11,000 + 1,000 = 152,000. Applying the 262/1,000 estimated prevalence of severe, irreversible noncardiac disease (1) that would exclude potential candidates from consideration, we have 0.262 x 152,000 = 39,824, the latter being the number of candidates who would be excluded. Their exclusion leaves 152,000 — 39,824 = 112,176, or approximately 112,000 candidates of all ages.

Maximum Age Considerations

According to the National Center for Health Statistics (NCHS), the following percentages of all cardiac deaths occur at the ages listed:

<80 years. 75%
<75 years. 57.5
< 70 years. 42
<65 years. , , ...30

From the application of cardiac deaths to the 112,000 candidates of all ages, we derive the following numbers of candidates:

< 80 years. 84,000
< 75 years. 64,400
< 70 years. 47,000
<65 years. 33,600

Thus, our estimate is that there would be 33,600 artificial heart candidates each year under the age of 65. Our estimate is not much different from the 1969 Ad Hoc Task Force on Cardiac Replacement's estimate, based on different assumptions and calculations, that there would be 32,168 candidates each year under the age of 65(l).

Patient Access to Implant Hospitals and Patient Refusal

We estimate above that 33,600 persons would be candidates for artificial heart implantation each year if all had access to hospitals capable of implanting an artificial heart and if all agreed to the replacement.

If the device is initially highly successful and/or if the patient selection criteria are relaxed overtime, as they have been for patients suffering from end-stage renal disease (ESRD), this figure might increase substantially. To allow for this possibility, we submit an "upper bound" of twice this estimate, or approximately 66,000 candidates.

Conversely, if large and intractable technical or other problems are encountered and/or if many potential candidates choose not to accept treatment with this device, the number of candidates might be substantially lower. Accordingly, we suggest a "lower bound" estimate of 16,000 candidates.

ECONOMIC ASPECTS

The economic costs of diagnosis, implantation, and postoperative care for artificial heart recipients are not easily predictable from present artificial heart prototypes, because there have been only a few human implantations and none of a totally implantable device. To provide a range of estimates, therefore, in the discussion that follows, we review the current cost information for three related medical technologies: 1) cardiac pacemakers, 2) coronary artery bypass graft (CABG) surgery, and 3) cardiac transplants. Data on projected device costs for the artificial heart were obtained from letters and interviews with manufacturers, as well as NHLBI reports. Three estimates of the major items of expense associated with artificial heart implantation and use are presented in table 1 on page 11. Following that are a discussion of personnel and facilities and a discussion of funding for R&D.

Artificial Cardiac Pacemaker

The implantable cardiac pacemaker is a complex device that, like the artificial heart, joins physicians with engineers and manufacturers. The first totally implanted pacemakers were reported in Sweden in 1959 and in the United States in 1960 (17,37,78). Clearly, the pacemaker is a clinical success. It has been dramati-

cally lifesaving and has enormously improved the quality of life for patients with heart block and other abnormalities of conduction. For purposes of this analysis, however, we are concerned with the costs, reliability, and longevity records of pacemakers. (For additional information, see app. A.)

From the outset, manufacturers of cardiac pacemakers predicted that energy stored in the battery would provide 5 years of pulse-generation function. This 5-year figure was based on battery capacity and calculated discharge rates; it did not include an allowance for the replacement of the pulse generator alone. Although some investigators expressed reservations about heightened expectations (78), there was a consensus that a 5-year pacemaker was at hand (17,37). That projection proved overly optimistic. Early battery failure necessitated pacemaker replacement in 60 percent of pacemaker recipients within 3 or 4 years. Even as late as a decade after the therapy became accepted, many pulse generators required replacement at 18 months. In addition, wire fractures, high thresholds, other component failures (e. g., self-discharge within the battery, inward leakage of body fluids), and infection required reoperation in about 30 percent of pacemaker recipients within 3 years (55,56). The predicted longevity was not achieved until 1975, with the availability of new battery technology (lithium).

The unanticipated complications of systems failures and recalls for recipients of cardiac pacemakers meant greater than estimated continuing care costs. Although the expectation had been for 3 to 5 years of fault-free system performance, the average system longevity during the first 3 years of pacing was only about 6 months. Some patients had in excess of 15 operations in 3 to *5* years.

