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U.S. DEPARTMENT OF ENERGY
FIELD TASK PROPOSAL/AGREEMENT

1. WORK PACKAGE NUMBER	2. TASK NO.	3. REV. NO.	4. PROJECT NO.	5. DATE PREPARED	6. CONTRACTOR NUMBER
		0		04-01-84	4455-000332

7. TASK TITLE	8. WORK PACKAGE TITLE
Heavy Ion Radiosurgery	

9. BUDGET AND REPORTING CODE	10. TASK TERM Begin:	End:	11. CONTRACTOR NAME	12. CODE (see instructions)
HA-02-07-01-0	Continuing	Open	University of California Lawrence Berkeley Lab.	

13. CONTRACTOR TASK MANAGER (Name: Last, First, MI) (FTS No.)	14. PRINCIPAL INVESTIGATORS (Name: Last, First, MI)
Alpen, Edward L. 451-5206 (FTS) (415) 486-5206	Fabrikant, Jacob I.

15. WORK LOCATION (See instructions): Name of facility, City, State, Zip Code	16. Is this task included in the Institutional Plan?	17. Does this task include any management services efforts?
Lawrence Berkeley Laboratory Berkeley, CAlifornia 94720	☒ YES ☐ NO	☐ YES ☒ NO

18. TASK DESCRIPTION (Approach, relation to work package, in 200 words or less)

OBJECTIVE: To establish stereotactic heavy-ion Bragg peak radiosurgery for brain disorders, including intracranial arteriovenous malformations (AVMs), as a nuclear medicine research method applied to the study of brain disease in man, to examine physical and biological properties of stereotactically-directed narrow heavy-ion beams in the CNS, for improving methods of dose-delivery and dose-distribution, and for establishing RBE/LET relationships for CNS tissue response. RATIONALE: Narrow beams of helium ions have superior biological and physical effects in brain over X- and γ-rays; heavy ions at the BEVALAC have advantages over helium ions and protons for CNS disorders in man, including less range straggling and multiple scattering for same residual range in tissues, improved dose-distribution in Bragg peak, and sharp lateral and distal borders, with greater sparing of critical adjacent CNS structures. EXPERIMENTAL APPROACH: Interactive charged-particle treatment planning and instrumentation/engineering design allow delivery of narrow heavy-ion beams to predetermined, 3-dimensional target volumes within brain or spinal cord; quantitative NMR and SPECT imaging at UCSF. PROGRESS: Clinical research program - over 55 radiosurgical brain patients with intracranial vascular disorders have been studied and treated with charged-particle beams. Research activities have expanded to applications of NMR and radionuclide SPECT imaging of CNS tissues treated with heavy ions. SIGNIFICANCE: On average, 500,000 people in the United States have life-threatening AVMs; the annual rate of rupture is 2-3%, the rate of rebleedin is 6% in the first year after hemorrhage and 2%/yr thereafter. About 10% die with first hemorrhage, 20% with each rebleeding. Stereotactic heavy-ion Bragg peak radiosurgery has the potential of conferring protection against rebleeding, in many cases leading to obliteration of the lesion with minimal morbidity and no mortality. FUTURE DIRECTIONS: Continued modifications and improvements of radiosurgical method to establish the long-term benefit of treatment of brain with stereotactically-directed narrow beams of accelerated charged particles; quantitation, using NMR and SPECT, of CNS tissue injury and repair and cerebral blood flow alterations following cerebral heavy-ion irradiation; development of the method of stereotactic heavy-ion Bragg peak cerebral irradiation (carbon and neon) at the BEVALAC.

19. CONTRACTOR TASK MANAGER

Edward L. Alpen
(Signature) (Date)

20. DETAIL ATTACHMENTS (See instructions)

☐ a. Facility requirements	☒ d. Background	☒ g. Future accomplishments	☐ j. Explanation of milestones
☒ b. Publications	☒ e. Approach	☒ h. Relationships to other projects	☐ k. ZBB Detail
☒ c. Purpose	☒ f. Technical progress	☐ i. Environmental assesment	☒ l. Other (Specify):

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OBLIGATIONS AND COSTS

CONTRACTOR NAME: University of California, Lawrence Berkeley Laboratory

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21. STAFFING *(in staff years)*	PRIOR YEARS	BY-2	BY-1 PRESIDENT'S	BY-1 REVISED	AUTHORIZED	BY-FY 1986
a. SCIENTIFIC		2.8	2.5	2.5		2.5
b. OTHER DIRECT		.3	.3	.3		.3
c. TOTAL DIRECT		3.1	2.8	2.8		2.8
22. OBLIGATIONS AND COSTS *(in Thousands)*						
a. TOTAL OBLIGATIONS						
b. TOTAL COSTS		290	290	290		310
23. EQUIPMENT *(in Thousands)*						
a. EQUIPMENT OBLIGATIONS		0		100		100
b. EQUIPMENT COSTS						
24. OTHER COSTS *(specify)*						
a.						
b.						
c.						
d.						

