THE MANAGEMENT OF

## Smallpox Eradication in India

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Lawrence B. Brilliant M.D., M.P.H.

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## To Neem Karoli Baba

## Foreword

Together Dr. Larry Brilliant and l visited West Bengal during the autumn of 1973. The purpose of our visit was to initiate, in collaboration with the state smallpox eradication officials, the first trial in our smallpox eradication program, namely a statewide search for hidden smallpox cases, mobilizing all available health staff in West Bengal, which had a population of sixty million. A similar trial also took place in the smallpox endemic states of Uttar Pradesh, Bihar, and Madhya Pradesh at that time. Over 6,500 cases were detected through this intensive search within a week, as compared to the 400 cases that were reported in the previous week.

The achievement was significant in the sense that the Indian smallpox eradication program officials discovered for the first time in the history of their campaign that they had seriously underestimated the magnitude of the smallpox epidemics. This recognition led first to a redefinition of the problem, second to identification of the priority areas for surveillance and intensive containment activities, and third to the mobilization of national and international resources to deal with the devastating smallpox epidemics in large areas of the Indian subcontinent.

Eighteen months of this intensified campaign accomplished the recording of the last smallpox case in India; the date of onset of rash was May 24, 1975. Intensive surveillance for hidden smallpox cases continued, maintaining the same number of national and international staff, until April, 1977. No more cases were detected.

In April, 1977, a Global Commission for the Certification of Smallpox Eradication—a panel of sixteen experts on smallpox eradication—visited India to review data and observe search activities in the slum areas, remote accessible areas, and recently endemic areas in the country. On April 23, 1977, the commission certified that smallpox had been eradicated from India.

Dr. Halfdan Mahler, director-general of the World Health Organization, once referred to the success of the global smallpox eradication program as a victory for program management. I feel that this is particularly true in the Indian campaign. The campaign started in 1962, but despite substantial efforts made by the program, until 1972 it was only partially successful, in mainly the southern states. However, in 1973 a dramatic change occurred, as already mentioned. From the management point of view, it could be said that a basic managerial change brought a dramatic solution to the problems, and the remaining objectives were accomplished in a short time.

#### viii Foreword

With the closure of the Indian smallpox eradication program, many nationals left the program, and all the international staff left India during 1977 and 1978. It was thought that the experience gained in the Indian campaign would be worth publishing, since it would be of great interest to workers in other public health programs. The 1978 publication of *Smallpox Eradication from India* by the South-East Asia World Health Organization (WHO) Regional Office fulfilled this need. However, it was also thought that the experience gained in India could be summarized from the management point of view. Dr. D. A. Henderson suggested that such a document could be a case study of the Indian smallpox eradication program.

In view of this, WHO requested that Dr. Brilliant write this book, *The Management of Smallpox Eradication in India*, in consultation with several management experts who were interested in the program. The book has been prepared for health officers who directly or indirectly participated in or were interested in the global eradication of smallpox, as well as for those who wish to study the eradication of smallpox from a managerial point of view. The latter include students and perhaps executives who wish to study the analysis of the success of an international program.

> Dr. Isao Arita Chief, Smallpox Eradication Programme World Health Organization, Geneva, Switzerland

## Preface

After the eradication of smallpox from India, the veterans of that campaign carried away with them a unique experience and many lessons. In the decade since the last case of smallpox occurred in India, many of these smallpox veterans have found new roles and have tried to apply the lessons learned from their experience to their new tasks in public health. Each has tried to sift the wheat from the chaff—learning which lessons from smallpox could be applied to new jobs, new diseases, new environments.

Other health workers, unfamiliar with the details of smallpox eradication, have wanted to study its history, in particular to discover what lessons can be learned about public health management from the smallpox eradication program. The literature on international development is full of accounts of successful pilot projects that turned out to be unsuccessful national programs, and specialists in international relations repeatedly caution students about the limitations of the special case. And smallpox eradication is indeed a special case.

The field of international health, like any human endeavor, proceeds through cyclic shifts of conviction and emphasis. A decade ago, the World Health Organization (WHO) enthusiastically supported single-disease campaigns and "categorical" or "vertical" eradication programs like those mounted against smallpox, malaria, and yellow fever, seeing great promise in a one-by-one attack on the ills that befall mankind. The focus of enthusiasm has recently shifted, and in much of WHO and the international health community the single-purpose campaign has lost favor and instead "horizontal" or "integrated" programs are currently preferred. Primary health care has become an important philosophy, and "Health for all by the year 2000" is its slogan.

This shift from single-disease programs toward integrated primary health care can be seen as part of a historic process—an earnest attempt to reach into ever more subtle causes of ill health in the poorest communities in the world. The declining attention to specific pathogens and rising attention to multiple risk factors of diseases and the environmental, social, and political correlates and determinants of ill health parallel the movement in medicine as a whole away from single-disease, single-pathogen syndromes and magic bullet therapy toward a fuller appreciation of each person and his health and general welfare.

But the debate between these philosophies of health management may lose its constructive vigor in substituting slogans for scientific management, and there is a danger that the lessons of past experience may be lost as well.

As in most highly polarized arguments, truth and reason probably lie somewhere between the two extremes in this debate. There is no doubt that the proponents of primary health care are motivated by the best kind of goal, that of making health care relevant to the needs of the most underserved communities in the world. Its achievement would certainly be an improvement over any single-purpose campaign. Nevertheless, a simple change from vertical to horizontal will not solve all the world's health problems, and some of the methods of sound management learned in the vertical smallpox eradication program are applicable to any program, vertical or horizontal. The combination of the intense commitment of the staff, the intense concentration on one problem at a time, and the problem-solving orientation of the smallpox program management led to the development of innovations in planning the program and formulating strategy and in organizing, implementing, and assessing the tactics of personnel management, logistics, information, finance, and relevant research.

A carefully planned, sustained, and evaluated attack was successful against one disease. It took more than a decade. Primary health care embodies simultaneous efforts on many fronts to achieve "Health for all by the year 2000." That leaves not much time to reach such an ambitious target— only fifteen years from today. It is essential that the managers of primary health care study and review the lessons learned from all past experience.

The case of smallpox provides many ways to study that experience. The WHO smallpox unit in Geneva has prepared exhaustive documentation on the smallpox eradication activities of more than sixty countries as well as on the global program. Several excellent texts are available that deal with country-level programs in Bangladesh and India, and more are coming. Additional books are planned on the history of smallpox in general and on the history of eradication in particular.

To add to this growing reference library on smallpox, WHO felt that a case study and analysis of lessons learned from the eradication of smallpox in India would provide an otherwise unfamiliar reader with some readily assimilated food for thought on those lessons that might apply to other health management needs.

This book was not prepared for an audience that is already familiar with smallpox or its eradication and certainly not for smallpox epidemiologists who experienced the eradication program by participating in it. This case study has been prepared primarily for managers of other health programs or students in the health sciences who hope to learn from a study of the management experience of smallpox eradication in India. Other readers and managers outside the field of health who also hope to learn—or who simply are motivated by the event to seek out its detailed history—may find something of use in these pages. For these reasons, chapter 1 of this case study is a chronology of smallpox eradication in India, presented in an informal narrative style. Chapter 2 analyzes aspects of program management, and chapter 3 summarizes conclusions from the case study and analysis, presenting the factors that argue against a broad generalization of lessons learned from smallpox eradication (such as the unique characteristics of the virus or the nongeneralizable qualities of a vertical or categorical eradication program) and then presenting the case for the generalizability of certain management lessons from the smallpox experience in India.

I hope that this material succeeds in bringing the experience of smallpox eradication to life again for each reader and that it usefully highlights some of the innovations and adaptations, successes and failures, and good and bad lessons that were part of the India smallpox eradication experience. And I hope that this experience ultimately helps all those who are seeking the alleviation of suffering to improve the management of other programs, whenever and wherever they are working.

## Acknowledgments

The idea for this book began with Dr. Isao Arita, chief of the World Health Organization (WHO) global smallpox campaign; Dr. D. A. Henderson, his predecessor in Geneva and now dean of the School of Hygiene and Public Health, Johns Hopkins University; and Dr. Joel Breman, formerly with the WHO smallpox unit in Geneva and now at the Centers for Disease Control (CDC) Atlanta. I am very grateful to these three colleagues for suggesting that I undertake this difficult but rewarding task. I am especially grateful to Dr. Arita for his patient encouragement at each step of the way, as well as for writing the foreword.

Professor James Austin of the Harvard School of Business Administration was the management expert whose work on the management of international health programs formed the model for the case study approach and the organization of the analysis in this book. From the early conceptual stage on, he was a kind and insightful consultant. Professor David McClelland, also of Harvard, helped by reminding me to view smallpox eradication per se from a broader perspective and by making me reexamine and learn from my own experiences instead of believing overmuch in academic theories. Professors Ruth Simmons and George Simmons of the University of Michigan also helped place the management of smallpox eradication in a more general management and development framework by comparing it to their own extensive experience in family-planning program management in India. Professors Fred Munson, Robert Grosse, and Jan de Vries, also of the University of Michigan, were likewise kind enough to read through one or more drafts and offer suggestions.

I am most grateful to my colleagues in the smallpox eradication program for taking the time to read and review various drafts of this manuscript. Dr. Henderson's early critique of the conceptual outline helped me reorganize my approach in a more practical fashion. His later comments augmented and corrected my limited knowledge of smallpox history with his wealth of experience. Dr. Breman was also kind enough to comment on the draft with great clarity. Dr. T. Stephen Jones and Dr. Stanley O. Foster, both of CDC, meticulously read through various drafts and offered extremely valuable suggestions.

One of my major concerns about writing this book in Ann Arbor, Michigan, was that it might easily be very far off the mark when again viewed from New Delhi, India. My Indian colleagues and friends who comprised the government of India half of the smallpox team helped to narrow that distance by continuously giving many extremely valuable suggestions and insights. I am grateful for the careful reading and helpful suggestions given by Doctors M. I. D. Sharma, R. N. Basu, Mahendra Dutta, and C. K. Rao. Dr. Sharma was kind enough to spend nearly one month carefully checking and rechecking detail after detail of two drafts.

Zaffar Hussain, a paramedical assistant from Madhya Pradesh with twenty years' field experience, read the manuscript and offered suggestions for improving its relevance to fieldwork.

My wonderful wife Girija, in addition to helping organize the book overall, wrote the first draft of the section on traditional health behavior. Economists Ken Warner and George Simmons of the University of Michigan helped Marianne Zebrowski enormously with conceptual problems when she was writing the economic analysis. Marianne brought her talents as a policy analyst to bear on the formidable task of analyzing costs and benefits of eradication as she wrote the draft of the "Evaluation" section of chapter 2.

I was barely out of medical school when I was fortunate enough to be allowed to work with the WHO smallpox unit in New Delhi in 1973. I had been living in an ashram in the foothills of the Himalayas, studying with Neem Karoli Baba. My teacher told me of the smallpox eradication program and of the great good smallpox eradication would mean for the people of India and sent me to volunteer to work with the WHO program. As our friends say in India, "Bhagwan jo kuch karte hai, Hamare mangalam keliye karte hai"—whatever God does, he does for the best.

I want to especially thank my WHO colleagues, who tolerated such a brash young newcomer (I had never seen a case of smallpox before), gave me a chance to work on the eradication of smallpox, and taught me about the epidemiology and management of the disease: Doctors Nicole Grasset, Bill Foege, Zdeno Jezek, Lev Khodakevich, Nick Ward; and Tony Scardaci, John Drescher, Henry Smith, and David Olsen. I am especially grateful to Dr. Grasset, whose dedication and commitment in her new field of blindness prevention has remained a constant source of inspiration and led us to create the Seva Foundation to continue health work in poor communities. I cannot be considered an unbiased observer of the event described in this case study, as my heart belongs to that most wonderful team and to those days we shared. In addition, after the last case of smallpox, the colleagues who remained on for the difficult task of documenting eradication produced a remarkable book that has been a great reference for me (Basu, Jezek, and Ward 1979).

This work was supported by a grant from WHO to the Seva Foundation and by a Professional Development Fellowship from the American Institute of Indian Studies. During this fellowship, I was on a leave of absence from the faculty of the University of Michigan. My thanks to these organizations for their financial support and the confidence that went with it.

Sonya Kennedy of the Institute for Social Research is the literary alchemist who helped translate my leaden prose into more golden words. Karen Brackney and Judy Gallagher spent many blurry-eyed nights typing draft after draft, and Kim Caldewey cheerfully checked references from the smallpox archives.

To all of these, my warmest gratitude; but of course, I alone am responsible for the opinions expressed in this book, which do not necessarily represent those of the World Health Organization or the government of India.

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## *Chapter 1* The Case Study

#### Before the National Smallpox Eradication Program

#### From Time Immemorial

The global eradication of smallpox is a unique health achievement. Once as pervasive as the familiar childhood diseases of measles, mumps, and chickenpox, but far more deadly, smallpox has now been eradicated worldwide. Its eradication from India was the crucial step, for smallpox was especially stubborn and virulent there, where *Variola major* killed one in every four who contracted it. It is easy to see why the rapid eradication of smallpox from the place that was for many years the world's principal endemic focus of the disease has been singled out as one of the great victories in the history of public health: only twelve months separated a peak of more than 8,000 infected villages in May, 1974, and 188,000 cases in that year, from the last indigenous case in May, 1975.

The eradication of smallpox in India is a major achievement because of the setting in which it was accomplished. With a population of 650 million, India is the world's second most populous country and the seventh largest in geographic area. Stretching from the Himalayas in the north to the Indian Ocean in the south, India embraces 14 major language groups and 1,652 mother tongues; thousands of ethnic groups and over 200 tribes; and a social structure based on the caste system. The complexity and subtlety of India's ethnic groups and languages may be unparalleled in any other country in the world. Thirty-one states and union territories (fig. 1) further complicate the setting.

The history of the people of India spans five millennia, during which empires rose and fell, and many great religions emerged—Hinduism, Buddhism, Sikhism, and Jainism, to mention the best known. Contemporary India is home to most of the world's major religions and is the site of several principal places of religious pilgrimage.



FIG. 1. Map of India showing states. (From R. N. Basu 1979. Courtesy of World Health Organization.)

Over the centuries during which smallpox struck Indian villages year after year, diverse and widespread legends, beliefs, and practices developed, reflecting the varied religious traditions. Smallpox was incorporated into the very fabric of Indian society—an important factor that had to be considered.

In India, as in many traditional societies, smallpox was often attributed to spiritual as well as physical forces (Imperato and Traore 1968; Morgan 1969; Mather and John 1973). The pantheon of Hindu deities reflects a variety of divine attributes, and smallpox is traditionally regarded as the manifestation of one of the deities, the goddess Shitala, or Shitala-Ma, whose name means "the cool one," or "cooling mother" (Maury 1969). In southern India her name is Mariamma (Mather and John 1973); in Maharashtra it is Mata-May (Junghare 1975); in rural Bihar she is Bhagwathi (Hassan 1975); in Madhya Pradesh she is Maharani; and in areas of eastern India she is Ai (Jaggi 1973). Other names for her include Devi Mata, Maha-Mai, and Jag Rani (Crooke 1968). In conventional Hindu theology, Shitala is one of seven (sometimes nine) sisters (sometimes mothers), each of whom is associated with a different disease. These diseases commonly include chickenpox, measles, mumps, and cholera.

Smallpox is attributed to the wrath of the goddess, which is especially likely to occur should rituals in her honor be neglected. At the same time, however, the goddess is regarded as having the power to mitigate the severity of the illness. A popular Hindi poem to Shitala says, "when the body burns with poisonous eruptions, you make it cool and take away all pain" (Prabhudas et al. 1977).

In addition to such spiritual explanations of the disease, smallpox is also attributed to excess heat in the body, to an imbalance of hot and cold, or to impurity. In Ayurveda, the ancient Indian medical system, illness is commonly attributed to such humoral imbalances (Babsham 1976). Traditional preventive measures include application of herbs, flowers, or animal products, which are thought to be cooling.

The most common traditional prophylaxis for the disease was regular fulfillment of spiritual obligations to Shitala. Religious ceremonies were periodically performed in her honor at temples dedicated to her throughout the country, in the village environs, or in the home.

The worship of Shitala sometimes conflicted with acceptance of smallpox vaccination, since some Hindus felt that vaccination would anger the goddess. Muslims did not worship Shitala, but some of them felt vaccination interfered with surrender to God's will. Hinduism, as the major Indian religion, was able to creatively integrate traditional health beliefs into the modern vaccination program. The vaccination pustule itself was sometimes honored as a manifestation of the goddess, in the same way that the eruptions of the disease were honored. In some parts of India, vaccination procedures ac-

quired characteristics of a public religious ceremony, and songs in Shitala's honor were sung while vaccinations were given (Hassan 1975). In the late nineteenth century, government vaccinators in Bengal actually performed part of the Shitala worship when a child was vaccinated (Crooke 1968).

Variolation, the practice of deliberate inoculation with smallpox scabs and pustular material, was practiced in India, commonly in areas bordering Pakistan, up through the early 1970s. This prophylactic inoculation of the smallpox (*Variola*) virus historically predates vaccination, which is the inoculation of the cowpox (vaccinia) virus. Before the advent of vaccination, variolation was the only effective, albeit dangerous, prophylaxis available. In India, the practice sometimes had religious overtones, since the local religious leader, often a *fakir*, performed the variolation procedure.

Traditional curative practices for smallpox were varied, reflecting the absence of any clearly effective intervention. When the disease appeared in a family, the household's regular habits of cooking and cleaning were often changed. A special worship of Shitala was often made at a nearby temple. The patient was given a special diet and kept isolated, and herbs were applied. The most commonly used herb was the *neem* plant (margosa, or *Azadirachta indica*), which was considered to have intrinsic "cooling" properties. Branches of *neem* were often hung outside the house of a smallpox patient.

Awareness of these traditional practices was later to be constructively incorporated into the eradication campaign. For example, since the appearance of *neem* over the front door of a house was often the only clue to an unreported outbreak, smallpox workers looked for this telltale sign of hidden outbreaks and made regular visits to Shitala priests as routine parts of the smallpox program's efforts to detect outbreaks that might otherwise be missed. During the early mass vaccination phase of the eradication program, the phrase "worship the Goddess and also take a vaccination" was used to accommodate both spiritual and epidemiological concepts of the disease.

The traditional ideas about etiology, prevention, and treatment of smallpox in India reflect the cultural and metaphysical setting in which the disease appeared. These ideas, evolved over centuries, form the backdrop against which the drama of smallpox eradication unfolded. The sharp contrasts between these long-established traditional health beliefs and the rapid success achieved by the eradication efforts provide important elements for a case study of the management of a successful public health program in a traditional society.

#### 1802-1962: 160 Years of Vaccinations

Jenner's discovery in Berkeley, England, in 1796 provided the weapon that would be so successfully used against smallpox. However, the nature of vaccinia and the relatively slow nineteenth-century travel and communication media limited worldwide dissemination and use of this innovation. The first vaccinations in England were given by armto-arm passage, involving direct transmission from a human donor to one or more vaccinees. Technical problems of producing the vaccine, transporting it, and monitoring its potency were all reduced to the availability of a suitable human donor. As the news of vaccination spread and requests for technology transfer were received from other countries, problems had to be solved in new ways. The Spanish government, for example, sent vaccine to their colonies in the New World via a human chain of donors-twenty-two young boys from a foundling home were serially vaccinated arm-to-arm to maintain a chain of infection during the long ocean voyage. However, such person-toperson chains of transmission could not be maintained for the much longer trip to India, and vaccine did not finally reach that country until 1802. The first successful Indian vaccination was performed that year in Bombay.

Twenty years later, systematic vaccination was being carried out in Bombay. However, most of the recipients were Englishmen residing there who thought of vaccination more in terms of personal prophylaxis than public health. By 1854, the United Provinces (now Uttar Pradesh) had established an active vaccination program. All along, however, variolation was being practiced in some areas of India, and it was not uncommon to see Englishmen vaccinated and Indian villagers variolated. But variolation could actually cause smallpox outbreaks as well as prevent them, and in 1870 the government condemned it as a dangerous practice. Instead, the government urged vaccination for all and in 1877 began to require vaccination reports.

Part of the reason for this attention to smallpox in those years may have been the epidemic of 1873–74, which claimed over 500,000 lives. In 1880, the Bengal Vaccination Act was passed. The main

thrust of this important law was to make vaccination compulsory in the port of Calcutta and in areas administered by the lieutenant governor of Bengal as well as to enforce vaccination of new arrivals in the port. Under this law, public vaccination stations were established, public vaccinators were appointed, and fines were to be imposed in the geographic areas covered by the law: 100 rupees (\$12) for adults who failed to vaccinate their children and 50 rupees (\$6) for adults who resisted vaccination themselves.

However, thirty years later, although vaccination had become increasingly popular among the colonialists in India, there was little evidence of its widespread acceptance in the villages of India. Vaccination was still not required in more than 90 percent of the country. And despite the fact that there was no systematic method for recording smallpox deaths until 1911 (Seal 1975; Basu, Jezek, and Ward 1979), the annual average registered death rate from smallpox was 0.39 per 1,000 population in 1909, and this was likely to be gross under-reporting.

After India achieved independence in 1947, the new government responded to reports of inadequate vaccination cited by a 1946 British colonial inquiry panel, the Bhore Committee, and made vaccination against smallpox an important public health activity (Seal 1975). At about the same time, in 1949, the regional committee of WHO called for compulsory primary and revaccination in all member countries. Ten years later, calling smallpox "a major public health problem in the Region," the regional committee stressed that "the initiation of an eradication programme should receive the highest priority" (Basu, Jezek, and Ward 1979).

Smallpox vaccination activities followed the same epidemic cycles as the disease itself, usually recurring with a five-to-sevenyear periodicity. A major epidemic in the 1950–51 season resulted in 410,819 notified cases, with 105,781 deaths, and stimulated national concern about smallpox control. When the next cyclical peak occurred in 1958, resulting in 168,216 recorded cases and 45,838 deaths, the national concern was intensified.

In 1959, at the eleventh annual meeting of the policy-making World Health Assembly meeting in Geneva, Dr. V. N. Zhdanov, a leading Soviet health official, introduced a resolution urging WHO to launch a global campaign to eradicate smallpox from the face of the earth. If WHO coordinated a global program, Zhdanov predicted, smallpox could be eradicated and "smallpox vaccination would become redundant." This resolution—suggested by a man who later served on the international commission that certified India free from smallpox—was adopted by the assembly the following year, but a major WHO effort did not emerge until eight years later, when WHO appropriated \$2.5 million from its regular budget and sought the required funding assistance from several donor nations.

The combination of a major domestic epidemic and increased international attention on smallpox was the catalyst for the government of India to appoint an expert committee in 1958 to review the alarming situation. This committee, under the auspices of the Indian Council of Medical Research (ICMR), was charged with "suggesting means for eradication of smallpox" (Basu, Jezek, and Ward 1979). In June, 1959, the group recommended establishing a National Smallpox Eradication Program (NSEP) "to vaccinate the entire population [then about 430,000,000] within a period of 3 years" (Basu, Jezek, and Ward 1979). But no national plans were drawn up. The only vaccine available was in liquid form (lymph), which was not heat stable, and few experienced epidemiologists were available to organize a successful vaccination program. Compulsory primary vaccination and revaccination were both required in only five states, compulsory primary vaccination alone was required in nine states, and no vaccination at all was required in the state of Assam and many of the districts of the state of Orissa. The committee suggested starting pilot projects in each state to obtain firsthand experience, argued in favor of "intensive revaccination" because of a perceived "waning of immunity after primary vaccination," and suggested that fragmented laws regarding immunization be made more uniform. Later it was learned that a single vaccination provided a longer period of immunity than had been thought. The committee was ahead of time in one way-it foreshadowed a later surveillance-containment strategy by urging early detection and notification of cases, with a village-level official (Panchayat secretary) given the responsibility to transmit information about smallpox cases by telegram or special messenger.

The committee recommended a type of scratch method of vaccination with four insertions—that is, four separate vaccinations for primary vaccination and two for revaccination. Because of a high vaccine failure rate and the perception that multiple insertions of

vaccine increased the success rate, many vaccinators in India traditionally gave up to six inoculations at a single time. This was a slight improvement over earlier practice and a welcome change from the anachronistic method of using a scarifying device known as the rotary lancet which frightened many from accepting vaccination and often produced scars even with impotent vaccine (see fig. 2). But even this reduction in number of insertions was not fully implemented for a decade.

Finally, the expert committee recommended setting up an infrastructure for the NSEP: it calculated a need for recruitment and training of at least 20,000 additional vaccinators, procurement of vehicles, changeover to freeze-dried vaccine with proper storage and distribution, and the organization of vaccination campaign/health education visits preceding or concurrent with the actual launching of the campaign (Seal 1975).

One study (Rao 1959), performed in Madras, showed that most neonatal vaccinations resulted in positive take rates with low levels of complications. The practice of neonatal vaccination had been previously resisted by some villagers who believed there was a higher risk of reactions in neonates and therefore preferred to vaccinate their children at a later time. However, the government began a moderately widespread practice of neonatal vaccination in Tamil Nadu. It is not known how many vaccinations were given. National tabulations of vaccinations were not begun until 1962, 160 years after the first vaccination in Bombay.

#### The National Smallpox Eradication Program Begins

Smallpox in the Third Five-Year Plan, (1961–62 to 1965–66)

In 1960, seventeen pilot projects were begun. Although their objective was to register and vaccinate each of the nearly 23 million inhabitants of the pilot project areas in each state and in Delhi, when the pilot projects came to an end on March 31, 1961, only half that number had been vaccinated. But the beginnings of a national plan were emerging, and the idea of the NSEP was firmly in place, having been officially made a part of the Third Five-Year Plan, which extended from 1961–62 to 1965–66. The Ministry of Health sanc-



FIG. 2. The rotary lancet. (Courtesy of World Health Organization.)

tioned Rs. 68,900,000 (\$8,600,000) to launch the NSEP. The USSR made an initial contribution of 250 million doses of freeze-dried vaccine, the first installment of which arrived in February, 1962, and a further donation of 200 million doses in 1964. The United States Agency for International Development (AID) provided 10,000,000 rupees (about \$1,200,000) to assist in payment of salaries and other expenses.

In 1962, the first year for which national vaccination statistics were recorded, 32.35 million vaccinations were reported; in 1963, 138.72 million—a fourfold increase. But there were inaccuracies in the vaccination reporting system and problems with the sometimes ineffective liquid vaccine; and despite the encouraging vaccination statistics, reported smallpox incidence in 1963 soared to 83,438 cases with 26,360 deaths, more than double the reported incidence at the start of the NSEP in 1963. In 1963, India alone accounted for over 80 percent of all known cases in the world (although this is a very soft figure because reporting inadequacies existed both in India and worldwide), and the 31.6 percent case fatality rate that year was the highest ever recorded in India. Something was wrong.

The NSEP had been conceived of as a three-phase program of preparation, attack, and maintenance. The preparation phase was to be an initial period of epidemiological studies of smallpox and pilot projects to provide field experience. During the attack phase, each sector of India's heterogeneous population was to be vaccinated; the goal was to vaccinate 80 percent of the population within two years. (The 1961 population of India was 439,234,771; 80 percent coverage would have required 351,387,816 vaccinations.) No distinction was made between primary vaccinations and revaccinations, although the importance of vaccinating newborns was often emphasized. The concept of "herd immunity" dominated smallpox eradicators' thinking at the time. Basically this meant that if enough people in a community were vaccinated and therefore immune to smallpox the disease could not perpetuate itself through the "herd" of people in that community. WHO as well as many governments stressed high vaccination coverage as the key to interruption of transmission. Under a standard pattern of operations, each separate NSEP unit was responsible for a population of about 3,000,000 and was supposed to reach the target of 80 percent vaccination coverage.

The recorded numbers of vaccinations performed by the NSEP in its first two years are quite impressive: over 324 million vaccinations, of which more than 38 million were primary vaccinations. Nevertheless, smallpox outbreaks continued unabated, despite the apparent effectiveness of the NSEP vaccination effort, which was measured only by the indication that a large proportion of the population had been vaccinated. If, instead, the relation between vaccination and disease incidence in a population had been systematically examined at this point, perhaps it might have pointed earlier to the ultimately successful strategy of disease surveillance and containment vaccination that in fact did not emerge until several years later, following an accidentally imposed test in the early 1970s.

From December, 1962, into early 1963, a large epidemic of smallpox in Delhi prompted an independent assessment of the NSEP by a specially appointed committee, which made some startling findings. First, the total coverage of vaccinations in the community was found to be 63 percent (as opposed to the more than 80 percent reported officially). Second, the success or take-rate of primary vaccinations was 86 percent; therefore, no more than 54 percent (86 percent take-rate, multiplied by 63 percent vaccinated) of the population had been effectively immunized during the campaign. Of the 223 smallpox cases investigated in Delhi, 56 had never been reported to the authorities and 188 of the victims (84.8 percent) had never been vaccinated. And of course, there was as yet no mechanism for careful epidemiologic investigation of such outbreaks by smallpox program staff. As a result of these disclosures, the Ministry of Health decided that the National Institute of Communicable Diseases (NICD) should undertake a series of assessments in various districts (Gelfand 1966). Their purpose was to verify the accomplishment of representative districts that had reported reaching the 80 percent attack phase goal.

In the meantime, with equipment provided by the United Nations International Children's Emergency Fund (UNICEF), freezedried vaccine was being manufactured in India for the first time. In 1962 the State Vaccine Institute in Patwadangar and the King's Institute in Guindy began to produce freeze-dried vaccine. The Institute of Preventive Medicine in Hyderabad joined them in 1964, and in 1967 the last of the four regional centers, the Vaccine Institute in Belgaum, began production. Although these centers produced generally high quality vaccine, there was a need to monitor quality, as there is in the production of any biologicals. Spot-checking was necessary, and it was important that an outside agency independently carry out systematic quality control. One of the recommendations of the 1958 expert committee had called for monitoring the quality of vaccine, but a proposed central-level vaccine-testing unit did not begin functioning until it was later absorbed into the National Reference Laboratory at the NICD. Getting central level quality control of vaccine continued to be a problem until quite late in the program.

The NICD assessment was to become an important milestone in the management of smallpox eradication in India. Independent teams were assigned to areas with 1,000 to 5,000 houses, and during a six-day period each team visited and interviewed a systematic sample of 1,200–1,500 people. An attempt was made to determine the coverage of the mass vaccination program and assess the current percentage of vaccination of the resident permanent population. The assessment teams found that vaccination coverage was exaggerated: the actual coverage of the population was far lower than vaccination reports. Even where the number of vaccinations was correct, it often reflected annual revaccinations of easily accessible sectors of the population, such as school children and workers in industrial plants. Meanwhile, many adults in urban slums and migrants in rural areas had never been vaccinated. The equal emphasis on both revaccination and primary vaccination had been—quite literally, for thousands—a fatal error in NSEP management policy. As a result, the community as a whole lacked "herd immunity."

Assessment teams observed that vaccinators were poorly trained, technically inefficient, and abrupt and callous in their approach to the public. The vaccinators' morale was often low: they had been hired as temporary workers only for the attack phase, without promise of continued employment. In certain areas, gross discrepancies were found between the percentage of those reported as immunized and the number actually vaccinated. In Chingleput, a district that had claimed 84 percent coverage, assessment teams found 65.6 percent; and in Banaras, a district of Uttar Pradesh that had reported 87 percent coverage, they found 66.4 percent. In many areas (some having claimed 100 percent vaccination) they found as much as half the population without primary vaccination (Gelfand 1966). Some local communities large enough to support smoldering epidemics had been missed completely. In some instances, persons deceased for several years before NSEP began had been registered and recorded as having been successfully immunized. In addition, since return visits to check take-rates were rare, several vaccination campaigns had been carried out with either poor quality vaccine or bad technique, in both cases affording no community protection.

Besides inadequate vaccination coverage, the NSEP was also taken to task for poor smallpox reporting. Many administrative and previously unappreciated social pressures against reporting smallpox came to light in the assessment. Village-level vaccinators, for example, were often chastised by their supervisors whenever they reported the presence of concealed epidemics. This was even more true at the family level.

Cases are often hidden to escape detection: the patient and his family often accept the disease as a visitation of the goddess Shitala Mata... and many wish to avoid compulsory hospitalization; the family and neighbors often wish to avoid the investigation and vaccination that may follow; the sanitary inspector may prefer not to know about a small episode that might cause a considerable amount of vaccination work; and the local medical officer may fear to report an outbreak that reflects upon the vaccination status of a community that is his responsibility. (Gelfand 1966, 1644)

The assessment did not, however, criticize the overall goal of the program, which was the prevailing global strategy at the time: mass vaccination. Instead, it concluded the goal was "based upon a plan that was generally reasonable within the context of public health practice at the present time, but which had met many unanticipated obstacles in practice" (Gelfand 1966, 1648). The assessment team recommended (1) increasing the overall goal of 80 percent coverage, thought to be too modest for an "eradication programme," and giving priority to the vaccination of infants, preschool children, and the floating population (migrants, transients, and homeless refugees who float from place to place); (2) insisting on the overall importance of primary vaccination; and (3) abandoning the rotary lancet, which was "time consuming and wasteful of vaccine, and which gave a low take rate and high infection rate" (Gelfand 1966, 1648). In addition, the assessment team urged that vaccinators be better paid and supported, that the results of vaccination be followed up, that more emphasis be placed on the maintenance program (maintaining high levels of vaccination coverage after the initial campaign), and that concurrent evaluation be added to program implementation.

Also needed was a better indicator of performance than simply the number of vaccinations reported. It was suggested that the data for monitoring progress should be provided by having the special smallpox unit in the Directorate-General of Health Service, Delhi, supervise all local NSEP units and gather the data to monitor percentage of successfully immunized (as opposed to number of vaccinations), as well as assess the validity of the periodical reports of smallpox incidence. In 1964, after reviewing the NSEP report and the recommendations of the recently completed WHO Expert Committee on Smallpox Eradication, the Central Council of Health set a target of 100 percent vaccination for the entire population. However, they failed to address the need for new management techniques to reach the larger goal. There was still no plan of operations.

#### A Period without a Plan, 1961–69

The third of India's five-year plans ended in 1966, but the fourth did not begin until 1969. The intervening years were difficult years for smallpox eradication, but not only because there were no development plans. The situation created by the recent Indo-Pakistan conflict, two successive years of severe drought, devaluation of the currency, a general rise in prices, and scarcity of many resources delayed the Fourth Plan and at the same time suppressed many ambitious health programs.

The NSEP did not escape the tumult of the period. The flurry of vaccinations that had resulted in a remarkable average of 127 million vaccinations per year for three years (1963-65) began to diminish as the attack phase moved on to the maintenance phase of the program. The annual rate of vaccinations dropped 35 percent, to 83 million per year, in the 1966-69 period, while the reported incidence of smallpox actually rose slightly, with 500 more cases reported in 1967 than in 1963. However, there were successes, especially in the southern states, where the health infrastructure was better developed and literacy higher than in the northern states; and epidemics as large as those of 1950-51 and 1957-58 did not recur in the first years of the NSEP as some had predicted they would given the historic five-to-seven-year smallpox cycle. But two things were becoming apparent: first, the target of 80 percent vaccination could not be attained with the existing management of NSEP, and second, greater vaccination coverage would not have been sufficient to interrupt transmission.

After the 1966 World Health Assembly voted to create a global smallpox eradication program, India did not immediately set up a WHO-assisted campaign as nearly all of the thirty-four other smallpox-endemic countries in the world started soon after. But in that year India did make a substantial contribution to world smallpox. The 32,616 cases reported there accounted for 35 percent of all the smallpox reported in the world. Still, India counted on its large army of trained health workers and the state NSEP programs to break the back of smallpox without external assistance.

But the country's alarming situation prompted another assessment of the NSEP, this time as a joint government of India–WHO undertaking in October and November, 1967, and the close collaboration that resulted laid the groundwork for future joint efforts. For this assessment, eight experts from WHO joined a similar number from the government of India and Indian institutions. They declared:

Mass vaccination alone does not constitute a smallpox eradication programme. Rather the function of mass vaccination is to reduce the incidence of the disease to a sufficiently low level to make it possible for other measures—case detection and containment of outbreaks—to eliminate the remaining endemic foci.

At that time, only four states and union territories (accounting for less than 1 percent of the country) were reported free of smallpox. The assessment team concluded, with some understatement, that: "the NSEP is still, in most areas, far from achieving its objective of smallpox eradication."

The commission specifically cited the unsatisfactory procurement, distribution, storage, and handling of vaccine. Refrigerators, if present, were often not in working order. The commission requested the central government to carefully monitor vaccine production by each vaccine production unit, which had still not been done. They asked each vaccine production institute to supply freeze-dried vaccine each month to a defined group of states in order to bring order to the chaotic distribution network. At the same time, something had to be done about the fourteen vaccine production units in India which were still producing the expensive liquid vaccine, which retained its potency for no more than forty-eight hours, was often contaminated, and caused many ineffective vaccinations. An estimated 35 million doses of this vaccine were still in stock, and they were a liability, because impotent vaccine not only failed to stop smallpox but also led to feelings that smallpox would not be eradicated. In that same year, India produced 1.41 million ampoules of freeze-dried vaccine and received nearly 6 million ampoules from the USSR.<sup>1</sup>

The rate of domestic production of freeze-dried vaccine increased from 14 percent of annual requirements in 1966–67 to 50 percent only three years later, and India became self-sufficient in 1973. At the end of the program, India became a net exporter of vaccine and was often called upon to donate vaccine to Bangladesh, Bhutan, Nepal, and Sri Lanka.

The regional unevenness of the NSEP was still a great concern.

While several southern states were making great progress, a few, mostly in the north, were faltering. The Indian constitution made health a "state subject," which meant the state and not the central government was the implementing agency, and the center could not easily impose standards of excellence or dictate program strategy or tactics. In 1967 there was a larger than anticipated epidemic of smallpox, which led to India's having an embarrassingly large share of the world disease. This motivated the central government to reclassify NSEP as a centrally sponsored program when the Fourth Five-Year Plan was finally begun in 1969–74. The central government could now prod lethargic states into action.