A 1976 study (74) analyzed the financial records of patients with more than 4 years (an average of 73 months) of cardiac pacing to establish basic cost figures. A cost estimate of $7,500 includes an average of $3,500 for the initial implantation and ***$4,000*** for continuing pacemaker maintenance costs. Modern followup methods, apart from complications requiring hospitalization and operative repair, are also costly. Electronic monitoring, directly or indirectly by telephone, represents the best available means of followup. Electronic monitoring by telephone promises to reduce the number of emergency admissions, but the procedure is costly. Third-party payers, Blue Cross and medicare, now pay $30 per telephone call; most patients are monitored twice monthly, some as often as weekly. Thus, the monitoring cost can approximate $1,560 per year.

Coronary Artery Bypass Grafts

The costs of CABGs have become an issue as the number of procedures has grown—from 20,000 in 1971, to 50,000 in 1974 (75), to an estimated 70,000 in 1977 (11), to 100,000 in 1978 (47). Figures from several studies analyzing surgical costs of CABG patients (24,32,47,59,75) were updated with assumptions about patient care for artificial heart recipients to arrive at the figures given in column A of table 1.

A study by Befeler (11) presents the range of costs for 20 CABG patients. Hospital charges for a 17-day average stay ranged from $6,525 to $22,142, for an average of $10,103. This figure includes charges for EKG analysis, cardiac catheterization, blood flow rate measurements, and other hospital fees that would be incurred by artificial heart recipients. The professional fees incurred by CABG patients provide the most recent comparable cost information for professional fees that might be incurred by artificial heart recipients. The surgeon's fee for CABG currently ranges from $2,000 to $2,400, averaging $2,200; the anesthesiologist's fee averages $974; and the cardiologist's fee averages $652. This brings the average professional fees for CABG to $3,826. When these fees are added to the hospital costs of CABG surgery, the total charges are $13,929. Allowing for inflation and national variation, we estimate an average cost of $15,000 for CABG surgery.

Heart Transplants

Recent successes in cardiac transplantation at Stanford University Medical Center provide a

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third cost comparison. Between 1969 and June 1979, Stanford completed 179 cardiac transplants, with 71 survivors (62). The survival rate of patients who receive heart transplants now rivals that of patients who receive kidney transplants from unrelated donors. About 70 percent survive to 1 year, and 50 percent survive afters years. The heart transplant patient selection criteria at Stanford are very stringent. Selection is based on factors that include the absence of infection, a psychological evaluation, and economic criteria. Patients must show they can provide transportation to and from Stanford during postoperative monitoring and must document that the patient's family can provide financial support during this period. Many of the recipients are young. Of 13 patients between 12 and 21 years old, 7 are still alive, with a 64-percent survival rate to 4 years.

In February 1980, the former National Center for Health Care Technology (NCHCT) recommended that the Health Care Financing Administration (HCFA) reimburse cardiac transplantation at Stanford under medicaid. Previously, a substantial portion of the costs was underwritten by the National Institutes of Health (NIH). A full recommendation on medicaid reimbursement for heart transplants is being prepared that will include suggestions for cost containment incentives, "distributive justice" issues for patients unable to afford the transportation to and from Stanford, and a consideration of whether it is necessary to regionalize (limit to four or five centers) heart transplants. '

Average costs for cardiac transplantation at Stanford in 1977 are listed below (62):

Transportation and lodging	$ 5,600
Evaluation cost	3,500
Hospital costs	62,000
Professional fees	30,000
Total	$101,100

These figures for cardiac transplantation do not include fees for the heart donors, which would not be encountered in artificial heart surgery. The largest contributing factor to the total cost of cardiac transplantation is the length of hospital stay, which averages 65 patient days. The average daily costs are between $400 and $500 (not corrected for inflation). The first 30 days after surgery are spent by cardiac transplant patients in intensive care at the highest service intensity and costs. Much of artificial heart implantation would be emergency surgery, according to our earlier patient selection pool, and charges for transportation and lodging would not be incurred. We have deducted these charges and reduced the hospital charges for cardiac transplantation by one-half (to account for the shorter hospital stay and fewer laboratory tests required by artificial heart patients) to arrive at the figures given in column C of table 1.

