OCT 17 1973

NATIONAL SCIENCE FOUNDATION

PROJECT SUMMARY

NSF GRANT NO.
GS-36308X1

NAME OF INSTITUTION (NSF DIRECTORY NAME)		ADDRESS OF INSTITUTION (INCLUDE BRANCH/CAMPUS & COMPONENT)
University of Pennsylvania		University Museum Department of Anthropology Philadelphia, Pennsylvania 19104
PRINCIPAL INVESTIGATOR Froelich Rainey	SOCIAL SECURITY NO. 000-10-0717	DIVISION (OFFICE) AND DIRECTORATE Social Sciences/Research SECTION
PROPOSAL NUMBER P4S0237-000 (74-02991)		PROGRAM Special Projects

TITLE OF PROJECT

Applied Science Center for Archaeology

SUMMARY OF PROPOSED WORK (LIMIT TO 22 PICA OR 18 ELITE TYPEWRITTEN LINES)

Year 2 of two-year continuing grant.

Original project summary still in effect.

DURATION GRANTED	AMOUNT GRANTED
~~12 months~~	~~$109,900~~

A copy of this summary has been sent to the Science Information Exchange at the Smithsonian Institution for reference and public records.

New acct. no.
5-26796

Return to E K Ralph

UNIVERSITY of PENNSYLVANIA

UNIVERSITY MUSEUM

Philadelphia, Pennsylvania

UNIVERSITY OF PENNSYLVANIA

PHILADELPHIA, PENNSYLVANIA 19104

PROPOSAL FOR RESEARCH SUPPORT

Museum Applied Science Center for Archaeology
(MASCA)

National Science Foundation

Division of Special Projects

Washington, D.C. 20550

Principal Investigator: Froelich Rainey, Director, University Museum and MASCA Administrator; Dept. of Anthropology, Graduate School of Arts and Sciences; Professor of Anthropology, The College

School: University of Pennsylvania — Department: University Museum

Starting Date: 1 September 1972 — Duration: Two years

FUNDS REQUESTED

First Year: $143,664 — Second Year: $109,900

Total two years: $253,564

CORPORATE NAME OF UNIVERSITY: THE TRUSTEES OF THE UNIVERSITY OF PENNSYLVANIA
(A Pennsylvania non-profit corporation)

Contracting Office: OFFICE OF RESEARCH ADMINISTRATION, Franklin Bldg, University of Pennsylvania, 3451 Walnut Street, Philadelphia, Pa. 19104

Date: January 1972

Approved: Froelich Rainey
Froelich Rainey
Principal Investigator
Director, University Museum

Approved: Elizabeth K. Ralph
Elizabeth K. Ralph, Faculty Associate, Associate Director of MASCA, Research Associate in Physics

Approved: Max E. Caspari
Max E. Caspari, Chairman
Department of Physics

Approved: ____________________
D. J. O'Kane, Dean of the Graduate School of Arts and Sciences

Approved: ____________________
William E. Stephens
Dean of the College

Approved: ____________________
John N. Hobstetter
Vice-Provost for Research

Approved: ____________________
Martin Meyerson, President

MUSEUM APPLIED SCIENCE CENTER FOR ARCHAEOLOGY

Abstract

Parts I to III of this proposal describe the past, present, and projected activities of the Museum Applied Science Center for Archaeology (MASCA) with emphasis on the latter two. The Center's principal studies include radiocarbon dating, thermoluminescence, dendrochronology, archaeological prospecting with various types of magnetometers and other instruments, and aerial photography with the use of aircraft and tethered balloons. Also, included is an Information Center containing abstracts, reprints and books on current developments in archaeological techniques.

Part IV enumerates the many laboratories, industries, institutions, and individuals who have collaborated (and those who continue their collaboration) with MASCA on short or long-term bases.

Parts V and VI respectively outline the future of MASCA as national center and the physical facilities available to it. A selected bibliography, the academic background and publications of the principals and a budget conclude the proposal.

OUTLINE OF PROPOSAL FOR MASCA

VI. (Cont'd)

d. Aerial Photography

e. Information Center

B. Radiocarbon Laboratory, David Rittenhouse Laboratory

1. Space

2. Equipment

C. Equipment Available in Other Departments of the University of Pennsylvania

1. School of Metallurgy and Materials Science and the Laboratory for Research on the Structure of Matter

a. Electron Microscopy

1) Transmission Types

a) Philips Em 300

b) Siemens Emiskop I

2) Scanning Type

JEOL JSM-U3

b. Analytical Chemistry

c. Metallograph and Photography

d. X-ray Diffraction

2. Department of Geology, Hayden Hall

a. Mirror Stereoscope

(For viewing aerial photographs)

b. X-ray Fluorescence Apparatus

c. X-ray Diffraction

d. Potassium-Argon Dating

MUSEUM APPLIED SCIENCE CENTER FOR ARCHAEOLOGY

I. INTRODUCTION

The Museum Applied Science Center for Archaeology (abbreviated MASCA) was initiated in 1961 by Professor Froelich Rainey. Its aim is to apply new principles and technologies developed in the physical sciences which are appropriate to archaeological and anthropological research.

Upon the successful application of carbon-14 dating in the laboratory (established here in 1951) and in others, it was felt that many more of the technological advances should be investigated for possible applications. As a beginning in this direction, work was started in the following fields:

1) Thermoluminescence dating of pottery
2) Development and use of instruments for archaeological prospecting
3) Information Center and the MASCA Newsletter.

Considering the complexity, scale and diversity of research now being carried out in many laboratories, the role of MASCA is to search out those new discoveries which can be adapted to archaeological purposes through experimentation and modification by its staff or collaborators. Presently, examples of this are radiocarbon and thermoluminescent methods of dating archaeological materials, and the use of magnetometers and aerial photography for archaeological prospecting.

MASCA is principally concerned with those developments in nuclear physics, chemistry, electronics, remote sensing, and other fields which are now producing fundamental changes in scientific technology. Archaeology, like so many other research disciplines, has taken a new direction as a result of these trends in science. MASCA is based upon the assumption that its new direction and changes in the future will continue to draw upon the adaptation of such techniques carried out by both physical scientists, archaeologists, and anthropologists.

Archaeologists in general have been slow to understand and accept as standard practice those scientific applications which have been thoroughly proven in the laboratory and in the field. Therefore MASCA recognizes the necessity of continual dissemination of information about such techniques to the research archaeologist. At the same time, MASCA inevitably performs a continuing day-by-day service in dating, geophysical surveying, materials analysis, and other tasks for archaeological researchers in the University Museum and other institutions. This is a service which is necessary for experimentation and development, yet it is not the center's basic purpose.

MASCA and Oxford's Research Laboratory for Archaeology (RLA) have been the only major organizations with a similar function in archaeology. The RLA is manned by physical scientists only and tends toward basic research - hence its specific objectives and operations are somewhat different from those of MASCA. The latter is based in an institution which carries on anthropological and archaeological research in practically all fields. This leads to a cross-fertilization between the physical sciences and anthropology-archaeology as well as to extensive experimentation both in the field and in the laboratory. Actually, MASCA is in existence because of the fact that the University Museum supports so many expeditions - about fifteen per year, on the average. Because of this large number of expeditions abroad, many of the field trials of our new techniques have been done in collaboration with other institutions where investigators are working on similar developments or at sites which are ideal for trials.

An example of this trend in recent years is the experiment in aerial photography and remote sensing. Both were begun in the course of the search for Sybaris in Southern Italy, first in collaboration with the U. S. Air Force, then expanded to collaboration with the Italian Air Force, continued with specific experiments in the southwestern U.S.A., then joined with the Department of Interior and the National Park Service to carry on experiments with the Royal Commission for Historic Monuments in England. This led to the establishment of a new position in MASCA for an investigator to work specifically on new techniques for aerial reconnaissance.

Discoveries relating to dating techniques have also altered the scope of MASCA's activities. For example, in recent years, measurements of tree-ring-dated bristlecone pines resulted in the discovery that atmospheric C-14 has not remained constant as originally assumed. Now MASCA and other laboratories are working on correction factors to make C-14 dating more accurate, particularly in prehistoric periods. Such research is fundamental in all facets of anthropology.

In sum, as new techniques were discovered and developed over the past ten years, MASCA has tended to search out those investigators, particularly in archaeology, whose work would be benefited by the application of specific techniques. It is this trend which is re-directing MASCA into a national and international center rather than a division of the University Museum, primarily concerned with the research of that institution.

Concurrently with this development, experience has shown that in a period of very rapid technological change, MASCA could be most effective by using the abilities of graduate students trained in the physical sciences along with others who are majoring in anthropology.

In the following pages descriptions of the various endeavors of MASCA are presented as well as plans for new projects.

II. EXPLANATION OF PRESENT AND PAST ACTIVITIES OF MASCA

A. Radiocarbon Laboratory

The radiocarbon laboratory at the University of Pennsylvania was established in 1951. It was initiated by Froelich Rainey and was constructed and has been operated by Elizabeth K. Ralph (with the help of assistants) since that time. It is one of the few laboratories in the world that has devoted itself almost exclusively to the dating of archaeological and anthropological samples. During the past 20 years over 2000 C-14 dates representative of more than 200 archaeological sites have been published. Emphasis has been in the establishment of chronologies for four main regions of the world - namely, the Near East and Mediterranean regions, Central America, South America and the Arctic. Among intensive studies have been the correlation of the Mayan calendar with the Christian, dating of some of the earliest sites and elucidation of human migrations in the western Arctic, the dating of occupations and climatic sequences for what is apparently the earliest site in eastern North America, comprehensive dating programs permitting archaeological interpretation of Mesolithic-Neolithic-Chalcolithic transitions in the Near East and the Anatolian Plateau.

The radiocarbon laboratory is the keystone of MASCA. Because the laboratory and its main staff are supported by the University and partly because of their record of achievement, it has been possible to obtain grants from the National Science Foundation, industries, and private contributors to carry out new programs.

The main function of the C-14 laboratory is the dating of archaeological samples submitted by or of interest to the departmental curators of the University Museum. Samples dated during 1970 were excavated at the following sites:

Lepinski Vir, Yugoslavia

Kyrenia shipwreck, Republic of Cyprus

Franchthi cave, Greece

Porto Cheli, Greece

Korucu Tepe, Turkey

Acem Hüyük, Turkey

Hotu cave, Iran

Nuk, Alaska

Puerco Indian River, Arizona, U.S.A.

El Tigre, Mexico

Marcavelle, Peru

Qaluyu, Peru

Pikicallepata, Peru

The NSF (through the Earth Sciences Division's grants, with E. K. Ralph as principal investigator) supports an additional counter for the purpose of analyzing tree-ring-dated sequoias and bristlecone pines as described under "Dendrochronology" below.

The Foundation for Studies of Modern Science has given us a small grant (total $10,850 for two years) to date samples representative of selected Egyptian dynasties. It is also of interest to us to date samples from the early Egyptian dynasties as mentioned previously.