At about this time, there was a development more than 7,000 kilometers away that was to have important repercussions in India. There had been a delay in the delivery of supplies for a mass vaccination program in eastern Nigeria, and on December 4, 1966, Dr. William Foege, an American advisor in Nigeria, began husbanding his scarce supplies of vaccine by intensively vaccinating only in the houses immediately surrounding newly reported cases. In each affected village (except for two individuals who escaped vaccination) the outbreaks ended within two or three weeks after vaccination began. At a time when less than 50 percent of the population had a vaccination scar, transmission was interrupted with a limited supply of vaccine. This experience documented that an outbreak could be extinguished by vaccinating people in a limited area around each new case, even if the general area contained many unvaccinated people.

A prerequisite for the success of this kind of intensive vaccination was the development of an effective surveillance system like those gradually being established in Brazil, East Africa, and especially in Indonesia. Indonesia and India, both in the WHO South-East Asia Region, had experienced similar administrative difficulties with a target of 100 percent vaccination coverage and with getting cases reported. A facial scar survey, carried out in Indonesia in February, 1968, revealed that less than 7 percent of cases that had occurred in 1967 were ever reported to the provincial health service. Efforts were made to improve the notification rate, and as a consequence the entire reporting system was monitored. Because of the two nations' similar problems earlier, when a dramatically successful surveillance-containment strategy was implemented on a wide scale in Indonesia in 1969, it was a message to India. Smallpox incidence in Indonesia plunged from 18,000 cases in 1969 to 2,158 cases in 1971 and to only 34 in 1972, the year transmission was interrupted. The Indonesian success inspired many Indian smallpox workers.

India's birthrate of 34.4 per 1,000 was adding 22,000,000 new and unprotected infants to its population each year. Subtracting the estimated 10,000,000 annual deaths gives approximately 12,000,000 added population each year. From 1962 to 1970 an average of 14,900,000 primary vaccinations were recorded each year, not enough to keep up with new births. But because of the large number of unvaccinated people in the country when vaccinations first began, even if primary vaccinations were effectively carried out each year at a rate that matched annual population growth, a large backlog of approximately 25 percent of the population would have remained unprotected.

But the Indonesian emphasis on case reporting was fresh in the minds of Indian planners. When the Fourth Five-Year Plan did begin in 1969, it was to emphasize surveillance. Along with this plan, however, was to come another plan, and for smallpox a more important one: the WHO–Government of India Plan of Operations for the eradication of smallpox.

#### A Plan of Operations, 1970

Some management experts consider planning synonymous with the formulation of strategies, because a plan outlines strategic actions in a program. Planning alone cannot ensure a successful program, but it is a key element of sound program-management practices. The NSEP entered the decade of the 1970s with neither a defined plan nor specific strategies, and the mass vaccination program was faltering.

In their Basic Agreement of 1959, WHO and the government of India stated a joint commitment to the eradication of smallpox. They updated this agreement on September 9, 1970, with a new Plan of Operations for the NSEP (see appendix 1). This plan, which proposed new methods and guidelines for implementing the smallpox campaign, represented an important agreement between WHO and the government of India as well as an attempt to develop strategies. The objectives of the plan were to achieve eradication and maintain it through surveillance. Three needs were identified: (1) sufficient personnel, (2) application of prescribed technical methods and procedures, and (3) freeze-dried vaccine. Also stressed were the importance of retaining the potency of scarce vaccine through quick transport, cool storage, and prompt use after reconstitution. The government of India took reponsibility for organizing production and distribution of the freeze-dried vaccine.

The plan established as a priority that all children under fourteen (among whom most cases were occurring) be vaccinated, as should those groups most likely to transmit diseases; in the case of a smallpox outbreak, mass vaccination in the outbreak area should be mandatory in order to effectively contain the disease. It affirmed the preferability of the bifurcated needle (a new method of delivering vaccine by a needle that held just the right dose of vaccine between two "bifurcated" prongs (see fig. 3), when available, to any other means of inoculation, though this was honored more in the breach than the observance.

The plan also recommended establishing a monthly review process, with program evaluation to be performed by the state government, the government of India, and WHO, as deemed necessary by the government of India and WHO. Surveillance and outbreak containment, accompanied by health education and publicity, were stressed as important components of the plan of action. The government of India was given the responsibility of educating the public about the disease and persuading citizens to report suspected cases, and it was stipulated that the smallpox program would be handled as a centrally sponsored national program until it reached the maintenance phase, when surveillance would be integrated into the basic health services.

In the Plan of Operations, the resource commitments of both parties were explicitly laid out. WHO agreed to provide epidemiologists and consultants from outside India to aid the government in independently assessing the program and training personnel and to offer fellowships, as necessary. It agreed to provide supplies and equipment not manufactured in India, such as vehicles, motorcycles, refrigerators, bifurcated needles, and spare parts. This stipulation was later relaxed so that WHO could directly purchase jeeps manufactured in India.

WHO also agreed to subsidize local costs, such as funds for payment of salaries, travel, or per diems, and to provide additional



FIG. 3. The bifurcated needle. (Courtesy of World Health Organization.)

assistance when mutually agreed upon. As time went on, WHO broadened its funding support to include items such as gasoline.

The government of India agreed to provide (1) storage facilities for, transportation for (before the plan transportation was rarely available even when it was necessary to investigate outbreaks), and distribution of WHO supplies and equipment; and (2) communications, fuel, maintenance, locally available spare parts, health education, and incidental expenses necessary for the successful execution of the program. It agreed to support the WHO international personnel with office accommodations and supplies as well as internal transportation. (The latter meant that the government was responsible for providing jeeps for WHO epidemiologists, but transportation was so essential, as it is in every health program, that when the government was unable to provide it, WHO provided the jeeps directly.) The government of India also agreed to provide assistance in obtaining residential accommodations and other facilities.

The Plan of Operations supplied extra staff, supplies, and technical assistance and provided a revitalizing influx of resources for the NSEP. Additional epidemiologists, consultants, and other tech-

nical advisors with smallpox experience in countries that had already eradicated smallpox now became available. Having seen smallpox eradicated elsewhere, they brought optimism and credibility to the Indian campaign.

Four WHO medical officers—the first WHO smallpox field staff in India—arrived, with their optimism, in 1971. The jeeps and motorcycles that were provided by WHO along with other supplies and equipment gave the staff increased mobility, allowing them to better supervise searches and outbreak containment. Surveillance workers could now expect a specially trained smallpox field worker, the paramedical assistant (PMA), to show up anywhere at any time. The use of freeze-dried vaccine, emphasized as an important strategy in the plan, improved vaccination take-rates to virtually 100 percent by 1971. In reaffirming the shift away from mass vaccination to surveillance and identifying high-risk and highly mobile populations for vaccination, the plan established a more efficient use of limited staff and vaccine and increased the availability of such key resources as transport and senior level epidemiologists-managers.<sup>2</sup>

This move to a strategy of surveillance-containment, the most important of the entire smallpox campaign, followed closely the recommendations of the recently completed WHO Expert Committee on Smallpox Eradication, which had met in Geneva. Five years had passed since the beginning of the WHO intensified global program. The expert committee reviewed the accomplishments and problems of the program and considered the strategy and tactics to be used in the years to come. Its major conclusion was: "The experience of the past 5 years clearly demonstrates that surveillance is the essential element in the strategy for eradication," and it stressed that "reporting must be strengthened everywhere. Every suspected case must be investigated at once, its source of infection traced and containment measures instituted promptly" (World Health Organization Expert Committee on Smallpox Eradication 1972, 10–11).

The 1970 Plan of Operations laid the basis for continued cooperation between the NSEP and WHO, allowing for the agreement to be updated through periodic addenda, to adjust WHO support as the program continued. With the flexibility of its provision for such changes, the Plan of Operations became an agreed-upon set of operational tactics that could be adjusted to incorporate any new, more effective strategies developed in the field.

#### Working in the Dark, 1971–72

As it was to turn out, the 1970 joint WHO–government of India Plan of Operations was little more than a point of departure. Despite its sound strategy and the incorporation of experience from Africa and Indonesia, a major element was missing. No one knew how much smallpox was present in India or where it was. Without this knowledge, resource needs could not be planned and targets could not be established. A realistic timetable for eradication was still out of reach.

India was not the only place with poor smallpox reporting at that time. One study indicated reporting efficiency of only 1.3 percent in rural areas of northern Nigeria; another estimated less than 6 percent efficiency in West Java. Henderson (1976) suggested that the 131,418 cases of smallpox reported worldwide at the start of the global program in 1967 might more accurately have been on the order of 10 to 15 million cases, reflecting a global reporting efficacy of 1 percent. Others estimated an 11.8 percent surveillance efficacy in Bangladesh as late as 1972 (Hughes et al. 1980). It is very likely that less than 1 case in 10 was reported to central health authorities in India in 1967 (Basu 1974).

The NSEP had done little to encourage reporting of smallpox. Under-reporting led to deceptively low mortality figures and in turn to a feeling that smallpox was not a major health problem in India. This produced a negative response from field workers. As less smallpox was reported, fewer resources were allocated and fewer vaccinators were available when an infected area was reported. The fewer the number of vaccinators to visit an area, the fewer the cases of smallpox that were found there. Only when smallpox happened to come to the attention of the Ministry of Health because of a newspaper report, a "call attention" motion in Parliament, or an international exportation (between 1962 and 1974, ten outbreaks of smallpox in Europe were imported from India) were more resources devoted to the eradication effort. If more vaccinators had been sent to infected areas, more smallpox might have been found, and in turn more resources and vaccinators sent to each outbreak area. until the foci were contained.

In some parts of the world, a case of smallpox would be quickly brought to the attention of a health worker or doctor for curative and

preventive action. In India, however, cases of smallpox were often suppressed. The reasons were complex and rooted deeply in cultural tradition and belief.

First of all, the public was aware of vaccination failures (e.g., from liquid vaccine made impotent by the heat). In addition, certain apparent failures influenced public perception. For example, smallpox and chickenpox were often perceived to be the same disease; in fact, both diseases have the same name in Hindichechak (Morinis and Brilliant 1981). Their patterns of seasonal incidence are identical, and since many of those vaccinated against a smallpox outbreak would subsequently get chickenpox, it was not unreasonable for some to conclude that vaccination must be useless. In addition, the incubation period of smallpox is seven to seventeen days, and symptoms of smallpox may not develop for a full two weeks. An infected but asymptomatic person, vaccinated ten days after exposure, would still develop the well-known symptoms of smallpox four days later, leading many to conclude not only that the vaccine was worthless but that it could actually cause smallpox.

Sometimes resistance to vaccination was really resistance to badly trained or poorly motivated vaccinators, as the following anecdote illustrates.

The public vaccinator . . . was a supercilious young man from Udaipur city . . . , who had passed a course in this specialty, and he regarded villagers as an inferior and stupid lot—especially when they refused to accept his scarifications. During his four day stay in Delwara, the task degenerated into a hunt. I would see a herd of children and young mothers come bolting out of an alleyway with hilarity and panic mingled in their shrieks, while the vaccinator pursued them, brandishing the weapons of his trade. (Carstairs 1955, 108)

To encourage Indian smallpox workers, WHO often cited other parts of the world where resistance to vaccination was much greater than on the subcontinent. The elimination of mass vaccination in favor of containment also reduced resistance, since it was no longer necesssary to vaccinate people in areas long free of smallpox. Moreover, since fewer numbers needed vaccination, proportionately more effort could be given to each resistor. A survey of vaccination resistance in Lucknow district in 1965 found that 18 percent of the population resisted smallpox vaccination, forming what was termed hard-core resistance to vaccination. It was noted that

Experience has shown that the resistance against the acceptance of vaccinations and revaccinations can only be broken through personal contacts and field demonstrations by vaccinating staff, including the officers practicing on themselves. (Gupta, Bagga, and Suraiya 1965, 7)

This experience had come from the Pilot Project for Smallpox Eradication in Sultanpur district, Uttar Pradesh, in 1962 (Gupta 1962). In this case, one of the NSEP pilot projects had paid good dividends. The subsequent practice of demonstration vaccination, whereby the vaccinator revaccinates himself in front of villagers to allay anxiety about the vaccine, was of great help in subsequent containment actions. This practice (with the less awesome bifurcated needle) plus better training of vaccinators, greater support for their activities from higher officials, and the restricted number and location of communities requiring intensive containment, were all factors in reducing resistance in the Lucknow pilot project from 18 percent to a negligible amount in the later stages of the intensified campaign. It is also important to understand historic reasons for villagers' skepticism about vaccination. One of the common names of smallpox-bashanto-translates as "spring sickness": it was in the spring that smallpox used to take its greatest toll. The spring is also wheat harvest time in northern India. According to the zamindari feudal system, still practiced in some areas, agricultural laborers get one kilogram of wheat for every sixteen that they harvest during the month of March. A major portion of the year's earnings thus depends on one's physical ability to bring in a maximum harvest during March, and when the vaccinator came to the village during the spring harvest season, each adult wage earner had to make a choice. If he had never had a vaccination before, it was fairly certain he would experience a major reaction (swollen arm, fever, malaise) for two days. The certain loss of work for those two days had to be weighed against the far more remote possibility of a fatal or serious case of smallpox. Often, agricultural laborers chose to forego the vaccine.

Naturally, some of these attitudes about smallpox carried over to some Indian officials who also felt that nothing could be done about the disease. As Henderson (1976) said about the area in general: "Support for the programme by health authorities was lukewarm; so many efforts to control smallpox had failed over so many years that the disease was widely considered inevitable and its elimination impossible" (p. 30). With such general resignation about the inevitability of smallpox, why report the disease?

India and Ethiopia were the last of the endemic countries to embark on a WHO-assisted program. In 1971, as noted above, the first four WHO medical officers had reached India. Along with their counterparts, the state program officers, they began to implement the WHO-government of India Plan of Operations and stressed surveillance and reporting. But it was a long and leaky channel of communications from the villages to the Central Bureau of Health Intelligence (CBHI) in Delhi, which compiled the weekly statistics. Breman (1976) estimates that half of all cases detected at one level were not passed on to the next level. There was a tendency to conceal smallpox cases at all levels in the earlier days of the program. Families concealed cases from health authorities out of respect for Shitala-Ma and to avoid the arrival of vaccinators: vaccinators suppressed outbreaks for fear they would be blamed for failing to vaccinate 100 percent of the population; old cases detected in previously unknown outbreaks were generally not included in reports. Even after detection, officials did not adequately contain the disease and did not feel they needed to report all outbreaks to the higher authorities. In addition, the reporting system itself proved to be a cumbersome procedure. Although the Plan of Operations called for smallpox to be reported by "telegram or special messenger," more than half of the states chronically reported late, sending reports by ordinary mail.

The Plan of Operations called for the government of India to "keep WHO informed of weekly incidence" (see appendix 1), but before the reporting system could even begin to keep abreast of smallpox trends, it had to be streamlined in two respects. First, the absence of a report could mean either the absence of smallpox or the absence of the reporter. Health officials often omitted the burdensome weekly report when there was no disease to report. But there was a critical need to keep weekly reporting channels open. For the purpose of resource allocation decisions, the fact that smallpox was not present in a primary health center (PHC), district, or state was as important as the fact of its presence. A weekly "nil" report was made a requirement of the centrally sponsored NSEP. Every Saturday, the 5,268 PHC medical officers were supposed to send their weekly epidemic report (WER) forms to the district, which forwarded them to the state on Wednesday; the compiled reports were then sent to Delhi the second Monday after the week in question. The signed report was marked "nil" if no smallpox was detected; this was the beginning of a management information system, a chain of information that ultimately determined the placement of epidemiologists, the allocation of jeeps, the movement of vaccine, and the attention of smallpox epidemiologists at state, national, and WHO levels.

But another reporting problem existed. Until 1972, the system required that cases detected months after their occurrence be added as "supplementary reports" to the previous month's or previous year's reports (Ministry of Health and Family Planning 1972; 1975). Current cases were reported in the week they occurred, but investigation of a new outbreak might yield previously undetected cases with onset months earlier. This called for time-consuming amendments and supplements to previous reports. The amendments became so burdensome that they were simply ignored, or current reports were delayed by recalculations of totals from several preceding months. This system encouraged massive under-reporting and its corollary, complacency. From 1972 onward a uniform reporting system was put into practice under which all cases detected during the week regardless of date of occurrence were included as a lump sum in that week's report. To central officers in Delhi, an epidemic of old, burned-out, but previously missed cases was as potentially serious as a current epidemic, because it meant a weak link in the chain of surveillance that stretched from villages in the most remote parts of India all the way to New Delhi, as shown in figure 4.

But even with a strengthened reporting network, improved communications, and routinized weekly reports, the smallpox leadership in Delhi was still working in the dark. As late as 1972, "case detection was inadequate, and the reporting systems were archaic; the importance of surveillance and containment was not appreciated" (Henderson 1974). There was still a long way to go from surveillance in the plan to surveillance in the field. 21,161 Vaccinators and Other Health/Nonmedical Workers

Primary Health Centers (PHC) (5,268 notification posts)

> District Health Officers (356 units)

Smallpox Program Officers (30 states and union territories)

Central Bureau of Health Intelligence (CBHI) Ministry of Health (Delhi)

World Health Organization

# FIG. 4. The reporting network that stretched from peripheral villages to New Delhi, as it was in 1971

In 1972, the worldwide number of smallpox cases jumped 69 percent over the 1971 figure, and India accounted for over 42 percent of the world's reported incidence. In many Indian states, the jump may have reflected improved surveillance and the new lump sum reporting of old, previously unreported cases. The principal endemic foci were in the north central region, within a 500-kilometer radius of Delhi, and in the states of Bihar, Madhya Pradesh, Uttar Pradesh, and West Bengal; over 79 percent of the 1972 cases were reported from these four states.

In the south there had been an excellent record of achievement in smallpox eradication, apparently from mass vaccination. In 1971–72, Kerala and Tamil Nadu interrupted transmission, and Karnataka and Maharashtra reported a considerably reduced smallpox incidence.

However, major epidemics occurred in the Gulbarga district in Karnataka. One of the four new WHO medical officers came to the area and carefully investigated the outbreak, which had begun in December, 1970, and continued through 1971, reaching a peak in April, 1972. A total of 1,359 cases of smallpox with 123 deaths had occurred in 1,128 villages and 5 municipalities, but the initial outbreak had been deliberately concealed. One of the sparks of the epidemic had ignited an outbreak in Kurkunta, a village on the border of Andhra Pradesh. From a cement factory there the disease had spread to a number of villages in Andhra Pradesh, where a large outbreak began to develop. Andhra Pradesh authorities investigated and traced the source of the outbreak back to Gulbarga. However, no smallpox case had been reported from Gulbarga in 1970 or the first eleven months of 1971. Field staff had in fact detected smallpox, but the medical officers of the PHCs did not report them to the state, perhaps due to fear of reprimand, which was a common response to such reports. This deliberate concealment and poor reporting led to the epidemic that brought attention from Delhi. To contain the outbreak rapidly, prompt detection of all cases in an area of two million people was required. All available health personnel, not just smallpox health workers, were mobilized for a weeklong, house-to-house search of the area. By carefully focusing containment vaccination around each newly discovered case, they eliminated smallpox from the district within weeks.

This experience appears to have provided India with its first successful containment operation. Moreover, while it certainly revealed the problems of incomplete reporting and concealment, it also showed what could be accomplished by deploying health workers ad hoc to conduct a thorough search of an outbreak area. As in many similar episodes in the smallpox eradication program, the leadership of the program highlighted the positive lessons, transforming a liability into an asset. Skeptics had said surveillancecontainment might work in Africa, but not in India. The Gulbarga experience proved the opposite: surveillance and containment could work even in that densely populated country.

From October 30 to November 2, 1972, as Indonesia was fast approaching the target of eradication while India was far away from it, a WHO Inter-Country Seminar was held in New Delhi. The seminar recommended that since previous experience had demonstrated the effectiveness of surveillance as a means of achieving eradication, full implementation of surveillance should be ensured. Every state was to be considered either endemic or nonendemic. Priority would be given to endemic areas, which would receive the largest amount of available resources, although active searches would also be performed in nonendemic areas in order to make sure they remained smallpox-free. The occurrence of a suspected case in a nonendemic area would be handled as a national public health emergency to prevent the reestablishment of endemic foci.

The group advised that staff and supplies from the smallpox program should under no circumstances be diverted to other programs—a point of major importance because smallpox program resources were continually being diverted to other health programs (especially family planning), making it difficult if not impossible for the smallpox program to meet its goals. In areas where surveillance teams had not been formed, state or national teams were to be created as soon as possible and provided with transport.

In order to effectively contain smallpox outbreaks, staff were to vaccinate 100 percent of all contacts and persons in the immediate area, and were to make follow-up visits to ensure that no persons had been missed. Lower socioeconomic urban areas (where vaccination coverage was lower) were to be given special attention. Once an area became free of smallpox, an active search for cases was to be carried out by visiting schools, markets, shopkeepers, religious and other local leaders, health stations and other sources of information; in addition, the smallpox recognition card was used in order to obtain better information on cases. This card, developed out of field experience in Indonesia, was a photograph of a child with a typical case of smallpox; by highlighting recognizable signs of the disease for a medically untrained search worker and the community, it became one of the most important weapons against case suppression.

The seminar also stressed the problem of failure to identify and confirm the source of infection, particularly when state lines had to be crossed. Written cross-notification was inefficient, as often some identifying information would be omitted or villages wrongly identified owing to phonetic spelling; district staff receiving the information were often uninterested or occasionally were themselves suppressing information; and so on. Any time an outbreak could not be traced to another known outbreak it meant that some unknown active smallpox cases were likely being hidden from epidemiologists. If they went undetected, active foci could persist and continue to spread infection.

The seminar further noted that this problem could only be overcome by creating state surveillance teams charged with the responsibility for investigating the source of infection for all outbreaks, particularly those whose source was outside the infected district. Until an adequate number of state teams could be constituted, district staff had to be directed to pursue and positively identify the source of infection in adjacent districts, whether or not state borders intervened. If this were done in company with the district staff of the district exporting smallpox, immediate containment measures could be undertaken. The seminar believed that if outbreak investigation were not actively pursued and supported by the state and national program staff, transmission could not be interrupted in India.

The November, 1972, seminar concluded on a positive note.

Provided that such a surveillance component is implemented in the programmes of India and the adjacent countries, it is possible that the incidence of smallpox could reach zero within 18 months. (Henderson 1976, 31)

The general strategy was developing for the intensified campaign that began in September, 1973, especially the ideas of active search and containment; surveillance teams to take responsibility for investigating sources of infection; and dividing the country into endemic and nonendemic regions for a progressive constriction of the endemic area. As predicted, the change in strategy in favor of surveillance would be the key. Without knowing where the cases were, everyone had been working in the dark. Once search and containment became the strategy for eradicating smallpox, it was, as the global commission's final report stated: "only a matter of time and colossal effort" (Global Commission for the Certification of Smallpox Eradication 1979).

The last endemic case of smallpox in India occurred in May, 1975, less than twenty months later.

#### As the Health Planners Saw It, 1973

One goal of this case study is to provide a basis for understanding the differences in perspective that produced different priorities for health planners and program managers. A WHO smallpox administrator in Geneva looking at India in 1973 saw a single country that accounted for 57.7 percent of the reported global incidence of smallpox (and by the following year it would account for 86.1 percent). But to the planner in the Indian Ministry of Health (Sanjivi 1971) or to the Health Cell in the Ministry of Planning, smallpox was not the major health problem in the country. This is part of the old debate between "vertical" and "integrated" approaches to health administration (Basu and Khodakevich 1977; Sharma 1973; Jezek and Basu 1978).

The 1972 WHO Inter-Country Seminar in New Delhi had summarized the state of the art of smallpox eradication. One of the seminar's major contributions was to create a climate of optimism. It made it seem possible that India could indeed eradicate smallpox in less than two years by concentrating its great resources of trained public health workers on breaking chains of transmission within endemic areas and fighting a defensive battle against importations into nonepidemic states. This strategy, however, was still not completely accepted by many in the government of India. There were two basic problems in convincing Indian health planners and policy makers. One was skepticism about the effectiveness of the strategy. Another was disagreement over the relative priority of spending resources on smallpox as opposed to other diseases. Yet planners agreed that in the long run, if eradication were possible, it would yield a much greater benefit than its cost. So in one sense both problems were in fact the same: the planners doubted that the new strategy could succeed in eradicating smallpox. Also there were many-in WHO as well as in the government of India-who felt that eradication could never really be achieved, so that mass vaccination was the best way to at least make some gradual improvements.

Part of the complacency in the official attitude toward eradication was due to the fact that there had been an apparent year-by-year reduction in reported smallpox: from 83,943 cases in 1967 to 30,295 in 1968, 19,139 in 1969, 12,341 in 1970, and 16,166 in 1971. From the Indian health planners' perspective, the trend was clearly a declining incidence. On paper, smallpox seemed to be disappearing at about the same rate as reported NSEP vaccinations were gaining cumulative momentum toward a perceived herd immunity. Neighboring Burma had eradicated smallpox and credited mass vaccination (World Health Organization 1977). Bangladesh was reported free of smallpox in 1971, although returning refugees from the Salt Lake Camp near Calcutta had reinfected the country in 1971–72. Most importantly in the eyes of Indian health planners, the Indian southern states had done very well with their NSEP, and it seemed only a matter of time before the Northern States followed suit.

The complacency with which Indian health planners seemed to await smallpox decline reflected the realities of dealing with competing demands for health resources in India. However high a priority it was for the world community as a whole, smallpox eradication was not a priority for India so long as the number of cases appeared to be declining. The relative impact of smallpox was negligible; other major diseases, such as malaria, were returning in epidemic form and demanding the attention of health planners and the political level at the Directorate General of Health Services (World Health Organization, Regional Office for Southeast Asia 1978).

An important prescription for India's future health-planning efforts was put forth in a health-planning monograph (with a foreword by the then president of India, V. V. Giri) published in 1971, when the first WHO smallpox medical officers were arriving in the country (Sanjivi 1971). This document argued against "copying other countries" by either adopting their system of medical care or accepting their list of priority diseases. In this proposed health plan, smallpox was very low on India's own list of priorities.

It is impossible to make judgments about relative disease importance in India in 1973, but a comparison of smallpox deaths with estimated deaths from other causes is useful, since health planners must consider relative disease mortality rates. Of the estimated population of 600,000,000, there were an estimated 10,000,000 deaths, one-third (3,500,000) of which were infant deaths. Even after the fivefold increase in reporting as a result of the nationwide active searches, smallpox deaths in 1973 totaled 15,434 (0.15 percent of India's total deaths). By contrast, Indian health planners estimated that tuberculosis claimed approximately 500,000 (5 percent). Another very large share, perhaps as many as 1,000,000 deaths (10 percent) was due to tetanus. Consider also the reported pattern of morbidity for the same year (bearing in mind the distortion caused by problems in under-reporting). Reported cases of whooping cough totaled 195,819, of cholera 40,819; and the estimates of malaria incidence ran close to 4,000,000 cases. The prevalence of leprosy was an estimated 3,720,000, of tuberculosis 5,000,000. And overall, the life expectancy in much of India was less than fifty years, with infant mortality close to 140 deaths per 1,000 live births. Diarrhea, not reportable as a specific disease category, may have accounted for up to half of the childhood deaths (Research and Reference Division, Ministry of Information and Broadcasting 1975; Central Statistical Organization, Department of Statistics, Ministry of Planning 1977).

In 1973 India had a gross national product of approximately \$66 billion, roughly \$110 per capita. Total central government expendi-

tures were \$2 billion, of which \$168 million (8.4 percent) went to health (Nyrop et al. 1975; Publications Division, Ministry of Information and Broadcasting 1978). While this amount was only \$.25 per capita, it was large by developing countries' standards.

Thus the competition for health resources in 1973 was tremendous. Expenditures on smallpox in that year were approximately \$3.3 million out of \$35 million allocated for communicable diseases. Nearly five times as much, \$17 million, was spent on malaria, which, since it is handled through a centrally sponsored national program, provides one of the few comparable expenditure classifications. Other health programs are less comparable, because health in India is a state subject, with more health outlays at the state than at the central level.

It is important to bear in mind the various perspectives on smallpox that existed in 1973. On the one hand, there were the continual differences between the epidemiologists and the health planners, or rather between the technical level and the political level. Epidemiologists—disease control officers—are supposed to control whatever disease they are responsible for; health planners are supposed to be sensitive to the total health care needs of the population. The situation was further complicated by the fact that reliable data for making\_rational health-planning decisions were unavailable.

Similarly, the perspective of the World Health Organization Smallpox Eradication Unit in Geneva was quite different from that of the health planner in New Delhi. The global eradication of smallpox would not eliminate malaria or diarrhea from India, nor was it intended to. Armed with resolution WHA 19.16, which made smallpox eradication a regular WHO budget expense for the first time, the Geneva smallpox unit was determined to succeed in implementing its mandate to eradicate smallpox from the world; salient to that goal was the fact that India accounted for more than half of the world's reported smallpox. Furthermore, nearly every subsequent World Health Assembly had reiterated that smallpox eradication was "a priority" and through resolutions WHA 21.21, WHA 22.34, WHA 25.45, and WHA 26.29 had continually stressed the need for all endemic countries to further intensify eradication efforts and make smallpox eradication national priorities as well as the global priority of WHO.

Although India had supported those resolutions, and the WHO smallpox unit was in a sense only implementing India's own policy, still many policy makers felt that smallpox eradication was more a priority for the United States or USSR than for India, which had so many competing public health priorities.

Such differences in perspective are inherent in any diseasecontrol program, and should be kept in mind as background to the discussion of management issues. Understanding the perspectives of both those who were determining world health policy in Geneva and those who were making national health policy in New Delhi provides insight into both the epidemiological and the management impact of the strategy of search and containment. To the planner in New Delhi, from whom the disease remained partially hidden through nonreporting, it appeared statistically far less important in India than it was, especially relative to other national health issues.

It is clear that eradication of smallpox in fact yielded enormous economic benefits to India. But for India's health planners, occupied then by emergencies and competing political demands on scarce resources, the long-term benefits from disease eradication were not a great motivation. Health planners are sensitive to immediate political realities, and the benefits of smallpox eradication would be realized only at some future time when the \$3 million annual expenditures for smallpox could be applied to other health problems. In the meantime, however, the cost of putting so many scarce resources into one program rather than into many health needs was high.

Smallpox eradication expenditures looked large to the health planners in 1973, but in reality the excess costs of eradication over continued smallpox control programs was marginal, and the benefits were to be enormous. But it was not easy to convince health planners of the economic wisdom of this decision, and moreover, they were not convinced that the strategy would work at all. Surveillance—particularly an active search that used all of India's health workers—was a major gamble. Only smallpox eradication would yield the prize; smallpox control could not.

The availability of a workable strategy of surveillance and containment was to change all the calculations of the health planners. Once India agreed to the strategy of active case search (that is, going out into the villages to find hidden smallpox instead of waiting for cases to come to the notice of health officials), a cumulative series of events was set in motion. The subsequent action of the government in making reporting a commendable action rather than one that might lead to reprimands or punishment and in providing rewards for reporting encouraged health workers and the general public to change old habits of concealing cases (Global Commission for the Certification of Smallpox Eradication 1979). In the following year (1974), when active case searches throughout all of India became one of the major activities of the health services, enough smallpox would be found to satisfy the demands of both project management and health planners. The meticulous house-to-house searches that began that year detected one of the last great epidemics in history, and smallpox, no longer a hidden epidemic, emerged as both important and urgent. Health planners, policymakers, and epidemiologists joined together to gamble on eradication.

#### The Intensified Campaign

#### An Optimistic Beginning, Spring, 1973

There was reason for optimism as 1973 began. The tropical temperatures that rapidly inactivated liquid vaccine had become unimportant due to the advent of sufficient locally produced freeze-dried vaccine (and India had discarded its stockpile of dangerously unreliable liquid vaccine). The rotary lancet was finally being replaced by the simple bifurcated needle. The weekly reporting system was improving, and with the new changes in vaccination techniques even newly trained vaccinators working in remote villages in 120-degree heat achieved vaccination take-rates approaching 100 percent. Effective vaccination, the major weapon against smallpox, was in readiness for the smallpox eradication campaign. The new strategy of surveillance and containment, written into the 1970 Plan of Operations, had been reaffirmed at major regional smallpox meetings in 1970 and 1972. Experience within India itself-in Gulbarga and a pilot area in Uttar Pradesh-confirmed that it could work. A plan for dividing the country into endemic and nonepidemic regions, for organizing active surveillance, and for providing rapid and effective vaccination in response to discovery of outbreaks seemed practical.

Careful epidemiological analysis was fast changing old notions about smallpox, and the secrets of smallpox transmission were being

discovered. Even in densely populated India, the disease was not nearly as contagious as people had thought. The virus is transmitted only from person to person. There is no vector (such as the mosquito for malaria, which still resists public health interventions), and despite popular fears about infected bedding, such fomites were proven not to be of any great epidemiological significance. It appeared increasingly possible that by concentrating India's effective vaccine on high-risk populations in the endemic regions of the country and restricting vaccination activities to infected villages, enough links could be broken in the chain of transmission to break the back of the disease. Tracing all known sources of infection backward to previously undetected outbreaks and following people potentially exposed to the virus forward to possible new outbreaks completed the epidemiologic system. Management adopted an effective, scientific strategy for smallpox eradication, and it made excellent costeffective sense from any perspective. Vaccine was a potent resource, to be carefully allocated. With surveillance to identify the high-risk groups, the intensified campaign consisted essentially of the strategy and tactics for delivering vaccine to those at highest risk and doing so effectively and efficiently. Now the strategy and the tactics only needed to be implemented.

Carrying out the plan required both personnel and transport, and transport was crucial both for using personnel and for providing supplies. In recognition of the critical and constantly recurring need for reliable transportation, the First Addendum to the 1970 Plan of Operations was a WHO contribution of fifty-one Toyota land cruisers and forty-seven Honda motorcyles. The Second Addendum added ten Volkswagen buses, and the Third Addendum prepared for a course to train the forty program officers in the new strategy. On January 8, 1973, the Fourth Addendum was signed, providing vehicles to the four WHO long-term staff members. A month later, the Fifth Addendum established provisions for WHO assistance for the coming two years of an intensified campaign: consultants, temporary advisors, fellowships, training courses, and more supplies and equipment.

But there was a major unresolved problem: the WHO longterm staff, with only smallpox to worry about, were able to devote their full time to tracing contacts, studying the epidemiology of the disease, and supervising preparations for the intensified campaign, but the district and state level epidemiologists who were to implement the NSEP had many priorities competing for their time and attention. Additional WHO long-term staff were needed.

At the World Health Assembly meeting in Geneva in May, 1973, the chief of the WHO Smallpox Eradication Unit met with the secretary to the government of India's Ministry of Health to discuss planning for the "intensified smallpox campaign" scheduled to begin in a few months in India and the three other endemic countries (Bangladesh, Ethiopia, and Pakistan). The World Health Assembly had once again stressed that smallpox eradication was the top concern of WHO and its member states, but special apprehensions were voiced about India. Pakistan was doing very well (except in Sind province), and Ethiopia was expected to interrupt transmission within one year, but many in attendance at the assembly feared that India would remain the last place on earth with smallpox. On the other hand, pointing to the recent successes in Haryana, Rajasthan, Gujarat, and many southern states, the WHO smallpox unit was confident that with India's well-developed health infrastructure, and given due attention by national and state levels, an intensive program could readily achieve success in India.

A coordinated, concerted dual strategy was worked out. First, a special program was established for the principal endemic states of Uttar Pradesh, Bihar, West Bengal, and Madhya Pradesh, to reduce sharply the incidence of disease in these four states, which had accounted for over 79 percent of the smallpox reported in India in 1972. This reduction was to be accomplished during the low transmission season between September and December of 1973, with the hope of eliminating persistent foci over the succeeding twelve months. Second, there was to be continuing, defensive effort in the other states where incidence was low, to eliminate remaining foci before the year's end and to maintain their smallpox-free status through rapid detection and containment of any imported cases (NSEP, Government of India, and WHO 1973). This second target area contained over half the population of India, although during the previous year fewer than one case in twenty had occurred there. Although the entire area was considered nonendemic, these twentysix states and union territories were further classified as either smallpox-free (seventeen states and union territories that had either reported "nil" cases or occasional importations that all had documented sources outside the state) or low incidence areas (nine states and union territories that surrounded highly endemic states and could not trace every outbreak to an importation from an outside state). The defensive effort in the nonepidemic states was to be vital. There had been an observation that smallpox epidemics—known to occur in five-to-seven-year cycles—moved through India in a clockwise fashion. Though data was incomplete, a decision was made to post extra WHO advisors in West Bengal, Madhya Pradesh, Bihar, and Orissa to defend against the next round of smallpox. It was the correct strategy.

For the principal problem states, a three-phase program was planned. The first phase (added to the overall plans almost as an afterthought) involved conducting an active search for outbreaks in municipal areas during the summer of 1973, to eliminate the urban foci that often sustained chains of smoldering infection through the monsoon season, disseminating the disease to the rural areas in the autumn. From September through December, 1973, a second phase (thought by WHO to be the most important part) was to consist of three weeklong, statewide searches. Since these three searches would require more vaccinators, all health and family-planning workers were to be deployed for each one. The third phase, to be adapted to the results of the searches, was expected to be a mopping-up operation from January to December of 1974. Some optimists believed that if each of the three successive searches uncovered fewer and fewer cases, they could hope for a new year without smallpox in 1975.

It was agreed (later confirmed in the Sixth Addendum to the Plan of Operations) that four additional long-term WHO medical officers would be assigned to the intensified campaign in India to assist at the state level in each of the four most endemic states. Because it was immediately vital to increase the mobility of the smallpox teams, an exception had to be made to the usual WHO policy under which the host nation was expected to provide any locally manufactured goods. Indian-made jeeps met the demand of immediacy; in order to allow WHO to purchase these vehicles, a compromise was reached under which the government of India relaxed its excise taxation rules, WHO purchased Indian-made jeeps with foreign exchange, and at the same time the government of India increased the monthly gasoline allowance for smallpox jeeps.

Municipal areas, until then semiautonomous in their smallpox activities, were also brought under the control of the central NSEP.