The annual cost of followup care for heart transplant patients at Stanford, after the first year, is approximately $8,800 (62,71). Inpatient followup care (medical surveillance, chest X-rays, lab tests, and EKGs) costs about $7,300, and outpatient followup care about $l,500. The higher continuing care costs for the first year and for those eight patients at Stanford who have had second heart transplants are not included in the maintenance figure. (Tables summarizing the inpatient and outpatient costs at Stanford are provided in app. B.)

Device Costs

Estimates of the cost of the artificial heart itself vary, depending on the energy supply. The following four energy supply systems are discussed in the report of the 1973 Artificial Heart Assessment Panel (51): 1) electrically powered, internal heat energy storage, 2) long-term internal secondary battery, 3) external secondary battery, and 4) nuclear power.

Two of these energy systems are used on LVADS that are undergoing testing and research today. One is an electrical-energy converter powered by an electrochemical battery. The other is a thermal-energy converter powered by an electrical or radioisotope-charged battery. Recent estimates of the future cost of these LVADs from NHLBI contractors provide the best proxies for what the potential cost of the artificial heart may be when, and if, it is mass produced. According to representatives from Ther-

' *The Blue Sheet,* Feb. **20, 1980.**

moElectron and Aerojet-General, an electromechanical LVAD designed for 2 years of reliable use, at a production level of 5,000 per year, will cost an estimated $10,000. A 5-year device may cost $13,000 or $14,000. In addition, the batteries for such a device will cost several hundred dollars a year. An LVAD driven by a thermal engine will cost an estimated $14,000, with no additional costs expected for a 5-year reliable form.

Willem Kolff, at the University of Utah, estimates that the first totally implantable artificial hearts will be air-driven and will cost around $14,000. However, many technical problems remain to be resolved (e.g., the development of reliable biomaterials), and costly solutions would increase these figures.

There is little potential for declining costs with mass production of the devices because of the high level of reliability demanded for the devices and the expensive marketing structure. Theodore Cooper, former director of NHLBI, confirmed this point in a 1979 interview (22), stating that he does not expect artificial hearts to be produced on a competitive basis; therefore, saturation and declining costs for the device are not apt to be realized.

Summary of Costs

Table 1 contains three estimates of the major items of expense incurred in the diagnosis, implantation, and recovery of patients undergoing artificial heart implantation. These items have been discussed in the preceding sections.

Our lower bound cost estimate (A in table 1) is based on the CABG proxy, a low estimate for the device of $10,000, and a low estimate for continuing care of $1,500 based on the experience of cardiac pacemakers. * We do not expect the technological and continuing surveillance needs of artificial heart recipients to be less than emergency medical treatment and monitoring costs of cardiac pacemakers. In addition to incurring these continuing medical costs, recipients will have to replace batteries yearly for the 2-year reliable LVADs that are being developed. ** These batteries will cost about $300 to $500 annually.***

Table 1.—Three Estimates of Major Items of Expense Associated With Artificial Heart Implantation and Use

Item of expense	A CABG proxy[a]	B Calculated fees	c Cardiac transplant proxy[b]
Implantation			
Hospital care	$10,103	$10,822	$31,000
Professional fees	3,826	5,300	30,000
Device costs[c]	10,000	12,000	14,000
Total	$23,929	$28,122	$75,000
Continuing costs[d]			
Medical care	$1,500	$2,000	$8,800
Batteries	300	300	—
Total yearly	$1,800	$2,300	$8,800

[a] CABG proxy for costs of hospital care and professional fees; cardiac pacemaker proxy for costs of continuing medical care.
[b] Cardiac transplant proxy for costs of hospital care (adjusted), professional fees, and continuing medical care.
[c] Based on estimates for electromechanical LVAD.
[d] Annual costs subsequent to implantation.

SOURCE: Estimates are derived from information provided in the text.

