ANALYSIS OF FEDERALLY FUNDED DEMONSTRATION PROJECTS: SUPPORTING CASE STUDIES

PREPARED FOR THE EXPERIMENTAL TECHNOLOGY INCENTIVES PROGRAM
U.S. DEPARTMENT OF COMMERCE

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CHERYL COOK, PATRICIA FLEISCHAUER, BRUCE GOELLER,
WILLIAM HEDERMAN, LELAND JOHNSON, EDWARD MERROW,
RICHARD RETTIG, JOHN WIRT

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PREFACE

During the past two decades, the federal government has been increasingly active in stimulating technological change and innovation in the civilian economy. Beyond research and development (R&D) activities, federally supported "demonstrations" of such innovations as nuclear power reactors, personal rapid transit vehicles, and desalination plants have been designed to speed their commercialization. Other demonstrations provide information for regulatory decisions, especially in the environmental field. On occasion, demonstrations have also been used to promote U.S. foreign policy objectives. In all cases, demonstrations are intended to show how a technology operates in a normal "real world" environment.

The results have been mixed. Some demonstrations have met their objectives, while others have not. As a result, many questions arise about what can be learned from this experience to enhance the effectiveness of federally funded demonstrations in the future. These questions are all the more pressing because, in contrast to the vast literature on R&D, demonstration projects have received little attention as a part of the process from basic research to commercial use.

Consequently, Rand undertook this study of federally funded demonstration projects under contract from the Experimental Technology Incentives Program (ETIP) of the Department of Commerce. ETIP's objective is to facilitate governmental policy changes that will lead to improvements in the environment for innovation and in the general vitality of the economy. ETIP pursues this objective by conducting policy experiments and studies in close collaboration with other federal agencies, for the purpose of developing and conveying knowledge and understanding of policy opportunities to appropriate decisionmakers. ETIP's interest in demonstration projects derives from the major role that such projects have played in a broad variety of government activities designed to stimulate innovation.

The purposes of the Rand study are (a) to identify major factors associated with successful and with unsuccessful project outcomes, and
(b) to formulate guidelines for federal agencies in improving the planning, implementation, monitoring, evaluation, and dissemination of results of future demonstration projects.

This study involved analysis of 24 past demonstration projects spanning a wide range of federal agencies, technologies, and project characteristics. The results are presented in three separate Rand reports:

- An executive summary (R-1925-DOC) encapsulating these results.
- A final report (R-1926-DOC) containing a general discussion of federal demonstration projects; the methodology and conceptual framework for the study; an analysis of the cases examined, including patterns and conclusions that emerge from them; and guidelines for federal agencies likely to be engaged in future demonstration activities.
- A compilation of fifteen supporting case studies of federally funded demonstration projects (R-1927-DOC).

We appreciate the many constructive comments on earlier drafts by Jordan Lewis, Director of the ETIP Program, John Logsdon of George Washington University, and Rand colleagues James Hosek and Elizabeth Rolph. We are especially indebted to the dozens of people in government and industry who gave generously of their time in answering questions and providing other information required in preparing the case studies.
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NUCLEAR SHIP SAVANNAH

by

John Wirt
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I. INTRODUCTION

This report is a case study of the N.S. Savannah, the world's first nuclear-powered merchant ship, built as a joint project of the Atomic Energy Commission (AEC) and the Department of Commerce's Maritime Administration. The N.S. Savannah project was initiated in the mid-1950s by the Eisenhower administration, as a demonstration to the world of a peaceful use of the atom.

The launching of the N.S. Savannah in 1959 was hailed as the beginning of a new era in ocean shipping, equal in importance to the conversions from wood to iron hulls and from sail to steam power. Nuclear-powered ships offered the potential advantages of lower fuel costs, higher operating speeds, and increased cargo-carrying capacity. It was recognized that the capital cost of atomic-powered ships would initially be higher but the projection was that as nuclear technology advanced this cost would decline to where, all economic factors considered, nuclear-fueled power plants would be cost-competitive with conventional power plants.

The vision of the N.S. Savannah opening a new era in merchant shipping has not materialized in the fifteen years since the ship's launching, although it may do so in the future. Although the N.S. Savannah's successful demonstration voyages represented a remarkable technical achievement, the ship was never economically successful for commercial service and the evidence is that nuclear technology has still not advanced to the point where economic factors favor constructing large numbers of atomic-powered ships for merchant fleets. However, should these economic factors change to the advantage of nuclear power, this great expansion may occur. What the N.S. Savannah demonstration accomplished was to pave the way for this to happen by demonstrating that nuclear-powered merchant ships can be operated safely and reliably in conjunction with fossil-fueled ships.
The *N.S. Savannah* program was so complex and involved so many people now scattered across the country that it was impossible to make this case study complete. Parts of the case study lack specificity because the persons directly involved could not be interviewed within the available travel budget. Also, some important aspects of the program have not been given proper emphasis because conflicting evidence could not be verified or reconciled within the time that was available for research. A complete analysis of the *N.S. Savannah* project would require much more research than was possible within the budget for this case study. An entire book has been written on just the labor relations aspects of the *N.S. Savannah* program alone.
II. ORIGIN OF THE N.S. SAVANNAH PROGRAM

The public record of the N.S. Savannah project begins on April 25, 1955, when President Eisenhower made a speech at the annual luncheon of the Associated Press in New York City:

We have added to the United States Program for Peaceful Uses of Atomic Energy an atomic-powered merchant ship. The Atomic Energy Commission and the Maritime Administration are now developing specifications. I shall shortly submit to the Congress a request for the necessary funds, together with a description of the vessel.

The new ship, with an atomic reactor, will not require refueling for scores of thousands of miles of operation. Visiting the ports of the world, it will demonstrate to people everywhere this peacetime use of atomic energy, harnessed for improvement of human living. In part, the ship will be an atomic exhibit, carrying to all people practical knowledge of the usefulness of this new science in medicine, agriculture, and power production.

Following this speech, the President submitted a request to Congress for a supplemental appropriation to build the ship. It was scheduled to be ready for demonstration cruises within the exceedingly short time of 24 to 30 months.

ATOMS FOR PEACE

At the time of the President's announcement, a broad, U.S.-led movement was emerging at the time among free-world nations to find ways of applying nuclear energy for peaceful purposes. President Eisenhower, and many others in the government, saw great possibilities for advancing U.S. foreign policy and economic interests around the world through finding and marketing practical applications of the nuclear knowledge that the nation had developed for military purposes. Achieving these objectives required R&D to develop these applications
and the creation of a worldwide community of interest in peaceful applications of nuclear power to induce markets for the technology developed. In the early 1950s, the AEC began supporting studies of the feasibility of applying atomic energy to the generation of electric power. These studies eventually led to the AEC's power reactor demonstration program, described elsewhere in this report. Somewhat later, in 1953, an International Conference on Peaceful Uses of the Atom was held in Geneva, Switzerland. This was followed in December of the same year by the President's announcement to the United Nations of the U.S. Program for Peaceful Uses of the Atom. Also, during this period Congress amended the Atomic Energy Act to allow private ownership of nuclear facilities and to declassify much of the available knowledge regarding nuclear energy. The President's proposal to build a nuclear-powered ship was one more aspect of U.S. efforts to advance the cause of atoms for peace.

It was widely felt that promotional efforts were necessary partly because of prevailing social attitudes toward nuclear power. The dominant public images of this new source of energy were military; the bombs dropped on Hiroshima and Nagasaki, the Navy's newly launched submarine Nautilus, and the nuclear weapons that constituted the nation's chief strategic defense against the Soviet Union. President Eisenhower thought that a nuclear-powered ship, capable of visiting ports around the world and carrying exhibits of the latest in U.S. nuclear and other technology would contribute to changing the public image of atomic energy and thereby create a climate favorable to emergence of a worldwide community of interest in peaceful applications of nuclear power.

THE PRESIDENT'S SHIP

All the evidence obtained in preparing this case study suggests that the idea of building a nuclear-powered merchant ship was primarily President Eisenhower's, although initial suggestions may have come
from various persons in his administration. At least, he strongly supported the idea and took a personal interest in the program that emerged, even to the point of making many of the major decisions himself. Other key figures were Lewis Strauss, who was chairman of the AEC, and James Hagerty, the President's Press Secretary. Hagerty was assigned primary responsibility in the White House for organizing the nuclear ship project.

The idea of building a nuclear-powered ship had been around in the government almost from the time of the first nuclear explosion in 1945. In fact, at the time of the President's announcement, the Maritime Administration was in the process of conducting feasibility studies of alternative designs for nuclear-powered merchant ships. These studies included designs for a tanker, a bulk freighter, and a passenger ship including specific considerations of alternative reactor systems.

Whatever the exact source of the President's proposal, the White House requested that Marad prepare a design for a nuclear-powered ship capable of cruising around the world and advancing the cause of atoms for peace. The White House specified that in order to be most effective in serving this objective, the ship should have a modern and pleasing appearance, carry passengers, and be capable of docking at downtown municipal piers. In this way, the ship's accessibility to the public and visibility would be maximized and possibilities increased for inviting large numbers of foreign dignitaries on board for demonstration cruises. Marad responded with a design for a 50,000-ton nuclear tanker, which the White House rejected. It directed Marad to prepare another design for a ship that would carry passengers, which it saw as necessary for the purposes that it had in mind.

Marad proposed a tanker because it was more interested in promoting the concept of a nuclear-powered U.S. merchant marine than the concept of atoms for peace. Their feasibility studies had clearly shown that to have a chance of being economically competitive with conventionally powered ships, a nuclear-powered ship should have large deadweight capacity, quick turn-around time in port, operate on long trade routes, and carry a bulk cargo of high density. The White House refused to consider such a ship as being far less useful for demonstrating a peaceful use of the atom than one designed as a public attraction and able to carry passengers from port-to-port on cruise-ship schedules.

The President was very clear on his objectives. In a letter submitted to the Joint Atomic Energy Committee on July 27, 1957, Roland Hughes, Director of the Bureau of the Budget, explained that the purpose of the peace ship was to carry the message of peaceful uses of atomic energy throughout the world as a "living, operating demonstration laboratory that through its own propulsion machinery and exhibits will give us glimpses of the future." Hughes continued that:

The President seeks no return on this vessel except the goodwill of men everywhere....Neither will the vessel be burdened by proving itself commercially feasible by carrying goods exclusively. Its value will not be in economic return or proven efficiency and speed of operation. Those will come later when we have learned new lessons of design. We can afford to wait four years, five years, and even more, for successful merchant ships with nuclear propulsion machinery. We cannot afford to wait more than a minimum amount of time to send the peace ship forth upon the seas.  

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During this early period, Admiral Hyman G. Rickover, both then and now director of the Navy's nuclear submarine program, suggested that instead of proceeding to develop a nuclear-powered ship from scratch, as Marad was intending, a spare reactor left over from building the submarine *Nautilus* should be used.

There followed an extended and complicated series of negotiations among officials in the White House, the AEC, and Admiral Rickover over the shape of the program that the President was proposing and assignment of responsibility for conducting it. There was concern in the White House about being able to control the program, and that it should not be associated with a branch of the military since the purpose was to demonstrate a peaceful use of the atom. According to one person interviewed for this case study, there was, however, some lack of understanding in the White House about the technology involved and, particularly, confusion about whether or not the Submarine Thermal Reactor (STR) could be made powerful enough to propel the ship that the President wanted.

**CONGRESSIONAL DEBATE**

The bill originally submitted to the Congress requested funds to build the President's ship under the existing authority of the Merchant Marine Act of 1936. In this way, approval of only the House and Senate appropriations committees would have been required to obtain the funds necessary to build the President's ship. However, Congress and particularly the Joint Committee on Atomic Energy (JCAE) and the House Merchant Marine and Fisheries Committee (MMF), took exception to this approach and called hearings on the President's proposal.

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1Admiral Rickover holds the dual positions of Director, Naval Reactors Division, ERDA (formerly the AEC), and head of the Nuclear Power Directorate in the Naval Sea Systems Command in the Department of the Navy.
The members of the JCAE generally supported the President's Atoms for Peace Program, and, in fact, had authorized a Panel on Peaceful Uses of Atomic Power a month before his speech to the Associated Press luncheon. However, the chairman felt that this committee should have been more fully consulted on the President's proposal before it was submitted to the Congress. The chairman of the JCAE did not become convinced of the need for a nuclear-powered ship until he was persuaded of its importance in a personal meeting with President Eisenhower. Most of the witnesses called to testify before the JCAE (including, of course, Admiral Rickover) expressed reservations that any ship constructed would be anywhere near economically competitive with conventionally powered ships unless considerable investment was made beforehand in R&D. In debate before the House, members of the JCAE spoke against the passage of a bill to authorize the President's program.

Chairman Bonner of the MMF, which had (and still has) jurisdiction over authorizing legislation for the Maritime Administration (including the Merchant Marine Act of 1936) also took a dim view of the President's plan although for a different reason than the chairman of the JCAE. Chairman Bonner believed the need was greater for a ship that would be a bigger step forward to a nuclear-powered merchant marine. For this purpose, he saw greater utility in building a vessel that would serve in a specific, commercial trade rather than as an international exhibit. In hearings on the President's proposal, members of the MMF committee questioned whether the nation's first nuclear ship should be a "peace ship" for demonstrating a peaceful use of the atom, or an "experimental" ship that would demonstrate nuclear propulsion for commercial merchant ships. Chairman Bonner went so far as to introduce his own bill that would have authorized the construction of two demonstration ships, one a "peace ship," and one an "experimental ship" that would be as economically viable as technically possible at the time. Chairman Bonner said in hearings on the President's bill that while his
committee thought that the President's proposal was good for "getting the idea of a nuclear-powered merchant ship across to the public," they were not ultimately interested in a "sideshow ship, or a carnival ship, or a Mississippi Riverboat," but "...something to develop and pioneer for the future."¹

Several witnesses, including Kenneth Davis, the director of the AEC's Reactor Development, and Admiral Rickover cautioned the MMF committee that economically efficient nuclear propulsion for merchant ships was many years away. Admiral Rickover emphasized that developing an efficient nuclear-powered merchant ship was not a simple problem and that an extended R&D program would be required. Moreover, he believed that the Maritime Administration should establish a strong in-house group of nuclear specialists to manage any such effort, as he had done in the Navy Submarine Program. The Admiral was greatly concerned that such a program would seriously disrupt the Navy's nuclear program through diversion of the few trained nuclear specialists available.²

The committee was told by Kenneth Davis that the President's plan was to install an STR reactor in an existing ship and as a result the ship constructed would not be economically efficient:

...Aside from the questions of small power output, the STR-type of reactor is adapted for a specific purpose very far removed from the propulsion of a merchant ship. It is designed to go in a submarine and those of you who are familiar with the layout and dimensions of a submarine will appreciate the difficulties of developing a nuclear power plant for such an application. There are other requirements—for operation under various conditions, for resistance to battle damage, and others which result in the STR reactor being a very special and expensive type of reactor.

²Ibid.
One important consideration is that the STR was designed to be as compact as possible and, therefore, uses highly enriched U-235 as fuel. Since there is relatively little U-238 present, essentially no plutonium is formed by the extra neutrons and the U-235 is simply burnt up with no replacement by plutonium. This is bad from two points of view. It is hard to get long lifetime for the fuel elements, and the economics are poor since the U-235 burn up costs as much or more than an equivalent amount of fuel oil. While this is not so serious on a special naval ship, it represents a very serious limitation for a nuclear ship. 1

Dr. Davis continued:

...that if we were to start development work now on the nuclear propulsion of merchant ships, it would be at least five years and probably more likely ten years before we would have a nuclear power plant installed in a merchant ship which would show us that we had the answer to the economical propulsion of merchant ships by nuclear power. 2

Then he added the comment which impressed the committee, however, "...if we do not start the necessary development work now, it will be even longer."

Ship operators testifying during the authorization hearings also generally supported the idea of building a demonstration ship but were not very enthusiastic. They indicated that most of their information about the President's proposal and nuclear power was obtained from "reading the newspapers." 3 They were concerned about: (1) getting insurance for nuclear ships, (2) training crews for nuclear service (it was pointed out that it took the Navy several years to train its nuclear crews), (3) the attitude of seamen toward going to sea in a nuclear ship ("Would they go into the engine room?")), and (4) the implications for crew scheduling (Ship operators often exchange crews on different legs of a voyage).

1Ibid.
2Ibid.
3Ibid.
Ship operators also expressed great concern about block obsolescence in their fleets and the unusually large number of technological developments on the horizon in maritime shipping. A large percentage of ships in U.S. fleets during the 1950s were built during World War II and would become obsolete in the 1960s, since ships normally have a twenty-year lifetime. Ship operators saw that they were going to have to make major new investments in ships in the coming years and that efforts underway at the time to develop large-scale gas turbine power plants, roll-on-roll-off ships, and standardized export packaging (now called containerization) were going to put them in the position of having to make some difficult investment decisions. Ship operators were concerned about the consequences of making the wrong decisions and committing themselves to technologies that might quickly prove to be outmoded. Nuclear power added one more element of uncertainty.

A bill authorizing the construction of one nuclear ship was finally passed by Congress on July 30, 1956, over fifteen months after President Eisenhower's initial proposal. This bill (P.L. 848) compromised on the issue of whether a "peace ship" or an "experimental ship" would be built in authorizing the construction of "one nuclear-powered ship capable of providing shipping services on routes essential to maintaining the flow of foreign commerce of the United States." In the conference report, House members directed that this "first experimental application of nuclear power should be a practical merchant vessel of combination passenger and cargo design" (emphasis added) which, as will be discussed below, is a contradiction in terms. Furthermore,

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1 Data in A. W. Kramer, *Nuclear Propulsion for Merchant Ships*, Atomic Energy Commission, 1962, indicate that over 93 percent of ships in the U.S. fleet in 1955 were built during World War II.


3 Ibid.
the conference report all but closed the door on the President's approach of installing an STR reactor in the ship to be built:

"...It was the contemplation of the conferees that the vessel would contain the most advanced type of reactor possible for a practical merchant ship which would be a definite step forward in the art of nuclear propulsion, utilizing all the experience and improvements learned to date. In other words, the reactor would not be one which has already been produced for other purposes. The project should be given the highest priority and completed as soon as is consistently possible for such an unproved design. It is also hoped that most of the design details of the reactor should be unclassified in order to facilitate maximum sharing of the information.¹

However, it was not determined in this case study what the Eisenhower administration's role was in influencing the Congress to adopt this language in their conference report. Perhaps the decision not to use the STR reactor was actually made in the White House.

Congress appropriated $32 million to develop the reactor and $12 million to build the hull, for a total of $44 million.

III. DEVELOPMENT OF THE N.S. SAVANNAH

The President signed the bill authorizing the construction of a nuclear ship on October 15, 1956, and released a statement stressing his long and deep interest in the project. The text of his statement indicates a shift in his conception of the vessel that was to be built:

We have had a nuclear-powered warship since the launching of the submarine Nautilus in January 1954. Merchant ship propulsion, however, is as yet unrealized—although it is one of the most promising applications of nuclear energy. Atomic merchant ships will be able to carry more cargo on long voyages than conventional ships because of the savings in fuel space. They will need less time in port, since they will operate for long periods without refueling.

This new vessel will be a floating laboratory, providing indispensible information for the further application of atomic energy in the field of ocean transportation. The reactor itself will be a definite step forward in nuclear propulsion. I am confident that the ship will be the forerunner of atomic merchant and passenger fleets which one day will unite the nations of the world in peaceful trade.

The plan was that the ship would be operated for approximately a year as a "peace ship," traveling to ports around the world and then for an extended period in commercial operations. In 1957, the President announced that the ship would be called the N.S. Savannah after America's first steam-powered ship the S.S. Savannah.

BASIC DESIGN OF THE N.S. SAVANNAH

The basic design of the N.S. Savannah (see Fig. 1) had been worked out between the AEC and the Maritime Administration during the time period since the original proposal had been submitted to Congress in 1955. The hull was to be a slightly larger version of a Standard Mariner-class
vessel, 595 feet long and weighing 22,000 tons. The reactor would be of a new design and the propulsion system would develop 20,000 shaft horsepower, allowing a cruising speed of 21 knots.

The principal design constraints were the White House's requirement that the ship must be outfitted for carrying passengers and the budget limitation of $44 million. It would have been possible and more efficient to build an all-passenger ship but this would have cost substantially more than $44 million by the time it was fully outfitted. Consequently, it was necessary to make the ship a combination passenger and general cargo ship. This meant that, because of the combination payload, average trip lengths in commercial service would be shorter and docking time increased. Because of union work rules, the crew had to be larger; if the Savannah had carried only freight the crew would have been about 50 instead of 109. Because there were to be passengers, there had to be a swimming pool--but the only convenient place to put this was over one of the freight holds, a position that made loading and unloading cargo from this hold more costly.

The requirement for a combination payload plus the limited budget provided by Congress also meant that corners had to be cut on outfitting the ship. In order to meet the budget constraint, the passenger load had to be limited to 60, and throughout the ship economy models of all kinds of equipment installed. The winches and cranes, for example, had only three ton capacity and were of pre-World War II vintage. These smaller winches cost less than larger winches but were much less efficient in cargo handling.¹ The out of date communications system was another example: the radio-telegraph was only 250 watts compared to the standard 500 watts or more; the ship-to-shore telephone used the same frequency as private yachts; and the intraship telephone allowed only one call at a time among ship's officers.²

¹Larger winches of the type usually installed on a Mariner class ship would also have been unsightly, and, therefore, conflicting with White House requirements that the Savannah be modern and visually attractive in appearance.
BASIC DESIGN OF THE REACTOR

The plan was to develop a pressurized-water reactor of a new type as the N.S. Savannah's power source. This reactor was much smaller than any commercially sized central power station reactors then being contemplated or under construction and was designed to operate on low-enriched uranium (U-235 constituted only a low percentage—4.3 percent—of the total uranium in the fuel rods). This led to problems because knowledge of the physics of low-enriched reactors was crude. Also, there was little experience on this kind of reactor with important engineering factors such as pump selection and location, and piping configurations. As an indication of how imperfect the models of reactor design were initially, the design team eventually learned that if they had built the reactor according to their first set of specifications, it would not have been possible to make it go critical. Also, the short time schedule on which the N.S. Savannah was to be built (which was inherited from the President's original proposal) and the budget constraint, meant that it would have been difficult to build and test a prototype of the reactor prior to building one for installation in the ship. The only reactor built was installed in the N.S. Savannah.

Moreover, at the time of the President's proposal, reactor technology in general was at a very early stage of development. Only the Navy, under Admiral Rickover's leadership, had rigorously developed and extensively operated power reactors. But, as indicated above, these were of a substantially different type than planned for the N.S. Savannah. Although the Shippingport reactor had already been completed and operated in a power grid, it was only a prototype and was highly inefficient. The first operational pressurized-water reactor of even modest commercial size for a central power station was still two years away from completion. Since pressurized-water reactors were the furthest along in development at the time, this meant that there was no extended operational experience with any power reactors other than in the Navy. The first prototype plant of the type of reactor next furthest along in development, a boiling water reactor, had just
been tested and engineers discovered that it produced three times more power than they had expected. With modifications, the evidence was that this reactor would produce an additional two-thirds more power.

Furthermore, most of the reactor development work at the time was for large-scale reactors of the size needed in central power stations. The reactor for a 100 megawatt power station, which is a small-sized facility by today's standards, is sufficient to produce over 100,000 shaft horsepower in a marine application. This much torque is enough to drive several hundred thousand ton ships at high rates of speed (over 30 knots). Because of the White House requirement for a ship capable of docking a downtown municipal piers, a much smaller reactor had to be built for the N.S. Savannah. This meant a great loss in efficiency and that engineers would be working in an area of greater technical uncertainty.

Even if the N.S. Savannah design team had been able to build a larger reactor, there would have been difficulty in building a vessel large enough to utilize it, because the largest ships under construction at the time were around 50,000 tons. Ships in the range of several hundred thousand tons did not begin to appear until the late 1960s. In the mid-fifties, shipyard facilities to build a ship of this size did not exist, and designers could not be certain of structural requirements for ships six times larger than anything ever built before. Ships have traditionally increased incrementally in size as naval architects gain experience with each new vessel built. Therefore, not only from the standpoint of reactor technology, but also ship construction technology, the N.S. Savannah was built at least ten years too early to be maximally efficient.

The Savannah's reactor design team also had other technical problems to deal with. One was that, because of the short time schedule, reactor design criteria had to be developed concurrently with actual development work on the reactor. As a result, there were many midstream design changes and difficult coordination problems among the reactor design group, the ship designer, and the shipyard, all of which were working
in parallel. The main criteria finally agreed upon for the reactor
design were: a power output of 74 megawatts, three years of continuous
operation between refueling, ability to enter the main reactor chamber
within 20 minutes of reactor shutdown, and no release of hazardous
radiation if there were rupture of the main cooling system.

Engineers also had to develop and test a "control rod drive"
system for moving the low-enriched fuel elements in and out of the
reactor core. Knowledge accumulated from building control rod drives
for land-based reactors was useful in this effort, but for a shipborne
reactor the control rod drives had to be able to withstand pitch-and-
roll motion and other environmental conditions not present in land
installations.

It was decided that the Savannah should have a highly automated
system for controlling the reactor during warmup, and the reactor
and propulsion machinery during operations, monitoring safety con-
ditions in the power system, and initiating scrams (automatic shut-
downs). The Savannah team started to work out a control system and
ship design that would have reduced the crew size by a factor of two-
to-three but were directed not to continue. The Savannah was then
to be the first U.S. merchant ship so highly automated.

Another initial technical problem area was safety. As the first
atomic merchant ship, extra precautions had to be designed in for
preventing nuclear accidents and making the N.S. Savannah safe in the
case of collision. Various components of safety were: adequate
shielding of the reactor to prevent radiation of passengers and crew,
methods for containing radioactive waste water and lubricants,
collision protection, and stand-by power systems.

ORGANIZATION OF THE N.S. SAVANNAH PROGRAM

A special project office reporting to both the Chairman of the
AEC and the Administrator of the Maritime Administration was established
for the N.S. Savannah program. Staff of the special project were
located in the Nuclear Projects Office of the Maritime Administration
and the Advanced Reactors Branch of the AEC. Contracting for the reactor and propulsion system was done through the AEC and for the ship through the Maritime Administration.

The first director of the N.S. Savannah program was Richard P. Godwin, an engineer, who had been director of technical operations for Dr. Edwin Teller at the Lawrence Radiation laboratory at Livermore, California. Godwin held the positions of both director of the N.S. Savannah program and the AEC's Maritime Reactors Division. In this latter position, Godwin was in the AEC's directorate for Reactor Development and counterpart to Admiral Rickover. Godwin served as head of the N.S. Savannah program until 1962, when he left the government and was replaced by John Robb, another AEC man. Robb left in 1964, and was replaced by Delma Crook of the Maritime Administration, who served until the program ended.

**CONTRACT MANAGEMENT**

Contracting for the N.S. Savannah was complex and required a great deal of management effort on the part of the Savannah program office. There were four major contractors -- a naval architect, a shipyard, a company to build the propulsion system, and a general agent to operate the ship -- and scores of subcontractors. There was no prime contractor, although the shipyard had responsibility for integrating all of the pieces furnished to it by the government through the other contractors. In this relationship, the government was in the middle and responsible for defining all of the interfaces.

**Contractor Selection**

Babcock and Wilcox (B&W) was selected as the propulsion system contractor on October 16, 1956. B&W had done one of the original feasibility studies for Marad on a pressurized-water reactor and was much further ahead in their design than any other potential supplier. Because of this lead, there was no competitive bidding; B&W was directly awarded a fixed-price contract.
The naval architect was George W. Sharp, one of the largest and best-known firms in the field. The Sharp firm had designed the Mariner-class hull for American President Lines, and was a natural choice. Again, there was no competitive bidding and the contract was fixed-price.

The Savannah project team wanted either Newport News or General Dynamics to construct the ship, because they had the most nuclear experience, but concerns by the Navy that these facilities should continue to be used for naval programs forced them to withdraw. All other shipyards except two were busy with orders because the Suez Canal had just been closed. These two yards were New York Shipbuilding and the Ingalls yard at Pascagoula, Mississippi. After direct negotiations with the two companies, Marad chose New York Shipbuilding because of the terms that they offered, even though they were in bankruptcy at the time. A fixed price contract was awarded on November 16, 1957.

Not being able to use Newport News or General Dynamics was a serious handicap to the N.S. Savannah program. The construction of a nuclear ship requires far more sophisticated production technology than building conventional, fossil-fueled ships, and New York Shipbuilding had no nuclear experience. For example, in nuclear ship construction, welding must be done to much higher standards and much more carefully inspected than with fossil-fueled ships. In the shipbuilding industry, it is standard procedure to send a ship on its shakedown cruise as soon as possible after construction is finished even if many of its subsystems have not been fully tested. Equipment problems are fixed "on the fly" during the shakedown cruise. Some may not even be fully solved when the ship first enters commercial service. This approach is satisfactory for fossil-fueled merchant ships, but would be extremely dangerous for nuclear ships. The N.S. Savannah team had to spend a tremendous amount of time working with and overseeing New York Shipbuilding throughout the entire construction period to assure that the N.S. Savannah was properly built.
Contracting Problems

The arrangement of having four separate contractors with no prime contractor created a difficult management problem. Many long meetings were held to iron out the terms of contracts and specify interfaces. Interface problems were particularly severe because of the design changes that were made throughout the construction phase and because in the rush to award contracts, terms were not very well specified. Furthermore, there were three outside regulatory agencies involved in the project -- the Coast Guard, the American Bureau of Shipping, and the Public Health Service -- and this made for complicated bargaining.

Interagency Agreement

Another problem area was deciding which costs would be paid by the AEC and which by Marad. The AEC had authority to fund overruns that Maritime did not have, so there were advantages to the Savannah project team in switching cost assignments around. The situation with regard to contractors and funding eventually became so complex that in March 1959 an Interagency Agreement was signed "to define specific areas of functional and funding responsibility and establish financing procedures applicable to the joint program."¹ The AEC accepted responsibility for the nuclear power plant, including experiments, maintenance, engine room operations, crew training, and establishing procedures; Marad accepted responsibility for ship operation, all other crew and maintenance costs, and overhead expenses incurred by the general agent. AEC and Marad shared the costs of community relations, crowd control, and demonstration runs.

Contract Performance

The contract management problems contributed to delays in constructing the Savannah, delays which extended the time for completion originally

¹Kuechle, op. cit., p. 16.
scheduled — 39 months (August 31, 1960, from the signing of the reactor contract — to 56 months (January 31, 1962).

The extent to which there were cost overruns is hard to determine because data are conflicting. Kuechle,\(^1\) in his well-documented account of the Savannah, gives data that the final construction cost was $82.6 million compared to the originally budgeted $44 million. Drewery\(^2\) in an unpublished manuscript gives data that final construction costs were $56 million, including $34.7 million for the reactor and $20.3 million for the hull. Total costs for the whole program including crew training, support facilities, R&D projects, and federal expenses were $106 million through fiscal year 1969.\(^3\)

OBJECTIVES OF THE SAVANNAH PROGRAM

While the immediate technical problem facing the N.S. Savannah was to get the President's ship built, it was clear from the beginning that there were many non-technical problems that would have to be solved before any demonstration cruises could be conducted. These problems ranged from training crew for the ship to obtaining insurance and arranging port clearances. In addition, no safety regulations existed for operating the ship in and out of ports, and there were few precedents from which to start.

By the late 1950s, it became clear that the ship would be successfully built, and the N.S. Savannah program team began to think ahead to the next nuclear merchant ship, and beyond this to the creation of a whole new merchant marine industry. The technical problems of building more efficient ships were seen as solvable with time and money. What loomed

\(^1\)Ibid., p. 32.
\(^3\)Ibid.
larger were the institutional problems of public acceptance, safety, insurance, union acceptance, crew training, and remote servicing of the ship. They began to see the *N.S. Savannah* as a foot-in-the-door that was useful for purposes of forcing these kinds of institutional changes and developments. Without the *N.S. Savannah* or some other demonstration nuclear ship serving as a wedge, it was thought that these institutional changes and developments, necessary for the emergence of a nuclear powered merchant marine, would not likely occur.

Thus, with the goal of creating a nuclear merchant marine industry in the back of their minds, but with the impending voyages of the *N.S. Savannah* clearly focusing their vision, the *N.S. Savannah* team began dealing with the wide range of institutional problems that had to be solved. An outline of the components of this effort was as follows:

1. Environmental Considerations
   A. Site Survey and monitoring. Procedures were developed for surveying ports and negotiating agreements with local officials. These included sending an advance team composed of a ship’s captain and engineer, reactor experts, health experts, and a lawyer to meet with local officials in each port to be visited. The purpose of these visits was to select a berth, assess tug availability, assess police and fire protection, and agree on docking procedures.
   B. Harbor surveys. Research studies of water flows in typical ports and harbors were conducted to determine radiation hazards from possible leaks and accidents.
   C. Countermeasures. Plans were developed for dealing with nuclear accidents, collisions, and power plant failures.

2. Design Criteria
   A. Ship accidents and collisions. Extensive studies of recorded ship accidents were conducted to determine collision protection requirements for the reactor vessel.

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1Kramer, op. cit., Chapter 2.
B. **Shielding and containment.** Specifications were developed for reactor shielding and containment of radioactive materials in case of power system failure.

C. **Nuclear literature search.** Studies were done to collect available information on radiation hazards.

D. **Design specifications.** An overall report was written on safety specifications for the *N.S. Savannah*.

3. **Acceptance**

   A. **Codes and regulations.** Existing Coast Guard and American Bureau of Shipping codes and regulations had to be reinterpreted and respecified for the *N.S. Savannah*. These included seaworthiness specifications, officers' licensing requirements, and inspection procedures.

   B. **Idemnification and insurance.** Laws had to be passed and international arrangements made concerning liability and indemnification in case of accidents. A series of international conferences were held and detailed negotiations conducted with several nations.

   C. **Public relations.** The public needed to be informed about the *N.S. Savannah* project.

4. **Operations**

   A. **Crew training.** An extensive program for training all crew members was developed. The training experience involved academic courses in nuclear engineering, training on a power system simulator and in a mock-up of the containment vessel, field training at various AEC reactor installations, and job training in the shipyard to familiarize the seamen with maintenance and systems operating procedures. Different training programs were developed for deck officers, engineers, and other seamen.

   B. **Operating procedures.** Detailed procedures covering all contingencies had to be developed for all phases of ship operations including at sea, in harbors and ports, and during refueling. All procedures were written into manuals. A port plan had to be negotiated with local officials and approved by the AEC for each port visited.

   C. **Shore facilities.** A mobile service vessel was constructed for handling spent fuel elements and transfer rods, radioactive wastes, and decontaminating system components.
A shore service facility was constructed in Galveston, Texas, as a home base for the Savannah where major repairs could be made.

The agencies involved in the support program included the Public Health Service of DHHEW, the U.S. Coast Guard, and three regulatory groups in the AEC: The Advisory Committee on Reactor Safeguards, which had authority to review all designs for new nuclear reactors; the Division of Licensing and Regulations, which reviewed every port plan prepared; and the Division of Compliance and Inspection, which had continuing responsibility to monitor the activities of the Savannah program and the operations of the N.S. Savannah.

Debates over safety procedures consumed a great deal of time and energy. As an example, one member of the Advisory Committee on Reactor Safeguards wanted the Savannah's reactor to be shut down 20 miles outside of intended ports and the ship towed into dock. When he was told that the procedure would violate sound navigational practices, he expressed disbelief and went to New York to talk to tugboat operators. They agreed that such a procedure would be hazardous to navigation. Only then did the member drop his suggestion.¹

In addition, the N.S. Savannah team started on the development of new, more efficient reactor technology to provide the base needed for an economically viable nuclear-powered merchant marine. The components of this development effort included analytical studies to identify the most economically attractive ship systems for nuclear power, reactor development work, and various advanced studies.

The various activities in the "nuclear ships program" (as planned in 1958) are diagrammed in Fig. 2. The analytical studies of advanced ship systems included a sea-train concept with a detachable engine vessel and a series of underwater vessels. The advanced reactor work included design studies of four potential reactor systems: an advanced pressurized water reactor; a boiling water reactor; a gas-cooled, closed

¹ Kuechle, op. cit., p. 43.
**CONSTRUCTION PROJECTS**

- NS Savannah
- Boiling Water Reactor

**DEMONSTRATION PROGRAM**

- Advanced Pressurized Water Reactor
- Boiling Water Reactor
- Organic Moderated Reactor
- Gas Cooled Reactor—Steam Cycle
- Maritime Gas Cooled Reactor (Government Owned Ship)

**OPERATION**

- NS Savannah
- Boiling Water Reactor
- Maritime Gas Cooled Reactor & Board Prototype
- Maritime Gas Cooled Reactor Ship

**RESEARCH & DEVELOPMENT PROJECTS**

- NS Savannah Upgrading
- Pressurized Water Reactor (NS Savannah)
- Maritime Gas Cooled Reactor (Land Based Prototype)
- Boiling Water Reactor
- Organic Moderated Reactor
- Maritime Gas Cooled Reactor Ship
- Advanced Studies

*Not included in 1960 budget due to absence of authorizing legislation.

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**Fig. 2—Plan for "Nuclear Ships Program"**

cycle reactor; and an organic-moderated reactor. A prototype of the advanced pressurized water reactor, called the CNSG reactor, which was more efficient and much smaller than the reactor that went into the *N.S. Savannah*, was actually developed and tested during the Savannah project. About half of the money appropriated for the *Savannah* reactor went into these projects along with AEC money from other sources (approximately $10 million).

Beginning in the early 1960s, the *N.S. Savannah* team began working within the administration to develop legislation for a second generation nuclear ship (or ships). They suggested that the next one should be a container ship, since their studies had shown this to be one of the most attractive alternatives. But this suggestion was before the container revolution in maritime shipping, and there was little enthusiasm in the Maritime Administration or the White House to moving ahead on such an advanced a concept.

**ECONOMICS OF NUCLEAR SHIPS**

The *N.S. Savannah* team was eager to make the next generation nuclear ship a container carrier because their studies had shown that radical concepts were needed to take maximum advantage of nuclear propulsion. This is because the capital cost of a nuclear-powered ship--both when the *Savannah* was built and today--is approximately 50 percent greater than for fossil-fueled ships. In order for nuclear-powered ships to be economically competitive, this greater capital cost (which looms even larger in a period of high inflation) must be offset by such factors as lower fuel costs, greater payload in the hull from space savings, optimal choice of routes, higher speed, and shorter turn-around time. The economics of these factors are such that highly specialized, large ships operating on long routes are the only ones that are cost-competitive with conventionally powered ships. These basic conclusions of the studies supported through the *N.S. Savannah* program still hold today. A recent report concludes that two of the most attractive designs today
are large (over 100,000 tons) container ships and large tankers.¹

Fuel costs are a great uncertainty in calculations of the economics of nuclear ships. These costs have currently shifted in directions favorable to nuclear power, but over the typical 20-year lifetime of a ship they are still very uncertain. The price of fuel oil will probably continue to rise in the future, but so may the price of enriched uranium and the cost of recycling spent reactor cores, both set by the Federal Government. (Reactor cores are not discarded but reprocessed to remove accumulations of residual plutonium.)

IV. DEMONSTRATION OPERATIONS

The *Savannah* was finally ready for operation in early 1962. It was planned that there would be three phases of demonstration cruises: Phase I, "peace ship" cruises to domestic ports; Phase II, "peace ship" cruises to domestic and foreign ports; and Phase III, experimental commercial service to domestic and foreign ports. On February 24, 1958, the Secretary of Commerce, with the advice of a Source Selection Board, had chosen States Marine Lines to be the operator. States Marine had long experience as a tramp operator.¹

PHASE I

The *Savannah* was delivered to States Marine Lines in May 1962, and after owners' shakedown cruises, made her first voyage in August 1962 from Yorktown, Virginia to Savannah, Georgia. Plans were for the *Savannah* to visit several West Coast ports and then return to Galveston, Texas, for maintenance.

Labor problems soon engulfed the proud new ship and eventually led to a complete shutdown in Galveston in May 1963 after the trip to the West Coast had been completed.² The dispute was primarily between deck officers, represented by the Organization of Masters, Mates, and Pilots (MMP), and the ship's engineers, represented by the National Maritime Engineers Beneficial Association (MEBA). The engineers claimed, and were supported by States Marine Line officers, that on a nuclear-powered ship, engineers had much more responsibility than on a conventionally powered ship and that, therefore, they should be paid more in relation to the deck officers, whose responsibilities were essentially the same as on a conventionally powered ship. Traditionally, deck officers have been the highest paid members of a ship's crew, and engineers have never been happy with this state of affairs.

¹Kuechle, op. cit.
²Ibid.
Matters were complicated by the historical situation: the
deck officers' union (MMP) was aligned with the National Maritime
Union (NMU) and the engineers' union (MEBA) with the Seafarers
International Union (SIU); and the NMU and the SIU are bitter rivals.
Bickering among the unions and States Marine Lines over pay, work
conditions, and the outfitting of the Savannah had begun when the
crews first boarded the ship for training in 1960, while it was
still under construction, and continued into the Phase I demonstration
runs. During trial runs, the N.S. Savannah was shut down on three
separate occasions for periods of several days at a time because of
these disputes.