One problematic detail remained, that of not enough leadership at the top of the program. During a 1972 inspection visit to India, the chief of the global program had noted:

In no other eradication programme anywhere in the world are there so many "privates" and "sergeants" and so few officers. Failure to develop a reasonable surveillance programme, a more sophisticated and far more successful approach to smallpox eradication than the previous strategy of mass vaccination, can be ascribed in large measure to this deficit. (Henderson 1972, 8)

The difficulties of India's assistant director-general (smallpox) in coordinating a disease-control program in twenty states with 20,000 vaccinators and many local languages and different health systems were already enormous. Now, with simultaneous searches to be made in four states and a defensive action being fought in the nonepidemic areas, strengthened leadership was needed at the central level in New Delhi (Henderson 1972).

The government agreed to provide at least one state-level Indian epidemiologist for each of the four priority states and to augment the central level where the entire NSEP had been functioning with only two full-time medical officers and little support staff. A central appraisal team of top Indian epidemiologists was drawn from other programs and institutes throughout the country. WHO paid a per diem and provided transportation. The officers who were recruited—the director of the NICD and two of his deputies and the assistant director-general (cholera)—joined the director of the CBHI, the assistant director-general (vaccine production), and the assistant director-general (smallpox) and his deputy to become the officers and leaders of what was to become India's largest health army.

This was to be the first of many reminders that men were more valuable than money. Perhaps more than any other management decision, it was the allocation of the finest epidemiologists in the country to leadership posts in the program that led to victory over smallpox. These Indian officers (officially labeled "central appraisal officers"), together with four counterpart epidemiologists (French, Czechoslovakian, and two Americans) and an administrative officer in SEARO, constituted what became known as the central appraisal team. This was the top management team which, along with WHO in Geneva, developed the strategy and plan of operations for the intensified campaign. A special relationship grew among this team. As they shared train compartments and dusty jeep rides, their hopes rising or falling inversely with the epidemic curve, they developed a unique friendship and camaraderie. Many were later to acknowledge this shared sense of responsibility as one of the deepest personal lessons from the campaign.

Beginning in June, 1973, the multinational group held frequent meetings to prepare, review, and revise six drafts of the Plan of Operations before a "Model Operational Guide for Endemic States" and "Model Operational Guide for Non-Epidemic States" were finally approved for the autumn campaign. These documents, issued under the joint auspices of WHO and the government of India, outlined a three-month plan of operations for mounting an ambitious drive to find every case of hidden smallpox in the endemic areas. To do this, twenty-two special teams were created, twenty of which would work in the endemic states. Half of the teams were headed by Indian epidemiologists recruited by the government of India from Indian institutes or from retirement. The other half were headed by non-Indian epidemiologists recruited by WHO.

A total of 230 epidemiologists from thirty-one countries<sup>3</sup> other than India would eventually head such teams. As many as 90 epidemiologists would be in place at one time, but as the autumn campaign began, there were less than one-quarter of that number (Basu, Jezek, and Ward 1979). Each epidemiologist worked in a zone covering an average of five or six districts (occasionally more than 10 million people per zone) and had as his peers or counterparts the regional, division, or district health officers responsible for the area. The special teams conducted training sessions, explained and organized the search for disease, supervised the implementation and evaluation of surveillance activities, oversaw rumor collection and the diagnostic verification of all detected rash-with-fever cases, and, when smallpox was detected, organized outbreak containment and cross-notification. Since the special active case search required the participation of all health and family-planning staff, it was a large organizational job; there were many managerial tasks and diplomatic missions to be performed in addition to epidemiology.

From August to September, at the state level, the epidemiolo-

gists and PMAs were given drivers and vehicles for their areas. Funds were distributed for gasoline, vehicle repair, travel allowances, and supplies-including the various search forms, smallpox recognition cards, and of course vaccine and bifurcated needles. A state-level presearch briefing was held for the special team members in every state. The special team members then repeated these presearch briefings at divisional, district, and primary health center levels. The organizational plan was the same: one search worker could visit one village in about one day. The hundred or so villages in each Primary Health Center (PHC) had to be divided among all available staff, usually fifteen to twenty health workers. A search schedule determined which worker would be in which village on which date. Supervisors had to be assigned workers to check upon at random, and those who served as PHC doctors had to be prepared to travel to verify many outbreaks of rash-with-fever, which meant training them in smallpox differential diagnosis.

Line listings of existing outbreaks and colored posters showing chickenpox and how it differed from smallpox were glued to the walls of all health centers. At each briefing session and training session, the experience of Africa was intoned over and over: it was possible to eradicate smallpox in India. Africa had done it. Indonesia had done it, and Pakistan would soon be free. India might be the last country to eradicate smallpox: the campaign was described as a race with neighboring countries and competition with nearby districts. Radio, press, and other media were invited in to tell the public where to report cases of smallpox. There was creative excitement in the air. In the Saharanpur district of Uttar Pradesh, the district magistrate led a parade of 5,000 Youth Congress volunteers who went door-to-door on "search parties" along with an elephant on whose sides were painted brightly colored slogans urging villagers to report smallpox.

The plan was simple: The search worker was to find all smallpox and chickenpox cases occurring within the last two months by visiting (1) children and teachers in schools, (2) the village head man, postman, and *chowkidar* (watchguard), (3) tea shops and the market area, (4) two or three randomly selected houses in each of the eastern, western, and central parts of the village, and especially (5) the *bastis* (lower socioeconomic class areas), which historically had much smallpox. Smallpox recognition cards were used and shown to village leaders, *pan* (betel nut) sellers, housewives, and children to see if they knew of any smallpox in the community. Whenever the teams went along the road to their next village, they were to stop at brick kilns, bus stands, migrant camps, *melas* (festivals), and market areas to gather rumors of pox diseases. It was an all-out attempt to find smallpox (NSEP, Government of India, and WHO 1973).

It should be remembered that the intensified campaign was to have three phases. The first phase had been carried out in July and August of 1973 as a "municipality drive," an attempt to clear the urban areas and municipalities of residual foci. It was only a halfhearted effort. The second phase, the "autumn campaign," had as its goals to "dramatically reduce smallpox incidence" by active search and containment during the postmonsoon period of low smallpox incidence. The findings from the autumn campaign searches were to provide the planning basis for the third or the "final attack" phase, which was expected to last from January to December, 1974.

The special teams, half of them led by Indians and half by WHO epidemiologists, organized the first searches of the highly endemic states during September and December.

Indian-led teams were assigned to sensitive border areas (along the India-China border); WHO-led teams frequently did better in state capitals, where the global implication of success and failure was a politically apparent matter. Both Indian-led and WHO-led teams did well, with similar rates of success and failure. There were ten special teams in Uttar Pradesh, eight in West Bengal, four in Bihar, and four in Madhya Pradesh. In addition to the eight longterm WHO medical officers in the country, four WHO short-term consultants were assigned to the Indian smallpox project, and four WHO medical officers were attached to the regional office at SEARO. Another two WHO medical officers from Geneva headquarters were leading special teams in West Bengal and Uttar Pradesh. These special team leaders helped plan presearch briefing meetings from state to PHC levels, transported supplies and equipment, and made payments to drivers, PMAs, and local vaccinators.

The first search was held in West Bengal. The supplies and equipment needed for that one state included: 100 copies of the Operational Guide; 10,000 small recognition cards and 3,000 large recognition cards; 100 copies of each district map, to be used to plan search workers' schedules; 3,000 copies of the searchers' village-byvillage schedules (PHC Form 1); 16,000 copies of the actual form for recording results of the village visit (PHC Form 2); 400 copies of the line listing of outbreaks, to be pasted on the wall of every PHC and district (District Form 1); and 3,000 copies of the special "search" edition of the weekly reporting forms that went from PHC to district level.<sup>4</sup>

The role of "special epidemiologist" had become increasingly administrative, requiring attention to such details as hand-carrying the correct number of various proformae. More than 15 million proformae of various kinds were printed, packaged, and dispatched from SEARO in 1974 alone. This was quite a departure from usual WHO procedures, and considerable difficulties arose at every level within WHO about such an activist role.

The results of the first search in West Bengal included only nine districts; the others could not be searched because of floods. Only forty-seven cases of smallpox were detected. In Delhi, program management was not certain whether a good search had found the few cases that existed or a poor search had missed many. But West Bengal appeared to be less heavily infected than had been expected.

The massive follow-up search conducted throughout the state in October identified only 143 infected villages, and Calcutta, which so many had feared harbored persistent foci, seemed to have far less smallpox than even the most optimistic had hoped.

#### The First Shock, Autumn, 1973

While early reports from West Bengal looked encouraging, in the Hindi-speaking areas of the Indo-Gangetic plain, the historic heartland of smallpox, more smallpox was found than anyone had thought existed in all of India.

In Uttar Pradesh, the organizational sessions were held in Lucknow on September 27 and 28. The governor, who had been personally interested in the campaign by an Indian saint named Neem Karoli Baba who predicted that smallpox would be eradicated "soon," chaired the session. The week before the search, Uttar Pradesh had reported only 354 cases occurring in twenty-one of the fifty-five districts of the state. The weeklong search was to be conducted from October 15 to October 20, 1973. No one knew what might be found when over 27,000 workers searched the 140,102 villages in Uttar Pradesh.<sup>5</sup>

In New Delhi, program managers waited-WHO staff in the modern five-story SEARO office building and Indian Ministry of Health officials at Nirman Bhavan, the building that housed the Directorate-General of Health Services. All cases were to be reported by telegram to both the government of India at Nirman Bhavan and the WHO smallpox unit in SEARO. Early in the morning of the first day, all was quiet. By midday, the telegrams started to come in, and all the lines of the WHO telex were soon tied up. The typical report was: "SMALLPOX OUTBREAK IN VILLAGE RAMPUR, DISTRICT LUCKNOW, U.P. SEVEN CASES ONSET FIRST CASE AUGUST 21, LATEST CASE SEPTEMBER 30. CONTAINMENT IN PROGRESS." The smallpox staff read the first few messages avidly to discern a pattern, but they were soon overwhelmed by the flood of telegrams. In the first search in Uttar Pradesh alone, 5,989 cases were discovered in 1,525 villages and urban areas from forty-five districts. This was seventeen times as much smallpox as had been reported a week before. Elsewhere the pattern was the same. In Bihar, there were 614 new outbreaks with 3,826 cases, and in Madhya Pradesh, 120 new outbreaks with 1,216 cases. Special containment teams had been created at block, district, and state levels, but the number of foci detected was levels of magnitude greater than had been expected (see fig. 5). A dam had burst.

If the smallpox team had thought they had a problem before, now they knew they did. Two lessons emerged from the first search of Uttar Pradesh. First, it was possible to mobilize India's latent health resources to reach the villages; and second, a shocking amount of smallpox had gone unreported, despite two solid years of work to improve reporting.

The all-India searches clearly identified problem areas: over 90 percent of the total disease incidence was located in four states: Uttar Pradesh, Bihar, West Bengal, and Madhya Pradesh. In accordance with the strategy of using resources on the basis of priority, these four states had been correctly classified as high risk, while the rest of India was considered either nonepidemic or smallpox-free. With search operations going quite well but with an unprecedented number of smallpox outbreaks being detected and contained, the effort had to be further intensified for the high-transmission season



FIG. 5. The shock: impact of active searches on reporting of smallpox cases, India, 1973. 1 = first active search; 2 = second active search; 3 = third active search. (From R. N. Basu 1979, 153. Courtesy of World Health Organization.)

that was approaching. The autumn campaign of 1973 blended into the 1974 yearlong phase three without decreasing its tempo. Resources were in short supply. The WHO regular budget was stretched to its limit to provide funds to continue the intensified autumn campaign activities through the following year. Far more money was needed than had been budgeted. But when the People's Republic of China declined to accept the \$900,000 budgeted for WHO program assistance to that country, the director-general of WHO, after consultation with the Chinese, courageously agreed to make this money available for smallpox in India.

The money problems were compounded by transportation problems that plagued the program during 1973–74, the period of the Middle East crisis and the oil embargo. WHO resources were straining to meet the rising costs of transportation, and these problems were increased by a series of transport-worker strikes. At the end of 1973, a strike by Indian Airlines workers threatened deliveries of vaccine, search forms, and epidemiologists. Use of road and railway transport was accelerated, but a strike of railway workers for several weeks in early 1974 further compounded the problems of moving supplies and equipment to the periphery. Material had to be sent by jeeps and trucks, but in April, 1974, the costs of gasoline and petroleum products in India nearly doubled overnight, threatening to interrupt the supply of gasoline needed for campaign transportation and creating severe financial difficulties for the program. During all of this, larger stockpiles of material, vaccine, bifurcated needles, operational guides, and so on, had to be maintained at state and district levels and regularly replenished in anticipation of strikes and floods.

In the early part of 1974, search operations were going well, but the incidence of smallpox soared, and by May the monthly incidence had reached 48,833 cases, a record month. There was substantial skepticism from all sides about the direction of the program. It was difficult to explain to the press, the public, and the politicians why, if things were going so smoothly, the incidence of smallpox appeared to be reaching all-time highs. Some high-ranking international epidemiologists, brought to India as WHO consultants, became overwhelmed by what they saw in the field and criticized the strategy of search and containment, suggesting a return to mass vaccination.

The southern states, which had done well all along since the inception of the NSEP, continued to show good results, but cynics countered by questioning whether any of the four endemic states had shown any promising results. Madhya Pradesh, because of its central geographical location, low population density, and relatively light smallpox epidemic became a pivotal state: a quick and decisive victory there would encourage the workers in other states and quiet the skeptics.

Madhya Pradesh had delayed its initial search until early November because of the rains and extensive floods. The first search revealed 192 outbreaks in seventeen of the state's forty-five districts, with a total of 1,216 cases. Most of the outbreaks were in the northern and eastern districts of the state, bordering the smallpoxafflicted areas of Bihar and Uttar Pradesh. The second search conducted throughout the state in December, 1973, revealed 215 cases and 53 new outbreaks.

By March of 1974, during the spring season, when the highest smallpox incidence would normally be expected, Madhya Pradesh was almost at target zero after five monthly searches of its 10 million households. One small disease focus, persisting in Shahdol district, one of the most underdeveloped tribal areas of the state, appeared to be all that stood in the way of "zero" in one of the endemic states and deprived the central level of a much-needed morale boost at a critical time. But there were problems in other states, particularly Bihar (one of India's least developed states), and the season of greatest smallpox virulence was at hand. Madhya Pradesh was about to be invaded by smallpox from Bihar; the worst was yet to come.

#### The Darkness before Dawn, Summer, 1974

In March, 1974, reports of smallpox began arriving from areas of Madhya Pradesh that had been thought free of the disease. Investigations indicated that these were not old, hidden outbreaks missed in earlier searches, but fresh importations from Bihar. The source of infection was traced to Tatanagar, an industrial city in southern Bihar. *Adivasis* (tribals) from Madhya Pradesh had traveled to that city, 200–500 miles from their homes, in search of seasonal employment. Struck with fever, they had returned to their native villages, where they subsequently developed the characteristic rash of smallpox. The disease spread, and within one month a shower of importations from Tatanagar had reinfected hundreds of households in Madhya Pradesh. Hopes for an early victory were smashed.

Madhya Pradesh was not the only state beset by importations of smallpox from Tatanagar. Within a short time, Tatanagar threatened to reinfect much of India that had only recently been freed from smallpox. Smallpox officers in seven other Indian states plus Nepal reported over 2,000 cases and as many as 500 deaths linked to travelers coming from the Tatanagar railway station.

The town of Jamshedpur, founded in the early 1900s by Jamshedji Tata, was one of the first towns in India devoted to heavy industry. Jamshedpur and Tatanagar, the adjacent railway station, were both named after their founder and continue to serve as one of the headquarters of Tata Industries. With the ancillary steel-based industries that adjoin the Jamshedpur industrial works of the Tata Iron and Steel Company (TISCO), the area is often referred to as the Pittsburgh of India. The relatively high income of the private sector industries contrasts with the neighboring areas of southern Bihar and northern Orissa, and therefore invites large numbers of poverty-stricken beggars and transients to pass through the Tatanagar train station seeking subsistence. The Tatanagar railway station would become infamous as the world's greatest exporter of smallpox. Despite the many investigations implicating Tatanagar as the source of the epidemic, the official weekly health records of the city showed only seven cases of smallpox reported. It was a classic example of case suppression.

Tata Industries were very proud of their city. A showplace of India, it had won several national awards as one of the most progressive in the country. The administration of the city was entirely in the hands of Tata Industries, and they were distraught that their city had become the focus of such unpleasant international attention. When top management was informed that the TISCO doctor had failed to detect one of the largest hidden smallpox epidemics, Tata and WHO entered into an agreement to quell the epidemic in Tatanagar. WHO provided technical guidance, Tata gave material, manpower, and management, and thus began one of the most ambitious urban campaigns in the Indian smallpox program. Within seventy-two hours, 50 doctors, 200 paramedical supervisors, 600 search workers, fifty vehicles, and other facilities were mobilized and the campaign started.

It was the first large-scale effort on the part of WHO to enlist the cooperation of local industries and private citizens in the effort. WHO's role as an international agency had limited its official contact to Indian government officials. But Tata provided something beyond men and resources that made the established strategy of search and containment more effective than it had been in the past: they provided an example of good management.

Tatanagar was only one of many problems being faced by the smallpox central command at that time. The number of outbreaks was increasing each week. The ratio of optimists to skeptics, always high in the past, was showing signs of erosion at every level. The sixth search conducted in Bihar in May was depressing. Of 69,836 villages searched, 2,622 were found with new outbreaks (3.75 percent of all villages). All thirty-one districts in the state were infected with smallpox; in eleven districts, 100 percent of all blocks were infected. One district, Monghyr, had 498 total active outbreaks, and Bhagalpur had 555 infected villages.

The WHO Southeast Asia regional smallpox surveillance report dated June 1, 1974, carried a large world map on the front cover showing what smallpox workers were facing in the villages of Bihar and Uttar Pradesh. While one-quarter of the world's smallpox was

shown coming from Ethiopia, Bangladesh, and Pakistan combined, fully three-quarters was found in the two Indian states of Bihar and Uttar Pradesh. At that stage in the program, India represented 82 percent of the known smallpox in the world. Although nine states and nine union territories were classified as smallpox-free, heavy battles were being fought against the disease in Uttar Pradesh and Bihar. The June surveillance report featured a note on the industrial area of Jamshedpur/Tatanagar, which by then had exported as many as 300 outbreaks of smallpox to other areas of India and Nepal. Many of those areas had previously been smallpox-free. Smallpox was reestablishing beachheads throughout India.

The number of active outbreaks contained (that is, removed from the list of "pending active outbreaks") had increased fivefold, from 107 in December, 1973, to 511 in May, 1974. The number of new outbreaks detected (added to the list of pending outbreaks) in the same period had multiplied even faster, increasing from 162 to 689. More pending outbreaks on the list meant more demand for containment staff and resources. More epidemic fires were being found than were being extinguished.

The sixth search in Uttar Pradesh in May detected 797 new outbreaks, with 1,759 villages still containing active smallpox, but in Uttar Pradesh, despite an increase in the total number of outbreaks, problem areas were becoming increasingly circumscribed. Unlike Bihar, where every district was infected, 82 percent of all outbreaks in Uttar Pradesh were located in only fifteen of the fifty-four districts. Unfortunately, in the season when smallpox incidence was still rising every week, the number of outbreaks contained per week was not increasing.

West Bengal was still struggling to clear up extensive foci that developed during the months of March and April. Despite a declining incidence, by mid-May there were still 444 foci known to be active in the state. Three-quarters of the foci were reported by only five districts, however, and had there been no importations West Bengal would have been making much better progress. Between January and April, 1974, over 386 importations into West Bengal were reported, over 342 of them from the neighboring state of Bihar. It was clear that the fate of the smallpox eradication program in parts of West Bengal depended greatly on making progress in Bihar. Madhya Pradesh, the hope of the program in the early part of the year, had also suffered repeated setbacks. Between March and May the number of outbreaks nearly doubled, mainly from the large number of importations from Tatanagar as well as from intrastate movements of *adivasi chetuas* (migrant wheat harvesters). For the state as a whole, the delay time in reporting new outbreaks was 18.6 days after the onset of the first case. This means that the average case was detected comparatively quickly. Two years earlier, in Gulbarga, outbreaks had escaped detection for more than a year; however, in a time of rapidly disseminating disease from the industrial areas of southern Bihar, 19 days was too long to wait.

Even Nepal was suffering from the onslaught of exportations of smallpox from India. In the first six months of the year, of 109 outbreaks of smallpox in that country, 102 were traced directly to importations from India. Over 90 percent of the importations in the late spring came from Bihar.

May and June are usually the hottest months in India, with daytime temperatures well over 100° F; conditions are especially difficult just before the welcome monsoon rains break from the sky, drenching the parched land with their cooling showers. May and June of 1974 were also the hottest, most difficult months in the campaign for smallpox eradication in India: a new case of smallpox was being detected there every minute, and the outbreak in Tatanagar was threatening smallpox-free states with a deluge of importations. There was flooding in the north, drought in the south, and the fear of famine throughout Bihar, causing population migrations that threatened to spread smallpox into new areas. It was the time of Java Prakash Narayan's civil disobedience movement against the government of Bihar. Strikes and civil disturbance threatened the system with total breakdown. During one critical period, all the government doctors in Bihar went on strike, and strikes by Indian Airlines and the railroad virtually halted vaccine shipments.

There was severe criticism of the basic program strategy from the political level; the national and international epidemiologists in the field were frustrated, tired, and skeptical; and many supporters in the general public were losing faith. The loss of confidence permeated parts of the WHO SEARO bureaucracy, and one of the highest-ranking officials felt compelled to write an internal memo expressing serious doubts about the basic strategy and suggesting that perhaps the program should be scrapped. His argument was that of a health planner. Although he felt that eradication was possible, he pointed out that many other countries had become free of smallpox by mass vaccination, without the large scale, foreign-assisted, extraordinary efforts that were being put into action in India apparently without much success. He pointed out competing demands on the same health staff: malaria, drought, and floods. He felt that if it became necessary to continue on beyond the end of 1974, the extra costs of a sustained intensified campaign would outweigh the benefits, and the entire strategy should be revised and the program managers replaced with doctors who were less fanatic about smallpox (see chapter 2 for a complete analysis). And then two explosions set off a chain reaction of international news coverage.

On May 18, 1974, India tested its first atomic device underground in Pokhran in Rajasthan. At the same time, smallpox outbreaks shot to a peak of 8,664 infected villages, with 11,000 cases reported in a single week. India captured many worldwide newspaper headlines with this double explosion. International newspaper reporters had flown to India from their Singapore or Hong Kong bases, interrupting their coverage of the Vietnam War to cover India's atomic explosion, arriving in India just as newspapers there broke headline stories of the fresh smallpox epidemic. From the Vietnam War to the atomic explosion to the smallpox explosion, the international journalists brought the story of India's epidemic to worldwide attention.

#### NEW DELHI, India AP-

A virulent smallpox epidemic, described as India's worst of the century, has killed an estimated 30,000 persons this year, the World Health Organization said Wednesday. The disfiguring scourge has attacked 103,830 Indians since Jan. 1, 20% more than the number of cases in all of last year, the organization reported. The outbreak has surged from village to village despite an intensive detection and vaccination drive launched last October with the aim of wiping out the dread disease by this summer.

This may not have really been India's worst smallpox epidemic of the century, but it has been correctly called the last great epidemic of smallpox in the world, and no one who fought in the campaign against smallpox in India will easily forget the months of May and June, 1974. It appeared it would take a miracle to eradicate smallpox. A miracle and a colossal human effort.

#### From Smallpox to Zeropox

#### A Colossal Effort, June, 1974, to December, 1974

It is not possible to know whether the 1974 outbreak was greater than the epidemic of 1875, or even epidemic seasons as recent as those of 1967. Because of substantial improvement in reporting efficiency, the annual incidence figures are not comparable. Retrospective estimates indicate that Bangladesh improved surveillance from 11.8 percent in 1972 to 83 percent in 1975, and if we assume a similar improvement in surveillance in India, it is possible that the 1974 epidemic was modest in comparison to earlier peaks. But in absolute terms, it was a tremendously large and terrifying epidemic of smallpox. Moreover, it occurred as India was emerging as a nuclear power, and there was a painful contrast between the successful nuclear achievement and the failure to eradicate an ancient disease. Newspapers editorially asked, "How can one justify the occurrence of a smallpox epidemic of these proportions in 1974?"

Of course the answer is that the epidemic of reports created by excellent surveillance was magnifying the visibility of the real epidemic. One result of the painful publicity was attention from higher political levels, and with that attention came the assistance necessary to eradicate smallpox.

Herein lies an important lesson. Ignorance can be bliss (at least for a while), but the painful knowledge acquired through a sensitive surveillance system may have a highly motivating effect. It can certainly bring resources.

On June 11, 1974, the board of directors of Tata Industries, parent company of TISCO and other Jamshedpur/Tatanagar industrial concerns, agreed to provide approximately Rs. 4.7 million (\$500,000) to assist in eradicating smallpox from the area, provided the government of India and the Bihar state government both agreed to such private industry support.<sup>6</sup> The secretary of Bihar approved in principle, Prime Minister Indira Gandhi agreed, and a WHO memo summarized the establishment of a semiautonomous

WHO-Tata-government of India-Bihar state smallpox consortium, to be called the Chhotanagpur Smallpox Eradication Program.

The assistance offered by Mr. Tata is a very important component in the total planning for the eradication of smallpox, and based upon the non-availability of comparable alternative resources . . . it is urgently necessary. (Brilliant 1979, 40)

On June 17, 1974, with 119,419 cases to date in India that year, the WHO–government of India central level smallpox team met with the secretary of health and director-general to outline an emergency program for all of India, but especially for Bihar. The directorgeneral repeated that the government target for eradication was 1979. WHO claimed the end of the current year was still possible with more staff.

Those discussions, later formalized as Addendum 13 of the Plan of Operations, resulted in a realistic reappraisal of the personnel and money needed to eradicate smallpox. It was decided to try to more than double the number of special epidemiologists, from the 50 who were in the field at the time to more than 100. WHO would initially provide 12 international epidemiologists and 6 operations officers; the government of India would attempt to locate 40 epidemiologists to go immediately to the affected areas, but if that were impossible, WHO would recruit more international epidemiologists.

Six central-level surveillance teams were set up and given responsibility for groups of states; they were to respond to emergency notices of smallpox as they developed. State surveillance teams were given the go-ahead to enter neighboring states, especially if in hot pursuit of the source of infection.<sup>7</sup> Continuing senior-level management was assured as well when the secretary agreed that the director of the NICD could be freed from malaria control duties and allowed to lead the smallpox eradication program full time. Although the decision to take key staff away from malaria may have slowed down that program, it allowed smallpox to be quickly eradicated. When smallpox was completed, a new cadre of excellent health officers was available to work on malaria, diarrhea, vaccine-preventable diseases, blindness, and other health programs. The importance of such excellent senior-level leadership cannot be overemphasized.

Recruitment of 300 additional containment teams was authorized; headed by young Indian doctors, most were to be sent to Bihar. WHO was given permission to hire helicopters and private air transport if needed, because of the Indian Airlines strike. And the vaccination check-post at the infamous Tatanagar railway station was ordered reestablished.

Now there was an urgent need for ground transportation for these teams-nearly 375 jeeps were required. After unsuccessful attempts were made to hire jeep fleets, WHO agreed to purchase 100 new Indian vehicles and hire 275 more; to pay for gasoline, oil, and lubricants; and to fund travel costs of the new epidemiologists and central surveillance teams. The new provisions in Addendum 13 were estimated to require \$1,406,531 if the intensified efforts were successful within three months, and WHO had budgeted only \$48,602 for supplies and equipment for the entire year and only \$266,966 for personnel. The Swedish International Development Agency (SIDA) was approached through its sympathetic representative in India. SIDA had already given a substantial amount to the program after a personal and unofficial appeal from Dr. Nicole Grasset, the WHO smallpox unit team leader. This time a much larger sum was needed, and the Swedish government once more proved to be the major benefactor of the program, eventually giving in excess of \$10 million for smallpox eradication in India.

Nature also became a benefactor; the monsoon rains came, and with them the long-anticipated but nevertheless dramatic seasonal reduction of smallpox transmission. But now was the time not to relax but to harness all resources.

For several weeks, the WHO office in New Delhi resembled a college. Over 100 junior medical officers were trained in smallpox epidemiology using case-study smallpox training exercises plus field trips to the outskirts of Delhi. Groups of epidemiologists passed through, usually en route to Bihar, stopping in Delhi to get a week's training, an advance of several thousand rupees (several hundred dollars) to be used in the field (an imprest cash account), supplies, and equipment.

On June 21, 1974, the chief secretary of the state of Bihar sent a special letter to all district magistrates informing them that they were to assume complete responsibility for carrying on and organizing the campaign in their districts. In effect the Indian administrative service (IAS)—India's very competent district magistrates—had given up hope that doctors alone could handle the epidemic and
took over command of the emergency epidemic control activities from the normal medical authorities, relieving the civil surgeon and district medical officers.

In the midst of this storm of activity, management needed a navigational beacon by which to measure and direct activities. That beacon was assessment.

From June, 1974, the infected village or urban *mohalla* (an urban neighborhood similar to a small village in the city) became the most closely watched assessment index. For brevity, these active foci were called pending outbreaks. They were "pending" on the list of active outbreaks maintained at each PHC and district, state, and central smallpox office. A pending outbreak was a village or *mohalla* in which any case of smallpox had an onset date recent enough to be considered still potentially infective itself or the source of infection for an incubating case. If no new cases had been found at the end of the pending outbreak was removed, often with great fanfare, from the list of pending outbreaks.

This way of identifying high-risk areas was really a form of prevalence measurement, something analogous to measuring the prevalence of risk of smallpox spread. It was an ideal management tool because for every outbreak, regardless of size, the same resources—a jeep, vaccine, proformae, gasoline, and containment staff—were needed to search every house in the village or *mohalla*, conduct a census and record the findings in meticulous detail in specially prepared containment books, and make periodic revisits. This index of program performance was the lighthouse that guided the smallpox staff through the rough and stormy seas of the smallpox cycles. Since efficient resource allocation was the most pressing management decision, the use of pending outbreaks was an excellent management control—provided all the outbreaks were found.

An award system was introduced, in which individuals received cash payment for reporting previously unknown smallpox outbreaks. To make sure that happened, another series of assessment measures was developed, based on the success of publicity about the Rs. 1,000 (\$120) reward, which was an important motivator to get the population to report smallpox and on the thoroughness of the house-to-house search. Complete detection of smallpox depended on an informed public, thorough periodic searches, and a

good network of secondary surveillance, which included marketplace surveillances, visits to schools and hospitals, and so on. The search was assessed by revisiting a sample of villages. The sample was not random; rather, the areas known to be weakest (with lowest performance on other assessment criteria), along with those most difficult to reach, were preferentially assessed. Thus the estimate was not of the average search effectiveness but was skewed downward, since the weaker areas were assessed more often. Since the surveillance system was only as strong as its weakest link, this form of assessment gave a more useful evaluation of it. This strategy allowed assessors to function also as second-level supervisors for problem areas. Assessment forms, guidelines, and job descriptions were drawn up. Assessors recorded what percentage of people interviewed could answer three questions in the affirmative: (1) Had they seen a search worker? (2) Did they know about the reward that was offered for any case of smallpox detected in India? and (3) Had they seen the smallpox recognition card?

Then came the tabulation of assessment. Each district was analyzed for percent of villages reported to have been searched in which people had actually seen the search worker. When there was a discrepancy between a searcher's report and the villager's memory, the villager's memory was given precedence, the reasoning being that if the search worker had been so easily forgotten the job had not been properly done.

The knowledge of the reward, however, was not an assessment of the search worker alone. It also assessed the effectiveness of an intensified publicity campaign that for several months had been directed from Delhi. If everyone knew of the reward (which was more than several months' salary for many), there seemed little likelihood that many cases could be kept hidden for long. Over the following six months, knowledge of the reward rose dramatically, showing the cumulative effect of a multimedia approach using radio, leaflets, word-of-mouth, rickshaws with loudspeakers in the cities, and puppeteers and announcements at weekly local markets. The higher the index of public knowledge of the reward in an area, the safer the smallpox staff felt.

Another assessment index proved important. As smallpox disappeared, surrogates for smallpox were looked for. Since some villagers lumped smallpox with chickenpox in a single category, and

the reward was bringing out all hidden cases of any rash with fever, it was decided to assess reporting efficiency not just for smallpox but for chickenpox and measles as well. Neighboring areas might differ from each other in their smallpox epidemiology due to better or worse vaccination activities, but it was reasoned that in the absence of any effective interventions for measles and chickenpox, the distribution of those diseases should be universal. Thus, if a district reporting little or no chickenpox was sandwiched between two others reporting much chickenpox, something was clearly wrong. The assessors turned into detectives.

Although each of these indices had a different implication for smallpox activities, the complete series of assessment indices added up to a comprehensive overview of the system's performance in each given area. This provided quantitative data to measure the progress of search operations. Apart from numbers of vaccinations administered, it was the first time such a quantitative supervisory evaluation had been initiated in India.

The ninth active search in Bihar was the week of July 18–24, the tenth, September 22-28, and the eleventh, October 27 to November 2. With each successive search, techniques became refined. In Bihar, with the operations in the north under the supervision of the district magistrates and with assistance from Tata administrators in the south, the assessment figures from the previous search were used to focus search activities for the following month. Each search was preceded by a state review meeting, district presearch meeting, and PHC-level planning meeting; it was at these meetings that the search schedules were drawn up and plans made for concurrent and postsearch assessment. (Many of the WHO epidemiologists being debriefed as they were leaving India said that these presearch meetings, particularly at the most peripheral levels, gave them the most confidence in the progress of the program, because it was there that careful village-by-village search plans were outlined, with attention to assigning the most experienced staff to the most difficult areas.)

In southern Bihar, the eighth search had shown both encouraging and discouraging signs. Although fewer villages were searched because the monsoons made them inaccessible, pending outbreaks showed a 45 percent increase, due to improved surveillance efficacy. This region of 20,000 villages had 1,000 outbreaks of smallpox.

By mid-August, the all-India emergency campaign was in full

swing; eighty-four epidemiologists from India and WHO were assigned and working at state and district levels to supervise and coordinate the active search; sixty-five were in Bihar, the rest in other states. To provide overall coordination, some twenty-five additional professional staff from the central government were mobilized to work full time. These included supply officers, administrative officers, and operational officers (men who performed a dual task as administrators and field epidemiologists) as well as seniorlevel epidemiologist-managers. This was a far cry from the 1972 lament that there were only two officers in the Nirman Bhavan smallpox headquarters.

In Chhotanagpur, for the week ending August 24, there had been 777 outbreaks at the start of the week, 250 new ones discovered, and 198 contained: a total of 829 on the pending list. This figure might have been discouraging but for the greatly improved assessment indices, which showed that the surveillance system was becoming extremely efficient. However, the unexpected struck. There was a drought in the south, and, as if in cruel counterpoint, floods in the north.

Throughout India, the active search was improving. During the monsoon, few smallpox foci remained outside the heavily affected areas of Bihar, Uttar Pradesh, Assam, and the border areas of Orissa, West Bengal, and Madhya Pradesh. Good work was being done in the south, which became free of smallpox in September 1974. In the northwest, the lingering foci in Jammu and Kashmir were eliminated.

After the monsoons, the pace of progress quickened. Uttar Pradesh, with nearly as much smallpox as Bihar but a much more developed health infrastructure requiring far fewer emergency resources, plunged from 866 outbreaks in July to 45 by year's end. The last case of smallpox in Madhya Pradesh had onset of rash December 23, 1974. As the first endemic state to reach the elusive target zero, Madhya Pradesh vindicated the strategy of search and containment.

Assam, which had recorded only eighty-seven foci in July, continued to have new outbreaks. The problem seemed to be that containment was ineffective. Vaccination around outbreaks was slow and inconsistent. In Bihar, which was experiencing similar problems, zealous epidemiologists occasionally made night raids to vaccinate a whole village at a time. Night halts by the teams in each

infected village became more and more common, especially after a Tata accountant calculated that gasoline costs to and from infected areas exceeded the costs of paying travel allowances for the teams to stay overnight.

A major problem was that infected households continued to receive countless visitors. The system of watchguards (a local resident paid to ensure that all visitors to an infected household were vaccinated), informally developed by paramedical assistants up to that point, was tightened. A watchguard's book was printed. Each visitor to an infected household was stopped by one of the aroundthe-clock watchguards. All visitors were revaccinated, regardless of previous vaccination status, and their names and addresses were recorded.

Poor families presented a special problem in application of quarantine. The poor had few reserves. Several weeks' isolation, which deprived them of whatever daily income they might otherwise obtain, was an unimaginable hardship. A young American epidemiologist purchased food for an entire family for several weeks to keep them at home. He sent the bill to WHO. At first the WHO administrators were incredulous: was the World Health Organization to pay for villagers' meals? (It did pay.) Paying for food, stopping of migration of potential carriers of smallpox was needed to protect public health. The smallpox unit stressed to the WHO Finance Unit the cost-effectiveness of rapid eradication, and the need for tightened isolation security around each of the decreasing number of cases became more and more obvious. With fewer smallpox outbreaks dotting the map, more time and resources could be devoted to each dot.

#### Operation Smallpox Zero, December, 1974, to May, 1975

From a peak of 8,664 infected villages in May, 1974, the epidemic curve fell consistently to 3,267 in August and to 980 in October; by November it had reached 343. The use of pending outbreaks or infected villages rather than smallpox incidence as a unit of measurement was to prove an important management innovation. Disease-control officers usually monitor the disease incidence (number of new cases reported in a particular time period). Using pending or active outbreaks or infected villages was a way of measuring the prevalence measure (number of villages infected at a given time)

that indicated active foci potentially capable of transmitting the virus. From the perspective of resource allocation it matters less if there are three or thirty cases of smallpox in a village than if villages hundreds of miles apart are found to be infected. The same containment team in the same jeep is needed, and the same number of vaccinations are given.

Epidemiologists like to see the epidemic curve, the graphical line of a disease over time, reach zero. And by November, 1974, smallpox epidemiologists in India were becoming confident, beginning to argue about just when the last case would occur. Pakistan had reached zero, with its last case on October 16, and for a time it looked as if India might have caught up with Pakistan despite a much later start. A countdown to zero was begun; the monthly surveillance newsletter listed pending outbreaks to "count down" to the zero which was expected shortly.

