Chapter 2

MULTIPLE PROTECTIVE SHELTERS

Chapter 2.— MULTIPLE PROTECTIVE SHELTERS

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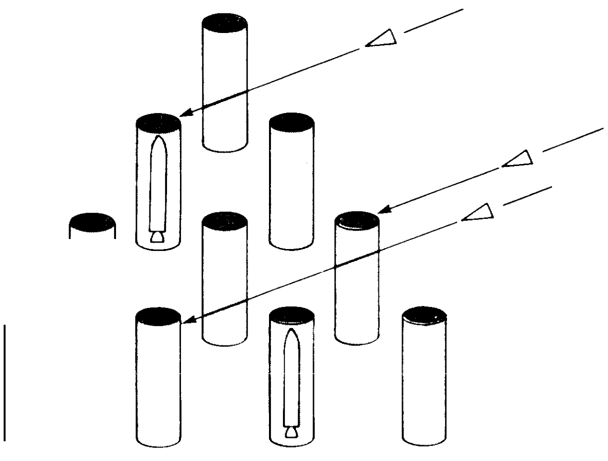
MULTIPLE PROTECTIVE SHELTERS

OVERVIEW

The multiple protective shelter (MPS) concept seeks to maintain the capabilities of a fixed land-based ICBM force, while protecting the force from Soviet attack, by hiding the m issiles among a much larger number of missile shelters (see fig. 9). If the attacker does not know which shelters contain the missiles, all the shelters must be attacked to ensure the destruction of the entire missile force Thus, the logic of MPS is to build more shelters than the enemy can successfully attack, or at least to make such an attack unattractive by requiring the attacker to devote a large number of weapons to attack a relatively smaller force.

In this chapter, the theory, design requirements, and some of the outstanding issues of MPS are addressed I n particular, the technical and operational requirements of hiding the missiles among the shelters, forma I I y known as preservation of location uncertainty (PLU), are examined This would be a new task for missile land basing, and it is now appreciated as one of the more challenging aspects of MPS. The compatibility of the missiles' location uncertainty with arms control monitoring is also discussed

Figure 9.— Multiple Protective Shelters (MPS)



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Inherent in the strategy of MPS is that the number of shelters constructed be keyed to the size of the Soviet threat. Growth i n the number of accurate Soviet warheads would require a larger deployment of missile shelters to maintain the same expected survival rate for U.S missiles. The sensitivity of missile survival and shelter number to the size of the Soviet threat is discussed by performing several MPS calculations related to possible Soviet growth The consequences of an "undersized" MPS are a I so exam i ned, and shelter number requirements are calculated.

These issues, keeping the missiles successfully hidden and determining the proper size of the MPS, are common to any MPS-basing mode, and are analyzed in detail in the section on the theory of MPS.

Much of this chapter is devoted to specific designs for an MPS, with a great deal of attention devoted to the Air Force's baseline system. This system has been in full-scale engineering development since September 1979, and was modified in the spring of 1980 to include a horizontal loading dock configuration for the missile shelter. As proposed, the baseline system consists of 200 MX missiles among 4,600 concrete shelters, with each m issile deployed in a closed cluster of 23 shelters. These shelters would be spaced about 1 mile apart and arranged in a linear grid pattern. Each shelter would resemble a garage, or loading dock, into which a missile could be inserted horizontally. Missile location uncertainty would rely on the use of specially designed missile decoys of similar, though not identical, physical characteristics to the real missile, and the employment of operational procedures that would treat missile and decoy alike. Large transport trucks could shuffle missiles and decoys among the shelters in order to keep the precise location of the missiles unknown to outside observers. Descriptions are provided of the layout and operation of this basing, m issile mobility and the "dash" option, command, control, and communications (C3), and estimates for system cost and schedule Air Force criteria used for siting the MX, and its regional impacts are also addressed.

In the discussion of regional impacts, emphasis has been on two particular issues. Because the A i r Force has already completed extensive studies and has published almost so volumes of materials (MX: Milestone II, Final *Environmental impact Statement; Deployment Area Selection and Land Withdrawal A cquisition, Draft Environmentl Impact Statement; and MX: Environmental Technical Reports)* relating to the environmental impacts of MX/ MPS basing, no attempt has been made to catalog the potential environmental impacts, to evaluate independently all of those impacts identified by the Air Force, or to critique the Air Force environmental impact statements (EISs), Instead, those documents have been used as resources, and attempts have been made to draw attention to those issues that are believed to be of most importance to the congressional decision making process, For more detailed information on particular impacts associated with MPS, reference should be made to the Air Force E I S documents and comments by the States of Nevada and Utah.

A variation of the proposed system would be split basing, where the system would be deployed in two noncontiguous regions of the country: the Great Basin area of Utah and Nevada, and the border region between Texas and New Mexico, This basing scheme would mitigate the regional impacts, at some addition to system cost.

In addition to discussions of the Air Force baseline system and split basing, several alternative MPS designs are examined. All of these have been studied in the past, but rejected by the Air Force for various reasons. These designs include housing the MX missile in conventional Minuteman- like vertical shelters, rather than the horizontal shelters of the A i r Force basel inc. Greater hardness against nuclear attack could be achieved with vertical shelters; however, missile mobility would be somewhat simpler with horizontal shelters.

Two previous baseline modes for the MX are also) discussed: the "trench" design, where the missile would reside in a long concrete-hardened tunnel several feet underground, and the so-called "roadable TEl," the immediate predecessor of the present baseline, where the missile and transporter were structurally integrated, and therefore had greatly enhanced molbil it y.

Another possibility would be the deployment of *Minuteman ///* missiles in an MPS mode, by constructing a large number of add itional vertical shelters in the present Minuteman missile fields. Proponents of this system claim it would provide an accelerated schedule for a survivable land-based missile force, since Minuteman missiles, support infrastructure, and most roads are already available. Mod if i cations to the Minuteman missIle would be required to deploy it in a mobile mode, and many additional shelters and missile transporters would need to be built. The extent of these and other modifications is addressed, as is system cost and schedule for completion.

Finally, several calculations of civilian fatalities resulting from a Soviet attack on MX deployment in multiple protective shelter fields are presented. These calculations help address the question of the extent to which a Soviet strike against an MPS deployment could indeed be regarded as " limited, "

THEORY OF MULTIPLE PROTECTIVE SHELTERS (MPS)

A land-based missile force in MPS relies for its survivability on the assumption that the attacker, in order to destroy the adversary's missite force with confidence, will be forced to target al I or most of the shelters if it is not known which of these shelters contains the missiles. MPS thus tries to draw a distinction between missile and target, by “immersing” the missile force in a “sea” of shelters.

MPS can also be regarded as “anti-MIRV” basing Just as MIRV (multiple independently tar-gettable reentry vehicle) technology allows one to attack many targets with one miss i le, MPS forces the attacker to devote many warheads to destroy one real target.

For this strategy to work, the tasks of “hiding” the missiles among the shelters and properly sizing the MPS system for a given level of survivability involve two key requirements Since the nature of these two tasks is similar for all MPS basing modes, their details and implications are discussed in this section of the chapter.

Preservation of Location Uncertainty (PLU)

Inherent in the strategy of MPS is that all shelters appear to the attacker as equally likely to contain a missile This assumption is important, since if the attacker were to find out the location of all the missiles, it would defeat the design of the system For the planned 200 MX missile deployment, for example, it could mean targetting as few as 200 reentry vehicles (RVS), one RV per MX missile, which is a small portion of the Soviet Union’s arsenal. The task of PLU — or keeping the missile location secret — is essential to successful MPS deployment. With increased study of this issue over the last few years, the defense community has come to realize the magnitude of the PLU task. What makes PLU so challenging is that It is a many faceted problem, dealing with a variety of missile details Moreover, PLU must be made an integral part of the design process at every level. Furthermore, the present expectation is that the design process for PLU will be ongoing throughout deployment, with continuous efforts at enforcing and improving missile location uncertainty through improved PLU countermeasures and operations,

To accomplish this task of missile concealment, it is necessary to eliminate all indications, or signatures, that could give away the location of the missile One such set is the set of all physical signatures of the missile and associated missile equipment. This set includes weight, center of gravity, magnetic field, and many others By utilizing these physical signatures, missile location might be inferred by making measurements outside the shelter or missile transporter, looking for those signatures that could distinguish location of the missile. Such signatures span the spectrum of physical phenomena, many with a range of detectability of hundreds of miles, if not adequately countermeasure.

A second set of missile signatures to be eliminated are operational signatures The task here is to eliminate all operating procedures that could distinguish the missile and thereby betray its location. Otherwise, missile placement might be inferred by observing personnel operations.

Internal information is a third set of signatures. This set includes the piecing together of many observations to arrive at a pattern recogn it ion of data from which one can infer missile location.

Soviet espionage efforts aimed at breaking PLU will also be likely, and counterintelligence efforts may be necessary.

Signatures

PHYSICAL SIGNATURES

The physical signatures of the missile run into the scores, with the magnitude and range of each dependent on design details and material construction of the missile, shelter, and transporter. Against each of these signatures that might compromise missile location it is considered desirable to design and install a set of specific countermeasures. These countermeasures include simulating missile signatures with decoys, masking or reducing the magnitude and range of the signatures, and confusing an outside observer by engineering a set of signatures that vary randomly from decoy to decoy in order to make it more difficult to determine which shelters contain the missiles.

Table 2 is a generic list of associated missile signatures present for any MPS system. A brief discussion of them is included here along with some possible countermeasures. A more detailed list and analysis is included in the classified annex.

1, Seismic/ground tilt results from the force of missile weight on the ground, both as seismic waves set up by the motion of the missile in transit, and static measures of its mass, such as the tilt of the ground in the missile's proximity, The seismic signature is particularly significant while the missile is in transport between shelters, since seismic waves can propagate for miles, with a falloff in wave amplitude that varies inversely with distance. Ground tilt caused by depression of the ground under the missile-laden transporter falls off somewhat faster with an inverse square law, and a maximum ground depression of the order of thousandths of an inch. The resulting ground tilts are measurable at a distance, A countermeasure for this signature may include a mass decoy.

2. Thermal sources arise from heat generated by electrical equipment associated with the missile, such as fans, heaters, and other environmental control systems. A measure of this heat is the power consumed by each shelter, typically 10 to 20 kilowatts (kW) at full operating power, Countermeasures for this signature might use thermal insulation and dummy powerloads at the unoccupied shelters.

3. Acoustic sources are due to such items as cooling fans and missile transfer operations at the shelter site. This signature might be countermeasure by simulation, such as suitably emplaced recording and playback devices.

Table 2.—Physical Signatures of Missile

• **Seismic/ground tilt**	• **Nuclear**
• **Thermal**	• **Radar**
• **Acoustic**	• **Gravity**
• **Optical**	• **Magnetic**
• **Chemical**	• **Electromagnetic**

SOURCE Off Ice of Technology Assessment

4. Optical signatures are significant primarily while the missile is in transport. Assuming that the transporter is covered, so that the missile is not directly visible, concern must be shown for the modal oscillations of the missile transporter in a loaded v. unloaded condition, tire deformation, exhaust smoke, and vehicle sway angle around corners. Sensors that might pick up this distinction range from sophisticated optics aboard a high flying plane to ground-based lasers or even observation with binoculars at a distance. A possible countermeasure for this signature is a massive decoy of the same weight and similar vibrational characteristics to the missile.

5 Chemical signatures are due to the routine volatile chemical release from the missile, such as propel I ant, coolant, plasticizers, and ozone. The missile transporter exhaust may a Isc) differ for a loaded v. unloaded case. Chemical concentrations are expected to be as high as 1 part per million (ppm), and methods of detection include laser scattering infrared absorption, Raman spectroscopy, and taking onsllte samples for later analysis, Countermeasures may include simulated effluents and a massive decoy load for the missile transporter,

6. The nuclear warhead on the missile has its own signature characterized by a set of gamma ray spectral lines particular to the plutonium isotopes contained in it. The warhead material also emits neutrons. Useful countermeasures include radioactive shielding,

7. Radar is a potential signature due to the large radar cross section of metal objects associated with the missile, such as launch equipment. I n addition, distinguishing the modal oscillations of the transporter due to different loacls may be radar detectable from a distance of several hundred miles. Countermeasures for radar include a massive missile decoy, and reliance on the metal rebar and a steel line for the shelter as well as earth overburden to radar-shield its contents,

8. Gravity field and field gradient measurements should be able to detect the mass of the missile at a range of several hundred feet.

Mass simulation is the most direct countermeasure to this threat

9. Magnetic field anomalies due to the large amounts of metal in the missile-launching equipment, if unshielded, can be detected by a magnetometer. Such detection techniques are analogous to magnetic anomaly detection of submarines, and similar countermeasures can be utilized. A missile decoy containing an appropriate quantity and distribution of high permeability (magnetic) metal might be used to help prevent an observer from distinguishing it from the missile.

10. Electromagnetic emissions generated by missile equipment during normal operations are another potential signature. In addition, radio frequency communication involving the missile could lead to missile location determination by radio direction-finding techniques Electrical transients may also be detectable Countermeasures to these signatures might consist of simulating powerline consumption by installing dummy loads inside the shelter, and communicating with the missile during normal operation over secure buried cable, rather than radio

The task for a potential attacker to defeat MPS by utilizing these signatures depends on the range of the signature to be exploited, the covertness needed to collect and transmit the data, and the degree of security provided for the MPS deployment area Presently planned security arrangements for the shelters are commonly reterred to as point security, Point security allows public access to all but a small restricted area around the shelter, and therefore allows access relatively close to the missile shelter Area security, on the other hand, would restrict access to most of the deployment area

Designing PLU for short-range observation, which is anticipated for point security, is more demanding than for long-range surveillance, since most, though not all, of the missile signatures are signiticantly stronger at close range For example, magnetic anomaly detection, which relies on measurement of magnetic tield gradients, falls off as the inverse cube of the distance from the source. This means that the strength of this signature at 100 ft is more than 1 million times as intense as this signature would be at some 2 miles away. Since close-in the magnetic details of the source become more important, the distribution of magnetic material in the decoy is more critical for adequate deception than it would be for distant observation.

In addition to the short-range signatures, there are also long-range signatures, such as detailed motions of the missile transporter and seismic waves, that are measurable at many miles.

The range of missile signatures strongly determines the degree of covertness that an agent must employ to collect missile location information. A signature that is visible at long ranges might require little or no cover to observe. In particular, long-range signatures would be particularly threatening if observable by satellite, since security would have little effect; and the impact on PLU would be catastrophic if such signatures could not be successfully countermeasure. Similarly, signatures that are measurable at several miles or tens of miles are also particularly threatening, since security sweeps would be impractical over so large an area, even if possible. In the case of long-range surveillance, the number of sensors needed would be small compared to the number of shelters, with the precise number dependent on signature range. It is not clear whether covert operation of sensors would pose a problem to the Soviets if they found a signature that was observable at such ranges On the other hand, short-range signatures would require some degree of covertness, perhaps by an implanted sensor, a roadside van, or "missile sensing" done under the guise of another activity, such as mining. Once missile location is determined there are a number of ways to transmit the information covertly.

For short-range shelter surveillance, many emplaced sensors, on the order of thousands, would be necessary to seriously degrade PLU, since a large portion of the shelter deployment would require independent observation. This task could pose a severe problem for the enemy agent. I n addition, the areas proximate to the shelter would quite likely be subjected to frequent sweeps by security forces. On the other hand, covert sensors that could detect missile presence in the transporter, while the missile is in transport, could be much more serious. Since point security would not secure the roads, implants in the roads must be prevented from determining the contents of the transporter. In a linear cluster arrangement, for example, if PLU on the transporter were to fail, then *one* missile-sensing device planted in the middle of the cluster would be able to determine which half of the cluster contained the missile, thereby effectively reducing the number of shelters in half, Therefore, PLU is particularly important for the transporter, and it must be constantly supplemented by security sweeps of the road network.

The Air Force program for deal ing with physical missile signatures consists of several approaches, the first of which is to eliminate the signatures, if possible, by system design. For example, if one construction material has a smaller signature than another, using the first material might be preferable, An example of this might be the use of nonferromagnetic material, if practical, rather than iron, in order to reduce or eliminate the magnetic signature.

These technical design requirements due to PLU have been established for the launcher, the mass simulator, the protective shelter, and the transporter. The list of these requirements needed to countermeasure the missile/launcher signatures, some of which were listed in the previous section, and the many others that are system- particular, is a very long list, that is discussed more fully in the classified annex to this sect ion

The second approach to countermeasure physical signatures after attempting to design them away could be to attenuate the signature by shielding. For example, heavy material shields gamma radiation. Thermal insulation might be used for heat signatures, and so forth.

A signature that cannot be designed away or attenuated might conceivably be masked or jammed, For example, a real signature that is measurable might be masked by an additional large, possibly random signal, thereby making it more difficult to extract the real missile signature from ,the “noise. ”

If these approaches were not feasible, an attempt to simulate the signature by the use of a decoy might be employed. This simulation is one of the purposes of the MX mass simulator, which will be placed in all of the unoccupied shelters, and in the transporter when simulating missile transport, Since the simulator is designed to weigh the same as the missile/launcher, it automatically countermeasures those signatures that arise from total weight. As discussed in the classified annex to this section, additional simulations will be required.

Finally, there can be physical security for the deployment area that would consist of monitoring the area and sweeps for sensors that might compromise missile location

OPERATIONAL SIGNATURES

In addition to physical missile signatures, it is necessary that routine procedures of missile transport and maintenance do not expose the location of the missile, This consideration means that when carrying out missile-related and mass-simulator-related operations, personnel must do the same things, in the same time interval , with the same equipment at al I sites. For example, when it becomes necessary to return the missile from maintenance to the shelter, the transporter must visit all of the shelters and either deposit or simulate deposit of the missile. I f the operator knows in which shelter he is depositing the missile, care must be taken that any actions on his part, such as outward behavior or conversation with colleagues, do not give clues to missile location.

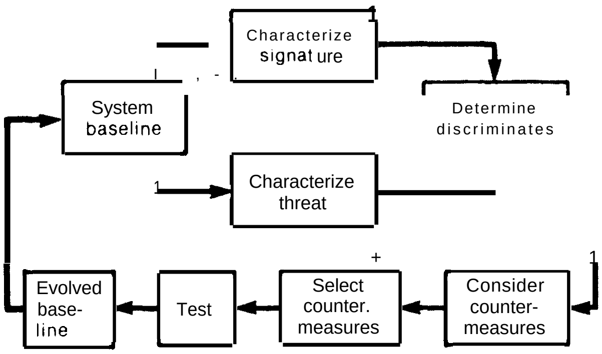
INTERNAL INFORMATION

This category includes piecing together many observations to arrive at any pattern recognition of data from which one may infer missile location, To deal with this consideration, the Air Force has set up a special compartment for PLU-sensitive data. Special access would be required to acquire this information. In addition, operational personnel will be constrained in their knowledge of missile locations. Under normal circumstances, maintenance and operational personnel will know the locations of only a small percentage of the missile force and the contents of the shelters.

PLU Design Process

Since the scope of PLU design is so broad, and the threat to PLU adaptive, the Air Force's overall approach to this task would be an iterative process (see fig. 10). Starting from the system baseline defined at a particular time, work would proceed to characterize missile signatures and the threat to the system, in terms of sensors available to the enemy and their access to the system. From these assessments, a determination of potential signatures would be made that offers a discriminant for the missile. Countermeasures would be developed, selected, and tested. Those countermeasures chosen would be made part of the new baseline. This process would then repeat itself. Thus, PLU work must be a continuing process, with signature characterization and needed mitigation an ongoing effort. In terms of schedule, signature testing on system components is underway now. Small scale testing for signatures will be done in the latter half of

Figure 10.—Preservation of Location Uncertainty and System Design



SOURCE U S Air Force

1981 through the Spring of 1982, with full-scale testing in the latter part of 1982 through 1983. These tests will be critical in the design of the transporter and mass simulator, as well as for the entire PLU task.

Assessment of PLU

Assessing the feasibility of the PLU effort is a difficult task. First, it is a genuinely new problem, and not a simple extrapolation of past engineering efforts. Since missile signatures and their countermeasures sensitively depend on the detailed design of the system, it is difficult and can be misleading to make general statements about PLU.

No physical analysis is known that can argue that PLU is a physically impossible task. Its analyses and countermeasures rest on well-understood physical principles. Until recently, however, there has been no research and development program on PLU, nor have there been full-scale field tests to validate many of the conjectures and analytical tools needed to design the system. In terms of PLU's scope, its detail-intensive character, and simply as a new technical problem, comparable previous experience or data are not available to guide in judging its feasibility. It is true that there is some analogy with submarine detection and location. Indeed, some PLU signatures, most notably magnetic, are common with submarines. Still, there are two important distinctions. First, in antisubmarine warfare (ASW), there is no present need to discriminate the actual submarine from a decoy, although resolving a submarine signature from a noisy background may be one of the lead tasks. Second, at a technical level, the details confronted with PLU and ASW are quite distinct. The environments and media are different, and the relevant signatures and the available distance at which the measurements can be performed are different (much closer for MPS). Simply stated, solving the technical ASW problem does not significantly help solve PLU, and vice versa.

In addition, it is not known at this point of technical PLU work, how feasible it will be to eliminate, attenuate, mask, simulate, or randomize *all* of the missile's signatures, or what the residual signatures will be. Since this is a detailed engineering task, confidence cannot be obtained until full-scale field tests have been done, when missile signatures can be more retiably identified and analyzed.

Thirdly, it may not be possible to be certain that PLU has not been broken by the Soviets; a break (or even a small fracture) of PLU may likely be a silent event. For all the scores of signatures that have been successfully countermeasure, it takes only one accessible uncountermeasured signature to imperil the survivability of the entire missile force. On the other hand, it is reasonable to expect that personnel running a vigorous program to monitor PLU in operation will be more aware of compromises in the system than an outside agent would likely be, Furthermore, a compromise in PLU would not necessarily be catastrophic, since a breach in PLU for several shelters or even several missiles would not significantly threaten the entire force. In any case, confidence in our having PLU is an important factor in its own right. In addition to being based on knowledge of our own system, confidence is also a state of mind, and not always easy to judge or predict,

Finally, the extremely high value of the knowledge of missile location must be emphasized. Because this knowledge holds the key to MX survival in a Soviet attack, a vigorous Soviet effort in this area should be expected, underscoring the technical and operational importance of the PLU effort. The Air Force effort for PLU, which several years ago may have underestimated its scope and difficulty, has more recently proceeded with a program that is comprehensive and realistic in its approach. However, whether this or any other program will succeed in developing a technology that will successfully keep the missile hidden is a technical assessment that cannot be made at this point, at least until full-scale hardware exists and can be tested for all missile signatures,

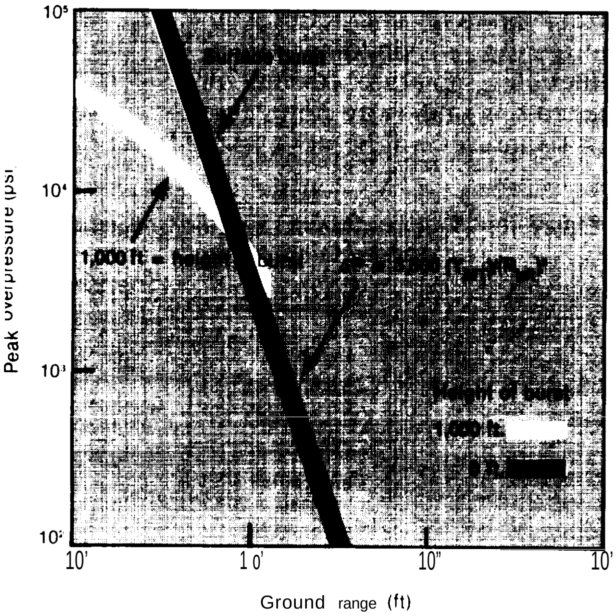
Sizing the MPS System

For MPS to provide a given degree of survivability to its missile force, an adequate number of shelters must be deployed so that the entire system can absorb an attack, and still leave the required fraction of the missile force intact. Determining the number of shelters to be built and the deployment area of the system depends on a number of factors: the hardness and spacing of the shelters, the accuracy and reliability of enemy missiles, the number of threatening warheads, and the size and survival requirements of the U.S. missile force,

Since the idea of MPS is not to build a shelter that can survive a direct hit, but one that can survive the effect of direct hits on its neighboring shelters, the requirements for shelter hardness are much less than for the typical Minuteman silo.

The overpressure experienced by the shelter depends on its distance from the nuclear detonation(see fig. 11). For any MPS system,

Figure 11 .— Peak Overpressure From 1-MT Burst



SOURCE RDA

there is a tradeoff between shelter hardness and shelter spacing. The harder the shelter is made, the closer the shelters can be spaced and still withstand the effects of nearby nuclear detonations. Conversely, the farther apart the shelters are spaced, the less hard the shelters need be made. I n practice, the shelter spacing and hardness combination is determined by cost trade-offs between increased shelter hardening (that requires a larger shelter and more concrete) and increased shelter spacing (that requires more roads and buried communications and electrical connections between shelters), in order to reach a cost minimum solution.

The reliability and accuracy of enemy missiles are also important factors for deciding how many protective shelters to build, Reliability is the probability that the missile, when given the order to fire, will fire and operate properly along its trajectory. When planning for shelter deployments, more shelters will clearly be needed for a high enemy missilereliability than for a low one. Missile reliabilities are typically between O 8 and and 1.0, and their effect on vulnerability calculations will be illustrated later in this section.

Missile accuracy is a measure of the missile's ability to land a nuclear warhead on its target Typically, missile accuracy is measured in terms of CEP, or circular error probable. CE P is defined as that distance from the target within which half of the warheads would land if target ted A large CEP means a less accurate missile; a small CE P means a more accurate missi le.

Missile Accuracy depends on a variety of factors, both internal and external to the missile The heart of the missile's guidance lies in its inertial measuring unit (I MU). Placed in the upper stage of the rocket, the IMU senses missile accelerations throughout the boost phase, integrates the signals to get velocity and position data, and uses this data to navigate the missile to the warhead's release point Contributions to target miss, called the error budget, include the following items:

- small errors of instrumentation and calibrat ion,
- knowledge of initial position and velocity of missile,
- I MU platform alignment,
- knowledge of gravity for the launch point region and missile trajectory,
- knowledge of target Iocation,
- RV separation from the missile bus, and
- errors during atmospheric reentry.

Knowledge of the missile's CE P and *reliability,* and the hardness of the target, allow the pro bability to be calculated that the target will be destroyed in an attack There are standard tables for this calcutat ion, but for present purposes, the following formula is adequate tor the probability that a reliable RV will destroy its target, or pk:

$$P_k = 1 - \exp1 \quad 26(YH$$

where

P_k = the probability of kill
Y = the yield of the weapon, in megatons
H = the hardness of the shelter, in thousands of p\ I
CEP = circular error probable, In kilofeet (thousands of ft)

For example,

Yield Y = 1 MT
Hardness H = 600" PSI (or () 6 thousand psi)
CEP = 1,800 ft (or 1 .8 k ilofeet)

then

P_k = 50% (or 0.5

This answer corresponds to the fact that the 600 psi contour for a 1 MT detonation occurs at the 1,800-ft contour. Since, by definition of CEP, half of the time the weapons would fall within 1,800 ft of the target, and halt of the time they would fall outside 1,800 ft, then the probability of k ill is exactly so percent

Typically, modern intercontinental ballistic missile (ICBM) accuracy is much better than this, and for shelters of hardness less than 1,000 psi, the probability of k i I I (given the proper yield) is close to 100 percent (or 1 .0). Furthermore, the furture trend is for pk to be so close to one that the expectation of destroying a I most any such target is approximately equal to the retiability of the attacking missile

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An MPS Calculation

A typical MPS calculation is now performed Suppose the reliability of the attacking missile times its Pk (which is the expectation of destroying the target) is 0.85, for example. Suppose further that there are 4,000 attacking warheads of I-MT yield each. The expectation is that this attack can destroy (4,000) x (0.85) = 3,400 shelters. Therefore, after such an attack, an MPS force of 6,800 shelters would have half of the shelters remaining. Without the attacker's knowledge of missile location it could be expected that half of the missile force would also survive (see table 3).