An impasse was reached when the company signed an agreement with
the engineers on May 1, 1963 setting their pay at a level in direct
conflict with an earlier arbitration award fixing the pay of deck
officers. The deck officers and engineers refused to sail until the
issues were settled, and the Savannah was laid up. Now instead of
a "peace ship" or "experimental ship," the Savannah was a "problem ship."

As the labor problems of the Savannah escalated, they became
front page news and began to consume the time of top-level government
officials including Secretary of Commerce Hodges, Secretary of Labor
Wirtz, and President Kennedy. On May 22, 1963, the Washington Post
carried an editorial entitled the "Sorry Ship Savannah" that declared
the ship was once again "where she [had] been found since her ill-
fated launching -- high and dry, with no crew, no operating agent,
o no immediate hope of getting on with the job."\footnote{1} Chairman Bonner
of the House MMS Committee said, "It's a national disgrace"\footnote{2} and
wrote a letter to the Secretary of Commerce requesting that serious
consideration be given to retiring the ship from service or trans-
ferring it to the Department of Defense.

\footnote{1}{Kuechle, op. cit., p. 212.}
\footnote{2}{"Atom-Powered Ship is a National Disgrace," \textit{Life}, V. 54, June
1963, pp. 40-40a.}
## Table 1
ARTICLES ABOUT THE N.S. SAVANNAH

### Prior to May 1962

<table>
<thead>
<tr>
<th>Article Title</th>
<th>Source</th>
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<tbody>
<tr>
<td>&quot;World Going Down to Sea in Atom Ships&quot;</td>
<td>Science News Letter, 2/57</td>
</tr>
<tr>
<td>&quot;1st Atom Ship Scheduled to Sail&quot;</td>
<td>Business Week, 8/57</td>
</tr>
<tr>
<td>&quot;Ships Going Atomic&quot;</td>
<td>Science News Letter, 12/57</td>
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<tr>
<td>&quot;Nuclear Ships&quot;</td>
<td>Science, 6/58</td>
</tr>
<tr>
<td>&quot;New Atom Ship Will Be A Lonely Pioneer&quot;</td>
<td>Business Week, 7/59</td>
</tr>
<tr>
<td>&quot;Launch 2 Nuclear Vessels&quot;</td>
<td>Science News Letter, 7/59</td>
</tr>
<tr>
<td>&quot;Symbol at Sea&quot;</td>
<td>Time, 8/59</td>
</tr>
<tr>
<td>&quot;Nuclear Ship Savannah Launched&quot;</td>
<td>Science, 8/59</td>
</tr>
<tr>
<td>&quot;Atom Merchant Ship Nears Final Test&quot;</td>
<td>Business Week, 11/61</td>
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<tr>
<td>&quot;Ready to go, Savannah&quot;</td>
<td>Time, 1/62</td>
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### After the May 1962 Labor Problems

<table>
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<th>Article Title</th>
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<tr>
<td>&quot;Atom Ship Becalmed&quot;</td>
<td>Business Week, 5/63</td>
</tr>
<tr>
<td>&quot;Atom-Powered Ship is National Disgrace&quot;</td>
<td>Life, 6/63</td>
</tr>
<tr>
<td>&quot;Alice in Atomland&quot;</td>
<td>Newsweek, 6/63</td>
</tr>
<tr>
<td>&quot;Incorrect, Illogical, [etc.]&quot;</td>
<td>Time, 1/64</td>
</tr>
<tr>
<td>&quot;N.S. Savannah: Trouble Ridden...&quot;</td>
<td>Science, 7/64</td>
</tr>
<tr>
<td>&quot;Whatever Happened to the Savannah?&quot;</td>
<td>U.S. News and World Report, 6/69</td>
</tr>
</tbody>
</table>
These labor problems were a key event in the history of the Savannah project. Before these events the Savannah was viewed positively, by some as a peace ship and by some as the ship of the future, but fundamentally there was wide agreement that the project was of benefit to the nation. After these events, the Savannah was almost as widely viewed in the press and by top-level administrators in the government as a problem ship that consumed their time and energies, and, in addition, was costing a great deal of money. Instead of reporting on the advanced technology of the ship and its mission of demonstrating the peaceful uses of the atom, the press began to write about its labor problems and to focus on the ship's design shortcomings. This shift in attitude is clearly reflected in the titles of press stories about the Savannah: before the labor problems articles had titles like "Atom Ship a Symbol at Sea"; but after the labor problems titles were like "Atom Ship a National Disgrace." The sample of titles in Table 1 clearly indicates this shift in outlook.

Another factor in the Savannah's changes of fortunes was that by late 1963 there had been two completely new administrations in charge of the government since Eisenhower's. Many we interviewed say that the Savannah's fortunes began to turn when Strauss left as Chairman of the AEC, a turn intensified when the Johnson administration came in.

It is interesting to speculate whether, if the Savannah project had been started in the summer of 1955 as originally planned by the Eisenhower administration, had been finished within the original time schedule, and had been managed to avoid the labor problems, this turnabout would have happened.

PHASE II

In June 1963, Secretary Hodges decided to cancel the contract with States Marine Lines and find a new general agent for the Savannah. In July, a contract was awarded to American Export Isbrandtsen. AEI
was chosen as the new general agent for the N.S. Savannah because its labor contracts for both the engineers and deck officers were with the same union, the Brotherhood of Marine Officers (BMO). BMO members agreed to accept standard wage rates and the labor problems were solved.

Phase II operations began in May 1964, after a new crew was trained, and extended through March 1965. During this period the Savannah operated extremely successfully and reliably. She visited 28 U.S. and 18 European ports, and everywhere she docked there were great crowds of visitors. Over 1,300,000 came aboard.

PHASE III

After these demonstration cruises, the Maritime Administration decided that in order to save money the Savannah should be operated as a bareboat charter. An agreement was reached with First Atomic Ship Transport, Inc. (FAST), whereby the company paid Marad one dollar a year for the ship and the Government would subsidize operating expenses. An incentive fee structure was agreed upon whereby FAST would be paid a direct subsidy to offset operating losses but would have to split any profits earned (or losses) with the Government. The Savannah was operated successfully with other AEI ships in regular trade routes. In this service, the passenger compartments were sealed off and the ship carried only freight.

During these Phase III operations, some of the shortcuts taken in outfitting the Savannah began to show up as serious problems:

- The tilt-back design of the ship's masts (which was adopted to improve its appearance) created difficulties in working the forward end of the hatches efficiently and led to gear failures.

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1 Kuechle, op. cit., p. 276. A "bareboat" charter is when the owner of a ship leases it to an operator without providing any crew.
The shorter than normal lengths of the Savannah's booms coupled with its broad beam (necessary to accommodate the reactor and its shielding) made the maximum attainable onshore reach 4 to 6 feet less than desirable, which complicated the loading and discharging of cargo.

- The less-than-standard lift capacity of booms and cargo gear required doubling and tripling of cranes when handling heavyweight cargos. Problems arose with the winches which were too light in lift capacity and unreliable in service. (Compared to a standard of 10 tons capacity and a minimum of 5 tons, the Savannah's winches were 3.3 tons.)

- The light construction of the Savannah's hydraulic hatch covers led to problems of damage and water leakage.

The principal effects of these design shortcomings were limitations on items of cargo that could be carried and inflated operating costs because of extra expenditures for repairs and stevedoring.

In 1968, Marad conducted a "nuclear fuel shuffle," which involved replacing four of the center fuel elements and rearranging the rest to boost power output. This operation was performed successfully and without incident. This was the Savannah's first, and only, refueling exercise.

In cost-cutting moves initiated in 1967 by the Johnson administration, the Maritime Administration announced that the Savannah was too expensive to operate and would be withdrawn from service on August 20, 1967, one year before the end of the three-year charter with FAST. The announcement aroused a storm of protest from Savannah supporters, who went to Congress and induced the MMF Committee to reopen hearings. Ship operators, labor leaders, and members of Congress
testified to the benefits of the *Savannah* as an image-builder for the nation. In June, a subcommittee of the Senate Commerce Committee held similar hearings, and eventually the Maritime Administration reconsidered its position and decided to extend the charter to FAST through 1971.

Marad then requested a special appropriation to keep the *Savannah* running, but the House Appropriations Committee decided that the funds would have to come from Marad's R&D budget. Since Marad's total R&D appropriation was about $6 million per year and the *Savannah* required $3,000,000 per year to operate,\(^1\) this meant that about one-half of Marad's limited R&D funds would have to be spent on the money-losing ship. Many administrators and staff in Marad were displeased by this situation, and a search was begun to find alternate uses for the *Savannah* that would not be as expensive to the agency.

Proposals were solicited every year over the next few years to find alternate uses of the atom-ship. One suggestion was to convert it to a fish protein factory; another to an oceanographic research ship; a third to a Liquid Natural Gas ship; a fourth to a hospital to accompany the *S.S. Hope*, and so on. None of these suggestions proved feasible, and Marad had no alternative except to continue the bareboat charter operation. With this turn of events, the *Savannah* had become a "white elephant;" she had no worthwhile mission, was expensive to operate, and yet could not be retired from service.

Members of the Savannah project team whom we interviewed stated that officials in the Bureau of Budget and the Department of Commerce became very critical of the *Savannah*’s high operating costs and viewed the ship as another example of government failure. In the shifting bureaucratic context of the *Savannah* project, forgotten was the original objective of demonstrating a peaceful use of the atom and instead the ship was judged as a demonstration of a new kind

\(^1\) Detailed data on costs appear in the next section.
of merchant ship. That the Savannah had not been designed for maximum efficiency and that everyone involved had known that it would not be cost-competitive with conventionally powered ships was lost in history.

The Savannah was finally retired from charter service in January 1970 and donated to the city of Savannah, Georgia, where it will become the center-piece in a Peace Museum dedicated to President Eisenhower.
V. DEMONSTRATION OUTCOMES

Despite the perceptions of many high level officials that the Savannah project was a failure because of labor problems and high operating costs, the demonstration was highly successful in achieving its primary objectives.

ATOMS FOR PEACE

In demonstrating a peaceful use of the atom around the world, the H.S. Savannah accomplished a great deal. There are no objective indicators of the extent to which public opinion was influenced regarding the uses of atomic energy, but the ship attracted tremendous crowds of visitors in every port she visited and was shown to many public officials around the world (but mostly in Europe). The foreign news media tended to be much more laudatory than their American counterparts.

A former director of the Nuclear Projects Office tells a story that indicates how much of an attraction the Savannah was in foreign countries. He had returned to a position in industry and was visiting Greece when the Savannah arrived in port. The officials he was visiting discovered that he had had some responsibility for building the Savannah. "The Greeks were tremendously impressed with the ship," he said. "They gave me a ride on one of their prized white stallions."

SAFETY AND RELIABILITY OF NUCLEAR SHIPS

The Savannah was also technically successful:

- The ship traveled over 332,400 miles on its first core (and 450,000 in total) with no radiation leaks or other hazardous accidents.
Unscheduled shutdowns of the power plant in Phase III operations accounted for 1,700 total hours, or 4.1 percent of the five-year period. During 853 days at sea, only six scrams and three other unscheduled shutdowns occurred. Reactor availability at sea was 99.88 percent.

Early in the demonstration runs, press reports tended to emphasize the technical problems of the Savannah, overlooking the fact that most of these were of minor importance (e.g., oversensitivities of safety monitoring systems) and typical of most sophisticated, new technology. The technical problems were often humorous in their consequences and made interesting reading, but cast an aura of technical failure around the ship that was unwarranted. The shortcomings in the Savannah outfitting (e.g., the winches and the communications gear) were a particularly rich source of these stories of failure.

The many safety criteria and procedures worked out for the Savannah were also an accomplishment of the demonstration, but these have probably been lost with the passage of time. The director of the Savannah demonstration says that if the group responsible for establishing these procedures had remained together and continued to function as new developments emerged, the accomplishments of the Savannah demonstration would have continued. But the group has been disbanded, and he thinks that a new group assembled to develop criteria and procedures for a new nuclear ship would have to start over again, almost from scratch.

This decay phenomenon suggests the importance of timing in capitalizing on the results of demonstration projects. If the Savannah had been followed immediately by other nuclear ship projects, there would have been a reason for the safety-regulations group to continue working on design criteria and operating procedures for nuclear ships, and to maintain their relationships with the other regulatory agencies involved. Then, the process of developing safety regulations for nuclear ships would probably have continued to evolve.
from the base laid down during the Savannah project. Because the Savannah has not been followed by other nuclear ships, this base has been lost.

**DEMONSTRATION AND LIABILITY**

Some progress was made in reaching agreements with foreign countries on policies for establishing liability should damage result from the Savannah's operations. Formal agreements were negotiated with 12 countries during the Phase I and II demonstration runs\(^1\) and with 14 countries during Phase II demonstration runs.\(^2\) All of these agreements, however, were temporary and applied only to the Savannah. An attempt was made to negotiate a permanent formal agreement with Great Britain as a model for negotiations with other countries but a final settlement could not be reached. For Phase III, foreign countries even required that agreements reached for Phases I and II be renegotiated because the shipowner had changed from the Government to a private firm.

Insurance for the general agent was obtained by gaining passage of an amendment (PL 85-602) to the Price-Anderson Act (PL 85-256) extending its provisions to the N.S. Savannah. This Act provides for up to $500 million of Federal funds to cover claims filed by the victims of nuclear accidents from AEC-licensed facilities, but the amendment applies only to the N.S. Savannah. A new amendment would be needed for the next nuclear ship.

It would have been much more significant if the Savannah's record of safe operations had persuaded underwriters and insurance firms to assume the functions of the Price-Anderson Act by offering to write insurance for nuclear ships. The Savannah's operations did provide a baseline of data on the safety of nuclear ships and precedents concerning limits on liability, but these accomplishments

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\(^1\) Belgium, Denmark, Great Britain, Greece, Ireland, Italy, The Netherlands, Norway, Portugal, Spain, Sweden, and West Germany. An informal agreement was reached with France.

\(^2\) West Germany, Portugal, Spain, Italy, Greece, Tunisia, Libya, Yugoslavia, South Korea, Hong Kong, Taiwan, The Philippines, Belgium, The Netherlands, and Turkey.
have apparently not sufficed to establish the viability of a private market for nuclear ship insurance, because the Maritime Administration has not been able to secure a commitment from private companies to provide insurance for the next nuclear ship.

**INFORMATION ON OPERATING COSTS**

Some information was also obtained on operating costs; it is summarized in Table 2. The Savannah required a subsidy of about $1 million per year to operate, which was about twice the normal amount for a conventionally powered U.S.-Flag freighter of Mariner class design. Unlike the subsidies for fossil-fueled ships, however, the Savannah's subsidy did not reflect amortization of the ship's capital cost, payments according to the provisions of the Price-Anderson Act, or expenditures for nuclear fuel, which were paid directly by the Government.

However, interpretation of the cost data from the Savannah's operations is clouded by the extra expenses caused by the shortcomings in the ship's cargo handling equipment. Nevertheless, valuable data were obtained on the costs of port operations attributable to special precautions necessary for nuclear ships, and on potential savings from the discovery that the mobile service facility was not needed because wastes could be safely contained within the vessel for discharge at sea or at shore service points. Also, refueling did not turn out to be as difficult and expensive an operation as some had expected.

**Training Programs**

The Savannah demonstration clearly proved that regular seagoing mariners could be trained at moderate expense to operate a nuclear-powered ship -- a practice which is at variance with the Navy's policy. An unexpected difficulty was a high rate of attrition. This occurred because opportunities for crewmen to advance in their careers were limited on board and could only be increased by transfer to other jobs on fossil-fueled ships.
Table 2 -- Summary of Costs of N.S. Savannah Phase III Operations
($ in millions)

<table>
<thead>
<tr>
<th></th>
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Cost calculation method:
Col 5 = Col 1 + Col 2 - Col 3 - Col 4
Col 9 = Col 1 - 1/2 Col 5 + Col 6 + Col 7 + Col 8 + Col 1

*A longshoremen's strike interrupted operations.

**For FY 1966, 1967, and 1968, Marad and FAST agreed on an incentive fee arrangement, whereby FAST would retain one-half of all profits up to a maximum of $200,000 and absorb all losses up to a maximum of $200,000. The balance was returned to (or absorbed by) Marad. For FY 1969 and FY 1970, Marad and FAST agreed on an incentive fee arrangement, whereby FAST was allowed to retain overhead and profit of 19 percent of gross revenue times the ratio of revenues to expenses.

TECHNOLOGY DIFFUSION

Although the diffusion of new technology into the maritime industry was not a major objective of the Savannah demonstration, there were some transfers of new technology to other commercial nuclear ships, Navy nuclear ships, conventional merchant ships, and land-based reactors. Because the ship's hull and outfitting were not technologically advanced, the transfers chiefly involved aspects of the propulsion system.

Power Plant

Most of the technology transfers from the Savannah's propulsion system were of auxiliary subsystems for reactor control and safety rather than of fundamental aspects of the nuclear power plant. The Savannah's reactor will not be duplicated in the future, since a second generation reactor developed within the Savannah program has greatly improved performance.

Thus far, Japan and Germany have made the most use of the fundamental reactor technology developed during the Savannah program. These two countries learned this technology by sending some of their technical experts to the United States to participate in the Savannah program through an exchange of information agreement established with the United States. The power plant used both on the Japanese and German ships was the second generation reactor developed in the Savannah program.

Other technical achievements of the Savannah program and their subsequent applications included:

- Control Rod Drive System. The Savannah program team developed a new type of control rod drive system as part of their R&D effort; this was not installed on the Savannah but has been picked up by some land-based reactors.
- Pressure Containment Check. A new procedure was developed for detecting leaks in the reactor containment vessel.
Collision Protection. A new design for stiffening the hull to prevent reactor damage in collisions was developed; the Germans and Japanese adopted this in their demonstration ships.

- Iodine Filters. Special filters to trap radioactive iodine in case of a nuclear core melt-down were developed and these have been adopted by land-based reactors.

- Variable Safety Procedures. Unlike emergency procedures for shutting down previous reactors, procedures for the Savannah's reactor were varied as a function of the reactor's operation history. This approach has been adopted for use by land-based reactors.

- Sabotage Blast Protection System. This system has been adopted by land-based reactors.

- Internal Security System. An organizational method of insuring ship security was invented and has been adopted for use by land based reactors.

Automated Control Systems

The Savannah's automated control system appears to have influenced the maritime industry to begin automating conventionally powered ships. Automation had been discussed among ship operators before the Savannah's construction but no ships had ever been built with automated control systems. Since the Savannah, several highly automated fossil-fueled ships have gone into operation; to what degree the Savannah stimulated their construction is difficult to determine.

In his book on the Savannah, Kuechle\(^1\) argues that the automation necessary on commercial nuclear ships may actually be inhibiting their greater utilization in merchant fleets, because the labor problems that surround automation remain to be solved. Experience with the several

\(^1\)Kuechle, op. cit., pp. 281-284.
automated ships that have been built and with operation of the N.S. Savannah suggests that automation entails difficult labor questions related to redefining work responsibilities and reducing crew sizes. Kuechle concludes that these circumstances have made operators reluctant to move ahead with automation (and as a corollary with nuclear ships) until these problems are resolved.

Industry Interest

During the period of the Savannah's demonstration cruises, ship operators expressed some interest in constructing additional nuclear merchant ships. In October 1963 the Pacific Mail Line offered to build four nuclear ships for use on their Pacific trade routes if the Maritime Administration would subsidize half the construction cost under their continuing shipbuilding program. A proposal was also submitted in October 1964 by American Export Isbrandtsen for a subsidy to construct four 30-knot nuclear-powered freighters for service to the Far East. In January 1964, Representative Garmatz introduced a bill in the House that would have authorized the Secretary of Commerce to assist companies to build nuclear ships.

The PML and AEI proposals and the Garmatz bill were coordinated by N.S. Savannah program managers as last-ditch efforts to save their plans for a nuclear-powered merchant marine industry. AEI was an ideal operator because their President, Admiral Will, was enthusiastic about nuclear-powered merchant ships, and because a four-ship fleet offered substantial benefits. With four-ships, frequent and regular high-speed service could be established, and training and crew rotation problems would be eased. These factors promised to increase revenues and cut costs.

Kuechle reports that:

Commerce Department reactions to the Garmatz bill and to the efforts by private steamship companies to promote a nuclear merchant fleet were less than enthusiastic. Sources close to Secretary of Commerce Hodges said that

1 Admiral Will was the captain on many of the N.S. Savannah's Phase II and III voyages.
he would not approve another nuclear merchant ship while he remained as Secretary because of the unfortunate experiences with the *Savannah*. Hodges himself indicated to a Senate Subcommittee in June 1964 that the labor problems on the *Savannah* had not been solved....

...This factor, coupled with [the] labor difficulties involving conventionally-powered automated vessels, was more responsible than any other...for the fact that the Garmatz bill never received a hearing and the Pacific Mail Lines and American Export proposals have never been implemented.¹

Another factor, and maybe a more important one, was that there was no support in the JCAE for building another nuclear-powered merchant ship.

¹Keuchle, op. cit., pp. 280-281.
VI. CONCLUSIONS

The Savannah program overcame great technological uncertainty in a relatively short period of time to demonstrate successfully: (1) atomic energy's peaceful potential, (2) the technical feasibility of building safe and reliable nuclear merchant ships and of training regular maritime crews to operate them, and (3) the political and legal feasibility of these ships using harbors and ports around the world. Moreover, information gained on operating costs will be useful in constructing other nuclear ships.

While a demonstration of economic feasibility was never anticipated by the Savannah's originators or designers, this impossible objective was gradually imposed upon the project. The Eisenhower administration originated the Savannah program to demonstrate a peaceful use of the atom and at one point planned to build the ship by installing a carbon-copy of the reactor from the nuclear submarine Nautilus in an existing hull. This plan would have permitted the ship to be constructed in a short period of time but would have resulted in a vessel with extremely poor economic characteristics. Congressional pressures changed the objective, the goal became the initiation of an economically competitive, nuclear-powered merchant marine. This objective paralleled the aims and interests of technical staff in the Atomic Energy Commission and the Maritime Administration who were bent on advancing nuclear technology for merchant marine applications.

The White House and the two agencies compromised on a combination passenger and cargo ship utilizing a hull of existing design but with a first-generation reactor having better economic characteristics than the Nautilus's reactor. This compromise opened the door to the concept of the Savannah as a demonstration of a commercially viable, nuclear-powered merchant ship.

When operating costs turned out to be high compared to conventionally powered ships and the House Appropriations Committee forced the Maritime Administration to fund these from its R&D budget, support among high-level officials for the construction of additional nuclear-powered ships declined and judgments veered to the view that the
Savannah project was a failure—a view that became the general, though largely incorrect, impression when assessed against its original objectives.

Because no nuclear-powered merchant ships had ever been built and power reactor technology was at an early stage of development, the design and safeguarding of the Savannah's nuclear power plant necessarily involved pioneering work. Several of the advances produced have since been utilized in many land-based and foreign maritime nuclear applications. Savannah's economically and technologically premature start, however, prevented the application of some of the information acquired, especially with respect to marine safety, because the United States built no nuclear-powered merchant vessels after the Savannah. The continuity of the technical organization that had learned the lessons of the Savannah project could not be maintained when funds for second generation ships could not be obtained.

The course of the project was influenced more by organizational factors than technical achievements. These organizational factors included: the competing forces that resulted in the ship's compromise design; the multiplicity of contractors and agencies involved in the project that created coordination problems during construction; changes in executive level administration; and, most importantly, labor problems. Labor problems did not revolve around nuclear safety, but were tied to training, automation, and other changes imposed by nuclear propulsion. In the final analysis, it was the labor issues that finally engulfed the Savannah project and greatly clouded the future of nuclear-powered ships.

The Savannah did not usher in the new era of nuclear-powered merchant shipping that some initially expected, because nuclear-powered ships are still not cost-competitive with conventionally powered ships. Neither has there been much governmental support for additional R&D and demonstrations to reduce the cost of this new technology. Since much of this cost is a function of exogenous factors, such as the relative prices of nuclear and fossil fuel, it cannot be greatly reduced by nuclear ship R&D and demonstration projects.
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U.S. Congress, House. *H.R. 4822. Mr. Tollefson. To authorize the construction of a nuclear-powered tanker for operation by the U.S. Maritime Administration, and for other purposes. 86th Congress, 1st Session. February 19, 1959.*


MECHANIZED REFUSE COLLECTION
(GODZILLA)

by

Patricia D. Fleischauer
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I. INTRODUCTION

THE SOLID WASTE DISPOSAL ACT

Concerned with what it called a "rising tide of scrap, discarded and waste material," Congress in 1965 passed the Solid Waste Disposal Act.* Under this original act and amendments made to it in 1970 and 1973, Congress authorized the expenditure of funds for the following purposes:

1) the demonstration of solid waste management systems which preserve and enhance the quality of air, water and land resources;
2) technical and financial assistance to States and local governments for the planning and development of solid waste disposal programs;
3) training grants in occupations involving design, operation and maintenance of solid waste disposal systems.

In support of these efforts, Congress set aside an amount not to exceed $72 million for fiscal year 1972 and $76 million for fiscal years 1973 and 1974.

Initially the responsibility of DHEW, monies authorized by the Solid Waste Disposal Act are now the responsibility of EPA. In particular, the demonstration activity of the Office of Solid Waste Management Programs (OSWMP) addresses itself to the directives of the Act by supporting two types of projects. The first are demonstration projects, funded for the purpose of demonstrating new and improved methods of solid waste management. The second type are termed study and investigations where the emphasis is on the demonstration of systems that advance solid waste technology. As part of its grant program, the demonstration activity has responsibility for development and review of grant applications, the monitoring of funded projects, and dissemination of information on completed projects.

MUNICIPAL SOLID WASTE MANAGEMENT

Municipal solid waste management is normally divided into the two major areas of collection and disposal. Collection includes pickup, transport, and transfer; disposal includes any required treatment. In most cases, either one or both of these major activities are the responsibility of either a private refuse collector or a municipal sanitation department. Only in small, rural areas is solid waste management the responsibility of the individual resident.

In terms of cost, collection is the most costly component of solid waste management. Some very rough estimates indicate that collection costs relative to the total cost of solid waste management range from 75% to 80%. Assuming a solid waste collection cost of approximately $10 per ton and a daily per capita generation rate of 3 pounds of solid waste, a reasonable collection service charge for a family of four would be $25 a year or about $2 per month.*

The above estimates are only a rough approximation. Other estimates of monthly service costs for conventional refuse collection run as high as $4 per home per month. In making these estimates, the conventional system is taken to be a rear loading truck manned by a driver and two workmen who handle cans, bags and other containers supplied by the resident. Containers or bags are emptied or placed in a hopper and compacted into the truck.

A conventional can-truck-dump system requires one collector for every 1000 population. But it is difficult to find the number of people necessary as the workman's job is hazardous, boring and demeaning. The National Safety Council, for example, has shown that the number of disabling injuries per million manhours worked is 98.9 for the refuse collection industry compared to 53.2 for police work and 33.0 among firemen. With the cost and problems of such a labor intensive activity, collection is a prime area in which to attempt cost reductions.

SCOTTSDALE REFUSE COLLECTION

Prior to 1964, refuse collection in Scottsdale was provided by a private collector. When the city began municipal refuse collection in March, 1964, it used a train system of one pickup truck and four 5 yard trailers with a three man crew of two collectors and one noncollecting driver. To haul refuse to the sanitary landfill, refuse was transferred from the train to a 30 yard front loading packer truck. Residential collection was provided twice a week with eight trains and three packer trucks. Technically the train system was economical relative to conventional rear loading truck systems, but indirect personnel costs were high. A poor safety record plus the effects of 120° summer heat which had resulted in heat stroke, dehydration and heat exhaustion of collectors, prompted Scottsdale to undertake a staff study in 1966 to investigate better methods of refuse collection. Over the next two years the group conceived and developed the ideas for containerization and mechanization, made preliminary economic projections and applied for a Federal grant to develop its concepts.

In general, Scottsdale proposed a two phase study to demonstrate the feasibility and economy of containerizing household refuse and mechanizing its collection and hauling. This broad objective called for development of a group of new pieces of equipment which would reduce overall costs, improve service to the customer, improve working conditions, and improve the sanitation and appearance of the collection stations. After being refused on its first request for funds, Scottsdale was subsequently funded to perform a study and investigation. The project began in March 1969 but before the end of the first year, the scope of the study was expanded and the study was reclassified as a demonstration project.
II. TECHNOLOGICAL BACKGROUND

CONTAINERS

The Scottsdale project demonstrated two technological innovations—the shared container for refuse and the mechanized collection process. From a system which collected single family, resident-supplied containers, the objective was to develop a container which would be shared by a number of families, would be light weight, yet durable and withstand the effects of sun and heat and be sanitary in that it would be dog and cat proof and not create a fly problem. Candidate materials were steel, aluminum, fiberglass and polyethylene. While having the advantages of permanence, long life, and numerous fabricators, steel was relatively heavy and noisy. The cost of a 300 gallon container was estimated to be about $90 each.

Fiberglass containers on the other hand, were more attractive, but also more expensive, averaging $120 for a 300-gallon container. In addition, manufacturers indicated that fiberglass was brittle and had limited impact resistance.

Polyethylene had the advantage that it could be cheaply molded, was relatively strong and flexible and could be protected from ultraviolet radiation and hence deterioration of the container.

After experimenting with a sample pickle vat provided by Fusion Rubbermaid of Salinas, California and a 160 gallon polyethylene container made by County Plastics of Farmingdale, New York, it was determined that the desired container should be made of polyethylene and have a minimum thickness of 3/16 of an inch. 350 containers were needed for the first phase of the demonstration and were to meet the following requirements:

1) Containers shall be round in horizontal section in the area of the gripping device and capable of being lifted and dumped from any angle.
2) Containers shall be designed to be picked up and dumped by a gripping device that applies 200 lbs radial force at a point one-third the height below the top edge of the container.

3) Containers shall be designed to regularly receive and dump 500 lbs in the case of 80 gallon containers and 1000 lbs in the case of 300 gallon containers.

4) 80 gallon containers shall be equipped with wheels to facilitate movement by the user. The container shall be designed to be stable, loaded or unloaded, with a portion of the weight supported by the wheels.

5) Containers will be equipped with lids which shall be curved or built up to drain, the sides shall overlap but not flare, and shall be hinged to open by gravity as the container is dumped.

Agreeing to manufacture containers according to these specifications, and at the most favorable price, County Plastics was awarded (by Scottsdale) the container contract.

The Phase I 80 gallon container manufactured by County Plastics was usable but did not have the desired durability. Changes were then made in the lid design and the wheel arrangement. Fusion Rubbermaid manufactured the second set of containers, the ones used in Phase II of the demonstration, but when further modifications were desired and the manufacturers would not guarantee the containers, Scottsdale went to yet a different manufacturer, Reuter Incorporated of Hopkins, Minnesota.

Reuter agreed to the desired improvements, and suggested using a cross linked polyethylene material called CL 100 manufactured by Phillips Petroleum. This material was expected to withstand the ultraviolet radiation which had caused the early containers, protected from ultraviolet deterioration only with inhibitors, to become brittle and easily broken. In addition, these containers were guaranteed by the manufacturer and the cost of the 80 gallon container was $50. There was a similar evolutionary process for the 300 gallon container.
MECHANIZED VEHICLES

The first of the mechanized vehicles, dubbed Godzilla by the city fabrication shop workers, was a modification of an existing front-end loader. The design and actual modifications were carried out by the city's equipment maintenance shop. The innovation consisted of setting a hydraulically controlled swing arm in a forklift frame which was turned sideways and attached to the front end loading mechanism of the truck. The swing arm and opposing hand were fastened to the inner frame of the forklift framework so they could be moved sideways across and out beside the edge of the truck. The collection truck then operated by stopping beside and behind the container, the pickup unit moved sideways to engage the container, the arm closed, lifted the container, moved back to center and dumped the container contents in the conventional way behind the cab. To set the container back down the process was reversed. All movements of the arm are controlled by the operator from within the cab of the truck.

Phase II of the study involved refining the mechanized vehicle in an attempt to produce a faster, more efficient system. To that end, Scottsdale developed first the Barrel Snatcher, also called the Son of Godzilla, and then the Litter Pig. Barrel Snatcher is a left hand, cab forward Diamond Reo chassis and is equipped with an eight foot telescoping arm that can be extended to grasp containers twelve feet from the side of the truck. Litter Pig, on the other hand, is a Shu-Pak side loading collection vehicle made by Western Body and Hoist which is equipped with an articulated back hoe style arm. Instead of the left hand drive, it has a right hand drive which improves visibility and accommodates manual loading. The original back hoe style arm proved difficult to operate so a telescoping arm loader, developed by Government Innovators and constructed by Arizona Special Projects, was used instead.

In addition to the three collection vehicles, a mobile transfer vehicle named Trash Hog was also developed. Basically the vehicle is a trailer with a special tailgate built like a segmented garage door. To work with the trailer the collection vehicles require special tailgates
and beefed up ejection systems so that when the truck and trailer are latched together back to back, the truck tailgate controls raise both tailgates. With both tailgates open, material is ejected from the truck into the trailer. The truck ejection system must provide the force sufficient to push material left in the trailer from previous loads. When filled, the trailer, not the collection vehicle, makes the trip to the landfill hauled by a tractor.
III. FEDERAL GOALS IN THE DEMONSTRATION

The Solid Waste Disposal Act was passed by Congress in 1965 and funding under this authorization began in 1966. The broad objectives of this act were to support efforts to study or test new approaches to solid waste management. In the initial stages, subjects for study were suggested by the applicants and led to unsolicited contracts, as in the case of the Scottsdale demonstration. As the EPA program developed and detailed information on solid waste became available, gaps in knowledge of solid waste management became apparent and the program began to solicit projects in selected areas.

In reviewing the studies funded since the program began in 1966, it is apparent that there is no single approach applicable to the variety of solid wastes produced. As the concept of solid waste management has developed, so has the scope of studies funded by EPA. Changes in product innovation and industrial process modification which affect the type of waste generated and changes in the living habits of the general population require almost constant modification of existing storage, collection, transport, processing and disposal practices. EPA's varied menu of projects reflects this need for change and its desire to fund projects that will improve means of solid waste management or advance the state of solid waste technology.

Scottsdale's broad objective in its study was to demonstrate a better method of collection in terms of cleaner, safer, faster and more economical operation. These goals clearly were consistent with EPA's broad objectives. The ultimate beneficiary of an improved means of refuse collection is the general public. They benefit both as taxpayers supporting municipal refuse collection and as residents who enjoy a cleaner city as a result of a more sanitary system.

Both EPA and the demonstration group in Scottsdale anticipated that the adopters of the containerized system and the mechanized trucks would be public and private refuse collection agencies. The new system
was expected to produce at least previous levels of service at less cost than existing manual collection systems. As a market for the innovation this group was diffuse. Cities typically have only one collection system, whether municipal or private. As a group, refuse collectors are represented nationally by two organizations, the American Public Works Association and the National Solid Waste Management Association. They operate relatively independently and without threat of competition from each other. While the cost savings of mechanized collection are attractive over the long run, the new system carries relatively high initial capital costs which, particularly in the case of municipal collection systems, could hinder adoption. A further factor, which could make this a difficult market, is the fact that public works departments are typically staffed by people who have "come up through the ranks" and hence may be less responsive to change, especially to something as radical as mechanized collection. Scottsdale, however, was an exception. Its public works director was an engineer with a master's degree in engineering, experience in industrial engineering and an interest in innovation.
IV. SELECTION AND OPERATION OF DEMONSTRATION

PARTICIPANTS

The agencies and principals involved in the selection, monitoring and performance of this demonstration project are shown in Fig. 1. First in the hierarchy is the Department of Health, Education and Welfare, the department originally authorized to spend money for the demonstration of improved means of solid waste disposal. This later became the responsibility of the EPA when it was established by Reorganization Plan 3 of 1970. Direct responsibility for the project was with the demonstration branch, under the direction of Anthony Muhich and his assistant, Melbourne L. Smith, in the Office of Solid Waste Management Programs (OSWMP). The grantee was the city of Scottsdale where William Donaldson was City Manager. Marc Stragier, head of the Department of Public Works, was designated project director.

SELECTION OF PROJECTS

Within EPA, selection of projects was the responsibility of a board composed of people from within the agency. When a proposal was received by OSWMP, it was assigned to one person who, in effect, became the project representative within EPA. It was the representative's responsibility to understand the proposal and present it for review by the selection board. The selection board, while deciding on demonstration projects, was also deciding on research and training grants as well as technical assistance projects. The competition was keen with demand for funds far exceeding supply.

EPA's first criterion in evaluating a demonstration project was feasibility. While supporting both demonstration projects, designed to test in operating situations new means for recovering or reusing waste material, and study and investigations, designed to advance the state of solid waste technology, its expressed interest in feasibility is evidenced by the fact that of 27 projects funded in calendar 1969, only seven were study and investigations.
When initially funded, the Scottsdale project was classified as a study and investigation. A second criterion was the existence of a good project plan. With these two criteria, EPA hoped to insure choosing a project which would be an application success. Given application success, they assumed diffusion would be more rapid and would be taken care of by the private market. There was no private contractor participation in the Scottsdale proposal and EPA did not impose private contractor participation as a condition of the grant. Hence, Scottsdale was on its own and had to solicit participation in the project of both container and truck manufacturers. *

**FUNDING**

Under the terms of the Solid Waste Disposal Act, the federal share for any project shall be not more than 75 percent. When it was first funded as a study and investigation, projected funding on the Scottsdale project was as follows.

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The project start date was March 1, 1969; the end date was February 28, 1971. Before the end of the first year the project was reclassified as a demonstration, the scope was expanded, supplemental funds were approved and the new funding schedule was as follows.

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</tbody>
</table>

* Prior to submission of its grant application, Scottsdale had sought the participation of the truck manufacturer. This had taken a year or two but was key to Scottsdale's decision to apply for the grant.

** Federal grants were committed on an annual basis. The numbers appearing before the parentheses indicate the annual amount paid by the federal government.
The project start date was still listed as March 1, 1969 but the end date had been extended to June 30, 1971. This was later extended to June 30, 1972. Actual project expenses totaled $285,095 of which the federal government paid $184,816 distributed as follows.

<table>
<thead>
<tr>
<th>Amount</th>
<th>Project Year</th>
<th>Fiscal Year</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 30,671</td>
<td>01</td>
<td>69</td>
<td>Containerization</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>development</td>
</tr>
<tr>
<td>26,655</td>
<td>01S1*</td>
<td>70</td>
<td>Truck</td>
</tr>
<tr>
<td>43,004</td>
<td>02</td>
<td>70</td>
<td>Improve</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mechanization</td>
</tr>
<tr>
<td>24,738</td>
<td>02S1</td>
<td>70</td>
<td>Litter Pig</td>
</tr>
<tr>
<td>59,738</td>
<td>02S2</td>
<td>70</td>
<td>Trash Hog</td>
</tr>
<tr>
<td>$184,816</td>
<td></td>
<td></td>
<td>Total</td>
</tr>
</tbody>
</table>

Compared to other study and investigation or demonstration projects awarded by EPA in 1969, the Scottsdale project was medium in size. Table 1 contains a listing of all study and investigation and demonstration projects funded in 1969, showing the total for the project, the total federal share and the federal share for 1969. As with the Scottsdale project, most of these studies were very short in duration and relatively small in terms of cost. Few lasted more than three years and the average total cost was less than $500,000.

Scottsdale financed its portion of the project from general revenue funds. Where actual costs were more than anticipated, the city made up any difference not covered by federal funds.