B. Dendrochronology

The tree-ring dating program is being conducted in conjunction with the radiocarbon laboratory. Tree-ring-dated sections of *Sequoia gigantea* and of *Pinus aristata* are providing samples of known age for C-14 dating (back to 5240 B.C.). By means of these, small fluctuations in the atmospheric C-14 inventory in past times are being assessed. When the magnitude and duration of the fluctuations are known, it may be possible to correlate them with one or more of their basic causes - namely, changes in the cosmic ray intensity, in the intensity of the magnetic field of the earth, and/or in the equilibrium conditions (the balance between the atmosphere and oceans). C-14 dates for these long series of samples of known age are also providing correction factors for the dating of archaeological specimens and others of unknown age.

The tree-ring part of the program is managed by Dr. Henry Michael in collaboration with the Laboratory of Tree-Ring Research, University of Arizona.

C. Thermoluminescence (TL)

Research in the possibility of using thermoluminescence for dating pottery was started in MASCA in 1959 by E. K. Ralph and has been pursued actively by Mark Han since 1962. Significant progress made during the past decade indicates that the method will be a reliable one, possibly comparable in accuracy to C-14 dating, or better in some instances. It has a significant advantage over C-14 dating in that the artifact itself (a few grams of pottery) is dated rather than charcoal or other carbon sample that is merely and sometimes erroneously associated with the occupation level to be dated.

The method is based on the fact that particles from traces of radioactive elements in clays bombard the other constituents and raise electrons to metastable levels. When the clay is heated, enough extra energy is supplied to enable the electrons to return to normal states. In this transition each one emits a photon of light. The final heating of a ceramic is, therefore, the starting point of the metastable electron accumulation. In the laboratory a few milligrams of finely ground ceramic are heated very rapidly so that as much of the light output as possible is detected before the onset of heat radiation. This light is detected by a photomultiplier tube, amplified, and recorded on an X-Y recorder versus temperature. For age determination, the rate of radioactive bombardment is also measured. In addition, the variations among clays in susceptibility to radiation damage is corrected for by artificial bombardment with X-rays and subsequent remeasurement of the glow curve.

The main emphasis continues to be the improvement of this technique of dating pottery. Therefore, we try to concentrate on the dating of series of samples - some of known age, some with associated C-14 dates or other forms of dating.

The first part of a more basic experiment has just been completed - namely, the measurement of the effectiveness of alpha particles versus betas, gammas, and X-rays in producing radiation damage. This has been an unknown factor that has been bothering TL workers for many years, and underlies many of the discussions and friendly arguments between the scientists at Oxford and MASCA. We found that the range of alphas in typical samples of pottery is 22 microns and that the alphas (even though more numerous) are 10% as efficient in producing TL, while betas are 16% and gammas 20% as efficient when compared with X-rays.

D. Archaeological Prospecting

With the threatened destruction of many archaeological sites due to the rapid encroachment of modern civilization, there is a great need for the acceleration of the finding of sites and for the delineation of structures within sites already found. Also, with the cost of labor increasing all over the world, it is becoming impractical to excavate unless there is a certainty that meaningful structures or levels of habitation will be found.

With this in mind, MASCA has tested and used instruments developed previously that are suitable for archaeological exploration. These include the Elsec proton magnetometer, the Gossen Geohm (a resistivity instrument), and various metal detectors and seismographs. In the course of the search for the ancient Greek city of Sybaris, buried at depths of 4 to 6 meters, it was found that proton magnetometers were not sufficiently sensitive for the detection of structures or archaeological deposits at these depths. Therefore, the collaboration of Varian Associates was sought, and as a result, a more sensitive portable cesium magnetometer (with digital readout and differential mode of operation) was designed and developed by them. This and a newer model with a small audio readout are described under "cesium magnetometers".

1. MASCA Cesium Magnetometers

a. Varian Associates Precision Portable Cesium Magnetometer Model 4920.

This instrument was designed specifically for archaeological prospecting by Varian Associates (611 Hansen Way, Palo Alto, California 94303, U.S.A.) at the request of the University Museum, University of Pennsylvania. The components are the readout, cesium sensor (or sensors) and 30-volt battery pack. It is lightweight and readily portable. For those interested in a detailed description, the principles of operation as well as its application in the search for Sybaris in southern Italy are described by E. K. Ralph, Frank Morrison, and D. P. O'Brien in "Archaeological Surveying Utilizing a High-Sensitivity Difference Magnetometer", Geoexploration, vol. 6 (1968), pp. 109-122.

The Model 4920 contains also a difference circuit for use with two sensors. The second sensor may be used either in a gradiometer arrangement or it may be placed in a fixed location in the center of a grid. The second sensor serves to cancel out diurnal and other extraneous magnetic variations, and only the difference between the fixed and movable sensors is read. In this mode of operation, its maximum sensitivity is approximately 0.05 gamma.

At sites with large anomalies of the order of 100γ or more, this extra sensitivity is not required, but use of the difference circuit eliminates the tedious process of correcting readings for diurnal changes. The great advantage of cesium and of other alkali vapor magnetometers over proton magnetometers is speed. The measurement display interval in this instrument may be selected on the basis of desired speed of operation, from a minimum of 1.5 seconds to infinite (or manual).

This cesium magnetometer is especially suitable for recording readings in a grid pattern.

b. Varian Associates Portable Search Magnetometer Model V-4971-Audio Type.

This instrument consists also of a readout, one cesium sensor, and battery pack. The big difference is with the readout. This readout is very much smaller and simplified. It contains an oscillator which can be varied with a control knob to match the Larmor frequency from the sensor. This readout is particularly suitable for doing rapid exploratory lines. One sets the dial at "null" and then while walking along, one need only listen to changes in the audio tone from the loudspeaker to know whether or not anomalies exist. If desired, one may pause to take a reading to find out the approximate magnitude of each anomaly.

This readout, referred to later as the "audio" readout, is most useful for preliminary exploration, and for finding the limits of sites beyond the areas covered in detail by grids. It is also the more suitable of the two for detecting narrow linear features such as shallow ditches.

2. Fluxgate Magnetometer

A new fluxgate gradiometer (Schonstedt Model GMB-2) has recently been acquired. It weighs a total of 5 lbs., is very portable, and very fast to use where only an audio signal is required - such as for preliminary runs at a new site. Its sensitivity is comparable to a proton magnetometer (about 2 gammas).

The first locally conducted field test of it was encouraging. The brick walls of a cesspool about 1/2 meter deep were detected very clearly. Also, there was no difficulty in locating an iron water pipe 1 meter deep.

3. Seismic-Sonic Experiments

It was found that standard seismographs were of little use in finding the relatively small archaeological features, usually located above much more massive geological changes - the wavelengths are too long. Therefore, experiments directed toward the development of a new sonic instrument were conducted. Much information about the problems involved has been obtained, but a successful portable design has not yet been achieved.

4. Field Surveys

Three of our four graduate student assistants have been trained in the use of magnetometers, resistivity instruments, metal detectors and in the techniques of archaeological prospecting. This training has taken place mostly at local historical sites.

More extensive magnetometer surveys were conducted during the spring and summer of 1971 at Aleria in Corsica, Gravina di Puglía in Italy, Kingscote in Gloucestershire, England, and at Wissant near Calais, France. F. Rainey and E. Ralph carried out these surveys with the help of B. Bevan (in Corsica) and with various volunteers at all sites. The successful finding of a variety of anomalies representative of archaeological features is being described in the respective survey reports.

The survey at Kingscote served also as a test of anomalies detected in aerial photographs. The correspondence between the aerial and magnetometer anomalies was excellent. All of the instrument surveys conducted by MASCA during the past 10 years are ...ented in Table I.

TABLE I

Summary of MASCA Instrument Surveys

Site	Buried Features Sought	Magnetometers	Resistivity Instruments	Supplementary Instruments
THE NEW WORLD U. S. A.				
Independence Square Philadelphia, Pa.	house foundations	excessive magnetic disturbances due to city location	good detection	
Rifle Works, Harpers Ferry, W. Virginia	structure of Rifle Works	excessive disturbances from modern iron	located turbine pit	seismograph provided some indication of turbine pit
Isle Royal, Lake Superior, Michigan	copper ore deposits	not suitable	not suitable	some hot spots were found with metal detectors
Fort Loudon, near Chambersburg, Pa.	trenches and embankments of fort	indications of location of trenches and embankments	not suitable	
Caleb Pusey House, Chester, Pa.	house and other building foundations	excessive magnetic disturbances due to location near town	excellent detection of eastern extension of house - later confirmed by excavation	
Hagley Mills, Wilmington, Del.	structures of powder works	located large conduit and many large iron fragments	some indication of location of conduit	metal detector confirmed presence of many large iron fragments and metal pipes

Site	Buried Features Sought	Magnetometers	Resistivity Instruments	Supplementary Instruments
Eleutherian Mills, near Wilmington, Del.	features of the garden of former residence of E. I. duPont	pieces of modern iron caused confusion	good detection of well, drain, and other features	
Hope Lodge, Whitemarsh, Pa.	foundations of mansion and out-buildings	not tested	good detection of foundations	
Snaketown, near Chandler, Arizona	features from period of A.D. 1 to 1400	excellent detection of large firepits - confirmed by excavation	not suitable	
Salvage site, near San Xavier, Arizona	small features representative of Indian occupation	test site for new cesium magnetometer; site was not especially suitable for magnetometers	not suitable	
Buttes Dam Site, no. of Tucson, Arizona	Indian occupation site	presence of magnetic volcanic rocks negated usefulness of magnetometer	not suitable	
Camden, South Carolina	wooden structures of Revolutionary Fort Camden	remains of structures sought did not offer magnetic contrast; located unsuspected gas pipeline	sandy soil and hence poor coupling to ground provided false anomalies	standard aerial photograph showe small variations in vegetation whi may correlate wi structures soug
Harvard Forest, Petersham, Mass.	collaboration with soil scientists to find out if different types of soil in this region differed in magnetism	magnetic bedrock at variable depths negated usefulness of magnetometer	not suitable	

Site	Buried Features Sought	Magnetometers	Resistivity Instruments	Supplementary Instruments
St. Croix Island, near Calais, Maine	former structures of early French settlement, A.D. 1604	detected a number of anomalies, probably representative of structures and graves	numerous ant hills and looseness of the soil due to the activity of ants or other causes, such as excess sand, caused false anomalies.	
Beverick Manor, New Jersey	Foundations of original Manor House	anomalies found		
Mount Clare House, Baltimore, Md.	Tunnel leading from house	not suitable	found foundations extending from house	
CANADA				
Fort Louisbourg, Nova Scotia	graves and tunnels under embankments	excellent detection of graves; vague indications of tunnels	grave detection confused by proximity of bedrock; some indication of tunnel locations	seismograph confirmed that bedrock was only 4 ft. deep; many iron objects detected with meta detector
Fort Lennox, Île-aux-Noix, Quebec	many structures and graves	good indication of region of structures, but not so precise as resistivity; good detection of graves	excellent pinpointing of structures-confirmed by excavation	metal detector located various metal objects at shallow depths; seismograph gave vague indication of bedrock
Campbellton, New Brunswick	Sunken ships	trial survey made on ice; good anomalies over known locations of two ships; to be continued this winter over unknown ships	not suitable	