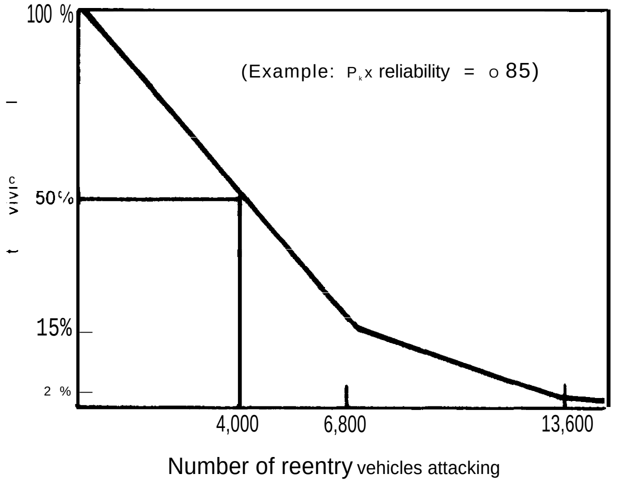
To address the sensitivity of missile survival to the size of the threat, using the above example as a base case, the percentage of surviving missiles v, number of threatening RVS is shown here in figure 12. As before, a reliability of 0.85 and a pk close to one is assumed. The number of surviving missIles falls off Iinearly with increasing numbers of attacking RVS at the rate of 0.85 shelters per RV, until RV number equals shelter number, 6,800 At this point, 1,020 shelters would remain, or 15 percent of the missile force would survive, If the attacker chooses, and if he has the warheads, he can attack with a second round of RVS. Assuming that he does not know which shelters he destroyed during the first round, he attacks all of the shelters again, with a 15-percent efficiency of targeting among the shelters that are still standing (since 15 percent of the shelters survived after the first round). Ideally the second slope is 15 percent of O 85, or 0.1275 shelters destroyed per RV, but fratricide effects (be-

Table 3.—MPS Example

Assume:
•200 MX missiles
•4,000 attacking warheads
•0.85 probability of kill times reliability
Requirement:
•50% survival of missile force
Shelters vulnerable:
•4,000 x 0.85 = 3,400 shelters
Shelters required:
•3,400/50°/0 = 6,800 shelters (assuming perfect PLU)

SOURCE Office of Technology Assessment

Figure 12.—Surviving Missiles v. Threat Growth for MPS Example



SOURCE Office of Technology Assessment

tween the first and second rounds) might flatten out this second slope significantly.

The rationale for MPS in this hypothetical example can be seen in the following way, Suppose the MX missile were deployed in an MPS with a ratio of 1 missile per 34 shelters. This deployment includes a total of 200 MX missiles, with 2,000 Mk 12A warheads, It would take, on the average, 34 perfect attacking RVS to destroy an MX missile with its 10 warheads, or a ratio of 3.4 attacking RVS to destroy 1 MX RV (assuming we had perfect PLU). This ratio would be in contrast to undefended silo basing, where it wou Id take at most two RVS (for a much harder shelter), to destroy 1 MX missile with its 10 RVS, or a ratio of 1 to 5, in favor of the attacker.

Shelter Requirements

This discussion is completed by addressing actual MPS shelter requirements for the MX set by the size of the possible Soviet threat. As discussed earlier, any MPS system is sized, in part, to the opposing threat; there is no absolute number of shelters that will guarantee safety for the missile force, but only a number relative to the opposing number of nuclear warheads. Therefore, for MPS to be survivable, it should be keyed to and keep pace with the evolving Soviet threat. Given the size and characteristics of this threat, the calculations for shelter number are straightforward, as illustrated by the above example.

The present Air Force baseline MPS system would deploy 200 MX missiles in 4,600 shelters, with a shelter to missile ratio of 23 to 1. This system size has been related to a projected Soviet threat of approximately 3,000 accurate RVs targeted exclusively against MX. This projection assumes that: 1) Soviet warhead number is constrained by arms control agreement, and 2) within these constraints, the Soviet Union did not attempt to make an all-out attempt to overwhelm the 4,600 shelter MPS. If the above assumptions on Soviet restraint are relaxed, then the threat against MPS will grow past the nominal 3,000 RVs, and the system will *need* to respond if it is to maintain its chosen requirement for survivability. This response can take the form of building more shelters, more missiles, a cost-optimum combination of the two, or a ballistic missile defense of the system, such as a low altitude defense system (LoADS), that is discussed fully in the next chapter.

Projections for Soviet forces devoted against MX depend, in the first case, on what the Soviets decide to do with their nuclear forces. One possibility is that they concentrate their efforts to address the vulnerability of their own ICBM forces. This concentration could take the form of a mobile missile, an MPS system similar to what we have discussed, ballistic missile defense, and perhaps other measures such as very hard shelters. Alternatively, the Soviets might decide to concentrate their efforts on a counterforce capability against MX. This counterforce could take the form of modifying their present modern missiles (particularly the heavy SS-18) to carry a larger number of smaller yield warheads (called fractionation). A third possibility is a mix of the two routes described above: part addressing their own vulnerability and part counter-MX.

Any effort to estimate the size and composition of future Soviet forces is highly uncertain—our intelligence is far from perfect, and in some cases the Soviet leaders themselves may not yet have made key decisions. An approximation of the threat has been sought, however, by making a series of conservative assumptions, including:

- continuation of 1970's trends in Soviet ICBM development and deployment,
- no major breakthroughs in ICBM technology,
- no contraints imposed by shortages of critical nuclear materials, and
- SLBMs not used to target U.S. ICBM silos or shelters.

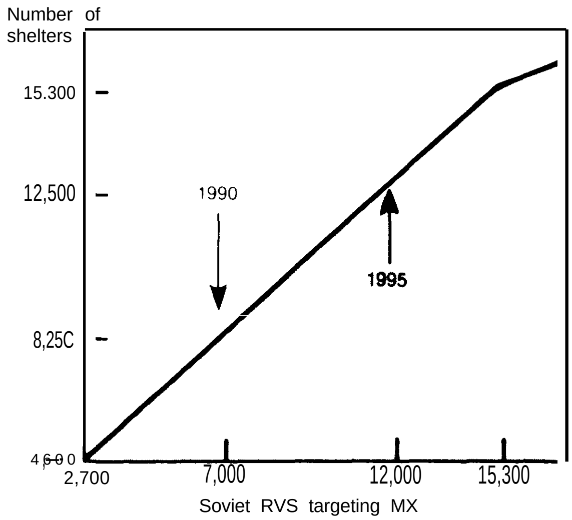
These assumptions amount to projecting the trends of the 1970's through the 1980's and into the 1990's. On this basis, an attempt has been made to estimate the number of Soviet RVs whose reliability, accuracy, and yield would be good enough to give an 85-percent probability of destroying an MX missile in a targeted shelter with a single shot.

It is estimated that the Soviets could have 6,000 to 7,000 RVs available to attack MX by 1990, and 11,000 to 12,000 RVs available by 1995. By 2000, the Soviet RV inventory could be so large that 15,000 or more could be aimed at an MX deployment. Furthermore, this rate of deployment would not require a greater Soviet effort to improve their ICBM force in the 1980's and 1990's than the effort they devoted to this purpose in the 1970's. In the face of the above Soviet threat, the baseline deployment of 200 MX missiles in 4,600 shelters simply will not suffice.

To give an example of the needed system expansion, a characteristic case is chosen: 7,000 Soviet RVs targeting MX by 1990, and 12,000 RVs by 1995 (it is assumed that in a first strike, the Soviets will expend approximately 3,000 RVs for 2-on-1 attacks against Minuteman silos and other U.S. strategic targets). The United States responds with a deployment designed to guarantee the survival of a fixed number of MX missiles, that is chosen to be 100 MXs as a representative number. Within this constraint, there is a continuous set of solutions that mix increased missile number and shelter number. In practice, cost optimization may be used to choose a missile/shelter ratio, and calculations based on actual MX cost models suggest that the ratio of 1 to 23 is not far from cost-optimum. Shelter number requirements are shown in figure 13. This graph shows that for an undefended MPS, approximately 8,000 shelters will be needed by 1990, and that by 1995, an adequate MPS will require approximately 12,500 shelters. (The knee in the curve occurs on the chart where reliability alone guarantees the required number of surviving MX missiles.)

Past the point of 8,000 to 9,000 shelters, it may be decided to deploy a ballistic missile defense, such as LoADS. It will become apparent that LoADS effectively doubles the price that the attacker must pay to destroy an MX missile in an MPS deployment. Therefore, if LoADS performs properly, an 8,000 shelter deployment with LoADS defense would be equivalent to a 16,000 shelter, undefended MPS deployment, and is commensurate with our projections for Soviet threat growth in the 1 990's,

Figure 13.— M PS Shelter Requirement for Projected Soviet Force Levels (100 Surviving Missiles)



Assumptions
- 1 mlsslle for every 23 shelters
- Damage expectancy O 85

SOURCE Office of Technology Assessment

In addition to properly sizing the MPS system, it is also necessary that it keep pace with the expanding Soviet threat, so that it is large enough to meet the threat at any given time i n its deployment. An expanding MPS that lags behind the Soviet force growth is not an effective deployment. Therefore, the rate of shelter construction should be chosen to keep up with the expected rate of Soviet growth. For an 8,000 shelter requirement by 1990, and an IOC (initial operating capability) for 1986, it would mean building shelters at the rate of 2,OOO per year, instead of the presently planned rate of about 1,200 per year. After 1990, additional shelters would need to be built at the rate of about 1,000 per year. Alternatively, a LoADS defense would need to be installed. It should be pointed out that the decisions on shelter construction rate and LoADS defense are long-leadtime items, and the decision to proceed would need to be made several years prior to construct ion.

Weapon Characteristics for M PS

Because the MX missile is stationary in an MPS basing, except for the periodic relocations during missile maintenance, the weapon's characteristics are essentially the same as fixed-silo ICBM basing. Thus, the system possesses a very high alert rate. It also has a quick and flexible response with a very hard target capability. The communications systems available are many and redundant, including land lines during peacetime and wartime radio links. Furthermore, the missile force is not dependent on strategic or tactical warning, unlike the bomber/ALCM leg of the Triad. It also has the highest potential for endurance and is capable of operating in a dormant (low power) mode for long periods of time with self-contained power supply (batteries),

Moreover, fixed land-based ICBMS have traditionally set the standard for missile accuracy, for several reasons Recalling the previous list of contributions to missile CEP, three relevant items are. 1) knowledge of initial position and velocity of the missile, 2) IMU platform alignment, and 3) the value of gravity in the launch point region and along the missile's trajectory Because the missile launch position is fixed, its position and velocity are known with great precision. Similarly, being stationary easily allows the IMU to keep track of its alignment In addition, gravity maps need to be prepared for the limited area in the proximity of the launch point These items tend to make pure inertial guidance much simpler for fixed missile basing than for com tinuously mobile basing that must u palate position coordinates and velocity by external aids if sufficiently accurate gravity data are not ava i table.

For MPS, once the missile is relocated, the guidance platform needs to go through a recalibration and realignment The requirement to reacquire CEP (i .e , highest accuracy) after relocation is 2 hours.

THE AIR FORCE BASELINE

The Air Force baseline system for the MX missile is an MPS system for a force of 200 MX missiles to be deployed i n the Great Basin region of Utah and Nevada. It would deploy these missiles among 4,600 hardened concrete shelters, a ratio of 23 shelters per missile. In the present design, the shelters would be laid out in clusters of 23: one missile per cluster; 200 clusters in all. Large, specially constructed transporter trucks would move the missiles with in the cluster to help preserve location uncertainty and to transport the missile to maintenance when the missile is in need of service.

The present schedule calls for an initial operating capability (IOC) of 10 clusters (10 MX missiles in 230 shelters) for 1986, and a full operating capability (FOC) for the complete system in 1989: an average construction rate of about 1 cluster per week, or 1,200 shelters per year, Testing of the missile itself is planned to begin early 1983, with a schedule of 20 flight tests before IOC.

This section begins with a detailed design description of the system, including missile and launcher equipment, shelters, transporter, and cluster layout. Land use requirements, based on siting criteria, needs of physical security, and other elements of the system are discussed, as are the regional impacts, both physical and socioeconomic, water availability, and impacts on regional energy growth. Finally, system schedule and cost for the current baseline system and the expanded systems are analyzed. The section is concluded with a treatment of a split-basing mode for MPS.

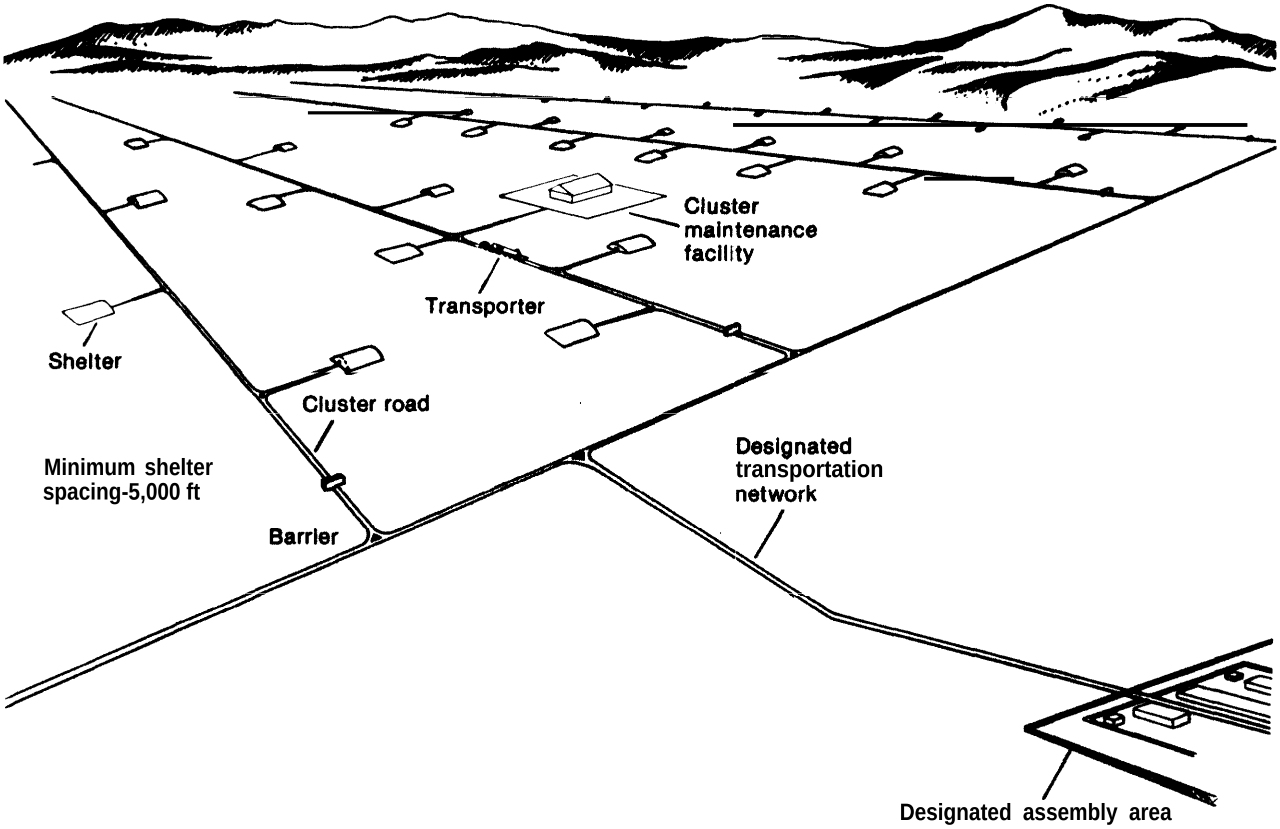
Discussions of preservation of location uncertainty (PLU) for the missile, and determining adequate shelter number, i.e., sizing the MPS, are covered in the previous section on the theory of MPS.

System Description

Figure 14 shows the general layout of the deployment and assembly area.

The missile is first assembled in an area outside the deployment area. The missile is assembled stage by stage, into a close-fitting missile cannister, that provides environmental control, allows for ease of handling during transport, and supports "cold" launch ejection from the capsule. This cannisterized missile is then joined with a specially constructed missile launcher. The launcher (fig. 15) that is deployed along with the missile as a structurally integrated unit, consists of the launching mechanism that erects the missile for launch, radio receivers for communication, and survival batteries after an attack. The launcher also contains an environmental control unit for continuous temperature, humidity, and dust control. The launcher'missile assembly is designed to weigh about 500,000 lb, and it is introduced into the shelter cluster where it is deposited in the cluster maintenance facility (where minor repairs also can be performed

Figure 14.—System Description



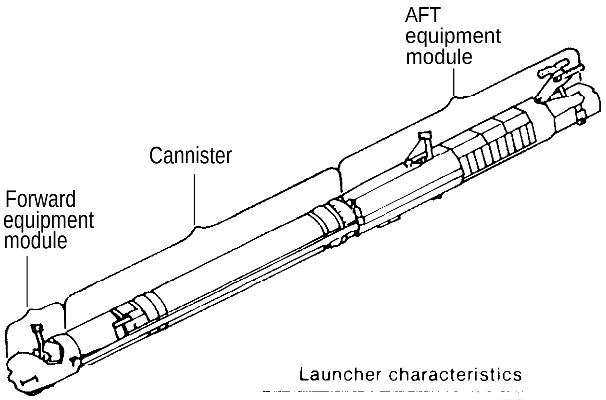
SOURCE U S Air Force

when necessary). From the cluster maintenance facility, the launcher/missile unit is then moved to its protective shelter via a specially designed and engineered transporter, which is also assembled in the assembly area and moved to its own cluster. In the current design, each of the 200 clusters will have one cluster maintenance facility and one launcher-l missile transporter, for a total deployment of 200 cluster maintenance facilities and 200 t ran sporters. Alternate designs under consideration call for "clustering the clusters, " so that fewer cluster maintenance facilities and transporters, perhaps one quarter of those that are presently planned, will need to be deployed.

Once the missile is placed in its shelter it remains there until movement is necessary, either for reasons of missile or launcher maintenance, changing missile location if necessary for preservation of location uncertainty, or for arms control monitoring by satellite. The same t ran sporter also installs a missile/launcher decoy, called a mass simulator, into the other 22 shelters that do not contain a missile. The purpose of the mass simulator is to make it impossible for an outside observer to determine whether a missile or a mass simulator is in a given shelter (or transporter), at a given time, by duplicating many of the physical characteristics of the missile with launcher

Throughout the missile deployment area thousands of miles of roads would be constructed to connect the shelters, clusters, and assembly area; in add it ion, thousands of miles of underground fiber optic cable would pro-

Figure 15.—Launcher



Launcher characteristics

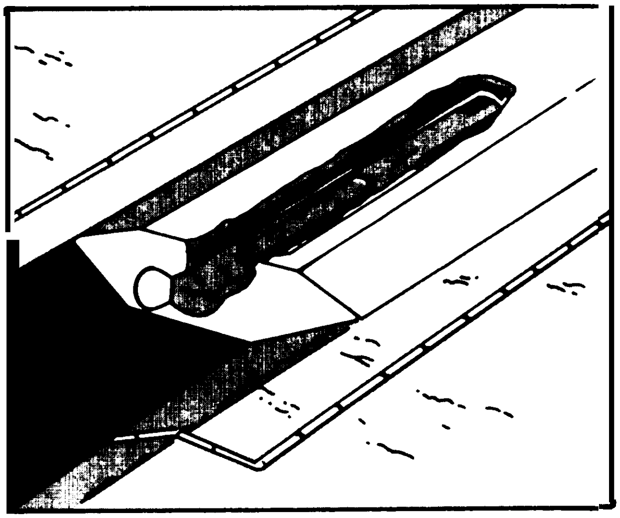
Length	*155* Feet
Diamete	110 Inches
Weight	500,000 Pounds

SOURCE U S Air Force

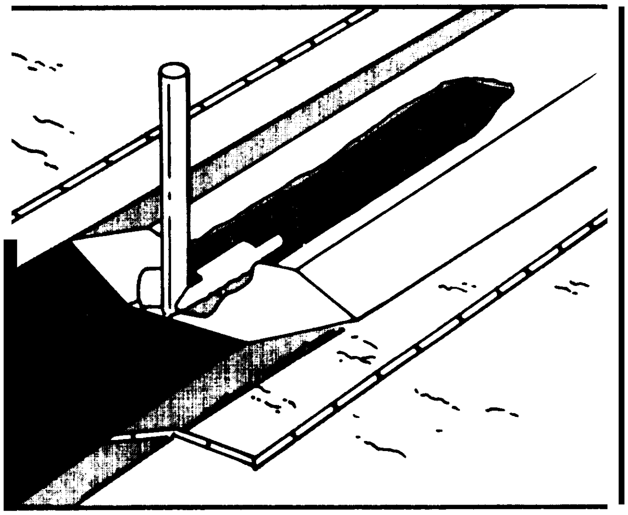
vide peacetime commun cat ion with the missile launcher The tiber optics would also transmit reports on missile and launcher status, and could transmit the order to launch the missile. Since these land-line communicantions could be easily interrupted and destroyed in a nuclear attack, the MX fields rely on backup radio communication links between the launcher and higher authority An airborne launch control center (ALCC), always on airborne alert, would serve as a radio relay for two-way communicat ion with higher authority Other radio links presently designed into the system that do not rely on the ALCC for relay, support one-way communication from higher authority to the missile launcher. All radio signals are picked u p by a medium frequency (MF) antenna, buried nearby each shelter

Since the missile is stored in a horizontal position while in the shelter, the missile launch sequence will involve opening the shelter door, a partial egress of the missile/launcher so the missile portion of the launcher is fully outside the shelter, erection of the missile to a near vertical position by the launcher, and finally ejection of the MX missile from its launch cannister by generated vapor pressure and subsequent missile engine ignition (see fig 16)

Figure 16.— Missile Launch Sequence



Closure opened



Launcher emerged and erected to launch position

SOURCE U S Air Force

Along with the above mentioned elements, the Air Force baseline includes two MX operating bases, including housing areas and airfields, three to six area support centers, and other support facilities.

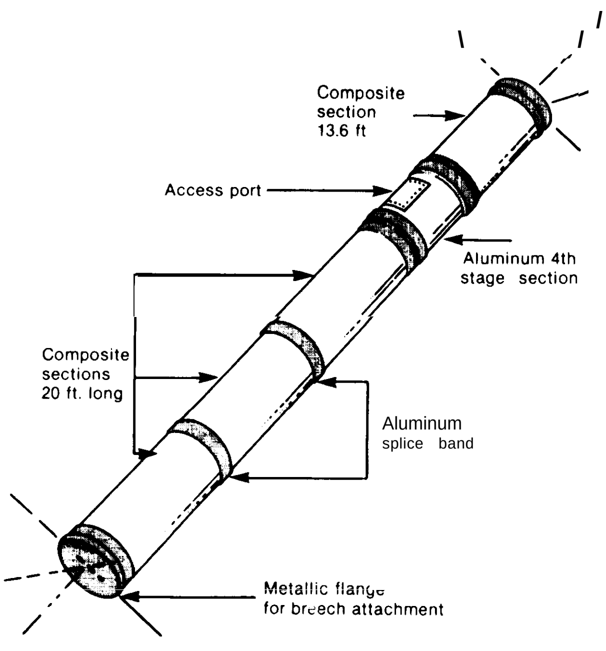
These elements are now discussed in detail. For notational purposes the term "launcher" will refer to the missile-cannister-launcher assembly.

Missile Cannister and Launcher

The missile cannister is a hardened tubular structure (fig. 17) designed to house the missile horizontally prior to launch, and to provide the impulse, in the form of high pressure steam, to eject the missile from the cannister, a procedure known as cold launching. The missile is supported in the cannister by a series of pads to restrain the missile and reduce loads on it during transport and nuclear attack. The pads are arranged as a set of circumferential rings along the motor casings. The high pressure steam for missile ejection is generated by a water cooled gas generator, producing pressures sufficient to eject the missile from the cannister with an exit velocity of approximatey 130 f t/see.

The launcher assembly (see fig. 15) is made up of several components, and several sections. These parts include a forward section, consisting of a forward shock isolation system to help cushion the missile during nuclear attack, and a set of rollers for transferring the missile to and from the transporter and protective shelter. The middle section of the launcher holds the missile/cannister assembly,

Figure 17.—Cannister Construction



SOURCE. U S Air Force

and the aft section contains command, control, and communications gear, emergency batteries, and a second set of rollers for missile transfer. Total weight of the missile-launcher unit is expected to be about 500,000 lb,

Erection of the cannister for launch is achieved by a Sliding block and connecting rod linkage, initiated by a pyrotechnic actuator.

Protective Shelter

The protective shelter would house and conceal the launcher and would be designed to protect it during nuclear attack. Essentially, it would be a cylinder of reinforced concrete, approximately 170 ft long, and lined with 3/8 inch steel to protect the missile against nuclear electromagnetic pulse effects. It would have a 14.5-ft inner diameter and 21-inch thickness; it would be buried under 5 ft of earth, with an exposed concrete and steel door 10 ft off the ground, as shown in figures 18 and 19. A garage type structure, the shelter would house the launcher horizontally; hence the name, horizontal shelter.

In the present design, allowance is made to have two plugs installed in the roof of each shelter Removing the plugs would allow selective viewing of the shelter contents by satellite to help assure arms control verifiability.

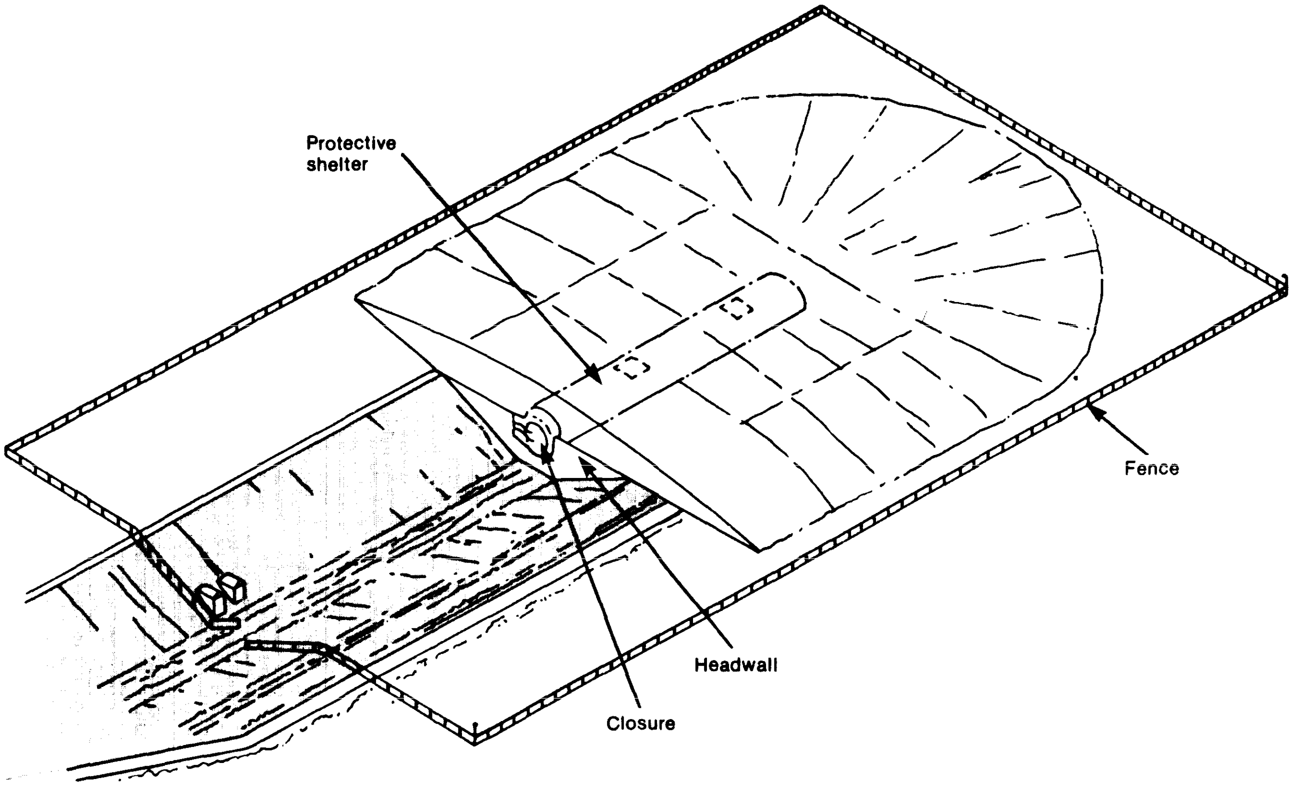
A fence around each shelter would enclose 2.5 acres, an area also guarded by onsite intrusion sensors and remote sensors as part of the physical security system.

