

NATIONAL RADIO ASTRONOMY OBSERVATORY

GREEN BANK, WEST VIRGINIA

MEMORANDUM ON 140 FOOT TELESCOPE

SEPTEMBER 12, 1960

THE MONTHLY REPORT FOR JULY CONTAINED A GENERAL DESCRIPTION OF THE 140-FOOT RADIO TELESCOPE WHICH IS NOW UNDER CONSTRUCTION AT THE CANTON, OHIO DIVISION OF THE E. W. BLISS COMPANY. IN THIS REPORT IT WAS STATED THAT THE WORK IN THE FACTORY WAS PROCEEDING RAPIDLY, BUT THAT THERE HAVE BEEN MANY DISAPPOINTING DELAYS.

DURING THE PAST MONTH THE COURSE OF EVENTS HAS COMPELLED ME TO INTERVENE IN THIS PROJECT AND TO MAKE CERTAIN RECOMMENDATIONS WHICH I BELIEVE ARE IN THE BEST INTERESTS OF THE OBSERVATORY AND THE FUTURE OF RADIO ASTRONOMY IN THIS COUNTRY. THE PURPOSE OF THIS MEMORANDUM IS TO DESCRIBE BRIEFLY THESE EVENTS AND TO OUTLINE THE PROCESS BY WHICH I HAVE REACHED CERTAIN BASIC CONCLUSIONS. BEFORE PROCEEDING, I WOULD LIKE TO MAKE CLEAR THAT THESE ACTIONS ON MY PART IN NO WAY REPRESENT A CRITICISM OF THE ABILITIES AND MOTIVES OF THOSE WHO HAVE BEEN AND ARE MOST INTIMATELY INVOLVED IN THE DAY TO DAY DIRECTION OF THIS PROJECT. THEIR SINCERITY AND DEDICATION ARE UNQUESTIONED, AND THEIR EFFORTS HAVE BEEN PRODIGIOUS. HOWEVER, IT IS MY DUTY TO VIEW EVERY OBSERVATORY ACTIVITY IN TERMS OF THE OBSERVATORY'S TOTAL EFFORT AND TO PROVIDE LEADERSHIP AND DIRECTION WHICH WILL ENSURE THE ACHIEVEMENT OF OUR STATED GOAL.

THE SCIENTIFIC REQUIREMENTS AT THE NRAO MAKE IT IMPERATIVE THAT THE 140-FOOT TELESCOPE BE FINISHED NOT LATER THAN IN 1962. THE REPUTATION OF THE OBSERVATORY HAS ALREADY BEEN DAMAGED AS A RESULT OF THE DELAY, AND CURRENT PROGRESS IN THE DESIGN OF SUITABLE RADIO ASTRONOMY ANTENNAS IS SO RAPID THAT AFTER 1962 THE PRESENT DESIGN WILL PROBABLY BE OUTDATED. AS I HAVE STATED REPEATEDLY DURING THE PAST YEAR, THE OBSERVATORY DOES NOT NOW ATTRACT RADIO ASTRONOMERS FROM OTHER INSTITUTIONS BECAUSE THE EXISTING EQUIPMENT IS NOT SUFFICIENTLY POWERFUL. THE MEMBERS OF OUR OWN STAFF ARE WORKING AT A CONSIDERABLE DISADVANTAGE BECAUSE THERE ARE NOW IN EXISTENCE OR IN THE PROCESS OF CONSTRUCTION, SEVERAL RADIO ASTRONOMICAL OBSERVATORIES POSSESSING MORE SENSITIVE INSTRUMENTS THAN THE 85-FOOT TATEL TELESCOPE.

THE RESEARCH PROBLEMS THAT CONFRONT US ARE URGENT AND CANNOT BE SOLVED WITH THE EXISTING EQUIPMENTS. HEESCHEN'S WORK ON GALAXIES AND DRAKE'S ON ACCURATE POSITIONS OF RADIO SOURCES HAVE ALREADY BEEN PUSHED ABOUT AS FAR AS IS POSSIBLE WITH THE 85-FOOT TELESCOPE. MY OWN SCIENTIFIC INTERESTS IN FLARE STARS AND THE BEHAVIOR OF SPECIAL TYPES OF RADIO SOURCES HAVE, FOR ALL PRACTICAL PURPOSES BEEN ABANDONED.

