now that the cost is so strongly dependent upon the tolerances imposed that one cannot deal lightly with factors of two. The shift from  $30''$  of arc to  $10''$  of arc which seems to have occurred somewhere along the way is not, in my view, justified by a realistic assessment of the requirements. Incidentally, the tolerance on location of the feed ought to have been reduced by a factor of three likewise to be consistent. This would imply accuracy and stability of feed location to  $\pm 1/24$  inch for a 70 ft. focal length, a number which brings out rather vividly the difficulty one is getting into. Presumably one should add the feed location error to the pointing and tracking error so that if we go back to a  $30''$  tolerance on pointing and tracking and  $\pm 1/8''$  on the feed we shall not be doing quite as well as  $5\%$  of the beam length at 10 centimeters in terms of overall accuracy of instantaneous beam direction. Nevertheless, I believe one is striking a pretty good balance between accuracy and cost with that choice.

Looking into the future I find in the A.U.I. study a projection of future developments which I cannot fully agree with, or about which at any rate, I feel very uncertain. I am still not convinced that the next major investment after the 140 ft. telescope should or will take the shape of a much larger instrument of the same type. Not that I expect the clamor for increased aperture, as such, to evaporate; there is about as much chance of that as that nuclear physicists will remain permanently content with any given number of Bev. But, to be specific, I am not sure that the Mark II telescope ought to be a conventional altazimuth instrument tracking over the hemisphere. Something much closer to a transit instrument, solar specialists to the contrary notwithstanding, may well yield the biggest scientific returns for a given total investment. Here I think one has to be wary of being led too far by analogy with optical techniques. There is no

fundamental technical reason why radio information cannot be accumulated without loss, day after day, in one hour chunks. If it turns out that there are enough interesting places to look at to keep such a telescope reasonably busy, it may be better to build four acres of aperture with limited tracking in hour angle than two acres that can look anywhere - if, as would not surprise us, the former would be as cheap as the latter. The perfectly valid objections of solar workers to such a compromise might be met by giving them an instrument adapted to their special problems. This is a speech I have made before and I would admit, indeed I would emphasize, that it is speculation, but so is the assumption that the altazimuth 500 footer is what radio astronomers will most need some years from now.

Incidentally, even supposing the ultimate instrument ought to be the kind described in the A.U.I. study, I can see no merit in the argument that the 140 foot telescope ought to be an altazimuth design because the bigger dish to follow will surely be altazimuth, and one learns by doing. It is cheaper to learn by thinking, in a situation like this. This is not to assert that the 140 foot dish ought necessarily to be equatorially mounted; but whatever it is, the design ought to stand altogether on its own merits. I would argue too, and even more vigorously, that a 250 ft. telescope can only be justified by the need for a 250 ft. telescope. Its value as a model for a larger one, realistically appraised, would only be a small fraction of its cost. A 1/100 scale model made of rubber might be more instructive. Until better arguments are presented than any I have yet heard, I cannot take very seriously the intermediate telescope which now appears in the projected program.

The short paragraphs on security clearance and classification (page VI-19) raise questions which I think the Panel should, before long, consider rather carefully. Anyone familiar with classified work in fields verging on radio astronomy can easily imagine problems arising in a classified context for which the advantages of a 140 ft. telescope would be very attractive indeed. What will be the extent of the obligation of the national facility to accept such projects? There are essential differences between this problem and, say, the problem of administering an atomic research program around a nuclear reactor, one of the important differences being that neutrons come out of many holes at once. It will be easy to tie up the telescope for a substantial fraction of the time if the contractor feels bound to yield to all legitimate requests coming from defense agencies. Likewise, the task of maintaining an open and truly academic research atmosphere while accommodating classified activity in its midst is perhaps more awkward here than in a national laboratory like Brookhaven. It will be hard to classify the frequency at which the radio telescope is currently operating, not to mention the direction in which it is pointing! It is not easy to imagine how one could insert a strictly classified experiment into the program of the telescope without rather extraordinary and peculiar measures

being taken. I feel sure there are ways of meeting the difficulties here envisaged. In the first place a classified problem requiring the use of the telescope can, nearly always, be separated cleanly enough from the context in which it has arisen to be treated as an unclassified scientific investigation. It can be, that is, if there is a determined and unlightened effort to do so on the part of the interested agency. But to encourage that kind of approach to the problem the contractor will need to be armed with a clearly defined policy.

Another speech I have made before concerns the relative importance of electronics. The Feasibility Study pays lip service to this notion, and perhaps that is as much as one can hope for at this time. But let's look at a concrete example. Ideas are floating about now which offer promise of a spectacular improvement in receiver noise figure. We have lived with  $T = 300$  in RTAv long enough. Townes' MASER has stimulated some of these ideas. Bloembergen here at Harvard has just thought up a scheme that looks really practical. I will bet even money that the next three years will bring an improvement of at least 10 db, and I actually expect to look in retrospect foolishly conservative. Now I am not suggesting that the facility budget a large sum for research leading to such a receiver. There is doubtless ample money and incentive in other quarters to promote such a development. What I want to emphasize by this example is that we have only begun to develop the observational techniques of radioastronomy. We do not have to live with present techniques as the astronomers have lived all these decades with glass and silver bromide, and we ought to be looking forward to electronic advances no less exciting and fruitful than the progression from 140 to 500 ft. diameter. I'm all for big dishes too, but I find it hard to decide whether to allow  $1/8''$  or  $1/16''$  sway in the feed support, when I am not sure we may not want a small cryogenic laboratory mounted out there on the end of it.

If I may use the word "preoccupied" myself, my chief disappointment in the A.U.I. study is its preoccupation with dishes and mounts. Perhaps that is necessary and proper at this stage, but let us not assume that dishes and mounts will keep the observatory in the forefront of the science. The future is not going to be that dull.

I hope these rather disjointed comments may add something to what is certain to be a lively discussion.

Sincerely yours,

E. M. Percall

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