Site	Buried Features Sought	Magnetometers	Resistivity Instruments	Supplementary Instruments
CENTRAL AMERICA				
Tikal, Guatemala	buried structure in N. Acropolis, W.Plaza, and Temple I	unable to tune proton magnetometer for magnetic field in this region	anomalies confused by structures too complex; could not distinguish structures from pits	
San Lorenzo, Veracruz, Mexico	Olmec monuments 1200-900 B.C.	excellent detection of monuments due to the fact that they were made of magnetic basaltic rock	not needed	
NEW WORLD Etzatlan, Jalisco, Mexico	Jalisco shaft tombs	top soil too magnetic		Experiments with new Bison Signa Enhancement Seismograph, but no difference in velocity between loose top soil and shafts.
THE OLD WORLD IRELAND				
Novan Fort, near Armagh, N. Ireland	mound site	indecisive results	not suitable	
Dun Ailinne, near Kilcullen, County, Kildare.	traditional royal site; possible seat of the "High Kings"	detected large anomaly representative of center of Iron Age occupation	anomalies confused by proximity of bedrock and boulders	
TURKEY				
Gordion	location of tombs under tumuli; structures on city mound; Persian road	variable magnetic earth caused anomalies much larger than ones anticipated from archaeological	located Persian road where it existed; and structures on city mound to depth of 2-3 meters	

Site	Buried Features Sought	Magnetometers	Resistivity Instruments	Supplementary Instruments
ITALY				
Sybaris	the 7th - 6th century B.C. city	See Rainey, F. and Lerici, C. The Search for Sybaris, 1967 MASCA used magnetometers at this site for a total of 2 years (over an 8-year period)		
Tarquinia and Cervetri	Etruscan tombs	reasonably good detection of tombs	approximately 50% detection of tombs, but very slow	seismograph not useful
Artena	city walls and structures	magnetic earth negated usefulness of magnetometer	good detection of foundation walls of structures	
Foce del Sele, near Paestum	6th century, B.C. Greek sanctuary	no archaeological features were detected although most of the zone of interest was surveyed	not suitable on alluvial plain	
Metapontum	6th century, B.C. and later Greek city	excellent detection of walls and structures	not suitable	magnetometer anomalies helped to confirm and to clarify anomalies detected in aerial photographs
Gravina	structures from many periods	many anomalies, but correspondence was confused because of presence of structures almost everywhere	not tested	

site	Buried Features Sought	Magnetometers	Resistivity Instruments	Supplementary Instruments
Veii	city site	erroneous anomalies, due to magnetic earth	ground was too dry in summer	
Siris	6th century B.C. Greek city	no true anomalies found; confirmed by drilling	not suitable	anomalies seen in infrared aerial photographs prove to be erroneous
GREECE				
Helice	7th - 6th century B.C. city	whole area covered with modern iron	not suitable	
Porto Cheli	4th century B.C. harbor walls	structures not detected due to lack of contrast in magnetism	ground was too dry in August; should be tried in wetter season	
Thera	Bronze Age structures	presence of magnetic volcanic gravel negated usefulness of magnetometer	not suitable due to loose pumice and great depth of structures	seismograph provided some indication of depth of bedrock and, hence, thickness of pumice layer
Elis	5th and 4th century B.C. city	excellent detection of walls which will enable reconstruction of part of the city plan	not suitable	
YUGOSLAVIA				
Divostin and other sites near Kragujevac	Neolithic houses	excellent detection of burned Neolithic house floors, and even of "city" plan at Grivac	not suitable	

Site	Buried Features Sought	Magnetometers	Resistivity Instruments	Supplementary Instruments
ITALY				
Ciro	other structures in region of Greek temple	several anomalies that may represent buried structures	not suitable	
Cosa	Roman harbor	magnetic earth	detection of some anomalies	
Gravina di Puglia	Neolithic occupation sites	good success in finding pits in tufa bedrock, pits representative of occupations	not required	
FRANCE				
Aleria, Corsica	Etruscan tombs	found Roman kiln with roof intact, and very early (possibly) Etruscan tombs	not suitable	
Wissant, near Calais	Roman fortress	promising anomaly found within the high enclosure	not required	
ENGLAND				
Kingscote, Gloucestershire	Roman structures	found many promising anomalies	not required	Anomalies were in exact correspondence with ones detected in aerial photographs

E. Aerial Photography

For many years a few archaeologists have made use of aerial photographs, usually ones that have been taken for other purposes. These photographs, although not optimal, have been helpful in the mapping of sites and in studying their topographies. Now, MASCA and other groups are making a concerted effort to obtain photographs and to utilize other techniques of remote sensing to delineate archaeological features as clearly as possible.

As mentioned on page 3, this activity of MASCA started in 1966 over the plain of Sybaris in southern Italy with the collaboration of the U. S. Air Force and Aerofototeca in Rome and was expanded to include the collaboration of the Italian Air Force. More recently, specific experiments have been carried out in the southwestern U.S.A. in collaboration with the Department of the Interior and the National Park Service; and in England, with the Royal Commission on Historical Monuments.

There are four overlapping goals of MASCA's aerial photography, namely:

1) The discovery of surface, underwater, or buried structures;
2) The determination, by topographic reconnaissance, of an archaeological site in relation to its immediate environment;

3) The mapping of ground plans and architectural details and of certain types of artifacts in excavations;

4) The creation of a library of aerial photography for instructional and archival purposes.

Diverse aerial platforms are required for the above types of photography. Airplanes, rented or borrowed, have been the backbone of our prior work. Satellite photography, from manned space missions and the earth resources technology satellites (ERTS) soon to be launched, will be valuable in obtaining an hundred square mile overview.

For low altitude photography, we are collaborating with Julian Whittlesey of New York City and now a Research Associate in MASCA, who plans to donate his balloons, kites, and "bipod" to the University Museum. His balloons and kites are excellent skyhooks for supporting cameras at altitudes of up to several thousand feet. A manned hot air balloon allows a photographer flexible camera positioning. Radio-controlled cameras are required for the hydrogen balloons and Jalbert airfoil kites because they do not have sufficient lift to carry a photographer. A "bipod" camera stand furnished with guide-ropes enables the precise positioning necessary for photogrammetry; the stand, in form of a giant inverted-V, holds a camera at its apex, some 30 feet above the ground. Bruce Bevan of MASCA worked with Mr. Whittlesey and learned the techniques of balloon photography during the 1971 summer field season.

F. Information Center

An extensive part of the work at the MASCA Information Center is the compilaton of author and subject indices which form a catalogue of scientific techniques of value to anthropologists and archaeologists and include reports of analyses, dating methods, field studies, and conservation methods. The abstracts of articles and references, and information on new developments which are the basic components of the files, are culled from many publications in diverse fields. The files are a source for the most recent information concerning archaeological techniques and include, in addition to published material, unpublished information, gathered from correspondence and experimental notes.

The Information Center, now that a considerable volume of data have been collected, is becoming more useful to members of the staff, students, and visiting scholars.

In addition to library and abstracting work a Newsletter is published twice a year, in which current developments in the field of techniques are reported. The mailing list now contains almost 2000 names and is world-wide. The center receives notes and articles from many foreign sources as well as from the U.S.A. There is a continuing need for such articles, notes, and reports and all persons engaged in work containing new techniques applicable to archaeology are urged to send us information.

MASCA has also edited (H. N. Michael and E. K. Ralph, co-editors) and written some of the chapters (F. Rainey, Foreword; E. Ralph, C-14; J. Winter, TL; H. Michael, Dendrochronology) for a Handbook on Laboratory Techniques entitled "Dating Techniques for the Archaeologist". (Published by the M.I.T. Press in November 1971).

III. DESCRIPTION OF PROPOSED NEW AND CONTINUED RESEARCH

In this section we are following the letter sequence of the previous section for the enumeration of activites which we plan to continue, but we shall emphasize only the expansion or new direction of those already described.

A. Radiocarbon Laboratory

1. Archaeological Dating

During the next year, we plan to continue the dating of representative samples from sites in Egypt and Greece as noted below:

1) Egypt - samples of "short-lived" materials that are truly representative of the middle and early Egyptian dynasties. Some of these samples were excavated by Lanny Bell (Assistant, Egyptian Section, University Museum) and others have been collected in Egypt by H. Michael.

2) Greece - samples of "short-lived" materials that are representative of the early Minoan periods. Recently excavated samples have been collected by H. Michael at Akrotiri on Thera, and related sites.

Some of the other series on hand in the C-14 laboratory are from the following sites:

Aikhjanoum, Afghanistan

Anangula, Arctic

Hasanlu, Iran

Haji Firuz, Iran

Bronze and early Iron Age Sites in Bohemia, Czechoslovakia

Korucu Tepe, Turkey

Port Royal, Honduras

Kish, Iraq

Franchthi cave, Greece

Dixthada, Alaska

Old Agora, Athens, Greece

2. Bristlecone Pines

We plan to continue the C^{14} dating of tree-ring-dated sections of bristlecone pines, with emphasis on the oldest samples as they become available.

3. Enlargement of the Radiocarbon Facilities.

During the 20 years of operation of the C^{14} laboratory, we have never succeeded in catching up with the backlog of good samples which have been submitted. Now, our present equipment is 15 years old, breakdowns are frequent, and the backlog of archaeological samples is increasing (caused also by the numerous expeditions that the University Museum supports). Also, the Department of Geology has been reorganized and expanded under the direction of Dr. Henry Faul and we are receiving requests to date geological samples.

Therefore, in collaboration with the Departments of Physics and Geology, and the University Museum, funds have been obtained to add a third counter to help this situation. This third counter is a liquid scintillation spectrometer as opposed to the two carbon dioxide proportional counters now in operation. The equipment and the chemical train for converting carbon dioxide to benzene have been installed, but in doing so we have used up every bit of space in the Radiocarbon Laboratory (rooms BW4 and BW6, David Rittenhouse Laboratory). Funds are needed to renovate, seal, and air condition an adjacent storeroom (which is available) in DRL. The operation of the C^{14} laboratory will be inefficient until more space can be provided. The specific costs of this addition and renovation are listed in the First Year Budget.

When this new liquid scintillation system is working smoothly, we hope gradually to replace the old proportional gas counting components with additional scintillation spectrometers, which are now less costly and available commercially.

B. Dendrochronology

Aside from the continuation of C^{14} analyses of bristlecone pine samples (mentioned under III, A-2), the laboratory plans to initiate, in collaboration with the University of Arizona, a dendrochronological examination of woods (mostly Pinus nigra) from the University Museum's excavations at Gordion, Turkey, in an attempt to establish a "floating" chronology and to correlate it with the 800-yr. floating chronology established by Bryant Bannister (University of Arizona) in 1965 on the basis of cross-sections of logs from Tumulus MM ("The Great Tumulus") at

Gordion. If successful, the project may enable refinement of the archaeological phases at Gordion.