Cases of smallpox declined from 3,806 in October to 1,533 in November and 893 in December. There was substantial progress in Bihar, which had halved the monthly reported number of new cases each month in the autumn; but then some disturbing trends were noted. Orissa and Uttar Pradesh showed no signs of interrupting transmission. In fact, the number of new outbreaks detected suddenly stopped declining. A plateau was reached, with 213 new outbreaks detected in India in December, compared with 275 in November (fig. 6).

This plateau was of great concern to project managers, because of the impending high-transmission season. The winter was fast approaching, and because the smallpox virus survives longer in dry, cool air, and because both pilgrimages and migrations increase in the dry season, it was the season of rapid transmission. Each of the infected foci represented a potential Tatanagar, which in this hightransmission season could rapidly disseminate smallpox and erode program gains. It had happened before in other countries. The worst trend was seen in active outbreaks. At the year's end, there were still more than 200 outbreaks pending in Bihar, a sufficiently high number to cause anxiety.

Word came that Bangladesh had suffered yet another tragic reversal. Floods in Mymensingh and Jamalpur caused large population dislocation. The Dacca *bastis* (slums) had been cleared overnight, and the poor families occupying these makeshift residences



FIG. 6. Operation Smallpox Zero — new smallpox outbreaks detected by week in India as of the start of Operation Smallpox Zero (December, 1974)

were removed by the truckload to the rural areas. With them, on their return to the villages, went smallpox, seeding the country with an epidemic that would take one more year to conquer. With the rising epidemic curve in neighboring Bangladesh, the plateau in India, and rumors of "unusually virulent strains" of smallpox, it was clear that something had to be done.

In the district of Gaya, the number of outbreaks actually multiplied fivefold during December, from sixteen to seventy-five. Was this the result of poor work, or was it the beginning of massive transmission in the high season? Careful assessment showed poorly conducted search operations and inadequate containment in Gaya. Outbreaks had been crossed off the pending list while cases were still active, and the result was satellite outbreaks. Once again, the infected foci concept proved its value as a monitor. Gaya is a major international pilgrimage site, and there were fears of long-distance spread. A senior WHO smallpox epidemiologist arrived on the spot, and intensive and prolonged containment activities began.

Whenever an oubreak was discovered, twenty to twenty-five vaccinators would arrive in the infected village, and containment vaccination would be completed within forty-eight hours, with twenty-four-hour watchguards posted at every infected household and food brought in. It was, in effect, a household quarantine. Entire villages were also cordoned off when necessary. Instead of a handful of vaccinators, a battalion of NSEP vaccinators, supplemented by ad hoc smallpox workers (paid only a WHO per diem of five to seven rupees—less than a dollar), would rush to each newly discovered infected village and camp there until no active case remained. Including Gaya, 102 new outbreaks were discovered in Bihar in January, 1975. Though that was fewer than the 147 newly discovered in December, some of the outbreaks were ominous.

The largest outbreak of the season was detected at Pawa Puri village near Gaya, eighty-eight kilometers from the state capital. This village is an important pilgrimage site for Jains because Lord Mahavira, sixth century B.C. founder of the Jain religion, died there. Forty houses in this village were found to be infected in early January. The outbreak was detected at the apex of the pilgrimage season, in a special pilgrimage year-the 2500th anniversary of Mahavira's death. More ominous was the fact that antivaccination sentiment runs high among Jains, who believe in ahimsa (nonviolence: it was the Jain concept of nonviolence that Gandhi adapted to the freedom struggle), which is interpreted to mean protecting animals-and all living things-from harm. Jains wear special shoes to minimize the chances of accidently killing insects and are strict vegetarians, and some wear white masks to prevent them from accidently inhaling a flying insect. Their opposition to vaccination stems from the pain inflicted on cows or buffaloes in the course of producing vaccine.

The Pawa Puri outbreak was unusual in its explosiveness. The epidemiologist stationed at Nalanda had first received a report of the outbreak in early January, 1975. Smallpox staff went to Pawa Puri, where they found sixteen cases of smallpox. Except for the index case, all had had onset of rash between January 7 and 12, and half had come down with smallpox on the same day. The average small-

pox case usually led to two or three cases in the next generation, depending on seasonal and other factors (Foege et al. 1971). But investigation suggested that one case had infected eight others. Eight secondary cases developing on the same day from one index case was quite unusual. Was it because of the high-transmission season?

During the infective period of the index case, nearly 2,000 pilgrims had visited Pawa Puri village from all over India and from as far away as London. There was concern that many might have returned to their homes incubating smallpox, and a retrospective listing of all pilgrims was prepared. WHO began an around-the-clock effort to alert health personnel in all parts of the country. Over 2,500 telegrams were sent in twenty-four hours.

The entire village was quarantined by Bihar military police. Twenty-four-hour watchguards were posted at the infected houses and at key areas in the village. A community kitchen was set up, with initial capital provided by a WHO epidemiologist, to feed patients so they would not leave their homes for food. Pilgrims were not allowed to enter sacred pilgrimage areas until they were vaccinated, but since many Jains did not believe in vaccination, the situation was difficult to control. When pilgrims were refused entry for lack of vaccination, the custodian of the sacred places objected. As had happened so often in India, however, local spiritual leaders came to the rescue. The Jain *muni* (religious leader) of the area made an exceptional gesture of support, and vaccination was accepted by nearly all in his community. Although the outbreak had been exported to five adjacent villages, Pawa Puri, an unusual and never fully understood anomaly, was under control by the end of February.

The district of Gaya, near Pawa Puri, reported 214 cases of smallpox in January, and 18 from February through April. These cases were to be the last ever in the ancient pilgrimage sites near Gaya. The success in Gaya and Pawa Puri showed that energetic containment could stop smallpox even in the high-transmission season. The innovations were rapidly institutionalized. Operation Smallpox Zero was declared—the final push.

Operation Smallpox Zero was launched at the beginning of 1975 with a new and stricter set of operational procedures. The village-byvillage searches, still made every month in endemic states, were changed to house-to-house. In the state capital of Patna, where extension of an epidemic from the infectious disease hospital was feared, there was actually a room-to-room search. Each case of rash with fever was treated as a case of smallpox until proven otherwise by either a differential diagnosis from a higher-level officer or a negative laboratory result. A rumor register was kept at each PHC. Every rash and fever case was recorded and monitored, and laboratory specimens were taken from the first cases in every suspected outbreak. All uncertain diagnoses were followed with containment, as was any chickenpox outbreak with a death. Twenty-four-hour watchguards (increased from two per house to four) were posted, and all villages within 10 miles (16 kilometers) of a case of known or suspected smallpox were searched. This sometimes required as many as 300 search workers. Everyone within a 1-mile (1.6-kilometer) radius was vaccinated. (This sometimes involved 4,000 to 5,000 people in the rural areas and up to 80,000 in densely populated cities.) A new target was set: no new cases should occur more than twenty-one days after initial outbreak detection. Any outbreak that persisted for a longer period was visited personally by one of the nine central appraisal officers, who investigated the causes of containment failure and instituted remedies. Market searches were intensified. A medical officer was posted to live in every infected village. Rapid vaccination (vaccinating everyone in an infected village within forty-eight hours) paid off with an unexpected dividend: resistance to vaccination was markedly reduced because by the time vaccination side effects appeared (usually after two-to-eight days), everyone had already been vaccinated.

To match the increased program needs, increasingly rigorous outbreak detection targets were set. But repeated assessment revealed that containment, even more than detection, was the problem (see fig. 7). The tactics shifted from active search to active containment, and house-to-house searches were intensified within the ten-mile radius around each outbreak. The searches were repeated two weeks later to detect any secondary cases that might have been in the incubation period during the first search. Visitors and potential visitors (all known relatives residing in the district) were listed and contacted by search workers. Any outbreak not traced to its source was grounds for a visit from the state program officer or central appraisal team, and investigation and vaccination of all potential contacts was intensified.

It paid off. The number of cases in each outbreak, a good





measurement of both the delay in detection and effectiveness of containment, began to decrease. Whereas the average size of an outbreak in May, 1974, was approximately seven cases, by January, 1975, it was less than five cases, and one outbreak in three was a solitary case. Each month saw a 40 percent decrease in the number of pending outbreaks. Except for the renewed threat from Bangladesh, expectations of zero were increasing. High-risk areas were outlined in red on district maps throughout India. Several risk factors were identified: Bengali-speaking communities, the jute industry, fishermen who worked in Bengali areas, sites of refugee camps in 1971, and proximity to Bangladesh. For more than a year, a line listing of all outbreaks in India was sent each week to the PHC level and above, showing source of infection, first and last case, and number of cases.

Operation Smallpox Zero was a refinement and intensification of existing surveillance and containment. Perhaps more importantly, it was extremely innovative in the area of quality control. Since mid-1974 the smallpox program had been continuously assessed at every level. When outbreak containment had been the key activity, assessment of containment measures pointed out deficiencies that existed in the actual implementation of set plans. Through the knowledge obtained from such assessments, reasonable standards had been established for the optimal rate at which a village could be vaccinated to minimize secondary spread. An optimal radius of immunity was determined, and the number of people needing vaccinations was calculated. These criteria were established on the basis of practical experience in achieving interruption of secondary transmission.

Operational research was used to establish the number of villages around the case to be searched to detect secondary outbreaks. Careful analysis of outbreaks that failed to meet program standards because containment was not rapid enough showed that satellite outbreaks most frequently occurred within a sixteen-kilometer radius. Consequently, thoroughly searching the sixteen-kilometer radius around each case became the new program target.

With the disappearance of known outbreaks, the program emphasis began to change to intensified surveillance. The sentinel indicators for quality control also changed. As secondary surveillance and search organization became the focus of the program, assessment of surveillance efficacy became the major smallpox activity of district officials and epidemiologists. There was a change in search strategy. In addition to detection in rash-with-fever cases, and especially detection and investigation of chickenpox cases, a second important function was added to the job of the search worker, who was now to educate the public more intensely than had been possible in the early stages of the program. This involved rewriting the search worker's job description during Operation Smallpox Zero. In addition to going door-to-door to inquire about the existence of rashwith-fever cases and displaying a recognition card to each person, the worker would now be expected to prominently announce the increased reward for the first reporting of an outbreak, to tell the villagers where to report a case of smallpox, and to inform the community on the progress of the campaign.

The assessment done to evaluate the searchers' performance evolved along the same pattern. Instead of monitoring the *output* of the searcher (number of villages visited or number of reward posters pasted onto houses), the *outcome* of the performance was carefully monitored. Individual interviews of large numbers of persons from a representative sample of villages were conducted. In the May, 1975, assessment alone, 4 million people were interviewed about the effectiveness of the search workers' job. Search efficiency was expressed as the percentage of the villagers who actually recalled the searchers' visit to the village, had seen the recognition card, and knew about the reward for reporting smallpox and where to report a case.

Here was a change in assessment strategy or quality-control monitoring similar to the change that occurred when the program moved from a vaccination campaign to an eradication effort. After 1972, instead of monitoring the number of people vaccinated the NSEP started to monitor trends in actual disease incidence. A more sophisticated measure of this was outbreaks pending in the infected areas. When there was no more smallpox to use as a quality-control index, a new assessment technique evolved to assist in determining how likely it was that a hidden case of smallpox could stay undetected. It was of great importance that the community know that smallpox should be reported, know what it looked like, know where to report it, and know that there was a reward; and so this index, the outcome of the search, rather than a simple monitoring of number of villages visited, became more significant. Special emphasis in this assessment was given to high-risk areas—areas considered to be more vulnerable to importations from Bangladesh and identified as such through the preparation of risk maps of each district.

The importance of assessment cannot be overemphasized. It was done at many levels by epidemiologists, state program officers, district health officials, PMAs, state surveillance teams, and junior medical officers. After each search, the results were compiled and made available for comparison. Singled out for additional resources were areas that were late or deficient in reporting (as indicated by an unexplainable lower incidence of chickenpox than their neighbors) or districts that did not achieve a predetermined target percentage of villages searched or of knowledge within the population of the search, the recognition card, the reward, or where to report a case of smallpox. When assessment results showed that a district did not meet minimal targets, that district was searched again, and the entire mechanism of presearch briefings-villages allocated to each search worker, supervisors' responsibilities, search week, reevaluation of results, and so on-was repeated. This is the essence of negative feedback in a management control system. The search was either satisfactory or it was redone until it became so.

In May, 1975, there were 25 known pending outbreaks in India, compared to 8,600 one year before. Eighteen were in West Bengal and the eastern states; most were 1-case or 2-case outbreaks imported from Bangladesh, which exported a total of 32 outbreaks to India in the first six months of 1975. So rapid was containment that in nearly half of these outbreaks there was no secondary case. The average number of cases per outbreak was 3.9, and the average reporting lag between the onset of first case and the report reaching the medical officer was thirteen days. From the 32 importations, except for 7 in Assam that created secondary satellites, there was only a single secondary spread, and that was in West Bengal.

April 7, 1975, was World Health Day. The theme was "Smallpox—Point of No Return." To commemorate the day, an all-India search was conducted. Approximately 115,000 health workers searched house-to-house in each of India's 615,000 villages and urban areas: no smallpox was found. Operation Smallpox Zero was working.

On May 17, 1975, the last known indigenous smallpox outbreak in India occurred in Pachera village, Katihar District, Bihar. Manjho, an eight-year-old boy, developed rash on that day. But surveillance activities did not stop with Pachera. The special searches of the border areas continued, and on May 24, 1975, the last known smallpox patient in India developed rash. Saiban Bibi, a thirty-year-old homeless Bangladeshi, had come in contact with a case of smallpox in the village of Thauri, Sylhet district, Bangladesh. She developed rash while living on the Karimganj railway station platform in Cachar district in Assam, where she was begging for food. On May 28, 1975, containment activities began, along with an active search of the entire district. There were no secondary cases, but no one knew whether to expect more importations from Bangladesh.

#### Certifying Eradication: The Two-Year Vigil

#### The Realm of the Final Inch, 1975-77

Perhaps the hardest task in the smallpox eradication program was maintaining the constant vigilance and intensive two-year surveillance period that had to follow the hoped-for last case in each country. The monthly progress reports, sent by the chief of the Global Smallpox Eradication Program to staff around the world, highlighted this critical and difficult time. In "Progress Report 32-Target Zero," sent just after it was hoped that the last case had been found on the Indian subcontinent, D. A. Henderson discussed the difficulties of keeping the work going: "Although the situation is highly encouraging, we are entering a most critical phase where optimism and/or complacency could prevent us from reaching our final goal." He quoted Professor Holger Lundbeck, director of the Swedish National Bacteriological Laboratory. Lundbeck had written a cautionary note that Solzhenitzyn's "rule of the final inch," from The First Circle, might well have been written with smallpox eradication in mind.

The rule of the final inch. The realm of the Final Inch. In the Language of Maximum Clarity it is immediately clear what that is. The work has been almost completed, the goal almost attained, everything seems completely right and the difficulties overcome. But the quality of the thing is not quite right. Finishing touches are needed, maybe still more research. In that moment of fatigue and self-satisfaction it is especially tempting to leave the work without having attained the apex of quality. Work in the area of the Final Inch is very, very complex and also especially valuable, because it is executed by the most perfected means. In fact, the rule of the Final Inch consists in this: not to shirk this crucial work. Not to postpone it, for the thoughts of the person performing the task will then stray from the realm of the Final Inch. And not to mind the time spent on it, knowing that one's purpose lies not in completing things faster but in the attainment of perfection. (Solzhenitzyn 1976, 161)

In India, smallpox activities did not stop with the discovery of Saiban Bibi, as they had not stopped with the containment of Pachera village. Throughout India, smallpox workers searched intensely and somewhat nervously all around their areas, fearful that somewhere, somehow, a hidden case of *Variola major* might place them and their programs in the company of three villages, one in Indonesia, one in Brazil, and one in Nigeria, with one unhappy event in common: all had stumbled at the threshold of the realm of the final inch. Months after smallpox had been thought to be eradicated in each of these countries, an outbreak had been discovered.<sup>8</sup> In fact, it was nearly part of the legend of smallpox that the last case might only be found on the eve of eradication celebrations.

The smallpox staff in India, however, believed they would not suffer such a fate; the surveillance system established there was by far the most sensitive that had been developed up to that time. Still, when six weeks had passed after the onset of Saiban Bibi's rash and the last outbreak was ticked off the active list, it was not without trepidation that the WHO staff agreed to hold a large celebration on August 15, 1975, India's Independence Day. The government staff hoped to link the attainment of zero pending outbreaks with Independence Day by holding a celebration honoring India's independence from smallpox. Dr. Halfdan Mahler, director-general of WHO in Geneva, was to attend. Significant media attention was expected.

The plan called for the then health minister, Dr. Karan Singh, to present a large *murthi* (statue) of Lord Shiva, the god of destruction, to WHO, representing the gratitude of generations of Indians who would henceforth be free of the destruction of smallpox. This gift would be sent to Geneva to grace the lobby of the WHO headquarters building. After the ceremony, Mahler was scheduled to fly on to Dacca, to meet with Sheikh Mujib Rahman, president of Bangladesh. Smallpox eradication in Bangladesh had not fared as well as in India, and many in WHO thought that the government in

Dacca would need to change certain policies if smallpox were ever to be eradicated from that country.

Many smallpox veterans did not sleep the night of August 15, fearful of a last-minute discovery of a hidden outbreak. Although events of a different order erupted, no outbreak of smallpox was reported. That night, Sheikh Mujib was assassinated, and the government of Bangladesh closed the airports and sealed the borders. Rumors of civil unrest and refugee movements circulated in New Delhi. Mahler went home to Geneva.

Within days, rumors that there might be a massive return of refugees increased. In 1971, an estimated 10 million had streamed across the Bangladesh-India border, carrying smallpox from India to Bangladesh. This time, they might carry smallpox from Bangladesh to India. In the first six months of 1975, there had already been thirty-two detected importations from Bangladesh, and although two-thirds of these were detected within fifteen days of onset of the first case and more than half were limited to a single case by rapid containment action, the earlier experience was still remembered with apprehension. In November, 1971, refugees returning to the newly created Bangladesh from Salt Lake Camp for refugees near Calcutta had seeded the infant nation with dozens of simultaneous outbreaks. Like a malignant cancer, the disease had spread throughout Bangladesh, overwhelming the smallpox program. It took nearly four years to recover from that experience. A return visit to India of the infection might overwhelm the sustained popular support needed for the final inch.

The potential epidemic had to be prevented from entering India. WHO and government of India smallpox eradicators turned eastward to the Bangladesh border and mounted an intensive surveillance effort in Bengali-speaking areas. The old maps were taken out and studied for a clue to possible migration routes, dozens of surveillance posts were set up at border crossings, and special searches were conducted in designated high-risk areas. A special effort was mounted to control importations among the pavement dwellers of Calcutta, thought at the time to be recent migrants from Bangladesh. (After careful study of the floating population, however, it was concluded that most were semipermanent, with closer ties to Bihar than to Bangladesh; but still surveillance was intensified.)

The two-year period of waiting and watching thus began omi-

nously. But in some degree, it had been established for just such reasons. The WHO Expert Committee on Smallpox Eradication had established the two-year period of active surveillance because twenty-four months was three times longer than any smallpox outbreak had previously eluded detection by a smallpox program. The realm of the final inch demanded meticulous attention to detail at the very end of the journey.

In India, there was little problem keeping up the momentum of searches as long as smallpox continued in Bangladesh, which shares with India a horseshoe-shaped border more than 1,000 kilometers long. And when Rahima Banu of Kuralia village on Bhola Island became the last case of endemic *Variola major*<sup>9</sup> in the world (with onset on October 16, 1975), the elation felt in Bangladesh was shared by 100,000 search workers throughout India. Almost miraculously, India had kept her independence from smallpox, without a single importation after August 15. And yet another eighteen months of active surveillance were required before an international commission would visit India to certify eradication.

Maintaining an esprit de corps and motivating themselves, colleagues, and others to work toward eradication had become a way of life for smallpox workers. People spoke of two infections, the virus of smallpox and the infection of zeropox, which began as the telex callback code in Chhotanagpur but soon became a shorthand term for the infectious enthusiasm of the eradicator.

In many ways, the smallpox eradication program was what sociologist Max Weber has called a "charismatic organization," quite different from the formal organizational structure commonly associated with WHO. But getting governments and workers motivated to eradicate smallpox was one thing. It was another to motivate the repetitive searches for two years, when there was no smallpox in India and none in Bangladesh and few personal or professional rewards other than the satisfaction of completing a job well done. This period of waiting, searching, and pressing on was one of the most difficult times, and yet it had to be borne. It was truly the final inch.

From August 15, 1975—the date of the independence from smallpox celebrations—until the arrival of the specially constituted international certification team, three all-India searches were carried out. Each was a house-to-house search of more than 100 million households. These searches, carried out in October and November of 1975, March

and April of 1976, and October and November of 1976, again employed over 100,000 health workers throughout the country. No smallpox was detected. From December, 1975, to February, 1976, a special series of searches was carried out in the border areas with Bangladesh and in districts with cultural or religious links to Bangladesh. Urban areas were searched during the three national searches and again in August, 1976, when a special monsoon search of 2,641 urban areas was conducted. Some remote and difficult-to-reach areas that had been missed during regular searches posed special surveillance problems. During 1975–77, special assessment surveys or special searches were carried out in Ladakh, Sikkim, Tripura, Mizoram, and Andaman and Nicobar Islands, and some difficult areas of central India. Facial pockmark surveys were also conducted. No smallpox cases with onset later than Saiban Bibi's were detected.

The three final all-India searches conducted in 1975–77 covered an average of 98.5 percent of the more than half-million villages in India in each search. Although no smallpox was found, chickenpox had certainly not been eradicated. The instructions to search workers to report all cases of fever with rash led to a high of 118,642 reported outbreaks of chickenpox, in which 379,297 cases were detected in the spring, 1976, search. The monitoring of reported chickenpox was a useful index of surveillance efficacy, but very sensitive to seasonality. A more important index was provided when the assessment teams that checked a sample of the villages found that 95.8 percent, 94.5 percent, and 97.0 percent had in fact been visited by a search worker in the three respective searches.

The search assessment itself had by this time become an impressive additional surveillance tool. In the final all-India search, nearly one-sixth of all villages in the country were revisited by an assessment team evaluating the efficacy of the search. In the final search, 107,409 villages were assessed—a very impressive figure when one recalls that the first all-India search had actually been a search of 241,074 villages in the endemic area and 40,418 villages in the nonepidemic states. Put another way, final spot assessment became so rigorous that nearly half as many villages were visited by an assessment worker at the end as had been visited by a search worker in the initial comprehensive searches three years previously.

In the spring, 1976, search, 682,151 out of a scheduled 692,189 villages were searched, along with 1,322 municipal areas. A staff of

142,176 people was mobilized to visit each house in every village. Six months later this colossal effort was repeated one last time. In autumn, 1976, three years after the first autumn campaign, the largest search of all was carried out by 152,441 health workers, including malaria and family-planning staff, who searched 668,332 villages, 99.1 percent of the villages targeted for search. They detected 20,076 outbreaks of chickenpox, with 41,485 cases. When 8,048 assessors visited 107,409 villages to check the work of the searchers, they found that 104,596 (97 percent) of the villages had been properly visited by search workers. Further, in 86 percent of 3,051,743 households that were visited by the assessors, someone had seen the search worker come to their house; 79 percent of the families knew where to report a case of rash with fever; 83 percent knew of the reward.

Increasing attention to assessment was the control that allowed program managers to quickly spot deficient areas and allocate scarce resources most efficiently, assigning jeeps, epidemiologists, and state surveillance teams to the areas with the poorest assessment. Thus the assessment performed the role that business analysts usually assign to quality-control measurements, assembly-line spotchecks, or marketing feedback indices. From the first search to the last, indices rose steadily, reflecting increasing surveillance quality.

Equally important, however, for the two-year postsmallpox period, were the results of laboratory specimens that were taken from cases of rash with fever, studied, and found to be diseases other than smallpox. During 1975, 702 specimens were examined, of which 141 had been positive for smallpox. In 1976, 640 specimens were examined, and none was smallpox. Bihar, the most problematic state during the intensified campaign, submitted 172 specimens from cases of rash with fever in 1976. All were negative for smallpox. By the end of November, 1976, the rumor registers were packed with names and addresses—1,951,487 cases had been entered as suspected rash-with-fever cases, visited, and examined; 833,412 cases of chickenpox were found.

And one more number. Zero cases of smallpox were found. And that, after all, was the most important statistic of all.

### The Certification of Eradication, 1977

No matter how good eradication looked on paper, it had to be certified in the field by an international panel of outside experts. Closing the books on smallpox required a careful and systematic process of deliberation—certification of eradication—by specially constituted international commissions convened by WHO. WHO established certain requirements to be met in order to formally certify a country as smallpox-free. The procedures included two years of active surveillance after the last detected case of smallpox, followed by a visit by an international commission to examine documentary evidence provided by the country and assess the validity of the documentation through personal field experience. The definition and criteria for smallpox eradication were established in 1972 by the Expert Committee on Smallpox Eradication, which stated:

Recent experience indicates that in all countries with a reasonably effective surveillance programme, residual foci can be detected within 12 months of apparent interruption. Thus, in countries with active surveillance programmes, at least 2 years should have elapsed after the last known case . . . before it is considered probable that smallpox transmission has been interrupted.

On the basis of this recommendation, four international commissions had already been constituted by WHO to certify smallpox eradication in the Americas (1973), Indonesia (1974), West Africa (1976), and Fakistan and Afghanistan (1976).

In preparation for the international commission's visit to India in 1977, the government of India created a National Smallpox Assessment Commission to perform an internal technical audit of the NSEP and its ongoing surveillance activities. The purpose of this innovative commission, which was composed of both Indian and international health workers, was to fully examine the surveillance process, to establish that no smallpox foci had occurred in India since May, 1975, to motivate staff to maintain careful surveillance until the arrival of the international commission, and to recommend a plan to further strengthen surveillance during the period of January through March, 1977. Such a national initiative was further proof of the government's commitment to go the final inch to ensure eradication.

At a review meeting held on January 20–21, 1977, the national commission reported that it found no evidence of smallpox in any of the areas visited by its members. While generally satisfied with the progress of surveillance programs in the state, the commission recommended that the NSEP strengthen surveillance activities during

the final three months before the evaluation of the program by the international commission. It reiterated that all suspected smallpox reports and chickenpox deaths must be fully investigated and that the diagnosis for other cases in each such outbreak confirmed by laboratory tests. By the end of February special searches were to be carried out by two or three basic reporting units in each district. The evaluation criteria for the efficiency of surveillance was the number of rash-with-fever cases (especially chickenpox) reported during the following three months, since the incidence of such cases was expected to steadily increase from January through March, based on previous epidemiological experience.

Documentation of surveillance activities was to be presented in the form of maps, charts, and files arranged sequentially, and the commission recommended that briefings be held at state, district, and PHC levels in order to review surveillance strategy and the requisite documentation. Supervisory staff at the state and district levels were encouraged to motivate local health workers to continue to perform careful surveillance. Large amounts of publicity about the reward were continued, along with press releases to educate the health staff and the public about the importance of the coming visit by the international commission.

In response to the recommendations of the national commission, a series of reports was prepared for review by the international commission, documenting smallpox epidemiology, vaccination procedures, surveillance, suspected cases, and the use of resources at all levels. Upon studying the reports of the central government and the National Smallpox Assessment Commission, the individual members of the international commission went into the field to examine firsthand the effectiveness of surveillance activities and the extent of community awareness about smallpox.

On April 23, 1977, the international commission declared India free of smallpox.

Based on its observation of the sensitivity of the country's surveillance system, the commission concluded that any transmission of smallpox would have been detected had it occurred since May, 1975. But India was still theoretically threatened with importations from neighboring countries, and the international commission recommended that primary vaccinations be continued until worldwide eradication was reached. Surveillance for suspected cases and labora-

tory confirmation of suspected cases were also to be continued until global eradication, to further ensure the validity of that certification.

The commission also urged that the experience of personnel from NSEP be analyzed and used as a lesson for other disease-prevention programs; that documentation of the program and lessons learned from it be used to provide a basis for epidemiological research and for training health personnel in the control of communicable diseases; and that the central government's report on smallpox eradication be published and made available to health workers throughout the world.

One important historical footnote brings the story full circle. The WHO-appointed international commission included Professor V. N. Zhdanov, the USSR emissary who had proposed in 1958 that smallpox be targeted for global eradication, as well as Dr. David Sencer, director of the United States CDC, which had lent the program many outstanding epidemiologists.<sup>10</sup>

The announcement of India's final liberation from smallpox touched off celebrations all around the world, both public and private. Perhaps the most deeply felt celebrations were of two kinds. The first, of course, took place in villages like Pawa Puri, Tatanagar, Pachera village, and Karimganj railway station, where smallpox history was made. The other celebrations were those in the homes of 100,000 Indian smallpox workers and in the thirty home countries of the international smallpox veterans who had learned so much from each other, from the disease that was their adversary, and from India herself while they managed to eradicate smallpox.

## *Chapter 2* Analysis and Commentary

#### Introduction to the Analysis

The case study presented in chapter 1 was a chronology of the management of smallpox eradication in India. In this chapter the management of the program will be analyzed using a conceptual framework developed by Professor James Austin. Austin has used this framework to analyze successes and failures in international programs dealing with family planning (Austin 1979), malnutrition prevention (Austin 1978), and xerophthalmia prevention (Dutta, Arora, and Rao 1975). The framework, slightly modified to apply to smallpox eradication, starts with general definitions and moves through management issues down to the specifics. The chronological case study will be taken apart and reorganized following the framework indicated by the chapter sections. Of necessity, many key points will be repeated. This redundancy may be disconcerting for readers familiar with the history of smallpox in India, but for readers new to the subject it is important to review the eradication effort from the vantage point of historical development as well as by placing it within an analytic framework.

#### Statement of the Problem

India had for centuries been one of the heartlands of smallpox. Smallpox had swept the world in great epidemics, often reemerging from the Indian subcontinent. From time immemorial, great epidemics recurred in India with a five-to-seven-year periodicity. Even after the arrival of vaccine in the country in 1802, there were devastating recurrences such as the epidemics of 1873–74 (500,000 deaths estimated), 1950–51 (105,782 deaths), and 1958 (45,838 deaths). Exportations to Europe and other countries in Asia were common (from 1961–73, ten importations to Europe were traced to India, and twenty-one of the last twenty-seven importations into Europe were

traced to the Indian subcontinent). By the middle of the twentieth century, national and international expert committees were frequently convened to consider the problem. The Bhore Committee, 1949, and the ICMR Expert Committee, 1959, pointed out problems with program planning and management. National assessment commissions (NICD assessment, 1963–64; joint WHO–Government of India assessment, 1967) pointed out serious managerial problems with implementation; and even the international WHO expert committee, 1972, specifically recognized that "India presents special problems" for the organization of a successful smallpox eradication program.

#### The Causes of the Problem

The virus *Variola major* is propagated best in densely populated areas.

As man is the sole host of the *Variola* virus and no animal reservoir exists, continuous transmission of *Variola* virus in the human population required aggregates of susceptible individuals such as first occurred about 5,000–6,000 years ago when agricultural development made it possible to support populations of more than 500 living together in one place (F. Fenner, personal communication). The disease apparently spread in all directions from the eastern part of Asia along with population movements due to trade, religious and political conflicts and exploration. (Arita 1979, 295)

Dr. I. Arita has suggested that the major problem in eradicating smallpox might be not the numbers of people vaccinated, but the *density of unvaccinated susceptibles* (D. A. Henderson, personal communication). In most of Africa, for example, while many were unvaccinated, population density was low, leading to a decreased overall density of susceptibles. In densely populated Asia, however, even though a high percentage of people had been vaccinated, the higher population density created a density of susceptibles that may have been greater than in any other part of the world. The actual propagation, epidemic force, or infection intensity could be related to this density of susceptibles times a factor for climate and a factor for frequency of interpersonal contacts. India's densely populated areas and high mobility (as many as 6 million people are on a train or bus or bullock cart traveling from one place to another at any given moment), its periodic large gatherings (e.g., the famous Kumbh mela, which attracts tens of millions every twelve years, or the Jagganath Car festival in Puri, Orissa, which attracts nearly a million every May), and its frequent smaller festivals or *melas* all provide ideal conditions for transmission. The seasonal peak of smallpox corresponds to the warm dry season, which lasts from March to June in most of India, and also to the marriage and traveling seasons.

In addition to these epidemiological problems, there were many management problems. India continued to use liquid vaccine long after it had been abandoned in other countries. A lack of refrigeration facilities impeded the early phases of the program until freeze-dried vaccine became dependably available throughout the country. India was very slow to adopt the bifurcated needle. Older methods of immunization such as the rotary lancet were not dependable and left large, disfiguring scars from bacterial infection, which caused resistance to vaccination and frequently created a false sense of confidence about successful immunization among those who had been vaccinated. With over 80 percent of the population living in rural villages and only infrequently having contact with health services, the technical problems were compounded by the logistical problems of providing effective delivery of vaccine to the periphery. A cumbersome reporting system made it difficult to get news of smallpox cases to the center. Finally, India's high birth rates added as many as 21 million infants to the susceptible population each year, new fuel for the fires of epidemic smallpox. Even if a 100 percent vaccination rate had been achieved through an annual visit to every house in the country, each year's tens of millions of unvaccinated newborns could have supplied new links to continue the chain of transmission.

The multiplicity of ethnic groups, languages, customs, and associated health beliefs in India is unmatched in any other country. The staggering number of relatively autonomous health and medical organizations at national, state, and municipal levels also compounded difficulties, as did the relative administrative separateness of cantonment areas, border areas, and tribal areas.

In brief, smallpox in India represented one of the most tenacious problems to be faced by the global campaign, and nearly all observers acknowledged that one of the most intractable difficulties

was administration. Delays and inefficiencies did not lend themselves to a successful emergency campaign.

Management practices in India had developed from the managing agency system imported by the British East India Company. The system was highly centralized with a rigid social structure. The Indian civil service, which became the administrative model for India, was a classic example of British rule—little delegation of real authority, a narrow span of control, and a wide social gulf from top to bottom.

In the Directorate of Health and in the health field, there was a chronic shortage of professionally trained administrators. Most programs were headed by physicians who had excellent technical qualifications but lacked management skills and experience. Coordinating a multiplicity of relatively autonomous smallpox organizations required several high-level managers, and at least until 1972–73, there were no more than one or two senior-level program managers in the office of the assistant director-general (smallpox), who as head of the NSEP was responsible for smallpox eradication in the nation.

The understaffed NSEP administration, not surprisingly, was having difficulty providing annual vaccinations to every one of the 150 million houses in the country! Compounding this management bottleneck were social and cultural issues unique to India. Perceptions about the inevitability of the disease existed in many villages and among certain health administration leaders. The average villager dared not dream of the eradication of smallpox; in the cultural framework of traditional India, that was a metaphysical contradiction. Within the Ministry of Health and within WHO many skeptics also doubted that smallpox could be eradicated, and many health planners and some policy makers questioned whether eradication was economically justifiable.

#### System Definition

The smallpox eradication network involved the central government of India, the various state governments, and Indian nongovernmental organizations (NGOs) as well as international agencies and bilateral donors. Organization chart 1 in appendix 2 shows these institutions and their roles as they evolved from 1962 to 1974.

From the periphery of India's more than half million villages

and over two thousand cities, through local, regional, and state governments, to the Directorate-General of Health Services, smallpox eradication efforts touched every level of government. The many semiautonomous agencies—the municipal boards, cantonment (armed forces) health directorates, railway health administration, and private industrial health concerns—complicated the system. For example, in one important epidemic area, there were fifteen autonomous political units—small company towns, corporations, railway colonies, or unincorporated urban areas—with a total population of approximately 800,000 people. Each unit was administered separately. There was no single administrative authority for public health. All of the units of the urban complex reported irregularly to the district medical officer of health (DMOH). Responsibility for reporting smallpox cases in border areas, the mobile population, and other high-risk groups was unclear.

The NSEP, with over 100 smallpox eradication areas, was an attempt to bring such autonomous entities together and organize an independent single line of command. A program officer was appointed for every state in the newly established posts of assistant or deputy director of health services (smallpox). From the district level down to the PHC there were no special NSEP officers, although 20,000 vaccinators were appointed. The NICD (which had organized the 1963-64 assessment) played a role by deputing trained epidemiologists and would later serve as the vaccine quality-control reference laboratory in addition to doing smallpox diagnostic laboratory testing. The four vaccine institutes were regional vaccine suppliers although a central officer, the assistant director-general (vaccine), was responsible for monitoring the quality and quantity of vaccine produced. The ICMR was to oversee research projects dealing with smallpox and had jointly organized the assessment of 1959. In the early part of the program, before the intensified campaign, there was little involvement of medical schools or NGOs. However, after 1974 organizations like the Lions and Rotary clubs, public sector corporations like the Hindustan Steel Company, and private sector companies like Tata began to play important roles in key areas.

Multilateral agencies such as WHO and UNICEF, which played important roles later, had very limited roles before 1970. With the exception of a small grant from United States AID in the mid 1960s and substantial vaccine donations from the USSR in 1962 through 1973, bilateral donors did not have much of a role until the intensified campaign. Oxford Famine Relief (OXFAM), whose \$100,000 donations of jeeps, volunteers, and supplies was to prove very important in 1974, became involved only after the epidemic of 1974. The WHO team was successful in mobilizing increasingly greater international and private resources during the intensified campaign; this was especially true after the epidemic of 1974.

This network of interested agencies must be distinguished from the formal government organization chart, which is shown in charts 2-4 in appendix 2. The simple organization chart for 1962–69 (chart 2) was inadequate to meet the growing need for surveillance and reporting. The 1970 structure (chart 3) shows the increasing emphasis given to the partnership, with the 1973 intensified campaign (chart 4) requiring even more cooperation, as exemplified by the emergence of the joint central command. It must be remembered that smallpox was a state subject in India, which meant the actual work of the intensified campaign was carried out at the state level. Charts 5-9 show the organizational pattern of smallpox work at the state, directorate, district, PHC, and municipality levels. While the example is that of Uttar Pradesh, similar structures could be found in other states. Like most government organizational charts, these contain a plethora of abbreviations and job titles that may puzzle the reader, but the charts are presented not so much for their detailed organizational components as to give the reader a feel for the complexities involved in supervising and coordinating such a vast army. This system was not a static one, and it grew wider and broader as the campaign continued. Increasingly, a dynamic temporary system of smallpox eradication was being grafted onto the permanent organizational tree.