25. OPTIONAL FIVE-YEAR PLAN *(in Thousands)* Constant BY dollars	BY+1	BY+2	BY+3	BY+4	TOTAL TO COMPLETE
a. TOTAL OPERATING OBLIGATIONS					
b. TOTAL OPERATING COSTS					
c. TOTAL EQUIPMENT OBLIGATIONS					
d. TOTAL EQUIPMENT COSTS					

26. MILESTONE SCHEDULE	PROPOSED SCHEDULE	AUTHORIZED SCHEDULE

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20. DETAIL ATTACHMENTS:

Attachment a. Facility Requirements: N/A

Attachment b. Publications:

Publications Fiscal Year 1983

Fabrikant JI, Holley WR, McFarland EW, Tobias CA. Heavy-ion radiography and heavy-ion computed tomography. Lawrence Berkeley Laboratory Report LBL-14001 (1982).

Holley WR, Fabrikant JI, Tobias CA, Benton EV. The physics of heavy-ion radiography and heavy-ion computerized tomography. Lawrence Berkeley Laboratory Report LBL-14316 (1982).

Lyman JT. Computer modeling of heavy charged particle beams. (In) Pion and Heavy-ion Radiotherapy: Pre-clinical and Clinical Studies. Elsevier Biomedical. New York (Skarsgard LD, ed) pp 139-147 (1983).

Publications Fiscal Year 1984 - 1st Quarter

Fabrikant JI, Lyman JT, Hosobuchi Y. Stereotactic heavy-ion Bragg peak radiosurgery for intracranial vascular disorders: Method for treatment of deep arteriovenous malformations. Brit J Radiol (in press 1984).

Lyman JT. Heavy charged particle beam dosimetry. (In) Proceedings IAEA advisory group meeting on advances in dosimetry for fast neutrons and heavy charged particles for therapy applications (in press 1984).

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Attachment c. Purpose:

NUCLEAR MEDICINE: STEREOTACTIC HEAVY-ION BRAGG PEAK RADIOSURGERY FOR INTRACRANIAL VASCULAR DISORDERS OF THE BRAIN

This nuclear medicine investigative program provides the radiosurgical research support for application of stereotactically-directed narrow heavy charged particle beams for the investigation and treatment of patients with intracranial vascular disorders, including deep arteriovenous malformations (AVMs) in the brain and spinal cord. Research is directed to:

(1) The investigation of the physical and biological properties of the helium-ion beam (184-inch Synchrocyclotron) and heavier (e.g., C, Ne) beams (BEVALAC) appropriate for producing narrow focal lesions in the central nervous system, including improved dose-distribution and dose-delivery within the brain and with rapid rate of energy loss without damage to adjacent critical CNS structures and neuroanatomical sites.

(2) To decrease or eliminate the threat of intracranial hemorrhage and progressive neurological deficit in persons with inoperable or inaccessible AVMs, using a safe, noninvasive heavy charged particle radiation procedure.

(3) To utilize current investigative nuclear medicine methods (including NMR and SPECT) to evaluate the CNS tissue response and altered cerebral blood flow dynamics in persons undergoing heavy charged particle stereotactic radiosurgery.

Attachment d. Background:

Intracranial arteriovenous malformations (AVMs) have been the object of investigation for over a century (Kunc, 1978; Nyström, 1978). However, deep intracranial arteriovenous malformations, including carotid artery-cavernous sinus fistulas (CCFs), have not been reported on or treated until the last two decades, primarily because of their variable symptoms, changeable pathoanatomical relationships, and inaccessibility to vascular brain surgery (Kunc, 1978). Recent advances in neurodiagnostic and microsurgical techniques have made direct neurosurgical treatment of some intracranial AVMs safer and more successful. Surgical treatment of AVMs involves total excision, where possible, or combined with ligation or intravascular occlusion of feeding arteries and shunting vessels (Kunc, 1978; Leksell, 1971). For deep-seated