**MONITORING**

The Scottsdale project had a total of four EPA project monitors, in addition to the project representative discussed earlier. The first was Stephen Lingle followed by Dennis Heubner, Erik Larson, and Donna Krabbe. Ms. Krabbe had previously worked largely in technical assistance. The turnover in project monitors experienced by this project was not unusual during this period for EPA. The agency budget had been

*"S" indicates supplemental funds granted above initial contract funding. The number following is the request number.
Table 1
DEMONSTRATION GRANT PROJECTS
(Listed in the Order in Which They Were Funded)
Calendar Year 1969

<table>
<thead>
<tr>
<th>Grantee</th>
<th>Total</th>
<th>Total Federal</th>
<th>Federal Cost '69</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nogales, Arizona</td>
<td>336,207</td>
<td>224,138</td>
<td>128,046</td>
</tr>
<tr>
<td>Association of American</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Railroad Car Dismantlers</td>
<td>289,100</td>
<td>192,700</td>
<td>192,700</td>
</tr>
<tr>
<td>San Diego, California</td>
<td>552,000</td>
<td>368,000</td>
<td>251,333</td>
</tr>
<tr>
<td>Santa Clara, California</td>
<td>77,340</td>
<td>51,560</td>
<td>51,560</td>
</tr>
<tr>
<td>Franklin, Ohio</td>
<td>2,471,858</td>
<td>1,647,905</td>
<td>46,667</td>
</tr>
<tr>
<td>Lynn, Massachusetts</td>
<td>84,350</td>
<td>51,550</td>
<td>51,550</td>
</tr>
<tr>
<td>Rye, New York</td>
<td>412,660</td>
<td>275,107</td>
<td>106,968</td>
</tr>
<tr>
<td>Greensburg, Pennsylvania</td>
<td>115,900</td>
<td>77,267</td>
<td>77,267</td>
</tr>
<tr>
<td>Scottsdale, Arizona</td>
<td>147,151</td>
<td>116,480</td>
<td>30,671</td>
</tr>
<tr>
<td>Stanford Research Institute</td>
<td>120,000</td>
<td>80,000</td>
<td>80,000</td>
</tr>
<tr>
<td>Battelle-Northwest</td>
<td>269,690</td>
<td>174,890</td>
<td>95,570</td>
</tr>
<tr>
<td>Oregon State University</td>
<td>230,565</td>
<td>149,555</td>
<td>69,855</td>
</tr>
<tr>
<td>Helena, Montana</td>
<td>196,849</td>
<td>131,233</td>
<td>95,233</td>
</tr>
<tr>
<td>Dutchess County, New York</td>
<td>81,000</td>
<td>54,000</td>
<td>54,000</td>
</tr>
<tr>
<td>Kansas City, Missouri</td>
<td>158,400</td>
<td>105,600</td>
<td>105,600</td>
</tr>
<tr>
<td>Kansas City, Missouri</td>
<td>496,149</td>
<td>330,765</td>
<td>165,893</td>
</tr>
<tr>
<td>Erie County, New York</td>
<td>1,552,000</td>
<td>1,034,667</td>
<td>626,000</td>
</tr>
<tr>
<td>Shelbyville, Indiana</td>
<td>472,360</td>
<td>314,633</td>
<td>276,453</td>
</tr>
<tr>
<td>Gainesville, Georgia</td>
<td>20,616</td>
<td>13,744</td>
<td>13,744</td>
</tr>
<tr>
<td>Des Moines, Iowa</td>
<td>302,376</td>
<td>201,584</td>
<td>73,857</td>
</tr>
<tr>
<td>Delaware State Board of Health</td>
<td>81,684</td>
<td>52,938</td>
<td>27,274</td>
</tr>
<tr>
<td>National Solid Wastes Mgmt Assoc</td>
<td>123,660</td>
<td>82,440</td>
<td>82,440</td>
</tr>
<tr>
<td>Lower Passaic Valley Solid Wastes Management Authority</td>
<td>1,668,500</td>
<td>795,667</td>
<td>50,000</td>
</tr>
<tr>
<td>Scottsdale, Arizona</td>
<td>277,225</td>
<td>184,816</td>
<td>57,336</td>
</tr>
<tr>
<td>United Housing Foundation</td>
<td>1,342,506</td>
<td>895,003</td>
<td>793,333</td>
</tr>
<tr>
<td>Tupelo, Mississippi</td>
<td>22,500</td>
<td>15,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Los Angeles County, California</td>
<td>126,170</td>
<td>81,670</td>
<td>81,670</td>
</tr>
</tbody>
</table>

Total: 12,028,816                     | 7,702,912 | 3,696,020     

aStudy and investigation.

bScottsdale, Arizona first as a study and investigation and later as a demonstration project.
cut substantially and offices were being eliminated, consolidated and moved. In addition, there was a change in emphasis. In 1969, solid waste management, particularly residential refuse collection, had been in vogue. By 1971 and later a new interest had taken hold within EPA, this time water quality and pollution.

EPA monitoring activities were generally at arm's length, especially in the case of this project which was punctual with its required reports and which presented few, if any, problems for the funding agency. A few site visits were made by EPA project monitors but these were mostly for the purpose of introducing a new project monitor. It is probably not inaccurate to say that the greater amount of time spent by EPA personnel was in the area of information dissemination. This activity will be discussed in a later section.
V. APPLICATION OUTCOME

The success of the Scottsdale project was evaluated in two ways. The first was an opinion survey of the residents of Scottsdale asking them for their reactions to the shared containers and the mechanized collection system. The second means of evaluation was technical and economic, relating the cost and level of service of the various mechanized systems to the cost and service level of several conventional collection systems.

OPINION SURVEY

The purpose of Phase I in the Scottsdale project was to determine the feasibility and public acceptance of a system of containerizing residential refuse into municipally owned containers. Primary concerns were the size of the container and the frequency of service. The combinations of container size and collection frequencies which were tested are listed below.

<table>
<thead>
<tr>
<th>Container Size in Gallons</th>
<th>Families Per Container</th>
<th>Collections Per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>160</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>160</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>300</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>300</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

While the containers were being distributed to residents, a visit was made to each home to explain the experiment, the use of the container and to administer a pretest survey. Residents were visited again at the completion of Phase I and administered a post test survey. These interview forms appear in Appendix A.

The results of these surveys indicated that before the experiment 60% of the residents felt the city was doing an excellent job of
refuse collection and this increased to 94% after the test. Willingness to share a container with a neighbor increased from 55% to 78% during the course of the experiment. The surveys were done by a group from Arizona State University and the attitudinal data were summarized using a rating system developed by the Scottsdale staff. Starting with 1.000 as a perfect service which every user would agree would be satisfactory, the following indices were developed:

<table>
<thead>
<tr>
<th>Level of Service</th>
<th>Favorability Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>160 gal., one per home, once per week</td>
<td>0.932</td>
</tr>
<tr>
<td>80 gal., one per home, twice per week</td>
<td>0.919</td>
</tr>
<tr>
<td>300 gal., two homes, once per week</td>
<td>0.904</td>
</tr>
<tr>
<td>300 gal., four homes, twice per week</td>
<td>0.868</td>
</tr>
<tr>
<td>160 gal., two homes, twice per week</td>
<td>0.860</td>
</tr>
<tr>
<td>Conventional train service, twice per week</td>
<td>0.651</td>
</tr>
</tbody>
</table>

This index indicated that all levels of service using a crude mechanized system (Godzilla) and city furnished containers, achieved a higher level of acceptance than the conventional twice per week train collection service. It was as a result of this index and cost considerations that the levels of service of 80 gallon, one per home, twice per week and 300 gallon for four homes, twice per week were chosen for Phase II.

During Phase II, another opinion survey (shown also in Appendix A) was taken to determine resident's reactions to the different service levels. The survey was conducted in December 1971 in two separate residential areas that had had mechanized collection for a period of one year. One area had been using the 300 gallon containers, shared by four families and placed in the alleys behind the homes. Collection had been provided by the Barrel Snatcher. The other area had had curbside collection provided by Barrel Snatcher but using one 80 gallon container for each home. The areas were similar demographically and both had previously had the train system of collection.

*The train consisted of one pickup truck and four 5 yard trailers.
When asked if the new method was an improvement over the old, 73% responded favorably. When asked if the mechanized system should be kept rather than return to the old train collection system, 75% responded affirmatively.

In addition to the surveys, the Refuse Division carefully investigated any complaints received by using service representatives. These representatives logged complaints and handled each one individually.

**TECHNICAL EVALUATIONS**

Phase I of the demonstration focused on problems and costs of containerization. The cost of collection with Godzilla was found to be less than with the conventional system. The table below indicates the cost estimates from Phase I. The $90 cost of the 300 gallon container has been amortized over five years and the collection costs of a Godzilla vehicle, such as labor, amortization, maintenance, etc. are included.

<table>
<thead>
<tr>
<th>Homes per Container</th>
<th>Container size (gal)</th>
<th>Collections per Week</th>
<th>Cost per Month per Home</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80</td>
<td>2</td>
<td>$1.42 $0.80 $2.22</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>2</td>
<td>0.82 0.60 1.42</td>
</tr>
<tr>
<td>1</td>
<td>160</td>
<td>1</td>
<td>0.58 1.20 1.78</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>1</td>
<td>0.51 1.06 1.57</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
<td>2</td>
<td>0.64 0.53 1.17</td>
</tr>
<tr>
<td>Train</td>
<td>2</td>
<td>2</td>
<td>1.75 0.00 1.75</td>
</tr>
</tbody>
</table>

These figures indicated that even a crude adaptation, like Godzilla, could under certain circumstances produce substantial savings. These figures also showed that it was more economical to provide twice per week service with a small 80 gallon container than to enlarge the container and provide once per week alley service. Note, in all cases the 80 gallon containers used curbside collection while the 300 gallon container used alley collection.

Phase II was intended to evaluate the economics of various mechanized systems. The vehicles compared were the rear end loader,
a modified rear end loader, Godzilla, the Litter Pig and the Barrel Snatcher. The rear end loader is a conventional collection vehicle widely used in the U.S. The truck uses one driver and two workmen who pick up resident-supplied containers or bags, dump their contents in a hopper at the rear of the truck and return the containers to their original location. This vehicle has the same capacity and service capability as the rear loader.

Godzilla, Litter Pig and Barrel Snatcher are all mechanized collection vehicles which require only one man who drives and controls collection from the cab of the vehicle. Godzilla, the prototype vehicle had a capacity of 28 cubic yards, Litter Pig had a capacity of 22 cubic yards and Barrel Snatcher a capacity of 35 cubic yards. They could serve 280, 277 and 357 homes per load respectively in twice weekly collection. The following table summarizes three measures of vehicle productivity—capacity, rate of collection and home/container ratio.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Capacity (cu. yds)</th>
<th>Rate of Collection (homes/hour)</th>
<th>Home/Container Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear loader</td>
<td>25</td>
<td>85</td>
<td>1</td>
</tr>
<tr>
<td>Modified rear loader</td>
<td>25</td>
<td>90</td>
<td>1</td>
</tr>
<tr>
<td>Godzilla</td>
<td>28</td>
<td>58/160</td>
<td>3.3</td>
</tr>
<tr>
<td>Litter Pig</td>
<td>22</td>
<td>131</td>
<td>1</td>
</tr>
<tr>
<td>Barrel Snatcher</td>
<td>35</td>
<td>61/271</td>
<td>3.3</td>
</tr>
</tbody>
</table>

The figures on comparative investment and operating costs are given below.

**VEHICLE INVESTMENT COSTS**

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Purchase Price</th>
<th>Financing Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear end loader</td>
<td>$27,000</td>
<td>$4,050</td>
<td>$31,050</td>
</tr>
<tr>
<td>Modified rear end loader</td>
<td>$28,000</td>
<td>$4,200</td>
<td>$32,200</td>
</tr>
<tr>
<td>Godzilla</td>
<td>$30,000</td>
<td>$4,500</td>
<td>$34,500</td>
</tr>
<tr>
<td>Litter Pig</td>
<td>$43,000</td>
<td>$6,450</td>
<td>$49,450</td>
</tr>
<tr>
<td>Barrel Snatcher</td>
<td>$45,000</td>
<td>$6,750</td>
<td>$51,750</td>
</tr>
</tbody>
</table>
VEHICLE OPERATING COST PER MONTH

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Labor</th>
<th>Administration and Overhead</th>
<th>Operating &amp; Maintenance</th>
<th>Amortization of Purchase</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear end loader</td>
<td>$2416</td>
<td>$725</td>
<td>$1000</td>
<td>$370</td>
<td>$4511</td>
</tr>
<tr>
<td>Modified rear end loader</td>
<td>1636</td>
<td>491</td>
<td>1000</td>
<td>383</td>
<td>3510</td>
</tr>
<tr>
<td>Godzilla</td>
<td>1030</td>
<td>309</td>
<td>1100</td>
<td>411</td>
<td>3850</td>
</tr>
<tr>
<td>Litter Pig</td>
<td>1030</td>
<td>309</td>
<td>1005</td>
<td>589</td>
<td>2933</td>
</tr>
<tr>
<td>Barrel Snatcher</td>
<td>1030</td>
<td>309</td>
<td>1500</td>
<td>616</td>
<td>3455</td>
</tr>
</tbody>
</table>

Using the formula

\[
\text{UNIT COST} = \frac{PO \,(C + RH)}{WCR} + K
\]

where

- \( P \) = number of collections provided per month
- \( O \) = total cost of operating a collection vehicle for a month in dollars
- \( C \) = number of homes served for each load
- \( R \) = number of homes collected in a normal hour of collection
- \( H \) = average haul time
- \( W \) = number of hours worked per month
- \( K \) = monthly cost of providing containers

the final comparison for the conventional versus the mechanized collection system is as follows:

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Collection Rate (homes/hour)</th>
<th>Once/week Collection Total cost</th>
<th>Twice/week Collection Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear loader</td>
<td>85</td>
<td>$1.86</td>
<td>$3.72</td>
</tr>
<tr>
<td>Modified rear</td>
<td>90</td>
<td>1.93</td>
<td>3.31</td>
</tr>
<tr>
<td>Godzilla</td>
<td>58</td>
<td>2.10</td>
<td>3.64</td>
</tr>
<tr>
<td>Godzilla</td>
<td>160</td>
<td>1.10</td>
<td>1.82</td>
</tr>
<tr>
<td>Litter Pig</td>
<td>131</td>
<td>1.40</td>
<td>2.25</td>
</tr>
<tr>
<td>Barrel Snatcher</td>
<td>61</td>
<td>2.28</td>
<td>4.01</td>
</tr>
<tr>
<td>Barrel Snatcher</td>
<td>271</td>
<td>.94</td>
<td>1.54</td>
</tr>
</tbody>
</table>

These figures, as well as the consumer survey, support Scottsdale's conclusion that mechanization of refuse collection is both feasible and economical and is the preferred service of the customers.
The Scottsdale project formally ended in June 1972. The city continued to expand the operations and by the fall of 1973 most of the city had mechanized residential refuse collection. The city continued to make improvements to the vehicle and is now seeking support for a modular truck. This truck would have a chassis to which various bodies could be attached to perform such operations as refuse collection, street cleaning, paving and digging. The body would be plugged in and operations performed via a single control box in the one man cab.
VI. DISSEMINATION AND DIFFUSION

EPA DISSEMINATION ACTIVITIES

In the preface to one of its documents, EPA states that an integral part of its demonstration activity is dissemination nationwide of the information developed by its program. To that end, it requires a written report from the grantee at the conclusion of each study. In the case of the Scottsdale study, this report was submitted February 1973 but is yet to be released by EPA. In addition, EPA generates a number of its own publications which either summarize or give abstracts of the projects funded by selected periods or covering selected topics. An example of one of these reports is Solid Waste Management Demonstration Grant Projects-1971; for grants awarded during the period June 1, 1966 to June 30, 1971. The description which this report contains of the Scottsdale project, first as a study and investigation and then as a demonstration, appears in Appendix C.

Technical symposia are another aspect of the EPA information dissemination program. In May 1971, five years after the start of the solid waste demonstration program, the Office of Solid Waste Management sponsored a symposium in Cincinnati, Ohio for the purpose of reporting on projects which appeared to have the best potential for the future transfer of improved technology. Thirteen projects were selected for presentation including the Scottsdale study. The symposium, which lasted three days, had a list of more than 200 registrants largely from business and consulting firms and state and local planning and sanitation departments.

EPA also has an Office of Technology Transfer. The original objective of this office, and an objective which dominates current activities, was to improve the construction of municipal waste water treatment facilities. Because of this emphasis, this office has done little to publicize mechanized trash collection.

A less formal, but effective means of information dissemination exists within OSWMP in the relationship which its personnel have with
both industry and state and local governments. No records are kept of
the requests for information, but OSWMP personnel indicated a current
working knowledge of what industry was doing, what local areas were
doing and something of the role that they play as an information inter-
mediary. Both groups call OSWMP regularly so they are in a position
to provide information to both.

SCOTTSDALE DISSEMINATION ACTIVITIES

Much of the information dissemination by Scottsdale has been viewed
by the city as public relations. It has used local and national press,
radio, television, magazines and professional publications both to
convince the residents of Scottsdale of the merits of the project and
to inform the public in general of the advances being tested in solid
waste management. The city purposely chose catchy names such as
Godzilla, Son of Godzilla (Barrel Snatcher), Litter Pig and Trash Hog
for the vehicles. It held a tea party when the first Barrel Snatcher
was delivered and introduced it to the children through demonstrations
at city schools and parks.

Newspapers, radio and television were also used extensively. In
1972, in celebration of Public Works Week, the local newspaper ran a
page of photographs of Barrel Snatcher, Litter Pig and Trash Hog. The
Mayor, City Manager and Public Works director have at one time or
another discussed the new mechanized system on radio or television.
In addition they have also made presentations to such local groups as
the Chamber of Commerce, League of Women's Voters and Earth Day Forums.
The City of Scottsdale's own publication "Steps Forward" has carried
several articles on the mechanized refuse collection system.

Nationally, articles on the Scottsdale project have appeared in
journals such as Fortune, The American City, Waste Age, Nations Cities,
Western City and Public Works. These span the range of business,
trade and professional journals. Stragier has appeared on television in
Seattle to discuss the project, and made presentations to such nationwide
professional organizations as the Western Division of Governmental Refuse Collection and Disposal Association, the American Institute of Aeronautical and Astronautical Engineers, the southeastern chapter of the International City Managers Association and the American Public Works Association.

In addition, the city prepared progress reports as well as a summary report describing the Scottsdale project. These reports have been sent to over 400 cities, private haulers, manufacturers and consultants. Representatives from more than 100 agencies have visited Scottsdale for operating demonstrations.

**DISSEMINATION ACTIVITIES BY "GOVERNMENT INNOVATORS"

In addition to the efforts of EPA and Scottsdale to publicize the study, a private firm, "Government Innovators," has also become involved. Stragier is now president of the firm which sees itself as filling a gap left in the information structure. That is, in addition to providing information to cities on mechanized refuse collection, Government Innovators will help install and maintain the new system. In this sense the firm is reducing the technological uncertainty associated with a change from conventional to mechanized collection. Through its efforts, the following cities have installed Godzilla-like systems: Coolidge, Arizona; Kearney, Arizona; Casa Grande, Arizona; Tempe, Arizona; Phoenix, Arizona, Huachuca City, Arizona; Taft, California; Alliance, Nebraska; Grants, New Mexico; and Ponca City, Oklahoma. As a small firm, with limited resources, it has concentrated most of its activities in Arizona.

**OTHER MECHANIZED SYSTEMS

**Tolleson Demonstration Project**

Similar to the Scottsdale project this was a one-year study, also sponsored by EPA, in Tolleson, Arizona. The purpose of this project was to demonstrate the feasibility of nonstop truck collection. This study ran from January to December 1971 at a total cost of $76,000 of which the federal share was $51,000. Briefly the idea in this study was to fasten containers to a horizontal arm installed perpendicular to the path of the truck. In collection the truck would pivot the containers around
the arm, receive the refuse from them in a tray and pivot the containers back into place. Phase I was a test of the design of the non stop truck and the durability of the container; Phase II would involve development and testing of the truck and Phase III was to be citywide implementation and demonstration.

This project was similar to the Scottsdale project in that it too used the concept of mechanized collection. An important difference, however, was that it was a less expensive system and it was being tested against a less sophisticated and poorer population.

Subsequent to the project, the inventor went into private business, as Strangier has, but the business failed. Tolleson is the only city using this nonstop truck system of collection.

**Bellaire, Texas.** Bellaire, Texas, uses a mechanized form of collection called Mechanical Bag Retrieval, developed by Gulf Oil Co. It is a standard 20 cubic yard sideloader truck equipped with a special conveyor and articulated arm. The backhoe style arm has a large basket which is suspended over the load, picks it up and places it on the conveyor belt. The truck features one hand control which allows collection from either side of the truck. Estimated cost of operation is $2.48 for twice weekly service including the supply of bags for each household.

**Fort Lauderdale, Florida.** The simplest of the mechanized collection systems is that used by Fort Lauderdale, Florida. A modification kit is attached to a rear loader so that containers are rolled to the lifting device, placed on a small frame by the workman who then activates a control to raise, empty and lower the container. This system costs about $3.47 per home per month including amortization of the cost of the 80 gallon container. Table 2 summarizes the information for conventional collection systems and the vehicles tested in Scottsdale as well as these other mechanized systems.

**DIFFUSION**

Diffusion of the technology demonstrated in Scottsdale can be assessed in two ways. One is to consider the number of containerized systems which have
Table 2  
COST PER HOME PER MONTH  
SELECTED COLLECTION VEHICLES

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Container</th>
<th>Crew Size</th>
<th>Container Size</th>
<th>Collection Size</th>
<th>Container Rate</th>
<th>Container Cost</th>
<th>Once/Wk Collection</th>
<th>Twice/Wk Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear End Ldr</td>
<td>Household</td>
<td>3</td>
<td>25</td>
<td>85</td>
<td>---</td>
<td>1.86</td>
<td>3.72</td>
<td></td>
</tr>
<tr>
<td>Modified</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rear Loader</td>
<td>80 gal.</td>
<td>2</td>
<td>25</td>
<td>90</td>
<td>.54</td>
<td>1.93</td>
<td>3.31</td>
<td></td>
</tr>
<tr>
<td>Godzilla</td>
<td>80 gal.</td>
<td>1</td>
<td>28</td>
<td>58</td>
<td>.54</td>
<td>2.10</td>
<td>3.64</td>
<td></td>
</tr>
<tr>
<td>300 gal.</td>
<td>1</td>
<td>28</td>
<td>160</td>
<td>.36</td>
<td>1.10</td>
<td>1.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litter Pig</td>
<td>80 gal.</td>
<td>1</td>
<td>22</td>
<td>131</td>
<td>.54</td>
<td>1.40</td>
<td>2.25</td>
<td></td>
</tr>
<tr>
<td>Barrel Snatcher</td>
<td>80 gal.</td>
<td>1</td>
<td>35</td>
<td>61</td>
<td>.54</td>
<td>2.28</td>
<td>4.01</td>
<td></td>
</tr>
<tr>
<td>300 gal.</td>
<td>1</td>
<td>35</td>
<td>271</td>
<td>.36</td>
<td>0.94</td>
<td>1.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shu Pak</td>
<td>Household</td>
<td>1</td>
<td>25</td>
<td>80</td>
<td>---</td>
<td>1.14</td>
<td>2.26</td>
<td></td>
</tr>
<tr>
<td>Modified</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shu Pak</td>
<td>80 gal.</td>
<td>1</td>
<td>25</td>
<td>100</td>
<td>.54</td>
<td>1.51</td>
<td>2.47</td>
<td></td>
</tr>
<tr>
<td>Non Stop Trk</td>
<td>55 gal.</td>
<td>1</td>
<td>12</td>
<td>174</td>
<td>.32</td>
<td>1.22</td>
<td>2.12</td>
<td></td>
</tr>
<tr>
<td>(Tolleson)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>Plastic</td>
<td>1</td>
<td>20</td>
<td>140</td>
<td>.91</td>
<td>1.83</td>
<td>2.73</td>
<td></td>
</tr>
<tr>
<td>Bag Retriever</td>
<td>Bags</td>
<td>1</td>
<td>20</td>
<td>140</td>
<td>.91</td>
<td>1.83</td>
<td>2.73</td>
<td></td>
</tr>
</tbody>
</table>

been installed. As indicated earlier, ten have been installed.  
Another way is to consider variations within the broader category  
of mechanized trash collection. As examples we have the  
Tolleson, Bellaire and Fort Lauderdale systems. These all came  
after the Scottsdale project and are felt by EPA to be local adaptations  
to the mechanization concept. Further examples of local adaptation are  
found in systems being tested in Visalia and Covina, California. Both  
of these systems are using modified Shu-Pak trucks manufactured by  
Western Body and Hoist. The manufacturer is actively participating  
in these experiments which are being undertaken at local expense.

Impediments to Diffusion

Two factors appear to have affected the rate of diffusion; 1) the  
need for local adaptation, and 2) the cost and nature of the solid waste  
industry.  
It could be argued that the biggest deterrent to diffusion has been  
the lack of good marketing by equipment manufacturers. While this is true  
it is quite possibly the result of what appears to be a need for local
adaptation of equipment design. It is something of an understatement to say that no two cities or towns are like, but differences in terms of the age and education of the population, industry, city budget, etc., will all affect the desired level and provision of public services. It is not surprising then to see a slightly different version of the mechanized concept in each application. But this need for local individuality also limits industry initiative. Unable to produce a machine which can be mass produced and which will be appropriate for all cities, a not unreasonable strategy for industry to follow is the development of a truck, such as Shu-Pak, which is an all purpose but easily modified vehicle. Then, on the basis of the desires of each city, an appropriate vehicle can be delivered. To develop a new vehicle each time would be too costly for both the cities and the manufacturer.

The problems of the cost and nature of the solid waste industry have been mentioned before. In replacing a man with a machine a city faces a large, one time cost instead of a small, annual payment in the form of the worker's salary. Additional city expense is incurred if bags or containers are provided by the city instead of the resident.

The nature of the industry has been characterized by EPA as one populated by people who have come up through the ranks. The implication is that as these people are generally less well educated, they are also less innovative and will be slower to adopt or adapt. They generally do not take the initiative needed to find funding, acquire equipment and put a new system together. Because mechanization is so different from what they are accustomed to and what neighboring cities have done, managers often consider the change to a mechanized system as one involving unreasonable risks.
VII. CONCLUSIONS

Was the Scottsdale project a success? From an application standpoint, the answer is an unequivocal yes as far as the funding agency, the contractor, and the general public are concerned. Yet this project faced great technological uncertainty as well as cost, demand and institutional uncertainties. The technological success is no doubt due to the fact that the innovation and the idea for the project came from the user. Stragier, as head of the department of Public Works, was the innovator and was personally very committed to the project. When efforts to get manufacturers interested in further developing the articulated arm failed, he set about having the work done in his department's repair shop. There was a well defined need. Refuse collection was costly and labor intensive. It was easy to demonstrate the need to experiment with a mechanized system and the resulting cost calculations supported the anticipated cost effectiveness of a mechanized system. There was also a well defined safety problem. If the mechanized concept was successful, those workers continuing in refuse collection would have safer as well as better jobs. Hence there was employee support for the effort. Any remaining institutional uncertainties were eliminated by the city's efforts to place, in other departments in the city, any displaced refuse collectors. In all cases this meant an improvement in the individual's job. The one uncertainty not answered by this demonstration was that of demand. While the public responded overwhelmingly to the mechanized concept, the demand for the system from other public works departments could only be inferred on the basis of the cost effectiveness demonstrated in Scottsdale. While there have been many requests for information on the system, there have been relatively few actual adoptions. Questions left unanswered, for example, were what characteristics of a community make it a likely candidate for adoption. Looking at those that first adopted the system one might venture such characteristics as largely residential, relatively small and relatively new. But this can only be
inferred on the basis of those cities which have adopted the system; not as a result of the demonstration itself.

The diffusion success of the project is difficult to evaluate. If it is judged solely on the basis of the number of Godzilla-like systems in use today then it would no doubt be labeled less than successful. But as noted before, if the emphasis is on the mechanization concept, then indeed it is somewhat more successful. In the absence of a definite answer to the question of diffusion success, the following are factors which may be important in whatever success the project has or has not achieved.

1. The refuse collection equipment industry is fragmented. Typically one manufacturer produces the truck body while another produces the compacter. Successful marketing of a product then requires some joint effort or an attempt by the compacter manufacturer to make its equipment conform to that of existing trucks.

2. There is a large element of local or regional influence in the use of refuse collection equipment. Typically cities adopt equipment which a nearby city has used. This suggests that to have the mechanization concept catch on faster, several small demonstrations should have been conducted throughout the country.

3. The idea for the innovation came from the user, not the producer. While their efforts at dissemination have been extensive, the efforts of the group in Scottsdale do not have the same objective as those of a manufacturer. That raises the question, would the idea have diffused faster if EPA had required private contractor participation in the project from the beginning? Perhaps yes, perhaps no. Certainly a cost sharing arrangement for equipment development would have saved project time, but the effect of regional influences and the absence of multiple demonstrations of the same concept might have overshadowed the efforts of a manufacturer to promote the idea.
4. The dissemination efforts of the results of the project were undertaken largely by the group in Scottsdale. EPA while committed, on paper at least, to information dissemination, in the case of this project did not follow through. They did hold a symposium on solid waste demonstration projects at which time the Scottsdale study was discussed. But in terms of distributing the final report, they delayed printing of that for a year. Most of their dissemination efforts have been informal, with people contacting the OSWMP office for information which they provide on request, much of it verbally.

The original Godzilla has been retired, but in its place in Scottsdale and other cities is an improved residential refuse collection system. What effect the government sponsored demonstration had on increased diffusion of technology can, on the basis of one case study, only be conjecture. However, one way of measuring the effect is by comparing Godzilla and the system being tested in Covina, California.* The technology for both of these systems existed in 1968. For various reasons, including the extensive use of plastic in the Covina system, Scottsdale sought to demonstrate the technology incorporated in Godzilla. The technology of the Covina system was not demonstrated by the government but had to wait for private development. It appeared finally in 1973, fully five years after work had begun on Godzilla.

*The Covina system is the invention of Gerhardt Van Drie of El Segundo, Calif. Known as the "jumping bean bag system," it uses a Shu-Pak sideloader refuse truck with a mechanized unit attached to the side which scoops up sacked refuse and then by conveyor moves the sacks up to the compacter unit.
Appendix A

SURVEY FORMS TO EVALUATE REACTION TO

MECHANIZED COLLECTION SYSTEM
INTERVIEW NO. _______

SCOTTSDALE REFUSE CONTAINERIZATION EVALUATION
(CONFIDENTIAL)

ADDRESS: ____________________________________________

INTERVIEWER: ________________________________________

CALLS: ______________________________________________

1. SAMPLE NUMBER: _________

2. PICKUP:
   1. Alley
   2. Curb

3. CONTAINER SIZE: _________

4. CONTAINER:
   1. Individual
   2. Collective

5. DWELLING UNIT:
   1. House or Duplex
   2. Apartment or Flat
   3. Rooming House
   4. Other (specify) ____________________________
INTRODUCTION:

A. "Hello, I'm representing the City of Scottsdale.
B. As you may have heard, the City of Scottsdale is going to try a new system of refuse collection. By refuse collection, we mean the normal garbage and trash which you dispose of.
C. We want to find out your opinions about present refuse collection service.
D. I'm going to read a few statements, and I would like to know if you strongly agree with them, agree with them, disagree, or strongly disagree with them."

(SHOW CARD)

CIRCLE CORRECT ANSWER:

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. First, the city is doing an excellent job of collecting refuse.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7. The city could do a better job of collecting refuse than it is presently doing.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>8. I would not be willing to try a more mechanized way of collecting refuse.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>9. Using more machines in collecting refuse would probably result in better service.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>10. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>11. The people who collect the refuse are doing a poor job.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>12. I could use more refuse container capacity than I presently have.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>13. I would not mind using a container which is owned by the city.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>14. Collecting refuse by hand rather than by machine probably costs more money.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>15. Collecting refuse by hand rather than by machine probably is faster.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>16. I would not share a refuse container with a neighbor even if it is big enough.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>17. Refuse is collected just about often enough for me.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
18. The city employees collecting the refuse are doing a good job.  

19. The refuse cans are usually replaced properly.  

20. XXXXXXXXXXXXXXXXXXXXXXXXXXX

21. The container covers are usually placed back on the cans after emptying.  

22. The area where the refuse containers are placed smells pretty bad.  

23. It's easy to keep all the refuse in the cans so it will not make the area messy.  

Now I would like to ask you for your comments on a few questions.  

24. What do you like most about the way refuse is presently being collected?  

Write in verbatim

Anything else?  

25. What do you dislike most about the way refuse is presently being collected?  

Write in verbatim

Anything else?
26. How do you think the city could improve its collection of refuse?

Write in verbatim

27. How many refuse containers do you presently use?

| One       | 1 |
| Two       | 2 |
| Three     | 3 |
| Four or more | 4 |

28. How well would you say you like the way refuse is being collected?

| Dislike it very much | 1 |
| Dislike it somewhat  | 2 |
| Indifferent          | 3 |
| Like it somewhat     | 4 |
| Like it very well    | 5 |

29. How long have you lived in this house?

| Less than 6 months | 1 |
| 6 months to 1 year | 2 |
| 1 to 2 years       | 3 |
| 3 to 5 years       | 4 |
| 5 to 10 years      | 5 |
| over 10 years      | 6 |

30. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

31. What is your telephone number? ____________________________

32. Time __________  Day of Week __________  Date __________

Thank you very much for your cooperation.
33. Respondent
   
   Same as Pretest 1
   Different but same household 2
   Different household 3

34. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

INTRODUCTION:

A. 'Hello, I'm ______________________ representing the City of Scottsdale.

B. You may recall that I talked with you (or someone in this house) about
   the new way we are trying to contain and collect refuse.

C. I would like to ask you your opinion about how the new system works.

35. First, what do you like most about the way refuse is contained in the
   new cans?

   Write in verbatim

Anything else?

36. What do you dislike most about the way refuse is contained in the new cans?

   Write in verbatim

Anything else?

37. What do you like most about the new way refuse is being collected?

   Write in verbatim

Anything else?
38. What do you dislike most about the new way refuse is being collected?

Write in verbatim

Anything else?

39. Do you think the city should stay with the old way or the new way of collecting refuse?

- Old way: 1
- New way: 2
- Don't know: 3

40. How well would you say you like the new way of refuse collection?

- Dislike it very much: 1
- Dislike it somewhat: 2
- Indifferent: 3
- Like it somewhat: 4
- Like it very well: 5

41. How do you think the city could improve on the new way of collecting refuse?

Write in verbatim

Anything else?
INSTRUCTIONS:

Now, I will need a few statements and I would like to know if you strongly agree with them, agree, disagree, or strongly disagree with them. (SHOW CARD)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>42. The city is doing an excellent job of collecting the refuse.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>43. The city could do a better job of collecting refuse than it is presently doing.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>44. I would not be willing to continue the new way of collecting refuse.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>45. Using more machines in collecting refuse would probably result in better service.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>46. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>47. The people who collect the refuse are doing a poor job.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>48. I could use more refuse container capacity than I presently have.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>49. I do not mind using a container which is owned by the city.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>50. Collecting refuse by hand rather than by machine costs more money.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>51. Collecting refuse by hand rather than by machine probably is faster.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>52. I will not share a refuse container with a neighbor even if it is big enough.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>53. Refuse is now collected just about often enough for me.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>54. The city employees collecting the refuse are doing a good job.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>55. The refuse cans are usually replaced properly now.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
56. XXXXXXXXXXXXXXXXXXXXXXXXXXXX

57. The container covers are usually placed back on the cans after emptying.

58. The area where the refuse cans are placed smells pretty bad.

59. It's easy to keep all the refuse cans so it will not make the area messy.

60. Dogs and cats are getting into the cans a lot now.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>56.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>57.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>58.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>59.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Thank you very much for your cooperation.

* These questions were asterisked to provide information on negative feelings toward the system. Used for statistical computation only.

XXXXXXXXX Used for keypunch purposes in computer program.
Appendix B

ATTITUDE SURVEY

OF

MECHANIZED REFUSE COLLECTION

IN

SCOTTSDALE, ARIZONA
ATTITUDE SURVEY
OF
MECHANIZED REFUSE COLLECTION
IN
SCOTTSDALE, ARIZONA

STREET ______________________ NUMBER ______________________

DWELLING TYPE: HOUSE _______ TOWNHOUSE _______

RESPONDENT: AGE _____ SEX _____ FAMILY POSITION: Father
Mother
Child

EVER INTERVIEWED BEFORE FOR THIS PROGRAM? YES _____ NO _____

HOW MANY LIVING AT THIS ADDRESS? ______

1. Which of the City services consume the largest portion of the City budget?

   Fire Protection
   Police Protection
   Refuse Collection
   Administrative Overhead
   Street Repair & Construction

2. Are you satisfied with your refuse collecting? Why or Why Not?

3. The City is doing a competent job of refuse collecting.

4. Your refuse is collected often enough.

5. You think it costs less to collect refuse by hand than by machine.

6. You think it is faster to collect refuse by hand than by machine.

7. You would prefer going back to the former method of refuse collection.
8. The noise of collecting refuse by the former method bothered you. ____________________________

9. The new cans help reduce odors around refuse containers. ____________________________

10. Refuse cans are replaced properly by machine after emptying them. ______________________

11. The City employees who collect refuse are doing a good job. __________________________

12. The area around the new refuse containers is easier to keep clean with the new system. __________________________

13. Use of the new system reduces noise when collecting. _________________________________

14. Use of the new system helps improve the appearance of the neighborhood by having fewer containers and by keeping it cleaner. ________________________________

15. This new system is more sanitary than the previous system. _____________________________

16. Use of the new system adds prestige or status to the neighborhood. ____________________

17. The City should go back to the old method of collection. ______________________________

18. Who takes the garbage out? Father  Mother  Child

19. Do you mind using a City provided refuse container? Yes  No

20. Do you have a garbage disposal? Yes  No

21. Have you ever had a delay in service with the new system? Yes  No  Sometime

22. Are the refuse container lids closed after emptying? Yes  No  Sometime

23. What kind of container did you use previously? Metal  Plastic  Other

24. How can the service of collecting your refuse be improved?
Appendix C

EPA Project Description

CONTAINERIZATION OF FAMILY REFUSE*

PROJECT TYPE: Study & Investigation

GRANTEE: City of Scottsdale, Arizona

PROJECT DIRECTOR: Marc G. Stragier, Director of Public Works,
City Hall, Scottsdale, Arizona 85251

ESTIMATED TOTAL PROJECT COST: $ 147,151

GRANTEE'S SHARE: $ 49,051

FEDERAL SHARE: $ 30,671 [01]
(By year of project life)
$ 67,429 [02]

DATE PROJECT STARTED: Mar. 1, 1969
DATE PROJECT ENDS: Feb. 28, 1971

OBJECTIVES: To demonstrate a new and improved method of storage and collection of solid wastes.

PROCEDURES: The project will be conducted by City personnel, and will be carried out in two phases, as follows:

Phase I - Public acceptance of a solid waste storage system involving joint use of container facilities by two to four homes will be determined. Some 500 homeowners in a typical family residential area will be asked to participate. Five groups of 100 homes each will be established. Each group will be provided a different size container (ranging from 40 - 200 gallons), a specified level of pick-up service (once or twice weekly), and a storage schedule (i.e., individually or jointly with other homes). Existing collection equipment will be modified to permit raising and emptying the containers. After the system has been operated for six months, each of the participants will be interviewed in detail, and public acceptance evaluated. If the system appears to be well received, the project will progress into Phase II, otherwise the grantee will not proceed further.

Phase II - The principal goal of this phase will be the evaluation of the economics of a mechanized collection system, in terms of those combinations which have proved most desirable to the public in Phase I. Indicated improvements will be made in the container, and the proper size and level of service combination to provide improved service will be selected. A truck fitted with a telescoping arm will be used for collection. The arm will be operated by the driver in his cab, and will be capable of being rotated and extended to serve containers on either side of the truck and even from behind the curb beside parked cars. The mechanism will lift the container, dump it into the hopper of the truck body, and return it to its position on the ground. A test program will be set up to demonstrate the operation of the proposed system, with cooperation of some 900 householders. At the end of a six-month operating

* Solid Waste Management Demonstration Grant Projects-1971,
period interviews will be conducted with the participants and methods investigated to improve the program before making final decisions regarding the optimum size, shape, and design of containers and operation of the system. Records will be kept of operating costs, time requirements, and economics of operation.

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OBJECTIVES: To demonstrate a new and improved method for the storage, collection, and transfer of solid wastes.

PROCEDURES: Public Works personnel for the City of Scottsdale will conduct the two-phase project.

Phase I will study public acceptance of a solid waste storage system where two, three, or four homes share container facilities. Some 500 homeowners--broken down into five groups of 100 homes each in a typical family residential area--will participate. Each group will be provided a different size container (ranging from 80 to 300 gallons), a specified frequency for pickup (once or twice weekly), and a storage schedule (individually or jointly with other homes). Existing collection equipment will be modified to lift and empty the containers. After the system has been operated for six months, each participant will be interviewed in detail, and if the system appears to be well received, the project will proceed into Phase II.

In Phase II a mechanized collection and transfer system, using those combinations which have proved most desirable to the public, will be economically evaluated. The "Barrel Snatcher" and "Litter Pig," specially designed trucks for collecting from alleys and curbs, respectively, will be built and demonstrated. Each truck will be fitted with a telescoping arm that can be manipulated by the driver in his cab to lift a container, empty it into the truck's hopper, and replace it. A test program will be set up with the cooperation of 900 householders who will be interviewed afterwards to identify ways of improving the program.

The transfer facility to be built and demonstrated is a mobile transfer station, the "Trash Hog," which will accept refuse from the "Barrel Snatcher," the "Litter Pig," and from slightly modified, conventional front-end loaders.

*Ibid.*, page 199
COMPUTER-ASSISTED ELECTROCARDIOGRAM ANALYSIS

by

C. Johnston Conover and Walter S. Baer
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<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>CDC</td>
<td>Control Data Corporation</td>
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<td>CEIS</td>
<td>Community Electrocardiograph Interpretative Services, Denver, Colorado</td>
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<tr>
<td>DHEW</td>
<td>Department of Health, Education, and Welfare</td>
</tr>
<tr>
<td>ECG</td>
<td>Electrocardiogram</td>
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<td>HCTD</td>
<td>Health Care Technology Division, DHEW</td>
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<tr>
<td>MSDL</td>
<td>Medical System Development Laboratory, DHEW</td>
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I. INTRODUCTION

The electrocardiogram (ECG) is an essential tool of modern medicine. More than 25 million ECGs are processed annually in the United States at an average price (to the patient) of about $20, placing the total ECG market at upwards of $500 million per year.