The following provides one example of organizational changes that occurred as the program developed in 1974. In the Tatanagar/Jamshedpur epidemic, although over 300 exportations were documented, there was little notice of the outbreak in Tatanagar area itself. One of the reasons was the multilayered administrative structure—the many autonomous units without an effective single line of command. The company doctor at TISCO had been negligent in reporting smallpox; the local Bihar state government, with 33 percent of its PHC medical posts vacant, could not mount an effective surveillance program. With the intensification of smallpox efforts, many community leaders volunteered to join the expanding mobilization. The discovery of the smallpox epidemic catalyzed vigorous community participation in the program. Rotary Club, Lions Club, Ramakrishna missions, Youth Congress, the local blood bank (they provided free cooked meals for 600 volunteer surveillance workers for one week) all provided assistance; the local industrialists in both the public sector (Hindustan Steel, Bihar Mines, and others) and the private sector TISCO, Tata Electrical and Locomotive (TELCO), Indian Tube Company, Usha Martin Black, and others) got volunteers from their factories, paid their salaries and expenses, and set up a central command headquarters in the Jamshed-pur town hall. Improved community awareness of the size of the problem led to an unusual degree of cooperation between sectors and among many varied groups.

Because it was discovered that the initial surveillance reports had seriously underestimated the size of the outbreak, an active search operation was organized in the second half of May, 1974. Of 1,203 villages within a forty-five-kilometer radius of Jamshedpur, 760 were searched. The search showed that 456 (approximately 60 percent) had as many as 726 active smallpox cases. When these new cases were combined with the 1,479 cases discovered in the urban areas, it meant that 2,005 cases of smallpox had been discovered through increased community participation in this one limited area alone. In Austin's framework, *system* usually means institutions. As the smallpox program developed and grew, the system widened to include many institutions, agencies, and organizations from all sectors of Indian life.

#### Setting Goals

Austin points out four principles of goal setting that characterize good management of successful projects in the developing world.

Goals, whether for the total system or the individual institution, should meet four fundamental requirements if they are to be of maximum utility: Goals should be specific. . . . Goals should be measurable. . . . Goals should be realistic. . . . Goals should be dynamic. . . . (Austin 1979)

Explicit goals are a prerequisite for effective management—they serve as guidelines for strategy formulation, motivating instruments, and as a basis for subsequent evaluation or concurrent assessment.

Both vaccination programs and eradication campaigns lend themselves to goals which are specific and measurable. For instance, before the strategy was changed to surveillance and containment, specific goals had been first to vaccinate 80 percent and later to vaccinate 100 percent of the population. Although specific and measurable, these goals were not realistic. Even in a militaristic setting like an army it would be difficult to achieve 90-95 percent vaccination. There are always exceptional reasons to avoid vaccination. Such vaccination rates are even more unrealistic for an entire country. In the Indian context, with limited penetration into the periphery by the health services, 100 percent vaccination was unrealistic. With India's 21 million new births every year it would have been necessary to continue to visit every person and every home in India each year for vaccination alone, and even then 21 million unvaccinated babies would have entered the population in each one-year interval.

This rather inflexible early goal was shifted to a set of strategies routinely called surveillance and containment. In 1970–72, goal setting in the area of reporting procedures was developing. Every PHC, district, and state was to collect and pass along all smallpox reports each week. This was a measurable, realistic, and specific goal. It was also dynamic, part of an improving surveillance system. As the program evolved, the goal of good reporting was extended as the site of the most peripheral reporting unit was refined from each PHC to every village and finally to every home in India. The frequency of reporting also changed. Although routine weekly reporting was still required, more attention was paid to periodic search reports, whether monthly or bimonthly or (later) even less frequent.

The 1970 Plan of Operations had been weak in setting goals. The only containment goal mentioned in it is that mass vaccination should be performed when an outbreak was discovered.

As the case reporting and surveillance became more and more effective, specific, quantifiable containment goals (called targets) became an important part of the program—especially in Operation Smallpox Zero. In August, 1973, the goal was to find as many hidden cases as possible and vaccinate the thirty households closest to each infected house. By January, 1974, the target was to vaccinate fifty households around each case, and later in that year the entire village was to be vaccinated and two watchguards posted to prevent contact between the smallpox cases and potentially unprotected individuals. Searches were conducted as far as 10 miles (16 kilometers) around the infected house to detect hidden cases. As the numbers of outbreaks decreased and more resources could be focused on each one, a supplementary second search was added to the containment requirements, to be carried out two weeks later because an incubating, asymptomatic case could have been missed in the first search. Saturation vaccination was increased to include everyone living within 1 mile (1.6 kilometers) of each case, and additional watchguards were posted. Careful outbreak investigation was made an additional target. The meticulous care afforded individual outbreaks reached a peak in 1974–75. In one outbreak in Pawa Puri village in Bihar, nearly 2,000 telegrams were sent to people suspected of having been in contact with an active case.

Each newly adopted epidemiologic measure aimed at containing the spread of smallpox became a target in its own right. For example, by 1975, any outbreak having secondary cases more than twenty-one days after the onset of the first case was considered a containment failure and was visited by a senior-level central appraisal officer who may have traveled 2,000 miles just to assess the work in the outbreak. Not only were these measurable targets, but they were reasonable ones that increased in sophistication only as the number of outbreaks decreased or increased staff became available. Because they were reasonable targets it was also reasonable to take stern administrative action when they were not met.

Another set of targets not unlike those of an advertising campaign was established for health education. A high level of public knowledge of the importance of reporting hidden cases was needed. Each district and state aimed at attaining a specified target knowledge level, defined as the percent of people knowing of the existence of the reward for reporting smallpox. The first target was set at 50 percent of the population. Assessment teams questioned nearly half a million people to see if they knew about the reward. When they found that target had been achieved (see tables 5 and 6) the target was promptly raised to 67 percent in June/July, 1975 and finally to 80 percent during Operation Smallpox Zero in 1975. The goals were dynamic and increasingly stringent as outbreaks became fewer and more resources could be shifted from containment activities to health education during the periodic nationwide searches.

The purposes of these targets were to increase surveillance, supervision of the active search, extent of publicity and reward information, and speed and coverage of vaccination.

This type of goal setting—specific, quantifiable, realistic, dynamic, and flexible—lent itself to measurable progress. Because each program activity now had a yardstick for measuring good performance, it was possible to spot poor performance areas and concentrate on them, so that resources were allocated more accurately.

Most of these targets, however, were intermediate objectives or operational goals. Targets were fluid and flexible, changing as the program became more sophisticated. There were in reality at least two tiers of goals. The highest goal was realistic, measurable, and explicit, but unchanging. From the beginning of the intensified smallpox campaign, it remained the same, an inspiring and motivating target of the campaign: target zero.

#### **Strategy Formulation**

Strategies and tactics are components of program management that affect the attainment of its goals, the final outcome of the program. Once goals are established, program management must plan how they will be achieved. Strategies provide a plan of action that guides management toward goal attainment.

We can think of two types of strategy formulation in the smallpox story: political strategies and technical or epidemiological strategies.

#### **Political Strategies**

For the most part, the formulation of political strategies originated with the active entry of WHO into the smallpox program. Once an international agency became involved in the national program, comparisons with programs in other countries became inevitable. There was a global competition to avoid being the last country infected with smallpox.

The political strategy of the smallpox unit was straightforward. Smallpox had been declared a priority by the World Health Assembly, and the government of India had subscribed to the resolution making smallpox eradication a high priority. However, this political commitment from the government had not been translated into manpower, jeeps, and a workable system. The major political strategy was to motivate decision makers to make smallpox a real priority. Only this would free the needed resources, permit the rule breaking that would be required, and encourage a sustained commitment from the technical staff. Fortunately, there was a convergence between the epidemiological strategy (searching for all cases) and the political strategy (making smallpox a priority). As the search detected more cases, the true size of the problem became more apparent and political pressure to control the epidemic mounted. Concern and embarrassment combined to open doors and provide access to political decision makers.

Once India began nationwide searches, a cumulative series of events was set in motion. This process kept going on and on, increasing its effect with each search. In management jargon, such a process is called an "iterative" or positive feedback loop. This positive feedback loop might be thought to have replaced an earlier, negative feedback loop that had been operative before the intensified campaign. The earlier feedback loop fostered suppression of smallpox reports, and the apparently diminishing incidence of smallpox led to consequent removal of health resources from the smallpox network. The sensitivity of the reporting system increased at least tenfold from 1972 to 1975, creating a sense of urgency that convinced health planners, policy makers, and politicians of the importance of smallpox eradication. Likewise, interest and support from well-known individuals, the media, and the political level provided motivation for the workers. Personal messages issued by the prime minister, governor, and chief secretaries as well as religious and cultural leaders exhorted the team to work harder and better.

It was important—essential—to keep morale in the field high by supporting the efforts of the search worker. These often unsung heroes were the people who had to travel an extra mile or to make yet another search of an area long believed free of smallpox. The weekly surveillance reports that were widely circulated and closely followed helped by stimulating interdistrict or interstate competition to eradicate. Finally, there was the rarely spoken possibility that India might be the last country on earth with smallpox. This was perceived as a national disgrace: Prime Minister Indira Gandhi had said that "smallpox is a disease of economic backwardness." Fears of trade embargoes, international quarantine, and loss of tourist

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revenue, while never explicitly mentioned, provided a constant incentive for India.

The interest generated from the political level made it possible to attract more resources and increase community involvement from outside the health sector. During the peak epidemic year 1974, for example, there were 188,003 cases of smallpox to be found and contained by 20,000 NSEP workers. A short-term infusion of additional staff was needed, and the political strategy of increasing smallpox's priority was directed at this need. For example, once the governor of Uttar Pradesh announced his personal commitment to eradication, other public officials in the state could not refuse to support it; in Bihar, once the chief secretary made smallpox eradication part of the duties of the chief civil authority, the district magistrate, and removed it from the hands of the district medical officers, the program gained extra managerial know-how and access to highlevel political figures.

#### Epidemiological Strategies

Once the goal of eradication was established, several epidemiological strategies were tried: (1) 80 percent vaccination coverage with lymph vaccine, (2) 80 percent vaccination coverage with freezedried vaccine, (3) 100 percent vaccination coverage with freezedried vaccine, (4) passive surveillance with mass vaccination around outbreaks (the 1970 Plan of Operations), (5) surveillance and containment (active case search, identifying high-risk populations, containment vaccination, with concurrent assessment).

When the NSEP was established in 1961, India embraced the global WHO-promoted strategy of mass vaccination. Because the objective of this strategy was to vaccinate every individual in the country (the target was initially 80 percent, herd immunity being thought to be sufficient to interrupt transmission), its evaluation criteria were based on program inputs and outputs (i.e., the amount of vaccine imported or produced, the number of people vaccinated, and so on). These were misleading indicators, however, for even as health workers reported more successful vaccinations, smallpox outbreaks were increasing.

This was, however, the state of the art in the 1960s. It was logical to assume that if all susceptibles became immune, transmission of the disease should be stopped. In fact, this strategy had been successful in Burma, the Middle East, and elsewhere, including the Sudan. The 1958 WHO expert committee report, which had declared "The target must be to cover 100% of the population" (World Health Organization Expert Committee on Smallpox Eradication 1972), provided technical justification for mass vaccination. Thus the standards adopted by the Indian government were internationally accepted ones.

In India by the late 1960s, the mass vaccination program was successful in achieving the highest vaccination coverage rates of any of the smallpox endemic countries in the world, but it was unsuccessful in its ultimate goal of interrupting transmission. The misplaced concern for vaccination coverage created a paradoxical attitude among the program staff who followed this tragedy: they were more worried about the percentage of vaccination coverage or the number of unvaccinated children than they were about the occurrence of smallpox cases.

However, by around 1970 the program staff (mainly Indian) started to seriously question why transmission was continuing despite such high vaccination coverage. This is where the concept of density of susceptibles is important. For example, in area A, where only 100 persons live in one square kilometer, vaccination coverage of 50 percent leaves only 50 susceptibles. On the other hand, in area B, where 1,000 persons live in one square kilometer, 90 percent vaccination coverage still leaves 100 susceptibles, which is no different from the number there would have been in area A if no vaccinations had been done at all there. The lesson here is that in densely populated areas such as urban slums, even 90 percent vaccination would leave enough susceptibles to maintain transmission.

The alternative to 90 percent vaccination was surveillance and containment, which had been implemented in West Africa, Brazil, and Indonesia. It had been shown there that transmission was interrupted more quickly and at much less cost than it would have been if the mass vaccination approach had been used.

From 1970 to autumn, 1973, WHO made substantial efforts to introduce and develop the strategy of surveillance and containment into India through seminars and visits by consultants and by increasing the number of WHO epidemiologists assigned to India from four to eight. However, the results were not satisfactory.

In the autumn of 1973, two weeks of active search were carried

out in the four endemic states by mobilizing all primary health center staff. Until the autumn of 1973, ad hoc mobilization of health service staff had been done for active searches and for occasional epidemic control, but the staff of Muzzafanagar district, Uttar Pradesh, working along with Dr. S. Moukhopod, a WHO epidemiologist from the USSR, proved that assigning the entire PHC staff for two weeks made it feasible to visit all the villages in order to detect any hidden smallpox. It was also seen that a municipality search could be effective during the rains, since the team could concentrate their efforts in accessible urban areas when the transmission rate was low.

Thus, the epidemiologic strategy of the 1973 intensified campaign developed from practical field experience and a better understanding of smallpox epidemiology. Following Austin's conceptual framework, this strategy development can be seen as (1) accurately assessing the magnitude and nature of the problem, (2) tracing the cause of the problem correcting, (3) understanding and working with the existing system, and (4) forming workable political and epidemiologic strategies.

The results of the autumn search were dramatic. First, it was obvious that the sheer amount of smallpox had been disastrously underestimated both by India and WHO. Second, a most effective way was developed to discover hidden foci. Third, and psychologically very important, Indian and WHO field staff agreed that with a sufficient number of containment teams smallpox could be eradicated.

The surveillance and containment strategy evolved over time. The measurement of its success no longer was the number of people with vaccination marks, but rather the number of people with smallpox. Although the difference in objective appears subtle, the new emphasis on outcome (smallpox incidence) was a breakthrough in the thinking of NSEP planners. With the new emphasis, the strategy became harmonious with the ultimate goal of decreasing smallpox incidence to zero.

The many specific tactics of surveillance and containment in India—active search and containment, dividing India into endemic and nonendemic areas, individual risk-area analysis, forward tracing the chain of infection or backward tracing the source of infection—are part of a generic lesson that has applicability beyond the smallpox eradication experience. Whether it is called scientific management, selective epidemiological control, or surveillance, it is distinguished from simple distribution of services in that it depends on the measurement of outcome: the reduction of morbidity and mortality.

Even the concurrent assessment that developed later in the program was a refinement of this epidemiologic strategy, which was used to allocate resources on the basis of priority. Priority was related to risk of smallpox: the geographic areas at greatest risk had most priority. Risk was in turn defined by reference to certain epidemiologic indicators. For example, late in the program, when smallpox was disappearing, chickenpox surveillance was used as a surrogate for smallpox surveillance and monitoring chickenpox incidence was a management device for detecting areas with weak surveillance systems. One finding from chickenpox reporting in May, 1975, was that the district of Dumka in Bihar reported no chickenpox, while neighboring districts reported a great deal. Program managers reasoned that Dumka was at higher risk of having hidden smallpox, because if it did not report chickenpox, its surveillance system was not capable of finding smallpox either. On this epidemiologic basis, a special surveillance team was sent to Dumka to search for hidden smallpox. The distribution of knowledge of the reward could then be assessed and mapped, and it was clearly shown that Dumka had a much lower general knowledge level than its neighbors, confirming earlier fears raised by Dumka's lower chickenpox reports.

Seen in this context, epidemiologic measurements such as risk ratio and attributable risk have a great value in guiding disease control efforts. One enduring result of the marriage between epidemiology and the management sciences was a growing mutual respect for the value of both systems.

#### Implementing the Tasks

The journey to eradication can be seen metaphorically as a voyage beset with many obstacles. Goals and strategies provide the manager with destination points and a navigation map. Concurrent assessment provides a sextant to chart progress in relation to the stars, but down-to-earth tasks are needed each day to keep the ship working and moving mile by mile toward its destination.

Task implementation in smallpox was a dynamic process, constantly recycling lessons learned through hundreds of natural experiments in remote villages. As fast as these innovations could be shared at monthly progress review meetings in each state, they were disseminated at the next presearch meetings to the most peripheral PHC levels. As the epidemiologic situation changed, the specific tasks changed. But the need for attention to detail did not change. Eradication, as one person put it, demanded perfection in detail and compulsive attention to specific tasks.

Tactics are methods used to implement strategy. Developing tactics involves attention to each program component—such as the procurement and distribution of supplies, management information systems, personnel management, financial management and budgeting—as well as research and development. An international health program also involves diplomacy and knowledge about intergovernmental affairs. These latter, along with leadership, motivation, and management style, are considered in the section entitled "Management Style."

This section on task implementation is organized according to the functional components of the smallpox eradication program.

Tactics will be discussed with reference to two periods: first, 1961–73, when the goal of eradication was just being articulated and the NSEP created; second, 1973–75, when the intensified campaign was in full swing.

#### **Organizational Tactics**

Formal organization charts, such as those shown in appendix 2, rarely reveal the actual working structure of an organization. Access to top decision makers is frequently so important that knowing whose offices are closest to the director's office may be more informative than seeing which box on the formal organizational chart is directly next to that of the director. In India, where organizational hierarchies are the legacy of British colonialism, requests and approvals as well as operational plans must come through a series of proper channels.

In the smallpox eradication program in India, the hierarchical relations of the organization chart were often breached. The success of the program relied on an understanding of the informal organizational structures of both government of India and WHO. A per-

sonal, persistent approach to administrators, politicians, bilateral donors, and Indian philanthropists characterized the organizational tactics of the smallpox team. An informal atmosphere, a group decision-making process, and an open, decentralized style characterized the operating relations of the joint WHO-government of India central command that emerged gradually over the months of intimate working together in field and office (see charts 2–4 in appendix 2). This frequently resulted in "level jumping," a term used in India to refer to the process of circumnavigating the formal chain of command. In the Directorate-General of Health Services, for example, if a junior officer goes straight to the director-general, or an assistant director-general goes personally to the health secretary or minister, they are level jumping. Nearly every senior Indian health official identified level jumping as one of the reasons for the smallpox program's success. Although level jumping cannot be a prescription for success in other programs (if everyone goes around the system, the system itself is destroyed) it is important to distinguish between the formal organization seen on paper and the informal organization that played such a key role in smallpox eradication.

#### Government of India—Health Structure

The program officer for the NSEP was the assistant director-general of health services (smallpox). Above his rank in the formal organizational chart were a deputy director-general (public health), a commissioner of health (approximately equal to an additional directorgeneral), and then the director-general of health services. But the organizational chart does not stop there. In India, as in most other commonwealth countries, technical leadership in a ministry (such as the medical officers in the Directorate-General of Health Services) are below two other levels of bureaucracy, the administrative and the political. In the administrative level, there were usually two assistants, such as the deputy and additional secretaries, both of whom usually outranked the technical officers, and above them was the secretary. In India, the phrase "the government has agreed" usually means a formal letter signed by someone from the administrative level, usually with the rank of at least under-secretary. The administrative level in the government of India is made up of several cadres. The higher-ranking administrative personnel (such as the secretary of health) come through the IAS, an elite corps of

professional administrators; the under-secretaries usually come from the central administrative services. Both are part of the permanent government of India administrative structure.

The highest level is the political level, where the minister of health officially has final say. A variety of assistants to the minister—special assistants, or the minister's personal assistant—wield great authority.

In the beginning of the program, the smallest matters, including the visits of the NSEP officer out of New Delhi to an outbreak, required permission from the administrative level. Simply moving from place to place while investigating smallpox spread required administrative approval. In the case of internationals working in certain states, permission from the political level was required to follow a source of smallpox infection. The technical level staff had responsibility for the program but little real authority to run it.

Later in the program, especially after the active searches began to reveal large-scale epidemics of smallpox in 1973, several factors increased the political power of the technical level Indian smallpox team: (1) the emergency epidemic, with its nationwide press coverage and parliamentary "call attention" motions; (2) the WHO resolutions calling on all countries to make smallpox eradication national priority; and (3) the foreign components of the program-the WHO medical officers, the readily available jeeps, and the independent funding sources. The independent funding made it possible for technical level staff to go to the minister for authorization to break rules without having to ask for new funding for the rule breaking. Such level jumping, although strongly discouraged by many, was a prime organizational tactic. The smallpox unit in WHO made use of a parallel approach: independent funding also made it possible for WHO smallpox staff to go to the regional director for authorization for many exceptions to WHO rules.

The Complex WHO Formal Organization

The regional director of SEARO was extremely supportive of the concept of smallpox eradication. As president of the twentieth World Health Assembly in 1967, he had said, "Eradication of smallpox is within our reach. The achievement of this important undertaking now depends exclusively on our will and determination." In the formal organizational structure of WHO, the smallpox unit was organizationally distant from the regional director's office. At the beginning of the program, the team leader (officially regional advisor for smallpox) and other medical officers (officially medical officers of the intercountry Smallpox Eradication and Epidemiological Advisory Team) had to report to two regional advisors in communicable diseases (RACDs). The RACDs in turn reported to two assistant directors (AD), one responsible for smallpox as a disease, and another responsible for disease control in India as a country. If both ADs approved a request, for example, the paper was then routed to two others: the chief of administration and finance (CAF) for administrative and budget implications, and the director of health services (DHS) for technical approval. Dr. Nicole Grasset, the WHO team leader, vividly recalls the complexities of the organization's formation.

The team leader remembers that when she received her briefing on her arrival in India (in 1970), most of the staff made her understand that (a) the eradication of smallpox would be a very difficult task and would take one or more decades and, (b) she must realize that it was essential that she know how to resign herself to things being done slowly in Indiaespecially in relation to national administrative procedures. She began taking this advice and resigned herself, as did all the SEARO staff, to the fact that it took approximately three months to get the clearance of a consultant to permit him to go to the field-she resigned herself to the fact that, even when she wanted a minor action approved, the request had to be agreed upon by two CD's (who rarely between them agreed, therefore, a compromise had to be obtained between the views of three persons, two of whom had no or little knowledge of smallpox methodology successfully used in other continents). The "compromise" then had to be approved by the AD of the country for which the action was to be taken, then by the DHS, and sometimes the RD (plus an administrative unit such as personnel or finance in most cases). Later the WHO smallpox team leader, with the help of the WHO unit in Geneva, was able to institute a formalization of "level jumping" such that the smallpox unit was given priority and was removed from the "communicable disease unit" and the Assistant Directors, and allowed to report directly to the DHS. (Grasset 1972, 41)

The Informal Organization—the Government of India– WHO Joint Leadership Team; the Smallpox High Command

Often an informal organization develops at the top management level in an intensive campaign. The joint WHO–government of India team, which was often called the central command or the smallpox high command, developed into such a joint leadership team.

The WHO side of the smallpox high command was composed of the WHO medical officers from the SEARO regional office and the WHO operations officer attached to the team. Although these four medical officers were nominally part of the Smallpox Eradication and Epidemiological Advisory Team and were in fact responsible for the smallpox eradication program in all eleven countries of the South-East Asia Region, in reality they spent most of 1973–75 working in India.

The Indian side of the high command was composed of the central level appraisal officers from the government of India and the NICD, which deputed its top three epidemiologists to aid the program. These officers included the assistant director-general (smallpox) and his deputy, the assistant director-general (cholera), the director of the NICD (who later became the government's acting commissioner of health), and two deputy directors of NICD.

An important element of most WHO programs at this time was the concept of counterparts. Originally linked to the need for developing national competence after temporary international programs fulfilled their mission, the concept of counterpart developed into national control of international programs and later into national self-reliance in management of health programs. In the smallpox eradication program, after some preliminary problems, the counterpart system worked very well, and the smallpox high command developed into a model of international cooperation in all ways technical, political, and personal.

Led on the Indian side by the commissioner of health or the acting commissioner of health and on the WHO side by the smallpox unit team leader of the Smallpox Eradication and Epidemiological Advisory Team, the titles and offices merged into an informal leadership partnership which, with its members trusting and liking each other, provided the impetus and the inspiration for eradicating smallpox from India.

At the highest level, this shared sense of purpose expressed itself in true international collaboration. Sharing train rides together back and forth from infected areas, attending monthly progress review meetings in every state in India, jointly making plans, assessing organizational tactics and strategy, and watching the incidence of smallpox wane or wax with the success of the efforts to overcome it led to a very unusual solidarity among the central command. The organizational charts and the charts of institutional roles fail to convey the sense of personal dedication and leadership that characterized the program participants who became emotionally tied to the success of the campaign. Many participants undertook personal initiatives beyond their job descriptions. There are many examples of such personal initiatives, but a few deserve special mention.

The team leader, Dr. Grasset, wrote personal letters to Prime Minister Gandhi on two separate occasions, asking her to send a message that could be used to encourage the health staff or to inaugurate one of the regional and rational meetings. In both instances, the prime minister wrote the requested messages, which had a great motivational effect for the workers.

In 1973, when the first search of the endemic states in India was being planned, officials in Uttar Pradesh refused to undertake a single-purpose search for smallpox only. They preferred an integrated approach in which the smallpox search worker would also perform ten additional health activities (e.g., taking blood for malaria, distributing condoms for family planning, distributing vitamin A, and so on). All these are extremely valuable health activities, but the integration and proper performance of so many activities would have required more supervision than was available, and earlier experience had shown that multipurpose visits of this type would simply not work without additional supervision. A well-known religious leader, very supportive of smallpox eradication, helped a WHO medical officer arrange an unofficial appointment between the governor of Uttar Pradesh and the smallpox team. The governor understood that if smallpox could be eradicated quickly, many resources would be released for malaria and family planning. He gave smallpox eradication priority, and invited all the highest health officials of Uttar Pradesh and the central level officers to the state meeting that he opened with inspirational speeches defending the shortterm, single-purpose smallpox search strategy.

At the peak of the smallpox epidemic, one of the key Eastern European medical officers was informed by his home ministry of health that he could not have an extension of his stay in India and would have to return to his country. The team leader personally visited that nation's ambassador to India and convinced him that it was essential that this medical officer remain in India until smallpox

was eradicated. The personal request for an extension was granted, and this important epidemiologist was allowed to stay.

At a time when the northern states were heavily infected and all the trains in the country had gone on strike for a long period, it was virtually impossible to travel from New Delhi to the infected areas. Supplies and equipment could be transported by plane, but program staff had to find other transportation. The team leader personally contacted the head of Indian Airlines, who allowed smallpox program staff high priority to travel by air, along with vaccine.

A direct appeal from the smallpox unit to the New Delhi-based regional director of UNICEF, the sympathetic local head of SIDA, and J. R. D. Tata, the chairman of the board of directors of Tata Industries, led to extrabudgetary funding for the program. Personally motivated WHO staff made requests to OXFAM, to local Rotary and Lions clubs, and so on, that brought extra funds and greater community participation. Over 90 percent of WHO smallpox funds in 1974–75 were the result of fund-raising efforts of WHO smallpox staff.

These direct personal appeals are examples of the informal organizational structure of the smallpox team. That informal structure became part of the reputation of the smallpox unit, which was quite different from the usual impression of international bureaucracy.

A special relationship embraced the joint WHO-government of India enterprise, and the teamwork between the two-the organizational tactics-acquired an additional dimension of international diplomacy. There was a certain Mount Everest effect in smallpox eradication; it was a challenging first to be accomplished, and it attracted a certain type of leader. The quest for eradication galvanized and excited smallpox workers, regardless of whether they were from the government of India, were from communist or capitalist states, or were physicians or administrators. The counterpart system, whereby WHO international and national program officers were teamed, worked to the best advantage of both. Within the central command, it was common for Indian epidemiologists to level jump within their bureaucracy by saying "WHO suggests that . . . ." Within WHO, it commonly occurred that after joint concurrence between government of India and WHO smallpox workers, the WHO smallpox staff would go to the regional director with the statement "the Government of India requests that . . . . " Both halves of the central command practiced this mutually beneficial ventriloquism. Each used the other side

to bolster their common desire for more resources and faster administrative action. This "using each other" is in the best tradition of diplomacy and is one of its purposes.

Another of its purposes is to bring about a compatibility of aims; only the amateur or the insecure thinks he can permanently outmanoeuvre his opposite number. In foreign policy one must never forget that one deals in recurring cycles and on consecutive issues with the same people; trickery sacrifices structure to temporary benefit. Reliability is the cement of international order even among opponents; pettiness is the foe of permanence. (Kissinger 1979)

But in the smallpox program, the government of India team and the WHO smallpox unit grew beyond any kind of diplomatic contest. There was mutual respect, born of long, hard days in the field sharing victory and defeat. Like an international mountainclimbing expedition, each group depended on the other to watch its smallest step, protect it from unseen dangers; at the end were the highest pinnacles of success, which they would share.

#### Logistics

Logistics involves the means of "getting there." In the smallpox program getting there included the physical flow of vaccine, needles, jeeps, gasoline, posters, reporting forms, operational guides, wall charts, and personnel.

Before the intensified campaign, WHO had played a limited role as far as logistics were concerned. Under the 1970 Plan of Operations, distribution of supplies was a government of India function. Apart from assisting with organizing the four vaccine production institutes (UNICEF provided supplies and equipment; WHO provided technical consultants), WHO's role was limited to that of purchasing supplies and equipment not available in India. The government of India was responsible for arranging local travel for consultants; for providing supplies (typewriters, office equipment) for WHO medical officers; and for dispatching forms, needles and needle holders, vaccination kits, and so on.

After the intensified campaign, many of these functions were centralized in the WHO regional headquarters (SEARO) and in administrative offices at state level. A new class of WHO consultants, the operations officers (the majority were public health advisors

from the CDC who had begun their careers as venereal disease investigators in the United States), served a dual function, occasionally working as epidemiologists at district levels or serving as supply officers, administrative officers, or logistics officers at state levels. In the SEARO headquarters, a stream of unusually gifted administrators rotated in three-to-six-month assignments. There were often two such administrative officers within the SEARO smallpox unit, a personnel officer and a budget and finance officer. WHO itself has units specifically devoted to personnel (PER), medical supplies (MS), budget and finance (BF), and administrative services (AS). To some extent, having administrative officers within the smallpox unit created a parallel internal system; but the administrative demands of the greatly increased smallpox unit required a separate logistical organization. In 1974, the smallpox unit hired over 100 consultants to work in India, more than all other consultants to all other WHO programs. A smallpox unit personnel manager was essential. On the supply side, 1 million bifurcated needles were imported and dispatched to the districts, 16 million forms prepared, printed, and shipped. The presence of trained and experienced administrative officers in the SEARO smallpox unit was without question one of the most important reasons for the smooth functioning of logistics.

One key input into the smallpox eradication program was essential: potent, dependable vaccine. Although, unlike needles and transport, vaccine production and delivery remained a government of India function, it provides a good example of how the combined WHO–government of India team handled logistics at various stages of the program.

To many outsiders, the eradication of smallpox is synonymous with vaccine, and it is true that vaccine-provided protection was the major weapon in the battle against the disease. The availability of such an effective biological weapon sets smallpox apart from diseases like malaria and cholera, which are usually grouped with smallpox in India.

In one sense, all over the world vaccine was a product to be marketed and distributed in a way analogous to the distribution of goods and services in a centrally planned economy and somewhat similar to marketing in a private sector corporation. The logistics of vaccine production, distribution, and quality control were analogous to the respective management parameters in other programs and industries. As the program developed, vaccine management became incrementally more sophisticated. In the period 1961–73, attention was placed on input; that is, the provision of enough vaccine. Donations from the USSR predominated, with 650 million doses given beginning in 1962. Many countries also contributed vaccine through WHO, but not all was of acceptable potency. Finally, as late as 1969, an estimated 32 million doses of low-potency, Indian-manufactured liquid vaccine still remained in stock.

Beginning in the 1960s, a major goal of the government of India was to become rapidly self-sufficient in the manufacture of high-quality, heat-stable vaccine. With the help of WHO and UNICEF, which supplied equipment, four centers in India were equipped to produce freeze-dried vaccine.

Table 1 shows India's drive to become self-sufficient in freeze-dried vaccine. By 1970, India was producing 50 percent of its requirements, and despite initial WHO concern about consistency and quantity of vaccine, by 1973 vaccine was no longer being imported.

From 1961 to 1972, one major NSEP objective was to maintain enough vaccine, needles, and supplies to carry out mass vaccination. Although vaccine production and importation were increased, quality control was difficult to achieve.

Experience throughout the program indicated that even one case of smallpox following an unsuccessful vaccination caused by low-potency vaccine could generate disbelief in vaccination. Only high-quality, heat-stable vaccine would do the job. In 1965, a central level smallpox vaccine testing unit was proposed, but did not begin to function until very late. In 1972, only one-third of the batches produced in the vaccine institutes were being monitored at the central level. In the ten-year period from 1965 to 1975, only 2.1 percent of all batches tested from India were rejected because of low initial potency, and less than 1 percent were rejected for lack of bacterial sterility. From 1969 to 1976, 241 batches were tested by WHO reference laboratories outside India. Only 9 (3.7 percent) were substandard. The double monitoring system (using randomly selected vaccine batches) paralleled quality-control mechanisms adopted in production lines and factories throughout the world.

If procurement, production, and quality control of vaccine resembled a factory administration, in the management of delivery of

TABLE 1.	Availability of Freeze-Dried Smallpox Vaccine
in India, 1	961–62 to 1974–75, in Millions of Ampoules

Year	Received from USSR <sup>a</sup>	Indigenous Production <sup>b</sup>	Total
10/1 /2	1.40		1.62
1961-62	1.02	0.04	5 73
196263	5.69	0.04	6.88
196364	6.79	0.09	0.88
1964–65	6.80	0.48	7.28
196566	5.78	1.42	7.20
1966-67	5.99	1.41	7.40
1967_68	4.50	2.35	6.85
1968 69	4 55	3.57	8.12
1060 70	4.80	2.88	7.68
1909-70	1.80	2.56	4.38
1970-71	1.02	3 52	5.17
19/1-/2	1.00	E 94	7 96
1972–73	2.10	5.80	10.11
1973-74	1.30	8.81	10.11
1974-75	<u> </u>	9.52	9.42

<sup>a</sup>One ampoule of Russian vaccine consists of 20 doses.

<sup>b</sup>One ampoule of Indian vaccine was to consist of 15 doses, but it was often possible to get more than this number from each ampoule.

effective vaccination the major analogy is to marketing. Factors in delivery of vaccination included:

- 1. the technique of administration (rotary lancet, bifurcated needle, jet injector, single or double insertion);
- 2. administration of the vaccination (itinerant vaccinators, state-level vaccinators, watchguards, and supplementally hired WHO vaccinators); and
- 3. target population (initially British colonists in the cities, later all those living in an epidemic situation in the countryside, neonates, and finally, with increasingly sophisticated selective vaccination, the population at risk).

These factors have to be looked at in the context of the changing goals and strategies of the vaccination program in India. By the beginning of the intensified program, a more heat-stable, freeze-dried vaccine had been introduced, which made vaccine quality easier to maintain. Primary vaccination take-rates rose to virtually 100 percent, allowing more effective use of a single vaccination. The important change in management evaluation was a shift from monitoring the number of people vaccinated to monitoring the immunization status of the population, using vaccination scar surveys.

As the strategy shifted from mass vaccination to surveillance and containment there were concomitant changes in the way vaccine delivery was assessed. Initially, output was important: the number of people vaccinated. A refinement of this was monitoring the vaccination status of the population and later its immunity status. Instead of evaluating vaccine potency, delivery systems, and the method of vaccination independently, all were simultaneously assessed at the point of delivery by surveying vaccination take-rates in the field.

#### Communications

Managerial communications fall into two major and several minor categories. The major categories are internal communications within the operating system and external communications between the operating system and the rest of the world. In the case of international programs, the internal/external dichotomy becomes somewhat more complicated. But it is useful to think of communications in the smallpox program as internal or external, as outlined below.

Internal Communications:

- 1. education, training, and periodic review of personnel in the program
- 2. the management information system (MIS) of surveillance, disease reporting, data analysis, and financial and logistical information and appropriate responses
- 3. communication between the WHO smallpox unit and other WHO units
- 4. communication between NSEP and certain branches of the Indian government
- 5. communication between NSEP officials and the WHO smallpox unit (informal contact between members of the central command)

#### External Communications:

- 1. health education, publicity about the reward, news releases about program progress
- 2. official communication between WHO/government of India and bilateral donors.
- 3. official communication between the government of India and WHO

In the following section the three most important components of this communications system—staff training, the MIS, and health education—are examined.

Training. Rapid, effective communications were the key to monitoring the changing epidemiologic picture, keeping all levels of staff informed of progress, keeping optimism and morale high, and quickly learning of problems that needed to be dealt with. Training all levels of participants in the smallpox program was one of the key ingredients in its success. Epidemiologists, especially academic epidemiologists, often lack field experience in rural societies; carefully preparing them for a three-to-six-month field assignment made the difference between a good, productive experience and one beset with problems. In most of the training programs, the entire operational guide was read aloud, paragraph by paragraph. Two field exercises were administered. The first was a hypothetical smallpox outbreak. The trainee's task involved tracing the source of infection, finding all contacts, and carrying out thorough containment operations. An example may be helpful. True to real life, the source of the infection in the exercise was from an infectious disease hospital. Many academic epidemiologists expressed dismay that such an unlikely source of infection had been chosen for a field training exercise. Once they reached the field, however, they understood why poorly guarded smallpox isolation hospitals created notorious smallpox dissemination hospitals. In the second exercise, the trainee (who may have been a professor of epidemiology from the USSR, a retired Indian epidemiologist, or a young doctor from the United States) was to play the role of the chief of a state smallpox program. As the program officer of Amber province, he had to beware of importations of smallpox from Greenville, investigate sources of infection from Yellow, and

worry about inconsistent reporting from one of his own townships, Redstone.