The shelter support equipment, including environmental control, AC/DC conversion, and emergency batteries, would be housed outside each shelter, but within the fence.

Transporter

The transporter would be a manned roadable vehicle that would carry the launcher within a cluster between shelters and the cluster maintenance facility (see fig. 20). It is also designed to transport the mass simulator, and to perform the exchange of launcher with simulator while parked at the protective shelter.

Figure 18.— MX Protective Shelter Site



The transporter would be a heavy vehicle, weighing 1.1 mill ion lb unloaded, and 1.6 million lb when loaded with the launcher or mass simulator. It would be about 200 ft long, 31 ft high, and would require 26 tires. The transporter's cargo bay would be constructed to hold a launcher and mass simulator, or two mass simulators, at the same time for purposes of exchange at a shelter (see fig. 21) This exchange is to be accomplished by providing two sets of rolling surfaces in the transporter, one for the launcher and one for the mass simulator, and an elevator inside the transporter to position the cargo for transport (see fig. 22). Transfer of the cargo at the shelter site would be accomplished by an electrically powered roll transfer.

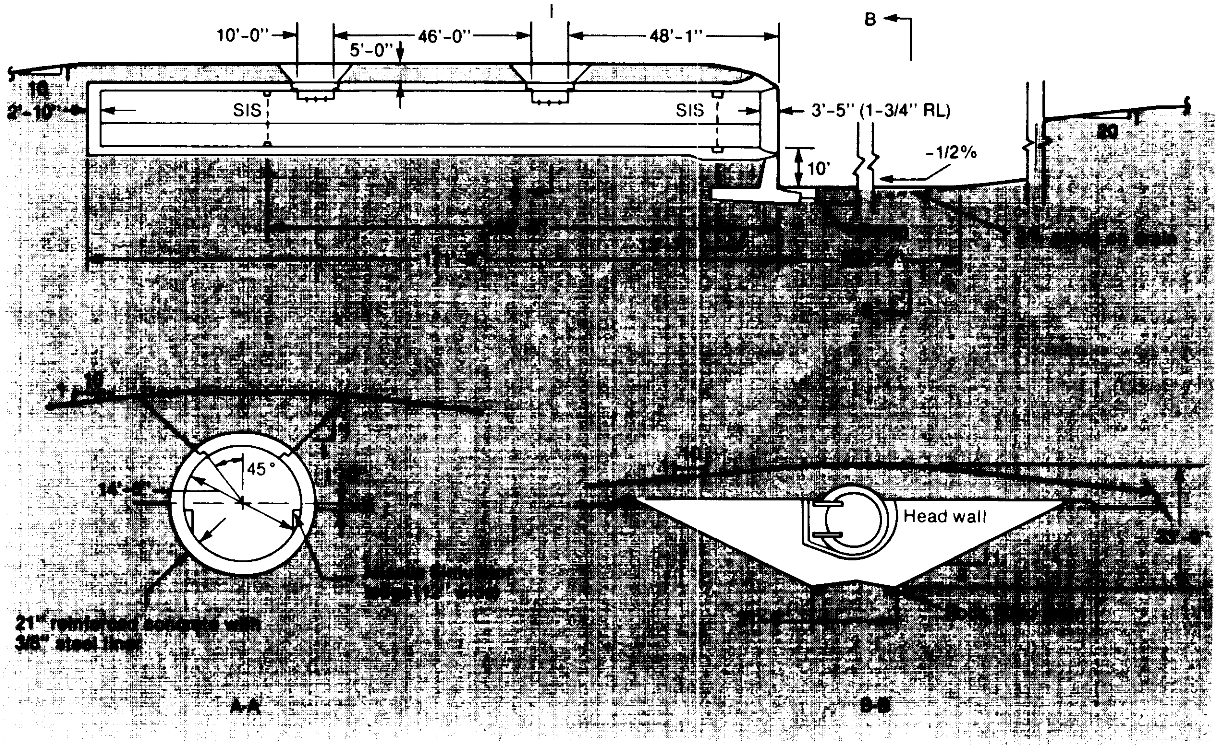
Like the shelter, the transporter is designed to have two ports on its roof to permit selective viewing of its contents for purposes of arms control verification.

The transporter is designed to protect itself and its contents from the electromagnetic pulse of a high altitude nuclear burst, but it would otherwise be vulnerable to nuclear attack. Power to the transporter would be supplied by 10 drive motors and 2 turbo generators. It would have a 15 mph capability on level road, and would have automatic guidance with manual override. It would be manned during all transport activities.

Mass Simulator

The MX mass simulator would be an arch-shaped structure made of reinforced concrete (see fig 23). It is designed to match the launcher's weight (500,000 lb), center of gravity loca-

Figure 19.— MX Protective Shelter

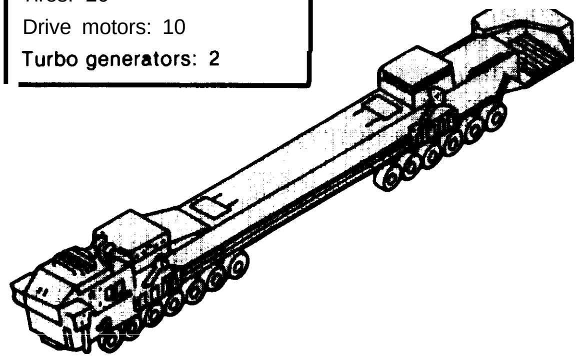


SOURCE. U S Air Force

Figure 20.—Transporter

Characteristics

Length: 201 feet
Width: 16 feet (over tires)
25 feet (overall)
Height: 31 ft 6 in.
Weight: 1,600,000 Pounds
(loaded)
Tires: 26
Drive motors: 10
Turbo generators: 2

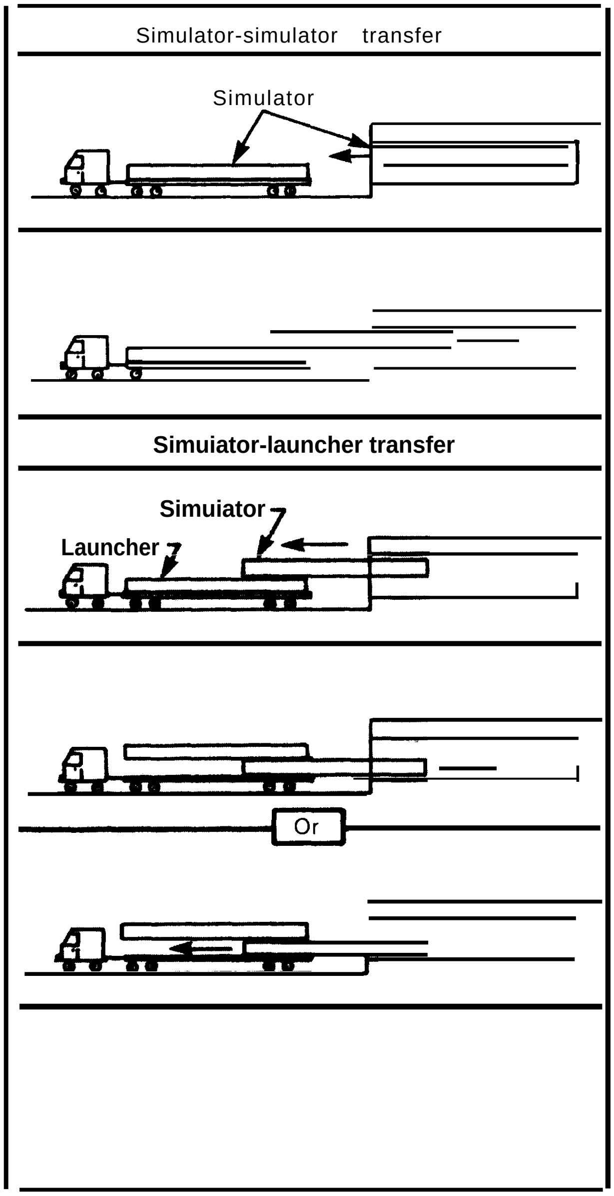


SOURCE U S Air Force

tion, external magnetic characteristics, and other signatures, so that when it occupies a shelter, or when it is carried by the transporter, it could not be distinguished from the missile by an outside observer, Square openings, or notches, are located in the top of the simulator arch, and aligned with the plugs in the shelter roof, so that during arms control verification activity, when all of the shelters are occupied by mass simulators and the shelter plugs are removed, a satellite could see through the openings in the mass simulator, and thereby observe the absence of the launcher in the shelter.

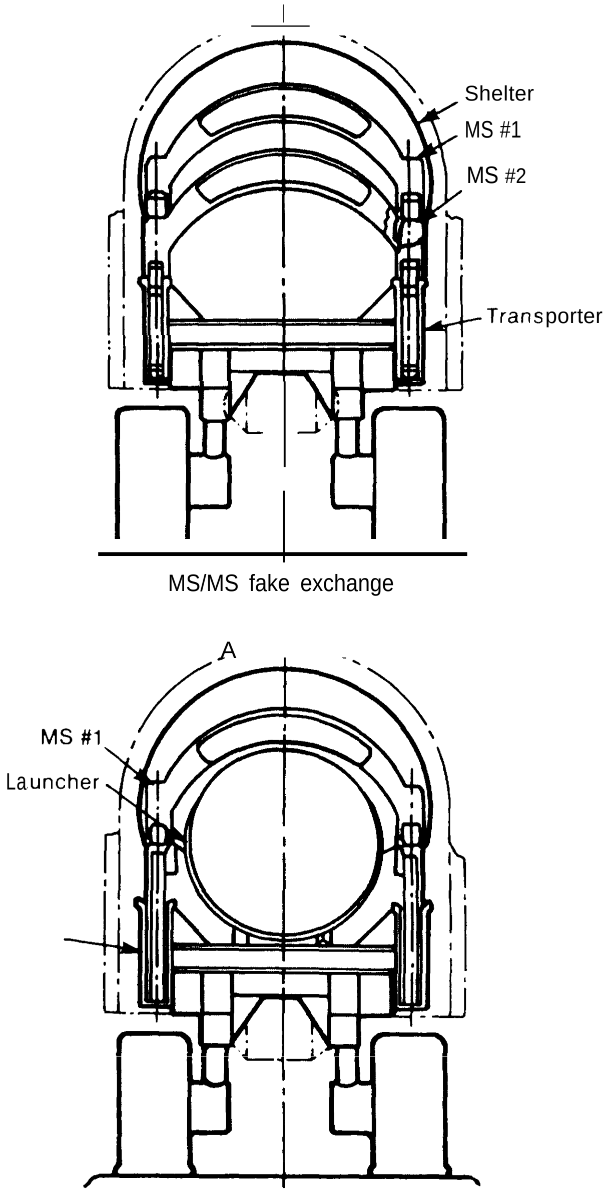
The mass simulator also would be provided with running gear to accomplish its roll transfer into and out of the transporter. There would be a separate, upper ledge in the shelter to support the simulator. For reasons of PLU, the simulator's running gear and its axial location would be the same as the launcher.

Figure 21.— Missile Launcher and Simulator—Transfer Operations



SOURCE U S Air Force

Figure 22.— Mass Simulator (MS) and Launcher Exchanges

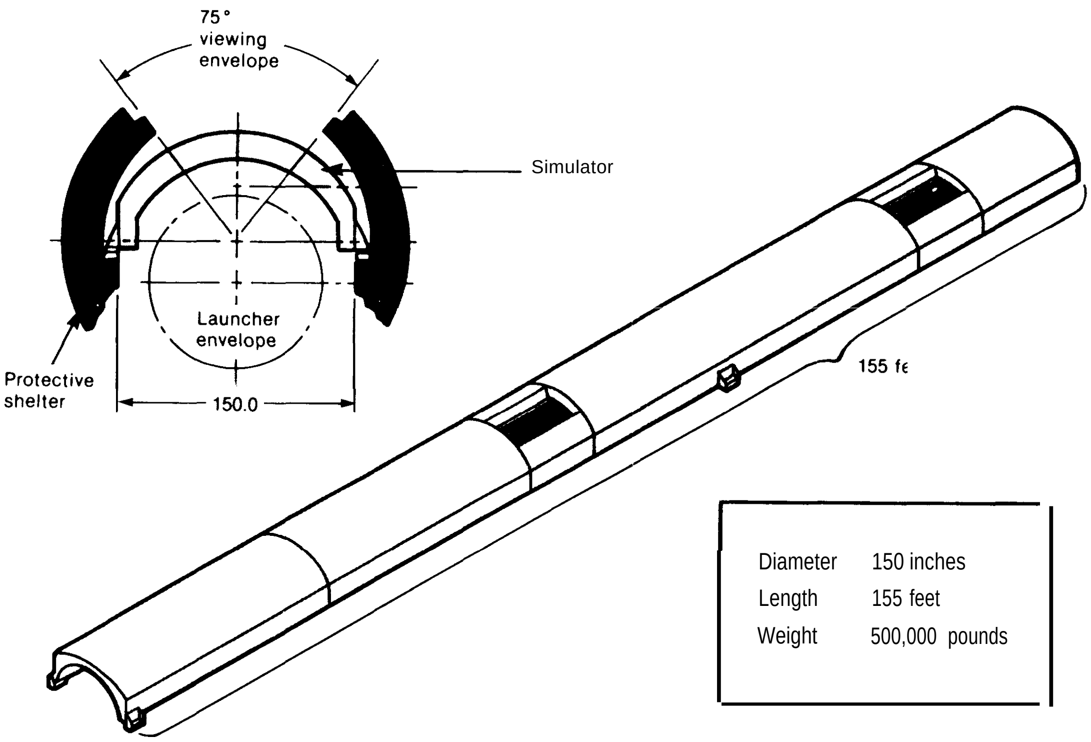


SOURCE U S Air Force

Cluster Layout

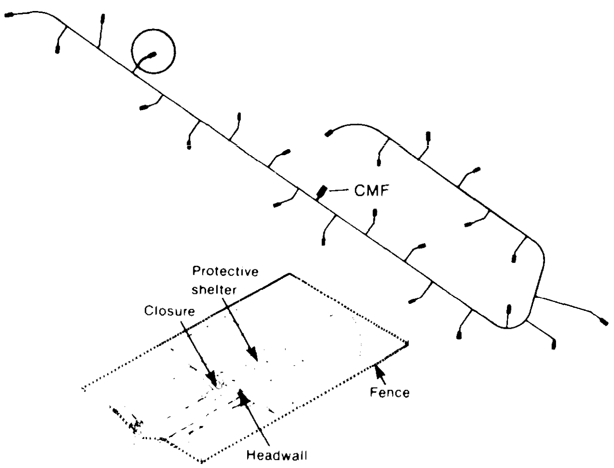
Each cluster would contain 23 shelters, arranged more or less along a linear string, and connected by a cluster road (see fig. 24). Spacing between adjacent shelters would be approximately 5,200 ft, with a minimum spacing of 5,000" ft In addition to the 23 shelters, each cluster would contain a cluster maintenance facility (CM F), where minor repair-s on the launcher could be accomplished, and that could house the transporter when not in use, Most of the time the cluster would be unmanned, except for maintenance activities, SALT verification, and security patrols

Figure 23.—Mass Simulator



SOURCE U S Air Force

Figure 24.—Cluster Layout



SOURCE U S Air Force

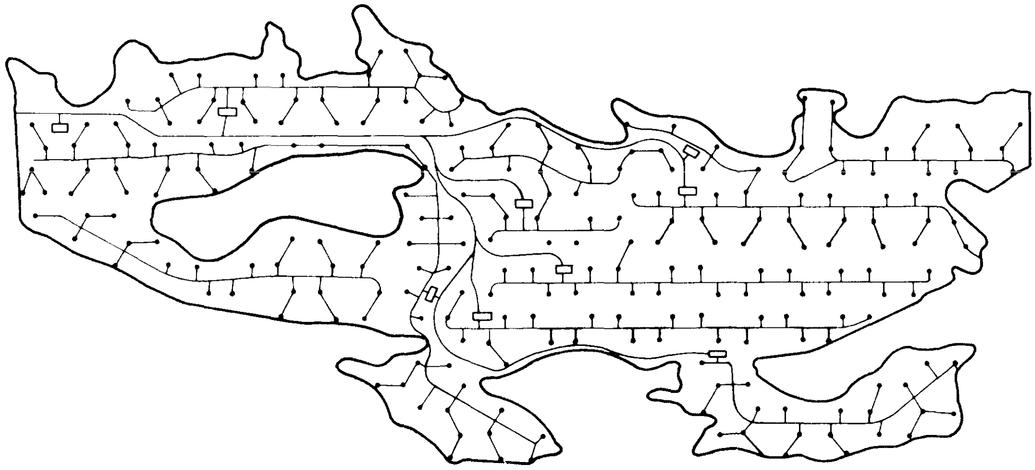
Within each valley, the shelters would be arranged in a close-packed hexagonal pattern (see fig. 25). The lattice is not completely filled, having approximately one-third fewer shelters than the spacing actually allows. The reason for this design is that the confluence of the shock fronts from the nuclear detonations at the vertices of the hexagon could be sufficient to destroy a missile placed in a shelter at the center of the hexagon. Consequently, this center shelter has been left out. In the event of a Soviet effort to increase their n umber of missile RVS, it is presently contemplated that these "gaps" in the hexagonal layout will be "backfilled" with additional shelters. If the Soviets fractionate their warheads, thus decreasing the individual warhead yields sufficiently, backfilling could be feasible.

Command, Control, and Communications (C^3)

The C^3 system (see fig, 26) is divided into two categories: peacetime and wartime. The peacetime/preattack C^3 system would consist of a centralized command control located in the operational control center (OCC), at the base, and a communications network spanned by an extensive underground grid of fiber optic

Figure 25.—Shelter and Road Layout

5,200-ft spacing



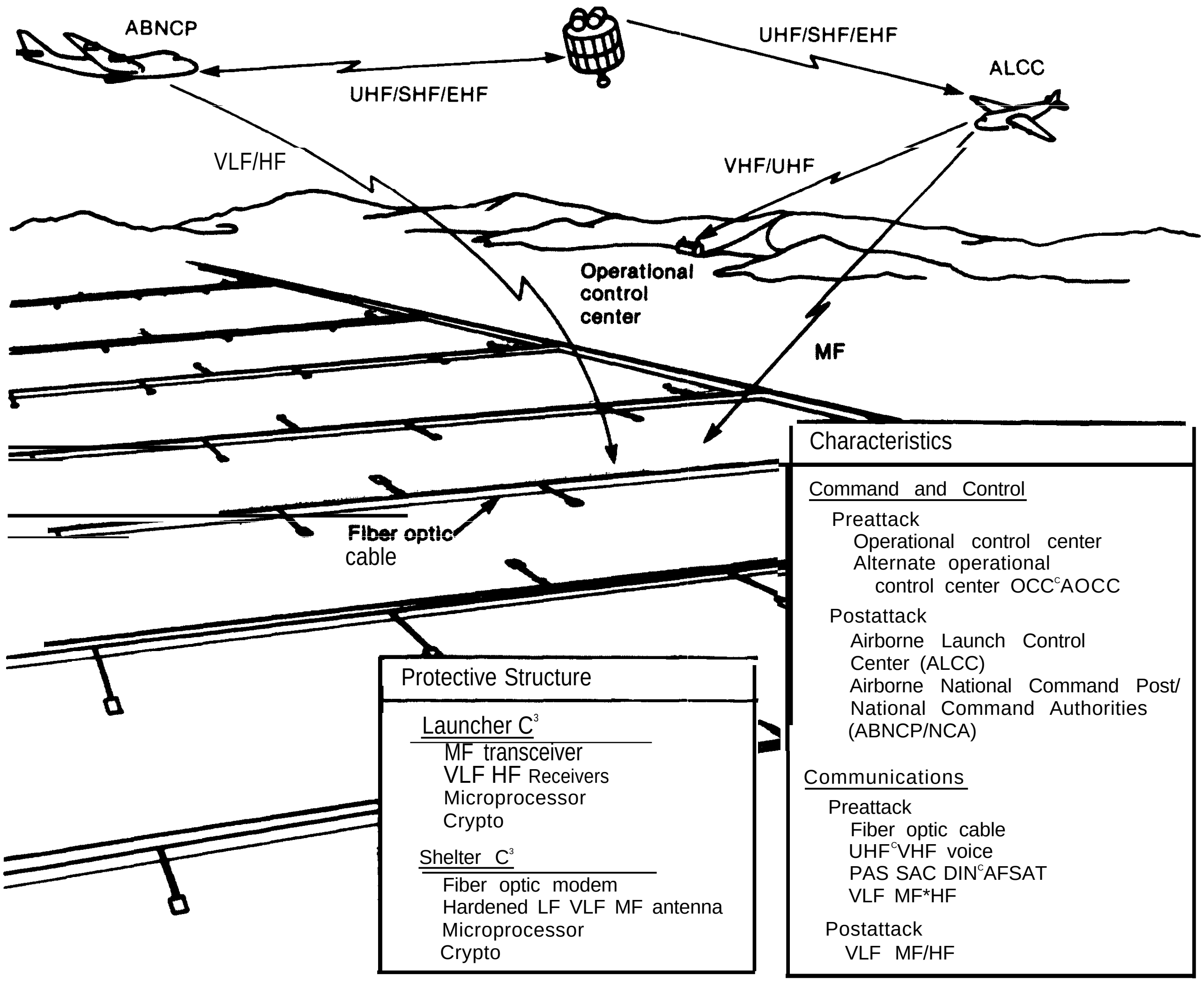
SOURCE U S Air Force

cable between the OCC and al I of the missile launchers The OCC would be in continuous two-way communication with higher authorities, including the airborne national command posts (Looking Glass, NEACP, etc) and the National Military Command System (NMCS) The fiber optic cable system would have a high data rate **(48** kilobits/sec) with a relatively long attenuation length, Because fiber optic cable is a dieletric, it is resistant to electromagnet loss pulse (EMP) effects By making the cable sufficiently thick, a protective metal sheath might not be required to protect it against gophers, gerbils, and the like, Each line contains three fibers (one for communication in each direction and one spare) PLU would be maintained by uniform formatting and message protocols for missiles and simulators The entire system would require about 11,000 miles of cable,

The peacetime C^{3}‘ system is not intended to survive a nuclear attack, since the operational control center would be a primary target, and fiber cable connectivity would be interrupted by cratering. The postattack C’ system would take over at this point. The postattack system would consist of an airborne launch control center (ALCC), that would have two-way communication with the missile force via MF (medium frequency) radio The ALCC’ plane would a I ways be airborne, with a backup ALCC on strip alert. Each shelter would have buried beside it a 600 ft crossed M F dipole antenna, that would serve as a receiving and transmitting antenna The transmitting power at the shelter is 2 kW, and with a soil propagation loss of – 30 db, would transmit 2 watts effetive radiative power MF was chosen, in part to combine the advantage of high frequency data rates with low frequency propagation through ionized, nuclear environments. In addition, MF does not propagate through (or, at least, is greatly distorted by) the ionosphere, making reception intentionally difficult by satellite. In the present design, MF would be the only means by which the missiles could “talk” to command authority Therefore, when the ALCC would no longer be operational, the launcher would not be able to report back to higher authority,

In addition to two-way MF radio, the baseline is designed to have one-way radio communication from higher authority directly to

Figure 26.—Command, Control, and Communications System



SOURCE U S Air Force

the launcher via high frequency (HF) and very low frequency (VLF) when the ALCC is no longer airborne (in-flight endurance of the ALCC is about 14 hours). Two-way communication between higher authority and the launcher via H F is presently contemplated, so that the launcher can give status and report back when the ALCC is not operational. We should point out that even if two-way H F were installed it would not necessaril y assure continus, long-haul communication. Because the ionosphere would be disturbed for a period of hours after the initial attack before slowly recovering, long-haul HF via ionospheric skywave cannot always be depended on (Adaptive HI techniques would not sol VP the interruption of transmission, a I though it could recover more quickly than conventional H F) H F antennas would probably have to be added to the system In addition to the buried MF antennas, since using the same MF antenna for HF transmission would incur a variety of technical problems,

To help assure receipt of the launch command by all of the launchers from the ALCC, the launcher that first received the message would rebroadcast the same message by MF groundwave to the other launchers. They, in turn, would receive and rebroadcast again, and so on, until all of the surviving launchers received the message. This simulcast transmission has been tested and verified in the field for completeness of coverage. As part of this process, preselected missile targets would be reallocated and reoptimized among the surviving missiles by an algorithm processed by one of the launchers.

Power Supply System

Power to operate the entire MX/MPS system (see fig. 27) is planned in the baseline system to come from local utility companies. Power would be received at two or more switching stations at 230 kV, 60 Hz. Area substations then receive this power at 138 kV and step it down to distribution centers at 24.9 kV. Power from the distribution centers to the shelters is conveyed underground, at 14.4 kV and is converted to DC before entering the shelter. Power consumption at all shelters would be approximately 15 kW, with simulator-occupied shelters consuming the same power as missile occupied shelters. As a backup to commercial power, each distribution center contains standby diesel generators to supply primary power when normal power fails. The diesel engines are designed to start automatically.

If commercial and backup diesel power are unavailable, emergency power would be supplied by battery on site at the shelter for shelter operations, and on the launcher for launcher and missile operations.

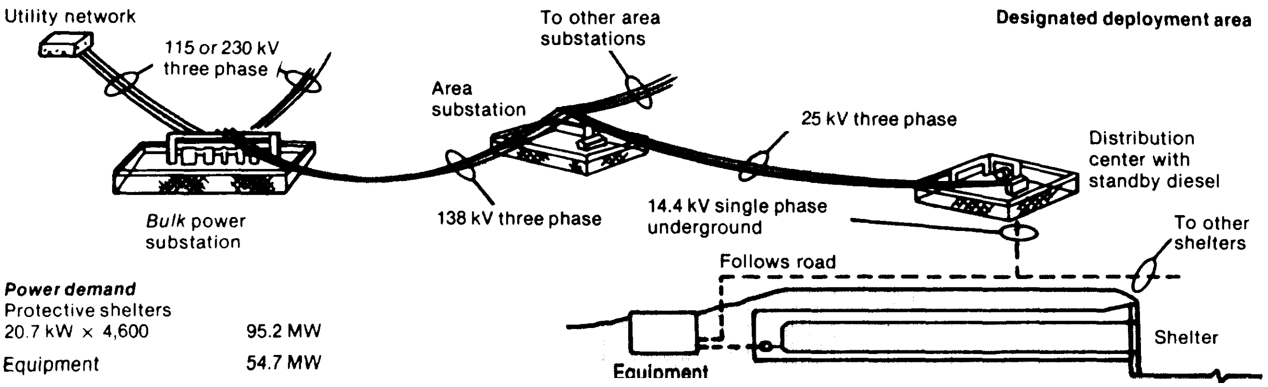
Survival power for the missiles after an attack would be provided by survival batteries ($LiSOCl_2$) to critical launcher and missile needs only. Survival time is classified and is included in the classified annex.