In the standard ECG procedure, leads from an ECG recording machine are attached to the patient, whose electrical heart signals are amplified and displayed on a strip-chart recorder that is part of the self-contained ECG apparatus. In a physician's office, clinic, or small hospital, the procedure usually is performed by a nurse or paraprofessional; in a larger hospital the equipment may be moved to the patient's bedside on an "ECG cart" operated by a specially trained technician. A technician can acquire roughly four ECGs per hour.

After an ECG tracing is acquired, the technician cuts and mounts it for interpretation by a physician. Some physicians in private practice interpret the ECGs they acquire, but most send them to specialists—electrocardiographers—for interpretation. Large hospitals generally have electrocardiographers in residence, while small hospitals (typically those with 200 or fewer beds) send ECGs by mail or courier to a larger facility for interpretation. The interpreted ECG, signed by the electrocardiographer, is then returned to the patient's bedside and included in his medical chart.

In Denver, prior to the computer-assisted ECG demonstration, the turn-around time from ECG acquisition to inclusion in the patient's chart ranged from about 24 hours in the major metropolitan hospitals to up to 72 hours in outlying facilities.* In emergency cases a

patient would often be brought by ambulance from a smaller hospital to a larger center for more rapid ECG interpretation.

The innovation demonstrated in Denver involved computer processing of ECG signals as an aid to electrocardiographer interpretation. In the demonstration system, * the ECG signals were acquired with a special cart equipped for recording them on magnetic tape or transmitting them by telephone to a central computer. The computer analyzed the data according to a stored program and transmitted an "unconfirmed report" to the hospital ECG center within a few minutes. This "unconfirmed report" was then sent back to be placed in the patient's chart, along with the original ECG tracing. A duplicate tracing and report were sent to the hospital electrocardiographer for interpretation. The signed "confirmed report" was then sent to the patient's bedside through a conventional delivery system (See Figure 1).

The potential benefits of the innovation thus include:

- reducing turn-around time for ECG interpretation;
- providing an immediate "unconfirmed report;"
- improving productivity of electrocardiographers (improving diagnostic accuracy is obviously an essential concern, but the principal benefit of the innovation is to let the cardiographer interpret routine cases more quickly, thus permitting him to concentrate on the abnormal cases);
- lowering overall ECG costs;
- reducing the cost, quality, and time differentials in ECG interpretation between large and small hospitals, clinics, and physicians offices;
- providing a common format for ECG reporting.

**TECHNOLOGICAL DEVELOPMENT**

**Early Federal Involvement**

In 1959 the U.S. Public Health Service (PHS) of the Department of Health, Education and Welfare (DHEW) contracted with Airborne Instruments Laboratory

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*The system underwent several technical changes during the demonstration, which are not further described here. For details, see Elliott, op. cit., pp. 4-21.*
Fig. 1--The Computer-Assisted Electrocardiogram Analysis System Used in the Denver Demonstration (Phase I.)

to develop equipment for the automated analysis of wave forms encountered in clinical medicine, such as electrocardiograms. The project was initiated by Dr. Arthur Rikli as director of the Heart Disease Control Program of the PHS. The equipment and computer programs were then transferred to an in-house PHS laboratory, the Medical Systems Development Laboratory (MSDL). Under the direction of Dr. Cesar Caceres, MSDL concentrated on developing computer hardware and software for the analysis and interpretation of the standard medical electrocardiogram. Software development represented a particularly formidable task.

By 1967, after eight years of R&D, the MSDL believed its system was ready for field test—that is, a test of technological but not economic feasibility in a real operating environment. Since the computer and data acquisition equipment represent substantial fixed costs, computer-assisted ECG analysis would be expected to exhibit economies of scale. Consequently, the two principal applications for this technology appeared to be

1) Large metropolitan hospitals that performed many ECGs daily; and
2) A number of small hospitals, clinics, and physician's offices, that could be linked by telephone lines to a central computer.

In 1967 and 1968, two major field tests of the technology were conducted in these two kinds of operating environments. Hartford (Connecticut) Hospital tested the MSDL system in a 1,000-bed operating hospital. A second field test funded by the Missouri Regional Medical Program linked ECG acquisition in physician's offices and hospitals to a central computer facility at the University of Missouri. While demonstrating that ECGs could be transmitted as much as 300 miles for analysis at a central facility, the Missouri field test suffered from technical problems such as the unreliability of rural telephone lines and queueing problems introduced by multiport operation. Neither project was continued beyond the field test. However, their results led to substantial technical improvements in the MSDL computer program.

*According to one participant, the Missouri field test could have been made operational if funding had been extended. The Missouri Regional Medical Program terminated support for the project in 1970.
Private Sector Involvement

The MSDL system was developed using a general-purpose digital computer (CDC-160A) built by Control Data Corporation (CDC). CDC spent more than $250,000 in additional system design and packaging of the MSDL system into a dedicated, "turn-key" ECG processor, "Cardiotest I." The first Cardiotest I was installed at Hartford Hospital, and a later, more sophisticated system was installed as part of the Denver demonstration.

MSDL also encouraged information exchange among researchers, users, and vendors through an informal "Data Pool" group. Data Pool members included CDC, Xerox Data Systems, IBM, and other computer manufacturers; as well as Beckman Instruments, Computer Instruments Corporation, Marquette Electronics, and other manufacturers of ECG acquisition equipment.

The DHEW program manager, who also served as the Data Pool coordinator, credits CDC and the Data Pool group for converting the MSDL software from CDC machine language to FORTRAN in late 1968. This opened the door for adapting the program for a variety of machines and reportedly speeded up the development-to-demonstration timetable by a year or more.

IBM, the Veterans Administration, the Mayo Clinic, and other groups were independently pursuing their own ECG program development and field tests during the late 1960s. In addition, Queens University, Ontario developed a computer-based ECG program closely patterned after the MSDL system. But as of 1969, there was little active marketing of computer-assisted ECG systems to hospitals or to private physicians, beyond the immediate health service environments of the program developers.
II. PLANNING FOR THE DEMONSTRATION

WHY FEDERAL INTERVENTION WAS DEEMED NECESSARY

Federal efforts to accelerate commercialization of this innovation appear based on the government's commitment to improve health care delivery, rather than because of any perceived failure in the commercial marketplace.* By the late 1960's, DHEW was under considerable pressure to "show" results from its multibillion dollar investment in medical R&D. The new emphasis on research relevance and health care delivery improvements was reflected in the Regional Medical Programs, new federal programs to combat cancer and other specific diseases, and reorganization of the federal health establishment to emphasize health care delivery rather than research.

As a part of a DHEW reorganization in 1968, a Health Care Technology Division (HCTD) was established in the National Center for Health Services Research with the mandate to "support technological innovations which promised the greatest improvement to our health care delivery system,",** through development projects, demonstrations, and information dissemination. The Division viewed improvements as "those changes which are needed to 1) resolve today's problems of spiraling costs, unequal access to health care, and overtaxed health manpower, and 2) prepare to help cope with the problems of the future.‖***

The 1968 reorganization also transferred the Medical Systems Development Laboratory to the Health Care Technology Division. Consequently, the computer-assisted ECG program that had been developed in the MSDL was

* One can speak of market failure in the sense that the perceived social benefits from improved health care exceed the perceived benefits to private firms, given the technological and economic uncertainties as of 1969. However, DHEW did not make this argument or try to quantify these factors before selecting the technology for demonstration.

** Elliott, op. cit., p. iii.

*** Ibid.
an obvious candidate for demonstration. The technology seemed well in hand; improvements in productivity seemed realizable; and, perhaps above all, the demonstration promised to be a showcase for the application of federally funded medical research and development.

**FEDERAL GOALS FOR THE DEMONSTRATION**

1. **Reduction in Technological Uncertainty.** The prior field tests in Hartford and Missouri had pointed out the problems with the MSDL computer software and the use of multiple input lines to the computer. Both the HCTD and industry recognized that considerable software development would be needed before computer-assisted ECG analysis could become a routine medical procedure. Thus, further reduction in technological uncertainty was a goal in the Denver demonstration, as evidenced by HCTD's reported initial commitment to invest an additional $100,000 in program development funds.

   Showing the technical feasibility of the multi-port processing system using remote telephone line entry also was an objective of the Denver demonstration. Otherwise, the hardware as modified by CDC seemed to be nearly completely developed. No major changes in hardware components (computer, acquisition equipment, etc.) were contemplated, although HCTD recognized that improved design incorporating human factors could be important to adoption. Such human factor improvements were left largely to industry.

   Demonstrating the operational success of the MSDL system seems to have been an implicit goal of HCTD.

2. **Reduction in Cost Uncertainty.** Reducing costs and showing economies of scale were principal federal objectives in the Denver demonstration. The Hartford field test had shown that a volume of 20 ECG's per day was far too low for breakeven operation. HCTD believed that several hundred ECG's per day were needed to breakeven, but the precise economics of the system in an operating environment were unknown. HCTD believed that industry needed such data before deciding to invest in the technology.
Moreover, resolving the scale economies question was important for determining how the system would eventually be commercialized; for example, could a single large urban hospital generate enough ECGs to justify its own dedicated computer? Would regional, multiport operations be acceptable to physicians and hospitals? With three metropolitan Denver hospitals containing nearly 1,500 beds originally committed to the demonstration, the Denver demonstration seemed able to address the issue of economies of scale.

3. Reduction of Demand/Institutional Uncertainty. The final objective was determining physician acceptance of the innovation. Physicians are the demanders of ECGs for their patients, but hospital electrocardiographers determine the ECG procedures used. Uncertainties surrounded the use of computer-assisted ECGs, both in terms of acceptance of the innovation by electrocardiographers and in the resulting changes (if any) in hospital procedures and organization.

The Hartford and the Missouri field tests had depended on heavy involvement by MSDL personnel and physicians oriented toward research and development. The Denver demonstration was designed for use by physicians and hospital administrators with no intrinsic interest in the technology per se. The Denver project was run by physicians who were clinically rather than research oriented, and who consequently would be expected to have better rapport with clinical cardiographers and other practicing physicians.

IDENTIFICATION OF TARGET AUDIENCES

HCTD, with its close ties to the medical community, clearly understood that decisions to adopt new medical technology are made by practicing physicians. In this case, electrocardiographers were viewed as the principal adopters and hence as the principal target audience. The implicit model for diffusion was that once the innovation was successfully demonstrated, cardiographers in other localities would press for (or at least not retard) adoption.

The demonstration was designed to aid the cardiographer and not to supplant or otherwise threaten him. Cardiographer productivity could be increased by the preliminary computer formatting and analysis. Since the cardiographer was to receive the same fee ($5) with or without the computer aided system, his income would not be jeopardized. Further, his status
was assured by requiring the "confirmed report" for the patient's permanent records. The argument was further made that the computer system permitted the cardiographer to concentrate on the more difficult, non-routine cases that required his skill and attention.

In addition to electrocardiographers, hospital staff and attending physicians were seen as principal target audiences. Physicians would presumably benefit by reduced turn-around time for ECG analysis, as well as from a high quality, consistent, and easily readable report. The attending physician would receive no increased economic benefit from the hospital based computer-aided ECGs, although physicians acquiring ECGs in their offices might be able to reduce their costs and consequently increase their profit from the computer-aided procedure.

Other target audiences included hospital administrators, third party payers, and the industry suppliers of computer hardware, software, and ECG acquisition equipment.* Hospital administrators had to be convinced that the computerized system would operate reliably and efficiently (e.g., no long down times) and that it would not add to hospital costs. Hopefully, the system would reduce costs and make hospital ECGs more profitable (hospitals generally make money on ECGs and other laboratory analyses). The acceptance of the system by third party payers was essential, since they reimburse costs for the vast majority of ECGs ordered in hospitals or as part of a private physician's diagnosis. Third party payers were seen as potential barriers to adoption of the innovation who had to be won over, rather than as potential supporters of adoption. In this case, the Colorado Blue Cross-Blue Shield approved a $3 surcharge for the computer-assisted ECG. The high status of the demonstration project leaders among Denver physicians was important in convincing Blue Cross (as well as the cardiographers, hospital administrators, and practicing physicians) to go along with the demonstration.

Finally, the cooperation and participation of private industry was seen by HCTD as essential to the demonstration's success. HCTD hoped and expected that the Denver demonstration would spur the hardware, software,

*Note that patients were not considered as target audiences, adopters, or users.
and acquisition equipment suppliers to improve their products and market them more aggressively in other areas. Still, the primary audience was viewed as physicians who would stimulate demand to which manufacturers would respond.

**CONSONANCE OF FEDERAL GOALS WITH THOSE OF OTHER PARTICIPANTS**

HCTD's goals seemed generally shared by the other project participants--the demonstration project leaders, hospital administrators, cardiographers, other physicians, Blue Cross, and industry. All would benefit, or at least not be harmed by the demonstration's success.

The one potential area of dissonance lay in industry's lack of confidence in HCTD's commitment to update the MSDL system. Although HCTD moved to make the MSDL software available on a variety of computers (see Section III), HCTD could give no positive assurance that periodic improvements would be made. In addition, the MSDL software was non-proprietary. Consequently, firms might be motivated to develop their own proprietary systems and promote them instead of the MSDL system. Indeed, some companies have subsequently argued that the MSDL software was dated and inadequate, and that they were forced to develop their own software despite the Denver demonstration.
III. OPERATION OF THE DEMONSTRATION

PROJECT SELECTION

Denver appears to have been selected because it had the right demographics, hospital arrangements, and other factors important for the demonstration, and because a leading Denver physician became personally aware of DHEW's interest in this area. Dr. Rikli (then Assistant Director or Programs, Division of Hospital and Medical Facilities) of the Public Health Service was instrumental in convincing Dr. Robert S. Liggett, Director of Medical Education, St. Luke's Hospital, Denver, to apply for a demonstration grant. While showing Dr. Liggett through the MSDL lab in Washington, D.C. in 1967, Dr. Rikli mentioned that he wanted to see the lab results demonstrated in a real operating environment. Dr. Liggett subsequently applied for a demonstration grant, but the original grant request was turned down by DHEW in 1967, presumably because of lack of funding.

Dr. Rikli moved out of the PHS management structure in the 1968 reorganization, but he encouraged Liggett to reapply for funds from the HCTD in the newly created National Center for Health Services Research where the MSDL had been transferred. A new application was submitted, and HCTD awarded a contract for a three-year demonstration project to St. Luke's Hospital in July 1969.

ORGANIZATION AND MANAGEMENT OF THE DEMONSTRATION

St. Luke's Hospital established a separate entity--Community Electrocardiograph Interpretative Services (CEIS)--to manage the demonstration. This was done in part to segregate the demonstration costs from general hospital operations, and in part to facilitate the use of common equipment among hospitals in the Denver region. The demonstration was intended to serve three Denver hospitals--St. Luke's, the Presbyterian Medical Center, and St. Joseph Hospital--during its first year.* Once successful, the service was to be offered to other hospitals in Denver, and then throughout the Rocky Mountain region. Both management principles and medical politics suggested that a new organization handle this planned expansion

*St. Joseph Hospital actually joined the demonstration a year later in January 1971.
of the demonstration.

Dr. Liggett recruited a physician well known in the Denver area, Dr. Robert V. Elliott, to become the CEIS Director. Dr. Liggett's own stature as a medical educator appears to have been crucial in obtaining the approval of both hospital administrators and physicians to participate in the demonstration. Dr. Elliott believes the hospital administrators were skeptical at first about the demonstration, but were willing to go along because of Dr. Liggett's persistence. Dr. Liggett himself, however, says that the administrators were "turned on" to the idea. Convincing cardiographers to participate was important in getting other physicians and hospital administrators to go along. A leading Denver cardiographer, Dr. Herbert B. Kennison, worked with Drs. Liggett and Elliott to form a "combined ECG Reader Panel" of physicians from the three demonstration hospitals.

Once the demonstration started, HCTD and CEIS assumed an arms-length relationship—neither particularly cordial nor antagonistic. Points of major controversy arose regarding program development funds and user fees (see below). The demonstration participants agree that the project never would have begun without federal funding, but they also point out that more than half of the demonstration funds eventually came from non-federal sources. On the whole, the relationship seemed to be one of mutual exploitation. HCTD used Denver as a showcase for the application of federally funded research, while CEIS used DHEW funds to establish itself as a pioneer of an important innovation.

INDUSTRY PARTICIPATION

Dr. Elliott believes that HCTD's verbal promise of $100,000 for computer program development was critical in obtaining the initial agreement of both administrators and physicians to participate in the demonstration. By January, 1970, however, when CEIS began actual computer operations, HCTD was hedging on its commitment. HCTD eventually stated that it could not provide CEIS with funds for program development—much to CEIS' dismay, since CEIS did not think the current MSDL program would be acceptable to Denver area cardiographers as an operating system. However, CEIS was then able to obtain program development funds from nongovernment sources, including CDC, Marquette Electronics, Beckman Instruments and the Colorado Heart Association. Industry contributed more than two-thirds of the $250,000 raised for program
development during the three year demonstration. Dr. Roger Simmons, formerly with the MSDL, was then brought in to become Director of Program Development at CEIS.

Dr. Simmons' salary was in fact paid by a research grant from CDC rather than from the HEW contract. However, CDC may have had little interest in the demonstration per se; rather, the company wanted to improve its software/hardware package to a point where it could be successfully marketed. CDC had the largest sunk investment in the MSDL system. CDC apparently also hoped for an endorsement or similar marketing advantage from the Denver demonstration, but none was forthcoming. "Medical ethics," according to one participant, kept CEIS from endorsing one vendor's equipment.

Both Beckman and Marquette were interested in opening up the market, since their interface and acquisition equipment could be used with any computer system. Marquette had an additional motivation for contributing to Denver's program development: Michael Cudahy, president of the firm, knew Roger Simmons and thought highly of his work. Once again, personal relationships proved important in establishing links between the demonstration project leaders and other important participants.

PARTICIPATION OF USERS

CEIS made certain from the start that there was ample opportunity for feedback from the electrocardiographers who were to overread the computer ECG interpretations. As part of program development, CEIS established a Criteria Evaluation Panel to recommend specifications and guidelines for computer interpretations of the ECG signals. This panel was composed of five leading cardiographers, but rather than simply impose their suggestions on the readers, CEIS presented the recommendations to the Combined ECG Reader Panel (consisting of 35 electrocardiographers from the participating hospitals) for their discussion and approval. This give-and-take, combined with the ever-improving accuracy of the CEIS program (which was clinically useful about 85 to 90 percent of the time) resulted in very strong professional support of the demonstration project.

Throughout the project, CEIS made no attempt to monitor overread fees. Electrocardiographers received their normal $5 fee for ECG interpretation even though the computer often allowed them to do their analysis in
half the time. In addition, CEIS stressed that the computer was simply a tool to aid in ECG analysis; it was not intended to replace the physician, nor did it require substantial changes in the physician's practice or in his professional relationships.

During 1970, Donald R. Barnes, the DHEW program manager, pushed for user fees to CEIS to recoup part of the cost of the computer-assisted ECG analysis. This was a matter of considerable controversy during the second year contract negotiations, but Mr. Barnes won out and by December, 1970, every participating hospital was charged a $3 fee per ECG read by CEIS. The $3 fee amount was set such that hospitals could still cover their costs without raising the charge to patients or third party payers. It also corresponded to an accounting firm's (Haskins and Sells) projection in 1970 that the CEIS cost would be $3 per ECG at a level of 353 ECGs per day. This was considered a reasonable target volume for the demonstration.

Dr. Elliott was quite concerned at this time that hospitals might refuse to pay, since they had originally been told no user fees would be charged during the three year demonstration. However, he and Dr. Liggett convinced the participating hospitals to accept the fees. In retrospect, Dr. Elliott agrees that the early imposition of user fees aided the adoption of the innovation. Hospitals did not have to face the prospect of large cost increases when the federal demonstration funds stopped. It was, he says, "a blessing in disguise."

User fees during the final 21 months of the demonstration amounted to $215,000, about one-third of CEIS's total operating expenses during that period. Dr. Elliott reports that user fees now account for about 90 percent of CEIS revenues.

Beyond user fees, the three participating Denver hospitals bore little financial risk. The federal contract paid for acquisition equipment and other necessary components. Moreover, the demonstration did not change hospital operations in any fundamental way. Hospitals could easily revert to the conventional ECG procedures if the demonstration were judged unsuccessful.

When the demonstration was expanded, the other participating hospitals purchased the ECG acquisition carts and telephone interface units with their own funds. Hospitals outside Denver also paid a telephone toll surcharge of $1 per ECG.

In 1971, a year before the demonstration contract ended, St. Luke's
and HCTD agreed that CEIS would be spun off as an independent, non-profit corporation. Consequently, even though CEIS was not yet operating at a breakeven level, its continuance beyond the demonstration period would not provide a financial burden to St. Luke's. Support from a Denver foundation (The Boettcher Foundation) aided CEIS during the transition.

PLANS FOR DIFFUSION

As the demonstration proved successful in the three Denver hospitals, CEIS planned to expand its service to other hospitals in the metropolitan area and eventually to hospitals throughout the Rocky Mountain region. Beyond this expansion of the demonstration, CEIS and HCTD had no explicit plans for diffusion of the innovation. HCTD believed that the companies directly involved in the Denver demonstration (CDC, Marquette, and Beckman) would have strong incentives to market similar systems elsewhere. Moreover, results from the demonstration would be disseminated widely to industry through the Data Pool group.

HCTD regularly supported conferences on computer applications in medicine for researchers, physicians, and equipment suppliers, at which the Denver results could be presented and discussed. HCTD also encouraged publication of reports, monographs, journal articles, and books as means of disseminating research results.*

Besides the Denver demonstration, HCTD attempted to stimulate diffusion through a "software certification" program. As described in Section II, HCTD encouraged CDC and the Data Pool group to translate the MSDL program from machine language to a higher level language--FORTRAN--that could be used on a large number of computers. As each computer manufacturer, service vendor, or user adopted the MSDL program, HCTD offered to certify that the program would run satisfactorily (in terms of accuracy and interpretive criteria) on its system. Certification was seen by HCTD as a way to reduce industry's risk and as a significant aid to marketing a computer-assisted ECG system. Each of the organizations listed in Table 1 received system certification from HCTD. Table 2 lists all of the major participants in the system development effort from 1969 through 1974.

*The progress of the MSDL development program and field tests had been reported at conferences and in journal articles. A state-of-the-art volume (Cesar A. Caceres and Leonard S. Dreifus, editors, Clinical Electrocardiography and Computers, Academic Press, New York, 1970) was published at about the time CEIS began the Denver demonstration.
Table 1
ECG DATA POOL
ECG ANALYSIS PROGRAMS ACHIEVING CERTIFICATION STATUS

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<td>SIGNA 5/6/7 FORTRAN IV-H</td>
<td>Xerox Data Systems</td>
<td>1/9/70</td>
</tr>
<tr>
<td>CDC 160-A</td>
<td>Biomedical Computer Services</td>
<td>6/3/70</td>
</tr>
<tr>
<td>IBM 360 (Model 40 and Larger)</td>
<td>Beckman Instruments</td>
<td>8/11/70</td>
</tr>
<tr>
<td>SIGNA 2/3 FORTRAN IV</td>
<td>Xerox Data Systems</td>
<td>10/1/70</td>
</tr>
<tr>
<td>DEC PDP 8-(Pseudo Assembly Language)</td>
<td>Berkeley Scientific Labs</td>
<td>11/3/70</td>
</tr>
<tr>
<td>DEC PDP 9</td>
<td>Medac</td>
<td>4/14/71</td>
</tr>
<tr>
<td>DEC PDP 8</td>
<td>Searle Medidata</td>
<td>5/14/71</td>
</tr>
<tr>
<td>IBM 360/40</td>
<td>Tennessee Valley Authority</td>
<td>8/15/71</td>
</tr>
<tr>
<td>DEC PDP 8</td>
<td>Phone-A-Gram Systems</td>
<td>10/5/71</td>
</tr>
<tr>
<td>IBM 360/50 (DOS)</td>
<td>Touro Infirmary</td>
<td>11/1/71</td>
</tr>
<tr>
<td>IBM 360/30 (DOS)</td>
<td>Space Age Computer Systems</td>
<td>4/5/72</td>
</tr>
<tr>
<td>NOVA 1200 (Modified)</td>
<td>Cortex 4</td>
<td>11/8/72</td>
</tr>
<tr>
<td>DEC PDP 15</td>
<td>Digital Equipment Corporation</td>
<td>11/30/72</td>
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<tr>
<td>DEC PDP 11</td>
<td>Searle Medidata</td>
<td>12/7/72</td>
</tr>
<tr>
<td>CDC 5400</td>
<td>General Dynamics</td>
<td>6/29/73</td>
</tr>
<tr>
<td>UNIVAC 1100</td>
<td>SPERRY UNIVAC</td>
<td>4/19/74</td>
</tr>
<tr>
<td>CDC 1700</td>
<td>Baltimore USPHS Hospital</td>
<td>9/15/74</td>
</tr>
<tr>
<td>IBM 360/50</td>
<td>National Institutes of Health</td>
<td>4/28/75</td>
</tr>
<tr>
<td>IBM 360/50</td>
<td>Central Intelligence Agency</td>
<td>5/20/75</td>
</tr>
</tbody>
</table>

Source: DHLEW Program Manager, private communication.
## Table 2

**PARTICIPANTS IN COMPUTER ASSISTED ECG SYSTEM DEVELOPMENT, 1969-1974**

### GOVERNMENT AGENCIES:
- Baltimore PHS Hospital
- Central Intelligence Agency
- Federal Aviation Administration
- Medical Systems Development Laboratory
- National Center for Health Services Research
- National Institutes of Health
- Tennessee Valley Authority
- Walter Reed Army Hospital

### UNIVERSITIES & HOSPITALS:
- Bowman Gray School of Medicine
- Cancer Prevention Center of Chicago
- Dartmouth University
- George Washington University
- Harbor General Hospital
- Hartford Hospital
- Queens University
- Reingold ECG Center
- Touro Infirmary
- UCLA Medical Center

### SERVICE VENDORS:
- American Health Corporation
- Biomedical Computer Services
- Boeing Company
- Clinical Systems Associates
- Community ECG Interpretative Service
- Medac
- Meditek
- Phone-a-gram
- Space Age Computers
- Synergetics
- Telemed
- Talservice
- Ultramation

### MANUFACTURERS:
- Beckman Instruments
- Berkeley Scientific Laboratories
- Computer Instruments Corporation
- Control Data Corporation
- Cortex IV
- Data General Corporation
- Digital Equipment Corporation
- Health Technology Labs
- Hewlett Packard
- Hoffman-LaRoche
- Honeywell
- International Business Machines
- Marquette Electronics
- McDonnell Douglas Automation
- Minnesota Mining and Manufacturing
- Searle Medidata
- Sperry Univac
- Xerox Corporation

**Source:** DHEW Program Manager, private communication.
IV. DEMONSTRATION OUTCOMES

EXPANSION AND CONTINUATION OF THE DEMONSTRATION

By August 1972, when federal funding for the demonstration ceased, CEIS was serving 20 hospitals containing 2,387 patient beds in four states. These participating hospitals are listed in Table 3. CEIS has continued to serve these hospitals since the federal funding ended. Other community hospitals in Colorado, New Mexico, and Wyoming have adopted the service since the demonstration, purchasing their own ECG acquisition equipment and interface devices. CEIS now serves 45 hospitals in 5 states.

The computer ECG analysis for all participants is performed at the CEIS facility in Denver. However, the electrocardiographer overread function for the eight participating Kansas hospitals is performed at the Central Kansas Medical Center in Great Bend, Kansas. The ECG tracing is transmitted to the Great Bend center, along with the CEIS computer interpretation, for electrocardiographer interpretation and return of the Confirmed Report to the Kansas satellite hospitals. The Presbyterian Medical Center and St. Joseph Hospital in Denver have also set up their own computer satellite facilities so that the electrocardiographer interpretation can be done in-house. Thus, the CEIS concept has evolved from a single central facility for computer analysis and interpretation to several centers for electrocardiographer interpretation, each connected to the central computer.

UNCERTAINTY REDUCTION

1. Technological Uncertainty. The demonstration significantly upgraded the quality and accuracy of MSDL interpretative software. No major hardware changes were made, but the software was changed considerably during the demonstration. This has improved the reliability of the computer interpretation to a point where less than 15 percent of the computer generated Unconfirmed Reports were changed substantially by the electrocardiographer.

ECG acquisition cart manufacturers (principally Marquette Electronics and Beckman Instruments) reportedly made several improvements in their equipment during the demonstration.
<table>
<thead>
<tr>
<th>Hospital Name and Location</th>
<th>Date CEIS Service Was Initiated</th>
<th>No. of Beds</th>
<th>Distance from CEIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presbyterian Medical Center, Denver, Colorado</td>
<td>1 Jun. 1970</td>
<td>438</td>
<td>1 mi.</td>
</tr>
<tr>
<td>Alamosa Community Hospital, Alamosa, Colorado</td>
<td>1 Jun. 1970</td>
<td>96</td>
<td>250 mi.</td>
</tr>
<tr>
<td>Brighton Community Hospital, Brighton, Colorado</td>
<td>17 Nov. 1970</td>
<td>65</td>
<td>30 mi.</td>
</tr>
<tr>
<td>St. Joseph Hospital, Denver, Colorado</td>
<td>11 Jan. 1971</td>
<td>554</td>
<td>1 mi.</td>
</tr>
<tr>
<td>Perkins County Community Hospital, Grant, Nebraska</td>
<td>10 Oct. 1971</td>
<td>78</td>
<td>250 mi.</td>
</tr>
<tr>
<td>Johnson County Memorial Hospital, Buffalo, Wyoming</td>
<td>13 Dec. 1971</td>
<td>48</td>
<td>300 mi.</td>
</tr>
<tr>
<td>Vail Valley Medical Center, Vail, Colorado</td>
<td>27 Mar. 1972</td>
<td>15</td>
<td>140 mi.</td>
</tr>
<tr>
<td>Chase County Community Hospital, Imperial, Nebraska</td>
<td>30 Apr. 1972</td>
<td>26</td>
<td>250 mi.</td>
</tr>
<tr>
<td>Memorial Hospital of Sheridan County, Sheridan, Wyoming</td>
<td>30 Jun. 1972</td>
<td>89</td>
<td>350 mi.</td>
</tr>
<tr>
<td>Central Kansas Medical Center, Great Bend, Kansas (includes eight satellite rural hospitals as follows)</td>
<td>30 June. 1972</td>
<td>190</td>
<td>450 mi.</td>
</tr>
<tr>
<td>Edwards County Hospital, Kingsley, Kansas</td>
<td></td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Ellinwood District Hospital, Ellinwood, Kansas</td>
<td></td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Grisell Memorial Hospital, Ramsom, Kansas</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Hoisington Lutheran Hospital, Hoisington, Kansas</td>
<td></td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Osborne County Memorial Hospital, Osborne, Kansas</td>
<td></td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Rush County Memorial Hospital, LaCrosse, Kansas</td>
<td></td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>St. John District Hospital, St. John, Kansas</td>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>St. Joseph Memorial Hospital, Larned, Kansas</td>
<td></td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>Melissa Memorial Hospital, Holyoke, Colorado</td>
<td>18 Jul. 1972</td>
<td>24</td>
<td>210 mi.</td>
</tr>
</tbody>
</table>

2. Cost Uncertainty. The economic data from this demonstration appears to have reduced the cost uncertainty regarding the use of computer-assisted ECGs.* CEIS's annual operating costs during 1971-72 were $308,000. At least 90 percent of this total appears to be the fixed cost of operating a 24-hour-a-day dedicated computer center with a highly professional staff. Assuming that all costs were fixed costs, the cost per ECG processed would range from $6.75 at the CEIS operating level during that period of 125 ECGs per day, to $0.58 per ECG at the system's full capacity of 1,440 ECGs per day. When the demonstration ended, the CEIS operating volume of 165 ECGs per day represented a cost of slightly more than $5 per ECG. Breakeven operation at the $3 fee level would require about 280 ECGs per day.

Nearly half the CEIS cost was due to professional staff and R&D costs related to the demonstration. CEIS calculated that a service bureau to process ECGs could operate at an annual cost of only $130,000 to $175,000, corresponding to breakeven operations with a volume of 120 to 160 ECGs per day at the $3 fee level. Since hospitals typically order one ECG per day for each 10 to 12 beds, a service bureau could break even by serving hospitals with a total of 1,200 to 2,000 beds, or any combination of hospitals, clinics, and physicians that would generate 120 to 160 ECG's per day.

Interestingly, the innovation as demonstrated in Denver did not reduce total costs of the ECG procedure, nor were the demonstrators (or HCTD) particularly concerned about this. The computerized procedure reduced hospital acquisition costs by no more than $1 per ECG,** but hospital costs were increased by the $3 CEIS fee (plus telephone surcharge outside of Denver). Electrocardiographer productivity was increased, perhaps as much as 50 percent (see below), but electrocardiographers captured the full benefit since their $5 fee remained unchanged. Costs to patients and third party payers remained unchanged. These economic costs and benefits appear roughly to

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*A detailed cost analysis of the CEIS system is contained in Elliott, op. cit., pp. 43-68.

**According to CEIS, hospitals generating 50 ECGs per day could hire one less technician (at $9,500 per year, including fringe), save 1/4 to 1/2 of a secretary's time ($2,000 to $4,000 per year), and eliminate space requirements for ECG clipping and pasting by adopting the innovation. Savings for smaller hospitals would be less, since technicians typically perform a variety of other procedures that would not be affected by the EKG innovation.
cancel each other at the CEIS level of operation. At a larger scale (such as commercial firms might undertake) the computer processing costs might fall to a point that the total cost of the procedure would be reduced.

3. Demand Uncertainty. The system demonstrated in Denver appears to have generated strong support from electrocardiographers, hospital technicians, hospital administrators and third party payers. As described above, the demonstration was designed to assist electrocardiographers and not to threaten them economically or professionally. According to the CEIS Director's report of the demonstration,

...the electrocardiographer's acceptance of computer-assisted electrocardiography depends on how well it helps him arrive at his diagnostic decisions and how much time it saves him in performing this service. The computer interpretation now grossly agrees with the electrocardiographer 85 to 90 percent of the time, requiring no amendment or only a minor amendment by him. And approximately half of his time has been saved on the average compared to the conventional method of interpreting the ECG.*

Hospital administrator and physician acceptance of the demonstration is indicated by the fact that all 20 hospitals that had joined CEIS during the demonstration period have continued to use the service. Three hospitals have each invested $14,000 to purchase a satellite computer facility tied to the CEIS computer. Finally, the Colorado Blue Cross and Blue Shield continue to include the $3.00 CEIS computer processing fee and telephone fees as reimbursable expenses.

4. Institutional Uncertainty. There were three sources of institutional uncertainty at the outset of the demonstration. First, it was not certain whether the system would be accepted by the electrocardiographers; it was reasonably assumed that physicians would be receptive to the idea inasmuch as it promised faster turn-around times and better patient care, but dissatisfaction on the part of electrocardiographers would have been

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*Ibid., p. 81.*
sufficient to prevent adoption of the innovation. As indicated above, the demonstration showed conclusively that electrocardiographers would accept the system so long as it represented no economic or status threat to them.

Second, it was uncertain whether the system would be accepted by hospital administrators given the cost uncertainties and possible institutional changes. Indeed, according to Dr. Elliot, even though the project was supposed to be wholly federally subsidized, it was only Dr. Liggett's prestige that persuaded St. Luke's Hospital to try the system on an experimental basis. The demonstration showed that the cost problem was manageable and that hospital staff would accept the new procedure. As a result, uncertainty about institutional support of the innovation by hospital administrators was eliminated.

Third, as the economics of the innovation became clearer, it was realized that third-party refusal to pay a portion of the costs could be a major barrier to permanent adoption. The Denver experience showed that third-party payers could be persuaded to regard the costs of the innovation as a legitimate reimbursable item.

5. Externality Uncertainty. Externalities were not explicitly addressed by the demonstration.

DIFFUSION

The technology for computer-assisted ECG analysis has diffused rapidly since 1969. DHEW estimates that nearly 10 percent of all ECGs processed in the United States, or more than 2 million ECGs per year, involve some computer interpretation. However, the role of the Denver demonstration in stimulating this diffusion is far less clear.

The emerging market for computer-assisted ECG equipment and services remains highly competitive. Several for-profit firms now market a computerized ECG analysis service to physicians' offices and hospitals nationwide, while a number of other firms offer such services within a metropolitan area. One of the national firms, Phone-a-Gram Systems, claims to have picked up a great deal from the Denver demonstration and prior Missouri field test, largely through the process of people transfer.
Dr. Russell Sandburg, who developed the criteria for Phone-a-Gram's ECG interpretations, originally worked on the Missouri project. The Denver group had worked closely with the Missouri group in developing criteria for computer-assisted ECG interpretation, and Sandburg states that the criteria now used by Phone-a-Gram are practically identical to those developed by Dr. Simmons at CEIS.

The Phone-a-Gram system, however, is quite different from that used in the Denver demonstration. Phone-a-Gram sells its service directly to physicians in private practice. The company has developed a low-cost communications interface device that transmits signals from the physician's own ECG acquisition machine to the Phone-a-Gram computer in San Francisco. A human operator in the Phone-a-Gram office adds necessary information about the patient to the ECG signals for computer processing. A Phone-a-Gram electrocardiographer then interprets the computer ECG analysis and sends a signed report to the physician. The electrocardiographer also is available for phone discussion with the physician, if necessary.

A second national firm, Telemed, claims to have been influenced little, if at all, by the Denver demonstration. The company was the first customer for the Xerox Sigma 5 program, which was certified by DHEW in January 1970 (before CEIS began operations). Telemed used this slightly modified MSDL program from 1970 until 1972, when it switched to software it had developed with backing from Pfiser Pharmaceutical Company. The Telemed program handled multiport ECG inputs quickly and efficiently and contained many desirable quality control features. Mr. Donald Barnes of HCTD has described Telemed's ECG processing services as the best currently available. According to company officials, Telemed processes more than 1,000,000 ECGs annually in "over 700 hospitals, medical centers, screening facilities, government installations, medical clinics, industrial facilities, and armed forces installations, which are distributed nationwide."*

*Letter from Dr. Louis C. Lax, November 18, 1974.
Telemed claims that the Denver demonstration did not aid in diffusion of the technology; in fact, it may have been counterproductive, in that it demonstrated an inferior software system that prejudiced some physicians against computer-assisted ECG analysis. The company's medical director makes this point strongly:

...Telemed did not learn very much from the St. Luke's demonstration and did not change even one iota of its operating procedures in response to what was learned at Denver. Rather, we were surprised to learn of the expense in taxpayers' monies which had been incurred to demonstrate the feasibility of something which we considered to be already a reality in terms of our very existence and operation prior to the advent of the Denver demonstration.*

However, DHEW officials believe that Telemed and other companies clearly learned a good deal about the market for computer-assisted ECG analysis from the Denver demonstration. Moreover, they profited from HCTD's software development at Hartford, the multi-port operating experience at Missouri, and the physician acceptance demonstrated in Denver in designing their own system and software. Telemed's basic decision to market a complete ECG analysis service, for example, was certainly reinforced by the Denver experience. Finally, HCTD argues that Telemed and other service suppliers benefited indirectly from the changes in ECG acquisition equipment introduced by Marquette and Beckman as a result of the Denver demonstration.

Of the three principal equipment manufacturers who participated in the Denver demonstration, Marquette Electronics is the most enthusiastic about the results. The company's president reports that the demonstration improved the state of the art and stimulated adoption in other places. Marquette, in particular, made some design changes in its equipment as a result of the demonstration, and has sold several hundred ECG acquisition carts since the demonstration.

Beckman's primary interest at Denver was learning about software. Beckman had received DHEW certification for an IBM 360 program in 1970,

and tried to market it after the Denver demonstration. They quickly found, however, that (1) they would have to train physicians to read the computer printout, and (2) electrocardiographers would not willingly lower their fees in order to allow hospitals to purchase the equipment. If anything, then, Beckman appears not to have learned from the Denver experience; by trying to market the equipment alone rather than a complete interpretative service, the company quickly ran into major difficulties. Beckman has since left the computer-assisted ECG market, claiming that in a hospital setting the computer competes directly with the physician.* Rather, Beckman is pursuing the ECG market in mass screening operations.

CDC has ceased active marketing of a dedicated computer for ECG analysis. The CDC pioneer system was no longer competitive with new offerings, particularly minicomputer-based systems developed by the ECG cart manufacturers and minicomputer manufacturers such as Hewlett-Packard.** CDC still offers a computerized ECG option in its clinical computer systems, as one of a wide array of medical tests and procedures, and has announced a new minicomputer system for ECG analysis.

IBM and Xerox presently sell their own proprietary ECG software packages. Neither company attributes changes in their equipment, software, or services to the Denver demonstration.

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*CEIS, of course, claims the opposite result.

**Dr. Caceres, the former MSDL Director, is now a consultant to Hewlett-Packard, and has helped them develop a computer-assisted ECG analysis system.
V. CONCLUSIONS

The Denver demonstration of computer-assisted electrocardiogram analysis definitely was an application success, as evidenced by the adoption of the innovation after the demonstration ended. By reducing uncertainties, the demonstration also aided private sector diffusion of this technology, although perhaps only marginally.

The demonstration probably speeded diffusion by no more than 12 to 18 months, since industry was independently pushing the technology. The economic benefit from accelerated diffusion has been captured completely by physicians and commercial firms; the benefit to patients presumably comes from faster and more accurate diagnosis, rather than from decreased costs.