C. <u>Thermoluminescence (TL)</u>

As in the C-14 laboratory, as samples become available, series representative of the Egyptian dynasties and of Minoan periods from Thera and related sites in Greece will be dated. Also, Professor Watanabe has agreed to send us series of sherds from the Jomon periods of Japan. On the basis of corresponding C-14 dates for the chronology of style changes, there is an apparent gap from 3500 to 6000 B.C. This may be related to the problems of the changes in the C-14 inventory, and it is hoped that TL dates will answer some of the questions. There is also an apparent gap in the series from Hasanlu, Iran and adjacent sites. Since we now have 79 C-14 dates for the Hasanlu periods, we are endeavoring to obtain more TL dates. It is planned also to date more <u>excavated</u> samples of early pottery from Çatal Hüyük and Haçilar, Turkey.

We expect to repeat the alpha experiment with several more types of pottery.

Experiments with the dating of faience and a variety of fired materials other than ceramics are planned. Egyptian faience is made from glazed powdered quartz. It is known that quartz has the property of yielding TL when subjected to radiation. In pottery most of the radiation is supplied internally from the clay minerals which contain measurable traces of uranium and thorium. In the case of faience, we find that, upon heating, the TL is readily detectable, but that it contains neither inherent uranium nor thorium. Its TL, therefore, must be due to its relatively small inherent K^{40} content and to external radiations, from the ground or walls of the tombs and from cosmic rays.

To measure the external radiation doses, which the objects of faience have received, we are planning to install TL dosimeters in the tombs where the objects were found. Arrangements have been made with the Egyptian anthorities to install suitable phosphors in five tombs at Thebes: - a) No. 34 (Tuthmosis III) b) No. 35 (Amenhotep II) c) No. 35 (Of Bekenhons) d) No. 269 at Dra-Abu-el'Naga e) Tanis Royal Tomb III (Psusennes I) for prolonged periods (six months to a year). We then plan to calculate the equivalent radiation from the TL response of these phosphors.

Preliminary experiments and calibrations with $CaSo_4$-Dy dosimeters (the types which seem to be optimum) have been performed. It has been found that their response at low dosage rates shows a linear relationship between yielded TL from gamma radiation. We are, therefore, optimistic that these dosimeters will provide accurate measurements of annual dosage rates from natural causes.

The reason for the emphasis upon faience is that numerous samples are readily available that are representative of the long period of time from predynastic times to as late as the fourteenth century A.D. If a consistent series can be dated, some of the ambiguities now apparent in the C^{14} dates may be resolved.

In regard to financial support, to conduct these experiments a second TL glow-curve apparatus is being assembled to measure the dosimeter materials (with funds from the current NSF grant GS 2716). This will be similar to the equipment now in use for pottery, but will be more flexible, and the photomultiplier tube (PMT) will be selected to match the spectral characteristics of the dosimeters. The parts, however, will be interchangeable with the present apparatus so that the second set may also be used for pottery by simply changing the PMT.

For the next two years, funds are requested for the following:

1) Replacement of components (both for the first TL glow-curve apparatus and for the alpha counters) - ones which have broken down fairly frequently and have caused serious delays.

2) New components (as listed in the First Year Budget) will enable us to detect TL with greater sensitivity and to determine the total photon yield, by integrating the TL

glow-curve area. Another spectometer is needed for use with a ninth alpha counter. Since the rates of alpha disintegration are so low, pottery samples must be counted for, at least, 100 hours. Therefore, we have found that nine alpha counters are required to keep abreast of our production rate of TL measurements.

D. Archaeological Prospecting

1. Instruments

a. Magnetometers

Our precision cesium magnetometer is now seven, and the audio assembly, four years old. From our experience with the precision readout, especially, we now know of improvements that can be made to make it slightly smaller in size and more rugged. The latter will help to reduce time-consuming breakdowns in the field as well as to permit non-technically trained personnel to use the equipment with assurance. Varian Associates is now manufacturing sensors which are slightly smaller and lighter which will contribute also to a reduction in the bulk and weight of the equipment. This will not only facilitate its use in the field, but will reduce the cost of shipping it abroad. Also, with the addition of a second differential system, it may be possible to keep one in Europe, which will further reduce shipping costs and occasional difficulties with customs.

We plan to purchase two of the new cesium sensors from

Varian Associates, but we may construct the readout ourselves in collaboration with the Department of Electrical Engineering.

b. Susceptibility Meter

In order to determine the suitability of a site for magnetic prospecting ahead of time, it is frequently necessary to measure samples of the soils and rocks, and the building materials (if known and available, such as those from a test excavation). These measurements help to eliminate costly and time-consuming trips to sites that have no contrast in magnetism between man-made and natural materials or have soils and/or natural rocks that are much more magnetic than the sought for features.

Since there is not a suitable susceptibility meter at the University of Pennsylvania, we have obtained the generous help of the Department of Geology of Princeton University. However, the meter there that is readily available produces only comparative readings. This makes it difficult to compare the magnetic contrasts from site to site. This, plus the fact that it is time-consuming to travel to Princeton are the reasons for our wanting to purchase a susceptibility meter (as listed in the First Year Budget).

c. Other Instruments

(1) Resistivity

We have three Gossen Co. Geohms and associated rods and cables. These units are ideal for resistivity prospecting at shallow depths (down to two meters). For deeper surveying, however, a more powerful instrument such as the Bison Model 2350 A is better. Until we have more demand for its use, however, we plan to rent (or borrow) this unit as needed.

(2) Seismographs

In the past we have experimented with a variety of seismographs, but again we have found the new Bison Signal Enhancement Model 1570 B to be the most suitable. Through the kind of collaboration of Bison Instruments, Inc. we borrowed the Model 1570 (the predecessor of the newer Model 1570 B) for use in Mexico during the 1971 winter field season. Therefore, we plan to borrow (or rent, if necessary) this seismograph as needed since our demand does not warrant the purchase of a seismograph at this time.

In order to continue seismic-sonic experiments in the laboratory (or locally, out-of-doors), we plan to purchase a few minor components to supplement our existing equipment.

2. Field Surveys

A few of the surveys listed in Table I may be continued during the next year. Another try is scheduled to be made in March 1972 in the region of Etzatlán (Magdalena Lake Basin), Jalisco, Mexico to search for shaft tombs. Prospecting "tools" will include aerial photography, the use of a bulldozer to clear away a meter of disturbed (non-archaeological) magnetic top soil at El Arenal, magnetometers, a resistivity instrument, and possibly a seismograph.

Requests have been received also for surveys to be conducted at the following sites:

a) Idalion, Cyprus (in collaboration with the University of Connecticut and Harvard University)

b) Camonica Valley, N. Italy (in collaboration with Prof. Emmanuel Anati, Director, Centro Camuno di Studi Preistorici, Brescia)

c) Sirii, S. Italy (in collaboration with D. Adamasteanu, Soprintendente alle Antichitá della Basilicatta)

d) Malyun, Tepe Malyun, S. Iran (directed by Robert Dyson, Curator of the Near Eastern Section, University Museum)

e) Various sites in England

   1) (in collaboration with G. de G. Sieveking, Assistant Keeper, The British Museum)

   2) (other ground surveys in connection with aerial photography such as that at Kingscote, in collaboration with John Hampton, Royal Commission on Historical Monuments)

f) Malkata, Thebes, Egypt (directed by David O'Connor, Associate Curator of the Egyptian Section, University Museum).

It is anticipated that the sites listed above will be suitable for magnetometer surveys although we are waiting to receive samples of soil for testing from several of them. Other field trips and experiments with more remote sensing will be described under "Aerial Photography".

Funds for travel and living expenses at the various sites will in some cases be provided for by the collaborators or expedition accounts. Student assistants travelling abroad will be supported by the Ford Foundation Fellowships.

E. Aerial Photography (AP)

For the sake of continuity, our caption continues to be "aerial photography". However, new experiments will fit more appropriately within the term "synoptic imagery". These will include both photographic and non-photographic (thermal infrared or radar) sensing from satellites, aircraft, and balloons.

We plan to initiate more tests of new synoptic imaging sensors for applicability to the search for buried objects. Underground artifacts indirectly reveal their presence by influencing the overlying soil and vegetation. This influence is often visible as a color anomaly, or in more general terms, a spectral signature contrast. Visible, infrared and microwave frequencies can be tested for the best visibility of anomalies. Initial results from an experiment in England show that false color infrared photography can enhance anomalous crop marks part of the time. More trials with photographic and thermal infrared mapping are required for general conclusions about the suitability of the infrared spectrum anomaly detection by imagery.

As we have learned from our collaboration with the Royal Commission on Historical Monuments (England) and others, one of the most critical factors in the success of AP has been the time of year that the photographs are taken. This is because of the fact that in many cases the contrasts due to soil moisture or plant growth are detectable for only one or two weeks during the year.

Plant growth contrast at any time is determined by two things: inherent contrast capability fixed by differences in soil with location, and the past history of precipitation and evaporation. Future soil moisture changes can be approximated with weather predictions. The difficult problem here is in determining plant growth at each time during the growing season as a function of soil moisture at that time. A crop agronomist could best handle this part of the problem.

Once the growth-time-moisture factors are understood, a resistivity meter may be used to record the soil moisture history for an area and the proper time for aerial photography can be predicted. This combination of techniques can save the very large expense of having photography taken when surface marks are not visible.

There are many indications now that crop marks can remain visible for a longer period of time if only selected portions of the visible and invisible electromagnetic spectrum are used for photography and sensing instead of the broad spectrum averaging done by panchromatic films.

The selection of the best spectral band combinations can be done by trial and error. It would be faster, however, to measure the spectral visibility of normal and anomalous crop growth by using a spectrometer in a field with known crop marks due to buried structures. With this complete information on the spectral contrast to be expected, an optimum photographic (or non-photographic infrared scanner) system can be designed.

The soon to be launched Earth Resources Technology Satellite (ERTS) will provide unique photography for archaeology. Since it is capable of taking 100 mile square photographs of any area of the earth, this big picture will provide an excellent overview of the context of an archaeological site within its countryside. Topographic factors, easily visible with the 200 foot resolution of the space cameras, can allow archaeologists to estimate the likely location of ancient roads and fields, to be tested later by field examination.

An excellent test site for this capability will be the southern Argolid Peninsula of Greece. Here, Dr. M. H. Jameson, Department of Classical Studies, University of Pennsylvania, and Dr. T. W. Jacobsen of Indiana University are currently making a regional study of the potential, in ancient times, for such factors as agriculture and transportation. Since they have been hampered by not having continuous coverage by aerial photography available, space photography would be doubly valuable.