Launch Procedure

Launch of the MX missile is accomplished in the following automated sequence (see fig. 28):

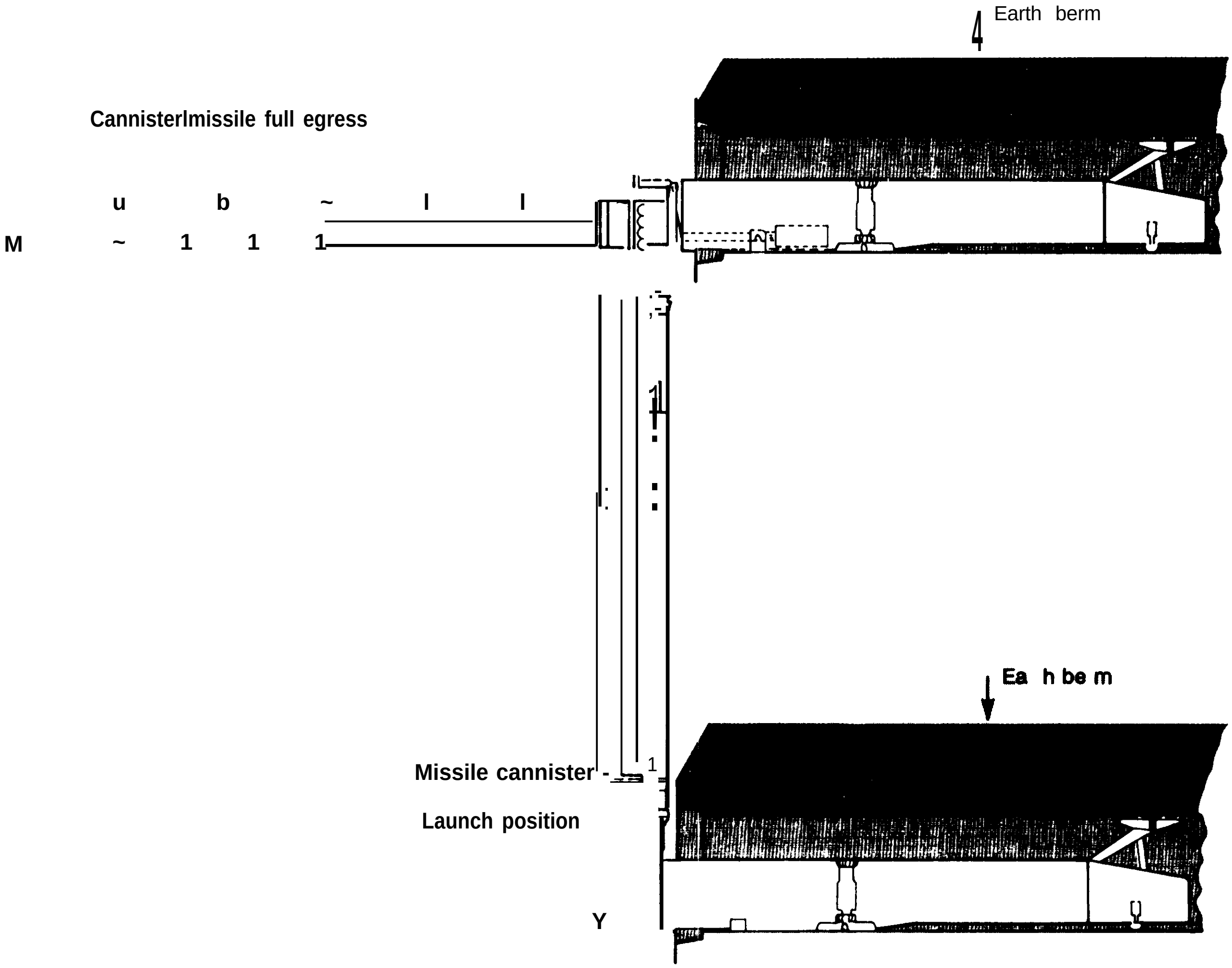
1. The launch message is transmitted to the missile launcher by radio communication from the Strategic Air Command (SAC), ALCC, or from the MX operating base via fiber optic land lines, if the attack has not yet destroyed them.
2. The launcher shock isolation masts are retracted and egress rollers are deployed.
3. The shelter door is unlocked and opened.
4. The launcher egresses from the shelter, by its own battery power, exposing the canisterized missile.
5. The launcher erects the missile to near vertical (85° to 90°).

Figure 27.—Electrical Power Distribution



Power demand	
Protective shelters	
20.7 kW x 4,600	95.2 MW
Equipment	54.7 MW
People	30.5 MW
	180.4 MW

Figure 28.— MX.CannisterlMi ssile Launch Sequence



SOURCE U S Air Force

6. The missile is expelled from the cannister by the hot gas steam generator, at an exit velocity of about 130 ft/sec.
7. The missile's stage 1 fires,

The entire missile launch sequence is designed to require several minutes.

Missile Mobility

In the baseline system, the transporters are intended primarily to move missiles between the cluster maintenance facilities and shelters for the purposes of maintenance, supporting arms control verification, and PLU, The transporters could also be used for relocation of missiies among cluster shelters (but not between clusters). Because there are 200 transporters and 200 missiles, it would be possible to move al I of the missiles at the same time, although this is considered very unlikely because it wouid leave all of the force outside the /protective shelters and exposed to a preemptive attack.

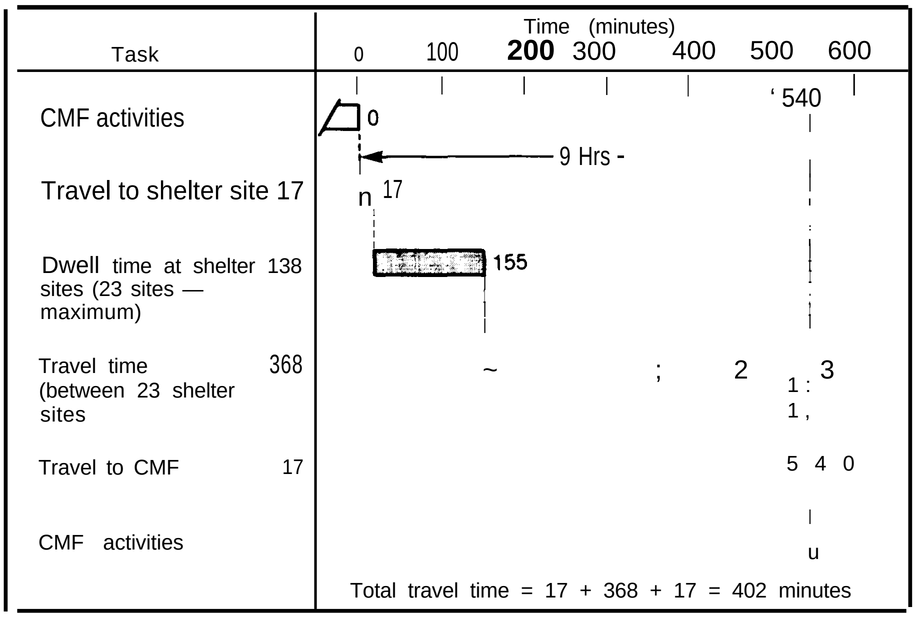
Another possibility would be to keep a fraction of the missi Ie force on transporters, on the road. When the warning of an attack came, the on-road missile force would "dash" into the nearest shelters.

There is some advantage to these mobility options, but there are limitations as well. If a partial or complete breakdown of PLU is suspected, then any number of missiles can be relocated in new shelters, This relocation would be performed by a visit of the missile transporter to each shelter, where it would either simulate or perform a n authentic missile pickup or deposit The time it would take to perform this operation for the entire missile force has been estimated to be about 9 to 12 hours, after which time the missile could be in a different position so that previous locat ion information possessed by the enemy would be invalid Figure 29 shows the timeline for this "rapid" relocation, A decision to relocate all of the missiles at the same time would be unlikely, in view of the earlier discussion. Depending on how PLU was broken, this relocation might or might not reestablish the location uncertainty If PLU had been broken by long-term efforts at data collection or espionage or both, then rapid relocation could reestablish PLU If, on the other hand, the enemy could locate the missiles through technical or other means in a short time, then no amount of relocation would reestablish PLU.

The second mobility option, the "dash" or hide-on-warning option, would place a portion of the missile force on the road, i n motion or parked near a shelter Upon warning of attack, the manned transporter would dash to the *nearest* shelter, deposit the launcher, and back off from the shelter so that the missile could egress and launch The time estimate for this operation is Slightly u rider 6 minutes, which would be required to respond to warning of a submarine launched ballistic missile (SLBM) attack, and secure the missile in the shelter before the attacking warheads arrive

The dash timeline for this operation is displayed in figure 30. Since the transporter is not designed to withstand an SLBM attack, it cannot be used after the attack. The advantage of this option is that it acts as a hedge against a complete breakdown of PLU, so that at least a fraction of the missile force might survive the initial attack This option assumes that the attacker does not know the location of the missile at the time of the attack This may or may not be true, since it depends on the ability of his reconnaissance to observe transporter location, and use this information to

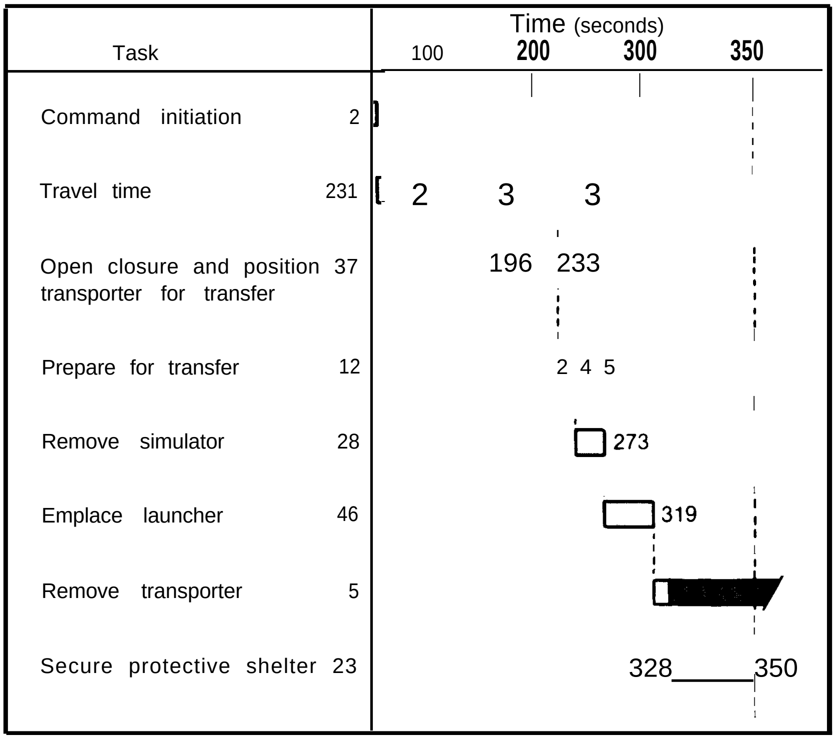
Figure 29.—Transporter Rapid Relocation Timeline



SOURCE U S Air Force

83-477 0 - 81

Figure 30.—Dash Timeline



SOURCE U S Air Force

target the shelter into which the missile would seek cover. Without commenting on the present Soviet capabilities to accomplish this task, it might not be wise for the United States to rely on dash as a substitute for PLU. The job of real-time reconnaissance and retargeting of shelters in order to defeat the dash option is not technically infeasible, although it may be high-risk in the near future. Thus, reliance on dash may be a useful hedge against a loss of PLU in the near term, but its long-term prospects are more uncertain.

Secondly, after a first attack, reconnaissance would be able to locate the transporter. Since the transporter would be located next to the occupied shelter, the attacker would know the location of the dashed missile, and could attack it on the next wave or by bomber force if the MX missile were not launched in the time remaining.

Finally, since dash relies on warning of attack, it would have a common failure mode with the bomber force, again underscoring the importance of maintaining a PLU-perfect system, rather than relying on missile mobility as a hedge.

SALT Monitoring Operations

The basic need to verify missile numbers for an MPS deployment, without compromising missile location uncertainty, is satisfied by allowing the means to count missile *numbers Without determining* specific missile location. This capability is being designed into the system, by following a slow, open, and observable missile and launcher assembly process in the assembly area. This process would allow national technical means to observe each missile constructed in the assembly area, before it is deployed in a shelter cluster. Second, there is a unique paved connecting road between the assembly area and the deployment area, and a special transporter vehicle to move the missile and launcher to the deployment area, Third, the missiles and launchers would be confined in clusters, with cluster barriers that would make removal and replacement of launchers and missiles observable by satellite.

To further facilitate SALT monitoring of the missile force by national technical means (NTM), plugs in the roof of each shelter have been designed as part of the system. The monitoring process would proceed as follows:

The transporter deceptively relocates the missile from the shelter to the cluster maintenance facility, leaving a mass simulator in each shelter of the cluster.

2. Special vehicles would clear the 5-ft overburden on top of the shelter, and the two SALT concrete ports would be removed from the top of the shelter, exposing the contents of the shelter to satellite reconnaissance,
3. The shelters would be left in this configuration for 2 days to accommodate NTM viewing,
4. The SALT ports would be replaced, the overburden restored, and the missile returned to one of the shelters. The estimated timeline for this process is illustrated in table 4.

Siting Criteria

There are three fundamental siting criteria that apply to any MPS site selection process:

- first, large areas of relatively flat land are necessary to permit clusters of shelters and to allow transport of the missiles among shelters;
- second, for the purpose of minimizing construction costs, it is desirable to have areas with minimal water resources and hardrock formations near the surface; and
- third, for the purpose of minimizing the number of people displaced or otherwise impacted by construction and to minimize threats to PLU from public activities, it is desirable to have a low-population density area,

The siting criteria indicated in table 5 reflect these principal considerations:

On the basis of these screening criteria, the Air Force identified 83,000 mi² of geotechnically suitable lands throughout the Western United States and defined six candidate areas for "militarily logical deployment" that were

Table 4.—Monitoring Timeline

Remove missile	1 day (12 working hours)
Remove SALT ports	1 day (12 working hours)
NTM inspection	2 days
SALT port replacement	2 days
Replace missile	1 day (12 working hours)
Total	7 days

SOURCE U S Air Force

Table 5.—Principal Exclusion/Avoidance Criteria Used During Screening

Category	Criteria definition
Geotechnical	Surface rock and rock within 50 ft.
	Surface water and ground water within 50 ft.
Cultural and environmental	Federal and State forests, parks, monuments, and recreational areas.
	Federal and State wildlife refugees, grasslands, ranges, and preserves.
	Indian Reservations.
	High potential economic resource areas, including oil and gas fields, strippable coal, oil shale and uranium deposits, and known geothermal resource areas.
	Industrial complexes such as active mining areas, tank farms, and pipeline complexes.
	20 mi. exclusion radius of cities having populations of 25,000 or more.
	3.5 mi. exclusion radius of cities having populations between 5,000 and 25,000.
	1 mi. exclusion radius of cities having populations less than 5,000.
Topographic	Areas having surface gradients exceeding IO% as determined from maps at scale 1:250,000.
	Areas having drainage densities averaging at least two 10 ft. deep drainages measured parallel to contours, as determined from maps at scale of 1:24,000.

SOURCE. U.S. Air Force

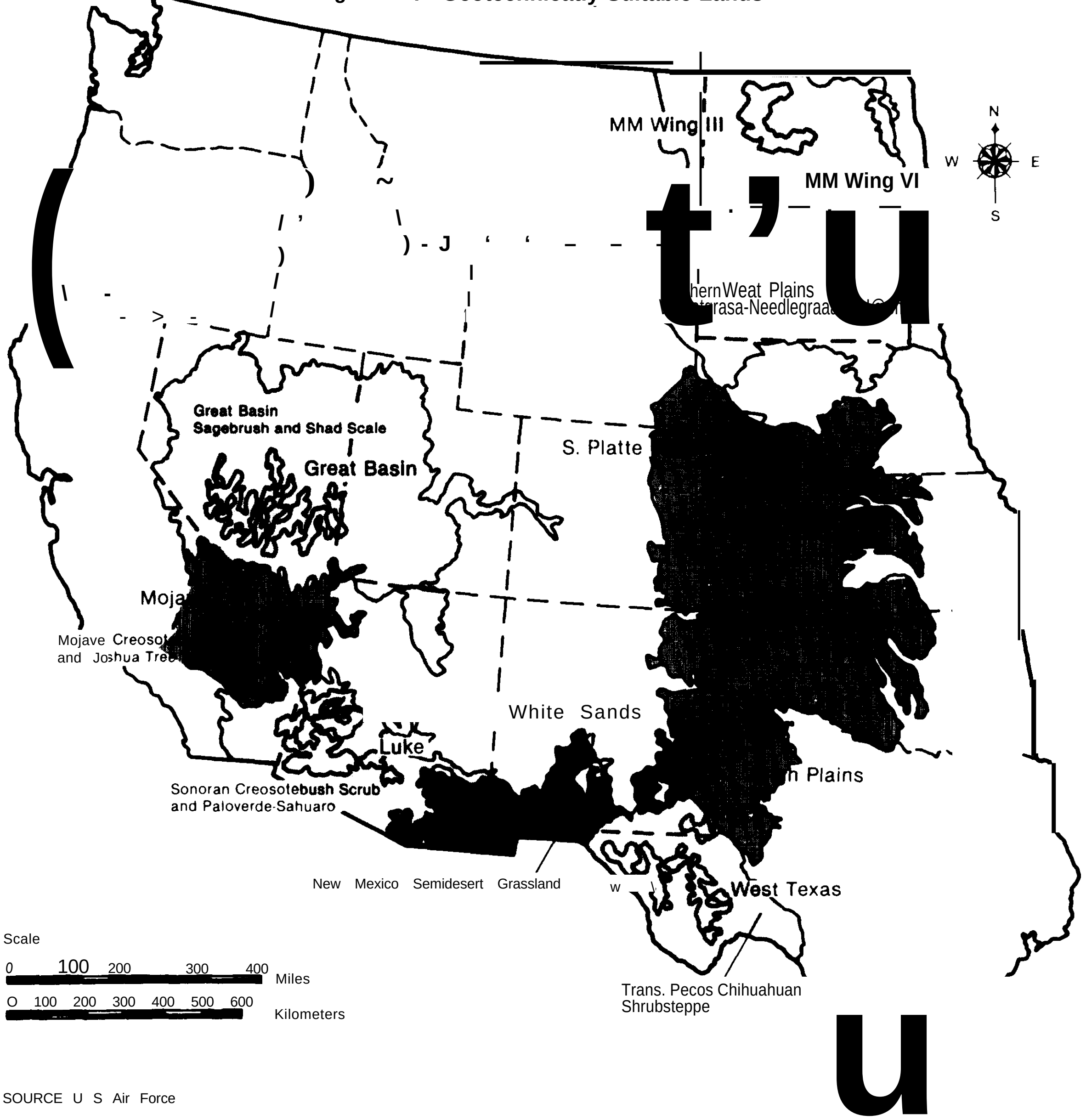
subsequently evaluated on the basis of distances from coasts (to reduce the potential effectiveness of sea-based forces), distances from national borders (to reduce vulnerability to "unforeseen threats")* as well as compatibility with local activities and the sense of Congress that the basing mode for the MX missile should be restricted to location on the least productive land available that is suitable for such purpose. "

*In contrast to the other primary siting criteria, OTA's assessment does not indicate that a measurable degree of security derives from locating MPS at least 200 miles from national borders, nor that Mexico and Canada pose significant "unforeseen threats" to MPS security.

Figure 31 indicates the areas of geotechnically suitable lands identified by the Air Force.

Of these areas, the Great Basin of Nevada and Utah and the Southern High Plains of west

Figure 31 .—Geotechnicatly Suitable Lands



SOURCE U S Air Force

Texas and New Mexico were identified as the only " reasonable risk" areas, and the Nevada/ Utah location was selected by the Air Force as the preferred area for MX/MPS.

Table 6 indicates the "candidate areas" identified by the Air Force along with the predominant vege ative characteristics of the region.

Roads

The MPS will have a substantial road network of approximately 8,000 miles.

The designated transportation net work (DTN), consisting of paved asphalt roads, 24-ft wide with 5-ft shoulders, wil I connect the assembly area with each cluster, and will total between 1,300 and 1,.500 miles. Inside each cluster will be roads connecting all the shelters and the cluster maintenance facility. About 6,200 miles of these cluster roads will be constructed, 21 -ft wide with 5-ft shoulders lders. These roads will be unpaved and treated with dust suppressant, and are designed to support the missile transporter. Large earth berms will prevent movement of the transporter between the DTN and the cluster roads. In addition, some 1,3oO miles of smaller support roads in the cluster area will be built to connect shelter clusters and support SALT-related activities, Figure 32 illustrates the construction profiles of the different roads.

Physical Security System

The Air Force has examined two basic systems for MPS security: area security, invoiving restricted access and continuous surveillance of the cluster areas; and point security, involving restricted access only to the missile shelters, command facilities, and other military facilities. Figures 33 and 34 compare the configurations of point and a red security systems.

Under area security, each cluster of shelters would be bordered by a warning fence and posted notices. Only authorized personnel would be permitted in the posted area, and their movements would be continuously monitored by remote surveillance. Security forces would be available at all times for dispatch to unauthorized intrus ions. To prevent the implantation and operation of sensors from aircraft, the airspace over the deployment area would also be restricted to an altitude of 5,000 ft, and controlled to an altitude of 18,000 ft (i.e., a permit would be required).

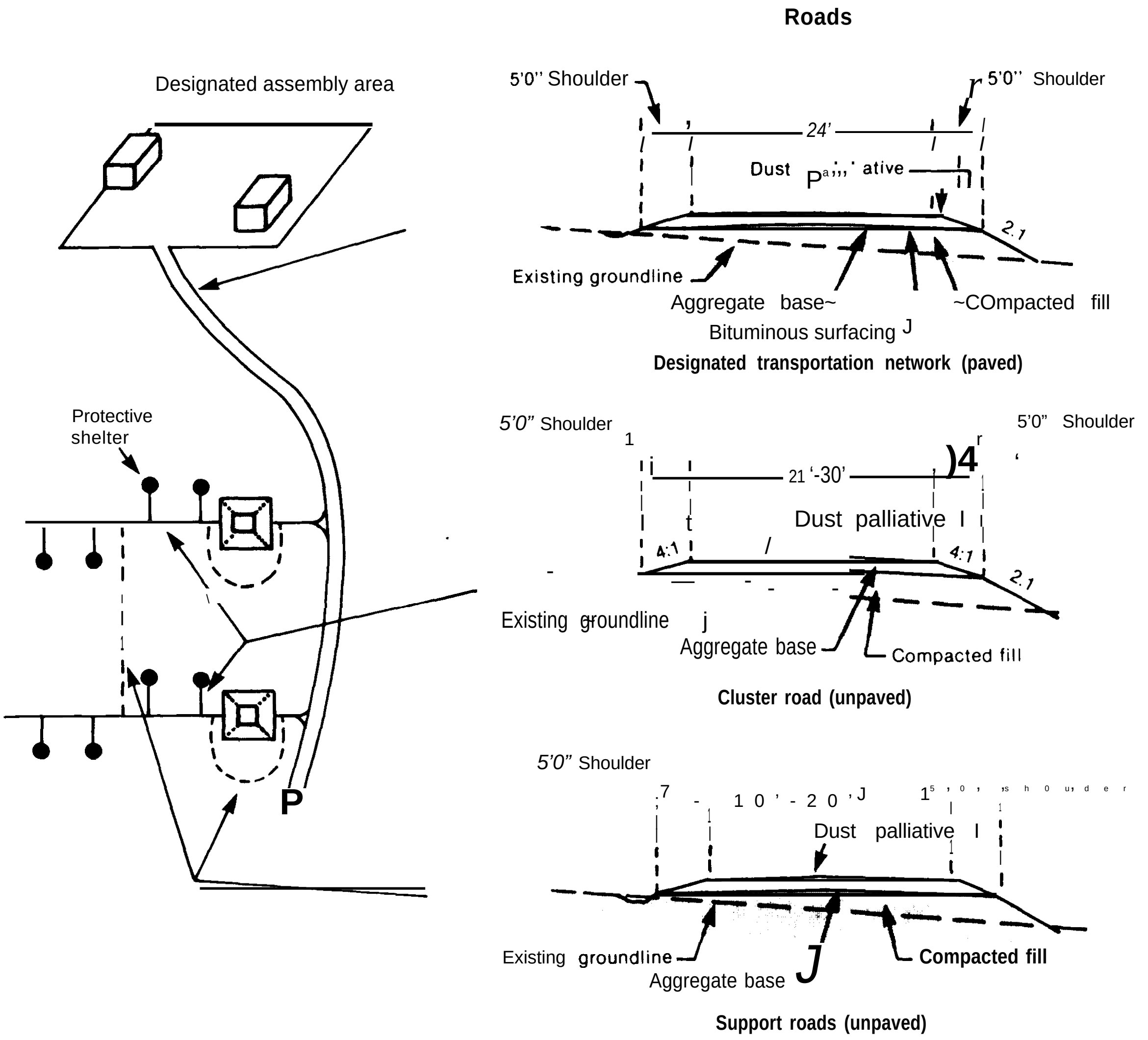
Under the point security system, each missile shelter would be surrounded by a fenced area of 2.5 acres, and only those 2.5-acre sites and necessary military facilities would be excluded from public access. Although the cluster roads would be separated from the paved DTN roads by earth berms to prevent movement of the missile transporters, the berms

Table 6.—Candidate Areas

Area	State	Ecosystem	Population		Private land ownership
			Urban	Rural	
Great Basin	NV/UT	Desert shrub/sagebrush/range	4,922	1,215	<10%
Mojave Desert	CA	Desert shrub/range	51,811	21,980	< 10%
Sonoran Desert	AZ	Desert shrub	77,670	13,183	10%
Highlands	AZ/N M/TX	Semidesert grassland/desert shrub	57,361	9,449	>50%
Southern High Plains	TX/NM	Plains/rangeland	83,921	15,504	950/0
Central High Plains	CO/KA/NE	Mixed grass prairie	54,479	15,123	>9570
Northern Great Plains	MT/ND	Mixed grass prairie	Unavailable		Unavailable

SOURCE U.S Air Force

Figure 32.— Road Construction Profiles



SOURCE U.S Air Force

would be otherwise passable and the public would have nominally unrestricted access to all unfenced portions of the deployment area.

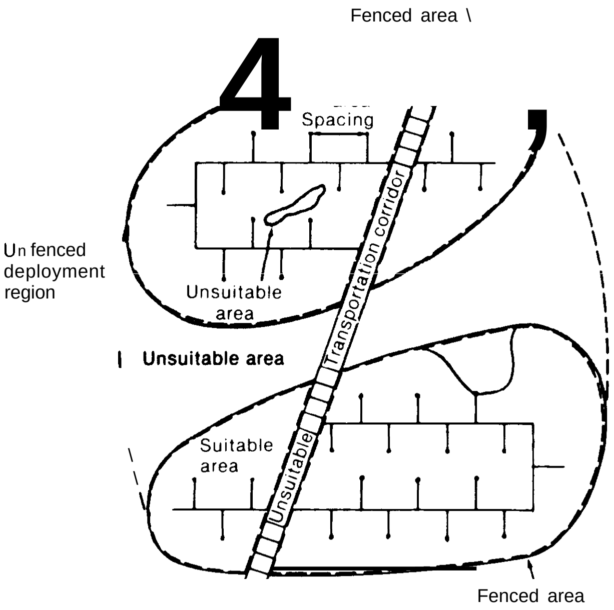
To accomplish this task, the physical security system would include the following safeguards and activities in the deployment area:

- intrusion sensors and access monitors at the (unmanned) shelter sites and cluster maintenance facilities,
- a large number (2,300) of small radars for cluster surveillance,
- four area support centers that would house helicopters for 30-minute response time to cluster-area sensor alarms, and
- roving ground patrols of 20 two-man teams.