Our second cost estimate (B in table 1) is based on our own calculations using current hospital costs, professional fees, and a middle estimate of $12,000 for the device. Consultations with cardiac surgeons suggest that the nonemergency patient will need to be hospitalized for 5 to 7 days prior to artificial heart implantation. Immediately after surgery, the patient will be placed in an intensive care unit for extensive monitoring and treatment for an anticipated period of 7 days. Normal progression of the recovery processes would be expected to require a hospital stay of about 21 days. Combining these length-of-stay figures with current hospital costs, we calculate that the recipient of an artificial heart would incur total hospital costs of $10,822. That total includes $6,300 for 28 days of care (7 days preoperatively, 21 days postoperatively) at $225 per day* and $4,522 for 7 days of intensive care at $646 per day.**

● There is a considerable difference of opinion about continuing cost estimates. One reviewer felt that both the cardiac transplant and pacemaker continuing costs were too *high.* Another reviewer felt that there would be numerous mechanical problems, so that even cardiac transplant estimates were *too Zow.* In table 1 we have presented a range of estimates, with $8,000 as the upper bound.

**See section on LVAD research below for a description.
***Estimate from Thermoelectron.
*Cost figures from the American Hospital Association.
**The amount reimbursed by the Health Care Financing Administration (HCFA) for intensive care.

We have added the professional fees stated for CABG patients ($3,826) and applied them to the surgical demands of artificial heart implantation. * The amount increases, because of the anticipated need for an associate surgeon (fee of $500) and two anesthesiologists, to $5,300.** When we add these fees to the hospital costs, we arrive at estimated charges of $16,122, well within the range of coronary bypass surgery. (Many of our interviewees compared implantation costs to present bypass costs.) Following hospitalization and discharge, the artificial heart recipient would presumably spend a reasonably prolonged period of recovery. We anticipate that during this recovery period the patient will require frequent visits to the physician at the hospital where the surgery was performed. For this reason, we expect the first year's costs to be similar to those for cardiac transplant patients, but we have chosen a lower continuing cost figure of $2,000.

Our upper bound estimate (C in table 1) employs the cardiac transplant figures described earlier. The only addition is the device figure of $14,000 for an air-driven heart, which would not require batteries.

It must be noted that for all three estimates we assume no surgical complications such as thrombosis, hemorrhage, and circulatory insufficiency. Such complications would require a longer hospital stay and could easily double the hospital costs.

● In an experimental procedure, professional fees are not ordinarily charged. However, *once* the artificial heart is deemed to be therapeutic, these fees will be incurred.

● *See discussion of personnel and facilities in the next section of this case study.

In summary, the hospital and implantation costs to the recipient of an artificial heart may approach the present fees associated with cardiac transplants and will certainly be higher than the present costs of CABG surgery. Table 2 lists varying total societal costs for the range of biologic or mechanical heart implants discussed in the previous section of this case study and also shows the impact on present facilities and personnel. Even the best estimates project an expense that an individual recipient would not be able to afford completely and that private insurance schemes would be expected to reimburse only partially (as with dialysis and heart transplants). To meet these expenses, which could easily reach $3 billion annually, the Government will have to consider new concepts in insurance or social security coverage.

Personnel and Facilities

An important consideration in planning for the clinical application of the artificial heart is the adequacy of present medical facilities and surgical teams. The agonizing selection of patients associated with the early days of hemodialysis points up the problem that a shortage of facilities and skilled personnel may create if preparations for the artificial heart are inadequate.

John Watson, Chief of the Devices and Technology Branch of NHLBI, believes that existing open-heart facilities should be adequate for artificial heart surgery and postoperative recovery (77). The growth in emergency cardiac facilities and personnel during the last decade and the plans for mobile care units and coronary facilities throughout the United States should pro-

Table 2.—Effect of Numbers of Implants on Available Societal Resources

Replacements per year	Total costs per year (in millions) with implantation costs of:			Implants per surgeon per year with number of available surgeons:			Implants per facility per year with number of available facilities:		
	$24,000	$28,000	$75,000	800	1,000	1,200	600	800	1,000
16,000	$ 384.00	$ 448.00	$1,200.00	20.0	16.0	13.3	26.7	20.0	16.0
33,600	806.40	940.80	2,520.00	42.0	33.6	28.0	56.0	42.0	33.6
47,000	1,128.00	1,316.00	3,525.00	58.8	47.0	39.2	78.3	58.8	47.0
66,000	1,584.00	1,848.00	4,950.00	82.5	66.0	55.0	110.0	82.5	66.0

SOURCE: Estimates are derived from information provided in the text.

vide a facilities base suitable for the transportation of candidates for artificial heart surgery. As noted below, however, artificial heart implantations may severely strain existing personnel resources.