Another valuable feature of the earth observation satellite is that it will be able to photograph any area once every 18 days. Its photographic resolution will be much too crude to see archaeological anomalies of the crop mark type which we detected in the experiment in England, which pointed out also that photography must be done at just the right time. In this test it was noticed that large geological patterns, apparently ancient buried river meanders, and the archaeological patterns near them both produced crop marks at about the same time. These geological anomalies will probably be visible in satellite photographs; therefore the satellite will tell us what time to take low level photographs from an airplane in order to see small features.

The upper Mississippi-Missouri valley in the great plains is the logical choice for a test site. Here we have the right combination of a meandering river, known crop marks indicating Indian sites, low population density, little forest cover, and the urgency of salvage archaeology.

For the above experiments we shall need the items of equipment as listed in the First Year Budget.

F. <u>Information Center</u>

We plan to continue the compilaton of abstracts and articles. With the addition to the staff of a full-time research bibliographer, we anticipate that this work will be done more systematically and that many more journals may be included in the list for regular inspection. The bibliographer will be assisted by volunteers and part-time secretarial help as at present.

We hope that we shall receive a sufficient number of reports, both from outside and from members of MASCA to publish our Newsletter more frequently than twice a year.

Our MASCA handbook entitled "Dating Techniques for the Archaeologist" has been published too recently (November, 1971, M.I.T. Press) to learn of its success. However, it has received favorable verbal comments, and we anticipate that it will be as useful as its intent. Therefore, we plan to publish others in the future and to up-date those already published if new editions are required. The next book scheduled will cover archaeological techniques that are or can be performed in the field. By these, we do not mean the standard procedures that archaeologists and anthropologists spend years to learn. We mean the application of techniques derived from the physical sciences that are now contributing to standard field research. Two diverse specific examples are magnetometer surveying and chemical techniques for the cleaning of objects which can be done at the site.

We plan to continue to acquire essential books for our small library and to enlarge our files of black and white photographs, colored lecture slides, and aerial photographs.

In the next sections, we shall describe some of the completely new or reoriented activities that we have not yet pursued actively.

G. Chemical Techniques

1. In the Field

In collaboration with excavators, geochemists, and engineers, we plan to experiment with chemical techniques in the field. For example, as an excavation progresses, there is frequently a need to consolidate walls or to eliminate a water problem. Sometimes, the problem is reversed, i.e., there is too much dryness so that contrasts in soil cannot be detected. We hope to devise chemical means of enhancing the contrasts in soils, both at dry and wet sites.

2. In the Laboratory

We anticipate the active collaboration of senior members and chemists from the Rohm and Haas Company in devising new means for identifications and classifications of elements and compounds that are significant components of artifacts. The know-how and facilities of the Rohm and Haas Research Laboratories will be sought also in the course of the search for appropriate chemical compounds for use at excavations.

H. Cavity Detection by Acoustic Resonance

Air-filled cavities, whether natural or man-made, are important in archaeology because of the possibility of the existence of artifacts within them. Laboratory techniques have already been developed for the detection of air pockets in walls by the changes they cause in seismic transmission and reflection. For field usage, simple and rugged equipment is needed for the exploration of large areas in the search for cavities.

The basic acoustic phenomenon of an air-filled cavity is the resonance of the included air over a sonic spectrum determined by the cavity dimensions when it is excited by broad spectrum seismic waves striking it. This acoustic resonance technique would be usable only when cavities are surrounded by compact, homogeneous material such as bedrock, which is the case with many tombs. This is because the moderately high seismic frequencies required would be absorbed in any other medium before reaching the cavity. Once a cavity is made to resonate, it slowly reradiates its energy by way of seismic signals which would be detectable on the rock surface by their characteristic drawn-out and narrow frequency tone.

At its simplest, the required field equipment would consist of a hammer for generating the seismic signal and a geophone-amplifier-earphone system for detecting resonance. However, concurrent theoretical and experimental work would be necessary to determine the practicality of this simple technique.

I. Talus Formation and Cave Mouth Blockage

Caves have provided much information about prehistoric man. Such a cave will typically be in the side of a cliff; its mouth will be at the top of a talus slope caused primarily by rock fall from the cliff above the cave entrance. One wonders how many caves are now hidden from the archaeologist because of cave entrance blockage by rock fall since occupation by early man.

Neither the processes of cliff erosion nor the rates are known for the variety of climates and rock types of interest. A determination of rock talus buildup over a period of several thousand years could indicate the presence of these earliest habitats and the desirability of locating any that might be present.

J. Fission Track Dating

Members of the Department of Geology under the direction of Dr. Henry Faul, Chairman, are now pursuing studies and experiments with the technique of fission track dating. Heretofore, the precision of the method has been limited by lack of knowledge of the decay constant for the spontaneous fission of U^{238}. This can be determined with samples of glass of known age of manufacture that contain a sufficient amount of uranium. Some have already been located and others are being solicited. This measurement and the completion of other related studies will greatly enhance the precision of fission track dating. It can be applied to archaeological dating as appropriate samples are found. For example, a pot was found recently with a piece of obsidian embedded in it. A fission track date for the obsidian would then date the firing time of the pot. In this case, it is an ideal means of cross-checking fission track and TL dating.

K. Instruction

1. In the Laboratory

At the present time, instruction in MASCA is somewhat hit-or-miss. Classes visit our laboratories frequently, some with previous instruction and some without. The scheduling also has been at the whim of the various class instructors.

Therefore, we plan to present a series of seminars at scheduled times so that each student will have a good background and understanding of dating and other techniques. The seminars will then be supplemented with visits to the laboratories and field trips in smaller groups. The seminars will be illustrated with color slides as needed and may eventually be recorded on films and tapes, which would allow a greater dissemination of information about the techniques of MASCA.

2. In the Field

Many graduate students (about 50 per year) who plan to follow careers in anthropology or archaeology are being instructed at excavations conducted abroad by members of the University Museum. Financial support for this program is from the Ford Foundation, and covers students' transportation to and from and living expenses at the sites of excavation. In addition to the benefits to the students for these traineeships, this grant enables the Museum to support more and/or larger excavations.

We anticipate that this grant will continue for, at least, three more years.

L. Summary

The MASCA projects may, at first glance, seem to be unrelated, but they are in truth logically tied together as follows:

1) Remote sensing - both aerial and balloon photography.
2) Near sensing - ground surveys with geophysical prospecting instruments - espeically, magnetometers.
3) Field chemistry and collection of samples for dating, followed by analyses in the laboratory.
4) Dating of samples in the laboratory - C-14 and TL, etc.
5) Information Center - the collation and dissemination of data gathered from pertinent literature, field surveys, excavations, and laboratory dating as well as of data related to other new techniques.

Before we turn our attention to the future of MASCA as a national facility, we include a section on our collaboration with other centers, research groups, individual scientists, and with other departments within the University of Pennsylvania. We feel that this information together with our activities, past and proposed, will provide the "background" for our becoming a national facility.

IV. COLLABORATION

A. Collaboration with Other Laboratories and Research Centers

1. Laboratory of Tree-Ring Research

MASCA has collaborated with the Laboratory of Tree-Ring Research (TRL), University of Arizona, since 1959. The uniqueness of this laboratory in respect to its program of field research and collection of ancient trees as well as the subsequent dating of the wood, has made collaboration a prime objective, particularly during the past six years. The precisely dated wood samples of the Tucson laboratory are the keystone of one of MASCA's important projects, that is, the comparison of dendro-dated tree-ring samples with radiocarbon dates derived from the samples. The observed consistent variations over a period of more than 7000 years formed the basis for MASCA's correction factors for radiocarbon dates. Further collaboration will be necessary in order to refine the correction factors, which are already of great significance to the archaeologist who deals with periods of human development prior to 1000 B.C.

Reciprocally, MASCA's radiocarbon dating of "floaters", that is, tree-ring samples which could not be readily dendro-dated, has helped resolve some of the problems encountered by the TRL.

C. W. Ferguson is MASCA's principal contact at the TRL.

He has been very active in extending the tree-ring chronology and informs us that an 8200 year span is in sight. He has also worked on a Grand Canyon series which has indicated a potential for extending the tree-ring series even further. Other untapped sources are the alluvial fans which cover the base of the Inyo Range and are known to contain preserved wood carried and buried into them by the many temporary streams during cloudbursts.

2. The Czechoslovak Academy of Sciences

Collaboration with Dr. Václav Bucha, Director of the Geophysical Institute of the Czechoslovak Academy of Sciences has been rather recent, but has increasing potential because the Geophysical Institute is seeking archaeo-geomagnetic samples from all over the world. The University Museum with its far-flung field expeditions and connections with many institutions and schools of archaeology is in a good position to satisfy these needs.

The Geophysical Institute was visited during June-July 1971 by H. N. Michael of MASCA and arrangements were made for archaeo-geomagnetic dating of pottery samples from Crete and Santorini (the Minoan series) and Egypt (Medinet-Habu). Some of the samples have been obtained and sent to Dr. Bucha.

Another example of the utilization of MASCA's findings in Czechoslovakis is the project of Dr. Evžen Neustupný of the Archaeological Institute of the Czechoslovak Academy of Sciences.

Utilizing correction factors on radiocarbon dates of a floating tree-ring chronology determined from logs recovered from a Swiss Neolithic site, he is trying to fit (and thus date) the floating chronology into the master chart that resulted from MASCA's known-age dating project and of that of H. E. Suess (Scripps Institution of Oceanography, La Jolla, California).

3. National Museum in Cairo

The laboratories which serve the National Museum in Cairo are, at present, primarily concerned with metallurgical analyses (by means of X-rays and other techniques), radiocarbon dating, and conservation of museum objects. The Director of Laboratories is Dr. Saleh Ahmed Saleh (trained in Poland) and the Director of the radiocarbon laboratory is Dr. Shawki Nakhla (trained in France). These two scientists and Dr. Zaky Iskander, the Director of Technical Affairs in the Department of Antiquities, collaborated with MASCA's programs in the past (mostly in the collection of dendrochronological, thermoluminescent, and radiocarbon samples) and are now collaborating with the placement of dosimeters in selected ancient tombs - the latter in connection with MASCA's experimental dating of faience.

4. British Museum

I. E. S. Edwards, Keeper, Department of Egyptian Antiquities, British Museum in London, has collaborated with MASCA over the past decade. Suitable radiocarbon samples from Egypt have been exchanged, and over the past two years MASCA's radiocarbon laboratory and that of the British Museum (directed by Richard Burleigh) have carried out comparative analyses of similar samples (in this case, reeds). Additionally, bristlecone and sequoia woods have been furnished to Mr. Burleigh for special irradiation studies.

5. Uppsala University

Ingrid U. Olsson, Director of the radiocarbon laboratory at the Institute of Physics, Uppsala University, Sweden, has recently received from MASCA ancient reed samples from Egypt for C-14 analyses. The point of this arrangement, as well as that with the British Museum, is to check radiocarbon results emanating from different laboratories by dating the same samples. Lanny Bell, Assistant, Egyptian Section, University Museum) collected sufficient quantities of this series of samples so that they could be shared among the three laboratories. Also, the reeds could be homogenized to make certain that each laboratory received identical samples.