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AVMs, including CCFs, surgical approaches are frequently too difficult and associated with significant risk of massive bleeding or severe neurological deficit, or failure of obliteration. Similar risks and complications are associated with electrothrombosis, cryocoagulation, balloon catheterization, and intravascular embolization with synthetic polymers (Kunc, 1978). Conventional radiotherapy as a method of induced thrombosis has been tried in the past (Johnson, 1975) but now has been generally abandoned as unsuccessful (Perret, 1975; Olivecrona and Ladenheim, J., 1957; Pool, 1962; French and Chou, 1969). Stereotactic charged-particle radiosurgery holds considerable promise for the treatment of deep-seated, large, or surgically inaccessible AVMs (Leksell, 1971; Kjellberg, 1977; Kjellberg et al., 1978; 1983; Kunc, 1978; Nyström, 1978; Backlund, 1978; Steiner et al., 1978; Fabrikant et al., 1980, 1983; Lawrence, 1983).

The incidence rate of known inoperable deep AVMs approaches one case per 100,000 annually for the whole population (Nyström, 1978). A fairly large number of deep AVMs escape diagnosis based on autopsy series; therefore the actual incidence rate might be twice as large. Inoperable deep AVMs comprise about 25% of all intracranial AVMs. In children, deep AVMs can comprise as much as 1% of neuropediatric hospital admissions. Deep AVMs appear most frequently in males; about 75% of patients with deep AVMs develop symptoms before 40 years of age. Mortality for all AVMs approaches 15%; it is much higher, perhaps approaching 25%, for deep AVMs owing to the more dangerous sites and the higher frequency of bleeding from some deep AVMs. Morbidity, including hemorrhage, neurologic disability, paresis, ataxia, brain stem dysfunction, coma and seizures, is often severe since deep AVMs are almost always located close to important brain structures. Hemorrhage occurs in up to 25% of patients; the incidence of severely neurologically disabled patients approaches 20%, although morbidity, as such, including severe intractable headaches, is very much higher (Kunc, 1978; Nyström, 1978).

A general concept in radiobiology is that blood vessels may be injured by ionizing radiation leading to thrombosis and hemostasis (Rubin and Casarett, 1968; Fabrikant, 1972). A mechanism is postulated involving three sequential factors: (1) vascular injury, (2) deviation of blood flow from the normal blood flow pattern, and (3) increased platelet activity, increased activation of coagulation, decreased fibrinolytic activity, leading to thrombosis and hemostasis. It appears that the small abnormal feeding or shunting vessels of an AVM possess hemodynamic flow conditions that differ from flow in normal vessels. These small shunting vessels are irradiated with the intent initiate thrombosis and hemostasis in the AVM with eventual complete obliteration.

Attachment e. Approach:

Charged-Particle Beams. A stereotactic radiosurgery beamline for the 230-MeV/u helium ion beam at the 184-inch Synchrocyclotron has been developed (Lyman et al., in press). This modified beam has a 14.7 cm range in water to the Bragg peak, with sharply delimited lateral and distal borders. The practical limits on beam diameter range from 0.6 cm to 4.0 cm. The unmodulated Bragg peak maximum dose is greater than 3 times the entrance dose and the width of the peak at 80% of the maximum is 0.7 cm. The range of the helium-ion beam can be modulated by a rotating acrylic variable thickness absorber to increase the width of the high dose region for this application to as much as 4.0 cm. The physical properties of this beam are similar to those of the proton beams

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that have been available for stereotactic radiosurgery at the Harvard Cyclotron Laboratory (Koehler et al., 1974; Kjellberg, 1977; Kjellberg et al., 1978, 1983) and at the Gustaf Werner Institute at the University of Uppsala (Larsson, 1980, Larsson and Sarby, 1974). The maximum range of the 230-MeV/u helium-ion beam is greater than that of these proton beams; therefore, more energy degradation is necessary to obtain the same residual range. Since the nuclear charge and mass of helium is larger than the proton, the multiple scattering and the range straggling can be less for the same residual range in tissues.