The following factors appear to have been important to the success of the demonstration:

Demonstration Funders
1. The federal funding agency (and its predecessor, MSDL) had previously developed ties with the private sector manufacturers.
2. The funding agency was strongly committed to achieving an application success.
3. The demonstration did not appear to threaten other projects of the funding agency.
4. Private firms contributed to the costs of the demonstration.

Demonstration Operators
1. The demonstration project leaders were professionally acquainted with the target audience of adopters.
2. The demonstration agency (St. Luke's hospital) and project leaders had high status among the potential adopters.
3. The operating agency was relatively autonomous in pursuing the demonstration (in terms of obvious political or other nonmarket constraints).
Target Audience

1. The target audience of adopters (hospital electrocardiographers) was clearly identified from the beginning.
2. The demonstration held promise of economic benefits to the adopters and did not threaten their status.
3. Adoption required relatively small change by the adopters (electrocardiographers and hospitals) relative to the perceived benefits.
4. The change was easily reversible if the demonstration had failed.

Demonstration Environment

1. The demonstration leaders sought to involve other groups that could affect the demonstration's outcome, such as hospital administrators and third-party payers.
2. A market-like environment was established early in the demonstration by charging hospitals for the service, thus easing the burden of adoption when federal funding ended.
3. The Denver demonstration came after two less successful field tests and profited from their experience.
4. The market for computer-assisted ECG equipment and services was perceived by the private sector as an expanding one.
5. The market was highly competitive, with companies in several different fields (mainframe computer, data acquisition, systems and service suppliers) striving to obtain market shares.


TELEPROCESSING OF MEDICAID CLAIMS

by

C. Johnston Conover and Walter Baer
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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>CISG</td>
<td>Clinical Information Systems Group</td>
</tr>
<tr>
<td>DHEW</td>
<td>Department of Health, Education and Welfare</td>
</tr>
<tr>
<td>HCTD</td>
<td>Health Care Technology Division</td>
</tr>
<tr>
<td>SSA</td>
<td>Social Security Administration</td>
</tr>
<tr>
<td>BC-BSA</td>
<td>Blue Cross-Blue Shield of Alabama</td>
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</table>
I. INTRODUCTION

This Report describes a demonstration in Alabama from 1971 through 1974 of a teleprocessing system for Medicaid billing of physician's services. The demonstration was sponsored by the Health Care Technology Division (HCTD), a part of the National Center for Health Services Research, of the U.S. Department of Health, Education, and Welfare (DHEW). It was designed and operated by the Clinical Information Systems Group (CISG) of the University of Alabama in Birmingham, in cooperation with the Medical Services Administration of the State of Alabama, the Equitable Life Assurance Society, and the Blue Cross-Blue Shield of Alabama (BC-BSA).

The practice of medicine involves keeping medical records and billing patients. At a time when high medical costs are of increasing concern, measures designed to reduce administrative costs and to save the physician's time appear very attractive. A 1972 study estimated that the average cost to the physician of preparing an insurance claim ranged between $1.25 and $2.50.\(^1\) Claim processing by the insurance carrier involves comparable costs. In 1973, BC-BSA, the local Medicare and Medicaid carrier in Alabama, reported an average cost of $2.35 to process a claim.\(^2\) In sum, administrative costs to process each Medicaid claim in Alabama probably ran between $3.60 and $4.85. Yet in 1973 the average reimbursement for ambulatory service claims in Alabama was only $10.00.\(^3\)

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\(^1\) Joel Krinsky and Phillip Hampton, Community Profile Data Center, Technical Paper Series No. 2, Contract HSM-110-70-43, Community Health Service, Health Services and Mental Health Administration, Department of Health, Education, and Welfare, 1972.


Both physicians and officials of government programs such as Medicaid that reimburse physicians for medical services have incentives to reduce the costs of paperwork. It is less clear that the carriers of government programs have similar incentives, since they typically operate under cost reimbursement contracts. However, cost-cutting incentives may apply to carriers that are selected on a cost competitive basis. In Alabama, carriers compete annually on a cost-per-claim basis to carry Medicaid services.

While practically all Medicaid carriers used computers to store claim information in 1971, the data generally were processed manually at least twice before reaching the machine. That is, a nurse or office assistant (or the physician himself) manually prepared a claim at the physician's office, usually duplicating information from the physician's own record system. The claim was then manually processed again by the Medicaid carrier to check for errors, appropriateness of fees charged, eligibility of the patient, and other routine information. Only after these steps were performed was the claim logged into the computer.

Costs escalate when claims must be returned to the physician for additional information. The Social Security Administration estimates, for example, that 15 percent of all Part B Medicare claims (physician's services) are rejected because of an invalid patient identification number.\(^1\) The claim then must be returned to the physician or the missing information retrieved via telephone by the carrier's clerical staff.

The Medicaid billing system demonstrated in Alabama used a push-button telephone equipped with a card-reader as an on-line input device to a central computer. Rather than filling out a claim form manually, the doctor's assistant would dial the computer and key in the information using a set of standard codes. To save time, special cards were prepared to enter four kinds of information: a) the doctor's name and Medicaid provider number; b) the patient's name and identification

\(^1\)Report on Simplified Physician Billing Project, Division of Systems, Social Security Administration, April 1973; reported in Mesel and Wirtschafter, on. cit., p. 3.
number; c) routine diagnoses (50 cards could handle over 2/3 of all diagnoses specified); and d) common medical treatments (50 cards represented 94 percent of all treatments for which Medicaid reimbursement was requested).

A series of recorded messages at the computer told the nurse or assistant what information was to be entered at each stage. Whenever the information entered was incorrect or incomplete, recorded messages also would tell the nurse or assistant what additional data were required. For users with experience with the system, the voice instructions could be replaced by a set of tones that told the user to enter the next line of information or to correct the current entry. As the data were entered, the computer program would check for relevant screening information. For example, it would check whether the physician number was valid, whether the patient was eligible for Medicaid, whether the date was correct, whether the point of service was appropriate (e.g., hospital vs. doctor's office), whether a diagnosis or procedure was valid, and whether the charges were within the allowable range. The screening did not indicate whether a diagnosis was medically correct or whether a given procedure was appropriate, but simply whether a number had been entered corresponding to a standard diagnosis or procedure.

The potential benefits of the innovation included:

- reducing claim input time at the physician's office
- providing immediate feedback on missing or incomplete information, thus reducing the number of claims submitted with errors
- reducing claim processing time at the carrier end
- reducing claim processing cost for physicians and carriers

TECHNOLOGICAL BACKGROUND

Using pushbutton telephones with voice answerback for data entry is by no means new; such systems have been used extensively in industry for
some time -- notably for credit card checking and inventory control. The use of the telephone for medical applications was studied by Arnold Pratt at the National Institute of Health (NIH) during the mid 1960s, and in 1969 Allen and Otten reported on the experimental use of the telephone as a computer input-output terminal.\textsuperscript{1} Thus the technology was readily available; the application to on-line Medicaid billing from physician's offices was the innovation demonstrated by CIGS in Alabama in 1971.

However, insurance carriers were rapidly developing their own automated billing systems during this period. In 1967 the Social Security Administration (SSA) funded development of a model automated system to handle Medicare claims processing. Alabama was one of the first states to adopt the initial version of the Model Medicare system in 1970, and a later, on-line version was adopted in November, 1972 to handle Medicaid claims as well. In the on-line Model Medicare system, claims are sent to the carrier by mail and screened manually for accuracy of information. Then they are entered into the computer system and displayed on a CRT screen for checking. The computer program checks patient eligibility and other factors and indicates incorrect or incomplete information on the screen. In some cases, changes can be made immediately by the clerk at the terminal; in other instances, the physician must be called for clarification; in still other cases, the claim must be returned for corrections. The on-line, Model Medicare system performs these checks quite similarly to the teleprocessing system demonstrated by CIGS; the principal difference is that the CIGS system maintains contact between the physician's office and the computer while the claim information is entered.

II. PLANNING FOR THE DEMONSTRATION PROJECT

ORIGINATION OF THE DEMONSTRATION

The demonstration idea came directly from a federal agency official's interest in exploiting teleprocessing technology for medical applications. In 1970 Dr. William Yamamoto, a physiologist spending a six month sabbatical at the DHEW Health Care Technology Division, became interested in the potential new uses of the telephone in medicine. The HCTD had been created in 1968 for the purpose of diffusing medical research and technological developments—particularly those flowing from federal R&D programs at NIH. Dr. Yamamoto persuaded Dr. Bruce Waxman, the HCTD Director, that telephone technology was ripe for medical innovations. He argued that a federally funded demonstration of a specific application in a real-life setting would stimulate diffusion to other communities, as well as spur additional, still unforeseen innovations.

Dr. Waxman and other HCTD officials were receptive to Dr. Yamamoto’s ideas. New telephone applications fit HCTD's mandate to exploit technologies that would increase access, reduce costs, and improve medical care. A number of projects involving the use of telephone technology were discussed and planned; among these were a system to provide emergency medical information to patients, and a system to give drug information to physicians.

PROJECT SELECTION

Dr. Yamamoto then began to seek suitable sites for telephone and teleprocessing demonstrations. The name of Dr. Emmanuel Mesel was brought to his attention as a physician who was involved in computing for the Alabama Medicaid program and who also had good ties with senior AMA officials in the state.

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Dr. Mesel had joined the University of Alabama Medical School faculty in 1969 and had established a Clinical Information Systems Group (CISG) at the University to perform contract research on medical applications of computers. CISG received a contract from the Medical Services Administration of Alabama in 1970 to work on coding of patient diagnoses and procedures for Medicaid billing. Dr. Mesel believed that this research would also have clinical applications, since data routinely collected for insurance claim records could be used for patient monitoring as well.

In 1970 Dr. Yamamoto flew to Alabama to discuss the possibilities of a telephone technology demonstration project. Dr. Mesel proposed that the technology be used for physician billing, because that was his principal interest at the time.

Dr. Mesel sent in a proposal for a demonstration in January, 1971. The project was rapidly approved by HCTD, and funding began on June 29, 1971.

**FEDERAL GOALS FOR THE DEMONSTRATION**

The HCTD's general mandate was to "support technological innovations which promised the greatest improvement to our health care delivery system,"¹ through development projects, demonstrations, and information dissemination. Diffusion of the innovation was HCTD's principal goal from the Alabama demonstration, as noted in its project report:

A successful demonstration would serve as a model for other communities that recognize the need for monitoring health care transactions as a first step towards rational management of their health system resources.²

However, no specific plans for diffusion were written into the demonstration contract.

²Mesel and Wirtschaffer, op. cit., p. 2.
The demonstration had other, specific goals in support of its diffusion objective:

1. **Reduction of Technological Uncertainty.** At the time of funding, there was relatively little uncertainty about the performance of the hardware components of the system. However, it was still not known whether the software could be written to handle all the information required for Medicaid claims without becoming too complex for physicians' assistants to use. The problems of coding patient demographics, diagnoses, and medical procedures were seen as especially difficult hurdles to overcome in software development.

2. **Reduction of Economic Uncertainty.** As the project report states,

   The objective of this project was to demonstrate that it is possible to reduce the costs of submitting claims from the physician's office as well as to reduce the costs of data preparation in the carrier's system.¹

By 1973, developments in voice-answercall technology (unrelated to the demonstration) made these cost-cutting prospects quite real, so that the demonstration in its third year emphasized cost reductions rather than technical system improvements.

3. **Demonstration of Acceptability to Physicians.** HCTD expected that physicians would adopt the innovation if it were shown to work and to save them money. This element of demand uncertainty reduction was an explicit goal of the demonstration.

4. **Expectation of Technological Innovations.** A key selling point used by Dr. Yamamoto was that the demonstration would spawn other related innovations in the application of telephone technology to medicine.

We note in hindsight that the demonstration did not seek to address the institutional issues surrounding the Medicaid carrier's possible lack of incentives for adopting a system competitive with the SSA developed system.

¹Ibid.
IDENTIFICATION OF TARGET AUDIENCES

Physicians

The first target audience of the Alabama demonstration was physicians and their assistants. HCTD initially hoped that CISG's university base, and Dr. Mesel's prior links with the state Medicaid program would help gain physician involvement in the project. As it turned out, these relationships had no influence whatsoever: few doctors knew of CISG or Dr. Mesel, and most participated because they recognized the possible cost savings the system offered. Dr. Mesel rank-ordered all physicians handling Alabama Medicaid claims by their volume of services and then contacted each one by telephone. Only three of the 40 largest Medicaid providers refused to participate in the demonstration at this initial contact stage. Roughly 20 percent of all physicians contacted had insurance billing clerks who did not want to work with a computerized system, and these physicians were excluded from the project. Once the project began, a small number of physicians dropped out because they did not feel comfortable with the system, and a few others dropped out because of poor telephone service in outlying areas. But for the most part, there were no major difficulties in identifying, contacting, enrolling, and retaining interested physicians for the project.

Medicaid Carriers

A major problem developed in dealing with the second target audience, however -- the Medicaid carrier. At the time that funding for the CISG project was under consideration, the Social Security Administration was well along in its own development of a computer processing system for Medicare claims. HCTD apparently briefly considered the possibility that the CISG system would be competitive with SSA's development, but decided to proceed anyway. They argued that the issue of whether SSA carriers would use the CISG system was one which could not be tackled until technological and economic feasibility had first been demonstrated.
CONSONANCE OF FEDERAL GOALS WITH THOSE OF OTHER PARTICIPANTS

The goals of HCTD appear to have differed significantly from those of the other participants. Dr. Mesel and CISG had a contract to perform, and they performed it. That contract said nothing about diffusion, although diffusion was apparently one of HCTD's expectations. HCTD believed that diffusion would follow from the application success of the Alabama demonstration and from the computer software and documentation it provided that would be available to potential adopters.

CISG's primary interest was in getting a patient database on line that could be used to provide clinical information to physicians. CISG was willing to concentrate on the billing aspects of the system in order to obtain the on-line patient database—although as it turned out, CISG never had time or funds to accomplish this during the contract period. Still, that CISG goal (which was not shared by HCTD) did not interfere in any way with the demonstration of a viable, on-line billing system.

The key source of goal divergence involved the incentives of the Medicaid carrier. HCTD assumed that if the technology were successfully demonstrated, the Alabama carrier would use it. Agency officials recognized that competition could arise between the SSA and CISG systems, but they believed that the feasibility of the CISG system should be shown before dealing with any potential conflict between systems.
III. OPERATION OF THE DEMONSTRATION

ORGANIZATION AND MANAGEMENT

CISG assumed full responsibility for managing the demonstration project. Off-the-shelf Touch-Tone⁴ Carddialer telephones were placed in physicians' offices by South Central Bell Telephone Company. The system used the University of Alabama's central IBM computer, along with IBM voice answerback equipment. IBM also developed the software packages for line control and hard-copy claims production under contract from CISG. The entire set of programs was designed in such a way that the system could run on virtually any of IBM's computers, from small, stand-alone 360/22 or 360/30 models to the larger 360/50 and 360/60 machines.

CISG and HCTD maintained relations strictly on a business basis. The HCTD program monitors were kept informed of the demonstration's progress but did not involve themselves in day-to-day operations. Both parties agree that the project was well managed according to the terms of the contract.

Now that the demonstration is over, both Dr. Mesel and Dr. Wirtschafter, his assistant, have expressed disappointment that there was not more coordination between HCTD and SSA prior to the demonstration. Such coordination might have given BC-BSA and other Medicaid carriers greater incentive to adopt the technology demonstrated by CISG.

There was some HCTD-SSA contact early in the contract period, but Dr. Mesel and Donald Barnes (the HEW project manager) did not visit SSA to make a formal presentation of the system until mid-1973, after the system had run for two years and HCTD was convinced of its acceptance by physician users. By this time Blue Cross-Blue Shield of Alabama was using the SSA Model Medicare System for Medicaid claims processing. Dr. Mesel had already been rebuffed by BC-BSA in his attempts to persuade them to use his magnetic tapes for direct claim entry (see below). But the Social Security Administration officials took a hands-off attitude. They said that if the carrier wanted to use the CISG system, it would be acceptable to SSA. However, SSA could not require Blue Cross to adopt the system if it had objections to doing so.¹ In

¹ Letter from James J. Fraher, Social Security Administration, October 23, 1975, "The Social Security Administration's part in the function of
retrospect, the HEW project manager believes that more coordination with SSA at the outset might have led to greater cooperation between CISG and BC-BSA.

INDUSTRY PARTICIPATION

Although both the Bell System and IBM were cooperative in developing the system, neither offered (nor was either asked) to cost share or otherwise subsidize development in any way. IBM performed its contract for software development quite satisfactorily, and there were no problems with Bell equipment. Both companies cited the demonstration in promotional brochures, but neither made any attempts to market similar systems.

PARTICIPATION OF USERS

Physicians

The primary motivation for physician use of the system was potential cost savings. The initial service was completely free to them, and the project paid for the training of their insurance clerks. Consequently, physicians saw very little risk in participating, and possibly much to gain.

Unlike the HCTD demonstration of computer assisted electrocardiogram analysis, physicians were not involved in designing the CISG system. CISG staff made the decisions to use the International Classification of Diseases codes for diagnoses, the AMA Current Procedural Terminology for treatments, and the Drug Product Information File Brand Drug Product Number to specify drugs administered.

Medicare claims processing by private carriers and intermediaries is one of approval/disapproval, based on cost and beneficiary service considerations, of contractors' recommendations for innovations in or changes to their existing processing systems. It has not been our policy to attempt to direct their corporate decision making activities—but to review the results to assure that the best interests of the Government are protected. As such, we would not have been in a position to direct Blue Cross/Blue Shield of Alabama to accept or reject direct input of the physician-generated tapes, and we do not anticipate adopting such a position in the future."

1C. Johnston Conover and Walter S. Baer, Computer-Assisted Electrocardiogram Analysis: Case Study of a Federal Demonstration Project, Case Study C in this volume.
The CISG system required the physician's assistant to code the claim information before dialing up the computer. Previously, the assistant wrote down the doctor's description of what was diagnosed, what treatments were given, and what drugs were administered. The problem of coding the information was left to the Medicaid carrier. Under the new system, the assistant had to understand fully what the physician had done. This imposed far more discipline on the physician than before, but at the same time it avoided most cases of returned claims because of unclear diagnoses or procedures. It also eliminated some physician frustrations from reimbursements of different amounts for the identical procedure performed on two different patients, because the carrier's coders had interpreted the verbal descriptions differently and had given different code numbers to them.

For the most part this discipline imposed on the physicians was beneficial; it made them clarify what they meant by particular procedure or diagnosis descriptions. Only a few physicians found the new procedure onerous and gave up using the system after trying it. Several other doctors withdrew because of poor telephone service in rural areas of Alabama. But, for the most part, physicians accepted the system -- even though they were never consulted on which codes would be most meaningful or useful for them to use. Presumably, the experience of both Dr. Mesel and Dr. Wirtschafter in their own practices made them sensitive to the needs of other physicians.

The demonstration phase ran for 29 months, from December 1971 through April 1974, with federal funding. During that time CISG served about 100 physicians (17 percent of Alabama physicians) and processed a total of 165,845 complete claims. By September 1973, the last month of free service to physicians, the system was carrying more than half of the statewide Medicaid billing load.

In October 1973, CISG instituted a $.25 charge for each billed medical service. Since the average claim contained two medical services,
physicians paid about $.50 per claim submitted. Some doctors stopped using the system when this fee was imposed, but the system still retained 86 percent of its prior workload. This gives at least one measure of physician demand for the service. The project report notes:

Those physicians willing to pay for the billing service were high-volume users mostly who appreciated the economies that the system had achieved for them in their office billing practices.1

The Medicaid Carriers

Problems with the Medicaid carriers provide almost the complete explanation of why the demonstration failed to diffuse. A good part of the difficulty arose from a change in carrier during the demonstration.

The Equitable Life Assurance Society, the Medicaid carrier in Alabama in 1971, showed considerable enthusiasm for the CISG system and agreed to cooperate in working with it. Equitable was at first reluctant to enter claim information from the CISG computer tapes directly onto its computer, since this would not permit screening by its own personnel. Consequently, CISG produced coded, hard copy claims from its computer file which were manually checked by Equitable staff before entering the carrier's data processing system. However, Equitable did install two terminals during 1972 to transmit pediatric claims directly to CISG. After on-line screening, magnetic tapes containing those claims were sent for direct entry to the Equitable computer system. CISG was hopeful that this approach could be extended to all claims.

Blue Cross-Blue Shield took over Medicaid operations in the state of Alabama in October, 1972 and began immediately to implement the SSA Model Medicare system. This required some modifications of the system to allow it to handle both Medicare and Medicaid claims.

Given this internal commitment to developing the SSA on-line system, BC-BSA officials said that they could not devote additional resources to making the adjustment necessary to handle tape-to-tape entry of claims.
from the CISG system. Dr. Mesel suggests that the modifications required would have been minimal, but BC-BSA was under considerable time and financial pressures at that time. By the time the BC-BSA Medicaid/Model Medicare system was fully operational in April 1974, CISG's federal funding had run out. Only if BC-BSA had agreed to pay part of the costs (e.g., a fee for use of the CISG tapes) could CISG have continued to operate its on-line system.

BC-BSA and CISG disagree on the cost effectiveness of the CISG system. BC-BSA officials claim they saw no substantial cost savings from the CISG system, so that even without the Model Medicare implementation problems they probably would not have used it. According to the BC-BSA Vice President for Government Programs:

Blue Cross and Blue Shield of Alabama expended considerable effort to assist Dr. Mesel with the implementation of his telephone billing service project. Blue Cross and Blue Shield of Alabama considered the implementation of the system on an in-house basis; however, the economics of the system in relation to other technology did not show it to be feasible at that time. 1

Yet CISG calculations indicate that Blue Cross-Blue Shield could save up to 50 percent of its processing time if the system were adopted. CISG contends that the edits performed on the data at the source would guarantee highly accurate information and would sharply reduce the costly manual coding and editing procedure now used by the carrier. Overall, Blue Cross-Blue Shield could save up to $1.00 per claim in processing costs, according to the CISG calculations. 2

BC-BSA also raised the issue of auditing hard copy claims as an objection to the CISG system. The high-volume Medicaid providers using the CISG system would be the ones reviewed most often for medical

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1Letter from Earnest L. Gilliland, October 10, 1975.

2See Table 1 on p. 19. It should be noted that BC-BSA now appears to be the only company willing to bid to handle Alabama Medicaid claims. Since 1972, the state has offered only the entire Medicaid package for bidding, rather than individual pieces such as physician services. Equitable and other carriers were interested in bidding for parts of the system, but not for handling all medical services. Consequently, BC-BSA may no longer have strong incentives to cut costs for fear of being replaced in the next bidding round.
necessity of procedures and similar checks for Medicaid abuses. BC-BSA required source documents from the physician for pre-payment audits, so they contended that tape-to-tape transfer from the CISG was not feasible (this requirement has recently been relaxed, according to SSA officials).

In summary, BC-BSA's refusal to accept tape-to-tape transfer from the CISG computer system effectively prevented the CISG demonstration from achieving full application success and contributed to the subsequent lack of diffusion success.

DISSEMINATION

The HCTD contract with CISG did not emphasize dissemination of information from the demonstration, and relatively little has taken place. The Mesel and Wirtschafter report describing the project was completed in August, 1974 and approved for distribution in November. As of October 1975 approximately 400 copies had been distributed. HCTD routinely sends any inquiries about the availability of software to Dr. Mesel, who reports that so far about a dozen contacts have been made. Dr. Mesel has completed a journal article for submission, and smaller notes have appeared in Alabama M.D., the Computers in Medicine newsletter, and Medical Economics.

Dr. Mesel also travelled to California to demonstrate the system to the Health Care Systems Administrators—a group that was operating an experimental automated billing system for Medi-Cal. While the group was impressed with the CISG results, they seemed, according to Mesel, more concerned about the future of their own system. The Medi-Cal experimental system was in fact not continued, so that no further use was made of the Alabama results.

HCTD contends that dissemination has been hampered by CISG's reluctance to release the machine readable software package necessary for trial adoption by the private sector. In the only contract transfer actively followed by HCTD to date, the potential adopter was "surprised" at the $1000 charge by CISG to make the materials available. HCTD evidently assumed that the software and documentation would be made available at a nominal cost, but these were never spelled out as "deliverable" items in the contract with CISG.
IV. DEMONSTRATION OUTCOMES

APPLICATION OUTCOME

After federal funding ended in April 1974, and without statewide acceptance by Blue Cross-Blue Shield, the CSG system could not afford to underwrite the telephone toll charges (principally inward-WATS lines) necessary for on-line operations. Consequently, the system has shifted to an off-line mode. The claim information previously transmitted by telephone is now entered onto a cassette tape at the physician's office, sent by mail to CSG, and transcribed by CSG personnel for batch input into the computer. No new physicians have been added to the system, and only those with a high-volume of Medicaid billings remain. The system still operates in the black, charging $.25 per billed service, and Dr. Mesel hopes that it will be able to expand further when new hardware becomes available (see below).

UNCERTAINTY REDUCTION

Technological Uncertainty

Technological uncertainty, while low at the beginning, was further reduced by the demonstration. The project clearly showed that the pushbutton telephone is a workable input-output device for medical teleprocessing applications. It demonstrated that coding for diagnoses, procedures, and other information needed for Medicaid billing was feasible with a fairly simple format. It also demonstrated that a card reader was a time saving and convenient adjunct to the basic push-button telephone, since 50 pre-punched cards accounted for 2/3 of all diagnoses and 94 percent of all procedures.

No other innovations emerged serendipitously from the CSG demonstration, as Dr. Yamamoto had originally hoped.

Cost Uncertainty

The demonstration succeeded in reducing cost uncertainty to a low level. It also showed that the system could achieve significant cost
savings if operated at a sufficiently large scale and coupled directly to the Medicaid carrier’s data processing system.

The project report presents a series of cost estimates based on the Alabama operating experience.\(^1\) The estimates separate costs to the physician from the costs of operating the central teleprocessing facility and the costs of claim processing by the carrier.

1. Costs to the Physician. For the 100 participating physicians, the incremental cost of the Touch-Tone\(^2\), Carddialer telephone, the modem, and a pro-rated share of the voice answerback equipment was about $25.00 per month. These physicians were high volume users averaging about 165 claims with 330 billed services per month (the average claim contained 2 billed services). Thus the average incremental hardware cost to the physician was about $.15 per claim. In addition, CISG charged the physician $.25 per service, or $.50 per average claim for its services.

Cost savings are estimated in terms of the time saved by use of the teleprocessing system. The project report estimates that "the average time to enter a claim via the on-line Medicaid billing system was less than 1 1/2 minutes."\(^2\) No pre-project survey of participating physicians was made to determine the average time for manual claim preparation, but a 1971 survey of 10 practices in Tampa, Florida, gave an average processing time of 37 minutes per claim.\(^3\) These two times cannot really be compared directly, since the Alabama teleprocessing system required that the physician's assistant code the claim before dialing-up the computer. Coding time was not included in the 1 1/2 minute estimate. Still, the report concludes:

"... anecdotal evidence from participants disclosed that most offices at least cut in half the personnel time required for claims billing. Reports from several high-volume group

\(^1\) Messel and Wirtschaffer, op. cit., pp. 35-54.
\(^2\) Ibid., p. 40.
\(^3\) Ibid, p. 38.
practices participating in the project indicated that their labor cost was reduced to one-third that of the cost using manual methods for claim preparation.  

Estimating, then, that the teleprocessing system saved 15 to 20 minutes per average claim for a physician’s assistant paid between $3.00 and $4.00 an hour, suggests a cost saving of $.75 to $1.30 per claim.

Net cost savings to the physician thus appeared to range from $.10 to $.70 per claim, representing substantial monthly savings in many cases.

2. Teleprocessing System Cost. The actual CISG operating budget for the billing system at its high water mark (approximately 17,000 claims during September 1973) extrapolates to $100,000 annually, or $.50 per claim. The charge to physicians was set at this figure to fully recover costs. CISG estimates that the cost per claim would be reduced to $.38 if the system operated at twice the September 1973 volume; that is, if it had been adopted for all Alabama Medicaid claims.

3. Costs to the Medicaid Carrier. Although Blue Cross-Blue Shield did not adopt tape-to-tape transfer from the CISG system, CISG estimated the cost savings to the carrier had it done so. The estimates, based on an earlier study of manual billing costs in Maryland, showed potential cost savings of more than $1.00 per claim (Table 1). CISG believes these estimates can be straightforwardly applied to other teleprocessing billing systems.

Demand Uncertainty

The project demonstrated that a demand for the service existed among physicians with high volumes of Medicaid claims, as evidenced by the system’s 86 percent volume retention when a $.25 fee per billed procedure

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1 Ibid, p. 40.

2 In their conclusions (p. 64), Mesel and Wirtschafter imply greater cost savings based on the 1 1/2 minute claim entry time, although they do not present a single estimate for overall savings.

3 "Anyone interested in developing an estimate of the cost to use the on-line system in another part of the United States should be able to apply the most appropriate budget model described in this section to the characteristics of his own service area." Mesel and Wirtschafter, op. cit., p. 53.
Table 1

ESTIMATED CARRIERS COSTS OF PREPARING INSURANCE CLAIMS USING MANUAL AND TELEPROCESSING SYSTEMS

<table>
<thead>
<tr>
<th>Cost Element</th>
<th>Manual System Cost per Claim</th>
<th>Estimated Percent of Manual System Cost Required by Tele-processing System</th>
<th>Estimated Tele-processing System Cost per Claim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Processing</td>
<td>$0.60</td>
<td>80%</td>
<td>$0.48</td>
</tr>
<tr>
<td>Data Entry</td>
<td>0.29</td>
<td>124%</td>
<td>0.36</td>
</tr>
<tr>
<td>Coding/Review</td>
<td>0.93</td>
<td>25%</td>
<td>0.23</td>
</tr>
<tr>
<td>Development (Error Correction)</td>
<td>0.53</td>
<td>50%</td>
<td>0.27</td>
</tr>
<tr>
<td>Beneficiary Services (Complaints)</td>
<td>0.26</td>
<td>100%</td>
<td>0.26</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$2.61</strong></td>
<td><strong>61%</strong></td>
<td><strong>$1.60</strong></td>
</tr>
</tbody>
</table>


*Estimates made by Mesel and Wirtschafter based on Alabama demonstration.*
was charged. However, the demonstration also faced the problem of carrier demand for (or acceptance of) the service, which was not resolved.

Institutional Uncertainty

The demonstration showed the feasibility of training physicians' assistants to use the teleprocessing system, which had posed a potential organizational problem. However, the project was not designed to address the major institutional problem it encountered -- the refusal of the Medicaid carrier to adopt the innovation. The demonstration sheds little light on the question of whether BC-BSA's reluctance to work with CISG is a special case or one likely to occur with other carriers. It points out the problem of not including a major potential adopter in the demonstration, and it reemphasizes the lesson that a single weak institutional link can effectively prevent adoption of an innovation.

Externality Uncertainty

No externalities were addressed by the demonstration.

DIFFUSION

No diffusion of the technology demonstrated in Alabama has yet taken place. The project ended in April, 1974, and no concerted efforts to stimulate diffusion have subsequently been taken by HCTD, CISG, or any private sector firms. Of course, had Blue Cross-Blue Shield of Alabama adopted the CISG approach for use with their own Model Medicare system, diffusion could have been quite rapid. SSA has encouraged Medicare carriers to standardize their practices, and a number of other states have Model Medicare systems in operation.
Late in the demonstration contract period, Chancellor Industries contacted Dr. Mesel after being referred to him by HCTD. The company had developed a membership verification system for use in hospitals to determine eligibility for Blue Cross-Blue Shield; the system used CRT terminals and an audio-feedback device. Company officials corresponded with Mesel about market possibilities for the CISP system and expressed interest in working with the physicians participating in the project. However, when federal funding ended, the CISP system went off-line and dropped the key-in, voice answerback technique in which Chancellor had displayed interest. The company has not proceeded further with any cooperative marketing plans.

Florida Blue Shield has developed a system using an "intelligent" terminal at the physician's office with built-in minicomputer and visual display. The physician's assistant enters claim data onto magnetic tape, prompted by a computer program stored at the terminal. A few edits are performed as the information is keyed in, and the ten most commonly used diagnoses and ten most commonly used procedures are pre-coded to save entry time (this is quite similar to the CISP dialer cards for diagnoses and procedures, but the Florida Blue Shield system designers report that they developed the idea independently). At night the terminal transmits the claim information to a central processor which performs additional edits using its central data files. Any claims that are incomplete or subject to question are then transmitted back to the remote terminal where the physician's assistant can review them and retrieve the missing information the next day. The system was developed by Texas Instruments within the last three years; the company reports that it did not use any of the CISP concepts in its development.

Technical people at Texas Instruments say that the market is clearly moving toward development of minicomputers that can handle all edits at the physician end without recourse to a central processor. The market appears promising, and several other manufacturers, including IBM, NCR, and Electronic Data Systems have shown strong interest in developing automated billing systems.
Dr. Mesel believes that the concepts demonstrated in Alabama will apply equally well to stand-alone, minicomputer terminals as to voice answerback teleprocessing systems. He hopes to see CISG operate a claim billing system based on minicomputers when the equipment is fully developed. How much, if any, of the CISG work such as coding format and screening procedure will diffuse remains to be seen. One must agree with Mesel and Wirtschafter's conclusion that "any further benefits to accrue from the use of this technology must await its extension and exportation to other health care delivery settings."\(^1\)

\(^1\) Mesel and Wirtschafter, op. cit., p. 65.
SHIPBUILDING RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM

by

John G. Wirt
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I. INTRODUCTION

Through its Shipbuilding Research Program the Maritime Administration (Marad) is attempting to stimulate innovation in the shipbuilding industry through the unusual method of organizing an inter-industry consortium of shipbuilding firms to help manage demonstration development and projects. This consortium, which is loosely attached to the Society of Naval Architects and Marine Engineers (SNAME), provides a direct way of involving shipbuilders in the management of a demonstration program.

Since 1970, Marad has provided support through this consortium for approximately 50 innovative projects costing $20 million. Each project involves the development and testing of a new technological device or production method and is followed by a formal demonstration in a shipyard to which all industry engineers are invited. Most of the projects supported are small and concern the pragmatic "nuts and bolts" problems of shipbuilding, not large-scale demonstrations of radically new technologies. The basic goal of the shipbuilding projects is to make incremental improvements in the productivity of shipyards through the introduction of new production machinery, methods, and plant organization and management policies. The concern is with the everyday production problems of shipbuilding. Projects that have been supported include welding, surface coatings, material handling, automation, ship production standards, and manpower and have involved replication of foreign technology, modification of an existing commercial product that has problems in shipbuilding applications, reassessment of standards and regulations in ship construction, preparation of handbooks on production techniques, and so forth. The projects within most of the programs are interrelated; that is, one project often complements another, leads to another, or is in some other way connected with other projects. The shipbuilding projects are more than collections of individual projects, and they manifest the properties of interrelatedness characteristic of cumulative technological development.
A study of the rayon industry\textsuperscript{1} indicates how important small, pragmatic technical changes can be in improving industrial productivity. An analysis of unit cost reduction in five rayon plants showed that such minor technical changes as reorganization of production methods, introduction of different or improved resource inputs, and improvement of machinery accounted for an average of 60 percent of all cost reductions in all plants over an approximately 20-year period. Major technical changes of the same kinds but more difficult to implement accounted for an average of 20 percent of all cost reductions over the same period. In sharp contrast, improvements in the quality of labor, economies of scale, and new technologies accounted for only 20 percent of the reductions in unit costs of production.

The productivity of U.S. shipyards as measured by value added per labor hour is low compared to other industries, although differences in wage rates and capital intensity among industries make precise comparisons impossible. The aircraft, the steam turbine and engine, and the locomotive industries, to list a few examples, are twice as productive as shipyards in terms of this measure. The productivity of all manufacturing industries is one-and-a-half times as great as shipyards. The productivity of shipyards is about the same as that of lumber mills and textile weaving.\textsuperscript{2} Furthermore, productivity has not been increasing as rapidly in shipbuilding as in all other manufacturing industries. All this suggests a need for cost-reducing innovation in the ship-building industry.

However, it is important to consider that the productivity of U.S. shipyards may not be appreciably lower than that of the most productive foreign yards, which are in Japan. Existing data indicate that Japanese yards produced approximately 47 compensated gross registered tons (cgrt) of ships per employee compared to a number somewhere between 41 and 50 in U.S. shipyards.\textsuperscript{3}

\begin{footnotes}
\footnote{Hollander, 1965.}
\footnote{Report of the Commission on American Shipbuilding, 1973.}
\footnote{Report of the Commission on American Shipbuilding, 1973, p. 81. In a footnote on page 81, the Commission notes that a check of several U.S. yards revealed that they anticipated an output of 21 to 28 cgrt per employee based on several series-production runs underway in 1973. This casts some doubt on these overall figures.}
\end{footnotes}
II. SHIPBUILDING INDUSTRY

The level of productivity and its rate of increase in shipbuilding is affected by a large number of factors peculiar to the industry. It is important to explain some of these factors in order to clarify why productivity is low and what role the Marad's Shipbuilding Research Program can possibly play in improving productivity through innovation.

UNSTABLE MARKET DEMAND

The world market for new ships is primarily dependent on the level of international seaborne trade which, as Table 1 indicates, has grown rapidly and steadily since World War II. Although no comparable data for actual numbers of ships ordered over the same time period could be found, evidence suggests that the changes in numbers of ships ordered on world markets are generally proportional to the overall level of world trade, except that year-to-year changes in the numbers of ships ordered fluctuate much more widely. These fluctuations are often caused by such exogenous events as the closing of the Suez Canal in 1956, which created a great increase in orders for new ships over a period of several years that is not fully reflected in the data on cargo weight in Table 1. For example, in 1956 U.S. yards had 350 percent more ship orders than they had in 1955. Another underlying factor is that many ships in the world fleet were built during World War II and are now being retired from service, thereby creating a surge in demand.

Also, the overall data on levels of seaborne trade do not indicate the trend toward increasingly larger ships or the trend toward much more highly differentiated, specialized types of ships, such as very large crude oil carriers, other bulk carriers, and container ships. These changes in the market structure provide opportunities for shipyards to specialize in certain kinds of ships, but increase their vulnerability to swings in the market. The data in Table 2 exemplify

these shifts over recent years. Another example is the recent rise in oil prices that has reduced demand for large tankers to the extent that many yards have suffered numerous cancellations of orders.

Table 1
DEVELOPMENT OF WORLD SEABORNE TRADE

<table>
<thead>
<tr>
<th>Year</th>
<th>Dry cargo</th>
<th>Oil</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metric tons</td>
<td>Increase/ decrease over previous year</td>
<td>Metric tons</td>
</tr>
<tr>
<td>1950</td>
<td>300</td>
<td>-</td>
<td>225</td>
</tr>
<tr>
<td>1951</td>
<td>350</td>
<td>23%</td>
<td>255</td>
</tr>
<tr>
<td>1952</td>
<td>390</td>
<td>3</td>
<td>285</td>
</tr>
<tr>
<td>1953</td>
<td>360</td>
<td>3</td>
<td>295</td>
</tr>
<tr>
<td>1954</td>
<td>390</td>
<td>8</td>
<td>320</td>
</tr>
<tr>
<td>1955</td>
<td>450</td>
<td>15</td>
<td>350</td>
</tr>
<tr>
<td>1956</td>
<td>490</td>
<td>9</td>
<td>390</td>
</tr>
<tr>
<td>1957</td>
<td>510</td>
<td>4</td>
<td>420</td>
</tr>
<tr>
<td>1958</td>
<td>480</td>
<td>-5</td>
<td>440</td>
</tr>
<tr>
<td>1959</td>
<td>450</td>
<td>2</td>
<td>490</td>
</tr>
<tr>
<td>1960</td>
<td>540</td>
<td>10</td>
<td>540</td>
</tr>
<tr>
<td>1961</td>
<td>570</td>
<td>6</td>
<td>580</td>
</tr>
<tr>
<td>1962</td>
<td>600</td>
<td>5</td>
<td>650</td>
</tr>
<tr>
<td>1963</td>
<td>640</td>
<td>7</td>
<td>710</td>
</tr>
<tr>
<td>1964</td>
<td>720</td>
<td>13</td>
<td>790</td>
</tr>
<tr>
<td>1965</td>
<td>780</td>
<td>8</td>
<td>860</td>
</tr>
<tr>
<td>1966</td>
<td>830</td>
<td>6</td>
<td>940</td>
</tr>
<tr>
<td>1967</td>
<td>880</td>
<td>4</td>
<td>1,010</td>
</tr>
<tr>
<td>1968</td>
<td>930</td>
<td>8</td>
<td>1,120</td>
</tr>
<tr>
<td>1969</td>
<td>990</td>
<td>6</td>
<td>1,260</td>
</tr>
<tr>
<td>1970</td>
<td>1,110</td>
<td>12</td>
<td>1,400</td>
</tr>
</tbody>
</table>

Note: Data excludes international cargoes loaded at ports of the Great Lakes and St. Lawrence system for unloading at ports of the same system; includes imports into Netherlands Antilles and Trinidad for refining and re-export. These figures are the average of loaded and unloaded quantities.