Because there would be unrestricted ground movement, there would also be no restrictions on airspace.

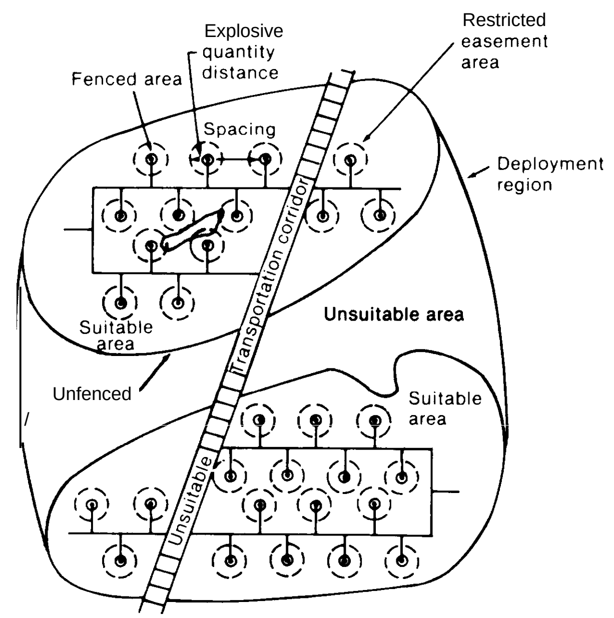
The manning estimate for security police, that includes deployment area patrols, area support center, helicopter crews, and base per-

Figure 33.— Area Security



SOURCE U S Air Force

Figure 34.— Point Security



SOURCE U S Air Force

sonnel is about 2,300, or about 25 percent of the entire manning estimate. This percentage is similar to that at the Minuteman wings.

At the same time, unrestricted public access to the deployment area would require increased security measures to counter against portable or emplaced sensors. Attempts would be made by the security force to deter persons who might be involved in planting sensors for missile detection, attempting to penetrate the sites, or sequentially visiting a number of shelters. Such measures also might include escorts accompanying al l transporter movements, and would, presumably, include frequent "security sweeps" to detect implanted sensors.

Furthermore, it is likely that additional controls would have to be exercised on activities within the deployment area. The Air Force has stated that restrictions on public use of the deployment area would not be necessary, and that ranching and mining activities could proceed "up to the fences. " However, mineral exploration and mining activities pose problems for PLU security, For example, modern geological exploration and development utilize sophisticated electronic equipment, and test for the same types of chemical, electrical, and magnetic signatures as would be associated with the MX missile. I n the event that potentially detectable differences exist between MX missiles and the decoys, unrestricted uses of geologic testing equipment would pose security threats,

Increased traffic due to the necessity of security sweeps to protect against the covert implantation of sensors in the areas surrounding roads and shelters wou ld, however, substantially increase impacts on the physical environment.

President Carter decided against the use of an area security system and directed the Air Force to proceed with point security in 1979, The Air Force presently believes that area security would be infeasible and unnecessary, Nonetheless, OTA'S assessment of the technical problems associated with PLU suggests several implications for the security system requirements of MPS. First of all, it is possible, as the Air Force maintains, that engineering solutions to the problems of missile and decoy similitude will permit point security as planned. Alternately, as has been noted, it is possible that problems of PLU technology will make MPS vulnerable to detection regard les< of security measures. Thirdly, it is possible that weaknesses in PLU technology could be offset by an area security system. Finally, it is possible that uncertainties in PLU technology would warrant operational restrictions on public activities within the deployment area, but outside the fenced exclusion areas established for point security, If Federal lands are used, this possibility raises questions regarding public access to public lands. For example, mineral explorations that utilize highly sophisticated techniques and equipment for the measurement of magnetic, gravitational, geochemical, and seismological characteristics could pose threats to PLU security if they involved the systematic coverage of areas containing many shelters. Livestock operations could be affected by routine PLU activities (such as security sweeps during calving season); and any interference with livestock operations or mineral activities could lead to litigation claims.

Land Use Requirements

The land use requirements of MPS basing would depend largely on the type of PLU security system adopted; but the land use impacts and implications would be defined as much by the configuration of the clusters as by the type of security system.

The total land area required for missile shelters, maintenance areas, support facilities, and operating bases, would consist of 33 mi^2: 19 mi^2 for missile shelters and maintenance areas (4,600 missile sites and 200 maintenance areas) and 14 mi^2 for the operating bases.* In addition to this land, however, 60 mi^2 of land would be required for support facilities and 122 mi^2 would be necessary for roads. The total land area defined by the perimeter of the individual clusters would be approximately 8,000 mi^2, and the total deployment area would be in the range of 12,000 to 15,000 mi2.

Figure 35 illustrates the relation of individual clusters to the basing area.

Under a point security system, only the 19 mi^2 of missile shelters, maintenance facilities, and operating bases would be fenced and excluded from public access. Otherwise, it is Air Force policy:

> to guarantee civilian access to all but the fenced portions of the MX deployment area. This means that c iv i l i ans will have essentially the same access privileges to the deployment area that they have always had. Agriculture can take place right up to the shelter fences, and camping, hunting, and mining can continue without hindrance by the Air Force.

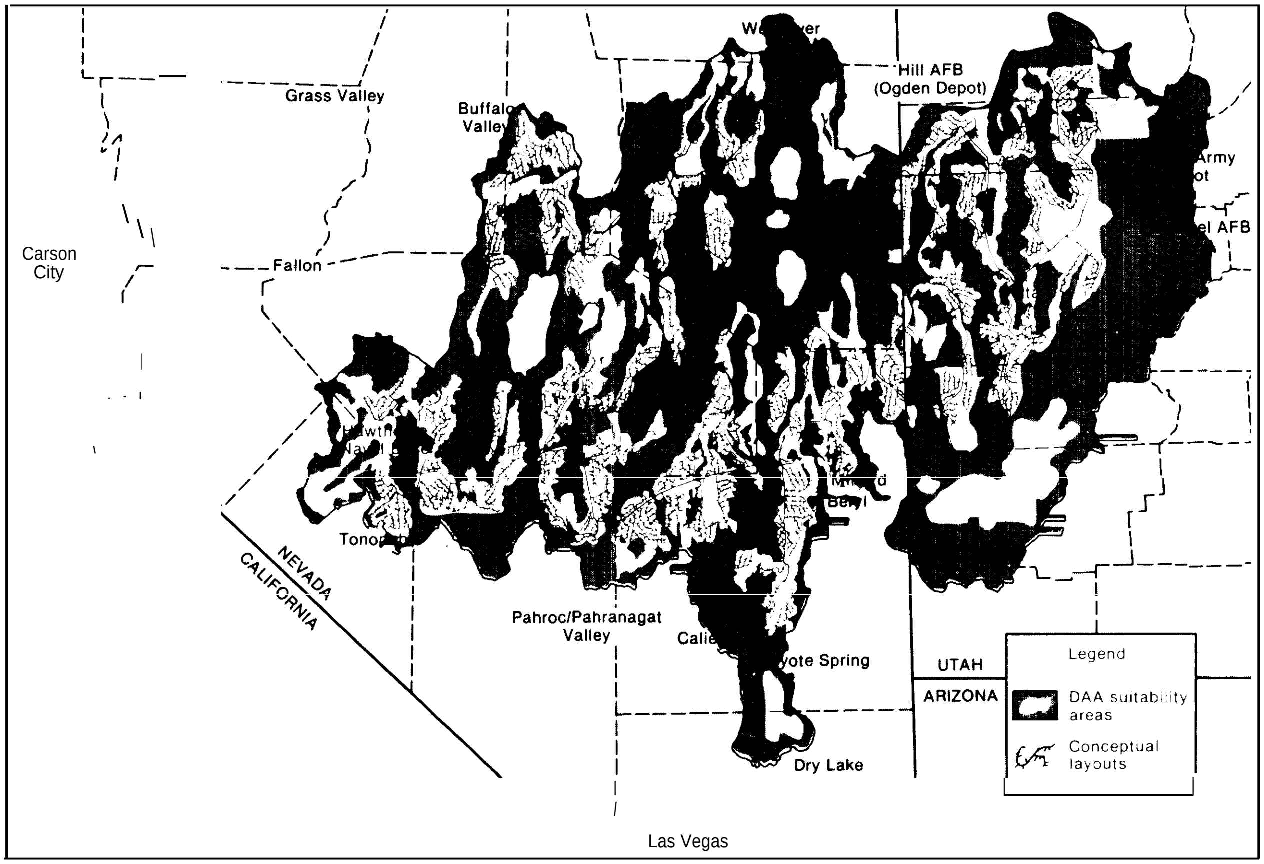
A potential conflict with this policy exists to the extent that Department of Defense safety regulations would require a safety zone of approximately 1 mi2 around each missile shelter; but this regulation would only limit the construction of habitable structures within the safety zone, and waivers could be sought for temporary structures necessary for mining or geologic exploration.

Thus, the total land requirement for MPS would involve an area of 12,000 to 15,000 mi2 for the baseline system, of which 8,000 mi^2 or more would be restricted from public access under an area security system, and less than 35 mi^2 would be restricted from public access under the proposed point security system, I n either event, however, approximately 200 mi2 of land would be converted from existing range to missile sites, roads, and operating bases.

*The Air Force has generally referred to this area as 25 *nautical* mi^2, rather than as 33 *statute* mi^2. Except where otherwise noted, all figures used in this report, however, refer to statute miles.

[1]Unclassified paragraph within *Classified Annex to MX Basing Area Analysis Report;* prepared by HQ USAF/RD-M, Dec. 24, 1980.

Figure 35.— Hypothetical MPS Clusters in Candidate Area



SOURCE U S Air Force

In the proposed deployment area of Nevada and Utah, virtually all of the lands involved would be federally owned land under rider the jurisdiction of the Bureau of land Management of the Department of the Interior (BLM) and use of the lands for MPS would require congressional action pursuant to the Engle Act (requiring congressional review of land withdrawals in excess of 5,000 acres for military purposes) Additionally, pursuant to the Federal Land Policy and Management Act, the Secretary of the Interior would have to approve permits for rights-of-way or withdrawals for roads, railways, pipelines, powerlines, and other construction-related activities.

In the event that non-Federal lands might be used, it would be necessary to acquire these lands through lease, purchase, easement, or condemnation. In either case, however, provisions would have to be made for the initial withdrawal of lands substantially in excess of the minimum requirements, to allow site-specific engineering studies and flexibility in final siting determinations for shelters, roads, and permanent facilities.

In its simplest form the implications of these land use requirements are twofold. First, the necessary withdrawal of lands, whether temporary or in perpetuity, and whether of private lands or public lands, will require the negotiated settlement of a wide variety of property claims and constitutionally protected rights. In the proposed basing area of Nevada and Utah, these claims would include patented mining claims (that are defined as legal property rights), oil and gas leases, BLM grazing permits, water rights, and Native American land rights; all of which are potentially litigious matters.

BLM Grazing Permits

In the case of BLM grazing permits, for example, BLM has authority for the integrated management of Federal range resources under the Taylor Grazing Act of 1934. The carrying capacity of the lands is defined in terms of animal unit months (AU MS, or the amount of forage needed for the complete sustenance of a single cow or horse or five sheep or goats for a single month). Allotted grazing rights are determined on the basis of the relative carrying capacities of private and public lands. Thus, the market value of private lands is tied to allotments for Federal land grazing permits, that are in turn defined by the carrying capacity of the land. The Air Force has estimated that MPS would affect less than 1 percent of the allotted AUMS in the proposed deployment area by dividing the total deployment land area (20,000 m i 2, by the amount of area removed from use (200 mi2). In fact, however, the lands removed from use would be drawn largely from the prime grazing lands between the bottomlands and benchlands of the valleys. Even if it were to be assumed that there would be no impacts on the range land beyond those 200 mi^2 directly removed from use, it is clear that the effects on livestock operations would be disproportionately great, and the value of private ranchlands would be diminished as a result. Similarly, these claims would be complicated by any effects of MPS development on the water rights that are integrally related to the carrying capacities of both the public and private lands.

Oil and Gas Leases

Although legally distinct, both oil and gas leases, and hardrock mining claims, pose similar institutional problems. Under the Mineral Leasing Act of 1920, Federal lands were made available for oil and gas exploration and development. Significant oil and gas leasing occurs in the proposed deployment area and estimates of the potential reserves within the overthrust Belt that cuts through many of the canal idate areas suggest the potential for greatly expanded exploration and development within the next decade. The Air Force policy clearly is intended to permit virtually unimpaired oil and gas exploration; but constraints on activities resulting from PLU restrictions could result in litigable claims.

Hardrock Mining Claims

‘Similary, MPS security requirements could result in litigiable claims based on hard rock mining activities. Unlike oil and gas activities on the Federal lands, that are leased rights, hardrock mining claims under the 1872 Mining Act are patent claims; i.e., legal title of the public lands are transferred by Government deed into private ownership. As such, patented mining claims create private property interests that are compensable, and to the extent that conflicts arise with MPS construction and operations, these claims would have to be settled. Unpatented mining claims present similar problems.

The problem of mining activities is particularly significant because current activities within the proposed deployment area include gold, silver, copper, molybdenum, uranium, fluorspar, barite, alunite, and beryllium; and exploration activities for new deposits utilize state-of-the-art sensing equipment for detection of physical anomalies essentially the same as those involved in PLU discrimination.

Native American Claims

There are a number of complex Native American issues that are related to the proposed Nevada-Utah basing area, probably the most significant of which is the land claim of the Western Shoshone. The Western Shoshone claim that much of the land in the Great Basin was never ceded to the United States and rightfully still belongs to them pursuant to the Treaty of the Ruby Valley, This claim could be settled in many ways ranging from a cash settlement to establishment of a new reservation, but failure to resolve the matter (which is currently In the courts) could leave a cloud on presumed Federal ownership of the proposed deployment area.

Other Indian land claims involve the designation of a future reservation for the recently created Paiute Indian Tribe of Utah (resulting from the amalgamation of several Southern Paiute bands and their restoration to a trust status in the 96th Congress), and possible disruption of the small Moapa Reservation (Southern Paiute) and Duckwater Reservation (Western Shoshone). Disruption of Indian water rights could also lead to litigable claims, and the desecration of sacred ancestral lands would clearly violate the protections of the Native American Religious Freedom Act

Water Availability

In the arid lands of the West, water availability is a controversial issue for all growth and development: first, because the physical availabliity of water is limited; second, because physically available water may be unsuitable for proposed uses; and third, because Instltutional requirements for water rights are complex and often ambiguous

In the case of MPS, relatively high-quality water would be required for construction activities such as concrete preparation, revegetation, and domestic uses, and lower quality water could probably be used for aggregate washing, equipment cooling, and dust control.

The Air Force has estimated the total water consumption of MPS baseline between 310,000 and 570,000 acre-feet including construction, and a 20-year operation I period, with a peak demand of 45,000 acre-feet per year (AFY) in the late 1980's and an annual requirement of 15,000 to 18,000 AFY during operations.

These estimates include requirements for the deployment area, operating bases, transportation systems, support facilities, irrigation of shelter sites and domestic uses of the work force, but do not include additional water for reveget at ion of other disturbed lands or estimates of larger work force populations. In terms of other large-scale projects, these re quirements are roughly comparable to the re quirements of large-scale coal-fired powerplants, that require about 10 AFY/MWe, and synthetic fuel plants, for which estimates of proposed facilities run from 4,000 to 20,000 AFY.

For the purpose of minimizing conflicts with existing water users, the Air Force has proposed using unallocated deep ground water reserves and has conducted preliminary tests of ground water resources. However, the use of deep water reserves poses several problems. In the proposed basing area of Nevada and Utah, the interbasin geology and hydrology is so complex that neither the resources of the deep acquifers nor their relationship to existing surface waters can be known with precision. Therefore, if ground water resources are utilized, effects on surface water and existing al locations would be difficult to predict. It is apparent, nonetheless, that if ground water resources are utilized, certain impacts and tradeoffs will be involved:

- in some areas, water tables would be lowered and both the energy requirements and the costs of pumping water would be i n creased;
- surface seeps, streams, and wetlands might be reduced or eliminated, thus affecting livestock, habitat, and dependent species;
- dislocation of existing surface and ground water rights could be extensive and lead to subsequent litigation; and
- particularly serious water shortage problems and conflicts with prior users appear likely in the vicinity of the proposed operating base at Coyote Springs.

Moreover, uncertainties regarding these problems are compounded by the fact that shortcomings in monitoring and recordation yield only approximate figures in water depletion and water rights.

On the other hand, if the estimated needs of MPS are compared to the existing surface water allocations of the proposed deployment area, it is apparent that sufficient water exists to accommodate the proposed baseline system. In comparison with an estimated annual water requirement of 15,000 to 18,000 AFY for operations and 45,000 AFY for peak year construction, there are 900,000 AFY of currently allocated water rights in the deployment area, and an estimated 300,000 AFY are allocated for future energy and mineral development, (See tables 7 and 8.)

Because the economic value of water is substantially greater for synthetic fuels and energy development than regional agriculture, proposed energy projects have been able to purchase necessary water rights from willing sellers (as in the case of the ıntermountain Power Project scheduled for construction in Delta, Utah, for which rights to 40,000 AFY have been purchased). Presumably the Air Force would be able to find willing sellers with in the MPS deployment area.

Table 7.— Water Required for MX

Year	Acre-feet Construction	Operation	Total
1981	168	0	168
1982	1,247	165	1,411
1983	6,807	510	7,317
1984	19,075	1,781	20,857
1985	26,744	3,760	31,825
1986	38,614	6,405	45,018
1987	37,653	9,545	47,199
1988	26,744	13,925	40,669
1989	12,906	17,615	31,464
1990	3,731	20,166	23,585
1991	2,152	20,166	22,319
1992	761	20,166	20,928
1993	262	20,166	20,475
1994	0	20,166	20,166
2000	0	20,166	20,166

SOURCE Air Force figures Include DDA, OB, transportation system. support fa Cilities irrigation of shelter sites, and domestic uses for operations personnel and their dependents

Table 8.—Water Uses

Irrigation	827,223
Livestock	2,514
Energy and minerals	65,330
Urban/industrial	13,593
Total	908,660
Future energy and minerals (period not indicated)	297,074

SOURCE MX Siting Investication Water Resources Program Industry Activity Inventory Nevada. Utah, Prepared for U S D A F BMO/NAFB, by Fugro National, Inc ,02, September 1980

"The United States could acquire existing water rights by eminent domain (condemnation) if Congress were to authorize such actions. However, even if existing land and water rights were not condemned, it is possible, given the scope of MPS requirements, that landowners, lessees, grazing permitters, and holders of existing water rights could contend that their rights had been either "taken" (and file claims for fair and just compensation), or " injured" (resulting i n a legal claim for damages based on tort and trespass law).

on the other hand, OTA's assessment indicates that ranching (and possibly mining) operations in the proposed basing area would probably close down in response to economic pressures, impacts on rangelands, and possible PLU restrictions resulting from MPS development. Moreover, the laws and regulations of both Nevada and Utah provide for the transfer of water rights on either a permanent or limited-term basis. For this reason it is likely that water would not be a limiting factor for MPS deployment unless it were necessary to construct more than 4,600 shelters or additional water was necessary for revegetation efforts. The issue of revegetation, however, is extremely controversial and pivotal to many of the physical impacts of MPS basing. Air Force estimates of water requirements include some water for revegetation of the missile sites, but no water for revegetation of disturbed lands. Since there are no established methods for revegetation of arid lands without substantial irrigation, the total water required for re-Vegetaion could far exceed al l available resources within the deployment area. Assureing an irrigation requirement of 1 AFY/acre, more than 3 million acre-feet could be necessary based on OTA'S calculations of possible land use impacts.

Physical Impacts

Any large-scale construction projects involve physical impacts that are dependent on site-specific characteristics of the area. Construction generally necessitates direct physical impacts on the soils, vegetation, livestock, habitat, wildlife, water quality, air quality, and other environmental characteristics of a region The severity of these impacts depends on their particular characteristics and their magnitude, on the ability of the ecosystem to adapt and recover from disturbances, and on values subjectively placed on the changes that occur I n the case of MPS basing, the expansive grid-pattern of the system, the magnitude of the land-use requirements, and the utilization of lands that have inherently limited capacity to absorb and recover from disturbances, could lead to widespread desolation of the deployment areas

The Air Force baseline proposal has been described as the largest construction project in the history of man, and it would involve, at a minimum, the disruption of 200 mi^2 of land for missile shelters, roads, and operating bases, as wet I as additional lands for temporary construction camps, haul roads, gravel pits, holding areas, and other construction related activities. I n the absence of irrigated revegetation, or the presence of prolonged drought, the likelihood of these impacts would increase, possibly causing fugitive dust from decertified lands to contribute to drought conditions that could affect agricultural productivity outside the boundaries of the deployment area

As indicated above, MPS basing requires a large deployment area, with a minimum of 4,600 shelters spaced at 1 to 2 mile intervals connected by 6,000 to 8,000 miles of roads throughout a geographic area of 12,000 to 15,000 mi^2 The construction of these facilities would directly disrupt at least 200 mi^2 of land surface: but because arid or semiarid lands would be required and the impacts would be spread over a grid rather than confined to a bounded area, the attendant impacts could spread significantly.

Impacts on Soils and Vegetation

The native vegetation of arid lands is necessarily highly specialized and inherently fragile, resistant to drought but vulnerable to the impacts of physical disturbance and vehicular traffic. Throughout the arid and semiarid lands of the West, including the proposed deployment area and most of the geotechnically suitable candidate areas, "invader" species such as Halogeton and Russian Thistle have colonized rangelands rapidly following the physical disturbance of lands and the removal of native vegetation. These invader species offer protection against further deterioration of the soils by agents of erosion, but the protection is of limited value insofar as Halogeton does not provide nutritious forage and may be toxic to livestock. "Complete recovery (of disturbed lands), " the Air Force has stated, "may take a century or more Long term establishment of Halogeton could prevent reestablishment of native vegetation, and i reversibly degrade the value of vegetation for future wildlife and livestock use.'"

Alternately, if not colonized by Halogeton or other "invader" species, the arid, loose-packed soils are vulnerable to structural disruption or compaction When compacted the soils increase the frequency of water runoff and sheet-wash erosion, and when disrupted the loose particles become susceptible to wind erosion. I n either case, the effects of erosion further degrade the land by altering both the physical and chemical profiles of the soil, and by impacting adjacent lands through the alteration of water flows and the abrasion of airborne particulates. Because arid lands generally have relatively low levels of biologic activity, soils are slow to reform, native species are slow to return, and the alterations of the land are likely to be irreversible without substantial human intervention.

The implications of these processes are of particular concern for MPS deployment because of the scale of the project and the potential for "spill-over" effects.

Although the Air Force claims to have been successful in confining the impacts of MPS-type construct ion act ivities to designated areas on test ranges, they have indicated that "a corresponding degree ot succes will pro b-

Deployment Area Selection Land Withdrawal Acquisition ably be u n likely (in the case of MX MPS) due to the magnitude of the project, "[4] and the amount of disturbed land is likely to increase throughout the c-obstruction stage while add i-tional lands would be disturbed atter construc-t ion as a consequence of off-road vehicle use a n d continued erosion [q]

Thus, the Air Force has indicated that in the absence of mitigation, "the significant adverse impacts from vegetation clearing would range from long-term to permanent, [5] Both as a re-sult of the magnitude of the project and the particularly large interface between disturbed lands and undisturbed lands, the potential im-pacts could spread far beyond the 200 mi^2 directly disturbed by construction of the mis-sile shelters, roads, and support facilities. The DE IS indicates that "the large number of cleared areas would result in a greater im-pact than would occur from the clearing of only a few such areas, "6 and "the more dis-turbed area, the larger the amount of vegeta-tion lying around the perimeter of the cleared areas which will be subject to erosion and f looding '" Consequently, the Air Force es-timated that vegetative clearing and the asso-ciated secondary impacts of construction ac-tivities could extend up to *0..5* miles from points of direct disturbance. Although this figure was considered in the DE IS only as "rough index, " it clearly indicates the poten-tial for extensive disruption of the deployment area,

If a vegetative disturbance area of only 0.25 miles from directly impacted lands is assumed, the construction of 8,000 miles of roads could resultin devegetation of 4,000 mi^2 of land; and if a perimeter of 0.25 miles around each of the 4,600 missile shelters is considered, an addi-tional 500 to 1,000 mi^2 of land could be lost (depending on overlaps with the impact zones of the roadways). Figure 36 i Illustrates this issue.

'Ibid, p. 4-99
'Ibid, p. 4-97
'Ibid, p. 4-97
'Ibid
'Ibid
'Ibid

On this basis, 5,000 mi^2 of productive range-lands could be lost in addition to lands im-pacted by operating bases, construction camps, haul roads, gravel pits, other construc-tion related activities, and secondary develop-ment resulting from the population influx associated with MPS construction and deploy-ment. If the impact perimeter is increased to 0.5 miles, as considered in the DE IS, the baseline system could impact 10,000 mi^2. And if it is assumed that the "periodic sweeps" re-quired by PLU activities would be concen-trated in roughly the same land areas within 0,25 or 0.5 miles from MPS roads and missile shelters, then, as we have indicated, the im-pacts could be permanent.

To mitigate these impacts the Air Force has proposed a variety of measures, including the reapplication , of surface soils where sub-surface soils are of lower quality; stabilizing slopes; securing mulches; planting vegetation; "minimizing) repeated disturbance of planted areas from livestock and off-road vehicle (ORV) activity until vegetation is adequately reestablished;" and irrigating planted areas that receive less than 8 inches of rainfall per year.