IT IS MY OPINION THAT AT THE PRESENT TIME THE NRAO HAS THE FINEST SCIENTIFIC STAFF OF ANY OBSERVATORY IN THE WORLD. I AM EQUALLY CONVINCED THAT, UNLESS THE 140-FOOT TELESCOPE IS PUSHED TO COMPLETION AT THE EARLIEST POSSIBLE DATE, TWO YEARS FROM NOW IT WILL BE IMPOSSIBLE TO MAKE THIS SAME STATEMENT.

IN THE DESIGN AND CONSTRUCTION OF LARGE, COMPLEX, UNIQUE, AND VERY EXPENSIVE SCIENTIFIC MACHINES THE TECHNICAL PROBLEMS ARE IMMENSE AND NEVER ENDING. WHEREVER POSSIBLE THESE PROBLEMS SHOULD BE MET WITH THE BEST TECHNICAL SOLUTIONS AVAILABLE. HOWEVER, DECISIONS MUST SOMETIMES BE REACHED WHICH FIT THE TOTAL ENVIRONMENT. FINANCIAL AND LEGAL CONSIDERATIONS WILL ALWAYS BE LIMITING FACTORS WHICH MAY REQUIRE A COMPROMISE OR MODIFICATION TO THE "IDEAL" TECHNICAL OR ENGINEERING SOLUTION. EQUALLY IMPORTANT IS TIMELINESS OF COMPLETION, OR EXPRESSED ANOTHER WAY, "URGENCY OF NEED." TO MY WAY OF THINKING THIS LATTER MUST BE THE CONTROLLING FACTOR IN THE DECISIONS FACING US AS WE BRING THE 140-FOOT TELESCOPE TO COMPLETION. DECISIONS REACHED IN THIS MANNER MAY WELL INVOLVE RISKS OR THE POSSIBILITY OF FAILURE. HOWEVER, IT IS THE REPUTATION OF THE DIRECTOR OF THE NRAO WHICH IS AT STAKE, AND THIS I AM PREPARED TO RISK.

ON MAY 5, 1960, THE E. W. BLISS Co. ADVISED US BY LETTER THAT THEY WERE NOT CERTAIN THAT THE LARGE SPHERICAL BEARING WOULD GIVE THE DESIRED PERFORMANCE (BECAUSE OF TRIAXIAL STRESSES AND WHAT LATER CAME TO BE CALLED BRITTLE FRACTURE FAILURE) AND THAT THEY WOULD ASSUME NO RESPONSIBILITY FOR IT. THEY TOOK THE VIEW THAT THE ORIGINAL DESIGN BY N. ASHTON WAS UNSATISFACTORY AND THAT THE RESPONSIBILITY FOR THE SPHERE WOULD REST WITH A.U.I. THEY THEN PROPOSED THREE ALTERNATIVE METHODS OF ALLEVIATING THE PROBLEM, AS FOLLOWS:

(A) PROVIDE COMPLETE THERMAL STRESS RELIEF OF THE COMPLETED STRUCTURE IN THE FIELD.

(B) MAKE CERTAIN DESIGN CHANGES IN THE SHOP AND IN THE FIELD TO PRECLUDE THE FORMATION OF TRIAXIAL STRESSES. (TO CUT

"MOUSE HOLES" IN THE HONEYCOMBED CORNERS OF THE SPHERE IN ORDER TO REDUCE TRIAXIAL STRESSES).

(C) SCRAP THE SPHERE. SUBSTITUTE A CASTING DESIGN AND BOLT IT TO THE POLAR SHAFT.

AS A CONDITION OF PROCEEDING WITH ANY OF THE ABOVE, THE E. W. BLISS Co. ASSERTED THAT THE ADDITIONAL COST AND DELAY WOULD BE A.U.I.'S RESPONSIBILITY.

AT A MEETING, ON MAY 16, 1960, WITH A.U.I. REPRESENTATIVES THE E. W. BLISS REPRESENTATIVES ADDED A FOURTH ALTERNATIVE, NAMELY, USING A HEATED BEARING TO AVOID TEMPERATURE DIFFERENTIALS AND THE THREAT OF BRITTLE FRACTURE. THIS THEY DID NOT RECOMMEND BECAUSE OF THE POSSIBLE FAILURE OF THE HEATING SYSTEM.