Table 2
MERCHANT SHIPS\textsuperscript{a} ON ORDER AND UNDER CONSTRUCTION IN WORLD SHIPYARDS, 1967-1971 (dwt\textsuperscript{b} in millions)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Tankers</th>
<th>Bulk Carriers</th>
<th>Freighters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>67.8</td>
<td>41.5</td>
<td>17.1</td>
<td>9.2</td>
</tr>
<tr>
<td>1968</td>
<td>82.4</td>
<td>53.8</td>
<td>18.3</td>
<td>10.3</td>
</tr>
<tr>
<td>1969</td>
<td>99.0</td>
<td>59.4</td>
<td>27.7</td>
<td>11.9</td>
</tr>
<tr>
<td>1970</td>
<td>130.7</td>
<td>75.5</td>
<td>41.5</td>
<td>13.7</td>
</tr>
<tr>
<td>1971</td>
<td>162.8</td>
<td>100.0</td>
<td>49.5</td>
<td>13.3</td>
</tr>
<tr>
<td>Total</td>
<td>542.7</td>
<td>330.2</td>
<td>154.1</td>
<td>58.4</td>
</tr>
</tbody>
</table>

\textsuperscript{a}1,000 tons and over.
\textsuperscript{b}Dead weight tons.

U.S. SHIPYARDS

As indicated in Table 3, U.S. shipyards have traditionally had only a small share (1.5 percent in 1971) of the world-wide market. In recent years, however, U.S. yards have been able to establish a larger share in a few kinds of ships, such as specialized container ships and liquid natural gas carriers. This development has reinforced a general tendency for U.S. yards to "specialize in complex and special-order ships requiring intense use of skilled labor"\textsuperscript{1} and to be able to sell other kinds of mass-produced ships only during surges in world wide demand. As a result, U.S. yards have experienced extreme fluctuations in their order books and have not been able to market series runs of mass-produced ships.\textsuperscript{2} The magnitude of these fluctuations for the U.S. industry as a whole is indicated in Fig. 1; of course, the fluctuations would be larger for individual firms.

\textsuperscript{1}Report of the Commission on American Shipbuilding, 1973, p. 67.

\textsuperscript{2}Instabilities in the level of federal funding for the U.S. construction subsidy program (see pg. 12) have contributed to these fluctuations.
Table 3
NATIONAL SHARES<sup>a</sup> OF SHIPBUILDING MARKET
BY TYPE OF SHIP, 1971

<table>
<thead>
<tr>
<th>Country</th>
<th>All Types (100%)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Oil Tankers (47%)</th>
<th>Combination Carriers (20%)</th>
<th>Bulk and Ore Carriers (17%)</th>
<th>Cargo Ships and Liners (11%)</th>
<th>Container Ships (4%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>1.5</td>
<td>2.3</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>11.6</td>
</tr>
<tr>
<td>U.K.</td>
<td>5.2</td>
<td>4.1</td>
<td>3.2</td>
<td>6.7</td>
<td>9.0</td>
<td>5.9</td>
</tr>
<tr>
<td>Denmark</td>
<td>3.4</td>
<td>5.7</td>
<td>---</td>
<td>1.7</td>
<td>2.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Finland</td>
<td>0.6</td>
<td>0.1</td>
<td>---</td>
<td>1.0</td>
<td>2.3</td>
<td>1.9</td>
</tr>
<tr>
<td>France</td>
<td>4.4</td>
<td>5.7</td>
<td>3.2</td>
<td>1.6</td>
<td>2.0</td>
<td>1.8</td>
</tr>
<tr>
<td>W.Germany</td>
<td>7.8</td>
<td>6.7</td>
<td>5.8</td>
<td>6.9</td>
<td>7.6</td>
<td>41.7</td>
</tr>
<tr>
<td>Italy</td>
<td>3.7</td>
<td>2.5</td>
<td>13.8</td>
<td>1.2</td>
<td>0.7</td>
<td>3.6</td>
</tr>
<tr>
<td>Japan</td>
<td>49.8</td>
<td>49.4</td>
<td>59.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>57.1</td>
<td>48.8</td>
<td>8.0</td>
</tr>
<tr>
<td>Norway</td>
<td>3.8</td>
<td>3.5</td>
<td>---</td>
<td>6.4</td>
<td>1.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Poland</td>
<td>1.3</td>
<td>---</td>
<td>---</td>
<td>4.1</td>
<td>3.3</td>
<td>---</td>
</tr>
<tr>
<td>Spain</td>
<td>3.2</td>
<td>2.6</td>
<td>---</td>
<td>7.4</td>
<td>3.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Sweden</td>
<td>8.1</td>
<td>12.3</td>
<td>10.6</td>
<td>---</td>
<td>0.2</td>
<td>---</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>1.3</td>
<td>0.4</td>
<td>4.4</td>
<td>1.6</td>
<td>1.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Others</td>
<td>5.9</td>
<td>4.8</td>
<td>---</td>
<td>4.2</td>
<td>16.8</td>
<td>19.9</td>
</tr>
<tr>
<td>Totals</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>


<sup>a</sup>Figures given in percent of total market of each type of ship.

<sup>b</sup>Percent of total market that each type of ship represents.

Fig. 1 -- U.S. Shipbuilding: Contract Awards including Major Conversions

Consequences of Market Instability

As a result of these fluctuations in their order books, U.S. yards have had:

- Extreme variations in the composition of the work force,
- High levels and widely fluctuating compositions of inventories,
- Poor utilization of facilities (typically 50 percent of capacity),
- Excessive demands on managerial and professional time and skills,
- Low levels of capital investment for years,
o Low levels of R&D expenditures (e.g., $4 million in 1970 for all shipbuilding firms), and

o Low profits (an average of 1.8 percent of revenues for 1961-1971 with several firms running chronic deficits\(^1\)).\(^2\)

In effect, market instabilities have caused U.S. shipyards to organize themselves for survival by minimizing their exposure to risk. With a more stable order book, U.S. shipyards could offer steadier employment to workers, reduce inventory needs and plan them more carefully, plan and secure needed capital in a more orderly fashion, afford to increase capital investment because of greater assurance of earning a reasonable rate of return, reduce overhead expenses, and allow support of internal R&D.

Conditions in shipbuilding are very similar to those in the construction industry where market demand also widely fluctuates, except that the risks to individual shipbuilding firms are larger because, the unit of output is much larger in relation to total industry revenues and because, instead of there being eight hundred thousand firms, there are approximately ten major firms. In 1971, the top four firms in shipbuilding had 46 percent of total industry revenues, the top eight had 65 percent, and the top twenty had almost 100 percent.\(^3\)

Consequences of No Series Production

As a result of the lack of series production, ships are more expensive to build in U.S. yards than in foreign yards where series production has been achieved. Therefore, U.S. yards have not been able to compete in the growing world wide market for increasingly larger, mass-produced ships. As the data in Fig. 1 indicate, this has meant

\(^1\)This amount of profits ranks 375th in *Fortune*’s list of profits among the nation’s top 500 manufacturing industries.


that the total number of ships built in U.S. yards has generally declined. With series production, design costs can be written off over a larger number of ships, production facilities and routines can be specialized for the construction of particular ship designs, inventories can be more closely controlled, and overhead can be reduced. No U.S. yard has achieved series production of ships with modern techniques and low costs, although two have come close.¹ The decrease in cost possible with series production is indicated in Fig. 2.

![Graph showing cost per ship versus number of ships built over 5 years for different types of ships.]


Fig. 2 -- Estimated Costs of Ships in Different U.S. Multiple Shipbuilding Programs

Some foreign yards, especially those in Japan, have been able to market series-production runs of ships. This has been possible largely because of governmentally authorized, and even initiated, cooperation among the yards within a country to decide which yards should build what kinds of ships. Antitrust laws in the United States preclude such an approach.

Lack of series production has also meant that the U.S. shipbuilding industry has not modularized ship production by prepackaging such items as machinery, piping, and deck houses, which could save on both maintenance and outfitting costs. Nor has the industry established uniform designs and tests for plate sizes, brackets, structural shapes, doors, shafting, electrical equipment, and much more. As a result of this fragmentation, suppliers cannot offer the lower prices that accompany a standardized line of products because they cannot use standardized jigs and patterns in manufacturing parts. U.S. yards have not made any effort comparable to that of the Japanese to develop such standards, nor have they participated in the International Standards Organization (ISO), which is endeavoring to set standards for ship equipment. In short, U.S. shipbuilders are not designing for production.¹

Another consequence of the lack of series production is that U.S. yards are often late on ship deliveries. For example, from 1970 through 1972, none of the 26 ships built in U.S. yards was delivered on time; the average delay was 10.6 months. Assuming a typical mix of ships, this much delay costs a ship operator approximately $1 million in lost revenues. In contrast, Japanese and Swedish yards are reputed to be usually on schedule.²

Climate of Protectiveness

An effect of both the downward trend in numbers of ships ordered from U.S. yards and the market instabilities has been that individual shipyards became extremely protective of their technical and market information; they have feared giving any of their competitors an

advantage. This protectiveness extended frequently to not paying expenses of managers and engineers to attend professional meetings. And if these professionals did go, they were often instructed not to volunteer information about company matters. As recently as a few years ago, less than 1 percent of the papers given at meetings of the industry's principal professional society, the Society of Naval Architects and Marine Engineers (SNAME), were on shipbuilding.

Naval Architects

Another problem is that for many years ship operators have tended to deal only with naval architects in developing designs for new ships that the operators want to buy. Shipyards have had to build from the designs produced by the naval architects and have not been able to consult with the operators about designs that could cut production costs. As a result, ships have been over-outfitted, particularly in crew quarters, and not designed to allow reductions in production costs. Part of the problem is that each shipowner has different shipping needs; but, at a minimum, it would be possible to standardize many of the more costly parts of the ships, such as the fore body, aft body, propulsion and auxiliary machinery, and the superstructure.

Naval Ships

As indicated in Fig. 1, a substantial proportion of the U.S. shipyards' business is in building ships for the Navy; however, almost all of these ships are built in three yards. Because of the highly technical nature of naval shipbuilding, most yards have decided to build either commercial or naval ships or have established separate organizations and facilities for each type. Instabilities are equally as high in the market for naval ships as for commercial ships, and reported profits are as low. Any earnings from Navy work are subject to review by the Federal Renegotiation Board and to possible downward

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1 Interview with Mr. Jack Garvey, the Director of the Shipbuilding Research Program in the Maritime Administration.


3 Ibid., p. 33.
revision to eliminate "excess" profits.

SUPPLIER INDUSTRY

Over one-half of the total price of a commercial ship is in materials and equipment purchased from suppliers. There are over 500 firms supplying the industry with items ranging from steel, wood and paint, to wire, pumps, propellers and engines. In essence, a shipyard is an assembly facility with an associated finance office and design department. Because of this high dependence on suppliers, suppliers are a potentially important source of shipyard innovations.

However, few suppliers have been responsive to needs of the shipbuilding industry. The lack of standardization is one factor, but another is that purchases by shipbuilders represent only a few percent of most suppliers' total sales. Thus, suppliers have tended to ignore shipbuilders' needs in developing new products and providing customer services. The steel industry is a good example. Although the shipbuilding industry spends more for steel than for any other material, its purchases are less than 2 percent of the total steel-mill output. Proposals by the shipbuilding industry that steel mills should offer the service of precutting plate and structural steel to shapes ordered by the yards (which would save on freight charges, the costs of waste handling, and the need for investment in cutting machinery) have been refused. Shipyards have also had problems in receiving deliveries from steel mills and, consequently, have had to maintain excessive inventories.

FEDERAL SUPPORT

Because the costs of building ships in U.S. yards are higher than in foreign yards, the U.S. shipbuilding industry is highly dependent on federal support for continued existence. The forms of federal support are:

- Construction differential subsidy, which compensates U.S. yards for the difference between what it costs them to build a ship and what it would cost a foreign yard to build the same ship. (The owners of ships built under the
subsidy program must be U.S. citizens).

- Various *tax benefits*, which allow shipowners to create tax exempt funds into which earnings may be deposited, provided that the funds are used only for purchasing new ships from U.S. yards.
- *Loan guarantees* and *lease financing* arrangements that in effect lower interest rates on loans available to purchasers of U.S.-built vessels to approximately the prime rate.
- *Cabotage laws*, which require that shipments from one U.S. port to another be in U.S.-built ships.
- *Cargo preference laws*, which require that a certain percentage (usually 50 percent) of cargoes in which the government has some property interest or was involved in originating must be shipped in U.S. vessels.\(^1\)

In effect, the cabotage and cargo preference laws guarantee a minimum market for U.S.-built ships, while the construction differential subsidy, tax benefits, and financing provisions lower the costs to American owners of buying U.S.-built versus foreign-built ships. Calculation of the remaining difference is extremely complex and no summary analyses could be found; but, theoretically, for owners who are U.S. citizens, the construction differential subsidy and financial provisions bring the costs of U.S.-built ships very close to the costs of foreign-built ships.\(^2\) Yet, the evidence indicates that, even when the costs are equal, ship operators still prefer foreign-built ships because of U.S. tax rates and regulations.\(^3\) It has been estimated that these subsidies plus contracts with the Navy account for more than 80 percent of all U.S. shipyard revenues.\(^4\)

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3. Ibid., p. 209.
4. Ibid., p. 175.
The United States is not alone in subsidizing shipbuilding, although the forms of subsidy differ considerably from country-to-country, as indicated in Table 4. For example, the Japanese government offers tax credits and low interest loans to shipowners in ways that create a large and stable world-wide market for Japanese-built ships. However, the Japanese neither directly subsidize construction nor protect domestic markets with cabotage and cargo preference laws. As a result, Japanese shipyards have a strong incentive to cut costs.

In contrast, the U.S. construction differential subsidy and cabotage and cargo preference laws insulate U.S. shipyards from cost competition with foreign yards. The construction differential subsidy is calculated on a ship-by-ship basis with the amount of payment being the difference between the lowest cost U.S. yard's quoted price for building a ship and the estimated price of buying the same ship from the cheapest foreign yard. The actual procedure for determining the amount of subsidy was complex. First, owners would obtain bids from foreign yards for a ship to be built under the subsidy program. Then the government would solicit bids for the same ship from U.S. yards. The government would then select the lowest bid from a U.S. yard and sign a contract with that yard for an amount equal to the difference between their price and the lowest foreign bid. The owner also signed a contract for the same ship for an amount equal to the lowest foreign bid.

U.S. subsidy programs were revised by the Merchant Marine Act of 1970 in ways designed to change the market incentives of U.S. shipbuilders. The Act does not change the overall levels of subsidies, but authorizes:

- A ten-year construction differential subsidy program to remove the uncertainty of periodic reauthorization required by the prior program.
- Negotiated contracts for new ships between builders and operators to reorient the subsidized market away from governmental procurement and toward bargaining between owners and builders.
- Extension of the subsidy to bulk freighters and tankers; the subsidy had previously been limited only to liners, i.e., ships hauling mixed cargo or passengers on regular routes.
Table 4
SUMMARY OF DIRECT AND INDIRECT SUBSIDIES PROVIDED BY GOVERNMENTS TO SHIPBUILDING

<table>
<thead>
<tr>
<th>Governments</th>
<th>United States</th>
<th>France</th>
<th>Germany</th>
<th>Japan</th>
<th>Spain</th>
<th>Sweden</th>
<th>United Kingdom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction subsidy</td>
<td>X</td>
<td>XX</td>
<td>X</td>
<td>—</td>
<td>X</td>
<td>(a) X</td>
<td>X</td>
</tr>
<tr>
<td>Grants</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Loans at reduced rates</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td>Tax benefits</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Credit guarantees</td>
<td>X</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td>Accelerated depreciation</td>
<td>—</td>
<td>X</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td>Tax-free reserves</td>
<td>X</td>
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<td>—</td>
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<tr>
<td>Research and development</td>
<td>X</td>
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<td>—</td>
<td>X</td>
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<tr>
<td>Cabotage restrictions</td>
<td>X</td>
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<td>X</td>
<td>—</td>
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<tr>
<td>Cargo preference</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Training</td>
<td>X</td>
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<tr>
<td>Government participation in shipyard ownership</td>
<td>X</td>
<td>—</td>
<td>X</td>
<td>—</td>
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<td>—</td>
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</table>

(a) To ailing shipyard.

The provision allowing negotiated contracts between shipbuilders and ship operators was intended to allow them to work out ship designs and financial arrangements mutually beneficial to both parties, and to eliminate the administrative problems of the government participating as a third party contractor. Through negotiation, the shipyards can offer cost-cutting alternatives and the owners can adjust their specifications to take advantage of these alternatives. The extension of the subsidy to bulk freighters and tankers opened up new market opportunities for U.S. shipbuilders by permitting them to build the kinds of ships currently in greatest world-wide demand.

REGULATORY AGENCIES

The two primary regulatory agencies in the U.S. shipbuilding industry are the U.S. Coast Guard and the American Bureau of Shipping (ABS), a non-profit organization sponsored mainly by insurance underwriters. The ABS (which prefers to be called a "classification society") exerts its regulatory power through inspection and approval provisions that insurance underwriters require to be written into all contracts for new ships. Three other agencies with lesser roles are the Federal Communications Commission, the U.S. Public Health Service, and the
Occupational Safety and Health Administration. Shipbuilding is regul-
ated by the Coast Guard from the standpoint of protecting the safety
of life at sea and by the ABS from the standpoint of preventing loss
of the vessel at sea. Both agencies are concerned with many of the
same parts of ships and, thus, there are problems of overlap; but,
each agency is concerned with different aspects of these overlapping
parts. For example, both agencies are concerned with the critical
electrical motors on a ship, but the ABS is mostly concerned with the
capacity and durability of these motors and the Coast Guard with
hazards to operating personnel.

In setting ship standards, these two organizations have tended
to be conservative and to rely on the tried and true. Nevertheless,
shipyards look to these two organizations for technical advice on
ship design improvements because they both maintain expert technical
staffs. These technical staffs could be an important source of
shipbuilding innovations, but their tendency is to comment only on
suggestions made by the yards rather than to recommend innovations
to the shipyards. The conservatism of these two organizations is
amplified by the tendency of the shipyards not to include innovations
in plans for new ships, which must receive prior approval from both
the ABS and the Coast Guard, in order to avoid any risks of these plans
being disapproved.\footnote{Many ship operators and financial insti-
tutions are also highly averse to taking risks with regard to innovations because they suffer
the consequences of innovations that fail. They have to live with the
ship that's delivered to them for 20 or 30 years. This factor also
tends to make the shipyards conservative with respect to innovations,
because they must respond to ship operator's preferences.} Delays in getting plans approved can cause seri-
ous disruption of production schedules, which is expensive to the
yards. As a Marad official commented in conversations concerning
this case study, this had led to a tendency in shipyards to grant
salary raises to engineers who have a clean record on getting plans
approved but not to engineers who have tried to be innovative.
As an example of how shipyards' aversions to taking risks affect
innovation, this same official cited one shipyard that came up with
a list of approximately 500 ways to cut costs on a new ship that it
was going to build. However, it decided to include only 200 of these
innovations on the plans that it was going to submit to the Coast Guard. The Marad official suggested that the shipyard ought to meet with the Coast Guard to discuss all 500 innovations before submitting its plans. In this meeting, the Coast Guard said that all but 60 would be approved.

**BARRIERS TO INNOVATION IN SHIPBUILDING**

Although the complexities of the shipbuilding industry make it difficult to determine precisely all of the barriers to innovation, the most important appear to be:

- Instabilities in the market for U.S.-built ships, which creates a tendency for shipyards to organize themselves for survival rather than for competition in the worldwide market for mass-produced ships.
- Traditional patterns of organization in the industry which have prevented shipyards from bargaining with ship purchasers for vessels that would be cheaper to produce.
- Lack of cost-saving innovations from material and equipment supply firms, because shipbuilding is a small percentage of their markets and because of a lack of design standards in the shipbuilding industry.
- Federal subsidies and laws that provide little incentive to cut costs.
- Conservative behavior on the part of regulatory agencies, which is amplified by the reluctance of shipyards to attempt innovations that might run afoul of the regulatory process and cause expensive production delays.
III. SHIPBUILDING RESEARCH PROGRAM

The Maritime Administration has not supported much R&D. None was supported prior to the initiation of the Nuclear Ship Savannah project in 1958, and then it had a small program of only about $2 to 3 million. These funds were used to support what James Higgins, the current Deputy Director of the Office of Commercial Development (OCD), calls "paper studies," i.e., hydrologic studies of hull designs, propellers, and so forth. According to Higgins, "The approach was to do smart things and hope that somebody would use them; but nothing happened--nobody ever used the results of the studies that we funded." Furthermore, all of the research was in the area of ship design and operations, and none was in the area of ship production, which Higgins thought was an area where major improvements could be made.

Higgins briefly outlined the history of the Shipbuilding Demonstration Program, saying that in the late sixties the concept began to emerge in the Office of Advanced Ship Development (OASD; a division of the OCD) that projects shouldn't be started unless industry indicated interest in the potential results. Thinking began to evolve on various ways of involving the industry in program management. In late 1969 an idea of forming an industry council to advise Marad on needs for R&D projects was presented to Maritime Administrator Andrew Gibson, who gave his strong support.

During this time, Congress and the Administration were considering amendments to the Merchant Marine Act of 1936, and the OASD worked to get an authorization for cooperative R&D program in shipbuilding included. Marad's only R&D authority at the time was Title I, Section 212(c), of the Act which authorized the agency "to collaborate with vessel owners in developing a plan for the economical construction of vessels and their propelling machinery of the most modern and economical types, giving thorough consideration to well-recognized means of propulsion, and taking into account the benefits of standardized production where practical and desirable." In the 1970 Amendments to the Act, the words "and shipbuilders" were
inserted after the phrase "to collaborate with vessel owners," giving Marad authority to start a program in shipbuilding. In the President's message accompanying the Act, there was a paragraph specifically spelling out an intention to support cooperative R & D:

We will also enlarge and redirect the maritime research and development activities of the federal government. Greater emphasis will be placed on practical applications of technological advances and on the coordination of federal programs with those of industry.1

On the basis of this authorization, the OASD moved forward in developing its plans. Since the passage of the 1970 Act, funding for all Marad R & D programs has been about $25 million per year.

ORIGIN OF THE SHIPBUILDING DEMONSTRATION PROGRAM

Shortly after the passage of the Amendments to the Act in November 1970, James Higgins, who was then the Director of the OASD,2 took the idea of forming an industry advisory-group to the Shipbuilder's Council, the industry organization that represents shipbuilders in Washington, to see if it would be interested in cooperating. The Council declined on the grounds that R&D was not its proper role. The Council directed OASD to a committee in SNAME.

This committee had been formed six months earlier by a group of ship-production engineers and managers who for some time had been displeased by the heavy public criticisms of the shipbuilding industry and the lack of any forum in SNAME for professionals involved in ship production. They also believed that shipyard engineers should be

1Message from the President of the United States transmitting recommendations for new Shipbuilding Program, October 23, 1969.
2Higgins has since moved up to his new position.
working with ship operators in designing new ships rather than receiving design specifications from naval architects. According to this group, ship production engineering had too low a status in the maritime industry hierarchy. Ship operators, naval architects, and researchers had technical committees in SNAME, but the specialists in ship construction did not. Members of the group urged the formation of a Ship Production Committee (SPC) in SNAME and received strong support from top-level shipyard management. The SPC was formally approved by SNAME in July 1969.

Subsequent to OASD's meeting with the Shipbuilder's Council, several other informal meetings were held among Higgins; his assistant Jack Garvey; Ludwick Hoffman, who was Chief of Marad's Office of Ship Construction; and Daniel M. Mack Forlist, the Chairman of the SPC, to discuss alternatives. One suggestion was that Marad should form its own advisory panel, but this was eventually rejected in favor of first approaching the SPC. In retrospect, Jack Garvey thinks that forming a government panel would have been a mistake. As a committee in a professional society, the SPC already had industry recognition and acceptance and was inherently coupled into the industry at the level of working professionals. A government panel might have taken a long time to reach such a stage.

In these discussions, the chairman of the SPC responded lukewarmly, but agreed that OASD should meet with SPC members to discuss possibilities. After several informal meetings with members of the SPC, Higgins was invited to present OASD's ideas at an SPC meeting. At this meeting, he explained OASD's eagerness to involve the shipyards in an R&D program and the general idea of the SPC serving as an advisory council to Marad. However, he added that OASD wanted such a council to do more than provide general recommendations. What was needed were suggestions for specific kinds of projects that the government should fund. He also mentioned that Administrator Gibbons strongly supported the program and that Congress had already appropriated the necessary funds. To indicate the government's commitment to participation, Higgins said that the industry would be

1Mack Forlist at that time was a top executive in the Bethlehem shipyard.
expected to contribute a portion of the total costs and that this meant industry would necessarily have a say in how an R&D program developed. The SPC members responded lukewarmly, but decided to appoint the OASD director to one of the SPC's technical panels to see what could be developed.

In this meeting, members of the SPC were skeptical that the OASD's director was proposing anything unusual and commented that these kinds of things usually collapsed after a short time. They also doubted that the government was really serious about wanting advice. Too many times, they complained, the government comes to an industry asking for advice on planning a new program that, in reality, has already been planned.

Higgins believes that another factor underlying the concerns of SPC members was the traditional relationship between Marad and the shipyards. For years, Marad had been one of the major buyers of ships from the yards through its subsidy programs (see Section II) and had often gotten into contract disputes that strained the shipyard's relationships with the government. All the contract paperwork that the industry had experienced in government programs was also a factor. In addition, many of the yards had recently been charged with numerous violations by Marad's Equal Employment Opportunity Office.

Higgins and his assistant, Jack Garvey, attempted to change the attitudes of SPC members towards OASD's idea by explaining it to shipyards in a series of discussions and by working with them to develop projects. By May 1971, the first list of projects was developed, approved by the SPC, and funded by Marad.

THE ANTITRUST ISSUE

Another source of the industry's reluctance to participate was a general concern about the U.S. Department of Justice charging them with antitrust violations if they jointly participated in a program that would involve meetings among industry representatives. In fact, legal counsels of one of the shipyards and the Shipbuilder's Council
warned the members on several occasions that other industries had previously taken a similar approach to cooperating with the government on an R&D program and had eventually become involved in antitrust litigation. On top of all their other problems, shipyards did not want to risk the extra burden of having to deal with an antitrust case.

The OASD group had consulted with Marad lawyers about antitrust problems. It was told that, while the law was clear that discussions between companies on strictly technical matters were not precluded, antitrust laws were extremely complicated and not always administered evenhandedly. There was a tendency, the lawyers said, for the law to be applied more strictly to oligopolistic industries than to industries where there is a large number of equal size firms. They further advised that it would not be worthwhile to approach the Justice Department for an interpretation of the law with regard to the legality of intra-industry cooperation with the government in the management of a technical program. The advice was that the Justice Department only tells you what you can't do, and only after you've done it. The Marad lawyers would not promise to advocate for the OASD if it went ahead and problems arose.

The OASD was in a quandary until the President issued a message on civilian R&D policy in which he explicitly stated that there is a need for greater cooperative efforts between industry and government to increase technological innovation and that "the way we apply our antitrust laws can also do much to shape research and development."\(^1\) During the press conference announcing this message, it was asked whether this statement of antitrust policy meant that the administration intends to apply antitrust law so as to allow joint arrangements among companies in supporting R&D. An administration spokesman replied that "we believe that [antitrust] policy as it exists [is such] that it will be possible for industry to form coalitions in joint research efforts that will be beneficial to the industry."\(^2\) Another

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\(^1\) Message to the Congress on Science and Technology. Shipbuilding was specifically mentioned as one of the areas most in need.

spokesman elaborated:

As you know, this is a very complex area that has developed through case law over a long period of time. A lot depends, for the reaction of the industry, on the advice they get from their lawyers. Some of the lawyers are not located in New York or Washington, but around the country. It is ... [our] impression from the discussions that we have had, that a number of these lawyers are risk averters and ... try to give advice which will certainly not raise any question at all [...] ... in doing so they overlook a number of opportunities.

... We have been in contact with the antitrust division (of the Justice Department) in the writing of this message and, obviously, they are the people who enforce the policies. The intent of this message and of the [President's] Economic Report was to give the basic guidelines.¹

In the President's Economic Report, it had been stated that:

The difficulty of a firm undertaking its own R&D efforts may be especially great when the firm is small in relation to the scale required for efficient R&D efforts. In some cases, this difficulty is overcome by the R&D activities of larger firms which supply machinery or materials to smaller firms, for example, by producers of farm machinery or seeds for farmers. In other cases there are firms and institutions that specialize in research and development as such. Also, firms may be able to share risks or pool their support of R&D through formal or informal consortia under today's legal and institutional arrangements. For example, in fragmented industries in which several such consortia are probable, joint R&D would not normally be considered a violation of the antitrust laws. On the other hand, joint efforts among leading firms in highly concentrated industries would normally be considered undesirable. In general, actions taken by private groups which lead to improved allocation of resources would not be in conflict with the antitrust laws; actions which lead to excessive market power would be.²


²Council of Economic Advisors, 1972, p. 91.
On the strength of this backing (and with the relevant portions of the President's message taped to their desks), OASD spokesmen proceeded to persuade the shipyards that they should actively participate in a cooperative program.

In OASD's visits with the top executives of all shipyards to sell them on the idea of cooperating with the federal government on an R&D program, the antitrust issue was always raised. OASD carefully explained that the policy would be

- Not to exclude any American yard from participation in the program, and
- Not to discuss prices of ships in any meetings.

OASD also explained that there were cases in the law firmly establishing that firms can exchange technical information in organizations that are part of a professional technical society without being in jeopardy of violating antitrust laws. The OASD had not been able to get a written commitment from the Maritime Administration that the agency would support the industry in any problems that arose, but the OASD officials argued with the SPC that "we will be in it as much as you are."

Subsequent to these meetings, all of the shipyards but one began to participate more actively in the program that the OASD had outlined. This yard (which had a larger legal staff than all of the others) stayed out of the program because of the antitrust issue until 1973.

**ORGANIZATION OF THE SHIPBUILDING PROGRAM**

The organization of the Shipbuilding Research Program that has emerged since the first projects suggested by the SPC were supported is shown in Fig. 3. The organization consists of the SPC; a series of nine technical panels under the SPC, each of which specializes in a different area of ship production; several program managers, who are employees of the shipyards; and, in addition, the Marad Shipbuilding Research Office.
Fig. 3 -- Shipbuilding Research Program Organization, 1974

SNAME Committees

SHIP PRODUCTION COMMITTEE

SP-1: Facilities

SP-2: Production Techniques

SP-3: Manpower

SP-4: Cost Control

SP-5: Organization

SP-6: Standards and Specifications

SP-7: Welding

O-341 Computer Aids to Shipbuilding

O-231 Surface Preparations & Coatings

Program Managers in Industry

Program Manager

Welding

Surface Preparations & Coatings

Material Handling

Outfitting & Reduction Aids

Program Manager

Automation Programs

REAPS

SPMIS

Program Manager

Ship Producibility Program

Program Manager

Manpower & Motivation Program

Program Manager

Marketing Program

Maritime Administration

SHIPBUILDING RESEARCH PROGRAM OFFICE

Facilities Programs

Program Manager

Research and Engineering into Automatic Production of Ships

Ship Production Management Information Systems
Ship Production Committee

The SPC is composed of top-level shipyard managers, mostly from the production side of their organizations rather than from the finance or marketing side. Their responsibilities include providing policy guidance on the overall direction of the program to the nine technical panels and to the Marad Shipbuilding Research Office and reviewing and approving individual projects submitted for funding by the technical committees.

Technical Panels

The nine technical panels are composed of mid-level managers and engineers from the shipyards and one representative each from the Coast Guard and the ABS. There are between 6 and 40 members on each panel, with one representative from each of the major shipyards on most of the panels. The technical panels have a number of important functions in the management of the Shipbuilding Research Program. They meet three to four times per year (at the expense of their companies) to discuss technical issues and problems and to develop ideas for new projects in their problem areas. Projects are performed either by a shipyard or an outside contractor, usually a supplier to the industry. The panels recommend budget levels for these projects and vote to select contractors for each project approved. After projects are underway, the panels also conduct progress reviews and advise the program manager on technical issues faced by the projects as they develop. In summary, the role of the technical panels in managing the Shipbuilding Research Program includes: formulating problems, generating project ideas, and providing advice to the program manager regarding technical issues and choices within projects.

It is critical to the overall management strategy that the members of these technical panels be shipyard managers and engineers who have line responsibilities for ship production. The panelists are not R&D personnel; they are production specialists with long experience in and direct responsibility for building ships. Panel meetings are a forum where these practitioners can discuss their mutual problems, present their ideas on how to solve them, and share in-house technical information. In the process of doing this, ideas for projects emerge.
Program Managers

The program managers from industry serve full-time, are located in the shipyard that employs them, and are responsible for project administration as well as providing individual project directors with frequent technical guidance. The administrative functions of the program manager include writing RFPs for approved projects (these RFPs are reviewed by the technical panels before they are issued), soliciting bidders, monitoring contractors, and generally performing as a contract officer. The technical functions of the program managers include ongoing review of major technical decisions in projects and assisting project directors in finding answers to technical issues. Because Marad's program categories do not match exactly the problem areas of the panels, some program managers are responsible for projects generated by several technical committees. But when there is correspondence between the program categories and the problem areas, the program manager is responsible for all of the projects from his panel and typically serves as its chairman. In summary, the role of the program manager combines the functions of a federal program officer (RFP writing and contractor monitoring), a chairman of a peer review panel in a federal R&D agency, and an R&D program manager in industry.

Program managers are selected by Marad on the basis of two main criteria: (1) the shipyard where the manager is employed should be a recognized leader in the technology of the program area, and (2) the shipyard should have a great interest in and express a strong commitment to the program. The first criteria is overriding, with the second coming into play when there is no recognized leader in the industry. The salaries of these program managers and usually of one or two assistants are paid by Marad; the shipyards provide office space and all overhead expenses.

Marad Shipbuilding Research Office

The Marad Shipbuilding Research Office is small, consisting of a director and one assistant who run the entire program. They have divided their budget into five program areas, most of which have components identical to the problem areas of the SPC technical panels. These program areas are indicated in Fig. 3.
RESOURCE ALLOCATION PROCESS

Once each year the project ideas submitted by the technical panels are submitted to the SPC for review and approval. The SPC may ask the technical panel to modify its proposals or may approve them without change. Approved project proposals (one-page outlines) are forwarded to the Marad Shipbuilding Research Office which reviews them and, if they are acceptable, assigns them to a program manager. The program manager then writes the RFP, has it reviewed by a technical panel, and distributes it for competitive bidding.

Project Selection

In the past, the SPC has approved roughly an equal number of projects for each technical panel. The total cost has been nearly equal to the Shipbuilding Research Office's budget. The Shipbuilding Research Office recently has reached an agreement with the SPC that, in the future, the SPC will request more proposals from the technical panels. These proposals are to be ranked by the SPC according to high, medium, or low priority. The Shipbuilding Research Office plans to obtain only enough funds to support the high priority projects and some of the medium priority ones. The Shipbuilding Research Office will choose the projects to support that it judges to be of most value. The primary criterion that both the SPC and Marad will employ in determining priorities will be the potential cost-benefit of the expected project results, as estimated by the technical committees. Both the SPC and Marad will review these estimates, with Marad retaining final authority to approve projects for funding.

The Marad staff does not want more influence over project selection and priorities than this system will provide. In essence, the system is organized so that technical panels have the key role in project selection. To the extent that a panel can continue to generate projects that are of more value to the industry than those of other panels (as indicated by cost-benefit ratios), then its share of the total funding will be higher. If the estimated value of its projects declines, then its share of the total budget will also decline. Thus, the primary influence on priorities among problem areas in the Shipbuilding Research Program will be the quality of projects proposed by the panels. This is a bottom-up or "proposal
pressure" approach to priority setting. As is described below, the SPC and the Marad Shipbuilding Research Office exert top-down influence on priorities in other ways.

**Cost/Benefit Calculation**

Cost/benefit ratios are estimated by the technical panels, the SPC, and Marad, using a framework that all have agreed upon. This framework is a layout of a hypothetical 80,000-ton ship, showing all of the material needs, welding requirements, equipment capacities, crew facilities, and so forth. A proposed project is evaluated by determining the potential savings in labor and material costs that would result from using the innovation to be developed in the proposed project in producing ten standard ships (nominally, one ship for each yard in the program). The cost figure used is ten times the cost to each yard of buying the innovation for the production of one ship, plus the estimated project cost. In most cases, this is an extremely conservative estimate, since the yards will be able to use the innovation for the production of several ships. The cost/benefit ratios of funded projects are typically in the range of ten to twenty, but some projects have had cost/benefit ratios of over one hundred.

The Marad staff has no illusions about the accuracy of the calculated cost/benefit ratios, yet it believes that they are a useful tool for weeding out undesirable projects. The ratios do not take into account either the probability of technical success or what the costs may actually be to finish a project. There are also other, more subtle problems; for example, when an innovation may produce substantial direct savings, but indirectly cause other costs to increase.

The size of these cost/benefit ratios is a strong indication of why cooperative efforts on innovation are needed among the yards. If the cost/benefit ratio is calculated on the basis of only one yard using the innovation and paying the entire project cost, then the cost/benefit ratios are typically much closer to one. Theoretically, it is not profitable for a yard to invest in a project with a cost/benefit ratio of one.
Project Characteristics

The kinds of projects that have been supported through the Shipbuilding Research Program cover a wide range. As the examples in Table 5 indicate, most of the projects involve innovations that will provide small improvements in ship design or production methods and equipment. A project may be to adapt a piece of equipment already on the market to shipyard uses, to replicate foreign equipment or production methods, to try out new materials handling methods, to evaluate alternative materials regarding their usefulness in shipbuilding, or to develop new procedures for production testing. Few projects actually involve R&D in the sense of creating, perfecting, and testing a fundamentally new piece of equipment or procedure. Application, adaptation, replication, and evaluation are more appropriate terms for describing the nature of most of the projects supported. Further detail on the characteristics of the kinds of projects supported is included in the next section on the Welding Program.

Priority Setting

The methods through which the SPC and the Marad Shipbuilding Research Office exert top-down influence in establishing priorities among different problem areas in shipbuilding are much less structured than the procedures for determining priorities among projects.

One way that priorities have been influenced is for one of the established technical committees to generate a number of related projects in a problem area that appears to be worth more effort. An example is the Welding Program, which was started in late 1972 after the Facilities Panel developed four good projects in welding and the Welding Program Manager that Marad had appointed recommended to the SPC that a new panel be established solely for welding. The argument was that welding is an important area (over 20 percent of the cost of a new ship is welding) and that many more worthwhile projects could be started. SPC approved the establishment of a Welding Committee. Since then, the Welding Panel has produced a considerable number of additional projects. Another example is the Surface Coating and Preparations Panel, which emerged from projects generated by the
E-31
Table 5
EXAMPLES OF PROJECTS SUPPORTED IN THE SHIPBUILDING RESEARCH PROGRAM

Materials Handling

- Development of an airlift platform for moving large structural steel subassemblies.
- Handbook of economic options for materials handling.

Surface Preparation and Coatings

- Development and testing of an automatic facility for spray painting structural steel shapes.
- Development of techniques for testing the longevity of new surface coatings.
- Evaluation of alternative pre-fabrication coatings for shipyard use.
- Development of a closed-cycle blasting machine.

Outfitting and Production Aids\(^a\)

- Assessment of the feasibility of ordering steel plates to decimal thicknesses.
- Testing of nylon rudder stock bearings.
- Evaluation of individual heat pump units to replace central airconditioning.
- Development of a system for multiplexing shipboard signal distribution instead of using separate cables.
- Preparation of a handbook for using lasers as an alignment and measurement tool.

\(^a\)Projects in the Welding Program are described in the next chapter.

Production Techniques Panel.

Another way that priorities have been influenced is for the SPC to decide through its continuing discussions of major problem areas in shipbuilding that a problem area is important enough to warrant trying to initiate a series of projects in that area even if none are currently being supported. In these cases, the SPC has usually asked the Marad Shipbuilding Research Office to organize efforts to initiate these projects. Two primary examples are the Ship Producibility Program,\(^1\) which is just getting underway with its first set of projects, and the Marketing Program. Marad has tried to generate some worthwhile projects in the marketing area but, so far, has not been successful.

Marad's usual approach to developing an initial set of projects is to convene a three-day conference involving shipyard representatives and technical experts. "Our approach for developing projects," Higgins says, "is to get the people living with the problems to talk with the experts." Indicative of Marad's management philosophy in the Shipbuilding Program, conference agendas are determined entirely by the participants, with Marad sitting on the sidelines acting only as conveners. Higgins says that letting the participants control the meeting is critical to producing good results. "It usually takes a day," he says, "before they really believe that we don't have a hidden agenda of our own ideas about how the program should go that will be sprung on them sometime in the meeting. It's when they begin to realize that we don't have an agenda and don't what to control the meeting that they really begin to work."