This helium-ion beam has proven suitable for neuroscience research to induce focal lesions in the central nervous system (Fabrikant et al., 1980). It provides good dose-localization and dose-distribution for stereotactic helium-ion radiosurgery in all patients with AVMs, including CCFs, thus far treated. Studies are in progress to develop beam characteristics of heavier ions, such as carbon ions with small uniform transverse profile and modified Bragg peak for improved dose-distribution at the BEVALAC. These heavier-ion beams have physical characteristics with unique advantageas for application to stereotactic Bragg peak radiosurgery of the central nervous system (Budinger et al., 1977, Fabrikant et al., 1980).

Heavy Charged Particle Treatment Planning. Considerable study has gone into the development of a stereotactic system for delivery of heavy charged-particle beams to intracranial AVMs (Lyman, 1983; Lyman and Chong, 1974; Lyman and Howard, 1977; Lyman et al., 1971, 1973, 1979, 1980, in press; Tobias et al., 1952; Chen et al., 1979; Budinger et al., 1977; Fabrikant et al., 1980, 1983, in press). The present procedure begins with the fabrication of a vacuum-formed polystyrene head-holder for immobilization of the patient. A stereotactic frame (Leksell, 1971; Lyman et al., in preparation) is attached to the head-immobilization mask, and adapted to cerebral angiographic and X-ray CT equipment and to the patient-positioner at the 184-inch Synchrocyclotron. Stereotactic cerebral angiography and CT brain scans are performed. The data are transferred to a VAX 11/780 computer system in our laboratory for interactive charged-particle treatment planning and provide the basis for treatment planning (Lyman et al., in preparation). Entry angles and beam ports are chosen to confine the high-dose Bragg peak region to the defined target volume while carefully protecting adjacent normal brain structures. Treatment planning programs use the CT data on a pixel-by-pixel basis to (a) design and/or select a collimator for each entry portal, (b) select the appropriate spread Bragg peak for helium-ion radiation, (c) select the appropriate residual range for each beam entry, (d) design appropriate compensators to contour the stopping region of the helium-ion beams, and (e) generate isoeffect and physical dose-distributions overlayed on the CT image (Lyman et al., in preparation).

Patient Treatment. Treatment with helium-ion beams is based on the individual computerized dose-distributions calculated from CT scans and cerebral angiograms (Lyman et al., in press; Fabrikant et al., 1983; in press). The patient's head is secured to the ISAH system (Irradiation Stereotactic Apparatus for Humans) at the 184-inch Synchrocyclotron by the polystyrene head-immobilizer (Lyman et al., in press; Lyman and Chong, 1974; Tobias 1980; Lawrence, 1983; in press). Necessary minor corrections of the X, Y and Z coordinates are made during a final alignment period prior to therapy. Presently, total doses of 45 Gy equivalent (GyE) are delivered to treatment volumes of up to 25 cm^3; the smallest volumes treated with the unmodified Bragg

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peak are about 0.12 cm^3, and the average volumes treated for most patients are in the range of 1.5 cm^3 to 5 cm^3. Treatment occurs through 1 to 6 entry portals, delivered daily for 1 to 3 days, depending on the treatment volume, and the volume of normal brain tissue traversed by the beam. Irradiation times per portal range from 1 to 4 minutes (Lyman et al., in press). The dose to the critical normal brain structures immediately surrounding the AVM is considerably less than 45 GyE. For a single beam; fall-off to 10% of the maximum central dose occurs within 4-6 mm and is much sharper (within 2-3 mm) along the lateral margins of the helium-ion beam (Lyman et al., in press). The central AVM dose, the aperture size, the number of ports, the beam direction, and the spread Bragg peak all determine the isodose contours.

Attachment f. Technical Progress:

In late 1980, our first patient with an inoperable deep intracranial AVM was treated with stereotactic heavy charged-particle radiosurgery using 230-MeV/u helium ions at the 184-inch Synchrocyclotron at Lawrence Berkeley Laboratory (Fabrikant et al., 1980). Since then, 55 patients with deep intracranial vascular disorders have been treated, and additional patients are presently planned.

Cerebral angiography and CT brain scanning are carried out prior to stereotactic radiosurgery and at selected intervals following radiosurgery. Extended follow-up to 36 months is done on a regular basis, and 48 to 60 months is planned for each patient as necessary.

Clinical objectives are to achieve changes in the intracerebral hemodynamic condition resulting in a decrease in (1) frequency of hemorrhages, (2) in neurological deficiencies, (3) subjective complaints including headaches, or (4) in frequency of seizures. Initial observations in all 55 patients thus far treated indicate that these objectives are being achieved. There have been no neurologic complications of radiation damage to the normal brain tissue; thus far, no evidence of brain injury or progressive or fixed neurological deficiencies have occurred as a result of the stereotactic radiosurgical procedure.