Interviews with cardiac surgeons indicate that the services of the current open-heart procedure team plus an associate surgeon and an artificial device engineer will be required for artificial heart implantation. The estimated personnel requirements in the operating room are listed below:

	Hours
Chief surgeon	4-5
Associate surgeon	2-3
Anesthesiologists (2)	7-8
Heart-lung machine operators (2)	7-8
Residents (3)	7-8
Nurses (3)	7-8
Technicians (2)	7-8
Artificial device engineer	4-s

These personnel requirements are extensive when superimposed on present needs for skilled surgeons and nurses for heart-lung work, heart transplants, arterial grafts, and pacemaker implantations. Artificial heart surgery, like heart transplantation, is likely to disrupt any hospital's schedule. In addition, the surgery is only a small part of the patient care process, which requires the time and resources of nurses, lab technicians, physicians, and engineers.

It is difficult to estimate the present number of cardiac surgeons, because currently available medical specialty statistics do not differentiate between cardiac and noncardiac thoracic surgeons. In 1976, there were 2,020 thoracic surgeons (3). Approximately 39 percent (780) are estimated to be active cardiovascular surgeons. The supply of cardiac surgeons has been increasing at about 15 percent per year (59), so shortly almost half of certified thoracic surgeons will be active in cardiac surgery. Using these figures, we have assumed that as few as 800 and probably closer to 1,000 surgeons will be available to perform artificial heart surgery in the coming decade.

In 1976, an estimated 600 hospitals were engaged in open-heart surgery, an increase from 432 hospitals in 1972. Under the assumption that no new facilities would be required for artificial heart implantation, if one postulates a total of 33,600 implants a year* and 800 hospitals have cardiac facilities, each hospital would average 42 implants per year. These centers will also have subsidiary concerns, among them the blood requirements necessary to prime the heart-lung machine for surgical bypass and emergency care of hemorrhage, pump oxygenators, and an inventory of artificial hearts available for immediate use. With a product whose demand could vary from 16,000 to 66,000 per year and whose reliability, longevity, and maintenance record still remain undocumented, accurate estimates of the major resource requirements are still not feasible.

R&D Funding

The NHLBI-directed program for the development and assessment of circulatory-assist and cardiac replacement devices is partially funded through contracts (see app. C). This family of contracts provides funds for researching blood pumps, power sources, energy transmission and storage, instrumentation, and biomaterials. There is no single major recipient of contract funds. As shown in table 3, the targeted contract program of the Devices and Technology Branch grew rapidly from $500,000 in fiscal year 1964 to $8 million by fiscal year 1976. Since then, the program has remained relatively stable at an average of $10 million a year. Figure 1 compares relative funding levels for NIH, NHLBI, and the artificial heart program for fiscal years 1964 through 1975.

NHLBI has also supported basic research for the artificial heart development program through extramural grant programs. The extent of these funds is difficult to delineate in the overall Institute grant figures. The responsibilities of the Devices and Technology Branch were broadened to include grants in 1975. Activities funded through regular and project grants include intra-aortic balloons, biomaterials, and prosthetic heart valves (see app. C). The branch also has unrelated grant activities on

*The manner of arriving at this estimate was discussed in the previous part of this case study.