However, on occasion Marad has taken the lead in developing a program area, which is another way that priorities have been influenced in the Shipbuilding Research Program. One example is the Research and Engineering into Automatic Production of Ships Program (REAPS), which involves ways of using computers and numerically controlled machines to automate the cutting of steel in shipyards. For over two

\(^1\)The Ship Producibility Program will involve developing basic ship designs that are easier to produce.
years the Navy has been trying without success to get the shipyards to adopt an automated system that a Navy contractor had developed. Marad thought that such a system could save the yards a lot of money, but saw problems in the Navy's system and its approach to getting the yards to use it.

Marad thought that, in general, the Shipbuilding Research Program should be devoting more effort to the whole area of applying computers in ship production and decided to convene a three-day conference on the subject. As a result of this conference, several ideas for projects emerged that eventually led the SPC to establish a Computer Aid to Shipbuilding Committee Panel. Contrary to the Shipbuilding Research Office's usual policy, it suggested one of these ideas: a demonstration in U.S. yards of the best commercially available computer system for controlling numerical cutting machines. Since all agreed that there were foreign systems better than all U.S. systems, the plan was that the government would buy an exclusive license for the best of these foreign systems and lease rights at lower cost to any U.S. yards willing to install one.

Five yards expressed an interest in this idea, and Marad subsequently worked with them to develop a project. The project turned out to have a much more ambitious objective than simply buying and demonstrating commercially available computer systems for controlling numerically cutting machines in the five yards. It was decided to design a fully automatic system for the conversion of plans for whole sections of ships into cut steel. This system, based on a computer system produced by Norway which was judged to be the best on the market for shipbuilding, must be fed with the dimensions of each of the plates to be cut. In the more fully automated system that the five yards decided to develop, specifications for the shapes of whole sections of a ship would be fed into the computer which would then calculate plate sizes and direct the numerically controlled cutting machine. The project was also to include the development of users' manuals and training programs for the new system. This project became what the Marad Shipbuilding Research Office calls its Research and Engineering into Automatic Production of Ships Program.
on which about $1 million per year is spent.\textsuperscript{1}

In summary, priorities are changed in the Shipbuilding Research Program mainly through efforts by the Marad Shipbuilding Research Office to convene conferences of shipyard production staff and technical experts to generate projects in problem areas that are important but in which not much activity is being supported. Again, the process is largely bottom-up, in the sense that a new priority will not emerge unless working-level professionals can come up with some solid project ideas, but with the top-down overlay of decisions by the SPC or Marad to convene these conferences and formally establish new technical panels and program categories.

\textbf{Diffusion Mechanisms}

Diffusion into the shipbuilding industry of the various innovations contained in projects supported mainly occurs through processes that are naturally built into the organizational structure of the program; however, there are also some managed dissemination activities.

\textbf{Technical Reports}

One of these managed activities is that all projects are required to produce a final report describing their results. Program managers are responsible for sending these reports to selected production managers in every shipyard. Usually, a note is attached to each report requesting that the manager distribute it among his technical staff.

\textsuperscript{1}This fully automated system is a significant project for the Shipbuilding Research Program to undertake because the innovation requires a redistribution of the workload in a shipyard. With full computer control, it is possible to cut steel so accurately that in final assembly there is much less need for trimming and fitting. But, the design department has to put much more effort into specifying the exact dimensions of a ship's cross sections and surfaces. An innovation that has this kind of organizational implication is typically less likely to be adopted and is more difficult to implement than an innovation that does not have organizational implications. But there is research that suggests that the implementation of an
Dissemination Networks

Marad is finding that the SNAME committee structure is a more effective means for disseminating information about the Shipbuilding Research Program as well as other agency news and technical information than their own Office of Public Information. Marad sends information releases to SNAME, which then distributes them under its own letterhead. SNAME has been enthusiastic about providing this service and is paying the costs.

Demonstrations

Program managers are also responsible for organizing a shipyard demonstration upon the completion of each project. Notices are sent to all of the shipyards in the country, inviting them to send representatives to these demonstrations. Typically, between 100 and 200 show up for each demonstration. The shipyards pay all of the expenses of those who attend.

Marad staff have found that these demonstrations are more effective than the reports sent out in persuading the shipyards to adopt project results. The director of the Shipbuilding Research Office said: "We find that the shipyard people don't believe in reports. They think that reports can be written to make them come out any way you want them to. Remember, these are production people. They want to see something new with their own eyes and to see it working in a place that's just like their own." He called this attitude of shipyard personnel a "kicking-the-tires syndrome." These representatives have to believe strongly enough in an innovation to risk persuading their supervisors to try it.

innovation that entails organizational implications is more likely to be successful if the adopting organizations develop (or redevelop) the innovation themselves. Thus, it is more likely that the participatory approach of the Shipbuilding Research Program will result in the successful implementation of innovations that have organizational implications than an approach where these kinds of innovations are developed by outsiders and then made available to the shipyards. (Berman and McLaughlin, 1975.)
Adoption by the Project Performer

Because many of the projects supported are performed by individual shipyards, one of the diffusion mechanisms built into the Shipbuilding Research Program is that a yard may decide to continue its project and expand it into its entire facility. This does not always happen, but it frequently does.

Marketing by Suppliers

Because most of the equipment projects supported are performed by current or potential suppliers to the shipbuilding industry, these projects also have a built-in diffusion mechanism. These suppliers market the equipment that they have developed to shipyards and, in some cases, to other industries. Marketing by supplier firms may be the most important of all the diffusion mechanisms functioning in the Shipbuilding Research Program.

The patents on equipment developed by suppliers are held by the federal government, as required by Commerce Department policy. Also in conformance with Commerce's policy, these patents have been placed in the public domain, which means that suppliers do not have to pay royalties but, on the other hand, do not have any market protection. As a result, most of the larger firms currently supplying the industry have not been bidding on project RFPs. Most of the firms that have been selected to perform projects are small or have never been in the shipbuilding market before.

Top-Level Support

Another aid to diffusion built into the Shipbuilding Research Program is having the top-and mid-level managers and engineers on the panels. Because of their positions, these managers and engineers have ideal opportunities to implement project results. Furthermore, their involvement in the origination and management of the projects supported carries an implicit commitment to implement the results; otherwise, the question arises of why the project was supported in the first place. Because all the major yards are represented on the committees and panels, there is typically at least one employee in
every shipyard who has been involved with each project.

**MARAD PHILOSOPHY**

As the discussion above reveals, Marad has granted the shipbuilding industry much more participation in the management of the Shipbuilding Program than simple consultation. Through the system of having technical committees and program managers come from within the industry, shipyard personnel have real control over the directions and activities of the program. Great care is taken to avoid any appearances that Marad knows what is best for the program or has an agenda of priority projects. Marad influences the program only through the mechanisms of retaining authority to review project proposals and to organize efforts to generate projects in new program areas. Higgins strongly believes that the federal government's usual approach of defining projects, hiring outside contractors to perform the desired work, and then expecting the industry to use the results is ineffective. "Too often," he says, "federal staff try to use a program to make a name for themselves rather than produce results. When this happens, it is clearly perceived by the industry and you lose them. We try hard to guard against our staff behaving in this way."

**Quality of the Technical Committees**

In line with this philosophy, the Shipbuilding Research Office does not interfere in any way with the operations of the SPC and the technical committees in SNME. Staff of the Office attend most meetings of the technical committees and participate in discussions both during and after formal meetings, but carefully avoid advocating particular policies or changes in committee operations. The Office fully expects that the committees will go through periods of strength and weakness as their memberships shift and good ideas for projects are exhausted, but it has no intention of ever directly intervening to correct problems that arise. For example, the Standards and Specifications Committee continued for some time after the beginning of the Shipbuilding Research Program to operate in the traditional manner of a
panel in a technical society and did not submit any projects to the SPC. This changed only when the original chairman of the committee left and a new one was appointed by the SPC. Now the committee is involved in projects in the Ship Producibility Program and operates as an effective participant in the Shipbuilding Research Program. The Office made no attempt to remove this chairman from his position or to be involved in the appointment of his successor.

Cost-Sharing

To guard against the industry's taking advantage of this freedom, the Office has a policy of requiring cost-sharing on projects and committee activities. Marad pays all the direct costs of projects (i.e., contractor costs and the salaries of program managers) but expects individual firms to pay committee members' expenses and the overhead costs of program managers as well as to provide facilities for any projects conducted in shipyards. It is estimated that these costs are between 50 and 100 percent of the direct costs. One of the main purposes of cost-sharing is to assure that only the projects that clearly will have positive value to the shipbuilding industry will be supported. The technical committees and the SPC have discontinued three projects before their planned lifetime because of poor results.

OASD decided to use this form of cost-sharing in order to minimize the amount of paperwork involved in managing the program. If industry contributed a share of the direct costs, then regulations would require that program managers would have to keep two sets of books that would have to be almost identical: one for the government account and one for the industry account. For small projects supported in the program, OASD thought that keeping two sets of books would be unnecessarily burdensome; therefore, the simpler method of the government paying all direct costs of contracts but no overhead was adopted.

Industry-Supported Consortium

The Shipbuilding Research Office considers that the program's ultimate success will be when the industry decides to take over the funding of the entire program. The Office is not currently pressuring
the industry to take over program financing, but it is taking a step
towards this in the REAPS Program. In setting up the REAPS Program,
Marad reached a written agreement with the five yards that, over a
period of five years, they would gradually assume the financing of
the whole program. No specific agreement was reached on the rate at
which industry payments would increase except that by the end of five
years industry would be paying 80 percent of the total costs. Although
this project is only two years old, the five shipyards have thus far
contributed a larger share of the costs each year. The Shipbuilding
Research Office hopes that this project will serve as an object
lesson in how the industry can cooperate in the support of innovative
projects.

Higgins believes that the initiative for the industry's taking
over the Shipbuilding Research Program (or forming their own program)
must come from within the industry rather than the government. In
his opinion, as the SPC and the technical panels become stronger, and
as the industry develops more confidence in the cooperative approach,
the industry will want more control and will be able to achieve this
only if it provides its own funding. He predicts that this will
happen in three to four years.

Support for the Program in Marad

The Shipbuilding Research Office has had some problems with top-
level administrators in Marad and the Department of Commerce who have
criticized the program as mundane and not doing much for these agencies
because the projects are so small and nuts and bolts oriented. One
of the Marad staff members who was interviewed for this case study
said that it was mostly the "program-types" in these agencies who
felt this way and not budget staffs. He said, "If it doesn't fly
ten feet off the water and go 150 miles per hour, they [the program
types] don't want to hear about it". This quotation offers further
illustration of how the attitude of the Shipbuilding Research Program
is different from that of the usual federal approach.
IV. WELDING PROGRAM

The kinds of activities supported by the Shipbuilding Research Program are best described by explaining the projects that have been supported in one of the program areas. The Welding Program has been selected.

PROJECTS IN THE WELDING PROGRAM

The Welding Program started with projects in two main areas: one-sided welding and welding equipment. Since then projects have developed in two other areas: welding standards and new welding technologies. A flow graph of the development over time of the Welding Program appears in Fig. 4.

One-sided Welding

In the first year, two projects were started in the area of one-sided welding, a method of joining together the large steel plates that are used to form a ship's hull. The Japanese use one-sided welding extensively, but American yards have not used it at all. The conventional method is two-sided welding, where plates are joined together by welding them first on one side and then on the other. One-sided welding reduces the number of welds that have to be made and eliminates the need for turnover apparatus, but it requires welding through greater thicknesses. To weld through greater thicknesses, special fluxes are needed, and the Japanese have not been willing to sell them unless a purchaser also buys their one-sided welding equipment and other supplies. For one-sided welding to develop in the U.S., the Welding Panel saw the need for a domestic supply of the required special flux and, consequently, supported a project to duplicate the Japanese flux.

Another project was to develop a vertical-butt, one-sided welding machine with capacity to weld not only vertically but also at all off-vertical angles and horizontally. Such a machine is mainly used in the dry dock to join together preassembled sections of a ship's hull. Existing vertical-butt welding machines were not capable of using high
were not reliable, and would not weld at all angles. The Welding Panel members had some ideas on how to achieve improvements. Consequently, a project was started to develop a new vertical-butt welding machine.

The contractor was successful in producing a machine that welds satisfactorily (i.e., produces welds that meet minimum standards) in the vertical positions, but it did not work well enough at other angles. In assessing whether or not to continue development to bring this machine's off-vertical capability up to standard, the Welding Panel came to realize from their recent experience with building super-sized ships\(^1\) that off-position capability was not as important as they originally thought because most of the welds on super-sized ships are either true flat or vertical. A decision was made to modify the carriage from the existing machine and use it to construct a welding machine small enough to pass through the drainage holes inside ships and make one-sided, down-hand welds from the inside. Avondale shipyards offered to conduct this project and proceeded on its own (at no cost to Marad) to work with the original contractor and other shipyards to develop this machine. It is now finished, has been demonstrated, and is being marketed by a supplier.

In the course of developing and perfecting this machine, Avondale and Bethlehem have had to experiment with various edge preparation techniques, backing materials, and electrodes to find the best combinations. The 3-M company was contacted, and it agreed to produce backing tapes. Other manufacturers have agreed to develop the needed electrodes. Other ideas on how to improve the machine have been suggested from many sources, including the Welding Panel, other shipyards, and the original contractor. The resulting machine has better performance and reliability than any other machine currently on the market. Thus, the vertical-butt welding machine project has lead to considerable supplier industry participation.

The Panel's experience with the vertical-butt welding machine project suggested a need to re-examine the standards for vertical and horizontal electroslag and electrogas welds in high-tensile ship steels and

\(^{1}\)U.S. builders were not making super-sized ships in quantity when the vertical-butt welding machine project was started.
Butt-welding machine being marketed

Technology for making one-sided butt-welds from the inside of ships

Institute new standards

Develop standards for welds in LNG ships

Reassess standards for electroslag and electrogas, horizontal and vertical welds

Butt-welding drive carriage produced with horizontal capability only

ONE-SIDED WELDING

WELDING STANDARDS

(+): Funded projects
(-): Unfunded projects (conducted by shipyards or supplier firms)

Fig. 4—Project and outcome history
Market high deposition electrodes

(+)
Develop high deposition electrodes

Lightweight power supply to be marketed

(+)
Develop second generation power supply

(-)
Shipyard test of wire feeder

(+) Develop improved plasma cutting machine

Market plasma cutting machine

Develop laser welding machine

Firecracker electrodes to be marketed

Gravity electrodes being marketed

(-) Develop gravity feed electrodes

(+)
Develop lightweight power supply

(+)
Develop continuous wire feeder

WELDING EQUIPMENT

NEW WELDING TECHNOLOGIES

(+)
Assess feasibility of laser welding

of projects in welding program
at high stress points in regular steels. It appeared that the standards were overly conservative and severely restricted the maximum tolerable head speed of the welding machine. As a result, ABS was awarded a project to conduct tests on these welding standards and make recommendations for changes. A report will be available shortly.

As a result of all these activities, there will soon be available a whole new welding machine and the associated production techniques and standards for making one-sided welds from the inside of ships.

Welding Equipment

Another project of the Welding Panel has been to develop a lightweight power supply for field welding. Power supplies currently on the market weigh over 500 pounds. The use of solid-state devices and electronic techniques offers opportunities for substantial weight reduction. The contractor's first design, although satisfactory in most respects, was too costly to be competitive. When some new solid-state rectifiers became available on the market, the Welding Panel decided to try again. This time the contractor was successful and produced a machine that outperforms existing power supplies and weighs less than 60 pounds.

Another idea was to develop an automatic, continuous-wire feeder for field welding which would enable welders to work for long periods of time without having to make frequent trips to resupply themselves with welding rods. The Hobart Company responded to the panel's RFP with an indication that it already had patents on a motor and drive system for a continuous-wire feeder that could be employed in shipyards if redesigned and repackaged. The Panel didn't know that this capability was available until the RFP response. A decision was made to award Hobart a contract to develop a continuous-wire feeder for shipyard applications. This machine has been field-tested in two shipyards and is now being marketed.

A third idea was to develop a gravity-feed electrode similar to what is used in some foreign yards. Hobart also responded to this RFP, and again indicated that it had the technology ready to produce what the Panel wanted. Hobart offered to develop and test it using its own funds, provided that the Panel could indicate that there would be sufficient demand for the project from the shipbuilding industry to make a profit. The Panel provided sufficient data to convince Hobart to proceed.
Subsequently, the Panel has pursued the development of two other kinds of electrodes: first, a firecracker electrode, and later, a new type of high deposition electrode. The idea for a project to develop a firecracker electrode was suggested by someone on the Welding Panel who had heard about a process developed by Batelle for welding vanes inside rotary pumps and thought it might be useful in shipbuilding. At a later time, the panel discovered that European companies manufacture an electrode that deposits more metal more efficiently than American-made electrodes by using more iron powder in the coating. A project is now underway to develop an American-made high deposition electrode for both manual and automatic welding processes.

**New Projects**

The Welding Panel has recently supported a project to assess whether or not lasers can be used to produce standard welds and will follow-up with additional developmental products to ascertain costs and estimate production schedules for the necessary equipment. A second project will be to assess standards for liquid natural gas ships which are becoming a major market for the shipyards. Third, the Welding Panel will support a project to improve the reliability of plasma cutting machines which are on the market but which have problems in shipyard applications.

**TRENDS IN PROGRAM ACTIVITIES**

The Welding Program exhibits some of the trends over time in project activities that the Shipbuilding Research Office has noticed characterize the panels that are performing effectively.

**Increasing Sophistication**

One of these trends is that, as a panel matures, it begins to consider technologies that are more sophisticated and advanced (e.g., laser welding) than those they considered initially. At first, the panels tend to suggest "catch-up" kinds of projects to duplicate a foreign technology or modify an existing device for shipyard application. But, as the panel matures, more developmentally oriented projects, with potentially more significant long-run consequences,
begin to emerge. A problem that the Shipbuilding Research Office sees is that, as the committees move into more advanced technologies, they will have more difficulty thinking of and developing projects. As the panels mature, the Office believes that it may be necessary to bring the panels into contact with greater numbers of research experts.

**More Concern with Production Methods**

A second trend is to support increasing numbers of projects concerning production methods and standards. These often are more controversial and difficult to implement than machinery and equipment innovations, but they potentially are very important in increasing shipyard productivity.

**Supplier Participation**

A third trend is toward more complex projects that may involve a shipyard working with a number of vendors or several shipyards working together to develop a whole system. The machine for one-sided welding from the inside of ships is an example of this.

**DIFFUSION FROM THE WELDING PROGRAM**

Although the Welding Program has not existed long enough for much diffusion of project results to have occurred, a summary of the current status can be given. This summary appears in Table 6. In general, all of the welding projects that have been finished have resulted in a product that will be marketed by a supplier firm. Some of the yards are already making use of the products that have completed final testing.
**Table 6**

**DIFFUSION OF TECHNOLOGY IN THE WELDING PROGRAM**

<table>
<thead>
<tr>
<th><strong>One-sided Welding</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flux for one-sided welding:</td>
<td>Will be marketed by Linde. The cost is high now because of limited demand.</td>
</tr>
<tr>
<td></td>
<td>The Sun Shipyard will organize a new production facility around one-sided welding.</td>
</tr>
<tr>
<td></td>
<td>Because the flux and a one-sided welding machine are now available domestically, other yards now have the option of organizing new facilities around one-sided welding.</td>
</tr>
<tr>
<td><strong>Vertical-butt welding machine:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Two sold, ten on order. Flux will be used.</td>
</tr>
<tr>
<td></td>
<td>Final product being marketed by Gilliland.</td>
</tr>
</tbody>
</table>

**Welding Standards**

| **New standards for electroslag and electrogas welds:** | Final report complete. |
| **Standards for Liquid Natural Gas ships:** | Project still being developed. |

**Welding Equipment**

| **Gravity-electrodes:** | Being marketed by Hobart. |
| **Lightweight power supply:** | Celesco is building a production line for 200 units per month. |
| **Continuous-wire feeder:** | 1,000 small models sold in first eight months; 50 large models on order. |
| **Firecracker electrodes:** | Project complete. |
| **High deposition electrodes:** | Project being developed. |

**New Welding Technologies**

| **Plasma-cutting machine:** | Project complete. |
| **Laser weld:** | Feasibility study completed. |
V. ORGANIZATIONAL CHANGES

The purpose of this section is to describe some of the organizational changes that the Shipbuilding Research Program is apparently causing in the shipbuilding industry. Although it is too early in the program to make a complete assessment, the indications are that these organizational changes may in the long run increase the shipbuilding industry's capacity to innovate. This increase could be more important for innovation than the specific technical changes that may result from the individual projects supported.

In general, these organizational changes are being caused by the Program as a whole rather than by individual projects. As indicated by the discussion at the end of the previous section, individual projects are having mainly technological effects.

INTRA-INDUSTRY COOPERATION

The most tangible organizational change in the shipbuilding industry is the creation of the SNAME committees and their involvement in generating and managing funded projects. The SNAME committee structure actually came into existence before the Shipbuilding Research Program began, but the Program has changed the way that the committees operate. Before the Shipbuilding Research Program started, the committees were functioning in the usual manner of technical society groups by sponsoring symposia, presentations of technical papers, and panel discussions.

Active Industry Support

A less tangible although far more important organizational change has been the increasingly active industry participation in the SPC, the

1The contents of this section are based on conversations with Jack Garvey and Robert Schafferon of the Shipbuilding Research Office, and with William Brayton, Welding Program Manager at the Bethlehem Shipyard.
technical panels, and the projects supported. Now, the SPC and the panels (at least most of the panels) are problem-solving groups involved in figuring out ways of improving productivity in shipbuilding. Through the committee structure, there is now more discussion of problems common to companies in the shipbuilding industry and more sharing of technical information. Furthermore, as described in the section on the Welding Program, shipyards are beginning to develop their own innovative projects that are either extensions of projects that the SPC has supported or are entirely new ones. James Higgins believes that the industry is becoming much more confident about cooperative research than it was in the beginning and is learning a great deal about how to manage it.

When the SPC and the technical committees first began, the participants were reluctant to discuss their common problems and to trade technical information. As discussed earlier, these attitudes were the product of the protective climate within the industry. Gradually, however, the barriers have come down, and now the participants are very eager to share information and discuss problems.

**Professional Communications**

One effect of the technical committees has been to change the relationships among production specialists in the shipyards. Prior to the formation of these committees, production specialists seldom attended SNAME meetings and tended not to know who their counterparts were in other shipyards. In fact, as discussed above, shipyards tended to discourage their employees from attending professional meetings by not providing funds for travel and by forbidding them to discuss their work with employees of other companies if they did go to technical meetings. ¹ Because of the technical panels in the Shipbuilding Research Program, production specialists in different yards have gotten to know each other and are contacting each other much more frequently.

The changes in relationships among colleagues brought about by the Shipbuilding Research Program are greater in some areas of shipbuilding

¹Conversation with Mr. Jack Garvey.
than in others. The greatest area of change is among outfitting, machinery, hull, and shop superintendents, who were rarely represented in SNAME and had no opportunities to meet their counterparts in other companies. Through the technical committees, these professionals now have a chance to speak with each other and communications networks are developing. In contrast, welding engineers have their own professional society and have traditionally been more close-knit. Welding is one area of shipbuilding where the industry has been near the forefront of technology.

Information Gate-keepers

Another kind of change in professional communication patterns that is beginning to occur is that some of the program managers in the Shipbuilding Research Program are becoming information "gate-keepers"\(^1\) in their specialty area of shipbuilding. That is, engineers in the shipyards are beginning to call these program managers with requests for information on new equipment and techniques, recommendations of who can help them with problems that they are having, and so forth. Officials in the Shipbuilding Research Office cite this as one of the more important effects of the Shipbuilding R&D Program and believe that it depends on the program managers being shipyard personnel and not federal staff.

Antitrust Law

Despite this increased technical cooperation and the innovations that have been produced, there is no indication that the industry is interested in completely taking over funding of the program. Marad is trying to lead the industry up to this step with the REAPS program, but, thus far, there are no indications of willingness to proceed. Fear of antitrust laws is apparently still a major barrier to industry funding of a cooperative program. The initial reluctance of the shipyards to participate in a joint research program funded by the government has been broken down, but the companies are still very leary of participating in committee meetings unless a representative of the Shipbuilding Research Office is present.

\(^1\)The role of gate-keepers in the innovative process has been carefully studied by T. J. Allen, 1969.
From conversations with the Shipbuilding Research Office staff, it is clear that they are also still very concerned about the antitrust issue. However, their concern has not led them to force a test of the law as it applies to the Shipbuilding Research Program. They naturally prefer to keep a low profile, having a higher priority on continuing with the program than risking its future by raising the antitrust issue.

In summary, the Shipbuilding Research Program has changed shipyards' perceptions of what is permissible under antitrust law, but has not resolved all the uncertainties.

**Competitiveness**

Other reasons for the industry's lack of interest in assuming funding of the Shipbuilding Research Program are less clear. One factor may be that, as long as the federal government is willing to fund the program, there is no particular reason why the industry should assume the burden. Another factor is the problem of how the industry could compel all the major firms to participate if joint funding were attempted. Because all firms would have access to most of the innovations produced by the Shipbuilding Research Program, whether or not they participated, there would be no strong incentive for any one firm to continue contributing its share. And, if firms started dropping out of an industry-funded program, the question of whether some firms were being excluded could be raised. This question would place the remaining firms in a tenuous position with regard to antitrust. The Shipbuilding Research Office has informally discussed the desirability of the industry taking over funding of the program with members of the SPC and others and the SPC did decide at one point to establish a position for a coordinator who would have responsibility for organizing industry funding; but, no other concrete steps have been taken.

The Shipbuilding Research Office has also funded a small study of the shipbuilding research consortia operating in foreign countries and made the results available to the U.S. shipbuilding industry in an effort to further suggest that the industry should take over the program. This study had little discernable effect.
SUPPLIER FIRMS

The visibility of the Shipbuilding Research Program and the contacts developing between projects and suppliers are beginning to reorient these suppliers into being more responsive to the needs of shipyards. The kinds of changes that are occurring include the assignment of specific salesmen to shipbuilding accounts, the establishment of shipbuilding as a marketing objective, and the assignment of expeditors to shipbuilding orders. Vendors are beginning to make presentations at meetings of the technical panels and to ask about needs of the industry. Some of the panels have been visiting the facilities of their supplier firms and holding meetings there. One particular example is in the area of surface preparations and coatings. Formerly, these suppliers catered to the ship operators for their business, but now they are beginning to contact the production departments in shipyards.

Another kind of change is that the shipyards are finding new sources of supply. This is happening through the RFP process as firms bid on projects. The firms that are being found tend to be much smaller than the shipbuilding industry's traditional suppliers, but much more competitive because of their need for business.

REGULATION

The representation of the Coast Guard and the ABS on the technical panels is one of the most significant aspects of the Shipbuilding Research Program. Both the program managers and the Shipbuilding R&D Office say that the reorientation of these representatives to a more positive and constructive approach to regulation is one of the most significant results to date of the Shipbuilding Research Program. By participating in technical panel meetings, personnel from the Coast Guard and the ABS can see first hand the effects of regulations on the shipbuilding industry and better ways of achieving the objectives of regulation.

SHIP PRODUCTION STANDARDS

On their own initiative, the SPC and the technical panels are beginning to consider ways of establishing production standards for the
shipbuilding industry. In particular, as a trial effort to explore various ways of establishing standards and to gauge industry's acceptance of the idea of standards, the Ship Producibility Committee has funded a study to develop standards for deck machinery. The Ship Producibility Panel has also decided to join the American National Standards Institute and the International Standards Organization as a way of finding out ways of setting standards. The Shipbuilding Research Office thinks that if these initial efforts are successful, the whole idea of production standards may "take off" because there is a lot of interest in it among the panels. The problems are formidable: decisions have to be made on what kind of standards to set (envelope, interface, or performance standards), how detailed to make them, and what procedures will be set up to modify them.

"SOFT-STUFF"

The formation of the Ship Producibility, Manpower and Motivation, and Marketing Panels is evidence that the SPC and the technical panels are becoming confident enough in their efforts to take on what the director of the Shipbuilding Research Office calls the "soft-stuff" in ship production. He says that nobody else in the industry is talking about things like manpower and motivation: "the companies won't touch the subject with a ten-foot pole." These developments are evidence that the SPC and the panels are moving beyond their initial efforts, which were mostly equipment development projects, to more complex and less tangible kinds of innovations.

INNOVATIVENESS

One of the more significant hoped-for effects of the Shipbuilding Research Program would be less conservatism among shipyards in trying innovations in their production methods and ship design, but no evidence that would support this hope could be found.
VI. CONCLUSIONS

PROGRAM STRATEGY

The strategy of Marad’s Shipbuilding Research Program is strikingly different than the strategies of other federal demonstration programs.

One important element of the strategy is decentralization of responsibility for program management from the federal government to the level of working professionals in the industry. This has been accomplished through the establishment of a shipbuilder's consortium where technical specialists representing all the major firms and the industry's two major regulatory agencies are involved in generating projects, deciding which should be supported, and monitoring performance. This decentralized structure provides a number of advantages: because all the major shipyards are represented, the projects supported meet industry-wide needs; because working level professionals are involved, the projects take into account the practicalities of shipyard operations; and because representatives of regulatory agencies participate, opportunities are opened up for developing innovations that might ordinarily be blocked. Marad has retained only authority to review and approve projects before funding, and it acts only in indirect ways to influence priorities. On paper and in reality, the program belongs to the industry and is only as beneficial to them as they make it.

Another important element of the strategy is that most of the projects involve innovations that will produce incremental improvements in shipyard productivity, rather than revolutionary change. These incremental improvements involve less risk than revolutionary innovations and can be implemented much more quickly because they fit easily into existing production processes. But even though individual projects involve incremental change, they are interrelated and cumulative technical progress of substantial proportions results. The decentralized management structure is probably critical to achieving this effect.

Another important element of the strategy is that a wide range of R&D activities from research-oriented work through exemplary demonstrations can be supported in an integrated way. The same personnel responsible for
developing and testing innovations are responsible for demonstrating and diffusing them. In fact, there is little differentiation of projects by type of R&D activity within the program. The decentralized management structure provides numerous built-in diffusion mechanisms.

One last element of the program strategy is that Marad sees organizational changes such as increased industry willingness to innovate, to tackle more difficult problems, and to cooperate as the most important payoffs of the Shipbuilding Research Program. In order to foster these kinds of changes, Marad emphasizes to the consortium that they are responsible for the success of the programs and tries to create environments that facilitate innovation rather than dictating to the industry what should be done. Any appearance that Marad is trying to take credit for the programs' successes is studiously avoided. Marad believes that getting organizational change will require sustained effort, that a large number of small steps will have to be taken to achieve success, and that heavy-handed government interference would be self-defeating.

**PROGRAM ACCOMPLISHMENTS**

Although the Shipbuilding Research Program is only four years old, there are numerous signs that this strategy is working.

One important change, one easy to overlook at the current stage of development of the Program, is that it represents the first significant R&D activity in the maritime industry in the area of ship production. Prior to the Shipbuilding Research Program, neither the shipyards nor the Maritime Administration supported much R&D activity. Furthermore, equipment suppliers, an important source of technical change in many industries, were not generating many innovations. Shipyards had low status in the maritime industry; ship designs were specified by shipowners and naval architects rather than by the shipyards, and the production managers and engineers in the shipyards were not active in the maritime industry's principal professional association. Now this situation has changed: Congress has approved Marad support of ship production R&D; the shipyards are beginning to support their own innovative projects (often based on projects supported through the Shipbuilding Research Program); most of the committees of shipyard managers and engineers in the
consortium are highly active,\textsuperscript{1} consideration is beginning to be given to considering ship designs that permit more mass-production methods to be used; and equipment suppliers are beginning to respond to the shipbuilders' needs. In short, there have already been some important organizational changes in the shipbuilding industry that promise a higher level of innovative activity in the future.

Another kind of organizational change that is occurring is that because of the consortium, the Shipbuilding Research Program is bringing into contact shipyard professionals who previously have not had much opportunity to talk to each other. These contacts are increasing lateral communications within the industry which may have considerable value in stimulating more innovation than will be directly supported by the program. Importantly, several of the industry personnel whom Marad has selected as program managers (who are employees of and located in the shipyards) are becoming information "gatekeepers" in their technical area of ship production. Research on the role of information gatekeepers has shown that they are important to the innovative process.

In effect, the consortium that has been established through the Shipbuilding Research Program is providing a system for technical communications that previously did not exist within the industry. This consortium serves simultaneously as a focal point for communication between professionals and as a base of operations for the program managers who are becoming information gatekeepers. As a bonus, the consortium is also beginning to serve as a channel for disseminating Marad technical reports and notices.

The participation of the regulatory agencies as working members of this consortium is apparently also producing change. Primarily, the regulatory agencies are beginning to reconsider some of their regulatory policies and to take a more constructive approach to regulation.

The benefits of the participatory approach of the Shipbuilding Research Program are nowhere clearer than in the initiative that the consortium is taking to consider production standards for shipbuilding; for years, the industry has resisted setting ship-production standards.

\textsuperscript{1} Because a group of managers and engineers from the shipyards had already formed these committees prior to the beginning of the Shipbuilding Research Program, the program is not the only cause of this increase in the level of professional activities. However, the Shipbuilding Research Program provided these committees with a raison d'être that caused them to reorient their mode of operation.
In addition to all these organizational changes, there is evidence that the technological innovations produced by individual projects are beginning to be used in shipyards, although few of these innovations have been available long enough for one to make a complete assessment of their usefulness. The strongest evidence of success is that all of the equipment innovations produced in the Welding Program (which is a component of the Shipbuilding Research Program) are being marketed by equipment suppliers and the earliest ones are selling well.

LIMITATIONS ON SUCCESS

However, despite these promising changes, there are some important limitations on how much overall effect the Shipbuilding Research Program is having on the industry.

One limitation is that the consortium will probably have to be funded at a much higher level before fundamental changes in the industry can be realized. In relation to total industry revenues of approximately $4 billion for commercial ship construction since 1970 (see Fig. 1), the Shipbuilding Research Program has been funded at a level of only $14 million. This is less than .02 percent of industry revenues.

Another serious limitation may be the lack of incentive for cost-cutting in the shipbuilding industry due to the structure of federal subsidy programs. With greater incentive to cut the production costs, the demand for innovations of the types produced by the Shipbuilding Research Program would probably increase. The Shipbuilding Research Program itself can have little effect on the structure of these federal subsidy programs.

Nor can the Shipbuilding Research Program alone stabilize the market for U.S.-built ships or enable U.S. shipbuilders to sell series production runs of ships. However, any increases in shipyard productivity resulting from the innovations produced through the projects supported will contribute marginally to reducing these two major barriers to increased productivity.

RATIONALE FOR A FEDERAL ROLE

Perhaps the most significant lesson learned from the Shipbuilding Research Program is the need for cooperative research rather than for participation by the industry in a federally supported program or for
federal support of individual R&D projects. It is the joint activity of industry professionals coming together to work on technical problems that is leading to all the organizational changes and the technically successful projects.

Skeptics might ask, if the organizational and economic benefits of cooperative research are so great, why has the shipbuilding industry not taken action before to establish a cooperative research program? These skeptics might add: what is the rationale for federal support of cooperative research? Isn't the industry in a better position to judge what is valuable to it than the government is?

On strictly economic grounds, there is a rationale for federal support of R&D in shipbuilding in that the cost/benefit ratios of projects are higher when they are supported collectively; but such a calculation does not take into account that there may be strong organizational barriers to cooperation that governmental intervention can reduce. These organizational barriers include: the extreme climate of protectiveness that had existed in the industry for years, which translates into a belief on the part of individual firms that they would never be able to cooperate with each other on R&D; the tradition within the industry of shipbuilders not having much say in the design of ships and the consequent lack of industry experience with managing R&D; the lack of support within the industry for professional activities; and overly conservative interpretation of antitrust law. The Shipbuilding Research Program apparently is causing changes that will reduce these barriers. Eventually, the time may come when the industry decides to form its own research consortium. If so, then federal intervention through the Shipbuilding Research Program will be shown to have eliminated these organizational barriers—a change that cannot be accounted for by standard economic theories.

A CONCLUDING NOTE

Marad recently has been approached by the chairman of the American Institute for Merchant Shipping (AIMS), an association of ship operators, with a request for assistance in establishing an R&D program in his organization similar to the Shipbuilding Research Program. The chairman had heard about how much the Shipbuilding Research Program was
accomplishing and thought that his industry could benefit greatly from a similar program. Marad is now working with AIMS to establish a cooperative program, including the provision of funds. Many of the same problems that initially occurred in the Shipbuilding Research Program are being experienced again. After a year of work, there is still a great deal of reluctance within the industry to participate; but progress is now beginning to be made. James Higgins says that he is amazed how similar his experiences have been in the AIMS program to what they were in the Shipbuilding Research Program.
BIBLIOGRAPHY


Message to the Congress on Science and Technology, President's Office of the White House Press Secretary, March 16, 1972.


FISH PROTEIN CONCENTRATE PLANT

by

Edward Merrow and Walter S. Baer
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<th>Abbreviation</th>
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<tr>
<td>AID</td>
<td>Agency for International Development, Department of State</td>
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<td>BCF</td>
<td>Bureau of Commercial Fisheries, Department of Interior</td>
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<tr>
<td>EDP</td>
<td>Experiment and Demonstration Plant</td>
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<tr>
<td>FDA</td>
<td>Food and Drug Administration, Department of Health, Education and Welfare</td>
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<td>FPC</td>
<td>Fish Protein Concentrate</td>
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<td>GSA</td>
<td>General Services Administration</td>
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<tr>
<td>IPA</td>
<td>Isopropyl alcohol process for the extraction of fish protein</td>
</tr>
<tr>
<td>LDC</td>
<td>Less Developed Countries</td>
</tr>
<tr>
<td>MSC</td>
<td>Marine Sciences Council--National Council on Marine Resources and Engineering Development</td>
</tr>
<tr>
<td>NAS</td>
<td>National Academy of Sciences</td>
</tr>
<tr>
<td>NMFS</td>
<td>National Marine Fisheries Service, Department of Commerce</td>
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The world presently harvests only a fraction of the estimated maximum sustainable yield of ocean fish. Among the primary reasons are that fish are difficult to store and transport without spoilage, and that most ocean fish are too small or too bony to make usable solid portions for human food. Consequently, developing a stable, concentrated food from fish would increase the number of fish species used for human consumption and make available additional sources of protein to a hungry world.

The idea of processing fish directly to produce a fish protein concentrate (FPC) dates back at least to the 19th century, but serious research in the U.S. can be traced to the efforts of an entrepreneur, Ezra Levin, beginning in 1950. By 1961 the Bureau of Commercial Fisheries (BCF), then part of the U.S. Department of Interior, began research on FPC. The BCF work led to the production on a laboratory scale of a nearly tasteless and odorless FPC in powder form, containing between 75% and 95% high quality animal protein. A small amount (about 10 grams) of this FPC would meet the daily adult requirement for animal (or "high quality") protein.

In 1966, with the support of the Marine Sciences Council (MSC) and the Agency for International Development (AID), Congress passed a law enabling the BCF to build a demonstration plant for FPC production. The plant was constructed in Aberdeen, Washington and began producing FPC in 1971. After a run of about 15 months, the demonstration plant was closed permanently with few of the original goals accomplished.

TECHNOLOGICAL BACKGROUND

There are two principal technological approaches for producing FPC. The first is an enzyme process in which ground fish are mixed with various enzymes that break down the protein into water soluble units and allow extraction of the remaining materials. BCF had experimented with several enzyme processes prior to the initiation of the demonstration project. The principal advantage of an enzyme process is that it produces water-soluble FPC which is easier to combine into acceptable food products. However, enzyme processes are still relatively poorly understood and the technology has never really proceeded beyond the research stage.
The other general approach uses solvents to chemically extract the fat, water, and other non-protein residuals from the fish. Chemical extraction processes are simpler and rest on a far more solid technical foundation than enzyme processes.

Ezra Levin developed one of the first chemical extraction processes for the production of FPC (which he called the Viobin process), using chlorinated hydrocarbons as a solvent. Chlorinated hydrocarbons are quite toxic and have shown to be carcinogenic in experimental animals. Consequently, the solvent used in the Viobin process must be completely removed from the final FPC product, since any residual chlorinated hydrocarbons could pose a health hazard. While no toxicity from Viobin produced FPC was ever documented, the potential hazard posed a serious problem for commercialization of the process. In addition, the Viobin process produced an FPC that was not fat-free, which meant that it smelled fishy, had a fishy taste and had a fairly short shelf-life.

BCE adopted a different chemical extraction in the early 1960's employing isopropyl alcohol (IPA) as the solvent. The IPA process had several distinct advantages over the Viobin process:

- Isopropyl alcohol is relatively non-toxic. It should not be ingested in large quantities, but in small quantities it appears not to be hazardous. For example, IPA is used in shaving lotions and perfume, and some amount passes into the blood stream without toxic effect. (The toxicity problem would be lessened by the use of ethyl alcohol, but this would subject FPC production to the restrictions the Department of the Treasury places on distilleries.)
- The IPA process results in a whiter, odorless, more tasteless, and more stable product than the Viobin process, because of more complete removal of fat.
- The IPA process is simpler than the Viobin process because only one solvent need be used. The Viobin process must employ IPA as a final solvent to reduce residual fat and chlorinated hydrocarbon levels.
Despite these advantages, a number of technological uncertainties remained to be resolved.