Radiation treatment objectives are to achieve hemodynamic changes, e.g., decrease in blood flow through the AVM with decrease in the size of the AVM until total disappearance. It has been observed both by the Karolinska group (Backlund, 1980; Steiner, personal communication) and the Harvard group (Kjellberg, personal communication) that hemodynamic changes occur progressively and are usually present before morphological vascular alterations. Since it may require up to 12 to 18 months before initial changes are observed and may not be completed in some instances before 24 months, and since most patients in our clinical research study have been treated within the past 18 months, it is not possible to provide observations on long-term follow-up at this time. However, in 7 patients, significant decrease in size of and the rate of blood flow through the treated AVM has already occurred. In one patient with a CCF, the fistula was completely obliterated at 3 months, and her pulsating exophthalmos, headache, and visual disturbances are completely relieved.

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Attachment g. Future Accomplishments:

Patient Evaluation and Follow-up. During the next four years, studies on treated AVM brain patients will emphasize the results of stereotactic heavy charged-particle radiosurgery with time.

(1) Neurological condition. Patients most frequently present with one or more of the following clinical features: hemorrhage, seizure, headache, neurological deficits, and mental deficits. The extent to which the changes in the hemodynamic condition following treatment of the AVM may result in decrease of neurological deficiencies, subjective complaints, frequency of seizures, etc., will be evaluated.

(2) Radiological studies. Cerebral angiography, X-ray CT scanning and certain special investigative studies (e.g., positron emission tomography (PET) and/or single photon emission computed tomography (SPECT) scanning and nuclear magnetic resonance (NMR) scanning) are being carried out or planned for all patients prior to stereotactic radiosurgery, and at intervals following treatment. The following changes, if present, will be quantified. (a) Hemodynamic changes, e.g., decrease in blood volume and flow through the AVM with decrease in size of the feeder arteries and shunting vessels and draining veins. These changes may be best quantified with PET and/or NMR scans, or digital radiography which may measure blood flow changes more accurately. (b) Anatomical changes, e.g. progressive decrease in the size of the AVM until total disappearance, potential transient or permanent distrubances in myelination processes, leading to demyelination, and early and late delayed radiation-induced injury in the brain (Sheline et al., 1980). As yet, no disturbances of myelination processes have been observed in any of our patients thus far treated with stereotactically-directed helium-ion beams.

Program Goals. Research in stereotactic heavy charged-particle radiosurgery for intracranial deep-seated neurovascular disorders in brain patients is designed:

(1) To introduce technical modifications and improvements of the radiosurgical technique---including stereotactic neuroradiological studies for quantitating radiation changes in the brain, computer-based interactive treatment planning, and beam delivery --- to achieve a safe and reliable therapeutic procedure;

(2) To evaluate the long-term results in patients treated with helium ions for AVMs of the brain and spinal cord;

(3) To develop the method using heavier ions (carbon or neon ions) at the BEVALAC for improved biological and physical effects. The advantages of heavier ions, over helium ions and protons, include narrow beams with less range straggling and less multiple scattering for the same residual range in tissues, and improved dose-distribution in the Bragg peak, with very sharp lateral and distal borders, and with greater sparing of critical structures in adjacent CNS tissues in the brain and spinal cord. The carbon-ion beam also provides potential for using a carbon-11 ion radioactive beam which is presently being investigated for achieving precise localization of the stopping points of the beam inside the brain (Tobias, 1983; in press; Tobias et al., 1971; Chatterjee et al., 1981; Fabrikant et al., 1980; Lawrence, 1983; in press). And (4) to

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perfect the methods for stereotactic radiosurgery at the BEVALAC for application at the clinical level at future medical accelerators (Alpen, 1983).

Physics.

Dosimetry of heavy charged-particles

Our present work utilizes the helium ion beam which is available from the 184-inch LBL synchrocyclotron. In the near future the AVM radiosurgery project will be moving to the BEVALAC. The heavier beams available at the BEVALAC should have improved dose localization and distribution. We will investigate the relative biological effectiveness of helium, carbon, neon, and silicon ion beams for radiosurgery. By employing various ions, dose, and fractionation schemes we hope to find optimal conditions for charged particle irradiation of AVMs while protecting critical brain tissues. We plan to study tissue response using techniques such as NMR and SPECT.