ON MAY 16, 1960, A.U.I. ALSO WROTE TO THE E. W. BLISS Co. IN REPLY TO ITS LETTER OF MAY 5, 1960, STATING THAT THE PROBLEMS OF THE E. W. BLISS Co. WERE NOT DUE TO DESIGN BUT TO UNSATISFACTORY SHOP AND WELDING PROCEDURES - PROCEDURES WITH WHICH A.U.I. HAD LONG BEEN DISSATISFIED AND WITH RESPECT TO WHICH A.U.I. HAD REPEATEDLY MADE SUGGESTIONS. THE ATTITUDE OF THE E. W. BLISS Co. WITH RESPECT TO SUCH SUGGESTIONS IS BEST REPRESENTED BY THEIR LETTER OF MARCH 4, 1960 IN WHICH MR. GILGALLON STATED "...MANUFACTURING PROCEDURES ARE SOLELY A FUNCTION AND RESPONSIBILITY OF THE CONTRACTOR..." THE A.U.I. LETTER WENT ON TO MAKE THE POINT THAT THE E.W. BLISS Co. WAS RESPONSIBLE UNDER THE CONTRACT FOR THE CORRECTNESS OF THE FINAL DESIGN AND THAT THE RESPONSIBILITY FOR FINDING A SOLUTION AND FOR ASSUMING ANY EXPENSE IT MIGHT INVOLVE RESTED SQUARELY WITH THE E. W. BLISS Co.

IN ENSURING DISCUSSIONS DURING JUNE AND JULY THE POSSIBILITY OF "NORMALIZING" THE SPHERE WAS DISCUSSED AT GREAT LENGTH BY A.U.I. AND BLISS REPRESENTATIVES. METALLURGISTS ARE OF THE OPINION THAT NORMALIZATION (HEATING THE METAL TO 1600° F) GREATLY DECREASES THE POSSIBILITY OF BRITTLE FRACTURE SINCE IT CHANGES THE STRUCTURE OF THE STEEL, STRENGTHENS IT, AND INCREASES ITS DUCTILITY. THIS, THEN, BECAME A FIFTH ALTERNATIVE.

A SIXTH ALTERNATIVE WAS PROPOSED BY MR. HALIK. THIS INVOLVED CUTTING A SECTION OF THE POLAR SHAFT (NOW IN GREEN BANK), SENDING IT TO SOME SUITABLY EQUIPPED PLANT, WHERE THE PRESENT HALVES OF THE BEARING COULD BE WELDED TO IT WITH

FREQUENT THERMAL STRESS RELIEVING AS REQUIRED. THE BEARING COULD THEN BE MACHINED ON A VERTICAL BORING MILL, STRESS RELIEVED AGAIN, AND SHIPPED TO THE FIELD IN ONE PIECE, OR AT MOST TWO, FOR FINAL REWELDING TO THE REMAINING SECTION OF THE SHAFT, AND ERECTION.

ON AUGUST 19, 1960 THE E. W. BLISS Co. WIRED A.U.I. REQUESTING AMONG OTHER THINGS THAT THEY BE DIRECTED TO PROCEED BUT DISCLAIMING ALL RESPONSIBILITY FOR THE SPHERE, REGARDLESS OF THE ALTERNATIVE EMPLOYED. BY THIS IT BECAME CLEAR THAT THE QUESTION OF DESIGN RESPONSIBILITY COULD NOT BE AVOIDED UNDER ANY OF THE PROPOSED COURSES OF ACTION. IN ADDITION, IN EVERY CASE ADDED EXPENSE WOULD BE INVOLVED FOR WHICH A.U.I. WOULD BE PRESSED TO ASSUME RESPONSIBILITY. THE COST OF NORMALIZATION AS SUCH WOULD ONLY BE OF THE ORDER OF \$15,000, BUT IF IN THE PROCESS THE SPHERE SHOULD GET BADLY OUT OF SHAPE A MUCH LARGER AMOUNT MIGHT BE REQUIRED, PERHAPS UP TO ONE-HALF MILLION DOLLARS IF A NEW SPHERE WOULD HAVE TO BE BUILT.