The engineering design for any large-scale FPC production plant also was subject to a good deal of uncertainty. In addition to the type of process, plant design depends upon the type of fish to be used. Lean fish are easier to handle simply because a significant problem in FPC processing is the removal and recovery of fat. Most of the initial research had been conducted on lean species, but by far the most abundant underutilized species are fatty fish such as anchovy and menhaden.

Was the IPA process ready for demonstration when the decision was made to construct a demonstration plant? Among those interviewed, answers to this question have ranged from an unequivocal "no" to a probable "yes." The differences of opinion reflect different assessments of what the demonstration was to accomplish. In retrospect, one can conclude:

1. The technology necessary to produce a completely non-functional FPC from freshly caught hake (a lean species) was ready for at least pilot plant operations.
2. The technology to produce FPC from fatty species such as menhaden and anchovies did not exist, but appeared to be within reach.
3. The technology to produce FPC with functional qualities (as outlined in Section IV) did not exist, and was not on the horizon.
4. The technology to produce FPC from fish held in refrigerated brine was inadequate, in that the yields from such fish were considerably below those from fresh fish. Fish flesh begins to break down (autolyze) very soon after the fish are caught. Autolyzed flesh dissolves in IPA along with the fat and other products that the IPA is meant to remove. The problem of holding fish in brine was not foreseen and caused problems for the demonstration plant, especially in light of the hake resources problems discussed in Section III.*

Thus the technological uncertainty surrounding FPC production was quite high when the demonstration began. As explored below, this high technological

*Earlier studies by BCF had shown that fish could be held in IPA or on ice for 1-2 weeks without degrading FPC production.
uncertainty worked in conjunction with other factors to create intractable problems for the demonstration project.

**Political and Institutional Background**

The BCF decision in 1961 to begin research on FPC coincided with the interests of the Kennedy Administration in expanding U.S. efforts to supply food to developing countries. Feeding the hungry abroad became a national goal for foreign policy and humanitarian reasons, as well as to provide an export market for U.S. agricultural surpluses.

Secretary of the Interior Stuart Udall was a strong supporter of the Administration's food program. Consequently, in 1963 a decision was made at the Interior Secretarial level to concentrate BCF efforts on the IPA process using lean fish. According to BCF technical personnel, many of the BCF research staff did not favor rapid commercialization efforts and wanted to continue research on a wider front. The decision to speed commercialization of FPC was based on political rather than technical grounds. Some research on other processes continued at the BCF labs after 1963 but at a much reduced level. New funds were used on the IPA process development and later on the demonstration plant.

The choice of lean fish was made in order to speed FDA approval of FPC. The Food and Drug Administration had become a strong and active opponent of the FPC concept. This was partly due to the real and potential problems associated with the Viobin process, but, according to one source, the FDA's position was hardened by informal contacts from the well organized milk and soya bean producers whose products would be in direct competition with FPC.

The importance of FDA opposition was stressed by all of our contacts as one of the major difficulties in commercializing the FPC innovation. Opposition to FPC was well-established FDA policy before the government embarked on the demonstration project. Originally, the FDA branded FPC a "filthy" product, not fit for human consumption. This ruling was based on the fact that FPC was made from whole fish, including heads, tails, and viscera. The FDA's logic was highly questionable, since other whole fish (e.g., anchovies and oysters) had long been consumed without menace to individual or public health. From an aesthetic viewpoint, no part of the fish would be recognizable in FPC. Still, the extent of opposition is
illustrated by the fact that an FDA Commissioner stood before a Congressional hearing on FPC waving a dead fish with the viscera hanging out and asked rhetorically if the American consumer would accept it as food for humans. The Commissioner's attitude did not improve when he learned that FPC had been served (without noticeable side-effects) at a luncheon he had attended sponsored by a Congressional supporter of the BCF program.

Consequently, the Interior decision to speed commercialization of FPC implied the need to gain FDA approval. Foreign policy objectives would not be served if the U.S. attempted to export a product that the government considered unfit for domestic consumption. Moreover, without FDA approval there was little prospect for private sector investment in FPC.

Much of BCF's research activity thus was directed toward producing an FPC product that FDA would approve. Secretary Udall asked for help and advice on FPC from the National Academy of Sciences (NAS). An ad hoc panel of the NAS reported in 1962 that a safe, wholesome FPC could be made from whole fish. Under NAS auspices, a Scientific Advisory Committee to BCF was formed the following year to review progress of the FPC program. By 1965, research had progressed to a point where the Committee recommended that BCF build and operate a pilot plant to produce FPC.

The creation of the National Council on Marine Resources and Engineering Development (known as the Marine Sciences Council, or MSC) in 1966 gave a greater push to the FPC program. The MSC was established by statute in the Executive Office of the President in order to give added emphasis and visibility to U.S. marine activities. As one new "initiative" in the marine resources area, proposed by BCF, the MSC seized upon FPC as a prime candidate for expanded government action.* It strongly supported legislation pending before Congress that would specifically authorize federal funds for FPC demonstration plants. The legislation was enacted in the fall of 1966 (PL-89-701), and the demonstration phase of the FPC program began.

II. PLANNING FOR THE DEMONSTRATION PLANT

SELECTION OF A "LEAD AGENCY"

As coordinator of all Executive Branch activities in the marine area, the MSC had authority to assign responsibility for an expanded FPC program. Surprisingly to some observers, the MSC chose the Agency for International Development (AID) as the "lead agency" rather than the BCF. However, BCF retained responsibility for building and operating FPC demonstration plants.

Initially the MSC wanted the FPC program housed in a special project office in the Department of Interior, similar to Admiral Rickover's Nuclear Submarine Program in the Navy. A special project office would bring greater visibility, access to political officials, and authority to hire senior project managers outside the Civil Service system. However, Secretary Udall opted against a special project office reporting directly to him. Although a supporter of the FPC program, Udall had other, higher priority items demanding his attention.

The MSC could not run the FPC program itself, because its charter did not permit operational activities. The only interested agencies were AID and BCF--both of which were weak organizationally and politically. Neither agency could count upon strong domestic interest group support for any of its projects, much less for the development of FPC.

Left with a choice between AID, which had a substantial interest in FPC development as part of its food program for developing countries, and the BCF, the MSC selected AID as lead agency. The MSC considered BCF to be too weak an agency to manage a major project involving technical, cost and demand uncertainties. BCF was oriented toward fishery development, not to the diffusion of processing technology or the development of new product markets. The agency was politically ineffective within the Interior Department, with Congress, and even with its own constituency, the U.S. fishing industry. The MSC believed that BCF lacked a comprehensive plan for fishery development and tended to respond only to crises. Moreover, BCF had very little experience with demonstration projects. The FPC project was the largest the agency had undertaken.
GOALS FOR THE DEMONSTRATION PROJECT

Government Goals

As is often the case, the "high policy" goals of the Administration and Congress were rather vague. BCF was to produce FPC for an AID marketing effort within developing countries. The FPC program contributed to a general foreign policy and humanitarian goal of "feeding the hungry". As a result, the program had high Administration support -- starting with Vice President Hubert Humphrey, who served as Chairman of the MSC -- in the period leading up to the concrete planning of the demonstration.

The government backers of the FPC program believed that private firms had not invested in FPC principally because of cost, demand, and externality uncertainties. A demonstration plant would help reduce cost uncertainty. The AID marketing program was aimed at reducing demand uncertainty. Successful demonstration of FPC production, coupled with continued political support for the program, was aimed at eliminating the FDA restrictions that represented the principal externality uncertainties. The MSC and other proponents assumed that a successful demonstration would lead to significant exporting of the FPC technology abroad by U.S. engineering firms and food processing companies.

AID's general goal was to develop protein resources and food production in selected LDCs. AID had no intrinsic interest in FPC; indeed, AID was oriented more toward agricultural than fishery development. AID's top management was never particularly enthusiastic about FPC vis-à-vis other food products.

BCF's goals were more specific. The agency sought to:

- Develop a hake fishery in the Pacific Northwest;
- Provide technical and economic data upon which the fish meal producers could rationally base entry into the FPC business; and
- Break down FDA restrictions on the manufacture and marketing of FPC.

All of these goals supported BCF's principal objective of strengthening the U.S. fishing industry.
The goals of the project shifted during the demonstration away from exporting FPC abroad toward emphasizing U.S. domestic consumption. This shift appears due to several factors:

- Failure of the AID marketing effort with FPC produced from the Viobin process. AID couldn't give this FPC away in Latin America; some of it reportedly still sits in warehouses in Chile.
- The change of Administration in 1969.
- Increased support for the project from the menhaden fishmeal industry.

Industry Goals for the Demonstration

Industry involvement in the demonstration was basically limited to the contractor, Ocean Harvesters. Ocean Harvesters was a joint venture formed by two companies: Sweco, an engineering equipment manufacturer which was to design and build the plant; and Star-Kist, a major fish processor, which was to provide the fish and operate the plant. (Star-Kist is a wholly owned subsidiary of H. J. Heinz, a major food processor.)

Sweco's primary goal was to get in on the ground floor of what it expected to be a substantial new market in engineering, construction, and equipment. (The IPA process proposed used some equipment of the type manufactured by Sweco, which heightened the company's interest in FPC.)

Star-Kist's basic interest in FPC was as an entree into LDC's that had undeveloped, exploitable fisheries. By developing expertise in operating an FPC plant, Star-Kist might ease some of the commercial problems caused by increasing nationalism in the LDC's, such as demands for part ownership, higher percentages of the profits, and the like. Star-Kist's goals were largely dependent on the success of the AID marketing, and were not aimed at the U.S. domestic market at all.

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*Before FPC from the demonstration plant became available, AID contracted with Alpine Marine Protein Industries for the delivery of 2 million pounds of FPC for distribution in Latin America. Alpine adopted the VIOBIN process developed by Levin but only about 20% of the FPC it produced met specifications. The rest either failed the minimum protein standard or failed to pass FDA regulations on microorganism and residual solvent counts. The Alpine contract was cancelled in 1969, and the company folded.*
TARGET AUDIENCES

The BCF identified three industries as the target audiences for the demonstration plant. They are listed below roughly in order of importance as perceived by the BCF:

1. The Fishing and Fish Processing Industry

This highly fragmented industry was the basic constituency of the BCF, but has never constituted a strong political force. Among fish processors, the producers of fish meal and fish oil were perceived as the central audience for the demonstration—in large part because FPC was viewed as a higher value-added product than fish meal and thus valuable to the industry. Several industry associations (e.g., National Fisheries Institute and the National Fish Meal and Oil Association) gave support to the FPC demonstration in Congress, but the overall industry attitude toward FPC was somewhat ambivalent. When the industry was in good financial shape, support for FPC was forthcoming, but in bad times the industry saw FPC as diverting the BCF from more important programs. Moreover, support for the FPC demonstration cannot be equated with significant interest in actually undertaking the production of FPC or otherwise investing in the product.

2. Fish Processing Equipment Manufacturers and Engineers

The BCF saw the equipment manufacturers and engineering firms as the principal diffusers of the technology overseas. These firms were interested in FPC simply as an opportunity to participate in supplying a new industry with capital equipment.

3. The Food Processing Industry

The food processors were presumed to be interested in FPC as a completely new source of protein additives to food. When the demonstration project was first funded, U.S. food processing firms were contacted but not stressed as a major target audience. No market study of food processor demand for FPC seems to have been carried out by the BCF until after the demise of the AID marketing program. At that time BCF contracted with two Cornell economists for a demand study which was published in August 1970.*

—Timothy M. Hammonds and David L. Call, Utilization of Protein Ingredients in the U.S. Food Industry (two parts) Ithaca, New York, Cornell University of Agricultural Economics. The only other economic study of FPC was completed even later: The Economics of Fish Protein Concentrate; J. W. Devanney, III, and G. Mahnken, Cambridge, Mass.: MIT Sea Grant Project Office.
In June, 1967 BCF sponsored a meeting with representatives of the above industries, the scientific community, and AID to outline its plans for the demonstration plant. The industry participants were asked if they had any plans for investment in FPC. The response was completely negative. When asked if the BCF should undertake a demonstration project on FPC, the response was, not surprisingly, positive. None of the participants were interested in putting forth any money. The attitude was one of "we'll wait and see." BCF also was unable to obtain commitments from food processors for purchase of FPC from the demonstration plant. (The BCF plans called for one half of the demonstration plant's output to go to AID and one half to U.S. food processors.) Still, this negative response from the industry target audiences did not prevent the plans for the demonstration from going forward.

**CONTRACTOR SELECTION**

BCF issued its RFP for an FPC demonstration plant at the public meeting described above. The meeting was attended by more than one hundred representatives from the commercial fishing, fish meal processing, engineering, and food processing industries.

A number of engineering companies subsequently indicated interest in bidding on the FPC demonstration plant. However, the largest engineering companies with the greatest capabilities did not respond. According to representatives from major engineering firms such as Bechtel and Blaw Knox, these companies judged the BCF process not ready for the demonstration plant phase.*

BCF eventually received seven proposals, of which four were judged to be technically adequate. In evaluating them, according to one participant, BCF "wanted someone to pick up and follow through with commercialism of the process." Consequently, BCF wanted a contractor with "fish experience" as well as engineering capability. BCF encouraged the formation of teams or consortia of companies to meet these objectives.

The winning bid was submitted by Ocean Harvesters, a joint venture formed especially to bid on the proposal. The partners in Ocean Harvesters were Sveco, a Los Angeles manufacturer of equipment for separating solids from liquids, and Star-Kist of Terminal Island, California.

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*The $1 million project may also have been too small to interest these large firms.
From the BCF's point of view, the choice of Ocean Harvesters seemed to represent the least of evils. The contract negotiating team, headed by Harold Allen, Chief of the BCF Branch of Technology, (the other members were an attorney from Interior and a BCF technical project leader) had misgivings that none of the proposals were adequate. But the team was under pressure from BCF to choose someone, and Ocean Harvesters seemed to have far the best understanding of the process taken as a whole.

BCF was impressed by Star-Kist's knowledge and experience in the fish business, and by the fact that Sweco had committed about $200,000 to test the use of Sweco screen and press separators for FPC production. BCF had doubts about the separator process contained in the Ocean Harvesters proposal which deviated from the centrifuge process developed in the BCF lab. Consequently, Sweco contracted with Professor W. W. Meinke of Texas A & M to develop a pilot scale FPC processor. The data from this pilot plant were extrapolated to a 50 ton per day plant as called for in the RFP. The results suggested that the separator process was technically feasible and nearly ten times cheaper than the centrifuge process.

In hindsight, some BCF personnel have indicated general unhappiness with Ocean Harvesters and especially with Sweco. Their chief substantive complaint concerns Sweco's choice of screen separators instead of the centrifuges favored by BCF. Centrifuges, they contend, would have been more effective although considerably more expensive. Yet given the budget constraints in the RFP, it is doubtful that anyone could have realistically proposed a full centrifuge process. Moreover, the RFP called explicitly for the processing of hake into FPC. The separators proved adequate for hake but were unable to work acceptably when the plant was modified for fatty fish. Finally, one reason why the FPC yields from the plant were low had nothing to do with Sweco's process, but with the use of old and/or frozen fish. This was a result of the plant's location (see below).

To the extent that BCF was dissatisfied with Ocean Harvesters, the problems can be traced to organizational failure within BCF. BCF was in

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*Sweco, commenting on an earlier draft of this report, disagrees: "It cannot be established, then or now, that the centrifuges are superior to the separator/press for making FPC in a true industrial situation."
complete control of the contracting decision. The agency seems to have been cognizant of certain technical and organizational weaknesses with Ocean Harvesters, but still proceeded rapidly to negotiate a contract which yielded up wide control over the project to the contractor. For its part, Sweco contends that the problems with the demonstration were compounded by its difficulty in obtaining basic design decisions and approval from BCF.

FUNDING

The original 1966 legislation authorized two FPC demonstration plants; one to be constructed and the other leased. The act authorized one million dollars for construction, but did not stipulate the size of the plant. That was left to the discretion of the Secretary of Interior. Two factors seem to have influenced the decision to build a plant which could process 50 tons of raw fish per day. First, a 1965 study by the NAS Scientific Advisory Committee suggested that 10 tons of FPC per day would be necessary for AID to carry out full market tests. By extrapolation from the BCF lab's process, this would indicate a plant processing around 70 tons of fish per day if it were to be the only source of FPC for AID. The other consideration was the BCF officials--particularly the director of the College Park laboratory--wanted to build a plant that would be politically visible for supporting Congressmen. The final figure of 50 tons was determined by BCF College Park officials.

The problem was that $1,000,000 was completely inadequate to construct a plant of that size. This was recognized when the responses to the RFP were received. (It is also likely that the gross underestimation of costs discouraged potential bidders on the project.) Before signing the contract with Ocean Harvesters, BCF returned to Congress and received approval to drop the leasing of a second FPC plant in order to put all of the authorized money into a single plant. This added another $700,000 for construction, but even this amount was insufficient. BCF found it necessary to drop the construction of a pilot plant intended solely for research purposes and to reprogram an additional $343,000 into the construction of the demonstration plant (see Table I). Other research activities were reduced to meet the operating costs of the demonstration plant.
### Table 1

**FPC BUDGET HISTORY SUMMARY**

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* Reprogrammed Construction Funds
According to Howard Wright, president of Sweco, the budget constraints made the full instrumentation of the plant simply impossible. He noted that some BCF personnel complained continually about the lack of instrumentation, but failed to come up with the funds that would permit further instrumentation.

As in the case of contractor selection, the inaccurate cost estimates for the plant can be traced to organizational weakness in BCF. In retrospect, the cost overrun could have been expected to cause difficulties for the demonstration program, given the scrutiny which the agency's budget receives in Congress.

SITE SELECTION

The FPC demonstration plant was located on the Pacific shoreline in Aberdeen, Washington. The plant was built in the small fishing port of Gray's Harbor, which was a marginal port in terms of tonnage and financial situation. The decision to locate the plant in Aberdeen was in hindsight a serious error that materially affected the application success of the demonstration.

Several factors contributed to the decision to locate the plant in Aberdeen:

1. Technological considerations

The BCF laboratory in College Park had concentrated almost completely on producing FPC from species of lean fish, in particular red hake from the Atlantic. Since it was expected that the College Park process would be essentially duplicated in the demonstration plant, hake was quickly locked in as the fish that would be used. Hake can be found either in the North Atlantic or in the Pacific Northwest.

2. The FDA problem

When the demonstration plant was planned, the FDA had been asked to approve only hake for FPC production. In February, 1967, the FDA issued regulations permitting FPC produced from hake and "hake-like fishes" to be sold as a "food additive." This is a category usually reserved for potentially toxic substances. The FDA regulations sets very conservative levels for microorganisms, fluorides, and residual solvents in FPC. Moreover FPC could only be sold in no more than one pound lots, making commercial
sales virtually impossible. Since a principal goal of the project was to further reduce or eliminate FDA restrictions, hake was the natural choice for the demonstration plant.

3. Congressional pressures

When Congress first authorized two FPC demonstration plants (one to be built, the other leased), it assumed that one would be on the East Coast, and the other on the West Coast. BCF soon discovered there would not be enough money for both plants, so the legislation was amended in 1968 to permit construction of only one plant.

According to several of those interviewed, a major reason the state of Washington was chosen was that Warren Magnuson chaired the Senate Commerce Committee which oversaw BCF. Senator Magnuson's support for FPC was instrumental in passing the original authorization. The plant first was to be built on Puget Sound, which offered a safe landing site for year-round fishing. Under pressure from Congresswoman Julia Butler-Hanson, who chaired the House Appropriations Subcommittee overseeing BCF, the plant was finally sited in Aberdeen, within the district she represented.

The move from Puget Sound to Aberdeen was opposed by BCF for two principal reasons:

1) Fish could not be landed in Aberdeen between the months of October and April due to heavy seas. This forced the plant to operate on frozen fish during those months, adding cost and lowering FPC yield;
2) Sewage facilities in Aberdeen were inadequate (this problem was not fully realized until after the plant was constructed and was complicated by the demise of a fish-rendering plant, as mentioned below);

According to our sources, Ms. Butler-Hanson was insistent and carried the day. Her support turned out to be critical in 1969 when she personally intervened with OMB to release the funds for the demonstration.

4. Support of Northwest Fisheries

BCF preferred to locate the plant in Washington rather than on the East Coast, in order to help promote the fishing industry in the Pacific Northwest. Given that the political considerations were probably sufficient conditions to explain the siting, this factor appears relatively unimportant.
5. Co-location with a fish meal plant

Aberdeen was deemed to be an acceptable site in part because a fish meal and oil reduction plant, the Pacific Protein Corporation, already was located in the Port of Gray's Harbor. Pacific Protein used hake, which would help insure an adequate supply of the raw material. Pacific Protein was also to use the leavings from the FPC process in its fishmeal operations. But Pacific was a new venture, financed entirely with government money, and the company ceased operations before the FPC plant was completed. The reasons Pacific Protein folded were a dip in the market price for fish meal and oil, and its inability to secure an adequate supply of hake. The FPC plant thus became the only user of hake in the area.
III. OPERATING THE DEMONSTRATION PLANT

The demonstration plant was finally completed in the spring of 1971, about two years after the specified (but unrealistic) date for its completion. By summer 1971 the plant began FPC production while still ironing out a number of engineering bugs. The relationship between Ocean Harvesters and BFC seems to have depended greatly upon the personalities involved in site monitoring at any particular time. There was little continuity in monitoring, and the 1970 reorganization of BCF into the Department of Commerce as NMFS complicated the problem.

The contract stipulated that 25% of the running time of the demonstration plant would be reserved for research and development by BCF. However, due to engineering problems (particularly in the solvent recovery system) and inflexibility of plant design, very little research was possible during the brief period in which the plant operated.

After the initial run with hake in the summer of 1971, fatty fish (menhaden and anchovy) were processed during November and December to determine the adequacy of the installed equipment. Plant modifications were then made in early 1972. The processing of fatty species was never very successful. The Sweco separators were inadequate for processing fatty fish, so that it became necessary to add a final stage using a centrifuge as had been originally designed by the BCF College Park lab. The production runs with menhaden and anchovy were so limited that little useful information was obtained.

However, time and money for the demonstration were running out. Legislation to extend the plant's authorization for an additional year was introduced in 1971 and passed the Senate early in 1972, but the bill then died in committee in the House of Representatives. Without further authorization, the Aberdeen plant was shut down in June, 1972. There were no serious attempts to revitalize the program, and the plant finally was sold at auction in 1974 and dismantled.

Thus, after more than five years of active planning, research, design, and construction, the demonstration plant was in operation for only about a year. During that year it operated close to full production for only
about four months, and was shut down completely for modifications for at least three months.

OPERATIONAL PROBLEMS

1. Hake supply

Probably the most vexing problem for the demonstration plant was the lack of a stable supply of hake. When the plant was sited in Aberdeen, the hake fishery in the Northwest was completely unproven, although prior marine studies suggested that the hake resource was adequate for the plant, ceteris paribus. But hake is a migratory fish, requiring a large coordinated fleet for an efficient catch. Three or four boats cannot easily stay on top of a hake school. The FPC plant demand was a maximum of 50 tons per day -- more than could be supplied by a few fishing boats, but considerably less than would be supplied by a full fleet. With the demise of Pacific Protein, the FPC plant was the only buyer of hake in Gray's Harbor. Consequently, the FPC plant was caught in the middle of the sharp and lumpy economies of scale of hake fishing.

Another problem with the hake supply was that the Russians moved their highly efficient, mechanized fishing fleet into the Pacific Northwest fishery to take hake as a "table" fish for direct human consumption. (Hake is now also sold as a table fish in the U.S., although it was not at the time the plant was started.)

According to Star-Kist officials, the company (which was responsible for securing fish for the plant) contended from the beginning that the hake resource problem would arise. Osman of Star-Kist argued that the choice of hake as the source for FPC was fundamentally in error. The concept underlying FPC was to make use of "trash" fish, which would otherwise be discarded or made into fertilizer or animal feed, for human consumption. Hake, argued Osman, should never have been considered a trash fish. Although Americans did not then use hake as a table fish, other nations did. In addition, the total supply of hake (or any other lean fish) would never be sufficient for large scale production of FPC.

Thus, the FDA notwithstanding, Star-Kist believed the demonstration should have concentrated on fatty fish such as menhaden and anchovy to
begin with. Menhaden are found either on the East or Gulf Coasts; anchovy are found on the California coast. Locating the plant in the state of Washington made it more difficult and costly to use these fatty species.

2. **Fluoride levels**

Pacific hake had a significantly higher concentration of fluoride in their bones than the Atlantic red hake that had been used in the College Park and Meinke processes. This was considered acceptable for AID use, since fluoride would be beneficial in many countries, but the PPC exceeded allowable FDA fluoride levels for U.S. consumption. Thus it became necessary to partially debone the fish before processing. This reduced yields, slowed production, and increased costs.

3. **Waste disposal**

The demise of Pacific Protein, which was to use much of the demonstration plant's residue for fish meal, coupled with the lack of adequate sewage facilities at Gray's Harbor, made the proper disposal of effluent very difficult. Left untreated, the effluent from the PPC plants would generate high microorganism counts in the local water. The production process had to be stopped on several occasions to allow the sewage treatment facilities to catch up with the plant's effluent.

4. **Lack of instrumentation**

Due to budget constraints, the demonstration plant contained very little instrumentation. This hampered monitoring of plant operations, led to unnecessary breakdowns of equipment, increased operating costs, and made extrapolation to commercial processes more difficult.

5. **Scale of the demonstration plant**

There was virtual consensus from our sources that the demonstration plant was too large. At 50 tons per day of fish input, the plant was at a "semi-works" scale. A true "pilot plant" would have used on the order of 1 ton per day; a "scale unit plant" would have used on the order of 5 to 10 tons per day; while a full commercial size plant would have used at least 200 tons per day.

The semi-works scale of the plant posed a variety of problems:

A. Given the size of the plant and the uncertain state of the technology, modifications were both time consuming and costly. This
meant that although the plant was to serve a research as well as a production function, it never could adequately serve research needs. BCF had originally planned to construct a separate continuous process pilot plant for research and had purchased much of the equipment necessary for its construction. The rapidly rising costs of the demonstration forced BCF to divert the final $300,000 programmed for the pilot plant into the Aberdeen plant. The use of a semi-works demonstration plant as a research facility is questionable in any case. It would seem to be a recognition on the part of BCF that the technology was not ready for demonstration.

B. The size of the plant made the $1 million cost figure absurd. Even with additional funds, the money was inadequate to construct the plant at the contracted scale. As one of our sources noted, it makes neither engineering nor economic sense to specify both the scale and the cost of demonstrating a new process. The cost overruns led to Congressional disfavor, as was evidenced when BCF petitioned for an extension of the project's life. Perhaps even more damaging to the long-run success of commercial FPC production was the diversion of money from basic FPC research and development caused by the cost overruns.

C. The scale exacerbated the hake supply and sewage disposal problems cited above.

D. The leap from the BCF batch process in its Beltsville laboratory to semi-works scale may have been technically too great. Several of our sources argued that industry never fails to construct a pilot plant first and then scales up from there, resolving technical problems as they appear. Industry can occasionally jump from a pilot plant to full commercial production but not from the laboratory to a semi-works scale. This accounts for a good many of the engineering problems that extended the construction time and hampered FPC production.

In sum, the decision to build a semi-works scale plant came from a desire for enough FPC to conduct market tests, from the perceived need for political
visibility for the project, and from the attempt by key BCF personnel to please agency management and Congress. The result of this decision was to seriously compromise the demonstration's ability to reduce the technological and cost uncertainties surrounding FPC production.
IV. OUTCOMES OF THE DEMONSTRATION

UNCERTAINTY REDUCTIONS

The outcomes of the demonstration project can best be assessed in terms of the reduction of uncertainty along a number of dimensions. (See Final Report, R-1926-DOC.) Federal intervention in this area was justified primarily because the levels of uncertainty surrounding the production and consumption of FPC were considered so high that the private sector was unlikely to become significantly involved. (An additional justification could be made in terms of furthering foreign policy objectives -- a relatively pure public good.) These dimensions of uncertainty addressed by the project and the extent to which the uncertainties were reduced are considered in turn.

Reduction of Technological Uncertainty

The project demonstrated that a pure, odorless, tasteless, and stable FPC could be produced from hake on a continuous, near-commercial scale. The demonstration plant product was significantly better than that produced by the Viobin process in every respect. However, it did not demonstrate the commercial feasibility of FPC production from species of fatty fish. This failure is significant because fatty fish will be the primary source of FPC if it is to be produced on a commercial scale. The demonstration did not attempt to develop an FPC with functional properties (see below).

Thus in terms of reducing technological uncertainty for private industry, the demonstration produced little in the way of significant results. The demonstration did at least define many of the problems that would have to be solved before commercialization could take place. But the reduction in technological uncertainty can only be characterized as disappointing.

Reduction of Cost Uncertainty

The demonstration did not result in significant reductions in cost uncertainty. Cost projections that were made before the demonstration appear to have been too low, but this seems due in large part to underestimates of the cost of fish. The costs of FPC are necessarily sensitive to the costs of
the raw material, since a minimum of seven pounds of lean fish are required to produce a single pound of FPC. The demonstration's failure to obtain cost data is described in a program review prepared for NMFS in 1972:

Sustained runs were not achieved with any type of fish. Consequently adequate operating cost data were not collected to enable an economic evaluation of the process or to extrapolate operating cost data for commercial plant operation.*

Discussions with representatives of food processing companies confirmed that they learned little about the cost of FPC from the demonstration, although they were fully aware of the project.

Reduction of Demand Uncertainty

The demonstration did not reduce the substantial demand uncertainties which FPC, as a new product, faced. In the U.S. and other developed countries, FPC represented a substitute for other protein supplements such as dry milk and soy flour, for which the markets were reasonably well known. FPC would compete on the basis of cost—the prospects for which were not bright. However, improving the protein quality of processed foods is only one reason why these supplements are used, and in many cases not the primary reason. Besides adding nutrition, protein additives are valued for their "functional" characteristics; i.e., they do something to improve the quality or extend the use of a good product. Desirable functional properties of protein additives include:**

- extension of product's shelf life
- emulsion stability and enhancement
- high and/or low temperature stability
- binding with water, fat, particles
- texture improvement
- flavor absorption or improvement

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** Hammonds and Call, op. cit., Part II, p. 3-4.
o enhanced dispersion in liquids
o addition of bulk (use as extenders).

By these criteria, the FPC produced by the demonstration had no functional properties whatsoever. The major food processors contacted cited the absence of functional properties as a major barrier to their adoption of FPC, even if it were cost competitive and readily available. A very limited market for non-functional protein exists in soft drinks, pet food and the like. This demand could be met more cheaply by the use of soy protein in one of its many forms. Thus the demonstration produced a product for which no clear domestic market existed.

Functional properties necessary for FPC penetration into some present protein markets have subsequently been developed on a small scale by Nabisco Astra Nutrician Development Corporation, a commercial food processor. Still, a good deal more research on functional properties must be done before FPC can be widely used in U.S. food processing. If functional properties are developed and the cost of FPC becomes reasonably competitive, then the market potential for FPC could be very large, since the demand for protein additives is expected to increase dramatically in the next decade.*

BCF did not recognize the importance of functional properties in the U.S. market in large part because the demonstration's original focus was on markets in developing countries. Knowledge of the demand for FPC overseas was to come from AID's efforts prior to the demonstration plant operations. But the AID marketing program was an abject failure. This seems due to both the unacceptability of Alpine's FPC because of its fishy smell and taste, and to AID's organizational and budget problems.

One food processing industry source argued that the AID marketing program was completely misconceived to begin with. His company's experience with marketing food products in LDC's taught them that the introduction of new products in these countries is very difficult, even when there is a great need for the product and the cost is low. The reason is that the diet in LDC's tends to be very limited, so that integrating a new product into the diet is quite difficult. Moreover, in LDCs, unlike the developed countries,

most products which could use a protein additive, such as bread and pastas, are produced in the home. His company has experienced difficulty introducing textured vegetable protein in LDC's despite the fact that it has excellent functional characteristics.

Reduction of Institutional and Externality Uncertainties

The demonstration did not explicitly address institutional issues, except with respect to FPC adoption in LDC's (as outlined above), and the FDA approval problem. The latter is classified in our framework as an externality uncertainty.

A primary obstacle to private sector entry into the FPC business was the web of restrictions placed on FPC by FDA. There was consensus from all sources—public and private—that as long as the FDA imposed restrictions on the production and sale of FPC, the private sector would avoid investment. Thus one of the principal aims of the demonstration was to break down these barriers.

The precise reasons for FDA's long opposition to FPC remain something of a mystery. One of our sources in NMFS suggested that the FDA was responding to criticisms of laxity. By being tough on FPC, the agency could show its dedication to consumer protection. There is no documented evidence that FDA was directly influenced by interest groups, but agricultural interest groups have consistently shown far greater political strength in the U.S. than fishery groups. * Groups opposed to FPC naturally used the FDA's conclusions to strengthen their arguments.

As the demonstration project proceeded, BCF presented the FDA with a series of petitions to extend FPC production to other species, alter the conservative fluoride restrictions (which necessitated deboning the fish in the demonstration plant), and eliminate the one-pound sale rule. Other petitions were presented by fish processors at the request of BCF-NMFS. These continued efforts have succeeded in removing the most burdensome restrictions on the production and sale of FPC, although the one-pound rule was eliminated after the demonstration plant closed down.

* See Wenk, op. cit., p. 313.
In terms of original goals, this has been by far the most successful outcome of the demonstration. Nabisco Astra (the only commercial producer of FPC at the present time) reported that it made its decision to greatly expand its FPC production after the last FDA restrictions were dropped in the summer of 1973.

Some of those interviewed questioned whether the demonstration project was really necessary in order to remove the FDA restrictions. If the private sector had expressed interest in FPC, they contend, the industry would likely have been successful in having the restrictions removed, particularly in light of their highly questionable justification. Given the state of industry disinterest, however, the demonstration project may have been the only means.

OTHER OUTCOMES OF THE DEMONSTRATION
Spinoffs

BCF-NMFS reports two principal technical spinoffs from the demonstration project. First, the fluoride problem resulted in the introduction of deboning equipment in the demonstration plant. The agency conducted a thorough review of available equipment and purchased Japanese equipment that was superior to that in use in the U.S. This equipment has been widely and rapidly diffused into the U.S. fish processing industry. It has been especially helpful to producers of fish sticks and cakes which represent an expanding part of the U.S. fish market. Second, BCF-NMFS was forced during the demonstration to develop improved methods to store and preserve fish prior to processing. These methods have been diffused to U.S. fish processors.

However, other sources expressed doubt that these developments would not have occurred anyway without the FPC demonstration. Sweco in particular reported no spinoffs at all from the demonstration in terms of new products or equipment development.

Dissemination of Information

The BCF-NMFS carried on a substantial and apparently highly successful effort to disseminate the results of both the demonstration and their research into FPC. The agency held two general meetings for industry
representatives interested in FPC development: one in 1967 in Washington, and one in February 1972 at the Aberdeen plant. MIT also sponsored a conference on FPC in 1972 in Cambridge, Massachusetts. The Aberdeen demonstration plant received a large number of visitors, especially from equipment manufacturers. Samples of FPC produced at the demonstration plant were sent to all major food processors for tests. Numerous articles on FPC written by BCF technical personnel have appeared in the major food technology journals. BCF developed a "Fish Protein Concentrate Package" containing virtually all available information on BCF research and the demonstration plant. The package has been widely distributed both in the U.S. and abroad.

The food processors contacted during this study were fully appraised of the demonstration and related BCF developments. Insofar as can be determined, dissemination appears to have been fully successful.

**Diffusion**

Despite the dissemination success, the technology developed at the demonstration plant has not diffused. The obvious reason for this is that the information from the demonstration offered no encouragement to private firms to enter the FPC business. Nabisco Astra is the only commercial producer of FPC at the present time. According to our contact at Nabisco-Astra, the company gained little useful information of a technical or economic nature from the demonstration plant. The company had developed its own process at the time of the demonstration and has proceeded beyond the technical level achieved at Aberdeen.

Contacts with private industry sources revealed no other plans for investment in FPC. Two food processing sources indicated a decreasing interest in FPC because it is a high energy consuming food, and increases in the cost of energy are likely to make it more expensive in the future even if technical advances are made.

Our NMFS contacts suggest that one outcome of the demonstration has been to increase support from the fish processing industry for FPC. FPC appears to have been placed on their political (if not economic) agenda.

This may aid the NMFS sometime in the future if it wishes to revive governmental efforts to stimulate diffusion of FPC technology. But, at present, there is really nothing to diffuse.
V. CONCLUSIONS

The FPC demonstration project, which was born on a wave of enthusiasm in 1966, died a rather quiet death in a Congressional committee in 1972. In the course of those six years, only one of the project's substantive goals was met—the removal of arbitrary restrictions by another government agency. The reasons for the project's failure to reduce the remaining uncertainties surrounding FPC can be summarized under three general headings: technology, organization, and lack of demand.

1. The technology necessary to carry out a semi-works scale demonstration project was not ready. The technology was available to produce FPC from lean fish, but the technology for producing FPC from fatty fish was clearly not ready for demonstration. As a result, the construction and operation of the demonstration plant were constantly bogged down in engineering problems, which, given normal constraints in time and money, made the application success of the project very unlikely. Semi-works demonstration projects are not efficient vehicles for research and development, as an engineering review of the demonstration plant documents.* An evaluation of that report by NMFS concluded that it would be necessary to construct a small pilot plant, a step neglected in the push to build the Aberdeen demonstration. The evaluation concludes, "The [demonstration plant] built from such a pilot plant would probably be more efficient and very different from the present one [the Aberdeen plant]."**

2. Organizational problems seem to have beset the demonstration throughout. Influential Congressmen and the Marine Sciences Council pushed the project but relied on BCF to carry it out. BCF had no clear model of how industry would pick up on the technology after the

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*Engineering Review Study of Experimental Demonstration Plant for Fish Protein Concentrate prepared for NMFS by P/E Development Co., Cincinnati, Ohio, 1972.

demonstration. AID failed in its overseas marketing effort. BCF could not keep political considerations from dooming the project; the agency, in fact, overpromised and under-delivered.

This was (as our sources pointed out) a "political project" in the sense that it was oriented toward political goals of Congress and the Administration rather than simply the commercialization of technology. Politically, the time was ripe for a major push in the development of FPC, although the technology was not yet ready for a full-scale demonstration. Organizationally, neither BCF nor AID could effectively pursue a major FPC project. In defense of BCF, some of its technical personnel warned of the impending problems and were overruled.

Politics governed not only the timing of the project, but also the siting of the demonstration plant. The siting turned out to be a major barrier to whatever application success the plant might have otherwise enjoyed. Political considerations were instrumental in the decision to build a semi-works plant. But the cost that BCF paid for not saying "no" to political pressures, and not slowing the project down until the technology became ready, was to retard seriously the R&D effort on FPC. In addition, the failure of the demonstration to provide adequate cost and market data has probably left industry less interested in FPC than they were before the project started.

The organizational problems of BCF were in no sense unique to this agency. But they were worsened by BCF's lack of experience with any demonstration project approaching the size and complexity of the FPC plant.

3. Finally, there was no demand for the demonstration that BCF performed. This would have been a sufficient condition to doom the major objectives of the program even if all else had worked well.

The FPC demonstration project did not come to a conclusion; it was terminated when Congress refused to appropriate funds for its continuance after June 1972. The major evaluation of the demonstration project concluded that its completion would require two additional years and up to $8 million.

Besides the disappointing results to that time, one of the primary reasons the project was not continued was an unfavorable shift in the political environment. The project, when it began in 1966, had significant support from the MSC (and in particular its chairman, Vice President Humphrey), from a number of Congressmen and Senators, and some involvement (if not support) from AID. FPC was a part of the political agenda of the Johnson Administration. At the beginning the demonstration's modest funding did not even arouse much opposition from the Bureau of the Budget. *

AID's involvement ended in 1969 when its overseas marketing effort collapsed. MSC support waned substantially with the change in Administration. Humphrey was out, and Vice President Agnew as chairman of the Council showed much less interest in FPC development. From 1969 on, the project was consistently opposed by the Office of Management and Budget (OMB). The funds for the demonstration had to be forced out of OMB by political pressure, in particular from Congresswoman Hanson. BCF chief Crowther, who had been an effective supporter of and manager for FPC, was replaced by someone with considerably less enthusiasm for the project. Given this reduction of political support in the Executive Branch and the lack of positive results from the Aberdeen plant, it is not surprising that Congressional support to keep the program alive was not forthcoming.

In sum, there are potentially valuable lessons to be learned from the FPC experience:

1. Demonstrations are difficult to operate successfully under conditions of high technological uncertainty. When technological uncertainty is high, either the demonstration project should be postponed, or if that proves impossible, it should be planned in a way that maximizes flexibility in terms of the demonstration's scale, timing, and funding.

2. On the basis of this demonstration, it would appear that the combination of high technological uncertainty and high demand uncertainty is a prelude to failure.

3. Political support can be as troublesome for the success of a project as political opposition. Congressional and MSC promotion of the demonstration (based on unrealistic plans from BCP) resulted in a premature shift of resources away from research and development. The political choice of the demonstration plant site—which can be most charitably termed a disaster—was also accomplished by friends of the project.

We expect that these lessons will be applicable to many federal demonstrations besides the FPC project.
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