6. Columbia University and Others

There are a number of scholars and laboratories in the U.S.A. with whom we collaborate in an informal way. Personal contacts and visits are usually annual or biennial, but telephone conversations and correspondence are more frequent. For example, for inquiries concerning flint, bone and related studies, we have the active collaboration of the following:

a) Dr. Ralph Solecki, Columbia University Lithic Laboratory and Typology Studies in the Old World. (Mr. John Witthoff, Associate Professor of Anthropology, University of Pennsylvania, specializes in similar studies in the New World).

b) Dr. Isabella Drew, Sackler Laboratory, Columbia University.
Studies of soils, bones, etc.
Dr. Drew and her students have recently made significant advances in the differentiation between the bones of domestic and wild animals by means of thin-section studies.

c) Dr. Dexter Perkins, J.
Faunal Research Group
Studies of animal bones

d) Ed Lanning, Columbia University
South American typology and shell studies

e) Dr. Shirley Gorenstein, Columbia University
Trace element analyses of obsidian artifacts from Columbia and Mexico

f) Dr. Bert Salwen, New York University
Studies of shell middens

g) Dr. A. V. N. Sarma, Temple University

Ecological inferences of shell midden contents, particularly organic.

This collaboration with Dr. Solecki and his close associates is listed as a specific example of work being done in other centers, which we have not attempted to perform here. However, by our awareness of their activities, we may refer requests to them and vice versa.

7. Brookhaven National Laboratory and Others

During the past ten years, we have collaborated frequently with the Brookhaven National Laboratory, Upton, N. Y. especially with Dr. Edward Sayre (Dept. of Chemistry) and Dr. Paul Levy (Dept. of Physics). Dr. Levy has been interested in and has been consulted in regard to the fundamental principles of the thermoluminescent phenomenon. From Dr. Sayre and also from conversations with Dr. Isodore Perlman (Lawrence Radiation Laboratory, University of California), we have kept ourselves aware of the progress being made and of the facilities available for trace element analyses by the neutron activation method. We have learned of the significant advantages of this technique over emission spectrographic and other older methods for trace element analyses. MASCA has supplied Dr. Sayre with a 2200-year radius of a giant sequoia for studies of nuclides at Brookhaven.

8. Conservation Center of Art, NYC and RLA, Oxford

For emission spectographic analyses, we have consulted the Conservation Center of Art, Institute of Fine Arts, New York University, and we have also been in touch with them for matters more closely related to conservation. Mark Han of our staff has been trained in the use of emission spectrographs, but there has not been enough demand here to warrant the purchase and time spent in calibrating our own instrument. Therefore, we have been sending samples for analysis to Martin Aitken's group (RLA) in Oxford where they do excellent emission spectrographic analyses for £1 per sample. As mentioned previously our contacts with the Oxford RLA, especially, in regard to thermoluminesence and magnetometers, have been frequent during the past ten years. These include, at least, yearly exchange visits and regular correspondence.

9. Forest Products Laboratory

Excavators who submit samples of wood for dating or other studies, frequently ask to have the genus and species (if possible) of the tree identified. The cooperation of Dr. B. Francis Kukachka of the Forest Products Laboratory, U. S. Department of Agriculture, Madison, Wisconsin in doing this service has always been given generously and with speed. Dr. Kukachka's reports of identifications have always been received within two weeks after submitting the samples.

10. Jodrell Laboratory

Jodrell Laboratory's Plant Anatomy Section, located in the Royal Botanic Gardens at Kew, England, provides to the interested investigator an invaluable and possibly unique service of identifying ancient and modern plant fragments. Dr. D. F. Cutler of that laboratory has collaborated with MASCA by identifying grasses obtained from Egyptian tombs and mud-walls of fortifications.

11. Corning Museum of Glass

A frequent visitor to our laboratories and an appreciated collaborator has been Dr. Robert H. Brill, Administrator of Scientific Research at the Corning Museum of Glass in New York. He has come in search of ancient glass of various types - some of known age, some with layers of hydration, some with abnormally high uranium contents, etc. From him and publications, we have been kept informed on the latest developments in the field of glass studies.

Our relationship with the Corning Museum illustrates as well as any the overall feature of our activities and contacts. Scholars such as Dr. Brill come to us for the following reasons:

1) Artifacts for study and analysis are available in the extensive collections of the University Museum.

2) The Curators of these collections are among the best in the world and because of MASCA's activities within the Museum they are well aware of the problems that can or cannot be resolved through findings of the physical sciences. We feel that this awareness makes consultations with them more valuable.

3) The activities and services of MASCA are usually related in some way to the visitor's interests. In this example there is the similarity between the behavior of glass and the quartz component of pottery as well as faience in regard to thermoluminescence and other effects.

4) The MASCA information center contains references to publications pertinent to the researcher's interests, and also disseminates news of new projects by means of its Newsletter.

B. <u>Collaboration with Industries</u>

1. <u>Varian and GeoMetrics</u>

In Sections II and III we have mentioned several specific examples of our contacts with industries - notably, Varian Associates for magnetometers; and Bison Instruments for resistivity units and seismographs. In regard to magnetometers and computer plots of results, we have had also the active collaboration of GeoMetrics (Palo Alto, California), and, especially, with the

President of the company, Dr. Sheldon Breiner, who was formerly with Varian Associates.

2. Texas Instruments, Petty Laboratories, and Sun Oil

Not recently, but very actively from 1961 through 1964, we have collaborated closely in the course of our seismic-sonic experiments with Texas Instruments, Inc. (Dallas) and with the Petty Laboratories, Inc. (San Antonio, Texas). A large part of this work was financed by the Sun Oil Company.

3. Du Pont

Currently, we are fortunate in having the active participation of Sam Carpenter and Hugh Sharpe (both members of the Board of Managers of the University Museum and active in the Du Pont de Nemours E. I. and Co., Wilmington, Delaware). Each owns and flies a private airplane, and they have both been generous in offering their services for aerial photography, especially, in Mexico and the southwestern U.S.A.

4. Rohm and Haas

Just recently, Dr. Otto Haas, Chairman of the Board of Rohm and Haas Company and a member of the Board of Managers of the University Museum, has volunteered his services to work with MASCA. As a start he is acquainting himself with our activities and visiting other centers of research such as the U. S. Geological Survey and RLA at Oxford. Eventually, his travels will be more extensive in his search for new ideas and techniques that are or can be applied to archaeological-anthropological research.

Specifically, he plans to use his know-how and the facilities of the Research Laboratories of Rohm and Haas to tackle the problem of the consolidation of mud bricks by means of polymer chemistry; and also to investigate better ways of remote sensing.

Also from Rohm and Haas, Darrel Butterbaugh, a retired research chemist, has joined MASCA as a part-time volunteer in the Information Center.

C. Collaboration with U. S. Government Agencies

1. U. S. Army

Collaboration for a different purpose was that with the U. S. Army in 1966. Through a subcontract to Westinghouse Electric Corporation we were asked to loan our Precision Cesium Magnetometer and to give technical assistance to perform tests over tunnels for the detection of metals. These tests were very successful, and led to the development of the cesium Audio Readout (Model V-4971) by Varian Associates. Even though designed for military purposes, it has proved to be very useful for archaeological prospecting.

2. U. S. Air Force and Geological Survey

In the field of aerial photography, we have had an excellent collaboration with Dr. Richard S. Williams. This began while he was associated with the U. S. Air Force in the Terrestrial

Sciences Laboratory of the Air Force Cambridge Research Laboratories at Bedford, Massachusetts. Dr. Williams obtained multispectral photography of the plain of Sybaris as part of the interdisciplinary search for the ancient Greek city. He is now working in the Earth Resources Observation Satellite Department of the U. S. Geological Survey and has lately collaborated on the recent aerial photographic experiment in England.

D. Collaboration with Other Departments at the University of Pennsylvania

1. Collaboration with the School of Metallurgy and the Laboratory for Research on the Structure of Matter (LRSM), University of Pennsylvania.

Our collaboration with the Department of Metallurgy (Univ. of Penna.) began in 1963 with a study of a corroded iron dagger by Mr. Reed Knox under the direction of Professor Robert Maddin, Chairman, and encouraged by Professor Cyril Stanley Smith (Institute Professor, M.I.T.). Subsequently, with the financial support of NSF Grant GP-4766 (1964-1966) entitled "A Training Program in Metallurgy and Archaeology", several graduate students participated in combined archaeological-metallurgical studies. These studies were supervised by Professors Maddin and Smith and by various Curators in the University Museum. The results of two of these were incorporated in PhD theses, and one formed the basis of a Master's Thesis.

The active participation of graduate students diminished at the termination of the grant. Now, however, we intend to resume this collaboration. This will permit members of MASCA, curators of the University Museum, graduate students, and visiting scholars to work with the personnel of the LRSM laboratories in using centers equipped with electron microscopes, microscopic scanners, non-dispersive X-ray detectors, X-ray diffraction equipment, and, of course, metallographic and photographic equipment. (The centers are listed in greater detail under "Facilities").

As leaders in archaeo-metallurgical studies, Professors Maddin and Smith form an ideal team. The former specializes in the study of non-ferrous metals and Professor Smith is renowned throughout the world for his studies of ancient iron. In 1963 Professor Smith offered and gave his active collaboration, and has offered to do so again, especially, now that he is retiring from some of his activities at M.I.T.

2. Collaboration with the Department of Physics

With the radiocarbon laboratory located in the David Rittenhouse Laboratory, which houses the Departments of Physics, Mathematics, and Astronomy, there are naturally frequent contacts with members of the Department of Physics, and a variety of workshops and services which will be mentioned under Facilities.

3. Collaboration with the Department of Geology

Since Dr. Henry Faul became Chairman of the Department of Geology about six years ago, this Department has become revitalized and has expanded greatly. From the beginning, Dr. Faul has been keenly interested in the Radiocarbon Laboratory and our dating programs and other activities. (Dr. Faul is well known for his construction and operation of Potassium-Argon dating equipment.)

As mentioned previously, we are collaborating closely in regard to the Department's experiments with fission-track dating. Dr. Jan Burchart is investigating fission-track analysis and its application to paleothermometry as well as dating.

The Department of Geology's petrologist, Dr. Ian Harker, is collaborating with MASCA in a geological study of The Magdelena Lake Basin in Mexico. This stratigraphic investigation may help to delimit the possible areas in which rock cut tombs will be found. If unlooted tombs can be located, a much better understanding of the ancient Indian culture in West Mexico will result.

A regional survey of the Argolid Peninsula in Greece is currently underway. The excavators in charge of this project are Dr. M. H. Jameson of the University of Pennsylvania and Dr. T. W. Jacobsen of Indiana University. Dr. Robert Giegengack of the Department of Geology is investigating the protohistoric paleoecology of this region and is attempting to understand the sea level fluctuations in this Mediterranean area.