ALL OF THE ALTERNATIVE PROCEDURES SUGGESTED BY EITHER BLISS OR OUR OWN STAFF MEMBERS AND CONSULTANTS WOULD INVOLVE FURTHER DELAYS. OUR LAST COMMUNICATION FROM BLISS, DATED AUGUST 25, STATES THAT THEY HAVE BEEN UNABLE TO FIND A FURNACE THAT IS LARGE ENOUGH TO ACCOMMODATE THE ENTIRE SPHERE AND THAT REACHES THE REQUIRED TEMPERATURE FOR NORMALIZATION. THEY, THEREFORE, SUGGEST THAT THE TWO HALVES OF THE SPHERE BE NORMALIZED SEPARATELY IN A FURNACE THAT SUPPOSEDLY IS NOW AVAILABLE. SUCH A PROCESS WOULD GREATLY INCREASE THE PROBABILITY OF MALFORMATION OF THE SPHERE AT THE HIGH TEMPERATURES REQUIRED, WITH A RESULTING DELAY AND GREATLY INCREASED EXPENSE.

THE CUTTING OF MOUSE HOLES OF THE SIZE RECOMMENDED BY BLISS WOULD PROBABLY NOT TAKE MUCH TIME BUT, ACCORDING TO AHEWSON, THIS WOULD REMOVE 37 PER CENT OF THE STEEL FROM THE SPHERE AND COULD BE TOLERATED ONLY IF STEEL PLATES WERE WELDED BACK TO CLOSE THE MOUSE HOLES ONCE THE SPHERE IS ATTACHED TO THE SHAFT. SINCE THE NUMBER OF SUCH HOLES IS LARGE, THE CLOSING UP OF THE MOUSE HOLES WOULD PROBABLY REQUIRE MANY MONTHS.

THE POSSIBILITY OF REDESIGNING THE SPHERE SO THAT IT MIGHT BE BOLTED RATHER THAN WELDED TO THE POLAR SHAFT WOULD RESULT IN ADDED DELAY AND EXPENSE. SIMILARLY, THE SUGGESTION THAT THE SHAFT BE SENT BACK TO A SHOP, THE SPHERE WELDED TO

IT AND MACHINED, STRESS RELIEVED, AND THEN SHIPPED AS A UNIT BACK TO GREEN BANK WOULD AGAIN INVOLVE SIGNIFICANT DELAYS AND LARGE ADDITIONAL EXPENSE.

MOST OF OUR OWN ENGINEERING CONSULTANTS ARE OF THE OPINION THAT THE METAL IN THE SPHERE IS INDEED FULL OF MINUTE INTERNAL CRACKS WHICH MIGHT UNDER SUFFICIENT STRESS TRIGGER A MAJOR STRUCTURAL RUPTURE. DESPITE REPEATED STRESS-RELIEVING IN THE SHOP (AT TEMPERATURES OF THE ORDER OF 1100 DEGREES) THE "LOCKED-IN" STRESSES BROUGHT ABOUT BY FIELD WELDING AND MACHINING WILL BE CONSIDERABLE AND AS A RESULT NO ONE CAN GUARANTEE THAT THE SPHERE WILL SUPPORT THE HEAVY WEIGHT OF THE YOKE AND SUPERSTRUCTURE IN COLD WEATHER. ON THE OTHER HAND, NO ONE IS WILLING TO STATE THAT THE SPHERE WILL FAIL UNDER THESE CONDITIONS AND THERE IS AGREEMENT (NOT UNANIMOUS) THAT WITH CAREFUL AND EXACTING PROCEDURES AND WORKMANSHIP THE SPHERE AS PRESENTLY DESIGNED AND FABRICATED MAY BE ATTACHED TO THE SHAFT SUCCESSFULLY. PROFESSOR ASHTON, THE TELESCOPE DESIGNER, HAS INSPECTED THE WORK AT CANTON AT LEAST ONCE EACH MONTH AND MAINTAINS THAT, DESPITE POOR WORKMANSHIP AND INADEQUATE PROCEDURES FOLLOWED BY BLISS, THE SPHERE IN ITS PRESENT STATE IS AMPLY STRONG ENOUGH TO DO WHAT IS EXPECTED OF IT. IT IS SIGNIFICANT TO ME THAT HE IS WILLING TO STAKE HIS ENTIRE PROFESSIONAL REPUTATION AND CAREER ON THIS JUDGMENT.