Through these two teaching exercises, the field was brought to the classroom, but that was not enough. The entire training groupusually ten to fifteen people-then went out to the real field, to a nearby village, selected in advance because of a chickenpox outbreak. Since in India no vaccination was contraindicated at that time, the population in the chickenpox outbreak was then vaccinated or "contained" by the trainees, and the team moved to the PHC headquarters, examined records chronicling the history of smallpox in that PHC, and critically evaluated the surveillance system before moving back to New Delhi. The field trainer was often a paramedical assistant—a lower grade of staff in the Indian context, but someone who really knew village-level epidemiology. Training was practical, not theoretical; consistent from New Delhi throughout the chain of command; taught by a field worker, not an administrator; and for those unfamiliar with English, taught at a speed and in a language they could understand.

Once the epidemiologists were trained, it was their job to administer the same training exercises at divisional, district, and PHC levels. Each well-trained epidemiologist or program officer had a multiplier effect; conversely, if techniques were *not* properly learned and passed on, errors would be magnified. Monthly review meetings provided a means for updating the original training, for introducing new targets or new financial regulations, and for disseminating a stream of new innovations—market searches, watchguards, containment books, rumor registers, and so on—that developed out of the experience of the more progressive areas. This operational research was a continuous process, each epidemiologist adding his or her experience in a constant process of refining technique.

Management Information System (MIS). The management information system is the pulse of an organization. A strong and healthy MIS reflects a strong and healthy management. A weak MIS reflects a moribund program. In the smallpox eradication program, no one ever spoke of a management information system, but the system that was developed gradually over time was nonetheless particularly robust.

The MIS provides managers with the data necessary to make strategic decisions. To design an effective MIS, the manager has to

decide what information is needed, how it can be effectively and efficiently collected, and what will be done about it once it is tabulated. Some are elaborate, computer-based systems generating operating schedules, time motion efficiency studies, and daily logs of minutia; others are broad-based and general systems using the "important event" or "milestone" concept. In the smallpox program, no one actually sat down to design an MIS; rather, an attempt was made to determine what information was needed and to design a simple system to gather it.

Although many aspects of the NSEP grew and matured *quantitatively* once the intensified campaign began, the MIS was a *qualitative* leap forward, as shown in tables 2 and 3. Before 1973, managers of the NSEP did have a flow of information from the field to guide their decisions; although that information was not always reliable, it was sufficient to classify states as epidemic, endemic, or nonendemic and was enough to focus attention on the problems of case suppression.

The epidemiological portion of the MIS was, of course, surveillance. The experience with surveillance and containment in Brazil, Indonesia, and Nigeria showed the value of incoming information about smallpox for efficient resource allocation. Foege's report on the Nigeria experience defined surveillance to include three specific components: a system for data collection, a system for data analysis, and a system for response. The primary purpose of a disease surveillance system was "to determine all aspects of occurrence and spread of the disease in order to control that disease" (Foege 1976). This is the epidemiological portion of the MIS. In theory, data collection includes minimally necessary data from the mortality registration system, hospital and physician morbidity reports, laboratory reports, individual case investigations, population surveys, studies of animal reservoirs, and demographic data on the population under surveillance or at risk. Analysis involves determining the natural history of the disease, discovering trends and changes in trends, determining points of vulnerability, and determining the effects of intervention on the disease.

A system for response, to complete the surveillance arc, includes the health service's response to the collected, collated, and analyzed data. The information should be disseminated to two groups: those who need it for administrative program planning and decision making and those who are involved in continuing data collection. Since the reason for collecting, analyzing, and disseminating information on a

MIS: Surveillance	Before 1973	After 1973
WER (weekly epidemiological report) smallpox incidence report	х	х
CBHI (Central Bureau of Health Intelligence) weekly reports	Х	Х
of smallpox incidence	X	
who werks (weekly epidemiologic report) published from Geneva, showing district-by-district smallpox incidence	X	X
Target zero newsletter—chief, smallpox eradication unit, WHO Geneva, giving global overview and highlighted special lessons	х	Х
for smallpox staff		
SWER (special WER for search weeks) Epidemiologists' weekly reporting form (smallpox prevalence— number of infected villages, supplies and equipment requests, financial needs, problems encountered, innovations, and suggestions from experience)		X X
Search summaries (for each state the tabulations of the SWERs and results of each monthly progress review meeting—feedback for the state)		X
Newsletter—SEARO surveillance report giving status of smallpox in the region (feedback for the whole program)		X
Surveillance team monthly reports		X

# TABLE 2. Components of the Management Information System (MIS) in the Indian Smallpox Eradication Program

disease is to control that disease, appropriate action becomes the ultimate response goal and the final assessment of the earlier steps of the surveillance system. Under the intensified strategy in 1973, India was divided into three areas: smallpox-free states, nonepidemic states, and

TABLE 3.	Financial Comp	onents of the	Management	Information
System (N	MIS) in the Indian	Smallpox Era	adication Progr	am

MIS: Financial Data	Before 1973	After 1973
Imprest account summaries		х
Budget reviews from		Х
the WHO Budget and		
Finance Officer (BFO)		
—a "control" of funds		
actually disbursed against		
targets		
Financial control reports		Х
made by administrative		
officers in smallpox unit,		
expenditures versus authorizations		

endemic states. Areas in India were ranked for selective resource allocation based on an assessment of their risk or probability of being the focus for disease. Although one can stretch the meaning of surveillance and containment to incorporate assigning priority to areas, surveillance and containment as used in the program at that time meant surveillance to detect which villages had smallpox and containment of the detected outbreaks.

There were some broader implications of surveillance.

- 1. When there was an outbreak of smallpox in the Yadav milk deliverer's community, for example, the Yadav communities in adjacent villages were selectively searched. Extension of smallpox from community to community was traced by searching high-risk areas.
- 2. When the Indian program moved in 1975 to a defensive action protecting India from importations from Bangladesh, certain places were considered high-risk areas and given priority attention: border areas with Bangladesh; remote and inaccessible communities such as Ladakh, Sikkim, and the Andaman and Nicobar Islands and others. In addition, risk maps were made for each area and preference was given to searching certain areas again, based on risk assessment.

In fact, even the containment of an outbreak at a village is a subset of a more generic management principle—efficient resource allocation. In the case of village-level containment, this meant defining risk by geographic proximity to a case of smallpox. Tracing contacts (to the extreme of sending out 2,000 cables to warn of possible exposure in the case of Pawa Puri) and tracing sources of infection (even to the extent of having state surveillance teams cross state borders in hot pursuit of the source) were all logical extensions of the identification of risk areas and concentration of resources on people at greatest risk of getting smallpox.

While most of the MIS information about high-risk areas came from the weekly reports from PHC to state levels, additional information was provided by the weekly reports of the special epidemiologists. These reports, which covered the entire geographic area of India, included three major elements.

- 1. Smallpox prevalence. The reports identified active foci, risk factors, newly detected outbreaks, outbreaks that had been removed from the list of active foci because four to six weeks had passed without cases, and total pending outbreaks.
- 2. Assistance and supplies required. In each weekly report the epidemiologist in the endemic areas or the state program officers in nonepidemic areas placed their orders for proformae, recognition cards, posters, needles, vaccine, and so on.
- 3. Problems and suggested solutions. Each epidemiologist was asked to list potential problems and obstacles every week. The first news of strikes, drought, floods, population migrations, or a breakdown in regular communications often came from a scribbled note at the bottom of the weekly reporting form. More important, each reporter was asked to suggest ways of solving or avoiding problems.

These reporting forms were simple and regular, and they were read and responded to with great care. Because they were short and important they never got lost in in-trays no matter how hectic other things were that day in the office. Longer reports would have been set aside.

To simplify the system, the epidemiologist's weekly report was in the shape of an aerogram—"inland letter," as it was called in India—similar to a large postal card. Since little effort was required and no long narrative or explanation was asked for, a reasonable, quantifiable target was set: to have every epidemiologist or program officer complete this form each Saturday. This target was progressive. As the program matured, more pertinent controls were built in, such as listing the names of outbreaks with no known source of infection, the names of villages with cases more than twenty-one days after detection, and so on.

This stable, simple reporting system augmented the formal weekly reporting system (shown in fig. 4), which reported the number of new cases detected in each PHC, district, and state. It was another example of the creation of a parallel smallpox system. Although the new reporting system was enhanced and supported, only smallpox data came through it; it was this weekly epidemiologists' report—a separate, independent source of information—that both confirmed the epidemiological status of the area and gave needed details about management requirements and potential bottlenecks.

The epidemiologists' weekly reports were read simultaneously by the medical officers in SEARO and the smallpox office in the Ministry of Health (initially, duplicate copies were sent by mail or telegram; later, by telephone or special messenger to both addresses); a third copy was sent to state headquarters in the endemic states. Supply needs were then passed to the WHO administrative officers, who attended to requests from the field (often, "Please wire Rs. 3,000 immediately.").

Requests from the field were accorded high priority, and a twenty-four-hour turnaround was not uncommon. The epidemiologists in the field initially asked for supplies well in advance in order to stockpile such things as needles, fearing long delays, but rapid and dependable responses from SEARO minimized the need for such insurance orders for additional unneeded supplies and thus reduced hoarding and pipeline wastefulness.

On this single form, several managerial systems were combined: the MIS, epidemiological surveillance system, logistics controls, and some financial reporting. This was the irreducible minimum information needed in Delhi to change tactics and even strategy of the program. It is an important lesson for other programs.

*Health Education.* The health education component of the smallpox program needed to deliver at least four messages to the villages: (1) smallpox was a disease that should be reported; (2) smallpox should be reported to the PHC or health worker; (3) there was a reward; and (4) when there was an outbreak, people who are at risk of smallpox should be vaccinated.

Before 1973, health education consisted mostly of large wall posters, with occasional films about the disease. During the intensified campaign, all available media were used: handbills were printed, advertising the reward in many languages; large posters were continuously printed; radio messages were prepared (occasionally with a tape-recorded announcement by a local leader urging reporting); and signs were painted on the back of rickshas, or even, when absolutely necessary, leaflets were airdropped by airplanes and helicopters. However, word of mouth was the most effective advertisement, since 80 percent of the country is illiterate. Smallpox workers painted slogans on the walls of ten houses in each village. The slogans, written with wet geroo, a saffron-colored, chalklike compound, lasted for months. More important, even if villagers could not read the slogans, the children inquired about them and passed the word. This word-of-mouth advertising was formalized after Operation Smallpox Zero began, when new job descriptions for search workers included informing one person in each house about the smallpox program and the need to report any case of rash with fever.

The health education message had changed over time. Viewed chronologically, the messages reflected the gradual evolution of smallpox strategy: first came "take vaccination" or "worship the Devi and take vaccination too"; second, "report smallpox"; third, "report smallpox, there is a reward of (Rs. 25; 50; 100; 500; 1,000— the reward was gradually increased as the numbers of outbreaks decreased) to the person who first<sup>11</sup> reports a case of smallpox"; and fourth, "report any case of fever with rash" and "report to the PHC."

Assessment techniques (to be discussed later) were aimed at checking the performance of the health educators who were in effect advertising the current message or slogan.

#### Financial Management

In most WHO programs, the financial officer is responsible for one function: disbursing and accounting for funds. This involves budgeting; actually disbursing cash; assessing accuracy of records; auditing; and calculating value received. The financial function usually does not involve generating funds. The smallpox unit deviated substantially from the usual WHO program in that the staff to a large extent generated funds from outside the regular budget of WHO. Funds were sought for the WHO Special Voluntary Fund for Health Promotion and from domestic sources within India. Fund-raising activities were remarkably successful. Without the extra funds brought in by WHO fund raising, it is doubtful that eradication would have been achieved, certainly not as rapidly as it was.

Approaches were made to several governments, to private philanthropists, to Indian corporations, and to other international agencies. Although WHO itself showed some resistance to fundraising efforts by project staff in the beginning, that approach has been institutionalized to some extent. Malaria programs in India have approached SIDA for funding along more or less the same lines, and the prevention of blindness program, the diarrhea control program, and immunization programs increasingly rely on extrabudgetary sources. Increasingly, bilateral aid funds are being channeled through WHO, increasing the position of the organization and decreasing the government's difficulties with coordinating many bilateral aid agencies.

Just as important as the international funds were the donated domestic funds. The rupee equivalent of \$500,000 given by Tatas was worth much more than the dollar amount because of the management skills that were donated along with it. Tata accountants calculated, for example, that it was cost-effective to pay for a medical officer and team to stay overnight in infected villages rather than paying for gasoline for a second round trip. Night vaccinations were an absolute necessity in contacting many working-age men, but medical officers had refused to stay overnight for want of accommodations. Some of the money saved on gasoline could be spent on support services to make the most economical use of each village visit. Moreover, although it was not a large dollar amount, Indian philanthropy brought many externalities that are not associated with foreign aid. In obtaining the domestic financial contributions of the Lions, Rotary, Tatas, TISCO, TELCO, and others, the WHO–government of India team also carried out the important function of building community support.

On the funds disbursement side, there were many innovations. As usual, a detailed operating budget was prepared by the central team. The accounting system (the financial part of the MIS) made it possible to compare actual and budgeted expenditures. Perhaps even more important was the flexible method by which funds were used in the field. The use of imprest accounts permitted an epidemiologist to carry large cash advances into the field for use in the program according to established guidelines (for example, paying per diems for locally recruited staff, paying for gasoline, hiring watchguards in the village where there was an outbreak, paying for printing of reward publicity, and so on) and to account for the specific authorized uses of these cash advances later. This was a very unusual innovation in the WHO financial accounting system and in fact created substantial initial controversy in the organization. But without the readily available cash, it would have been impossible, for example, to pay for gasoline for jeep travel.

The use of imprest accounts in the field with postexpenditure justification of disbursements replaced the cumbersome process of seeking approval for an expenditure weeks or months before the funds were disbursed. Dr. P. Deish, the government's former commissioner of health, credited the flexible financial policies of WHO as one of the most needed and valuable characteristics of the program.

For the campaign not only enough finances were required but there was need for tremendous flexibility in incurring expenditure. Provision was made to spend money on petrol, oil and lubricants, maintenance of vehicles, publicity, employment of workers and for giving reward to those reporting smallpox. Check and control limits for these were laid down. For undertaking effective containment of detected outbreaks, there was no limit. The objective was to eliminate the focus as quickly as possible. During the period July 1973 to December 1975, the Government of India spent Rs 102 million (about \$12.5 million U.S. dollars), the State Governments spent another Rs 94 million (about \$12 million U.S. dollars) and during the same period the WHO's contribution was Rs 67 million (about \$8 million U.S. dollars). WHO's contribution was about 20 percent of the total. (SIDA's contribution about Rs 60 million—\$7.5 million U.S. dollars). Understanding

WHO financial controllers found ways of expediting financial matters and delegating considerable financial powers to workers in the periphery. (Deish 1978, 10)

Budgeting, usually such an important part of standard financial function, was of less importance in the smallpox program, simply because financial forecasting was completely dependent on the epidemiological situation. More smallpox meant greater resource requirements; financial forecasting thus became dependent on epidemiological forecasting.

#### Management Controls

The control system is intended to assure the manager that operations are proceeding according to the implementation design (Austin 1979). There were both financial and operating controls, and they were either preventive or curative. In the case of smallpox eradication, there is overlap between management controls and epidemiologic assessment. For simplicity, epidemiologic assessment is considered separately below under the section entitled "Evaluation."

In the early days of the NSEP, prior to the intensified campaign, all of the financial controls were handled through the government of India. NSEP funds were established as a part of the routine five-year planning exercise; thus the preventive and curative financial controls were those of the government of India. A five-year budget established how much money could be spent; strict financial guidelines prevented over-use of budgeted funds—in fact, in most of those years the NSEP had been unable to use all the funds budgeted for it.

In the operating (logistic) area, the major issue was vaccine. Until late in the campaign, vaccine institutes were so poorly organized that some states were overstocked with vaccine and others poorly stocked. As for the epidemiologic control function, this rested with the CBHI. The routine weekly WERs, which were to have been sent from PHC to district to state to the CBHI, were poorly organized. It was not unusual for states such as Bihar to be several months late in submitting the district reports that had been accumulating at the state capital. A control system would consider the delinquent or absent reports to be a warning and contact the delinquent reporting unit to demand updated reports. In 1972, WHO urged the establishment of a weekly "nil" (no cases) report from those PHCs that claimed to have no smallpox. This was the beginning of the establishment of a control function in the epidemiologic system. Previously, the absence of any report could have been understood as indicating either the absence of smallpox or the absence of the reporter. Using "nil" reports established a control function: the absence of a nil report could only mean a laggard reporting system.

After the 1973 intensified campaign began, the program rapidly expanded and material systematic control procedures became more critical (Austin 1979). Rapid growth made direct supervision of all staff impractical. A system of supervision from the primary search worker up to the state program officer was required. This control system, which developed slowly, by a process of trial and error, is shown in table 4.

At the most peripheral level, the presearch meetings held at PHCs established a plan for each of the approximately twenty searches carried out in the endemic areas. Each borrowed supervisor (malaria supervisor, sanitary inspector, family-planning supervisor, and so on) supervised three or four search workers. With an average of one hundred villages per PHC and ten to twenty PHC staff, each worker had an average of one village or one urban *mohalla* to search in one day. A *mohalla* is a city area about the size of a village of 400 to 1,000 people. With a schedule (PHC Form 1) and a daily reporting performa (PHC Form 2), the worker went from house to house in his assigned villages. In the early stages of the intensified campaign, the supervisor also visited about one or two villages a day and was thus able to physically assess the work done in approximately one-third of all villages.

Later, as the program neared its conclusion, these supervisors were joined by PHC medical officers who left their other duties at the PHC to visit villages and make an independent evaluation of some rash-with-fever cases. A triage system was established. The sensitivity of the surveillance system at the most peripheral level (the percentage of actual smallpox cases detected) was increased with each successive search, while the specificity (the percentage of negative cases correctly identified as negative cases) was decreased with each successive search. In addition to their supervisory functions, higher-level staff, from inspectors to medical officers, were

TABLE 4.	Epidemiologic	Control, Supervision,	and Assessment
in Typical	Primary Health	Center (PHC) or Block	ζ.

Number of villages in block	100 98	
search worker during each search <sup>a</sup> Number of villages supervised by primary	33	
supervisor Number of villages supervised or	15	
assessed by PHC medical officer Number of villages assessed by district	2	
officers Number of villages assessed by	2	
other (outside) assessment workers		

<sup>a</sup>An average of 2% of villages were missed in each search; rotation of the staff and repeat visits to missed villages ensured uniform complete coverage.

asked to check the diagnosis of cases. The increasing sensitivity and decreasing specificity resulted in the detection of hundreds of thousands of nonsmallpox rash-with-fever cases, all of which required verification.

There was another management control at the PHC level. The PHC-level search worker had to obtain the signature or thumb print of the village head man for every village he was to visit, and had to write the reward slogan on ten houses. In the early days of the program, when supervision was less sophisticated, the first-level supervisor simply checked to be sure that the village head man's signature or thumb print was accurate and counted the reward slogans in the village.

The financial controls were established through guidelines authorizing the amount of money that could be spent for gasoline, for hiring special search workers, for reward publicity, and for the rewards themselves. The imprest account system allowed the epidemiologists to make on-the-spot distributions of cash, making it unnecessary for repeat visits to headquarters to get more funds. It was not possible to require a person in the field to submit a purchase order to someone in the finance department for approval. Rather, the financial department made periodic comparison of actual and budgeted expenditures. When actual expenditures exceeded budgeted allocations, the finance officer (who traveled from SEARO in New Delhi to the state-level monthly progress review meetings) could make decisions and take actions to handle excess expenditures. These deviations from the budget were, in turn, a critical input into future financial decision making. Comparing budgeted to actual expenses was important in understanding the interrelatedness of financial control and operating control. In the smallpox eradication program, giving financial control to the operating level staff—the special epidemiologists weakened preventive control over fund disbursement, but the trade-off—a decentralized ability to respond to a rapidly changing environment and epidemiological situation—facilitated the program goals.

#### Research

Research carried out in India was mostly of the operational variety: data were gathered because they were needed to plan, implement, or evaluate the program, not for the sake of fundamental science. Research in India was problem-oriented, both to ensure research relevance and to answer immediate questions for the program. For example, in 1975, when India was nearing zero incidence but Bangladesh continued to have large epidemics, there was grave concern about Calcutta. Especially problematic was Calcutta's floating population, a constantly shifting mass of poverty-stricken migrants, rumored to number more than 100,000, who were thought to have come from Bangladesh. A research project carried out on the streets of Calcutta showed that (1) the number of pavement dwellers was probably closer to 10,000 than 100,000; (2) they were a stable population who had lived on the pavements of Calcutta for decades; and (3) their ties were mostly to Bihar, which was now smallpox-free, rather than to Bangladesh. This finding reassured the smallpox staff, but more important, it allowed project management to release resources allocated to surveillance of the incorrectly presumed highrisk pavement dwellers and direct them where they were really needed, at border surveillance posts. Another example was the research effort aimed at determining the extent to which market surveillance could replace house-to-house searches. Research projects were carried out in several areas of Bihar and Madhya Pradesh, simultaneously comparing the surveillance reports gathered by searchers at the weekly markets and in the more elaborate house-tohouse searches. It was shown that although market searches could not replace house-to-house searches, they were effective supplements, providing a useful way of assessing the house-to-house searches.

Early in the program, studies in Tamil Nadu showed that neonatal vaccination was effective and produced few harmful sequelae; later field studies showed that a single insertion of smallpox vaccination was as effective as the two, four, or even six insertions of vaccine used earlier. Field studies with the bifurcated needle proved its superiority to the rotary lancet, as earlier field trials of freeze-dried vaccine had shown its superiority over liquid lymph.

A pilot project in several districts of Uttar Pradesh in early 1973 expanded and refined the Gulbarga experience of house-tohouse search, using staff from many different programs; this experiment was instrumental in providing experience for the operational guide drawn up for the autumn, 1973, intensified campaign. Analysis of data from outbreaks that had failed to meet established targets for either early detection or prompt containment showed that secondary or satellite outbreaks were commonly within a tenmile (sixteen kilometer) range of the primary outbreak. This led to the establishment of a safe zone, wherein all houses within sixteen kilometers were searched (early in the program, only once; later, twice) to be sure satellite outbreaks had not escaped the surveillance system. Operational research also pinpointed the need for watchguards, for closing disease-spreading infectious disease hospitals, and for careful attention to finding all smallpox contacts. As outbreaks decreased, each newly detected one became more important, containment became more sophisticated, and more resources could be devoted to each of them. At each stage of program refinement, operational research identified the next step to be taken to stop the spread of smallpox.

Gathering demographic statistics and studying trends of smallpox over time were an integral part of the epidemiology and of project-planning implementation and evaluation. Perhaps, however, it was in the field of evaluation that research was most appropriate. Much of the research data gathered later in the smallpox program were compiled explicitly to provide the international certification commission with the information they needed to evaluate the outcome of the program and declare smallpox eradicated from India.

There were many research questions of interest that were never investigated because the program went forward with the single purpose of eradication. Smallpox disappeared from India so rapidly that many of its secrets will always remain hidden. When research efforts are initiated explicitly to alleviate a problem rather than for research investigation purposes, many interesting questions will remain unanswered. But the important problem will be solved: for example, there is no smallpox left in India.

#### Evaluation

Three kinds of program evaluation are important to our case study: process, outcome, and economic. Most program evaluations focus on outcome evaluation, measuring the extent to which a program succeeds in reaching its final goals, such as landing on the moon or eradicating smallpox. Process evaluation, on the other hand, involves analyzing individual program components. (Program evaluators also refer to these techniques as "formative evaluation" [studying how to make a program work better] and "summative" evaluation [studying how well a program works] [Russi and Williams 1972].) It is apt to be considered an internal matter, part of administrative monitoring. In the smallpox program this process evaluation was called assessment, and outcome evaluation was known as "certification of eradication." Certification was itself the major program evaluation in the sense of evaluating whether the program accomplished its goals. Economic evaluation, which consists of analyzing program costs and benefits and cost-effectiveness, will be treated last in this section.

#### Process Evaluation or Assessment

Management has been metaphorically compared to a long journey toward a set goal; strategies provide the plan, and specific operating tasks are the day-to-day travel instructions. Landmarks, milestones, and warning flags are needed to prevent deviations from the plan or to alert the manager to potential deviations. These warning flags and milestones were provided by assessment.

Assessment was accomplished by combining process evaluation and management control. For example, in spreading the word about the reward, the program was in effect advertising it. In a commercial marketing operation, in order to evaluate the process of reaching potential customers a random probability sample of different areas of interest would be drawn, and the percentage of those knowing about the item being advertised (the reward) would be calculated. In addition, an effort would be made to find out how they learned about the reward, and the media habits of those who knew and did not know about the reward would be compared. In fact, far more attention would be paid to the 15 to 40 percent who did not know about the product, and their media habits and demographic characteristics, than to those who did know about it. An attempt would be made to reach them with publicity. In the smallpox program, instead of random samples, which would have been far better statistically for assessing the public's knowledge of the reward, skewed samples were drawn, placing heavier emphasis on areas where the assessment system had produced warning flags. Areas with known weaknesses in surveillance were assessed more frequently. Although this led to lower assessments of knowledge of the reward (or other assessment parameters, such as the percent of those who had seen the recognition card, the percent who had actually seen a search worker, and so on) than would have been obtained from random population-based data, the smallpox surveillance system was only as strong as its weakest link; preferential assessment of the weakest link was a good supervision strategy in this case.

The assessment data that was gathered became increasingly more elaborate as searching methods were refined and the absence of active smallpox permitted containment resources to be diverted to the search operations. During the two-year period of active surveillance that followed the last case of smallpox, for example, several hundred thousand rash-with-fever cases were recorded in PHC-level rumor registers. At the end of each search, a PHC or municipality search summary report was added (a new form, PHC search summary Form 3). The number of search workers from each of the various programs was recorded, and each case of rash with fever (chickenpox, measles, or other disease) was recorded. In areas with no smallpox, searchers concentrated on the population at highest risk. Results were assessed at the PHC level by the PHC medical officer, who was instructed to personally assess one village and one *mohalla* assigned to each worker. Since the average PHC had nearly fifteen workers, this meant that in the final searches there were two levels of supervision at the PHC level: 1 in every 3 villages was visited by the supervisor, and it was intended that 1 in every 7 would be assessed by the PHC medical officer. With an average of 100 villages per PHC, this meant that 100 were visited by a search worker, 33 were visited in addition by a supervisor, and 15 more were visited in addition by the medical officer (see table 4).

This hierarchy of supervision continued above the PHC level. The district medical officer was instructed to assess the work in the PHCs. At least 5 schools and 10 villages per PHC (chosen from various parts of the PHC, with special attention to including places that were difficult to reach) were to be assessed, and approximately 100 or 200 people in each block were to be questioned at random about their knowledge of the reward and whether they had seen a search worker during the search period. Each special epidemiologist was asked to personally assess 75 villages or *mohallas*, 25 schools, and 10 markets. State surveillance teams, district mobile squads, and market search teams were supposed to assess 100 villages and *mohallas*, 30 schools, and 10 markets. District-level medical officers were to assess at least 2 villages or urban areas, 1 school, and 1 market in each PHC in their district.

This hierarchical assessment and supervision system provided significant milestones. When aggregated, the assessment statistics from May, 1975, and July, 1975, showed the results of this wellorganized system. Over half a million people were surveyed (tables 5 and 6) to assess the quality of surveillance. The assessment system, in a sense, became a search in itself.

This assessment guided program managers in deciding where to increase emphasis. If less than 95 percent of all the villages assessed in a block had been searched, the search was continued or repeated until all villages had been searched. Depending on how great the risk of smallpox was thought to be in a poorly searched area, the re-search was either "punitive" or carried out because of a genuine program need. In areas thought to be smallpox-free, a punitive re-search was carried out, making the same staff devote an extra week to the task. In poorly searched, high-risk areas, the re-search was done by diverting staff from other blocks that had been well searched or by hiring ad hoc search workers from the community.

Concurrent assessments started during the search itself. The

TABLE 5.	General Smallpox Knowledge in the
Population	at Large, June and July, 1975, in Percentage

State	Individuals Interviewed	Knew about Latest (July) Search	Knew about Rewardª	Had Seen Recognition Card	Knew Where to Report Suspected Cases
<u>_</u>			(0%	(FØ	<u> </u>
Bihar	227,182	72%	63%	63%	00 %
Uttar Pradesh	23.252	60	53	53	44
West Bongal	102 808	64	64.4	69	47.9
west bengai	142,000	70	72	74	65.8
Assam	142,047	79	01	70	70
Tripura <sup>b</sup>	12,751	88	81	70	70
Total	508,042	73	66.7	66.2	59.5
(Target)		(67)	(67)	(50)	(50)

<sup>a</sup>In districts that had only recently introduced the Rs. 1,000 reward, assessment results reflect general knowledge of either the Rs. 100 reward or the Rs. 1,000 reward.

<sup>b</sup>Assam and Tripura figures are for June search; other states are from July search.

effectiveness of the search was determined and expressed in terms of the percentage of households where anyone had seen a search worker come to their house during the search, had seen the recognition card, knew about the reward for reporting smallpox cases, and knew where to report. When risk maps of each district were prepared, the high-risk areas identified were given special emphasis in the assessment.

# Outcome Evaluation or Certification of Eradication

The most important step in program evaluation is to identify and define measurable goals with which outcome achievements may be compared. Without a quantifiable goal, a target to aim for, progress is very difficult to measure. This is true for measuring the final outcome of a program as well as for monitoring each step along the way toward the final goal.

In the long history of attempts to prevent or conquer smallpox in India, three general goals developed in succession: (1) individual prophylaxis, (2) disease control, and (3) disease eradication. These goals were not always pursued in the context of government programs. From time immemorial until the late 1800s, when the Bengal Vaccination Act mandated smallpox vaccination, smallpox prophylaxis was an individual choice among options, with a personal goal of individual protection. Whether the method was to propitiate a

TABLE 6.	Results of	f Active Se	arches in Higl	n-Risk Area	s, June and J	uly, 1975		
State	Total Villages	Villages Assessed	Percentage of Villages	Percentage Searched	Chickenpox Outbreaks	Percentage of Villages with Chickenpox	Total Chickenpox Cases	Chickenpox Deaths
Bihar	82,000	10,311	12.5%	92%	554	0.7%	1,078	0
Uttar Pradesh <sup>a</sup>	143,000	7,361	5.1	90	п.а.	n.a.	n.a.	n.a.
West Bengal	48,000	3,260	6.8	92	1,527	3.0	3,164	0
Assam <sup>b</sup>	22,254	8,032	36.0	66	1,808	8.1	4,650	0
Meghalaya <sup>b</sup>	4,515	п.а.	n.a.	п.а.	30	0.7	133	0
Tripura <sup>b</sup>	4,159	504	12.0	97	230	5.5	507	1
Total	303,928	30,488	10.0%	94	4,149	1.4	9,532	1
(Target)		30,393	10.0	(95)				

TABLE 6.

search during month of July. special s σ щ Uttar Pradesh represent only those districts searched eastern wing are for June search. wing for <sup>a</sup>Figures 1 <sup>b</sup>Figures 1

goddess, apply herbs, or follow special diets, efforts were directed more toward preventive than curative goals, though a few curative measures—such as donkey's milk and *neem*—were sometimes used.

With the arrival of vaccine in India in 1802, a form of protection more effective than herbs and safer than variolation became available. Nevertheless the concept of smallpox as a public health problem and government-organized programs to reduce morbidity and mortality among the general public did not develop until much later. Even vaccination programs set up in Bombay in the 1800s and later in the United Provinces (now Uttar Pradesh) were established mainly to encourage individual protection for as many people as possible. It was not until the Bengal Vaccination Act that the goal of smallpox activities of India shifted from individual prophylaxis to a broader public health goal of disease control.

In 1959, almost eighty years later, the expert committee established the target of eradication, with its plan for an NSEP. This same committee had had a difficult time evaluating earlier smallpox activities because of the lack of quantifiable targets for smallpox control. After subsequent agreement between WHO and the government of India, the goal of smallpox eradication was confirmed, and the NSEP was established. Program effectiveness would be judged by the absolute, quantifiable target of eradication: zero smallpox.

No national statistics exist on the number of people who were either variolated or vaccinated before 1962. Even after individual protection from smallpox became a government function, at least in some parts of India, there was no possibility of measuring progress until either output (number of vaccinations performed) or outcome (incidence of smallpox) was recorded. Further, the output statistics were inadequate measurements of protection, because available vaccine was often too weak to provide a sufficient level of immunity. The NICD program evaluation in 1963 introduced a new measurement of effectiveness—the percentage of the population adequately immunized (percent vaccinated multiplied by vaccine efficacy). Although this was an improved and a quantifiable target, it was still an output measurement. The outcome—smallpox incidence—was not being monitored.

When the NSEP was established, the goal ostensibly switched from individual protection to eradication, with targets of 80 percent

and later 100 percent vaccination coverage. The government was generally pleased with the increasing amount of reported vaccination coverage, but these targets were never reached, nor did smallpox incidence decrease appreciably (much less reach eradication).

When the joint WHO–government of India Plan of Operations of 1970 recommitted India to the goal of eradication, the reported incidence of smallpox was decreasing. But the measurement tool the reporting system—was not accurate. The apparent effectiveness of the program was an illusion that was shattered when increasingly accurate measurement uncovered a high number of unreported cases, raising reported smallpox cases to seemingly epidemic levels. Before 1970, the NSEP was neither making effective progress toward the final goal of eradication nor even adequately defining the problem so that measurable targets could be set.

In 1977, when the International Commission to certify smallpox eradication in India convened (see the section in chapter 1 entitled "The Certification of Eradication, 1977"), the success of the program was measurable: it had met a quantifiable goal, the attainment of zero incidence of smallpox in India.

The certification of smallpox eradication in India was the program evaluation of the intensified campaign (1973–75). In 1977, after a two-year surveillance period failed to detect a single case of smallpox, the certification procedure (Ministry of Health and Family Planning 1975) confirmed that the measurement of program outcome (zero incidence) met the prescribed goals (eradication). In that sense, the program was 100 percent effective. Two years later, in 1979, a global commission certified the entire world free of smallpox, further attesting to program effectiveness in India (Global Commission for the Certification of Smallpox Eradication 1979).

#### Economic Evaluation<sup>12</sup>

An economic analysis of the costs and benefits of eradicating smallpox is an important element of the broader analysis of the case history. Many of the things that worked for the eradication program resulted from investments predicated on confidence in an unusually profitable outcome—smallpox eradication. In order to determine which of the strategies and tactics of the eradication program may be economically feasible for other disease control programs, some understanding of economic concepts and terms is useful.<sup>13</sup>
First, it is important to keep in mind that the costs and benefits referred to in this analysis are those of program results rather than of the disease per se and that a benefit is a negative or averted cost, while a cost is a negative or forgone benefit. For example, smallpox treatment costs saved by preventing disease would be considered a benefit, while the loss of productivity due to vaccination complications would be a program cost. As a further example, high smallpox mortality rates mean many premature deaths, in the sense that average life expectancies are not fulfilled. Although the full human tragedies of these deaths cannot be measured, the resulting loss of productivity to society can be, and it provides a way of analyzing the costs and benefits of health intervention programs. If loss of productivity from disease mortality is avoided because of a successful program, one of the benefits of the program can be measured by the resulting increase in productivity.<sup>14</sup>

The social welfare, or social efficiency, of smallpox eradication may be seen from two perspectives: the costs and benefits of eradication itself and the costs and benefits of components of the eradication program. The following section will discuss economic issues inherent in the debate over control versus eradication, and the final section in this discussion will look more closely at the efficiency of the strategies and tactics that were developed to reach the intended goal.

## Costs and Benefits of Smallpox Eradication

Before the creation of the NSEP, the goal of smallpox activities in India was to control rather than to eradicate the disease. Control and eradication differ in assumptions about final outcome, in their needs for resource allocations, and in the ways in which costs and benefits accruing to each may be perceived.

Disease control is the more common approach to battling any disease. For some diseases (such as cataracts or cancer), there is no choice between eradication and control, because we do not have the technical or administrative means for eradication. In other instances, as for malaria, the control option is chosen because the economic costs of pursuing eradication are very high.

Control programs generally involve smaller start-up costs than eradication programs, especially since available funds can be allocated annually into a control program to produce relatively proportionate results, which can be improved (within the limits of technical feasibility) as more resources are allocated to the program. However, disease control programs require continuing allocations of resources because the level of program effectiveness must be maintained in order to prevent an increase in the disease incidence. Thus, ongoing program costs must be subtracted from benefits as they accrue in the future. In fact, future benefits of the program are largely dependent on the continued payment of recurrent costs; moreover, where population growth rates are high, increased allocations of resources will be needed in order to maintain the same level of program effectiveness.

For a disease eradication program, costs of the program stop when the targeted disease is completely eliminated, while benefits may continue to accrue indefinitely in terms of economic savings and human suffering prevented. Although eradication involves higher initial investments—both in terms of direct costs and in the diversion of scarce managerial talent and resources from other programs into the eradication effort—the future benefits accruing from successful eradication will eventually outweigh the higher start-up and operational costs.

A key determinant in the economic preferability of the control or the eradication option, then, is the time frame within which the decision maker wants to have some measure of return that maximizes the investment of currently available resources. Because limited resources must be distributed across a multitude of society's needs, the political time line for the evaluation of social programs is often rather short.

For example, a public health decision maker may have \$9 million available for all health programs over three years. If it takes, hypothetically, \$9 million to eradicate smallpox in three years, then the decision maker can (1) invest \$3 million a year into a program to eradicate smallpox or (2) invest \$1 million a year in a control program designed to vaccinate high-risk groups and reduce the incidence of smallpox to levels deemed socially acceptable. If he chooses the three-year smallpox control option, \$2 million a year will still be left to put into other disease control measures—for example, an integrated primary health care service that might concentrate on a program for control of diarrhea (or another major health problem that causes loss of life and productivity). However, maintaining this

level of combined disease control will require continuing yearly investments of \$1 million for the smallpox control, plus \$2 million for the diarrhea control (assuming stable prices for vaccine and oral dehydration and stable secular trends), over an indefinite amount of time.