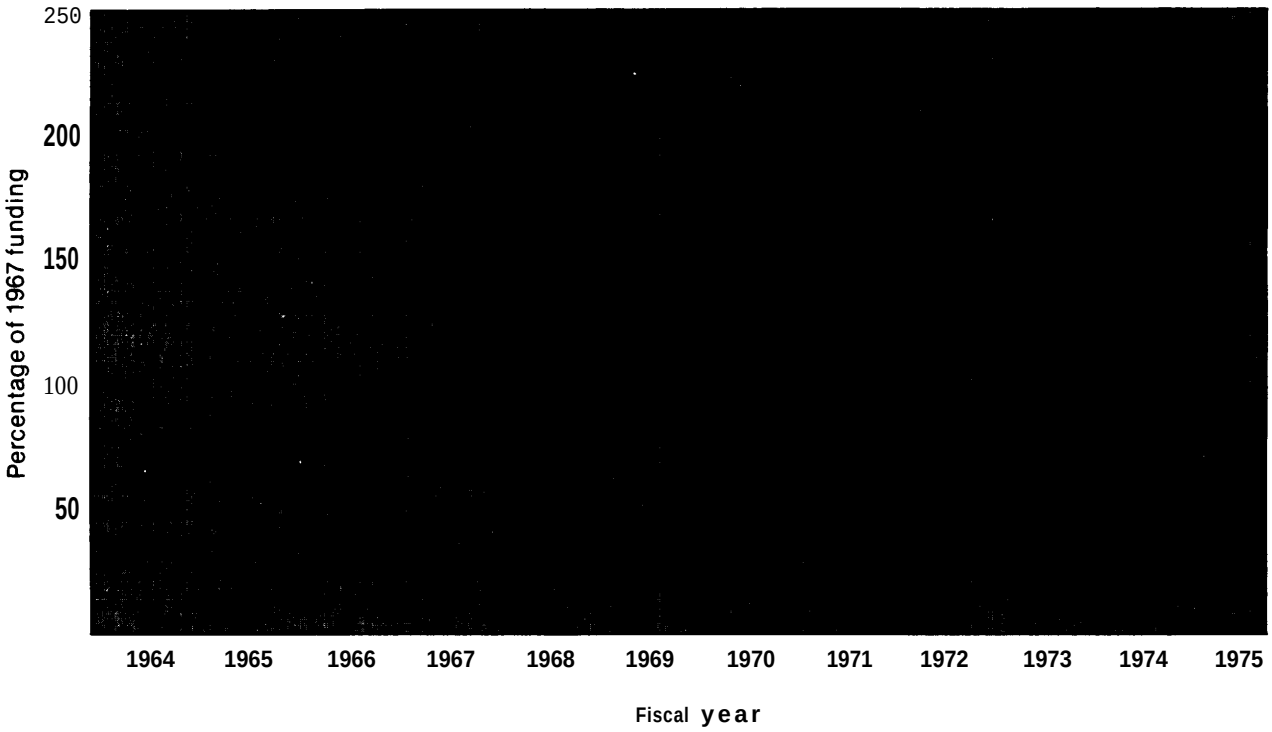
Table 3.—NHLBI Devices and Technology Branch Contract Funding, Fiscal Years 1964-79

Fiscal year	Programs							Total
	Materials	Energy systems	Blood pumps	Bioinstru-mentation	Special programs	Oxygenators	Physiological testing	
1964	$ 209,085	$ 93,856	$ 278,183	$ 0	$ 0	$ 0	$ 0	$ 581,124
1965	0	0	0	0	261,756	0	0	261,756
1966	843,242	728,500	316,555	0	1,680,857	0	335,777	3,904,931
1967	1,735,469	2,909,378	1,377,433	0	898,406	467,747	1,165,876	8,554,309
1968	2,130,569	1,365,749	1,533,379	617,456	149,818	590,440	1,454,113	7,841,524
1969	1,062,462	2,902,329	1,345,945	479,833	239,012	495,766	1,862,252	8,387,599
1970	1,089,083	2,660,840	1,476,869	312,657	9,000	338,460	3,388,334	9,275,243
1971	1,115,375	3,165,036	1,793,847	146,023	446,757	676,786	1,873,712	9,217,536
1972	905,044	3,897,469	2,386,193	251,386	62,548	381,161	2,700,718	10,584,514
1973	1,877,930	2,822,000	1,971,222	183,513	42,500	43,848	2,996,743	9,937,756
1974	557,214	3,471,258	2,466,405	560,030	44,978	0	851,655	7,961,540
1975	440,069	3,480)204	3,448,612	1,707,659	0	0	56,196	9,132,740
1976	3,274,000	3,182,000	3,082,000	1,492,000	908,000	0	0	11,938,000
1977	3,259,000	3,883,000	3,098,000	2,040,000	921,000	0	0	13,201,000
1978	2,373,000	4,034,000	2,899,000	2,235,000	577,000	0	0	12,118,000
1979a.	1,700,000	3,700,000	3,300,000	1,800,000	500,000	0	0	11,000,000
Total. . . .	$22,571,542	$42,295,619	$30,773,643	$11,835,557	$6,741,632	$2,994,208	$16,685,376	$133,897,577

[a]Estimated.