UNDER THESE CIRCUMSTANCES, I BELIEVE THAT WE MUST GO ALONG WITH THE RECOMMENDATION OF MR. ASHTON AND TRY TO USE THE SPHERICAL BEARING AS IT IS. THE PROBABILITY IS GREAT THAT THE INSTRUMENT WILL PERFORM IN ACCORDANCE WITH THE SPECIFICATIONS AND I HAVE, THEREFORE, RECOMMENDED TO A.U.I. AND NSF THAT BLISS BE DIRECTED TO SHIP THE SPHERE TO GREEN BANK, TOGETHER WITH ALL THOSE COMPONENTS THAT HAVE BEEN FINISHED, LEAVING IN THEIR SHOPS ONLY THOSE PARTS ON WHICH ADDITIONAL SHOP WORK IS REQUIRED. THIS DECISION WAS REACHED AFTER A FULL DAY OF LISTENING TO AND CONSIDERING THE VIEWS OF DR. EMBERSON, HIS STAFF AND CONSULTANTS, ON AUGUST 17. MESSRS. BURCHILL AND DUNBAR WERE ALSO PRESENT ON THAT DAY. AT A MEETING IN WASHINGTON WITH THE NSF ON AUGUST 30 I AGAIN WEIGHED THE PROS AND CONS, REACHED THE SAME CONCLUSION, AND A DECISION WAS ADOPTED IN ACCORDANCE WITH MY RECOMMENDATIONS. DR. L. V. BERKNER WAS INFORMED OF THIS DECISION BY CABLE BECAUSE I FELT THAT SO IMPORTANT A MATTER COULD NOT BE DEFINITELY ADOPTED WITHOUT HIS CONCURRENCE. HE REPLIED BY CABLE THAT HE APPROVED THE DECISION AND MR. EMBERSON HAS ISSUED THE NECESSARY ORDERS TO BLISS. THIS, IN EFFECT, IMPLIES THAT:

A) A.U.I. COULD BE FORCED TO ASSUME THE RESPONSIBILITY FOR THE DESIGN OF THE INSTRUMENT. (UNDER THE CONTRACT THE RESPONSIBILITY FOR THE WHOLE INSTRUMENT RESTS WITH BLISS BUT IT SEEMS CLEAR THAT BLISS MIGHT GO TO COURT AND REFUSE TO SHIP ANY PARTS OF THE TELESCOPE UNTIL A COURT RULING WAS OBTAINED. THIS COULD INVOLVE A DELAY OF SEVERAL YEARS). ON STRICTLY LEGAL GROUNDS, IN WHICH I DO NOT PROFESS COMPETENCE, IT SEEMS TO ME THAT ORDERING THEM TO PROCEED WITH THE ESTABLISHED DESIGN AND AN EXISTING FABRICATED COMPONENT REDUCES THE CHANCES OF DELAY AND ADDITIONAL COST, AND REMOVES THE QUESTION OF DESIGN RESPONSIBILITY EXCEPT IN THE CASE OF MAJOR STRUCTURAL CATASTROPHE, WHEN AND IF IT OCCURS.

B) A.U.I. AND THE OBSERVATORY TAKE A CALCULATED RISK WITH RESPECT TO THE PERFORMANCE OF THE BEARING. IT IS PROBABLE THAT ANY MINOR FAULTS THAT MAY DEVELOP DURING THE PROCESS OF WELDING THE SPHERE TO THE SHAFT IN THE FIELD AND IN THE PROCESS OF LIFTING THE ENTIRE STRUCTURE TO THE CEMENT PIER CAN BE REPAIRED WITHOUT ENCOUNTERING INSUPERABLE DIFFICULTIES. AT WORST, AT THAT TIME, WE COULD CONSIDER THE NECESSITY OF A THERMAL STRESS RELIEVING FURNACE IN THE FIELD. THERE REMAINS THE POSSIBILITY THAT THE ENTIRE BEARING WILL BE FOUND TO BE UNACCEPTABLE OR INOPERABLE. IF SO, WE SHALL HAVE TO FACE THIS PROBLEM DURING THE SUMMER OF 1961 AND DECIDE WHETHER TO MAKE A NEW BEARING, REDESIGN THE INSTRUMENT SO THAT IT WOULD PERFORM AS A TRANSIT INSTRUMENT, OR SCRAP THE ENTIRE PROJECT.