On the other hand, what if the entire \$9 million is invested in a three-year program that results in the eradication of smallpox? After the \$9 million investment, there would be no need to maintain a vaccination program, and thus in all future years the entire health program budget—say it continues at the rate of \$3 million a year may be put toward other disease control programs. In nine years, it may be argued, the eradication program would pay for itself.

 $\frac{\$9,000,000 \text{ total costs}}{\$1,000,000/\text{year}} = 9 \text{ years to recoup costs}$ 

However, this assessment is not completely accurate, since other benefits were forgone when the decision maker no longer had \$2 million for each of the three years to put into diarrhea prevention measures. Over the three years, he has lost the benefits of \$6 million that might have been invested in a diarrhea program. As a result the health system may have borne what economists call opportunity costs in the form of preventable deaths and suffering caused by diarrhea, a net increase in hospital and/or other health care costs, a net increase in work days lost as a result of diarrhea, and so on.

Another consideration is that money that is put into a disease eradication effort might instead be put into goods for immediate consumption. People put more value on current consumption of food and other needs than on future consumption. This is especially true in less affluent societies or in times of scarcity. This reduction in the value of benefits (and costs) over time is called "discounting."<sup>15</sup>

For these reasons it may, in fact, take longer than the hypothetical nine years to reap the full economic benefits of the eradication of the disease. Health planners, serving a public that is interested in seeing immediate short-term results, are often unwilling to promote a policy that will not generate net economic benefits for many years. As a result, disease control programs may appear more attractive than disease eradication programs, even though the latter may have greater long-term benefits. The Indian central government health budget allocated an average of Rs. 38.3 million (\$4.5 million) annually to smallpox from 1973 to 1977 (Basu 1974). With that budget constraint, the alternatives that achieved the most vaccination output would probably have been control programs. With input from the states and increased input from WHO, total expenditure equalled approximately Rs. 100.3 million (\$12.4 million) per year from 1973 to 1977 for the smallpox eradication program.

There was a threshold point at which smallpox eradication became economically feasible and preferable.<sup>16</sup> The higher start-up costs of a smallpox eradication program are due in part to the increased opportunity costs of shifting (even for very short times) health workers already committed to malaria and family-planning programs into participation in intensified activities such as the weeklong active searches. Also included in higher initial costs are opportunity costs of diverting scarce high-level health managerial skill to smallpox. When the government of India assigned its top epidemiologist managers to the smallpox eradication program, other programs lost their services for a time.

Inherent in the measurement of opportunity costs is the amount of marginal benefit derived from placing additional funds into a program to promote elimination of the disease rather than reduction of its harmful sequelae. In the case of a disease that has a low morbidity rate or few harmful sequelae, an eradication program may not be justified, even if such a goal is possible, due to the limited ultimate benefits that may be derived from relatively large inputs of resources. Eradication of staphylococcus, for example, falls into this category.

Smallpox was an attractive candidate for eradication, since an effective vaccine was available and the disease had only human-tohuman transmission. But the full benefits of smallpox eradication in each country required global eradication to remove threats of importations. If one country's program failed, the threat of continued outbreaks would negate many of the benefits that would result from global eradication. The eradication of smallpox in India provided many international benefits that gave donor nations and the global community incentives to promote the eradication, rather than the control, of smallpox in India and the other endemic countries.

The costs and benefits of carrying out a disease eradication

effort in a particular country may therefore be seen from three different perspectives: (1) that of the individual country, (2) that of donor nations, and (3) that of the global community.

## Costs and Benefits for India

*Costs.* The costs to India for the eradication program included direct program costs, indirect medical costs and lost productivity resulting from vaccination complications, and opportunity costs of applying valuable health resources to smallpox eradication rather than to other health or social programs. Included in direct program costs were: vaccine production and distribution; provision of health workers to perform vaccinations and surveillance; provision of mobile containment teams; publicity and rewards; administrative overhead; airfare; jeeps; spare parts; gasoline; and consultants.

From 1970 through 1973, the Indian central government expenditures for direct costs were Rs. 96.5 million (\$12,781,000, or \$3,195,250 per year). From 1974 to 1977, the country increased its expenditures to Rs. 162.8 million (\$19,026,000, or \$4,756,500 per year). States provided even more program funds—Rs. 180 million (\$22.5 million) during each of the two periods.<sup>17</sup>

Although direct costs may be fairly easily ascertained from the program archives, indirect costs are much more difficult to estimate.<sup>18</sup> They include losses to the economy as a result of program implementation. For instance, a worker in the field may miss two days of harvesting rice because his arm is swollen from a vaccination. The value of each day of harvest is worth Rs. 10 on the market, resulting in a loss of Rs. 20 of productivity because of "absenteeism" from the fields. A WHO estimate of indirect smallpox program costs to India calculates indirect costs of the program from 1970 through 1977 as Rs. 36 million (\$4.8 million) per year, or roughly half of the direct program costs.<sup>19</sup>

Besides direct and indirect program costs, however, the application of Indian health resources to the smallpox campaign resulted in important opportunity costs, since benefits that would have accrued to alternative uses of available resources were foregone. For instance, personnel were borrowed in large quantities from other programs such as malaria, family planning, and leprosy in order to assist smallpox staff during active searches and during the peak of containment periods. Approximately 100,000 health workers<sup>20</sup> were taken from other health programs for a total of nearly 10 million work days to perform searches, which, at Rs. 75 per week, meant that approximately Rs. 150 million (\$20 million) were diverted from other programs to smallpox. For the period 1973–76, this totaled about \$4 million per year. As a result of these reduced resources, other public health programs may have functioned less effectively, and, for example, may have failed to prevent cases of malaria or provide services to leprosy patients. These costs are included in the opportunity costs shown in table 7.

*Benefits.* The economic benefits resulting from smallpox eradication include, of course, the treatment costs of cases averted after the disease had been eliminated. They also include the increase in productivity resulting from a reduced death rate and from illnesses averted. These are often called human capital benefits and commonly include preservation of wages and productivity that would be lost through absenteeism, savings of the replacement costs of lost labor associated with absenteeism, and the replacement costs of labor.

The economic productivity lost each year as a result of premature deaths due to smallpox may be conservatively estimated at \$96 million.<sup>21</sup> Productivity lost as a result of morbidity (one month's incapacitation per case) is roughly \$0.2–2.0 million per year.<sup>22</sup>

Basu estimates that the intensified campaign saved \$132.2 million from July, 1973, to December, 1975, as a result of decreased requirements for hospital beds, staff time, and drugs (Basu 1974; Basu, Jezek, and Ward 1979)—roughly \$52.8 million in treatment costs saved each year as the result of eradication. (This average is, naturally, a conservative figure, since savings were likely to be higher in 1975 when no cases were treated than in 1973 when incidence was high.) When combined with savings in economic produc-

TABLE 7.	Summary of Average Annual
Domestic C	Costs of the Indian Smallpox
Eradication	Program, 1970–73

Category	Cost (in U.S. \$)
Direct Indirect Opportunity	\$8.4 million 4.8 million 4.0 million
Total	\$17.2 million

tivity, the benefits to India from eradication may be estimated at roughly \$150 million per year. The estimated annual benefits to India resulting from the eradication of smallpox are summarized in table 8.

Many externalities have resulted from the Indian campaign. These are benefits that have accrued as a result of the program but were not original objectives of the eradication effort. They include the management skills developed by Indian medical personnel and health administrators in the course of successfully eradicating smallpox, increased public optimism and acceptance of health programs, and other benefits that were left behind when the NSEP was terminated. Dutta, Arora, and Rao (1975, 211) have noted that

Success of the campaign produced a tremendous impact on the morale and productivity of the general health services and increased the prestige of the health workers and health programmes. It also led to increased emphasis on early case finding which is an essential prerequisite to a disease control or eradication programme as one of the most important functions of the general health services.

These are benefits that go beyond economic analysis. Even population control efforts may have benefited from smallpox eradication, if the child survival hypothesis<sup>23</sup> is correct; it suggests that if child mortality due to diseases like smallpox is decreased, parents will have fewer "replacement births" and "insurance births," and the birth rate will go down (Taylor, Newman, and Kelly 1976).

At the same time, the conquest of smallpox has increased India's status in the global health community and helped the country avoid censure. The elimination of smallpox is likely to result in improvements in the quality of life in India in many ways.

Some might argue that India would have gained more from a gradual eradication of smallpox rather than an intensified smallpox eradication program, because a control level of program effectiveness would have been more economical in the long run due to high opportunity costs brought about by mobilizing from other programs the many health workers needed for the large-scale searches of every home in India. However, as costly as it was to search an enormous number of households in India (searches done as often as every month in endemic states), a rough estimation of costs and benefits suggests that marginal costs of the intensified campaign

TABLE 8.	Summary of	Annua	.Benefits	of the	Indian
Smallpox <b>E</b>	Eradication Pr	ogram,	1970–73		

Category	Benefit (in U.S. \$)				
Economic productivity	\$96.0 million				
(from premature deaths) Economic productivity	0.2-2.0 million				
Reduced medical care	52.8 million				
Total	\$149.0-150.8 million				

were quickly recouped. We can divide the marginal, or additional, costs of the intensified eradication program (as opposed to the expenditures of the NSEP during 1970–73) by the marginal benefits gained by eradication that were not being realized by the NSEP before the intensified campaign. The numerator consists of the marginal expenditures India made on the intensified eradication program (1974–77) that were over and above the 1970–73 NSEP levels. The denominator reflects the marginal productivity gained as a result of fewer deaths and illnesses after the eradication of smallpox.

Marginal costs of an intens gram to central governmen	\$3,437,000	
Marginal productivity due to deaths averted/yr.	+ Marginal productivity due to illness prevented/yr.	\$28,927,288/yr.
	-	= 43.4 davs

According to this calculation, the marginal cost of the intensified program was paid for by increased productivity alone in 43.4 days without smallpox.<sup>24</sup> To summarize: each year, India recoups its total investment in smallpox eradication by a tenfold margin. Every six weeks without smallpox, India receives an economic benefit equal to the extra direct cost of the central government and states expenditures for the intensified campaign.

## Costs and Benefits for Donor Nations

For donor nations, the cost of smallpox eradication was the direct cost to their respective national budgets of contributing money, manpower, or supplies such as vaccine to the support of the global program, including the India campaign.

Let us look at one donor for whom complete figures are available. The United States provided \$2.1 million per year during the ten-year global program, with benefits accruing at a substantially higher rate. According to one economist, Norman Axnick of CDC (Spring 1975), United States expenditures in 1968 to prevent a single case of smallpox were approximately \$150 million.<sup>25</sup> Due to inflation, the comparable figure (in 1978 dollars) would have been over \$300 million had not India and other nations achieved eradication.

Thus, the annual benefit of \$300 million (in 1978 dollars) continuing into the future significantly dwarfs the United States contribution of slightly more than \$3 million per year (in 1978 dollars), which, in fact, ceases now that smallpox has been eradicated. Even at a very high rate of discount, the United States has regained its investment many times over. Conservatively, it recoups its total ten-year international contributions to global eradication (\$21 million) every 26 days that the world is free of smallpox.

As a result of the successful eradication of smallpox, other nations have now eliminated their own programs for smallpox vaccination and the surveillance of incoming travelers. Resources that they allocated to vaccine production can be shifted to other important disease-control efforts, and they retain the economic benefit of costs forgone in treating unexpected outbreaks of smallpox in their own countries.

In terms of net economic benefits, smallpox eradication is clearly one of the best investments that developed countries have had an opportunity to make. In a 1977 speech in Dacca, Bangladesh, WHO's director-general, Dr. Halfdan Mahler, stated that smallpox eradication is a \$2 billion gift from the less developed countries (LDCs) to the developed world. Actually, it is probably an *annual* gift of \$2 billion!

## Costs and Benefits for the Global Community

The global community as a whole, and the United Nations in particular, benefits enormously from mankind's first victory over a killer disease. Benefits include those economic gains that accrue to donor nations and to endemic nations in particular, as well as benefits from the new, heightened optimism about the potential of international health programs. Despite ideological differences in orientation between the vertical or independent program approach of smallpox eradication and the current integrated primary health care philosophy of WHO, it is doubtful that a proposed goal of "Health for all by the year 2000" would have been contemplated if the world had retreated from the goal of smallpox eradication as it had retreated from the goal of malaria eradication. The total direct costs of global eradication were roughly \$312 million.<sup>26</sup> If savings resulting from the global eradication of smallpox are over \$1.2 billion per year, then the world recoups its total twelve-year expenditures on smallpox eradication every at least four months. (This figure, of course, does not include indirect costs or the positive and negative externalities that resulted from global smallpox eradication.) It is staggering to think that the program costs of eradicating a disease that has caused so much misery for so many centuries can be regained in so short a period, and by all parties concerned.

Of the \$50 million cost of India's smallpox eradication campaign from 1972 through 1976, WHO contributed \$11 million (22 percent) of the funds. Approximately \$1 million (2 percent) came from WHO's regular budget, while \$10 million (20 percent) came from the voluntary fund, the bulk of which was provided by SIDA.

When WHO Director-General Mahler visited Washington, D.C., in 1978, President Carter stated that if WHO had never achieved anything except the eradication of smallpox, it would be reason enough for the U.S. to pledge continuous commitment to its work. This statement reflects an important positive externality increased public support for both national and international public health programs, which has resulted from the eradication of smallpox. Smallpox eradication has brought together individuals from all over the world in a successful effort to work for a common goal, and the spirit it generated may encourage other UN projects. In development meetings, there is increasing emphasis on mutually beneficial cooperation, rather than assistance. In the case of smallpox, global eradication was a cost-effective way to improve health conditions for India as well as for donor nations, each of whom probably recouped their marginal investment in the first few smallpox-free months.

## Economic Efficiency of Program Management

The efficiency of the smallpox eradication program may also be viewed in terms not only of its overall goals, but also of each program component, i.e., strategies, procurement and distribution of

vaccine, management information systems, personnel management, finances, and concurrent evaluations.

Since the entire cost of the intensified campaign was recouped during virtually each month without smallpox, it is not too farfetched to say that each month's delay nearly doubled the cost of the program. Although no such explicit statement could be made during the campaign, there was unequal knowledge of the order of magnitudes involved, and this led to another conflict. Program management stressed that time was money in the eradication campaign. This sense of urgency was generally not shared outside the program.

Some examples are useful here. In 1972, a government of India program officer was not permitted to travel by air, thus necessitating train rides of up to three days to visit certain outbreaks. By 1974 all senior staff traveled by air. When an outbreak was detected in the early part of the campaign, a cross-notification had usually been sent by regular mail. As the campaign intensified, cross-notifications were made by telephone. In fact, much of the program communications in the later stages were carried out by telephone (a request for urgent supplies or authorization to spend additional unauthorized amounts of money could travel from the field to Delhi and from Delhi to Geneva and back to the field in seventy-two hours). Telephone bills for the smallpox unit in Delhi were much higher than for those of other units in WHO. In the case of a disease that could be eradicated, insistence on use of the less expensive but much slower and unreliable postal system would surely have exemplified the penny-wise and pound-foolish false economies that plague many similar endeavors.

The same may be said of extra expenditures in the field to pay for watchguards used to isolate smallpox cases, to procure and deliver food daily so that no one from an infected house had to leave to go to the market, to ship vaccine by air rather than train, to make routine use of photocopy machines rather than risk the loss of critical documents. Even providing each WHO medical officer in the field with a typewriter, which was not usual WHO procedure, was later seen as cost-effective against the background of tremendous economic savings by eradication.

Ultimately, both India and the donor nations regained their investments in the first few smallpox-free months. However, there had been a continuing problem about whether WHO should provide funds for gasoline for Indian jeeps in the program. Without gasoline, surveillance teams could not visit outbreaks, vaccine could not be delivered, assessment could not be supervised. Delays would be inevitable. The costs of gasoline had to be seen against the overall economic profitability of rapid eradication. The same is true for extra manpower at every level. Naturally, these calculations may not apply to other types of programs. Efficiency for disease eradication is quite different from efficiency for continuous primary health care, and this analysis is not intended to imply that what was efficient in the smallpox eradication program is necessarily economically efficient or even feasible for other programs.

Expediency had another externality, this one negative. Many long-held rules were broken in order to quickly implement the smallpox program, since every minute delayed might mean another exposure to smallpox and a prolongation of the campaign. Exceptions to standard practices placed a strain on the system. Other programs with less obvious benefit-to-cost ratios had to follow the prescribed rules;<sup>27</sup> smallpox got exceptional treatment.

This has, as might have been expected, produced some negative externalities, or backlash. Some WHO administrators resented the frequent exceptions that the smallpox team insisted on. The speed and enthusiasm of younger workers were not always easily assimilated by the WHO administration. Many rules were broken. There were smallpox enthusiasts and antagonists at many levels of administration. As the disease slips into history, however, and the uniqueness of the program becomes apparent, the backlash diminishes. Increasingly, it is hoped there is agreement that the economic and human returns on the investment made by all parties more than justified the speed and exceptional efforts made in the exceptional smallpox eradication effort.

## **Management Style**

The role of management includes integrating all the preceding components. Some of those components can be measured, but management style is more difficult to quantify. It is difficult to assess the critical elements of leadership and dedication.

Several explanations have been given for the dedication of the senior level staff. First was the Mount Everest effect—the challenge

of achieving a medically important and inspiring humanitarian first. In bureaucracies beset with problems of prestige and pensions, it took a very special kind of person to work toward eradicating his own career. Once smallpox was eradicated, there would be fewer career opportunities for smallpox experts!

Another source of commitment was the infectious enthusiasm of eradication. Elsewhere it has been called the zeropox virus, and the infection it produced was not unlike the fervor of a charismatic organization.

Smallpox eradication was a special purpose campaign with high motivation. Alvin Toffler (1970, 122) predicts the future belongs to such programs—organizational structures aimed toward special purpose campaigns, which he calls "adhocracy." The adhocracy uses special purpose personnel, and this was certainly the case in the smallpox program, where unusual people who enjoyed moving from place to place, free from many long-term personal relationships, and who did not like to be office-bound were often best suited for the campaign in the field.

The management style of the Indian smallpox campaign became especially distinct during the intensified campaign in 1973, when there was a need for many Indian and foreign epidemiologists. In personnel management, finding such people was of paramount importance. First, in selecting potential epidemiologists, emphasis was on special purpose personnel. Indian epidemiologists were usually over fifty, while internationals were often in their twenties and thirties. WHO (or rather the smallpox unit in Geneva) recruited the best young epidemiologists from many different countries rather than depending on careerists. The younger epidemiologists brought fresh ideas; in addition, they did not expect the high salaries that more senior physicians do, a considerable further benefit, as WHO per diems and salaries are low compared to those usually paid in developed countries. By contrast, Indian special epidemiologists were frequently retired ("but not tired"), well-respected health officials from nearby states who could be quickly mobilized. The constant movement of people-whether of Indians from one state to another or of internationals from their home countries to India-freed the workers from any long-standing personal relationships and redirected their primary allegiances to the independent, informal smallpox organizational structure.

With carefully recruited, highly motivated, loyal special purpose personnel working in the campaign, it was possible to decentralize decision making, delegate responsibility by function, and provide fertile grounds for creative problem solving in autonomous, regional programs assessed on the basis of the incidence of smallpox. Periodic review meetings provided the opportunity to rapidly communicate successful innovations from the most peripheral field stations to program units throughout the entire country and to maintain enthusiasm.

Those epidemiologists or junior medical officers who were not able to effectively contribute were sent home, regardless of whether home was in Bombay, New York, or Moscow. Unlike a permanent health program where such transfers or terminations can rarely be carried out expeditiously, the smallpox program employed temporary staff, and even when the inevitable political pressure mounted to keep someone, the temporary assignment rarely lasted long enough to cause harm. On the other hand, a program officer who was dynamic and might undiplomatically run afoul of a state's political sensitivities could often be kept on—political force from the state capital was met with political force from New Delhi.

There was another advantage of shifting Indian epidemiologists from their home states to others. It was often much easier for an outsider to take appropriately strong action than for a local, who might feel long-term social or political pressures against doing what the immediate situation required. The benefits conferred by the use of outsiders were obvious in comparison to situations involving highlevel officials in their home states, where they did not feel free to make hard decisions or to break rules because they knew they would have to continue to work in the same place years later with the people whose rules they had broken. The internationalists or retired Indians from other states could return to their home states having done a good job and keep their memories of excellence without later being penalized for their enthusiastic support of the smallpox program. This cross-fertilization also added an element of outside assessment.

The internationals sometimes brought with them the extra advantage of having seen smallpox eradicated in another country, and by intoning their experiences over and over again, they convinced others that it was possible to eradicate smallpox by using surveillance and containment.

To make sure staff functioned at their peak, procedures for training were developed. National and international epidemiologists, junior medical officers, and even state surveillance teams went through week-long training periods upon entry at WHO, SEARO, or the Ministry of Health, and also at the state level in endemic states. For internationals, this training highlighted cultural and demographic characteristics. During their briefing, they were introduced to all the proformae and search materials that would be used and went through training exercises in which they simulated taking charge of field programs in hypothetical districts or states. They were also instructed in the art of fund disbursements (the imprest account holders had a very important role to play as fund disbursers in the field) and in the epidemiology of smallpox.

Their written job descriptions required them to submit weekly reports so that progress in their areas could be monitored in New Delhi. These periodic reports included monitoring new outbreaks detected, old outbreaks contained, and pending outbreaks. In addition, field epidemiologists were expected to bring their imprest accounts up to date each month, submitting receipts for all funds disbursed at the monthly meetings held in the capital of each state.

Personnel management ended with debriefing sessions held in New Delhi for departing epidemiologists. In addition to completing the accounting for their imprest accounts and preparing turnover notes to be used for briefing their replacements, the epidemiologists were asked to describe what, in their opinions, were the strengths and weaknesses of the program in their area. This form of debriefing became more sophisticated toward the end of the program and included questions that changed over time to meet shifting program needs. One of the most important questions was "What is the weakest geographical area in your area of responsibility?" Others included "What is the thing that the WHO and government of India high command is doing worst?" and "What is the best thing that we are doing?"

For example, analysis of twenty debriefing forms from the period just before the last case was found shows that the single most commonly cited best thing being done was the presearch meetings at the PHC levels. This attention to planning the search at the most peripheral level was reported as a reason for feeling optimistic about the thoroughness of the search. As for the weakest element in the program, the results were more varied, but usually dealt with the way WHO paid its staff, or occasionally with the fact that the actual job in the field turned out to be much more administrative than the epidemiologists had been led to expect, or that initial training in New Delhi was too short.

Nearly all of the field personnel reported that the support that they received from headquarters was superb and rapid. The supervision they received was only occasionally a field visit from a senior officer; it was, however, a careful analysis of the assessments of their area using management controls to ensure that operations were proceeding according to design. The warning flags of the system allowed project management in New Delhi to oversee from a distance, assuring maximum decentralization and regional autonomy and encouraging innovations while ensuring uniform quality work.

The esprit de corps and friendships that evolved between the Indian and WHO team leaders was perhaps unprecedented in a health campaign in India. Victory over smallpox was the common goal. Each group had to surmount obstacles within its own bureaucracy, and each used its counterpart to help overcome its internal problems, through level jumping or informal private appeals or by stressing the other side's strong feelings. In reality, there was no "other side"; rather, there was a shared sense of purpose, and the brotherhood of comrades-in-arms. Inspired participants were willing to work long hours under difficult circumstances, to forgo vacations, and even on occasion to use their own salaries to fund aspects of the program. The willingness to take on a variety of nonprofessional tasks, routine or innovative, managerial or epidemiological, center stage or backstage, is especially noteworthy.

This led to the slogan "management by inspiration" and was studied by T. S. Jones (1976), one of the participants in the Indian smallpox campaign, who felt that this motivation came from three major sources.

- 1. a common goal that was attainable in the near future
- 2. a sympathetic group of co-workers who shared and encouraged belief in the goal
- 3. an emergency-like work situation (the program was often referred to as being on a war footing) with the concomitant

Eradication	Distant	Approaching	Nearer	Nearer	Achieved, insecure	Achieved, secure
Current Satisfaction	Usually high, depends on view of progress	Usually high	Usually very high	Usually very high	Reduced, secondary goals increase in importance	Low, secondary goals become most important
Smallpox Presence	Current, very real	Current, very real	Current, diminished	Current, diminished	Distant, but threatening	Distant, unreal
Appropriate Program Measures	Train staff, short visits to many infected areas	More attention to each case	Increased attention to each case	Increased attention to each case	Strengthen border surveillance	Planning, paperwork
Analysis	Must reduce the mass of infected persons to manageable level	The tide has been turned, must re- double work to assure continued progress	Eradication is al- most achieved, must increase effort	There may be hid- den cases that threaten to start a new outbreak	Must protect the smallpox- free zone	Maintain morale, document campaign
Epidemic Situation	Many cases in many places, increasing numbers	Many cases in many places, but decreasing numbers	Few cases in a few places	Zero cases (just after the last case)	Zero cases (for months, but pox in nearby area)	Zero cases (for many months, no nearby pox)
Stage	1	р	ť	4	J.	ę

TABLE 9. Motivational Stages in Eradication of Smallpox in India

increase in output and unification that such disaster situations invoke. (P. 10)

Jones regards the smallpox eradication program as similar to the charismatic authority model described by Weber (1958). A charismatic organization depends on a special sense of mission to attract participants and is held together "by the perceived extraordinary nature of its purpose" (p. 15). It continues only as long as this sense of purpose remains. The possibility of eradicating a hideous, often fatal disease provided purpose enough.

Paradoxically, as shown in table 9, the same features of the program that created this motivation and sense of purpose also limited its stability. As the target of zero smallpox came closer and closer to reality, the sources of motivation and dedication began to recede. Fewer cases required less staff, decreasing the critical mass of sympathetic co-workers. After the last case, as the smallpox-free interval lengthened, the tone of the campaign shifted from that of an emergency-like situation to one of careful but less exciting and less romantic meticulous surveillance. Although the humanitarian and professional satisfaction of each phase of the program was the same in theory, meeting the enemy face-to-face and seeing actual cases of smallpox were far more powerful incentives than reporting "nil" cases week after week after week. It took a different personality to continue to go the final inch toward certification of eradication.

The motivational component of the eradication program will be one of the most difficult to carry over to other public health programs, especially those maintenance programs, such as primary health care, that must sustain constant effort year after year. If the smallpox campaign had stretched out for decades rather than years, the unique special purpose of the campaign might well have changed, and with it the personnel it attracted and the nature of their commitment, and perhaps even the final outcome.

On the other hand, it may perhaps be possible to re-create the same specialness of purpose throughout WHO by adopting some of the same principles of motivated leadership. After all, health for all is the most lofty and inspiring target that health workers could work toward.

## *Chapter 3* Conclusions

## Lessons for the Future

The purpose of this book is to examine what was learned from the experience of a successful health program and to make those lessons useful to managers of future programs. Since this necessarily implies different diseases, different programs, and different countries, smallpox eradication cannot be offered as a model. The reader must read the case study, go through the analysis, and draw his own conclusions about which lessons are relevant for any particular problem, culture, or program.

In chapter 1 the chronology of the smallpox eradication program in India was reviewed, and in chapter 2 the management issues involved in the program were analyzed. In this chapter conclusions about management tools that worked in the smallpox eradication program are discussed and lessons for the future are suggested. WHO is continuing to document the lessons learned by many participants in the smallpox campaign, and there are likely to be as many different views as there were participants or observers.

As the success of the Indian smallpox eradication program grew increasingly secure, Dr. M. I. D. Sharma (acting commissioner of health for the government of India) began opening the monthly progress review meetings with his own list of important factors in the smallpox success story.

This list of recipes, presented in table 10, illustrates one way to look at the lessons learned from smallpox eradication. Within this list are many lessons unique to smallpox and some unique to India—or perhaps unique to eradication programs in India. But also included are many lessons that can be applied to other disease control programs, to the organization of primary health care, and even to problems beyond the health sector.

The lessons from smallpox eradication that are most important, naturally, are the ones that can be applied to other programs. When-

	1 1
Ram	a Hindu name for God, an incarnation of Lord Vishnu
Rahim	a Muslim name for God
Resources	manpower, jeeps, and money from WHO, SIDA, and others
Reporting	the weekly epidemiologic reporting system, the surveillance re- ports, the management information system that allowed target- ing of resources
Rewards	for stimulating improved case detection
Recruitment	of good epidemiologists from around the world
Retired	(but not tired) Indian epidemiologists (the employment on an unusual basis by WHO of Indians to work in India tapping India's vast army of specialists retired at age 55 or 58 according to Indian government regulations)
Responsible and resourceful staff	at all levels
Routine supervision	of all facets of the program
Regular communications	a regular surveillance newsletter to keep everyone informed of progress and problems
Rains	the monsoon that brought down seasonal transmission
Recognition cards	that helped the search worker find smallpox
Relevant research	field and operational research, innovations from the field— market searches, watchguards, as well as freeze-dried vaccine, bifurcated needle, and so on
Re-search	Going back and doing the search over again if it was not good enough the first time
Rapid containment	of outbreaks
Rapid administrative action	to get personnel hired and fired; to move supplies and paper- work across the country or across the office
Rigorous assessment	to find weak spots in the strategy and implementation of the program
Review meetings	the presearch training sessions at PHC, district, and state lev- els to prepare the search and the postsearch progress review meetings each month
Rules	especially the rule that any outbreak that persisted more than 21 days after detection and still had secondary cases had to be visited by senior level staff

TABLE 10. Review of Recipes for Eradication of Smallpox in India

## TABLE 10.—Continued

Regulations	especially regulations like flexibility of fund disbursal through the use of the imprest accounts
And the routine breaking of rules and regulations	

ever this subject is discussed within the international health community two positions emerge: one, that smallpox eradication was a unique, unreproducible event, with very few useful lessons for others; the other, that smallpox eradication provides a good model or lesson for other programs.

The truth probably combines elements of both positions. As a participant in the smallpox eradication program and one who was profoundly affected by the experience, this author cannot be considered an objective, unbiased observer. However, in the remarks that follow, an honest attempt has been made to take an evenhanded aproach and to distinguish those aspects of the Indian smallpox eradication program that were unique to it from those that can provide general management lessons for other disease control programs.

## Factors Unique to Smallpox Eradication in India

In the economic development literature, much attention has been paid to the limitations of the special case. There is a concern that each nation and each program has specific characteristics that are unique and should not be copied by other countries or other programs. For smallpox and its eradication, at least three categories of uniqueness must be considered: (1) the unique epidemiology of smallpox; (2) the unique economics and politics of eradication (as opposed to disease control); and (3) the unique psychology of smallpox eradication.

The Global Commission for the Certification of Smallpox Eradication (1979) has identified six epidemiological characteristics of smallpox that facilitated eradication (see fig. 8). There are additional epidemiologic characteristics of smallpox that although perhaps not 1. The recognition of smallpox cases is a comparatively simple matter. Subclinical infections, although recognized as occurring among partially immune persons, are not important since the individuals so infected do not transmit infection.

2. Smallpox is transmitted solely from person to person. There are no known animal reservoirs.

3. The transmissibility of infection is low and epidemics develop slowly. Between each generation of cases there is an interval of two to three weeks. In most circumstances when transmission occurs, one individual infects between one and five others.

4. Possibly infected individuals can be readily identified because transmission requires close contact between infected and susceptible persons, most commonly in the home, hospital, or school.

5. The number of chains of transmission at any one time is usually relatively small.

6. With the development of a surveillance system that discovers and traces all outbreaks promptly, small but rapid and thorough containment actions can break the transmission chains and smallpox can be eradicated within a relatively short time.

## FIG. 8. Characteristics of smallpox facilitating eradication

unique, limit the general application of program techniques. First, there are no important biological vectors (as in the case of malaria and yellow fever) and no environmental reservoirs of the disease (as in the case of polio and tetanus). The smallpox program was fortunate in that it could deal with humans only, avoiding problems of mosquito resistance and the formidable difficulties of environmental control.

This was not only of epidemiologic importance, it was also extremely significant from a managerial perspective. The smallpox program did not have to change cultural habits and traditions beyond inculcating the need to report smallpox and accept vaccination. As difficult as it was to deal effectively with cultural beliefs about smallpox, it would have been much more difficult for programs like diarrhea control, where sanitation and economic issues predominate; or for xerophthalmia, where changes in diet are important; or for family planning, which deals with intimate events that have been traditionally free of state interference. It is far easier to achieve public cooperation in reporting smallpox and taking a vaccination than to change fertility, diet, and fecal habits that have been centuries in the making.

Another factor important to smallpox eradication and rare elsewhere is so obvious it might be overlooked: the availability of a potent vaccine. Of course, good management was the crucial element in creating a climate that permitted development of abundant, reliable, locally produced, heat-stable vaccine and encouraged the dissemination of a recent innovation, the bifurcated needle. However, effective biologicals for many health problems still elude science, and whenever the lessons learned from smallpox are raised in the company of family planners, malariologists, or primary health theorists, the absence of any equivalent to smallpox vaccine is often cited for the argument that lessons learned from smallpox are not generalizable.

Throughout the smallpox program new lessons were learned in the area of vaccine development. WHO encouraged multiple sources of production, and UNICEF provided many countries with the technical know-how and resources to produce vaccine on a regular basis and also provided travel assistance that permitted vaccine production experts to visit other laboratories around the world, to share techniques, and to establish common minimum standards of potency and stability. These are certainly important lessons for programs that have vaccine delivery as part of their strategy. Vaccine management in smallpox has provided lessons for the Expanded Program in Immunization (EPI) in India, and if eventually vaccines are developed against other diseases like malaria and leprosy, the vaccine-related lessons from the smallpox program will be more generally relevant.

Another factor that limits, to some extent, the generalizability of the smallpox eradication experience is the communicability of smallpox. Some of the international cooperation, as well as some significant donations from the private sector, no doubt derived from altruistic motives. However, the feeling of vulnerability to contagion, requiring constant vigilance at airports, surveillance at border crossings, and attention to immunization levels, loosened government purse strings and encouraged several countries to agree to send their most talented epidemiologists and doctors thousands of miles away to participate in smallpox eradication. The resources that were made available to smallpox eradication were in part motivated by self-concern, some of which could be translated into economics. It is clear (see the section in chapter 2 entitled "Evaluation") that donating money, vaccine, and manpower was at least as much in the interest of the donors as it was in the interest of the recipient countries. Dr. Halfdan Mahler has called smallpox eradication a \$2 billion gift from the developing world to the developed world. Certainly there were gifts in both directions, but the point is that it will be difficult to duplicate the level of international aid and collaboration that the nature of this disease stimulated. Leprosy, which is as disfiguring and frightening a disease as smallpox, nevertheless does not convey the sense of immediate emergency that smallpox does. Yellow fever, which is as deadly as smallpox, does not perhaps evoke such deep-seated psychic dread as smallpox. And of course, primary health care, which will touch more lives and has the potential to benefit far more people than eradication of any of these diseases, is a far less dramatic effort.

In many parts of the world, there was a strong public will to eradicate smallpox. The disease, terrifying in its appearance and tragic in its consequences, has gripped the imagination of mankind for as long as records exist. The support given to the smallpox program is in part traceable to the general public determination to conquer this ancient scourge. This was certainly true at the highest political level in India. Dr. V. T. H. Gunaratne, former regional director of SEARO, stressed this.

Of the lessons learned from the eradication of smallpox, most important is that it is the commitment, the perseverance and the will of our Member States which are the prime determinants of success in the field of health. (World Health Organization, Regional Office for South-East Asia 1978, 105)

Another aspect of the unique psychology of smallpox was the enormous attraction involved in the potential "first" of eradicating a disease that had been a major worldwide scourge for centuries. This drama is not unique to smallpox. Elements of it are seen in reports of the early efforts to eradicate malaria, in efforts to eradicate yellow

fever, and even among some people working to eradicate yaws. This charisma and esprit de corps can certainly be re-created in future eradication programs, but prolonged international interest in disease control programs is more difficult to sustain. As important as charisma, however, are the economic realities of a disease eradication program when compared to the economics of a maintenance program of disease control. Despite the limitations of the simplistic cost-benefit analysis presented in this book, it is obvious that compared to disease control, eradication presented enormous economic advantages for both the smallpox-endemic countries and the nonendemic potential donor countries. These payoffs not only helped mobilize resources for the eradication program, they also justified extraordinary speed (and the extra costs speed creates, such as special delivery of parcels, airfreight instead of sea mail; air travel instead of train; and most of all, administrative priority to all things marked smallpox). This speed was cost-effective because eradication was possible. Because eradication was possible, a temporary organization could be established, with temporary staff, temporary offices, and a sense of urgency. It is much more difficult to generate a feeling of urgency and to make the same cost-effectiveness arguments in the case of cataract or leprosy or even childhood deaths from diarrhea-not because the consequences of the diseases are less tragic, but because the benefits of program success are less dramatic.

The commitment to urgency was justified by the psychology, economics, and epidemiology of smallpox eradication, and it in turn provided money, manpower, and momentum to the smallpox eradication campaign. Although other diseases in today's environment may not be able to generate that commitment of money, manpower, and momentum, one factor that was responsible for the eradication of smallpox certainly can be reproduced, and that is the management. The economic, political, and psychological urgency of smallpox eradication was no doubt unusual, if not unique, and facilitated program development. However, a review of the case study of smallpox eradication in India (as well as globally) makes it clear that it was the program management that was responsible for organizing the manpower, raising the money, and perpetuating the momentum. The management of the comparatively advantageous elements of the nature of smallpox is what made it possible to eradicate smallpox from India in 1976 instead of much later, and good management is what overcame equally important comparative disadvantages: the tenacity of the disease in densely populated India; the cultural traditions that hid cases and resisted vaccination; the ease of transmission and high attack rates; and the tremendous pessimism that had developed about all disease eradication programs after the previous well-known failures in programs to eradicate malaria and yellow fever. Within the management of smallpox eradication there are lessons to be learned that are relevant to many areas of public health and international program management.