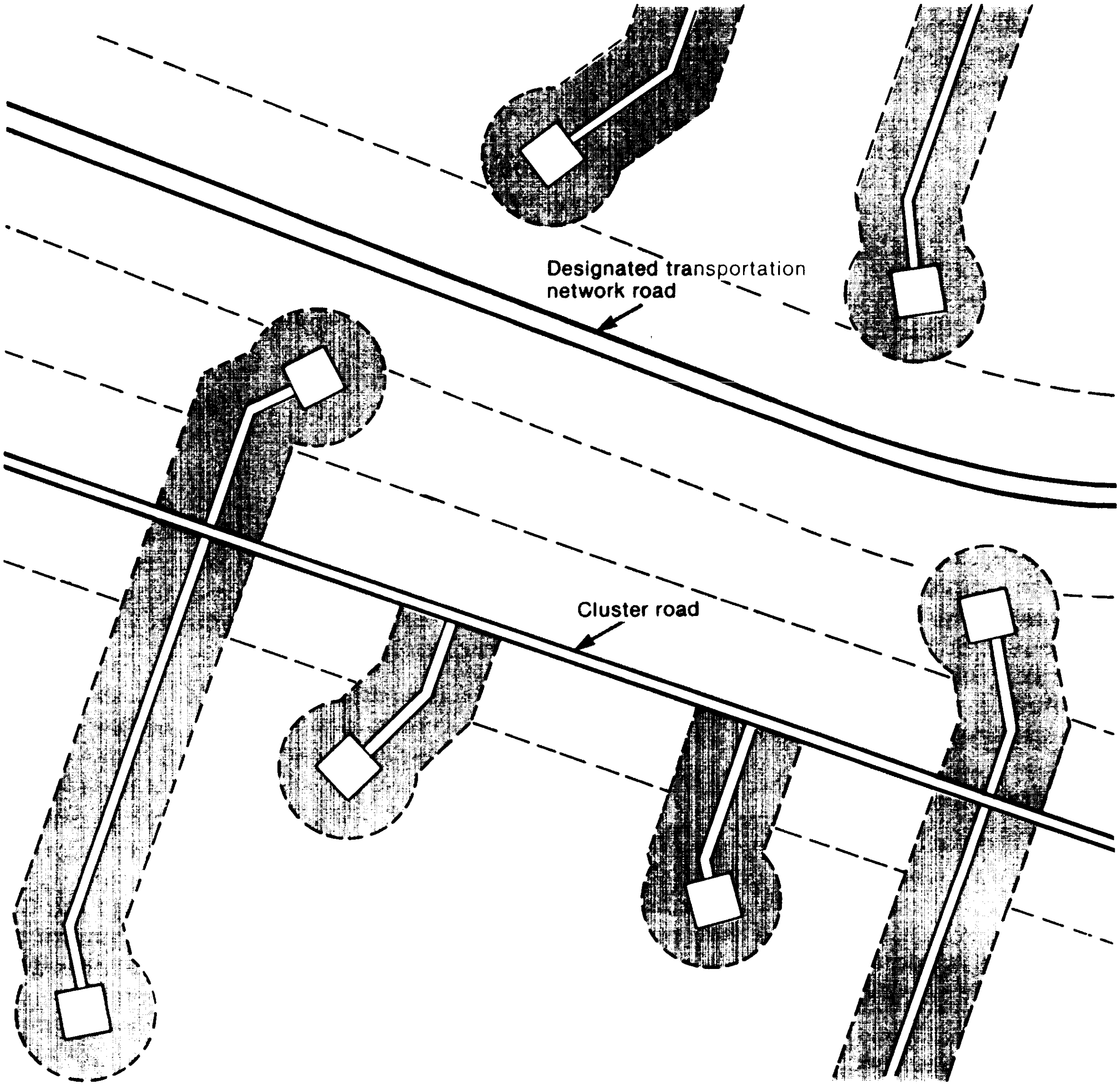
These last two mitigation measures are par-ticularly important, not only because of their value to successful revegetation, but also because of the impacts they suggest on ranching operations, water requirements, and the costs of MPS deployment, As the Air Force not es:

> Planting efforts usually fail in areas which recieve less than 8 inches of precitation an-nually (which includes roughly 80 percent of the projected disturbed area), unless irrigation is used Revegetation water is not included in water estimates presented in this report [EIS] and would increase requirements significant-lV [q]

In fact, if 1 AFY/acre is required for revegeta-tion, and 5,000 mi^2 of land is disturbed by con-struction and secondary impacts, successful revegetat ion would require more than 3 mil-lion AFY. Even using much more conservative

[9] 4-99

Figure 36.—Potential Vegetative Impact Zone



SOURCE Off Ice of Technology Assessment

assumptions, the DEIS notes that "a comprehensive revegetation program would be very expensive. [10]

These potential impacts of MPS development are especially significant in the context of western regional development. During the past decade, expanded energy development and population growth have greatly increased pressures on the physical environment to the point where they may be straining the region's life support systems and there is increasing concern about the potential spread of desertification throughout the region. Desertification generally refers to the degradation of arid lands to the point where they can no longer support life, and it tends to break out, "usually at times of drought stress, in areas of naturally vulnerable lands subject to pressures of land

"1 10 lbid

use."[11] Estimates of U.S. lands vulnerable to desertification range from 10 to 20 percent of the continental United States, and the President's Council on Environmental Quality recently warned that the threat of continued desertification could have "far-reaching implications in terms of the Nation's food and energy supplies, balance of payments, and its environ merit."[2] Symptoms of desertification are already present throughout many parts of the arid and semiarid West— including overdraft of ground waters, salinization of topsoils and waters, reduction of surface waters, unnaturally high erosion, and desolation of native vegetation[13] — and projected expansion of Western energy resources will involve continued pressures throughout the region during the next decade.

In this context, any number of alternate impact scenarios, inciuding expanded resource development, rapid population growth, off-road vehicle traffic, or prolonged drought conditions, could contribute to increased desertification: but MPS in arid lands, because of the magnitude of its grid configuration, clearly poses the greatest potential threat.

Weather Modification

Desertification within the deployment region also raises questions of potential atmospheric effects that are highly speculative at this time, but which, because of their potential implications for domestic agricultural productivity, deserve attention.

The Air Force has calculated that "fugitive dust" emissions from MPS construction (based on 200 mi of land disturbance) would result in tenfold to twentyfold increases in atmospheric particulate, and violations of standards promulgated u rider the Clean A i r Act, These em issions would degrade air quality over a wide area (including several national parks), and there is a possibility that health problems could result from spore-laden dust churned up from the desert soil,

other concerns, however, are suggested by recent studies of atmospheric particulate that suggest that climatic effects may result from increasing aerosols of fine particulate in the lower atmosphere. While the back scattering of solar energy tends to decrease total atmospheric heating and thereby cool the lower atmosphere, absorption of radiant energy by particulate matter tends to increase the temperature while simultaneously acting as condensation nuclei that adsorb moisture and retard cloud formation. The net result of these effects, depending on their relative magnitudes and a variety of other considerations, could be to increase temperatures in the lower atmosphere and decrease precipitation. Moreover, these effects may be most likely in arid regions, as evaporation from moisture in more humid climates would tend to offset the increasing temperatures brought about by absorption of radiant heat.

The long-distance transport of fine particulates from desert regions of the world has been well-documented, but the potential ef - feel-s of resulting climatic alterations are unknown. I f a causal relationship exists between fugitive dust emissions and downwind weather mod if i cation, extensive fugitive dust emissions from MPS deployment in the Great Basin could have substantial economic impacts on agricultural productivity outside the deployment area; and as in other matters discussed in this section, drought conditions during the construction period would exacerbate the potential threats.

Least Productive Lands

Finally, in considering the physical impacts of MPS basing, it should be noted that the Department of Defense Supplemental Appropriation Act of 1979 included "the sense of Congress that the basing mode for the MX missile should be restricted to location on the least productive land available that is suitable for such purpose."[14] Accordingly, the pro-

[11] *United Nations Conference on Desertification*, Aug. 29-Sept. 9, 1977 Plan of Action and Resolutions, pp. 1-2, New York, 1978.

[12] *Desertification of the United States*, President's Council on Environmental Quality, Washington, D.C. 1981.

[13] Ibid

[14] Public Law 96-29, 6/27/79

posed deployment area in the Great Basin of Nevada and Utah reflects this criteria, It is not the */east* productive land among the ,geo-technically suitable areas; but it is *among* the least productive, and is considerably less productive than the High Plains regions that extend from Texas and New Mexico up through Colorado and Nebraska to Wyoming,

However, the more productive agricultural lands have an inherently greater capacity to absorb the impacts of construction activities and, in contrast to the Great Basin, could be revegetated with relative confidence. For this reason, the total amount of land lost to agricultural productivity might be considerably less than in areas where revegetation is more difficult. If it is assumed that 200 mi of {and would be lost in a grassland ecosystem and that the market value of crops is $80/acre/yr, then the total economic loss associated with this basin[g] option would be approximately *$10.2* million per year. And if twice as much land would be lost to agricultural productivity in the Great Basin, with the market at approximately $5/acre/yr, then the net agricultural loss would still be less than 10 percent of the lost crop value in a grassland ecosystem. Based on this rough estimation, 3,200 mi' of rangel and would have to be lost to equal the lost agricultural value of 200 mi^2 of crop land.

Therefore[r] if the impacts of MPS construction can be confined to the designated areas during construction, and mitigation measures are not very expensive, the economic costs of deployment in "least productive lands" would appear to be considerably less than i n more productive croplands. But if it is assumed either that the impacts will spread in arid lands, or that mitigation measures to prevent the spread of impacts will be more than $10 mill ion per year, the economic costs of " least productive lands" are likely to be at least as great as the costs of using more productive lands

Socioeconomic Impacts

The socioeconomic impacts of MPS basing, like the physical impacts, are closely related to the siting criteria. As previously noted, the criteria require sparsely populated areas for the purpose of minimizing the interface between the public and PLU activities. In theory, selection of a deployment area with a minimum number of people might ensure that a minimum number of people would be affected by the rapid growth associated with MPS construction. In reality, MPS construction is likely to affect not only the residents of the deployment area, but migrants drawn to the area by MPS construction opportunities, residents of surrounding urban areas, and communities dependent on regional energy development that could be constrained by MPS manpower and materials requirements. The affects, however, would be varied. On the one hand, construction activities would provide new jobs and employment opportunities, higher wages, and the potential for accelerated regional development, including expanded economic activities and community services; and once completed, the operating personnel associated with MX/MPS would provide a stable economic base within the surrounding community. On the other hand, the process would transform the economic structure of the existing communities and pose enormous problems of growth management resulting from uncertainties in the size and regional distribution of the project work force and secondary populations.

Community Impacts

The literature of socioeconomic impacts associated with western energy resource development clearly indicates that there are many adverse affects associated with rapid growth, and the single most important factor that influences these impacts is the size of the existing community population prior to development.[15] In general, communities with

*This cost equation is, in fact, much more complicated, and is dependent on a wide range of highly uncertain variables. Nonetheless, it illustrates the approximate form of the tradeoffs involved

[15]For more information, see *BLM Social Effects Project Literature Review;* prepared for the Bureau of Land Management, Department of the Interior by Mountain West Research in Association with Wyoming Research Corp. in draft, January 1981.

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larger populations (at least 10,000-25,000 people) have the capacity to absorb greater population influxes without suffering adverse affects. To the extent that infrastructures of housing stock, schools, roads, sewers, health care facilities, and administrative services all exist prior to rapid growth, these facilities often can absorb much of the population increase, and the marginal costs of expanding services and facilities are relatively small. Insofar as the Air Force siting criteria for MPS exclude areas with cities of more than 25,OOO people within 20 miles, adverse socioeconomic effects would be essentially unavoid able

Based on recent experience with Western energy resource development, these i m pacts would include a restructuring of the local job economy as new jobs are created and existing residents change jobs in hope of new opportunities and higher wages; changes in the lifestyle of relatively isolated and closely integrated communities; inadequate housing, roads, sewers, schools, health care facilities and administrative services; regional wage and price inflation; and increased stresses on individuals, families and communities. It is also worth noting that local residents are usually unable to compete successfully with new migrants for skilled labor positions and higher paying jobs, and that few new jobs go to unemployed residents of the area, fewer still to women and minorities, and virtually none to Indians.

As a consequence of the influx of new migrants with a relatively high proportion of well-educated or skilled laborers, competition for jobs does not always benefit existing community residents. Existing businesses are often unable to compete with the higher costs of wage and price inflation; new small business operations are frequently unable to compete with the high capital costs and risks associated with meeting rapidly expanding business opportunities; existing residents may resent the influx of new residents and associated changes in community lifestyles; incoming residents often find adjustment to reduced levels of social services and amenities difficult; and increases in alcoholism and child abuse tend to appear as manifestations of these increasing community pressures.

Finally, in the isolated ranching, mining, and farming communities of the Western States, social ties between families and neighbors tend to be especially strong, and both administrative government and the provision of social services may be deeply rooted in informal community mechanisms. This relationship is true in general throughout the isolated communities of the Western States, and it is particularly true of the Mormon communities of southern Utah, in which the integral relationship between church, family, and community would be profoundly disturbed by the influx of a large number of migrants who could not be assimilated into the fabric of this cu lt u re.

These issues are complicated by the fact that the Western States are in a process of rapid growth and transformation, and that virtually all of the available literature has been drawn from experiences with western energy resource developments that have been relatively large in relation to the existing community sizes, but that are relatively small in comparison with the manpower requirements and geographic expanse of MPS. In contrast to large-scale coal-fired powerplants and synthetic fuel facilities with construction work forces of 2000 to 5,000 people, located at specific sites that could be clearly defined in relation to the surrounding communities, estimates of the baseline construction work force for MPS range from 15,000 to 25,000 people; and the Air Force is considering the use of as many as 18 temporary construction camps spread throughout a geographic area of 15,000 mi^2 for construction of MPS, Furthermore, there is evidence to suggest that in several instances the net impact of rapid growth on small communities has been positive. Following the boom-bust cycles of rapid growth and decline, the communities have readjusted to lifestyles closely resembling preimpact conditions, but with the added benefits of expanded facilities resulting from an increased population base, Thus, it might be the case that individual communities within the deployment area might benefit from MPS deployment, or alternately, that the effects of MPS deployment might be indistinguishable from the effects of accelerated mineral resource and energy development in surrounding areas. In general, however, it appears that the residents of small communities in the deployment area would be unlikely to benefit from MPS development, and probably would face the loss of existing ranching and mining operations within the area

At the same time, the larger urban areas on the periphery of the deployment area would be affected by MPS development in a totally different way Unlike small towns faced with neither the administrative nor the financial capacities to accommodate large-scale growth, larger urban areas with these capabilities would be faced with uncertainties regarding the magnitude and the location of the growth that might occur. unlike large-scale energy developments in which clearly defined locations for planned facilities reduce the uncertainties of planning decisions to questions of timing, financing, and scale, the magnitude of MPS and geographic dispersion of the proposed development complicates these issues substantially

In contrast to large-scale powerplant developments with construction work forces of 2'000 to 4,000 people, estimates of the onsite work force required for MPS development range from 15,000 to 25,000, and OTA'S analysis indicates that actual construction work force requirements could be as high as 40,000 people In this case, the total population impacts of MPS could be in excess of 300,000 people Because regional economic impacts are a function of the magnitude and distribution of the work force population and associated growth, and the range of possible population impacts is so great, it is worth looking at the basis for these figures in some detail.

Work Force Estimates

The Air Force has estimated that MPS construction would require a peak construction work force of 17,000 workers and a total population of slightly more than 100,000 during a period of overlap between construction activities and initial operations

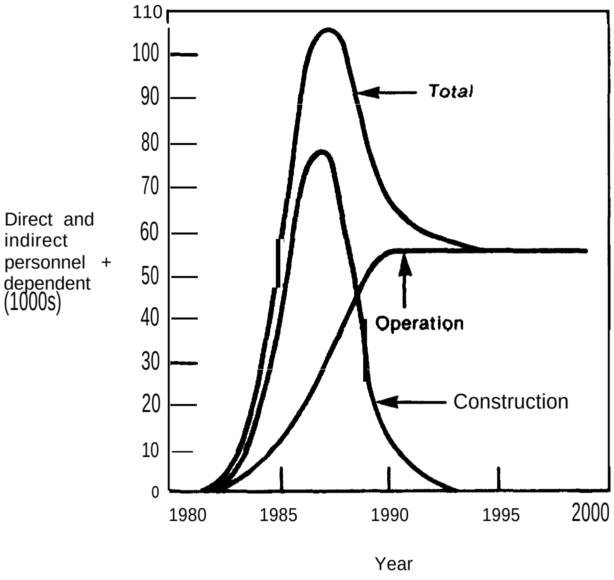
Figure 37 illustrates the approximate relation between the population of the construction work force, operating personnel, and their dependents.

In fact, these figures represent conservative estimates By the time the DEIS had been prepared, the construction work force figures had been revised upwards almost 40 percent* – and they fail to reflect the uncertainties that are associated with all of these estimates

Figure 38 illustrates the direct construction work force estimates (including onsite and "life support" labor) of the Air Force, the Army Corps of Engineers, and joint Air Force/Army Corps task force on manpower estimates. Figure 39 illustrates the relationship between on-

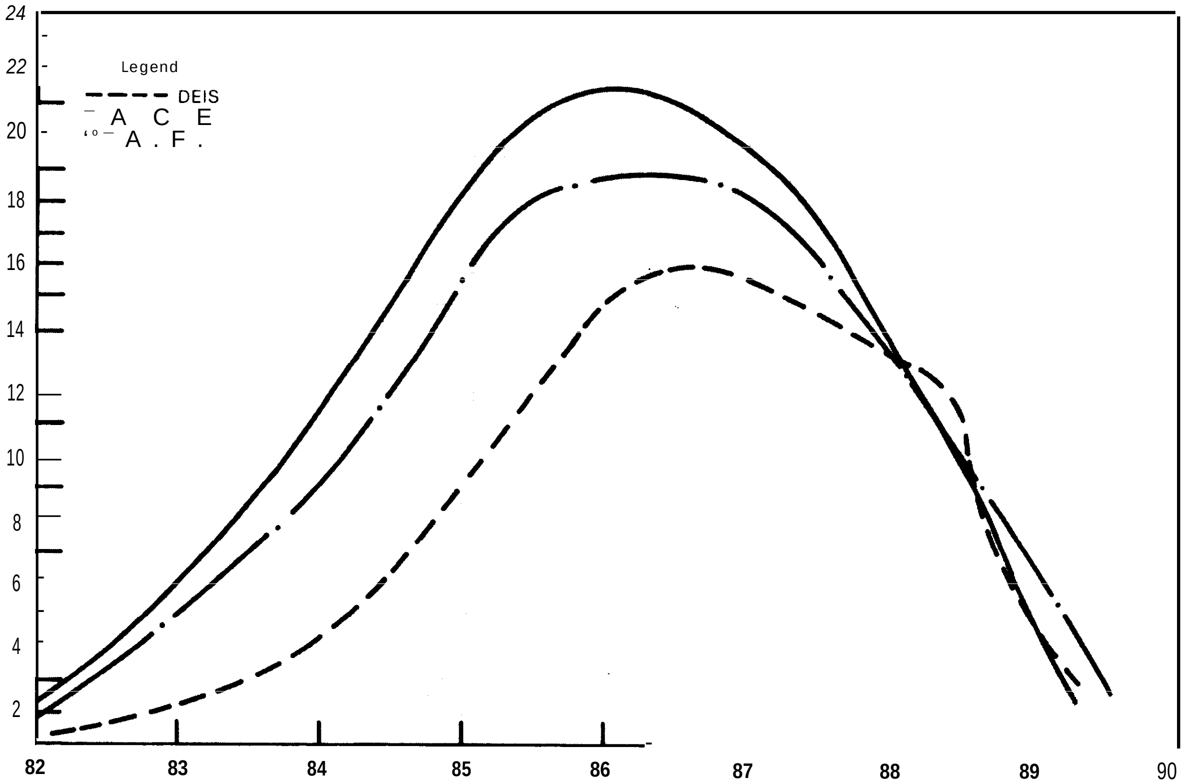
*The Draft Environmental Impact Statement on Area Selection was published along with an errata sheet which contained revised work force estimates based on a joint task force of the Air Force and the Army Corps of Engineers, but the analysis contained in the report was based on the earlier (lower) estimates

Figure 37.—Construction Work Force, Operating Personnel, and Secondary Populations



SOURCE U S Air Force

Figure 38.— Baseline Work Force Estimates



Annual average direct construction work force (including life support)

A. F./DEIS 1,150	2,000	4,450	10,800	17,050	15,450	13,050	4,800
ACE 1,160	6,940	14,305	19,750	23,730	16,900	12,670	4,725
A. F.IACE 2,035	5,590	9,510	17,910	18,560	17,670	12,765	5,490

SOURCE A F /DEIS Chapter 1, Errata Sheet, Table 11

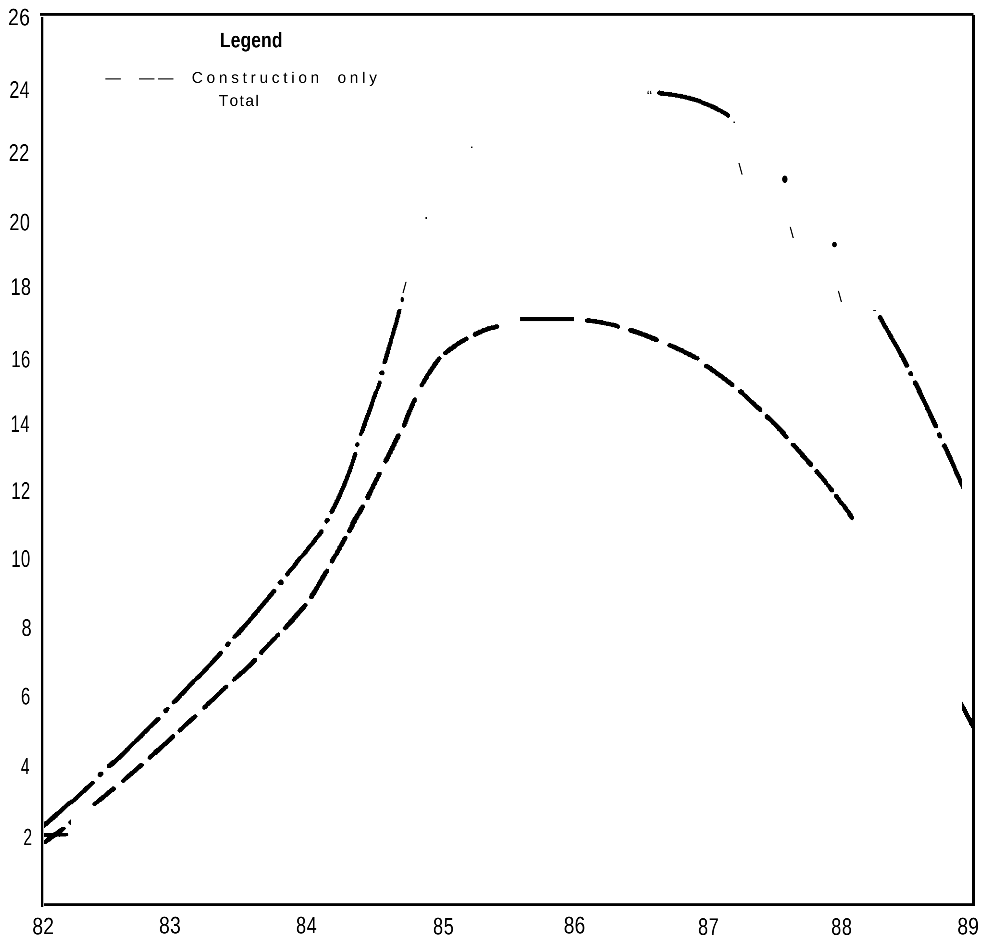
site construction labor estimates and estimates of the total construction work force required.

Estimates of the costs and manpower requirements of major construction projects, however, have characteristically underestimated actual costs and manpower needs. Evidence from various studies of this problem suggests that these overruns result in part from revisions in engineering designs while construction is in progress, delays caused by late deliveries of major components or bottlenecks in materials supplies, and difficulties in utilizing manpower and materials efficiently on a time-urgent schedule. Tables 9 and 10 provide two indices of these problems. Table 9 indicates the average cost overruns in weapons systems, public works projects, major construction projects, and energy process plants, and table 10 compares the projected and actual manpower needs of large-scale coal-fired powerplants.

If all overrun factor of 73 percent is assumed on the basis of the average manpower overrun associated with coal-fired power-plants in the West * the manpower estimates for MX/MPS would increase to more than 42,000. As a l so

' The average manpower overrum from coal powerplants in the West is used here because it represents construction of a known technology (rat her than a new" technology) in the arid West Other projects such as nuclear powerplant or synthetic fuelplants involve higher degrees of new technologh development

Figure 39.—Comparison of Onsite and Total Construction Work Force



Construction only	**1,832**	**5,031**	**8,559**	**16,120**	**16,700**	**15,900**	**11,490**	**4,941**
Life support	203	559	951	1,790	1,660	**1,770**	**1,275**	**549**
Assembly and check out	0	400	1,000	3,550	6,000	6,000	5,900	5,750
Total	2,034	5,990	10,510	21,460	24,564	23,670	18,665	11,240

SOURCE Off Ice of Technology Assessment

Table 9.—Cost Overruns in Large-Scale Projects

Type of system	Actual cost/ estimated cost
Weapons system	1.40-1.89
Public works. ., ., ...	1.26-2.14
Major construction ., ...	2.18
Energy process plants.	2,53

SOURCE Office of Technology Assessment, 1981

noted (see pp. 42-44 and 86-89) MPS construction might require an accelerated schedule to build 8,250 shelters by 1990, in which case manpower requirements would increase another 60 percent to almost 68,000 construction workers. Figure 40 indicates the total construction work force required if the baseline figures were increased 60 percent to allow for

Table 10.—Estimated and Actual Construction Work Forces for Coal-Fired Powerplants

Plant (and State)	Estimated peak	Actual peak	Percent change
Antelope Valley (N. Dak.)	840	1,370	+ 63
Boardman (Oreg.)	760	1,482	+ 83
Clay Boswell (Minn.)	900	1,560	+ 73
Coal Creek (N. Dak.)	980	2,113	+ 91
Laramie River (Wyo.)	1,390	2,200	+ 58
White Bluff (Ark.)	1,100	1,900	+ 72
Average overrun			+ 73

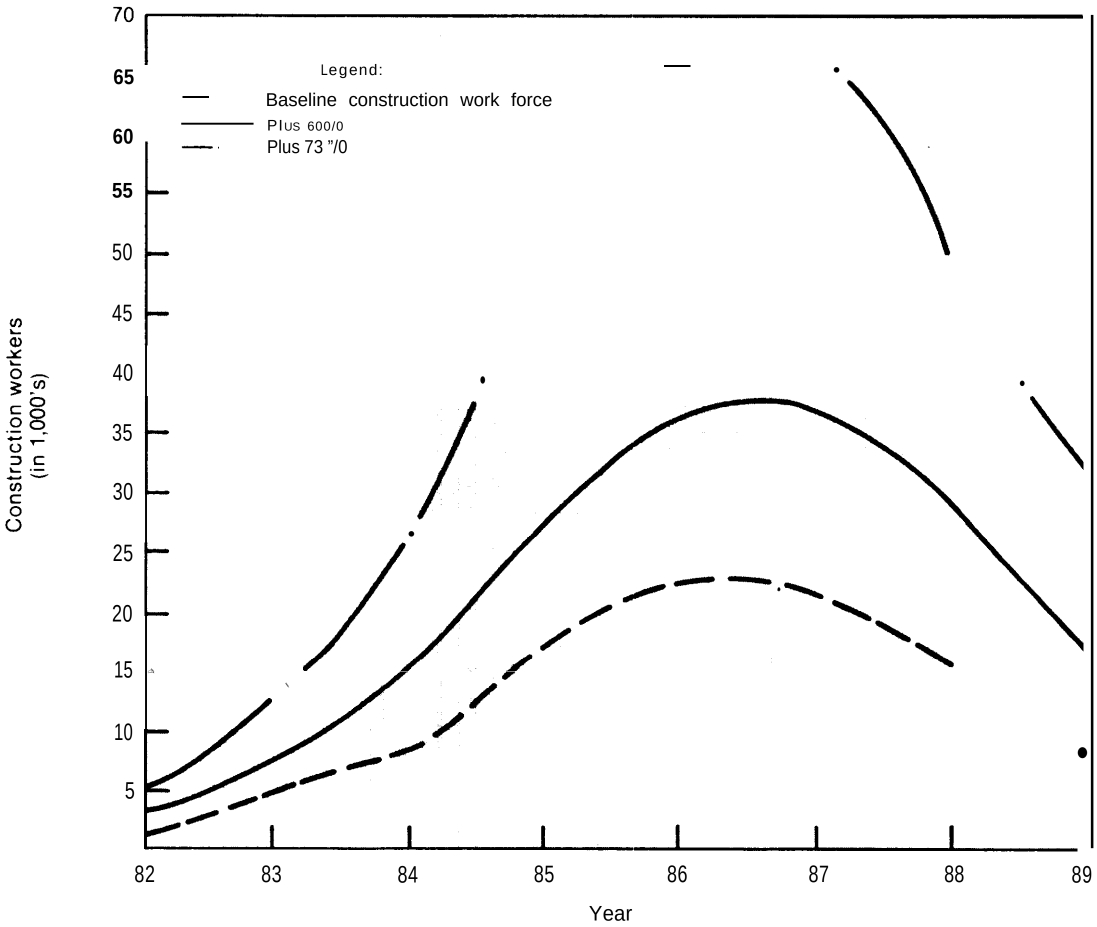
SOURCE: Gilmore/DRI.

an accelerated construction schedule and 73 percent to allow for manpower overruns.