C) ADDITIONAL FUNDS WILL BE REQUIRED TO COMPLETE THE PROJECT. THE AUGUST 30 DISCUSSIONS WITH THE NSF MADE IT CLEAR THAT WE ARE IN A POSITION, FINANCIALLY, TO PROCEED WITH THIS PROJECT. DETAILS OF THIS AGREEMENT MAY BE SECURED FROM MR. BURCHILL OR MR. CALLENDER.

AT THE TIME OF THIS WRITING THE EFFECT OF MY DECISION IS STILL UNCLEAR. BLISS INFORMED US, AS OF SEPT. 1, THAT BECAUSE OF THE PENNSYLVANIA RAILROAD STRIKE, THEY WERE UNABLE TO SHIP ANY PARTS OF THE TELESCOPE TO GREEN BANK.

THE POLAR SHAFT WAS DELIVERED TO GREEN BANK ABOUT A YEAR AGO, IN TWO PIECES. DURING THE WINTER DARIN AND ARMSTRONG, SUBCONTRACTOR TO BLISS, SPENT MANY WEEKS WELDING THE TWO PARTS OF THE SHAFT TOGETHER. THIS WORK WAS COMPLETED EARLY IN 1960. SINCE THEN THERE HAS BEEN NO ACTIVITY IN CONNECTION WITH THE 140-FOOT TELESCOPE AT GREEN BANK. DARIN AND ARMSTRONG HAVE CLOSED THEIR FIELD OFFICE. THE SHAFT

LIES AT THE FOOT OF THE PIER AND THE TWO LARGE DERRICKS HAVE LAIN IDLE AND UNUSED FOR ALMOST A YEAR.

THE SUMMER OF 1960 HAS PASSED AND IRRESPECTIVE OF THE ACTUAL TIME OF SHIPPING, WEATHER CONDITIONS MAY MAKE IT IMPOSSIBLE TO ACCOMPLISH MUCH IN THE FIELD BEFORE NEXT SPRING.

I KNOW, AND YOU SHOULD KNOW, THAT MY RECOMMENDATIONS TO PROCEED WITH THE SPHERE AND OTHER COMPONENTS OF THE TELESCOPE IN ACCORDANCE WITH THE ORIGINAL PLAN, THE RESULT OF SUBSEQUENT AGREEMENTS, AND THE CONTRACT AS WRITTEN, RUN CONTRARY TO THE VIEW OF SOME OF OUR OUTSIDE CONSULTANTS AND OF MESSRS. EMBERSON AND HALIK. IT IS HOWEVER STRONGLY SUPPORTED BY THE DEPARTMENTAL CHAIRMEN IN GREEN BANK AND BY MR. ASHTON. I SHOULD LIKE TO HAVE THE APPROVAL OF THE TRUSTEES WITH RESPECT TO THE ACTION I HAVE TAKEN. LACK OF UNANIMITY WITH REGARD TO PROCEDURE DOES NOT MEAN LACK OF UNANIMITY WITH REGARD TO OUR ULTIMATE AIM. THE WORD "SCHISM" HAS BEEN MENTIONED DURING THE PAST FEW WEEKS TO DESCRIBE THE RELATIONS AMONG STAFF MEMBERS OF THE NRAO WITH REGARD TO THE 140-FOOT TELESCOPE. IN CONSULTING THE DICTIONARY I FIND THAT THIS WORD SUPPOSEDLY MEANS "TO TEAR - SPLIT - RENT." AS DIRECTOR OF THE OBSERVATORY I STATE EMPHATICALLY THAT THERE EXISTS NO SUCH THING IN THE NRAO AS FAR AS I AM CONCERNED.

O. STRUVE