We are collaborating also with Dr. Giegengack in the C^{14} dating of travertines and associated wood samples from Havasu Creek in the Grand Canyon, Colorado.

4. <u>Collaboration With the Department of Chemistry</u>

For many years we have had contacts with various members of the Department of Chemistry. Our closest and most continuous has been with Dr. John G. Miller who is the Professor in charge of the Mass Spectrograph which we use for the measurement of C^{13}-C^{12} ratios (a small correction factor for C^{14} dates).

5. <u>Collaboration with the Department of Electrical Engineering</u>

Members of the university's electrical engineering department are now collaborating with MASCA on the development of new archaeological exploration techniques. In addition to optical imaging system, the possible advantages of radar and passive microwave imagery are being investigated. Electromagnetic sensors can provide both additional spectra for anomaly imaging and underground penetration, and for detection which is impossible with optical wavelengths. One technique already investigated is that of 3D radar with stereoscopic image pairs. The new high resolution side-looking or synthetic aperture radar will also be investigated for possible archaeological applications.

In addition, the potential of very low frequency electromagnetic probing is being tested. When radiated over the surface of the earth, these waves are skewed in response to variations in underground resistivity and magnetic susceptibility. This may lead to a much faster means of resistivity prospecting, which thus far has been time-consuming because of the need to position four probes in the ground for each reading.

The electrical engineers from the Department who are collaborating with us are Dr. H. N. Kritikos and his doctoral student, Mr. A. K. Jordan. A third engineer and collaborator, Dr. B. Steinberg, is Director of the Valley Forge Electronics Research Center.

6. University Museum

Except for the Radiocarbon Laboratory, MASCA is housed in the University Museum. In the Museum also are the Departments of Anthropology (including American Archaeology) and Classical Archaeology as well as all of the Curators of the various sections and collections. Naturally, our contacts with many members of the staff are frequent and fruitful.

Just recently the Museum has begun a closer collaboration with the Office of Archaeological and Historical Preservation of the National Park Service, U. S. Department of the Interior. Dr. John Cotter, Regional Director, is now resident in the Museum.

7. Summary of Collaboration

We have by no means mentioned all of our contacts within the University nor without, but only some of the more recent specific examples of collaboration. Most of these exchanges of ideas and information have taken place biennially or more frequently; whereas others have been "one shot" affairs for specific purposes. Naturally, our contacts within the University are more frequent.

E. Visiting Scholars and Scientists

In presenting these examples, we hope that we have made it clear that MASCA is now a center to which visiting scholars are attracted. In the future and with our expanded facilities and space, we plan to invite scholars and scientists to come here to contribute their know-how for specific projects. For example, as part of our expanded program directed toward the development of chemical and other techniques which will be useful in the field, we may want some one to come here to experiment with the preservation of mud bricks; another, to find means of enhancing contrasts in soils, etc. For these experiments we now have available a large (800 sq. ft.) well-equipped laboratory room.

V. THE FUTURE OF MASCA AS A NATIONAL FACILITY

A. The Information Center

The ultimate aim of any successful research is the dispersal of its findings to those who are seeking pertinent information and who can further test and apply the findings in field and/or laboratory situations. The same is true about purposefully collected information from various fields which play a role in the type of service that the MASCA Information Center has been providing for some years.

The expansion of the services described above will demand first, increased frequency in publishing the existing MASCA Newsletter and second, the intensification of scientific information collecting and correspondence. This, eventually, will call for additional staff and for the full-time employment of a highly qualified editor-abstractor-correspondent, and of a secretary-typist.

B. The Training of Graduate Students

The position of MASCA in the University Museum and the University of Pennsylvania has made it possible for MASCA to accept and occasionally employ students whose special interests and skills pointed to successful training in a particular subdivision of the Center or within the scope of one of the Museum's many field expeditions. The departments of Anthropology, Classical Archaeology, and divisions of Egyptology, Oriental Studies and Biblical Archaeology are all incorporated in the Museum.

It is proposed that, with the help of a Ford Foundation grant, the training of graduate students be systematized by:

1) The establishment of regularly scheduled seminars and/or workshops of short duration, staffed by MASCA's scientific personnel; these would be open to all interested students, the majority of them presumably from the departments mentioned above.

2) Participation in field trips by qualified graduate students from various institutions in the United States and from abroad. This part of the program has been carried on for some years but could be readily expanded in view of the Museum's many expeditions. At present, the Ford Foundation stipulates that students participate in field work in foreign countries only. With additional funding this could be extended to include the more "remote" parts of the United States - namely, Alaska and Hawaii.

3) Participation of carefully selected, qualified students in the day-to-day activities of the Center. This will enable the student to familiarize himself thoroughly with the details of on-going research and eventually make it possible for him to test the findings in a field situation. We visualize such participation as part-time, relatively long-term (one

or two years), and based on either an hourly wage or a credit system to be worked out with the departments involved, or, a combination of both wages and academic credits.

C. Coordination of Research Efforts with Appropriate Agencies and Institutions

There are precedents of MASCA's research facilities being utilized through contracts with agencies of the federal government of the United States, such as the Park Service, Air Force, and Department of the Interior, those of Canada, as well as with several state governments. Approximately a dozen such contracts have been carried out in North America alone, and many more in other parts of the world. The contracts dealt usually, but not exclusively, with ground or aerial surveys at archaeological sites.

The limiting factors to additional service of this type by the Center include

1) Shortage of trained personnel;

2) Shortage of the highly specialized and costly equipment;

3) Shortage of travel funds.

With additional monies on a regular basis, and time to train teams to operate the equipment and interpret the results, MASCA should be in a position to provide further valuable services to archaeology.

One other limiting factor that should be mentioned is that our services must conform with the policies of the University of Pennsylvania, and, especially, with those of the University Museum. For example, we do not intend to accept samples for dating that are not important nor pertinent to a scholar's research. In line with the new policy of the Museum - namely, that no artifacts will be accepted as gifts nor be purchased that have come from unknown proveniences, we shall not perform services, such as TL tests for authentication, that will in any way contribute to the robbery, smuggling, or augmentation of prices of stolen antiquities. By "stolen" we are referring, especially, to objects that have been excavated unofficially and removed from their countries of origin illegally.

Again, we should like to emphasize that as a national facility, we expect to adapt techniques that have already been developed in the physical sciences and apply them to research in the social sciences. In other words, we intend to be useful rather than to conduct pure research with a large staff of highly trained specialists. We feel that our best function is to utilize the work of many laboratories and industries, to coordinate their results, and to apply them. Of course, we shall not overlook our own discoveries and improvements such as those achieved in our experimentation with the dating of pottery by thermoluminescence.

Estimated budgets for the third to fifth years, and for the sixth to tenth are included in this section.

D. Budget Proposal - Third to Fifth Years

1. Salaries and Wages

a. Research Personnel (A-2)

1) Physicist, Geologist, Engineer, or Chemist	$14,000
Full-time - 12 months	
FTE - 12 months	
2) Five Research Fellows	
Three summer months - full-time	
Academic year - half-time	
FTE - 8 man months	
(5 x $4,150)	20,750
3) Editor - Supervisor of Instruction	11,000
Half-time - 12 months	
FTE - 6 months	
Total A-2	45,750

b. Other Professional

Research Chemist (A-1)	14,000
Full-time - 12 months	
FTE - 12 months	

c. Secretarial, Clerical, and Administrative

1) Research Bibliographer II (A-3)	8,165
Full-time - 12 months	
FTE - 12 months	
2) Secretarial, Clerical, and Administrative Assistant (A-3), Half-time - 12 months, FTE - 6 months	4,665
Total A-3	12,830
Total Salaries	72,580

D. (Cont'd)

d. Employee Benefits

15.5% of A-2 (45,750)	7,091
8.5% of A-1 (14,000)	1,190
7.9% of A-3 (12,830)	1,014
Total Employee Benefits	9,295
e. Overhead (37% of Salaries)	26,855
Third Year Total - Salaries, Benefits, and Overhead	108,730
Fourth Year Total	119,600
Fifth Year Total	113,560
Total Salaries, Benefits, and Overhead for Three Years	341,890

D. (Cont'd)

2. Equipment

a. Radiocarbon Laboratory

1) Second Liquid Scintillation Spectrometer	$ 6,000
2) Replacement Geiger Counters	3,000

b. Dendrochronology

Automatised Dendrochronograph	5,000
Increment Core Borers and Other Tools	1,000

c. Thermoluminescence

1) X-Ray Machine, approximately 65 KV, 30MA, with Cu target	8,000
2) Replacement of Older and Less Reliable Alpha Counter Scalers, Discriminators, and Amplifiers with Baird-Atomic Spectrometers Model 530 (or equivalents) (5 x $3500)	17,500
3) New X-Y Recorder	2,500

d. Instruments for Archaeological Prospecting

Design and construction or commercial manufacture of a completely new instrument	50,000

D. (Cont'd)

e. Aerial Photography	
1) Field Spectrometer (Perkin-Elmer or equivalent)	10,000
2) Multispectral Camera (International Imaging Systems, Mark I, or equivalent)	8,000
3) Multispectral Film Viewer (II S, Mini-addcol or equivalent)	8,000
4) Thermal Mapper (Bendix, Model TM/LN-2 or equivalent)	16,000
5) Large Format Aerial Camera (government surplus)	400
f. Equipment for New Projects	10,000
Total - Equipment	145,400

3. Expendable Equipment and Supplies (3 years)

a. Dendrochronology	500
b. Thermoluminescence	7,000
c. Archaeological Prospecting	5,000
d. Aerial Photography	9,000
e. Information Center	4,500
f. New Projects	6,000
Total - Supplies	32,000

D. (Cont'd)

4. Services (3 years)	
Machine Shop	3,000
Electronics Shop	4,500
Rental of Prospecting Instruments	3,000
Aircraft Rentals	10,000
Printing of MASCA Newsletter	5,000
Other Printing and Duplicating	1,500
Other Services	3,000
Total - Services	30,000
5. Travel (3 years)	
Domestic	3,000
Foreign	9,000
Total Travel	12,000
6. Expenses (3 years)	
Consultants and Visiting Scholars	10,000
Total - for subsequent 3 years	571,290

IX. E. Budget Proposal. Sixth to Tenth Years

(The total for 5 years for all expenses is listed without allowance for possible increasing costs)

1.	Salaries, Benefits, and Overhead	$ 600,000
2.	Equipment	250,000
3.	Expendable Equipment and Supplies	60,000
4.	Services	50,000
5.	Travel	60,000
6.	Expenses	20,000
	Total for Subsequent Five Years	$ 1,040,000