## General Lessons from Smallpox Eradication in India

When one reviews the many arguments against using smallpox eradication as a model for other programs, it becomes clear that although smallpox is not a model, the lessons learned in the eradication effort are very important. The marriage of good management and good epidemiology (in about equal measure), which forms the essential lesson of this case study, also formed the essence of the smallpox eradication program in India (and elsewhere). Unless this marriage and its offspring of management and epidemiologic innovations are understood and respected, other programs are not likely to take advantage of the lessons learned from smallpox eradication.

With this in mind, some general lessons from the case study that seem relevant to other health programs will be reviewed here (following the outline presented in chapter 2).

The first step in any program is to understand and analyze the problem. Problem definition must be qualitative and quantitative. It must be a dynamic process, capable of continuously changing as the problem itself changes over time. In the case of smallpox, it was this constant process of redefining the problem to take new developments into account that led first to the creation of a system for recording vaccination (when the problem was redefined as "not enough vaccination"), later to disease reporting (when the problem was redefined as "too much smallpox"), and finally to a sensitive surveillance system (when the problem was redefined as "smallpox must be eradicated"). Monitoring vaccination reports, graphing the annual incidence of smallpox, and later deleting infected villages from the list of pending outbreaks—all these were epidemiologic interpretations of the management problem. This epidemiologic management is as needed for monitoring progress toward vector control in malaria as it is in monitoring progress toward "Health for all by the year 2000." The important lesson is that once a problem begins to be understood and analyzed, it is possible to monitor changes in that problem. In case of public health, such constant monitoring of the state of the problem is called surveillance.

Investigating the causes of the problem means studying both the epidemiologic and the managerial causes. In an epidemiological sense, when we seek the causes of the problem we must ask about descriptive epidemiology: how many cases, where are they located, what is the seasonal periodicity, what are the secular trends, what proportion of reported cases are coming to the attention of the authorities (what is the sensitivity and specificity of the surveillance system), what is the case-fatality rate and the incidence of other complications. In short, we are making an epidemiological study of the problem.

From the management perspective, we need to assess both the system and the management environment, test existing strategies for any weaknesses, determine what potential management bottlenecks may be present that prevent the implementation of important tasks. In both cases, data gathered should be simple enough to use but sophisticated enough to meet the needs of decision makers. An epidemiologic program always gathers data about the enemy, whether the enemy is a single disease or a broad spectrum of illnesses. Good management for such a program must ensure that data are built into the management information system, and the data must be used to test the feasibility of strategies and to formulate tactics.

To achieve this integration, disease-control officers must be both scientists and managers. A political determination to achieve health for all is essential, but without an integration of epidemiology and health management the problem cannot adequately be defined, analyzed, and overcome.

The case study given above provides many good examples of the way an integrated epidemiological and management approach made it possible to understand and analyze the problem at hand and act on the information. Early in the program, data were available to show that the spring was the time of the high incidence peak of smallpox (as the name of smallpox in Bengali, *Bashanto*, or "spring visitor," implies). An autumn campaign was decided on, to take advantage of the fact that the lowest period of incidence was the monsoon, during which viral survival rates were low and the isolation imposed by washed-out bridges and impassably swollen rivers reduced transmission. The program management incorporated the seasonality of smallpox into program planning: the first autumn campaign was an attempt to get surveillance and containment moving as soon as the monsoon receded, before smallpox had a chance to build up its epidemic force. Likewise, the first push of Operation Smallpox Zero was set in motion just before the high transmission period began, to avoid facing an epidemic resurgence of smallpox with insufficient staff.

The specific month-by-month seasonality of smallpox is not generalizable to all diseases, but there is a generalizable lesson. In studying the seasonality of the disease, program managers were looking for the weakest points in their adversary, smallpox—even personifying it and gathering resources as a good general gathers troops. The seasonality was unique, but the general lesson is that good disease management requires that the magnitude and characteristics of the disease(s) be learned. Basing strategy and tactics on epidemiologic data is good management.

Even the surveillance and containment strategy was an example of this marriage. A good manager must know how to efficiently allocate scarce resources (vaccine) on the basis of priority (risk factors). Once the reporting system was integrated into a management information system, it produced and transmitted the surveillance information that allowed program managers to define the problem and continuously refine their approach in periodic review meetings during which both new information and resulting changes in strategy and tactics were disseminated.

Many other innovations of the smallpox program—for example, active case search and market surveillance—can be traced to this mixture of epidemiology and management. All were developments based on a refinement of understanding of the problem of smallpox, a periodic redefining and measuring of the problem.

In any public health program, the system in which the program is to be carried out must be understood in its broadest potential sense. Its real potential, not its imaginary or historic limits, should be respected. The WHO-government of India relationship at

the beginning of the program was sometimes as adversarial as it was collegial. The colleagues on both the WHO and government of India teams could only use each other later and help each other level jump because they had studied and understood the political and administrative system they and their counterparts were in. Likewise, the courageous acts of the team leader in finding funding from SIDA, the Tatas organization, and other sources had to be initiated informally, from outside the limited official system, in order to get the resources needed to achieve the goal of eradication. The last of Dr. Sharma's guideline recipes (table 10) is to regularly break rules and regulations, but this cannot be done beyond certain limits. A good manager is a good game player who understands the real limits of the system (which are not necessarily those given in the rule book) and acts within them. It might have been against the rules to undertake personal appeals like those made to Prime Minister Gandhi, the Tatas, and the government of Sweden, but because of the costs and benefits involved, it was almost as if the written rules of the government of India and WHO were partially suspended in the case of smallpox. With everyone understanding that, no real rules were broken. Managers in other programs must be sensitive to the difference between the formal system (and its written rules) and the real system as it is understood by its insiders.

There are risks in ignoring rules and breaking regulations, and the willingness to take those risks might have been greater in a temporary program that was not, for most of the participants, a lifetime career. One would expect less rule breaking in a permanent system, not just because the usual rules are more appropriate for long-term programs but because the long-term career risks are higher for the managers. There is no lesson, as there is no rule, that tells one when to break rules. However, to some extent, experience from smallpox eradication does corroborate an important aphorism: You can't make an omelet without cracking a few eggs.

Program goals should have several tiers or levels of subtlety. The first-level goals (objectives) should be specific, measurable, realistic, dynamic, and flexible. Input from the field, from an MIS, should provide the incremental information to define and redefine program goals. In the case of smallpox, the goal matured over time from that of 100 percent vaccination to that of zero smallpox. A second tier of goals (targets) should be time-bound whenever possible, and should be specific numerical targets. In the case of smallpox, some examples might be surveillance coverage (how many villages had been searched within a certain time period), surveillance effectiveness (how many outbreaks of smallpox eluded the searcher), and extent of reward knowledge (how many people knew of the reward at a certain point in time). Although few of these specific targets are directly transferable to other programs, a multitiered approach to goal setting is useful elsewhere, for it allows managers to use epidemiologic assessment of secondary goals and to keep sight of the primary objective.

For example: in the case of primary health care, a statement of primary goals ("Health for all by the year 2000") has been made. Individual time-bound targets have not yet been specified, but presumably they will be forthcoming for each specific disease and each intervention; they will be the ingredients that make up the program. Once the components of health are defined, however, epidemiologic targets will be of great importance in helping policy makers reach specific targets for each component of the program without diluting the political and motivational goals of the lofty, important, but difficult to measure objective of health for all.

Planning any program is in part an exercise in strategy formulation. Strategies can be political, managerial, and epidemiological. Good planning must take into account economic realities and political costs and benefits. In the case of smallpox eradication in India, epidemiologic strategies (improve surveillance) converged with political strategies (motivate high-level Indian government officials to allocate more resources to smallpox). Whether this convergence was by design or accident, it is an important lesson for all programs: technical and political strategies must be harmonious.

Planning must also be flexible. One of the strengths of the epidemiologic strategy of surveillance and containment is that the specific techniques (e.g., active search, dividing India into endemic and nonendemic areas, making risk assessments of various communities, careful epidemiologic tracing of contacts and index cases) are nothing more than an application to disease control of sound management principles of resource allocation. One overriding characteristic that distinguished the program based on this strategy was a constant evaluation of the progress based on the outcome of the program (the number of cases, of pending outbreaks, of infected states, and so on) rather than on output (the number of vaccinations given, of epidemiologists put into the field, and so on). Outcome-oriented strategies are applicable to all programs in the field of health. "Health for all by the year 2000" is certainly an outcome-oriented goal, and it is to be hoped that the strategies will also be outcome-oriented, based on sound epidemiologic and managerial principles.

Tactics in public health must always be dynamic, not static, changing to meet the ever-changing political, economic, managerial, and epidemiological situation. Information from the field is constantly recycled; lessons learned in remote areas are brought to planners and implementers as refinements and improvements in tactics. A major lesson from the smallpox program that applies to many others is the need for continual attention to new detail, a continuous reformulation of tactics.

In any bureaucracy there are both formal and informal hierarchies. Both will be used by the good manager. Often, the formal hierarchy adds legitimacy to a program but it is the informal heirarchy that gets things done. The most essential part of this informal organization is the central or top management team. It is in this group, however it is defined, that interpersonal relationships are so important. When the program is an international one, diplomacy and tact are often more important at this level than technical issues. The smallpox program was able to break many rules and regulations because its informal team of top management had strongly shared identical views. Both halves of the team reinforced mutually desired tactics by calling on the formal legitimacy of their counterparts to bolster their position within their own organization. However, this approach has serious limitations. In the case of a temporary program like smallpox, much of the rule breaking was tolerated because the tail (smallpox) would only wag the dog (the health system) for a short period. When many different programs simultaneously practice such organizational tactics, a health care system can degenerate into warring feudal kingdoms. For example, the fieldom of malaria eradication could battle the fiefdom of filariasis control for the use of the spraying teams each needs. Battles between specific programs to obtain exemptions from the rules lead to backlash, as general administrators and planners lose patience with such power struggles and fights for preeminence. An honest look at WHO in the postsmallpox

years must acknowledge some degree of backlash against the zest of the eradicators. Programs that do not have eradication as their goal and that are not short-lived cannot afford to risk such backlash. Attention must be paid to a thorough and realistic evaluation of the boundaries of the system in which the program is working.

One of the most important lessons from smallpox eradication was the need for well-trained, nonmedical operations officers and administrative officers. In the smallpox program, the epidemiologists were the team leaders, and in the field they looked after logistics implementation in their areas. However, at central offices, in Delhi, and in the state capitals, there were operations officers who applied good management principles to the flow of vaccine, supplies, personnel, and money. These logisticians appeared to the epidemiologists to be magicians in their ability to sort out tangled lines of supply. Too many health policy makers think of administrative officers as a luxury. Having the properly trained people to handle the logistics is a necessity in any kind of program. Logistics management requires the same expertise in management controls as disease management-the same attention to detail in defining the problem and its causes, understanding the organizational system, setting proper goals, formulating appropriate and effective strategies, implementing tasks, and evaluating the work done.

Communication within the organization and between the organization and the outside world needs to be consistent, rapid, and honest. Staff training is a key aspect of communications often minimized by programs that do not realize that each badly trained person can propagate errors up and down the line of communication. In the smallpox program, practical field training was important, and the use of case studies was very helpful.

Once in the field, staff need to be part of a regular communication system. Surveillance newsletters and periodic review meetings keep program staff involved in disseminating new tactics or refining old procedures. A flow of simple, regular information from each person in the field is vital to keeping a management information system that is usable. Too much information from the field can overload the central office and obstruct the appropriate response, which must be rapid and dependable in order to keep field staff well supported. In the smallpox program, it is generally acknowledged that the vast majority of such important innovations as recognition cards, watchguards, the reward, and containment books came from field staff, and a major role of managers is that of stimulating field staff to creatively tackle problems as they arise. If management tries to discourage complaints, as happened in the early days of case suppression, it will suppress the knowledge that the problem exists, but the problem itself seldom goes away. An attitude of problem-oriented practical experimentation in the field, with dependable support from the center, is a prerequisite to problem solving in many programs. There is an implied arc in this system. Information comes from the field in a simple form, and the health service responds to the collected, collated, and analyzed data. The information is returned to those who need it for administrative decision making and to those involved in continuing data collection. Although the management information system that developed in the Indian smallpox program was unique to that program, the circumstances by which it developed and the needs that stimulated its development are similar to those in many other programs. A study of the management information system and the surveillance network may be helpful to other program managers.

Communication between the program and the public must be honest, and it must flow in both directions. It is essential that program staff be fully knowledgeable about the community's beliefs about disease and its causation. The cultural interpretations of smallpox varied so dramatically every hundred miles that the various traditional views needed to be learned by the Indian as well as the foreign smallpox staff. Other countries and programs may have differing problems, but the way disease is perceived by the community must be understood and respected. Likewise, health education (informing the community of the program's view of disease and prevention) must be emphasized-and its effectiveness evaluated. It was not enough simply to advertise the fact that smallpox should be reported and that there was a reward. Periodic assessment of the impact of health education (the number of people who knew about the reward) was as important as evaluating the stability of the vaccine. The messages of health education must also be dynamic, not static, so they will evolve as the program evolves. Establishing honest, regular, and reliable two-way communication between the program and the people is of great importance to all concerned.

Many WHO smallpox program staff were personally involved

in raising money that was used in the program. This lesson may not be possible or appropriate to apply in many programs, but for some it is an important one. On the other hand, in many programs it is harder to spend money than to raise it. Inefficient financial practices that impede the appropriate use of budgeted funds create one of the greatest obstacles to improving public health in many developing countries. Flexible financial policies do not mean laxity, excessive generosity, or sloppy financial controls; they imply such innovations as the imprest accounts that allowed financial officers to exercise curative rather than preventive controls, often circumventing timeconsuming levels of bureaucratic pro forma approvals that had been required before gasoline could be purchased or health education posters printed. A practical problem is that few government health staff are at ease handling money; corruption is rarely talked about and difficult to deal with at all levels. Health programs make elaborate controls to prevent corruption, usually because it is nearly impossible to discipline people caught misusing money. However, such preventive measures against corruption often prevent program implementation as well. The approach in the smallpox program was to increase good staff recruitment, to carefully train the staff about allowable expenditures, to motivate them, and to exercise stringent curative financial controls each month. There is obviously a trade-off here, but the imprest account system allowed team leaders to disburse funds up to a certain limit with no prior approval. This allowed for decentralized decision making and rapid response by field teams when problems were encountered. The use of imprest accounts in the field with postexpenditure justification of disbursements and strict personnel actions in cases of misuse or corruption was an improvement over the cumbersome process of seeking approval months before funds could be disbursed. Such a system worked for a temporary program. It is not clear how well it would work for a permanent one, but it is certain that in many countries and many programs existing financial control systems choke off initiative and stifle program implementation.

Assessment—that is, concurrent evaluation—of progress toward management and epidemiologic goals is an essential part of any program. One chain of assessment in the smallpox program consisted of assessing vaccine quality, quantity produced, distribution to storage and health centers, use in the field, and effectiveness

(as judged by scar surveys). In other programs there will be other things to assess, but the need for assessment is clear. In the smallpox program there was resistance at first to the idea of spending so much time and so many resources assessing work already done when it was obvious that there was still much more work to do. Some felt that it would be better to put it off until the end of the program, so that there would be more progress to show on the evaluation. However, the purpose of assessment is not simply to show progress, but rather to feed information into the management information system in order to continuously change the tactics needed to meet program goals. Resource allocation decisions cannot be made as effectively without a system of continuous assessment of personnel recruiting decisions, purchase of supplies and equipment, budgeting to meet likely program requirements, and even the decision whether to seek extraordinary outside funding. These decisions must be based on realistic assessments of the program's strengths and weaknesses. There is another reason to invest the time and money to have regular assessments. Assessment in the field provides supervision and encouragement to staff and creates a standard of excellence and good morale that should never be underestimated. Many people lament the expert committees, advisory committees, and assessment committees that proliferate in many programs. The case study here clearly shows that such periodic outside review was important in developing strategy and tactics in the NSEP and could yield a similar dividend in other programs.

As a program expands, developing systematic epidemiologic and management control procedures is very important as a means of avoiding the gulf that often separates the field from the office when direct supervision of all staff has become impractical. Controls like the weekly "nil" report to separate absences of smallpox from the absence of the reporter are certainly generalizable lessons, whereas scar surveys and surveillance of surrogates like chickenpox were specific for smallpox. But the general concept of management controls is vital to a program's health.

Research carried out in the smallpox program in India was of the problem-oriented variety. Operational research was more important than basic science in the case of smallpox because the scientific elements for disease control were already in place. Research was carried out to gather the data that were needed to plan, implement, or evaluate the program. Because management and epidemiology were integrated, the program could control and organize its own research. In other programs, research may often follow a more laissez-faire approach than it did in smallpox. There, research proposals to count the number of pox in various types of smallpox cases were ignored in favor of research that helped measure the risk of the floating population in Calcutta. The management of a program must be able to encourage, fund, and support research-minded colleagues who can find answers to the program's most pressing questions. Often this effort is enhanced by a decentralized approach, which encourages local problem-solving initiatives. Other types of coordinated research that are important are pilot projects that test field methods, clinical trials of vaccines and therapeutic agents, and so on. These and other categories of research need to be integrated into program management.

Many programs lose momentum and are prematurely declared to be successful. This occurred from time to time in the smallpox program, with many countries announcing eradication prematurely. It did not occur in India, but it might well have, because it is a reaction that reflects human nature. The realm of the final inch, the meticulous attention to detail for a two-year period of painstaking and sometimes unrewarding surveillance, is one of the most revealing aspects of the smallpox programs. In the malaria eradication program, there were countries that came very close to eradication, only to see the parasite come back with a frightening resurgence. Many ambitious health care targets of the 1950s have been abandoned because the sheer will and perseverance to pursue them on and on was lacking. Smallpox, it must be remembered, was a temporary program and might have faced similar problems had it droned on for decades. But the momentum was sustained for two years beyond the finishing line. This period of built-in evaluation acted also as an assurance that the work of eradication would not falter at the final threshold of success. The use of outside evaluators and the importance given to outside evaluation was another incentive to keep up high standards of work. As in all of the program, evaluation at this stage was based on outcome, not on output.

The use of outside consultants, whether from other areas of the same country or from other countries through WHO, was important in smallpox eradication and is likely to play an important role in other projects. Facing the social and political pressures in one's home area often inhibits objectivity and direct action, but visitors from another state or nation do these jobs well, knowing that since they can return to their homes elsewhere, they will not face the inevitable penalties and repercussions of their honest criticisms.

There is one aspect of the style of management of the smallpox program that is generalizable but undefinable: the characteristic of good leadership. Much has been written about what makes a good leader, and there are many different opinions. Leaders are often charismatic, able to communicate their enthusiasm and commitment to the task at hand. The triumph of the zeropox virus over the smallpox virus was a victory for leadership. Even in the blackest days of the campaign, the leadership remained confident of victory. It is beyond the scope of this book to attempt to deal with the personalities and qualities of leadership in smallpox eradication, beyond stressing the important fact that outstanding leadership played a vital role in smallpox eradication and good leadership is a necessary ingredient in any successful program.

# Appendixes

## Appendix 1 The WHO–Government of India Plan of Operations and Addenda

On September 9, 1970, the World Health Organization (WHO) and the government of India agreed upon a general Plan of Operations for the eradication of smallpox. The agreement was based upon the relationship between WHO and the government of India that was established in the basic agreement of July 16, 1952.

The objectives stated in the Plan of Operations were: (1) the eradication of smallpox by vaccination surveillance and containment measures and (2) the maintenance of achieved eradication.

Methods proposed for reaching the goal of eradication were based on three basic needs: personnel, technical methods and procedures, and vaccine. The plan stipulated the importance of providing adequate staff; of applying technical methods and procedures as contained in the manual of instructions prepared by the directorategeneral of health services; and of using vaccine that was freeze-dried and of prescribed potency and stability.

The plan of action stated that overall technical direction would be provided by the Directorate-General of Health Services, with each state preparing detailed plans of actions in consultation with the Directorate-General. It also provided general guidelines for the operation of the smallpox program in India, including aspects such as vaccine transportation and storage, vaccination performance, program evaluation, surveillance and containment, health education and publicity, and the duration of assistance from WHO.

Vaccine was to be transported by air, or if that were not possible, by the most rapid means of transport. All supply points were to retain in stock one month's worth of vaccine, and vaccine was to be stored in refrigerators. In the field, where refrigerators were not available, vaccine was to be kept in a cool place, but was to be used within one week. It was to be kept moist and was to be used within six hours after reconstitution. Vaccination was to be given to all children under fourteen, but priority was also to be given to urban communities and groups most likely to transmit disease. Revaccination was to be done selectively, also targeting high-risk groups. Mass vaccination was to be mandatory in the case of a smallpox outbreak. Vaccinators were to inspect all primary vaccinations for success, record all failures, and revaccinate if necessary. It was stressed that the bifurcated needle was to be used wherever possible.

A review of the progress of the program was to be done every month, and scar and pockmark surveys were to be carried out periodically.

Surveillance and outbreak containment was to be carried out from the beginning of the campaign. The program was to include the detection and prompt reporting of smallpox cases and suspected cases and the immediate initiation of containment action by specially designated mobile teams.

Health education and publicity were recognized as necessary components of the program, since it was important to increase consciousness among the public and to promote voluntary vaccination and prompt notification of cases. The plan recommended that cooperation of the health unit in each state or territory be sought for the development of an education program to encourage vaccination and case notification.

Assessment was to be done by the state government, the government of India, and WHO at intervals deemed necessary by the government of India and WHO.

Duration of assistance from WHO for implementing the project was planned initially for two years, with automatic extensions until international assistance by WHO ended.

For the administration and assignment of responsibilities for the eradication campaign, WHO and the government of India agreed that the program would be handled as a national program until it reached the maintenance phase, when it would be handled over to basic health services. The government would organize production and distribution of freeze-dried vaccine, provide health education, and supply reports to WHO as agreed. WHO would be represented by SEARO.

The Plan of Operations also stipulated the resource commitments of both parties:

## Commitments of WHO

- 1. Personnel—WHO agreed to provide four epidemiologists plus three short-term consultants for three months each in 1970 and 1971 to assist in the assessment of the program and training of personnel, as well as to provide the cost of travel for WHO personnel within the country while on duty.
- 2. Supplies and equipment—WHO would supply vehicles, motorcycles, refrigerators, bifurcated needles, and spare parts that were not available in India, as and when required through addenda to the plan of operation, with titles retained by WHO.
- 3. Fellowships—as necessary.
- 4. Local costs—WHO would provide funds for payment of salaries, travel, per diems, and contingencies for additional full-time personnel up to Rs. 1,125,000 per year.
- 5. Additional assistance—personnel and financial and technical assistance would be provided when mutually agreed upon.

Commitments of the government

- 1. Appropriate facilities for storage, internal transportation, and distribution of WHO supplies and equipment would be arranged by the government.
- 2. Necessary telephone, telegraph, and postal communications would be supplied for project personnel.
- 3. Fuel, maintenance (including staff), spare parts, and registration and related charges required for the vehicles provided by WHO would be supplied by the government.
- 4. Activities for health education of the public and public information would be performed.
- 5. Necessary incidental expenses would be provided.
- 6. Office accommodations, furniture, equipment, stationery, secretarial assistance, telephones, and telegraph and postal communication for international personnel would be made available by the government.
- 7. Transportation at the duty station for international personnel would be provided.

- 8. Assistance in obtaining suitable residential accommodations for international personnel during the period of their official duties in India would be provided.
- 9. Such other facilities as agreed upon between the government and WHO would be provided.

The government of India agreed to report progress of the project to WHO, to notify WHO of estimated costs to the government of carrying out commitments, to make evaluation facilities available to WHO, and to assume responsibility for dealing with claims brought by third parties against WHO and its representatives.

After the original Plan of Operations, WHO and the government of India agreed on twenty addenda to aid the implementation of the program between December, 1970, and December, 1976. These addenda were formalized through exchanges of letters that addressed matters such as the assignment of personnel, increases in supplies and equipment, and other additional assistance that needed to be provided as the program intensified.

Almost half of the addenda authorized the provision of vehicles and supplies, such as jeeps to transport field workers through difficult terrain and refrigerators for the storage of vaccine. (First, Second, Seventh, Tenth, Eleventh, Fourteenth, Fifteenth, Seventeenth, and Eighteenth Addenda).

The Third Addendum (September 15, 1971) allowed for the establishment of a training course on smallpox eradication for program officers at the state level and medical officers at the district level in the northern states, where smallpox incidence was greatest. The intensified course was planned to last three days and included approximately forty-five participants.

The Fifth Addendum (February 14, 1973) provided technical staff to the project in 1973 and 1974. For both years, four epidemiologists were to be provided, along with three epidemiologist-consultants for three months in 1973 and two months in 1974 and two additional temporary advisors for one week in 1973. In both 1973 and 1974, three two-month fellowships for training in surveillance activities were to be provided, and another training course, to be held for one week in 1973 with forty participants, was planned. Subsidies for salaries, travel, per diems, and a contingency for additional personnel employed full time at national and state levels were set at \$50,000 in 1973. In the smallpox campaign in India, WHO exhibited flexibility in its operating policies, which improved its ability to respond to special needs of the program on the subcontinent. Through the Fourth Addendum in January, 1973, WHO for the first time authorized the use of local subsidies to cover expenses of gasoline and minor repairs of vehicles. At the same time, it specifically provided one jeep to each of the four WHO medical officers assigned to the project in India. In September, 1973, WHO significantly altered its assistance policy as stated in the Plan of Operations by authorizing the purchase of thirty-seven jeeps of Indian manufacture for use in the program in that country as part of an increased effort to eliminate endemic foci (Seventh Addendum).

By June, 1973, the government of India was planning an intensive three-month autumn campaign, focusing on the most highly endemic areas of India. The purpose of the autumn campaign was to "accelerate the elimination of smallpox in the highly endemic states of India and to prevent importations in the smallpox-free areas." In order to aid this intensified effort, the Sixth Addendum (June 14, 1973) authorized that an additional four medical officers be assigned for two years to assist the program at the state level.

Recognizing the importance of continuing to strengthen the campaign during the critical pre-monsoon period of 1974, WHO and the government agreed to assign five WHO consultants as replacements, plus an additional six consultants for the three months from March until the monsoon (Ninth Addendum). During this period the government further intensified the active search and outbreak containment campaign.

In May, 1974, the Twelfth Addendum provided replacements for the 11 WHO consultants provided by the Ninth Addendum and the 7 other medical officers (who would be away during the monsoon months) in order to maintain increased staffing during June-August. For the "substantially increased effort in the eradication programme" described in the Thirteenth Addendum of July, 1974, WHO agreed to supply approximately 103 special epidemiologists, 9 administrators and operations officers, 81 surveillance teams, and 45 special containment teams throughout the monsoon period and until the end of December.

By 1975, as the intensified campaign was winding down, WHO and the government were implementing plans for resource needs

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for a year at a time. In the assistance planned for 1975 in the Sixteenth Addendum, four epidemiologists for the year and eighteen months of consultants were provided, as well as two fellowships for the training of national staff in surveillance. The Nineteenth Addendum provided assistance for 1976, including four epidemiologists for twelve months each and two consultants for three months each. The Twentieth Addendum, providing assistance for 1977, also provided four epidemiologists for one year each and allowed four consultants for six weeks each. The subsidies for salaries, travel, per diems, and contingencies for additional personnel rose from only \$100,000 in 1975 to \$150,000 and \$314,000 in 1976 and 1977 respectively, when the subsidy also included the cost of increased reward publicity after eradication was believed to have been reached.

Appendix 2 The Management of Smallpox Eradication: Organizational Charts 

	Coordination		Collection and Dissemination of Information			Provision of Goods and Services			Financing			
	1962	1970	1974	1962	1970	1974	1962	1970	1974	1962	1970	1974
GOVERNMENT OF INDIA: institutions with direct responsibility to DGHS (central) Ministry												
of Health state ministries	х	х	х	х	х	х		х	х	Ŕ	х	х
of health district health	Х	х	Х	Х	Х	Х	х	х	х	Х	х	х
offices, PHCs		····		X	Х	Х						
GOVERNMENT OF INDIA/STATES: semiautonomous institutions National Institute of Communicable Diseases Indian Council on Medical Research vaccine production			х	x	x	x			X			
institutes medical schools							х	х	х			

## CHART 1. Smallpox Eradication Network in India, Institutional Roles, 1962, 1970, and 1974

army cantonments, municipal corporations, railway, etc.	 		x				······	
INDIAN NONGOVERN- MENTAL ORGANIZATIONS corporate philanthropists (Tata organization, coal mines, etc.) other philanthropical organizations (Rotary, Lions clubs)			x			x		x x
INTERNATIONAL AGENCIES WHO UNICEF, others	x	x	X	x	x	x x	Х	x
BILATERAL DONORS SIDA, USSR, United States AID				x	x	x		x
INTERNATIONAL VOLUNTARY ORGANIZATIONS OXFAM						X		X

DGHS = Directorate-General of Health Services PHC = Primary Health Center SIDA = Swedish International Development Agency AID = Agency for International Development

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CHART 3. WHO – Government of India Smallpox Eradication Program Organizational Chart, 1970-72

Paramedical

Assistants

PHC Medical Officers

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Vaccinators

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CHART 5. State-Level Smallpox Organizational Pattern, 1973-77, Uttar Pradesh Example





District Level, 1973-77, Uttar Pradesh Example



Of the 879 primary health centers in Uttar Pradesh, 673 were in maintenance phase in 1973 and 202 were in nonmaintenance phase. BHWs and vaccinators were under the sanitary inspectors, health inspectors, and smallpox supervisors. Although sanitary inspectors were not of higher rank than health inspectors or smallpox supervisors, in practice this was usually the case.

CHART 8. Organizational Pattern at Primary Health Center Level, 1973-77, Uttar Pradesh Example



CHART 9. Organizational Pattern of Smallpox Program for Municipal Boards, 1973-77, Uttar Pradesh Example

## Notes

- 1. A Russian ampoule contains twenty doses, while an Indian ampoule contains fifteen. The Russian vaccine established quite a reputation for potency in India. Although occasionally spurned by villagers because of its perceived strength (many revaccinations with the Russian freezedried vaccine gave a positive take because the liquid vaccine used for the primary vaccination had been ineffective), its effectiveness helped motivate the change to domestic production of freeze-dried vaccine.
- 2. In addition, this focus on high-risk populations offered some of the excitement of curative medicine and relieved some of the monotony of routine vaccinations. This change—from vaccinating 600 million people to fighting a visible enemy, a disease, an outbreak of smallpox—provided a more positive atmosphere for the field staff.
- 3. Afghanistan, Australia, Austria, Belize, Bolivia, Brazil, Canada, Czechoslovakia, Denmark, Ethiopia, France, Ghana, Indonesia, Japan, Mexico, Nepal, the Netherlands, Norway, Poland, Romania, Singapore, Sri Lanka, Sweden, Switzerland, the United Kingdom, the United States, the USSR, West Germany, Yemen, and Yugoslavia. It is doubtful that any "UN army" ever had representation from so large and diverse a group of nations.
- 4. Copies of all of the proformae used during the searches are reproduced in the book *The Eradication of Smallpox from India* (Basu, Jezek, and Ward 1979).
- 5. The global commission felt that "the most innovative concept" in the Indian campaign was this "search week" program.
- 6. The request was made unofficially by two SEARO medical officers, mindful that the available government resources in Bihar were not adequate to contain the huge and growing epidemic in the 100-mile radius around Jamshedpur.
- 7. This capability was an important point first raised in the 1972 WHO seminar and now implemented.
- 8. The intervals during which smallpox remained undetected were: in Brazil, four months; in Nigeria, five months; in Botswana, from two to six months (three separate episodes); in Indonesia, eight months (large numbers of cases had occurred that were known to lower-level health staff but administrative confusion in reporting kept the outbreak hidden). In Nigeria, information about the cases was known to have been intentionally suppressed.
- 9. Two types of smallpox were of epidemiologic importance. The last

endemic case of *Variola major*, which kills 1 in 5, occurred in Bangladesh. The last case of *Variola minor*, which kills 1 in 100, occurred in Somalia.

- In addition, the distinguished scientists on the Commission included: Dr. J. Kostrzewski (Warsaw, Poland); Dr. J. Cervenka (Bratislava, Czechoslovakia); Dr. W. A. B. de Silva (Colombo, Sri Lanka); Dr. F. Fenner (Canberra, Australia); Dr. H. Flamm (Austria); Lt. Gen. R. S. Hoon (New Delhi, India); Dr. T. Kitamura (Tokyo, Japan); Dr. W. Koinange-Karuga (Nairobi, Kenya); Dr. H. Ludbeck (Stockholm, Sweden); Dr. A. M. Mustaqual Huq (Bangladesh); Dr. D. M. MacKay (London, United Kingdom); Dr. M. F. Polak (Nijimegen, Holland); Dr. R. Roashan (Kabul, Afghanistan); and Dr. U Thein Nyunt (Rangoon, Burma).
- 11. Later there were two rewards, one to the general public who reported and a duplicate reward to the health worker receiving the report.
- 12. The economic analysis presented here is that of M. C. Zebrowski, a policy analyst formerly at the University of Michigan. I am grateful to her for providing her analysis and for drafting this section.
- 13. Economists refer to "economic efficiency" (also called "Pareto optimality") as a state of equilibrium in a perfectly competitive economy, in which no one can be made better off without someone else being made worse off. However, when the desired result is to maximize welfare, rather than economic gain, the concept of economic efficiency is not very useful because it does not allow one to address the issue of disparately distributed costs and benefits among the population. Consequently, a policy analyst must somehow measure the level of social efficiency that represents the level of costs and benefits to the general public welfare, and in order to measure the level of social welfare resulting from a health program, costs and benefits must be translated into some comparable unit, such as national currency. Where market prices are unattainable or inappropriate, shadow prices must be calculated. Pareto optimality is an economic term more useful to theory than applicable to practice, for it assumes not only perfect competition but also the absence of externalities. Externalities, defined as uncompensated costs and benefits that accrue as a result of an action, are generally quite widespread. For example, the Tata family offered both staffing and managerial skill to the smallpox program to aid the containment of smallpox in Jamshedpur. After the epidemic was overcome and the Tata help was ended, the health workers involved in this campaign no doubt retained managerial knowledge that the Tata staff had taught them; however, this social benefit is not included in economic gains to society, because it cannot be easily estimated.
- 14. The question of the economic value of lost productivity in a situation of underemployment is controversial and is beyond the scope of this analysis.
- 15. The discount rate in the private sector is usually the market rate of

interest, i.e., the rate at which a person can gain the most by investing his available resources. In order for him to be willing to defer consumption, his personal discount rate must be lower than the prevailing market rates; otherwise he would prefer to spend his money now. The social rate of discount is usually much lower than the market rate, for society generally does place a high value on future consumption; however, economists do not agree on the appropriate social rates of discount for various social programs.

- 16. It could not have been predicted beforehand just where that threshold would be, because no one knew how many resources would be needed to eradicate.
- 17. The percentage of funds supplied by each source for the period from when WHO first began giving assistance to the NSEP until eradication was as follows: central government 34 percent (1970–73), 36.7 percent (1974–77); states 63.6 percent (1970–73), 40.7 percent (1974–77); WHO 2.4 percent (1970–73), 21.3 percent (1974–77); and bilateral donors 1.3 percent (1974–77). Most of the 21.3 percent that WHO contributed in 1974–77, however, was donated by SIDA to WHO specifically for the Indian smallpox program.
- 18. The India smallpox program archives are available on microfilm at WHO, Geneva. See Hughes et al. 1979.
- 19. WHO memorandum, J. F. Wickett to record, January 17, 1978. Again, there is the problem of loss of productivity in a situation of less than full employment.
- 20. The actual figures were 63,890 workers during the searches in 1973, 80,847 in 1974, 116,829 in 1975, 134,412 in 1976. Of these, approximately 80 percent were searchers, 17 percent supervisors, and 4 percent medical officers who assessed field operations. Only 21,161 were vaccinators or supervisors on the NSEP payroll; the rest were deputed from the malaria, trachoma, leprosy, and family-planning programs or dispensary or PHC staff.
- 21. These calculations are based on age-specific morbidity and mortality rates found in an analysis of 23,546 cases during the intensified campaign (1974–75) and a multiplier using the average yearly death toll of 22,036 with 46,512 nonfatal additional cases (the reported averages before the NSEP began). These figures are no doubt conservative due to under-reporting and population growth. We have also assumed a fifty-year life expectancy at birth, and a per capita gross national product (GNP) of \$110 per year. Expected years of life remaining at each age were calculated from life tables in government of India sources based on the 1970–71 census.
- 22. According to Basu, Jezek, and Ward (1979), only 2 to 10 percent of all smallpox cases that occurred before 1972 were ever reported. This means that the original calculation of \$0.2 million per year in productivity lost as a result of morbidity may, in fact, be as much as \$2 million per

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year. (Nonfatal smallpox cases were much less likely to be reported than were deaths due to smallpox.)

- 23. The hypothesis says that as long as parents cannot expect all their children to survive (due to ubiquitous diseases that cause childhood mortality) they will not voluntarily reduce fertility unless external sanctions, forces, or incentives are imposed. The correlate is that improved infant and childhood survival rates and the elimination of obvious and accustomed childhood killers like smallpox will motivate families to reduce fertility.
- 24. It should be noted that this calculation includes only direct program costs and only those benefits related to productivity; other marginal costs and benefits are very difficult to calculate.
- 25. It is interesting to note that the estimated annual savings for smallpox eradication in the United States in 1968 (\$150 million) was the same as the savings to India in 1980 (\$150 million).
- 26. This figure, stated in Annex 14 of the Global Commission Report (Global
- Commission for the Certification of Smallpox Eradication 1979), includes WHO regular budget and voluntary fund expenditures, bilateral aid, and an estimated figure for national expenditures.
- 27. Some mistakes were brought about by this sense of urgency. Once the smallpox unit at SEARO sent an order to Geneva for items not available in India—photocopy paper, electric typewriter ribbons, and the like. The order, to be airshipped to New Delhi, inadvertently contained other office supplies, including paperclips. It is easy to understand the outrage felt by the chief of administration and finance upon checking the order and finding that paperclips had been airfreighted from Geneva to New Delhi, certainly not the best example of appropriate technology, thrift, or good management. But such mistakes were the exception, and in a program that imported 6,696,750 bifurcated needles and thousands of other items, such errors are to be expected.

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