Population Estimates

Similar uncertainties affect estimates of the secondary populations associated with the construction work force. Assumptions must be made regarding the ratio of new secondary employment (e. g., construction of new housing, grocery stores, gas stations, etc.,) by MPS con-

Figure 40.—Construction Work Force: High-Range Projection



Baseiine construction work force	2,034	5,990	10,510	21,460	24,S60	23,670	18,666	11240
Plus SO%	**3 a**	**9,884**	16,816	34,336	39,296	37,872	29,864	17,964
Plus 73 "/0	**5,630**	**16,860**	**29,091**	**59,401**	**67,993**	**65,518**	**51,664**	**31,112**

SOURCE Off Ice of Technology Assessment

struct ion and operations, and additional assumptions must be made regarding the demographic characteristics of the construction work force. Despite the fact that the characteristics of western energy project construe tion labor forces have been studied, significant uncertainties exist, and the population impacts of MPS could vary considerably depending not only on the number of construction workers involved, but the relative numbers of single and married workers, and choices they make regarding residential locations and commuting alternatives. Using the Task Force baseline estimate of construction work force size (see fig. 38), figure 41 illustrates the range of secondary population growth associated with the base case assumptions using three different sets of demographic assumptions,

Finally, if these factors are considered in conjunction with one another, a wider range of population growth scenarios results. Figure 42 illustrates the range of possible population growth scenarios resulting from alternate assumptions regarding the location and demographic characteristics of the primary work

Figure 41.— Range of Secondary Population Growth

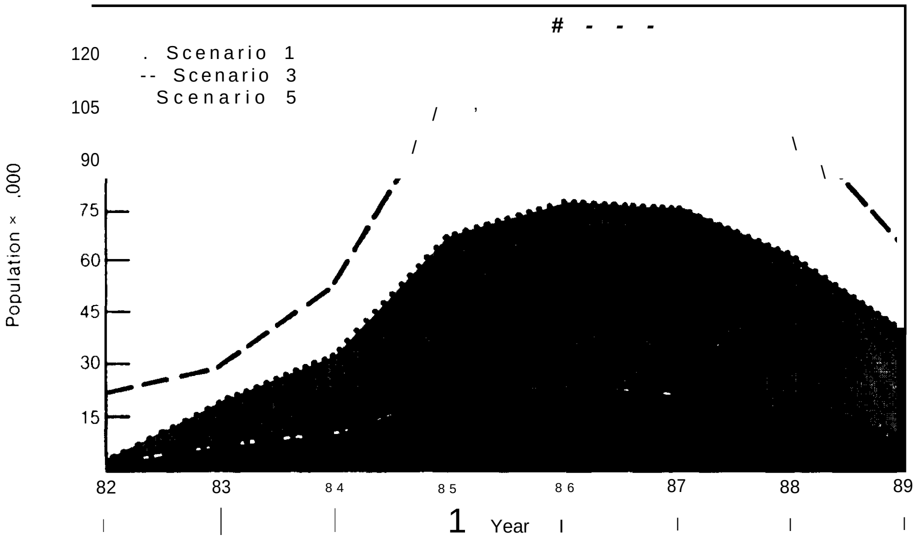


Table 2 summarizes these data:

Scenario 1 (x 1 .73)	3,404	18,289	32,576	67,681	78,796	76,949	62,035	38,699
Scenario 2 (x 1 73)	2,839	12,594	22,382	27,789	53,595	51!917	41,895	25,944
Scenario 3 (x 1 73)	4,356	29,689	53,167	110,876	129,458	126,668	102,449	64,333
Scenario 4 (x 1 .73)	2,493	7,380	12,872	26,346	30,313	29,371	23,313	14,169
Scenario 5 (x 1 73)	2,174	6,412	11 ,2?5	22,940	26,303	24,629	20,070	12,127
	1982	1983	1984	1985	1986	1987	1988	1989

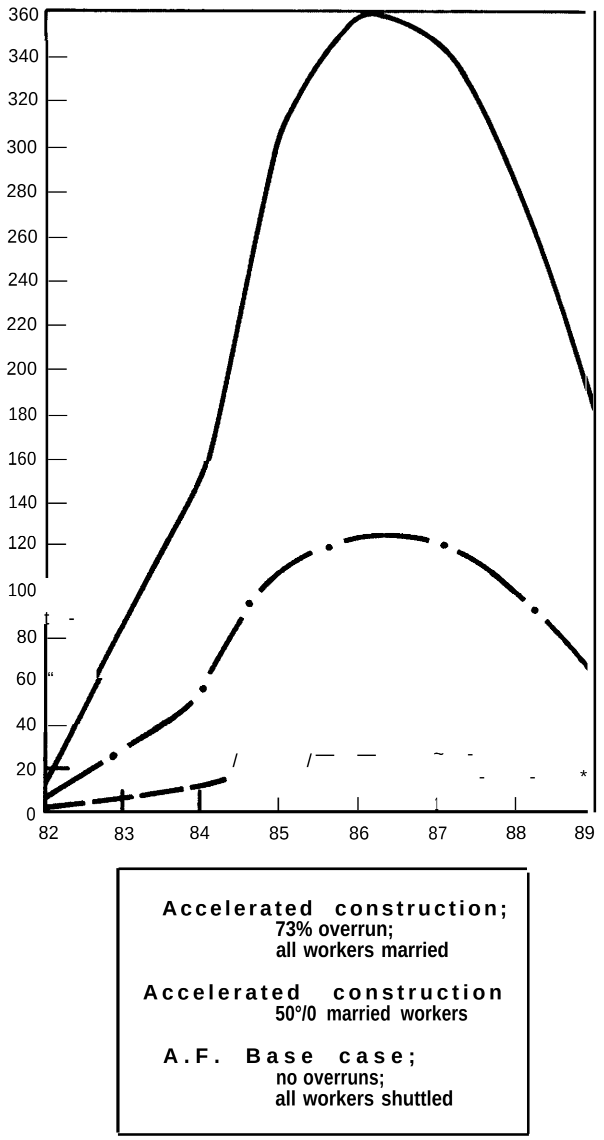
Scenario 1 0511 single + 0.489 married
Scenario 2 0375 single + O 25 married + 0375 shuttled
Scenario 3, all workers married
Scenario 4. all workers single
Scenario 5 all workers shuttled

SOURCE ERC p20/Office of Technology Assessment

" /footnote from page 25

SOURCE Off Ice of Technology Assessment

Figure 42.— Range of Potential Population Growth



Accelerated construction; 73% overrun; all workers married	12,057	82,179	147,166	306,904	358,339	350,617	283,578	178,073
Accelerated construction 50% married workers	5,446	29,262	52,121	108,289	126,072	123,118	99,256	61,918
A.F. base case; no overruns; all workers shuttled	2,174	6,412	11,225	22,940	26,303	24,629	20,629	12,127

SOURCE Off Ice of Technology Assessment

force, the rate of MPS construction, and the possibility of an overrun in construction labor requirements.

If the operational personnel and dependents are also factored into this scenario, the peak population would obviously increase. From the standpoint of regional growth management, the magnitude of MPS development and the uncertainties inherent in the population growth scenarios pose serious economic problems. Based on Air Force estimates of projected population growth, OTA has estimated that the costs of socioeconomic mitigation could run as high as $7 billion during the construction and operation of MX/MPS, and adverse impacts would result either from the underinvestment in capital facilities, or from overinvestment. Furthermore, because MPS would involve such a large geographic land area, these uncertainties are compounded by the fact that it cannot be known precisely where various levels of development would take place.

The social impact assessment literature clearly suggests that one of the instrumental factors in successful impact mitigation is the process of political negotiation with impacted communities to plan for social change, economic development, and growth management. In the case of MX/MPS the highly speculative nature of population distribution and impacts, together with the urgency of the time schedule for construction, would effectively preclude such planning to optimize the potential benefits or mitigate the adverse impacts of MX/MPS.

Regional Energy Development

The socioeconomic impacts of MPS are further complicated by the likelihood that MPS basing would affect the availability of manpower and materials for regional energy development. During the past 10 years, domestic energy developments have been affected by delays and constraints caused by shortages of skilled labor and critical materials. During the next decade most of these constraints are anticipated to continue and to the extent that MPS requirements overlap, they could further inhibit regional energy development.

Initially, MPS would require substantial amounts of basic construction resources, such as concrete and steel. Although it does not appear that MPS baseline construction would overwhelm the existing markets for these materials, it is likely to strain the transportation network that supplies these materials throughout the Western States, and in the event that an expanded system were necessary, industrial capacity would have to be expanded.

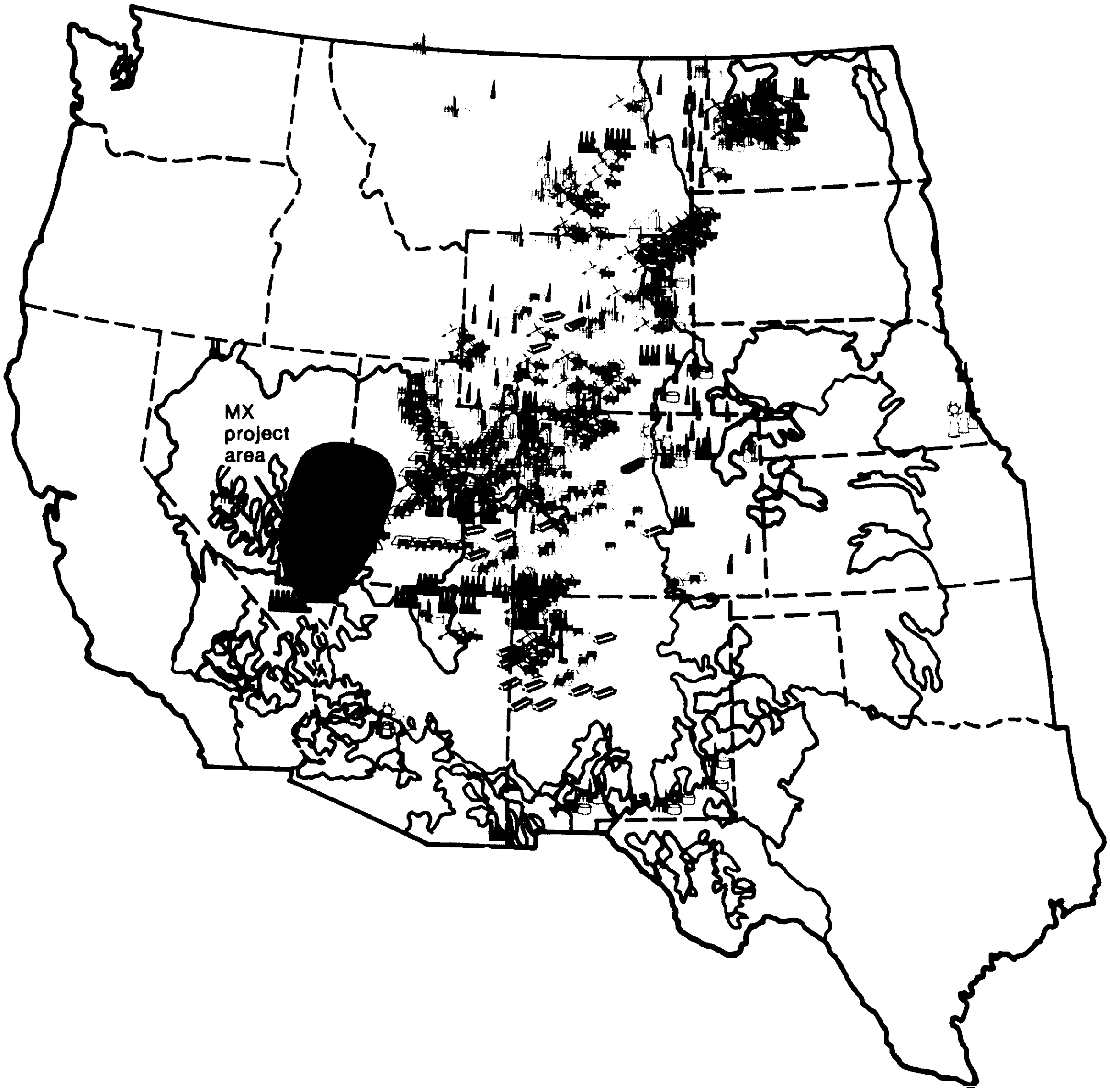
Secondly, MPS would require certain critical materials, including special metal alloys, castings, and forgings, that could create bottlenecks in supply. The domestic castings and forgings industry has little flexibility, and if specialized components are required for 4,600 shelters, constraints could affect availability in the energy and aerospace industries.

The Air Force has identified a general list of critical materials, but information regarding material components may be related to PLU design considerations, and OTA has been unable to identify more information regarding special materials and alloy requirements. Conversely, MPS could affect domestic supplies of critical materials if PLU requirements constrain mineral exploration and development in the deployment area. The proposed basing area contains gold, silver, mercury, barite, lead, molybdenum, tungsten, zinc, and lithium.

Finally, based on estimates of the skilled labor forces necessary for this energy development, and analysis of the training programs currently available in the Western States, shortages of skilled labor appear inevitable in western energy resource development.

As can be seen in figure 43, all of the candidate areas occur within a multi-State region that currently employs 280,000 people in energy and nonfuel mineral development. Because the construction labor force for this development, including general construction labor, semi-skilled and skilled tradesmen, engi-

Figure 43.—Cumulative Energy Activity in the West



SOURCE AbtlWest. 1981

neers, and experienced managers, is regarded as highly mobile and projected to be in short supply, the labor requirements of MPS construction could affect resource development throughout this 10-State area. Training programs are underway to offset some of these labor shortages in several States, but they are unlikely to have a major effect on the shortages because many of the skilled positions require training and experience (that are in turn dependent on skilled instructors) and because the clemand for labor changes rapidly with construction plans and schedules.

System Schedule

The MX/MPS schedule is highly success-oriented and requires specific actions by Congress if both IOC and FOC are to be achieved. Given these actions and no major development problems, it is possible both dates can be accomplished. In all probability, however, some Slip in IOC should be expected. The current DOD review of basing options is delaying actions required to ensure even a possibility of meeting IOC Unless a timely decision is made, leadtimes required will inevitably cause a delay in achieving the IOC date.

Table 11 .—System Time Schedule

Land withdrawal application filed	7181
Legislation to Congress ., .	1/82
Legislation approval	5182
SATAF activated , .	1182
Start construction to operating base	4182
Firstmlsslle test flight .	1/83
Misslesslle production contract award .	7183
DSARC III-missile .	7183
Start construction in deployment area	1/83
First cluster available	8/85
Full base support available	9185
Initial operating capability	7186

SOURCE Off Ice of Technology Assessment

Most of the land required for the preferred Air Force basin$_{g}$ location for MX/MPS is Federally owned and under the control of the Bureau of Land Management, Department of the Interior (DO I) Transfer of the necessary land to DOD requires congressional approval. The schedule, as planned by the Air Force, is predicated on a basing decision in June 1981, and allows a public comment period between July and October, with the legislative package ready for congressional consideration in january 1982 Final approval and land availability is scheduled for May 1982.

A June 1981 basing decision did not take place while the Air Force and DO I are exploring means of expediting the withdrawal application process, the application must be specific in terms of base and deployment area, and both the land withdrawal application and congressional enabling legislation will have to address complicated issues such as the land claims of the Western Shoshone and State school lands in Utah. Slippage of the land withdrawal action would impact all other dates associated with base and deployment area construction and leadtimes would also be required to ensure adequate electric power supplies, to purchase water rights where needed, and to obtain necessary permits, Although it is difficult to assess the extent of slippage likely to occur, it is doubtful that an IOC of 1986 can be met, and system costs would escalate along with any slippage in IOC, Foreseeable slippages could also impact FOC, although a slip in IOC would not necessarily delay final operating completion,

The missile deployment and production schedule may also present some problems. A production decision is scheduled early in the flight test program, and, in fact, before the missile-cannister-shelter tests take place. I n addition, long leadtime materials' authorization is scheduled to occur in February 1983, or 1 month after first flight and 5 months before the production decision Problems in the flight test program under these conditions could lead to overall program delays, renegotiation of production contracts, and, perhaps, substantially increased costs. It is also not clear that the Air Force has the authority to release contracts for long leadtime material before the production decision is formalized

The countermeasures subsystem, both for the missile and for the decoy system, also may present scheduling difficulties Long leadtime items for prototype systems were scheduled for approval in April 1981. This has not occurred, and the delay will probably postpone initial deliveries of prototype hardware and impact on qualification tests and perhaps the missile test program itself.

The formal submittal of a budget estimate for funding deployment area construction is scheduled for October 1981. This submittal will include an update of Military Construction Program (MCP) costs based on the outputs of the 1980 Systems Design Review a site-specific estimates of protective shelter cost.The uncertaintaties introduced by the DOD review of basing options tend to inhibit the deveopment of background material and internal Air force-DOD review of the revised baseline estimates supporting the budget request Delays in the basing decision may make it difficult for the Air Force to adhere to the normal budgeting schedule and prduce estimates with the degree of accuracy recuired red This problem will be intensified if the basing decision is other than horizontal shelters in the Nevada-Utah area

In OTA'S judgment, the IOC date is likely to slip 6 months to 1 year. A slip in IOC date would increase costs by approximately $7s mill ion per month, so that the anticipated increase in MX/MPS cost would be on the order of $0.5 billion to $1,0 billion. Given a decision to proceed with adequate funding on a year-to-year basis, OTA believes that the FOC date could be achieved even with the IOC Slippage. This belief is predicated on the fact that funding and procedural mechanisms are provided so that long Ieadti me resources can be marshal led for use when required,

System Cost

OTA had an independent cost assessment conducted of the Air Force baseline system. The cost was estimated for all stages of the system, from development and investment through operation and support for 10 years of deployment.

In determining system cost, it should be understood that the baseline configuration for MPS is not yet firmly fixed, as certain technological tradeoffs are still being considered by the Air Force. The Air Force is in the process of updating costs, but until the baseline configuration is finalized, new estimates are considered internal Air Force data and were not made available for OTA'S analysis. In lieu of this data, the Air Force provided detailed briefings covering methods used to estimate costs and provided substantial backup material to support their *previous* estimate of $33.8 billion (fiscal year 1978 dollars) In addition, the draft environmental impact statement (DE IS), particularly its technical appendices, contains additional information useful for estimating costs. Also, some of the design changes adopted as a result of the late-l 980 design review have been incorporated into the estimate. Inputs drawn from the backup material supplied by the Air Force have been used but approp r iate adjustments have been made, based on information contained in the DE IS and other published sources. Therfore, a systems configuration has been selectected as a basis for cost analysis that is compatible with Air Force plans but which is Slightly different in detail from the configurate ion used for the previous Air Force estimate

There is some contusion about the Air Force baseline estimate A cost of $33.8 billion is often quoted This dllar figure refers to the baseline estimate, in constant 1978 dollars, and includes 1 ()-year O&S (operation and support) costs for a tot all lifecycle cost This figure when escalated to 1980 dollars is $399 billion lifecycle cost, with a total acquisition cost of $338 billion (This estimate also excludes the cost of i m pactmitigation) The Air force's baseline estimate for the 4,600" shelter system if shown in table 12

Table 12.—Air Force Baseline Estimate 4,600 Shelters (June 1978) (billions of dollars)

	FY78$	FY80$
Development (RDT&E)	**$ 6.7**	**$ 7.9**
Investment		
Aircraft procurement	**$ *0.3***	***$ 0.3***
Missile procurement	12.6	14.9
Military construction	9.0	10.7
Total investment ., ...	$21.9	$25.9
Total acquisition.	$28.6	$33.8
0 & s costs	$ 5,3	$ 6,1
Llfecycle costs	$33.8	$39.9

SOURCE U S Air Force

Because of the controversy over these estimates, it is important to understand the conditions under which they were developed, and their degree of accuracy. The MX Program has cons idered a wide variety of basing modes, including silos, trenches, and air mobile in add ition to the present horizontal plan. For each basing mode, several configurations were studied and costed, an important consideration for each mode. In order to have a quick-response estimating capability with a reasonable degree of accuracy, a cost model was developed by the Air Force. This model was parametric, in which cost factors were developed for specific characteristics (or parameters) that describe a particular function, and required resources such as transportation and handling costs. This model was used to develop the Air Force's June 1980 estimate for MPS.

After reviewing the Air Force model in detail, it appears that the methods used in it are sound and reflect serious considerations of the major problems to be overcome in completing the MPS option. The estimates, therefore, have a reasonable degree of validity and accuracy, and it is possible that the acquisition process could be completed within the $33.8 billion estimate. For several reasons, however, OTA believes that the cost would be about $3.5 billion greater than this estimate. Program delays are already putting upward pressure on potential MPS costs, and additional delays in the construction process should be expected.

Furthermore, *any* cost estimate at this time must contain a high degree of uncertainty. Generally, it is hoped that an underestimate of one item will be offset, at least partially, by an overestimate of another item. Conditions under which the MPS program is being conducted—optimistic schedule, massive scale, remote location, and new technology—put pressure for cost growth on almost all elements of the program. A clearer picture of the limits of expected costs can be obtained only after a number of significant issues are resolved.

Deployment is planned for a very remote, sparsely populated area that does not have the necessary infrastructure to supply meaningful support to the construction activities required or to absorb easily the influx of service and contractor personnel required to operate and maintain the system once in place. In addition, some of the deployment area is of historical and archeological interest, imposing limits on the siting and construction of MPS facilities and roads. These conditions have impacts on the costs of the MPS system. OTA's cost estimate, therefore, concentrates on detailing the resource requirements to develop, procure, construct, and operate the system. Construction and check out of facilities and equipment systems present a most severe problem in cost estimating. While it is not too difficult *to es*timate the construction cost of a given structure, the estimating process becomes very complex under the conditions that exist for MPS. First, the workers must be recruited outside the deployment area since the skills and numbers required probably do not exist locally. Because of this situation, temporary construction camps must be established and housing, food, recreation, and health care must be provided for the workers. Everything from construction materials to loaves of bread must be brought into the area over what is, at best, a limited transportation network. In addition, the technical facilities must meet exacting standards to ensure survivability, postat tack launch capability, and to protect PLU Thus, in addition to construction workers, there must be managers and inspectors to ensure quality control, personnel to prepare food, truck drivers to provide transportation, clerks to receive and store materials, and a number of other supporting personnel, Solid and liquid waste must be disposed of i n an environmentally acceptable manner.

Other are as where precise cost estimates difficult include:

- **MX missile. 'The decision for full -scale** product ion is scheduled to be made long before the flight test program is completed and before the missile/cannister combination has been tested. Such a pro-gram is feasible, but risks complications late in the test program causing design changes, delays, and production cost creases over those estimated.
- **Missile Decoy.** This system, vitsl to the V iability of MPS is not yet fully designed Projected development and procurement cost are highly uncertain at this time.
- **Missile Transporter.** This transporter will be the largest truck-like vehicle ever constructed and it includes highly sophisticated automatic controls, communications, and decoy systems.
- **Command, Control, and Communications (C).** Not all portions of this subsystem have been specified at this time,

- **Electromagnetic Pulse (EMP) Hardening.** It does not appear that sufficient attention to quality control was reflected in the original Air Force estimate. Welds on the steel liners installed in the Safeguard ABM system for EMP purposes were found to be a problem requiring special inspection procedures, The MPS documents do not discuss the welds required on the steel liner installed in each shelter.

With the exception of construction issues and the missile decoy, these uncertainties are normal for advanced and complex weapons systems at this stage of development. If the earlier Air Force estimate of $33.8 billion has not properly assessed the support required to accomplish the construction program, the estimate could be substantially low. An error in estimating the cost of individual protective shelters is greatly magnified because a minimum of 4,600 shelters is required. Similarly, inadequate consideration of resources required to support the construction effort will be magnified because of the remoteness of the proposed deployment area.

Notwithstanding these uncertainties, a comparison of the Air Force baseline estimate to OTA'S estimate has been made (see table 13). OTA estimates the total acquisition cost for the Air Force baseline, with 4,600 shelters, is $37.2 billion (fiscal year 1980 dollars), and a total lifecycle cost of $43.5 billion. As previously mentioned, the OTA estimate is $3.5 billion greater than the 1980 baseline estimate developed by the Air Force. This differential includes:

- $06 billion in schedule contingency for missile RDT&E,
- $0.7 billion for engineering changes in system components,
- $0.6 billion in construction costs primarily associated with increased life support costs,
- $0.7 billion in A&CO costs reflecting military pay for the Air Force personnel involved in this activity,
- $0.9 billion in other adjustments.

As indicated in table 13, the Air Force has not budgeted costs for the MX program for program management and its Site Activation Task Force,

Cost and Schedule of Expanding the MX/MPS

As noted above, the proposed 4,600-shelter system represents a baseline scenario. How-

Table 13.—Comparison of Air Force and OTA Cost Estimates (billions of fiscal year 1980 dollars)

	USAF baseline estimate	OTA baseline estimate
Develpment		
Missile related	$ 5.025	$ 5.025
Base related	2.839	2.837
Other	.710	1.310
	$8.574	$9.172
Investment		
Nonrecurring production	$ 1.110	$ 1.110
Equipment procurement		
Missile system	4.990	5.226
Transporter/vehicles	1.634	1.634
Decoy	2.321	2.321
C^3	0.915	0.915
Ground power	0.542	0.756
Physical security	0.335	0.335
Support equipment	1.692	1.692
Aircraft procurement	0.350	0.439
Total equipment & spares	$12.779	$13.320
Engineering change order	$ –	$0.666
Facilities construction	10.035	10.649
Assembly and checkout	1.318	1.995
Program management		0.222
Site activation task force		0.037
	$25.242	$27.999
Operating and support		
Replenishment spares	$ 0.647	$0.647
System modifications	0.187	0.234
Depot maintenance	0.227	0.227
Operations and maintenance	1.480	1.611
Military personnel	2.077	2.077
Civilian personnel	0.410	0.410
Training	0.192	0.192
Other	0.910	0.910
	$6.130	$6.308
Total lifecycle cost	$39.946	$43.479

SOURCE Office of Technology Assessment

ever, MPS basing might require as many as 8,250 shelters by 1990 and 12,500 shelters by 1995 in response to an expanded Soviet threat. The environmental impacts of such systems would, of course, be substantially greater than those of the baseline.

If we assume, as our projections suggest, a need for 8,250 shelters in 1990 and 12,500 in 1995, all resource requirements would change dramatically. OTA has calculated the additional resource requirements, and has estimated the gross changes that would be required in the construction schedule and work force. Table 14 indicates the land use requirements associated with these scenarios.

Under a high-growth scenario the construction work force and population projections also would increase dramatically.

If it becomes necessary to expand the system by building these additional shelters and missiles to keep up with an expanded Soviet threat, there would be a significant impact on cost and schedule for the MPS system. In light of projections for Soviet warhead buildup, we estimate costs for an MPS expansion under the following assumptions:

- a total of 8,250 shelters can be deployed in the Southwest by 1990, retaining the ratio of one missile to 23 shelters and 1 mile spacing;
- a total of 12,500 shelters can be deployed by 1995 in the Southwest, retaining the ratio of one missile to 23 shelters and 1 mile spacing; and
- presently planned clusters are not backfilled in order to enhance survivability.

It seems possible to achieve the first goal, 8,250 shelters in operation by 1990, provided there are no serious missile or site development problems, and that a decision to proceed is made in the near future. A shelter completion rate of approximately 2,000 per year would be required, This rate represents about a two-thirds increase in the presently planned construction rate (approximately 1,200 per year). As in the baseline case of 4,600 shelters, however, schedule slippage is likely. An expanded program schedule would also be in jeopardy unless funding and authority mechanisms are provided so that the required resources can be programed and marshaled for use when required.