VI. FACILITIES

A. MASCA Laboratories, University Museum

1. Space

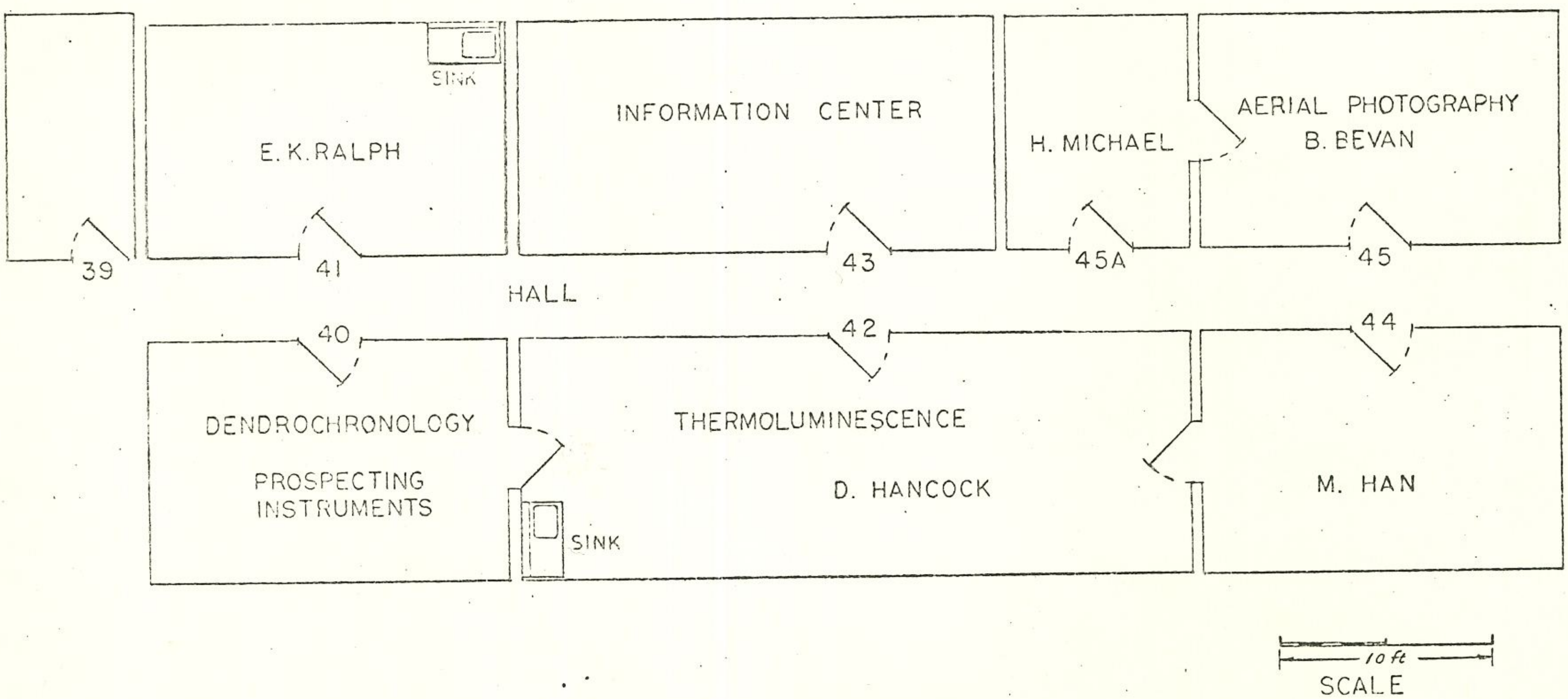
With the opening of the new wing of the University Museum, additional rooms have become available as MASCA laboratories. These are shown on the attached floor plan. In addition to these there is the well-equipped laboratory, Room No. 48A (800 sq. ft. with sink, drainboard, adequate shelving, and work tables) for the use of visiting scholars. This room is near the others and, separated from Room No. 44 by a narrow stairway. The rooms are adequate in size, but are poorly ventilated, and even with windows open slightly, the city dirt pours in. Therefore, we are requesting in the Budget for a filtered fresh air and cooling system; it is planned to locate this in Room No. 39. (See Table II)

2. Equipment

a. Thermoluminescence

Equipment purchased with NSF grants GS-566, 1028, 1568, and 2716 is available in MASCA. This includes the glow curve apparatus with a linearly controlled heating programmer and eight functional alpha counters. X-ray apparatus is available in the Department of Physics. Beta and gamma sources are available through the cooperation of Dr. Suntharalingam at Jefferson Medical College. However, for convenience we plan to

Table II. MASCA LABORATORIES, UNIVERSITY MUSEUM



purchase a Sr^{90} beta source; and another Po^{210} source to continue the alpha experiments. Grinding equipment, dosimeters, and other minor components have also been purchased.

b. Dendrochronology

A dendrochronograph and low-power microscope, for measuring the widths of tree rings, were purchased several years ago. H. N. Michael has collected and tree-ring-dated an adequate number of sequoia and bristlecone pine samples for MASCA's studies, for exchange and exhibit. The collection also includes other woods that were at one time or another processed in the laboratory, such as Lebanon cedar, black pine from Anatolia, and zapote from Central America.

c. Equipment for Archaeological Prospecting

As described previously, we possess two cesium magnetometers, one proton, and one fluxgate magnetometer; three Geohms; metal detectors; and sesmic-sonic components. We have also tools and test equipment including a battery-powered oscilloscope.

d. Aerial Photograph

As a result of the flights in Southern Italy, we have two different sets (2000 each) of photographs of the plain of Sybaris and surrounding hills. From more recent experiments, we have 1000 prints taken over various archaeological sites in England, and 8 rolls of transparencies of the Snaketown, Arizona region.

Only minor items of equipment have been acquired so far - such as a hand stereoscope and a light table.

e. Information Center

This contains a small library of books and articles from periodicals, extensive card files of abstracts indexed both by author and subject, and also the central MASCA files.

It is now located in a larger room (No. 43). One end is reserved for work space, and the center portion of it is now equipped with a sizeable table and chairs for those using the files.

B. Radiocarbon Laboratory, David Rittenhouse Laboratory

1. Space

The C^{14} laboratory is now located in two connecting rooms (BW4 and BW6), each 20 x 20 ft. As mentioned previously, with the addition of a third counter, this space is no longer adequate. We have the permission of the Department of Physics to acquire a third room (BW8) which is adjacent to BW6. This will add, at least, 20 x 30 ft., but must be sealed, air-conditioned, and equipped with the usual laboratory outlets plus a large sink and a fume hood.

2. Equipment

Major items of equipment, at present, are the two carbon dioxide proportional gas counters and associated electronic components, a liquid scintillation spectrometer, carbon dioxide combustion and purification train, and benzene conversion train. There are also benches and tools for the construction and repair of equipment in the C^{14} laboratory, as well as a student and a staffed Machine Shop in the Department of Physics.

C. Equipment Available in Other Departments of the University of Pennsylvania

1. School of Metallurgy and Materials Science and the Laboratory for Research on the Structure of Matter

a. Electron Microscopy

1) Transmission Types

a) Philips Em 300

b) Siemens Emiskop I

2) Scanning Type

JEOL JSM-U3

Accessories include a non-dispersive X-ray detector which permits the analysis of chemical composition with the differentation of about one micron.

b. Analytical Chemistry

In this center, experiments can be carried out in the following areas of chemical analysis: electroanalytical measurements (including high and low impedance potentiometric titration, polarography, amperometric titration, controlled potential and controlled current coulometry), analytical absorption measurements in the ultraviolet and visible regions of the spectrum and flame photometric analysis. The center also has available a Jarrel-Ash Mark IV emission spectrograph (3.5 meter, photographic), a Perkin Elmer Model 303 atomic absorption, a Perkin Elmer Model 900 gas chromatograph, and Picker radio chemical counting equipment capable of scintillation counting and geiger counting.

c. Metallograph and Photography

This facility now has new fixtures to facilitate the grinding of epoxy mounted specimens. These fixtures will enable one to surface grind non-magnetic samples prior to using the lapping machine. The center also now makes its own diamond paste, at a great saving over the commercial product. The photography lab has also acquired a 35-mm Pentax camera for production of 35-mm slides.

Not mentioned previously is the fact that we have the excellent services of the photographic laboratory in the University Museum.

d. X-ray Diffraction

The X-ray Diffraction Research Center provides the facilities to pursue many different types of studies using X-rays as a tool in materials research. Some of these studies are the determination of crystal and molecular structures using powder and single crystal techniques, precision determination of lattice constants, elemental analysis by fluorescence of substances with elements of atomic number greater than twelve, identification of materials, crystal orientation, crystal perfection, small angle scattering and phase changes at high temperatures.

A major piece of equipment in the center is a Picker four circle single crystal automatic diffractometer with an incident beam graphite monochromator. The diffractometer is controlled by a Digital Equipment Corporation PDP-8 computer equipped with a disk file and control and an expander disk.

The Center plans to acquire a scanning digital microdensitometer in the near future.

2. Department of Geology, Hayden Hall

The following is a list of equipment that we have used or plan to utilize as the need arises.

a. Mirror Stereoscope
   (For viewing aerial photographs)

b. X-ray Fluorescence Apparatus

c. X-ray Diffraction

d. Potassium-Argon Dating

e. Rubidium-Strontium Dating

f. Equipment for Petrographic Examinations

g. " " Fission-Track
   Dating including Microscopes

h. Magnetic Anisotropic Separator and Vibration
   and Wilfley Tables

i. Rock Crushers, Saws, etc.

3. Other Departments

Under "Facilities", we have necessarily repeated some of the items already mentioned under "Collaboration" and in other sections. In order to avoid more repetition, in this section, we have omitted the Departments of Chemistry, Electrical Engineering, and possibly others. We should like only to emphasize that we are truly interdepartmental in nature, and that we have the willing cooperation of many Departments in the University of Pennsylvania.

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VIII. PERSONNEL

A. The Organization of MASCA is shown in the attached block diagram (Table III).

B. Curricula vitarum of the paid Staff and Student Members are attached.

MASCA PERSONNEL

Froelich Rainey
Director

Elizabeth K. Ralph
Associate Director

RADIOCARBON LABORATORY

U. of Pa. Support	NSF Support
E. K. Ralph	Henry Michael (part-time)
Barbara Lawn	Raymond Costa
John Hedrick	

THERMOLUMINESCENCE

- Mark Han
- Douglas Hancock

INFORMATION CENTER

- Francesca Giegenaack (part-time)
- Darrel J. Butterbaugh

MASCA PERSONNEL

- Froelich Rainey, Director
  - Elizabeth K. Ralph, Associate Director
    - INFORMATION CENTER
      - Francesca Giegenaack (part-time)
      - Darrel J. Butterbaugh
    - ARCHAEOLOGICAL PROSPECTING INSTRUMENTS AND SURVEYS
      - F. Rainey
      - E. Ralph
      - B. Bevan
      - Student Assistants and Volunteers
    - NEW PROJECTS
      - AERIAL PHOTOGRAPHY
        - Bruce Bevan & Collaborators
      - CHEMICAL PHYSICAL AND OTHER STUDIES IN FIELD AND LABORATORY
      - FISSION TRACK DATING
        - Collaboration with Dept. of Geology
      - EXPANSION OF C-14 LAB
        - Collaboration with Dept. of Geology

Table III

MASCA PERSONNEL