Treatment planning

We will be developing three-dimensional treatment planning in order to better confine the radiation solely to the volume being treated: We plan to incorporate NMR imaging of AVM patients into our treatment planning method. The new methods developed will be compared to our present techniques. We hope to use NMR imaging to measure blood flow into AVMs. If these new methods utilizing NMR imaging are succesful, we will then have a safe, noninvasive technique for diagnosis, treatment planning, and follow-up.

SPECT. SPECT has been applied to physiological measurements of local cerebral glucose utilization, local cerebral blood volume, local cerebral blood flow and to demonstrate cerebral infarcts. Because of the desirable biological and chemical behavior of selected positron-emitting isotopes, there is emphasis now on positron-emission computed tomography in brain research. Winchell et al. (1980) proposed that the initial distribution of IMP [N-Isopropyl-p-[^{123}I]Iodoamphetamine might be useful for imaging relative regional brain perfusion in humans because first-pass extraction efficiency in rat brain was high, washout was slow, brain-blood ratios were high and the physical properties of I-123 ($T_{1/2}$ = 13 hr, 159-keV photon) were favorable for scanning. Localization in the brain was considered to be primarily in high-capacity, relatively nonspecific, binding sites for amines. Kuhl et al. (1982) demonstrated local cerebral blood flow mapping in humans by SPECT of IMP. They demonstrated the validation of a method for quantitative mapping of local cerebral blood flow in human brain by SPECT, using intravenously injected IMP combined with a modification of arterial input sampling. These results suggest that SPECT with IMP, or with other similar compounds such as HIPDM (N,N,N'-trimethyl-N'-[2-hydroxy-3-methyl-5-[^{123}I]iodobenzyl]-1,3-propanediamine has promise for diagnostic study of cerebrovascular disorders. We plan to assess the feasibility of evaluating regional cerebral perfusion in patients using SPECT and I-123 HIPDM (Kung et al., 1983) to detect acute or chronic blood perfusion changes in brain tissues. The patients examined will be those treated with stereotactic heavy charged-particle radiosurgery in this clinical research program. Accordingly, our program, in collaboration with Professor Robert Hattner, Division of Nuclear Medicine (Department of Radiology), University of California School of Medicine, San Francisco, will be using the new SPECT system at the Medical School in all our patients undergoing

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stereotactic heavy-ion Bragg peak radiosurgery for intracranial vascular disorders.

Attachment h. Relationship to other Projects:

The fundamental research program in physics and biology applied to the clinical program is (1) DOE Contractor Number 4453/000329, Focal Lesions in the Central Nervous System -- Heavy-ion Medical Research, Professor J.I. Fabrikant, Principal Investigator. The clinical and laboratory research is also a collaborative effort with the Department of Neurological Surgery (Professor Y. Hosobuchi), the Department of Radiology (Professor D. Norman; Professor T.H. Newton, Professor Robert Hattner). Additional collaborative projects include (1) Cardiovascular Flow and Metabolism, NIH/HL 25840, Professor T.F. Budinger, Principal Investigator, (2) Heavy-ion Radiobiology and Oncology, NIH/NCI/CA 15184, Professor C.A. Tobias, Principal Investigator, (3) Treatment of Cancer with Heavy Charged Particles, NIH/NCI/CA 19138, Professor J.R. Castro and Professor C.A. Tobias, Principal Co-Investigators; (4) Advanced Design Research, Heavy-Ion Medical Accelerator, NIH/CA 30236, Professor E.L. Alpen, Principal Investigator, (5) Additional collaborative research studies at LBL include BEVALAC Beam Time and Operations, 4405/000742, and (6) Evaluation of Treatment Planning for Particle Beam Radiotherapy, NCI agreement Y01-CM-20110, J.T. Lyman, Principal Investigator.

Attachment i. Environmental Assessment: N/A

Attachment j. Explanation of Milestones: N/A

Attachment k. LBB Detail: N/A

Attachment l. Equipment List and Justification:

FY85: The Biology and Medicine Division has a VAX 11/780 Computer for use in three programs; cost to be allocated equally. For this project computer time is used for advanced image reconstruction necessary for stereotactic localization and treatment planning of AVM lesions for charged-particle radiosurgery in brain. Total: $300,000; allocated to this project: $100,000

FY86: VAX 11-780 Computer use allocated to this project (cf FY85) $100,000

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ATTACHMENTS

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