SOURCE: National Heart, Lung, and Blood Institute, Devices and Technology Branch, Bethesda, Md., 1979

Figure I.—Comparative Program Growth: NIH, NHLBI, and the Artificial Heart Program, Fiscal Years 1964-75



SOURCE: National Heart, Lung, and Blood Institute, Bethesda, Md.

diagnostic instruments and therapeutic devices. John Watson, of NHLBI, has estimated total grant spending since 1964 at $30 million. For fiscal years 1977 through 1979, the grants specifically related to the development of the artificial heart were $10 million. Approximately $3.5 million in grants were funded in fiscal year 1978.

The $164 million spent to date on the NHLBI artificial heart program ($134 million in contracts, $30 million in grants) represents the bulk of the total cost of developing an artificial heart, but several research institutes and technology firms have held Department of Energy (DOE) contracts (totaling $17 million) to develop a nuclear engine for an LVAD or totally implantable artificial heart. Contractors include the University of Utah, Westinghouse, Andros, Arco, and Aerojet-General. We have estimates from only one contractor on the size of these funds, though we have contacted other recipients for information. That firm has spent almost $7 million to date on thermal energy development. The financial history of the artificial heart program at DOE is summarized in table 4.

In 1968, the Atomic Energy Commission (AEC), now DOE, initiated a program at Los Alamos Scientific Labs for the development of plutonium-238 (Pu-238) fuel for the artificial heart. In 1971, contracts were awarded to several university research centers (University of Utah, Cleveland Clinic, University of Washington) to begin biomechanical and biomaterials studies. According to Donald Cole of DOE's Office of Health and Environmental Research (20), DOE funding has recently ended.

It is by no means clear, however, that interest in nuclear energy as a power source for the artificial heart has ended. In early 1979, NIH solicited proposals for research into a clinical thermal energy system, and in November 1979, 3-year contracts for $900,000 and $795,000, respectively, were awarded to Aerojet-General and the University of Washington. The thermal engine to be designed can be driven by one of two energy sources: thermal (e.g., lithium salts) or nuclear (e. g., Pu-238). Of these two sources, Pu-238 is acknowledged to be clinically the more attractive, because lithium salts must be reheated at intervals not exceeding 4 to 8 hours.

Table 4.—Financial History of the Artificial Heart Program at the Department of Energy

Contractor	Period of performance	Title	Cumulative costs
Westinghouse Electric Co.	4/19/71 - 6/30/78	Nuclear-powered artificial heart	$10,005,103
Hittman Associates	3/74 - 3/75	Development of a radioisotope heat source subsystem for heart devices	16,000
Universities Center.	8/1/73 - 7/31/74	Artificial heart controls support	19,033
University of Washington	6/15/71 - 9/14/78	A program to evaluate the mechanical properties and biocompatibility of materials for the ERDA artificial heart	457,883
TRW, Inc.	4/19/71 - 6/30/75	Radioisotope heat source for an artificial heart	527,499
Cleveland Clinic	2/15/72 - 12/31/77	Artificial heart supporting services	257,499
Cornell University.	9/74 - 9/30/78	Biological effects of implanted nuclear energy sources for artificial heart devices	371,666
Sinai Hospital	9/1/75 - 8/31/76	ERDA artificial heart program review	9,874
University of Utah.	6/15/71 - 6/30/79	Biomedical engineering support	1,719,880
University of Utah.	6/15/71 - 9/14/77	Materials testing and requirements for the ERDA nuclear-powered artificial heart	357,208
Westinghouse Electric Co.	5/1/72 - 4/30/73	An investigation of high-performance thermal insulation systems	132,421
Los Alamos Scientific Laboratory.	7/1/72 - 9/30/77	Fuels and source development	2,083,000
Mound Laboratory	7/1/72 - 6/30/73	Fuels and source development	59,000
Pacific-Northwest Laboratory.	7/1/72 - 6/30/74	Recipient radiation exposure	163,000
Pacific-Northwest Laboratory.	7/1/72 - 9/30/77	Population radiation exposure	145,000
Pacific-Northwest Laboratory.	7/1/73 - 10/1/76	Pu-238 from Am-241	315,000

SOURCE Information provided by the Department of Energy, Washington, DC.