While OTA does not have the information available to detail all resource requirements for the expanded program, no resource constraints (construction materials, equipment, or skilled personnel) are anticipated provided that sufficient leadtime is availble between the decision to undertake the program and peak construct ion periods The Nevada Power Co., for example, cannot presently meet peak demands for electric power and has existing purchase agreements with outside utilities. Long-term agreements with the company would be required if commercial power is to be used to support the construction and operations phases of the MPS program as planned. other such commitments would be needed

Table 14.—Land Use Requirements

	Acres		Acres		Acres	
Shelters	11,040	(17)	19,872	(31)	29,808	(46)
Roads	74,824	(1 17)	134,683	(210)[b]	202,024	(315)'
Operating						
Bases and support	51,456	(80)	92,620	(144)	138,931	(217)
Direct lands	137,320	(214)	246.176	(386)	369,264	(576)
Potential impact zoneb	2,560,000	(4,000)	4,608,000	(7,200)	12,521,738	(19,565)
Numbers of shelters		4,600		8,250		12,500

[a]Does not assume backfill

bThis figure is based on the 0.25 mile disturbance zone discussed on page 70 and represents both the potential arid lands Impact zone and an approximation of the land area which might be subject to restricted use under an expanded PLU security program

SOURCE Off Ice of Technology Assessment

Referring to table 16, it can be seen that it will cost about $20 billion more to deploy and operate 8,250 shelters, and about $40 billion more for 12,500 than the presently planned 4,600 shelters. The estimate assumes that a third operating base (OB) will be required for the expanded system, and, in addition, that the OB will have the associated missile assembly and contractor support facilities for the 12,500 shelter option.

Costs were obtained by scaling up the baseline cost estimate for 4,600 shelters to the year 2000. The additional 5 years were considered so that 10 full years of operations for the 12,500 shelter option could be included.

Costs were also estimated for the cases in which additional shelters would be backfilled into the original clusters (by filling in the gaps of the original hexagonal-array deployment). This approach would reduce connector costs

Table 16.—Lifecycle Cost of 4,600, 8,250, and 12,500 Shelters to the Year 2005
(billions of fiscal year 1980 dollars)

	Number of shelters		
	4,600	8,2<0	12,500
Development			
Mi:;sile	$ 5.0	$ 5.0	$5.0
Basing	2.9	3.0	3.1
Other.	1.3	1.4	**1.5**
I-otal	**$ 9.2**	**$ 9.4**	**$9.6**
Investment			
Missile	*$ 4.3*	*$ 6.1*	*$8.1*
Cannisterllauncher	0.9	1.5	2.2
Transporter .	1.4	**2.4**	**3.6**
Const ructioniactlvat ion	**12.6**	**19.9**	**28.5**
Other. .	**8.8**	**13.7**	**19,1**
I-otal	**$28.0**	**$43.6**	**$61,5**
Operating and support costs			
Anlual	*$ 0.469*	*$ 0.719*	*$ 0,969*
Lifecycle costs			
To FOC . .	*$38.6*	*$55.2*	*$77.7*
To the year 2000.	*$43.5*	*$62.4*	*$82.6*
To the year 2005, . . .	*$45.7*	*$66.0*	*$87.4*
Operating personnel			
Military personnel .	***10,900***	***16,450***	***22,000***
Civilian personnel . .	1,700	***2,600***	***3,500***
I-otal	12,600	*19,050*	*25,500*

SOURCE Off Ice of Technology Assessment

SOURCE Off Ice of Technology Assessment

(roads, powerlines, etc.) and other nonshelter facilities, for the first 2,300 additional shelters. Afterwards, entire additional clusters would need to be built to accommodate the additional shelters. For these cases, a 10-year lifecycle cost savings of $4.5 billion for the 8,250 shelter option and $5.3 billion for the 12,500 shelter option was estimated.

Operating personnel requirements were based on a detailed analysis of personnel for the 4,600 shelter option provided by the Air Force and scaled for the expanded options.

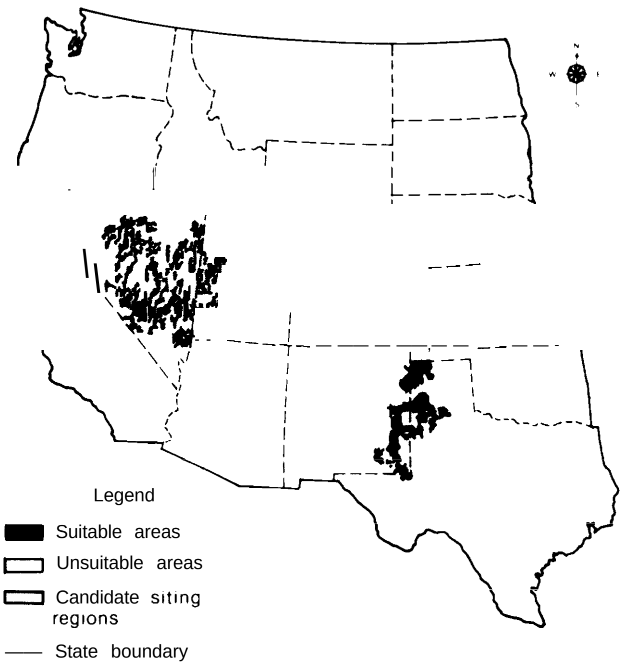
This method provides reasonable cost estimates for comparative purposes. Time and information available for the estimate did not, however, allow for a full investigation of the impact of the increased requirements for scarce resources (some missile materials and propellants) or the potential impacts of economics or diseconomies of scale on the construction program. Final estimates, therefore contain a significant degree of uncertainty and further analysis is required before actual funding levels can be determined with precision.

Split Basing

The proposed MX/MPS basing plan calls for the location of all shelters and support facilities over a broad geographic area. Deployment clusters would be located in valleys of the Great Basin and would be separated by the mountain ranges which separate the valleys; but the system would otherwise be operationally contiguous.

The "split basing" option would be similar in all functional respects except for the fact that a large area of nondeployment land would separate the operational deployment areas. In both cases the same number of missiles, shelters, and land area would be involved, and in both cases there would be two operating bases. Figure 44 shows the geographic distribution of the proposed Air Force split basing alternative.

Figure 44.—Proposed Split Basing Deployment Areas



SOURCE A F /DEIS

From an operational standpoint, there are no significant differences between contiguous basing and split basing, Both alternatives require the same number of missiles, shelters, and operating bases; and both have the same functional requirements for command, control, communications, security, and support.

From the standpoint of the costs of construction and the environmental impacts, however, there are several notable differences,

First, construction of split basing would cost approximately 10 percent more than the baseline, as there would be some necessary duplication in geotechnical investigations, in electronic and mechanical systems, in transportation and logistics, and some additional costs in land acquisition resulting from the need to negotiate easements or title for a larger percentage of private lands. (See table 1 7.)

Second, impacts on both the physical environment and the regional economy could be substantially different. Although the general nature of the impacts would be fundamentally the same as those resulting from the proposed basing option, specific impacts could differ

Table 17.—Air Force Estimates of Additional Split Basing Costs (in millions of fiscal year 1980 dollars)

RDT&E		$ 121
Geotechnical	$ 63	
Electronics	27	
Mechanical	16	
Deployment	5	
Procurement	......	2,171
Airborne lunch control	59	
Helicopters	29	
Initial spares	10	
Mechanical	28	
Electronics	157	
Logistics	63	
Initial spares		
Deployment (A&CO and training)	$1,761	
Milton	......	$1,183
Real estate	$ 527	
Road network..	53	
Remote surveillance	11	
Construction O&S	32	
Training facilities	54	
Design funds	41	
Designated assembly area and contractor support area. . . .	465	
Total		$3,475

SOURCE US Air Force

significantly based on the site-specific characteristics of the impact regions.

In general split basing would mitigate the impacts on the physical environment by dispersing the direct impacts, and could have the effect of avoiding impacts on certain areas altogether, or avoiding critical thresholds in particular instances. In regard to socioeconomic impacts, split basing would complicate the issues of land-acquisition and integrated planning, but offers the possibility that impact levels would be within the management capabilities of more communities, and thus result in more beneficial impacts and fewer boomtown conditions.

In the case of socioeconomic impacts there may be a third qualitatively different type of impact associated with split basing. In addition to the reduction of adverse impacts noted, and cases in which the reduction in impacts effectively eliminates the adverse impacts (e.g., a case in which the reduced growth level resulted not only in a reduction of the level of overcrowding in schools, but reduction to a level that presented no over-crowding), split basing could transform negative impacts into positive impacts in instances where the level of new growth was with in the carrying capacity of the existing social infrastructure.

Thus, not only would the level of negative impacts be reduced, but in many small communities, and most likely in the larger towns close to the operating base areas, negative impacts could become positive impacts,

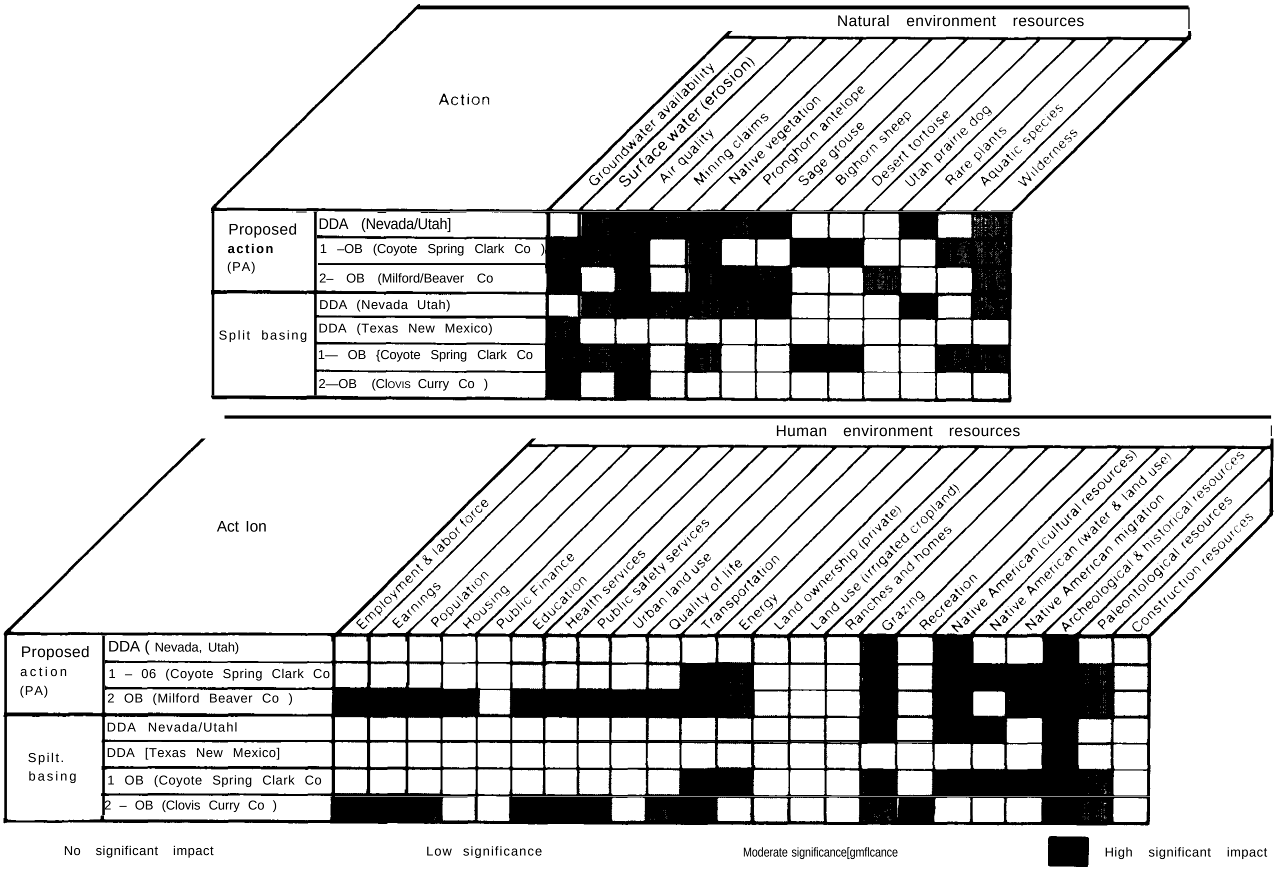
Physical Impacts

Based on the Air Force resource analysis relevant to the split basing option, it is apparent that split basing would have significantly less impact on wildlife and the physical environment than the baseline option. * (See fig. 45,')

There are, however, other complicating factors regarding the proposed split basing option. In the Great Basin of Nevada and Utah, virtually al I of the land is owned by the Federal Government, and the dominant economic activities (ranching and mining) are subject to lease and permit authorities. In the split basing deployment area of New Mexico and west Texas, 95 percent of the land is in private ownership and is used primarily for crop production and livestock. The differences between use of rangeland and cropland, and the differences between private and public ownership of the land, raise potentially significant questions. First, as noted above, the use of croplands would take a greater amount of agricultural land directly out of production; but, the higher productive capacity of the land would also facilitate restoration of the impacted areas. As a result, considerably less land would be likely to be lost from productivity.

'See *DEIS matrix, and 36 p 1-1,* including vegetation, habitat, and protected and endangered species Additionally, the Air Force has Indicated that impacts on the characteristics of the pristine environment, archaeological and historical sites, local populations, and economic adjustment, would also be reduced under the split basing option

Figure 45.—Summary Comparison of LongTerm Impact Significance Between the Proposed Action and Split Basing[a b]



[a]While there may be an overall estimate of no impact or low impact when considering the DDA region as a whole it must be recognized that during short term Construe. tion activities specific areas or communities within or near the DDA could be significantly Impacted
[b]The reduction in DDA size for Nevada\Utah under split basing does not neceddstily change the significance of impact on a specific resource Many Impacts occur in a limited geographic area which is Included in both the full and spilt deployment DDAs, or are specific to the OB suitability zone

SOURCE U S Air Force/DEIS

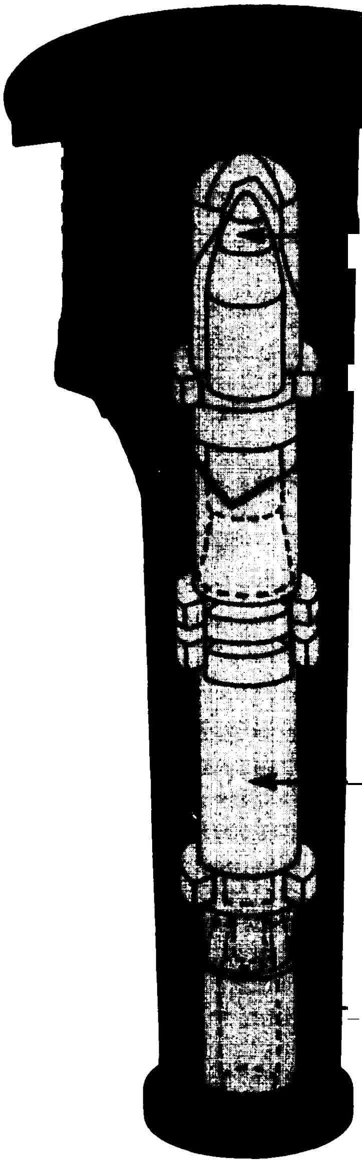
Second, the legal basis for conducting necessary PLU activities is more clearly defined in relation to privately owned lands than it is in relation to public lands. In the case of private lands, it would be necessary to negotiate easements to allow for access to shelters and for periodic "security sweeps" and investigations; but the contractual basis for such arrangements are unambiguous In the case of the public lands the necessity of periodic sweeps raises legal questions regarding possible restrictions on public use or access to public lands.

Finally, in terms of land acquisition, it is uncertain whether the political process of land withdrawals necessary for use of the public lands might be more or less cumbersome than the process of individual negotiations with private landholders. It does appear likely, however, that the process of acquiring lands through both the congressional land withdrawal process and private negotiations, would be more cumbersome than reliance on Federal lands alone.

VERTICAL SHELTERS

An alternative to employing horizontal shelters for MPS is to house the missiles in more conventional vertical shelters. (See fig. 46.) Aside from the difference between whether the missile is stored horizontally and erected to vertical for launch, or stored vertically in a ready launch position, there are several important issues. One issue, and perhaps the primary one, is shelter hardness. Pound for pound of concrete, vertical shelters are more resistant (harder) to the effects of nearby nuclear detonations. Shelter response is easier to analyze and we have more experience in testing and building vertical shelters. A second important issue is the ease and speed of missile movement, particularly the insertion and removal times of the missile at the shelter. A horizontal shelter allows a simple roll transfer of the cargo between the transporter and the shelter; transfer for a vertical shelter requires the additional transporter operation of erecting the missile to vertical for insertion and removal from the shelter. A third issue, arms control monitoring, is discussed below.

Figure 46.—Vertical Shelter



SOURCE: U.S. Air Force

Shelter Hardness

There are several damage mechanisms to a missile from a nuclear detonation. These mechanisms are airblast, ground shock, electromagnetic pulse, radiation, and thermal effects. Airblast results from the intense compression of air at the explosion, that propagates away from the source as a supersonic shock wave. An airblast results in overpressure destruction, and it is particularly severe on aboveground objects (such as the shelter door of a ***horizontal*** shelter) that must withstand the reflected loads of the incident shock front. For a vertical shelter, with a shelter door that is flush with the surface, there are no reflected loads, and door requirements are far less severe than for the horizontal shelter. In addition, ovalling of the horizontal tube is a more serious problem than is the compression on the vertical shelter.

The task of testing and modeling for dynamic (wind) pressure is also more difficult for horizontal than for vertical shelters. Because the dynamic flowfield for the horizontal case is sufficiently complex, adequate simulations are difficult. The result is a less complete capability to test and validate a horizontal shelter design. Nevertheless, it is believed that with a sufficiently comprehensive validation program, confidence in horizontal shelter hardness can be adequately established.

Ground motions result from the "air-slap" of the shock front hitting the ground as well as propagation through the earth of upstream coupled energy. The damage mechanism of dominant concern is the missile coming up against and forcibly hitting the shelter wall from the inside, as the shelter moves with the ground, To design for this in a simple MPS shelter, the missile is given enough space inside the shelter to move before coming up against the shelter wall. This space between missile and shelter is called rattle space, and for shelters several thousand feet distant from a 1-MT nuclear detonation, typical rattle space is tens of inches. Since at ranges of interest ground shock motions are typically larger in the vertical than horizontal direction, vertical shelters require less concrete than do horizontal shelters, since the inside diameter of the shelter does not need to be as large. In addition, the missile is constructed to be more resilient to motions along its length than transverse to it.

For radiation and thermal effects, since the flux direction on the surface is along the ground, more stringent requirements for the horizontal shelter door are necessary than for the surface-flush vertical door. Electromagnetic pulse effects do not appear to discriminate strongly between horizontal and vertical shelters, although the greater radiation attenuation afforded by the vertical shelter would ease hardness requirements for radiation-induced electromagnetic pulse,

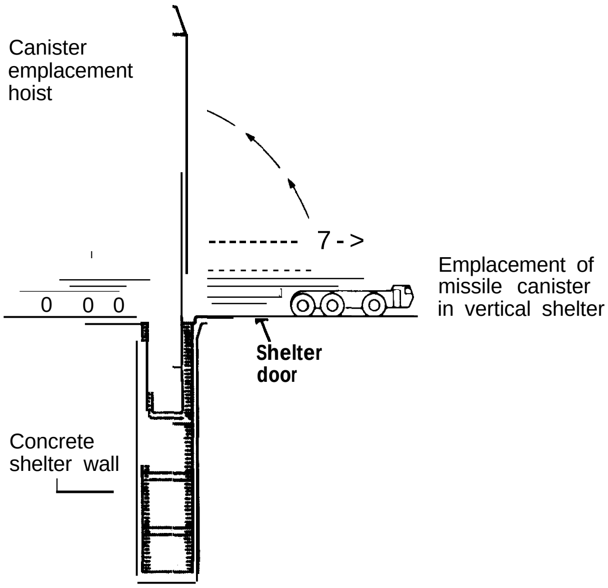
In summary, it appears that building a survivable horizontal shelter is a more demanding task than would be the vertical shelter, and vertical shelters can be easily made more than 1,000 psi hard, whereas the design and hardness validation of a 600 psi horizontal shelter pushes state of the art engineering, Nevertheless, for an MPS system, this *hardness should be enough.* MPS does not rely on the shelter surviving a direct attack, but by surviving the effects of an attack on neighboring shelters, To the extent that a fractionated threat would reduce warhead yield, consideration might be given to building a sufficiently hard vertical MPS, perhaps several thousand psi hard, in order to withstand the increased threat without building more shelters. Nevertheless, because shelter kill probabilities are exceedingly sensitive to missile accuracy, and Soviet missile accuracies are projected to continue to improve, hard vertical shelters still would not be likely to survive a direct attack. Therefore, shelter number requirements for vertical shelters might not be significantly different from horizontal shelters. (This question is more thoroughly addressed in the classified annex.)

Even though vertical shelters will be harder, the state of knowledge of electromagnetic pulse effects is not considered firm enough to allow shelter spacing for *any* shelter design much less thay 5,000 ft, which is the current spacing for baseline horizontal shelter MPS. However, there exists the possibility that vertical shelters could be more densely "packed" in the same area (e. g., by backfilling) and would therefore require less land for the same number of shelters.

Missile Mobility

For the Air Force baseline, it is stated that as a hedge against a loss of PLU, the missiles would have the capability of rapid relocation and an on-road hide-on-warning capability against SLBM attack. This reliance on missile mobility makes missile transfer timelines important to the choice between horizontal and vertical shelters. The relevant difference here is the time required for insertion and removal of the missile. Because the transporter for the vertical system must perform missile raising and lowering operations with a strongback, rather than the roll-transfer operation for the horizontal system, the transporters for the two systems are designed differently. (See fig. 47 for the transporter designs that have been studied.) Although a horizontal shelter transporter has not yet been constructed to test timelines, an operational vertical shelter emplacer has been constructed and tested at the Nevada Test Site (NT S). Remove and install

Figure 47.—Transporter for Vertical Shelter



SOURCE U S Air Force

timelines for horizontal and vertical systems based on these transporter designs and on the NTS field tests as shown in figure 48, The vertical system timelines are based on extrapolation of test data, such as increased automation, adding more hydraulic pumps for the strongback lift actuator, and so forth in order to optimize transfer time. Horizontal system timelines are based on the current baseline design. Using these two transporter designs and the test figures, emplacement and removal times are slightly under 5 minutes for the horizontal system, and somewhat over 22 minutes for the vertical system can be seen, It must be emphasized that these figures are based on given transporter designs; different timelines may be derived based on unfamiliar designs. Also, the figure for vertical emplacement is based only on design mechanical constraints. No consideration has been given to further constraints that may be imposed by explosives handling,

Based on these figures, relocation time for the vertical system is longer than for the horizontal system, due only to the transfer times. When adding travel times, relocation for the horizontal system is about 9 hours, and for the vertical system, 15 hours.

For hide-on-warning dash from the road, emplacement figures for the baseline horizontal are presented in figure 49 but none was available for the vertical. Because of the very tight timeline for the dash missile emplacement operation, it would necessarily take a very different vertical system transporter to satisfy the 2-minute insertion schedule needed to support an SLBM-timeline dash. Among the current conventional designs, only the horizontal system could support the SLBM dash.

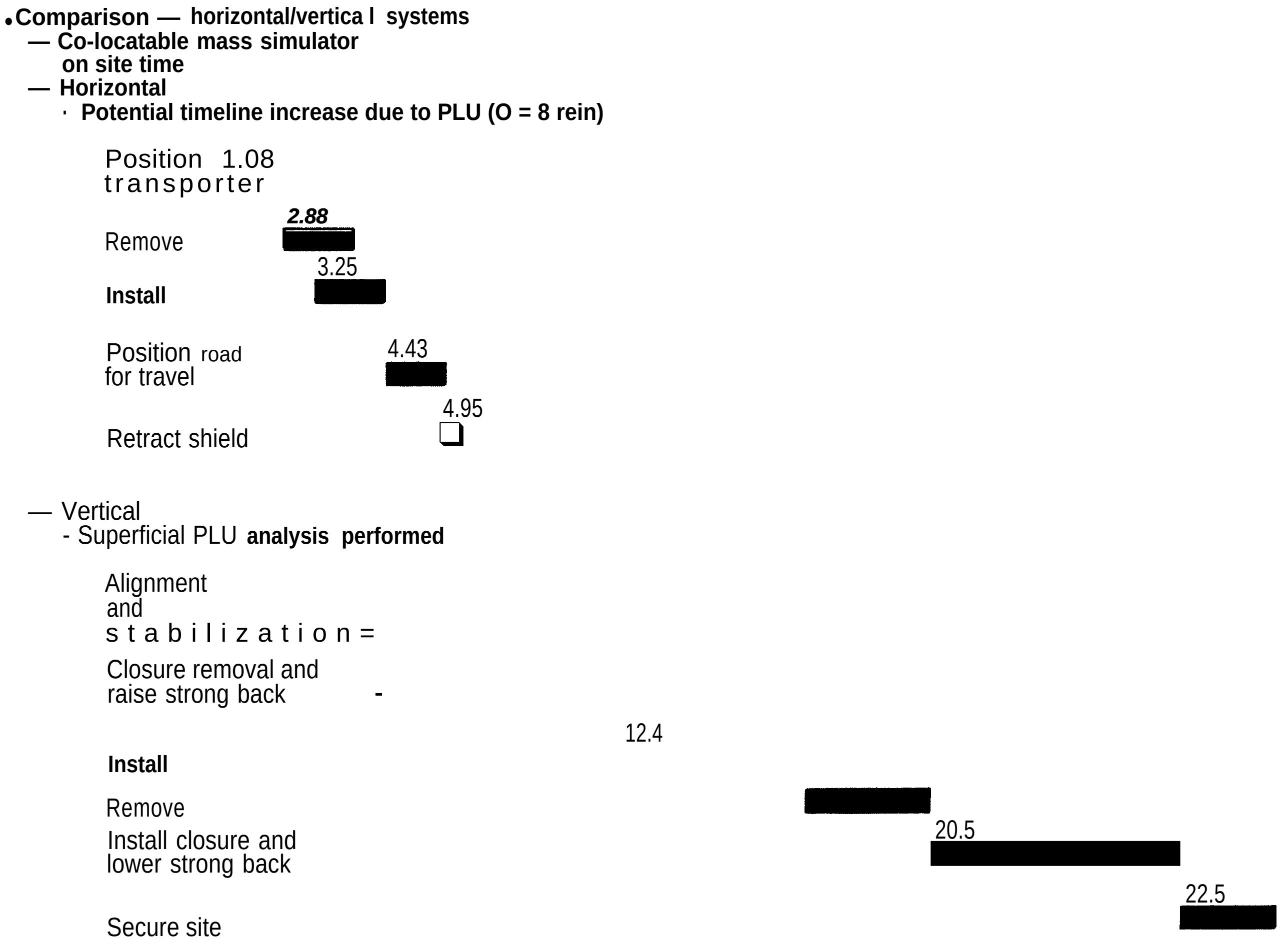
PLU

Because most of our detailed understanding of PLU has come only in the last several years, when the baseline system has been horizontal, it is difficult to say with confidence if PLU provides an adequate basis for preferring a horizontal or vertical shelter. We do not know as much about the signatures and countermeasures for the vertical system to make a reliable comparison. It is almost certain, however, that many of the countermeasures designed for the horizontal system will need to be modified or completely replaced for a vertical system. The mass simulator will probably be quite different. (An early design for a vertical simulator, called the "chimes," because it was composed of four vertical rods, may not be feasible because its vibrational modes are similar to the discarded T E L simulator concept; see pp. 97). Much PLU design work would have to be done to resolve these questions.

costs

OTA estimated the cost of deploying the MX missile in vertical shelters in the Great Basin region of Nevada and Utah. The estimate assumes that, with the exception of shelter and transporter costs, the costs associated with vertical shelters are the same as the costs associated with horizontal shelters, Thus, the costs of the missile, C^3, physical security, ground power, environmental control, support facilities, roads, and other support elements are considered to be independent of shelter design at least in total. Other ground rules include:

Figure 48.— Remove/Install Timelines for Horizontal and for Vertical Shelters



SOURCE U S Air Force

- 4,600 shelters;
- 200 deployed missiles, one per cluster of 23 shelters;
- shelter spacing of about 5,000 ft;
- approximately 8,000 miles of roads; and
- IOC and FOC dates identical to MX/MPS in horizontal shelters.

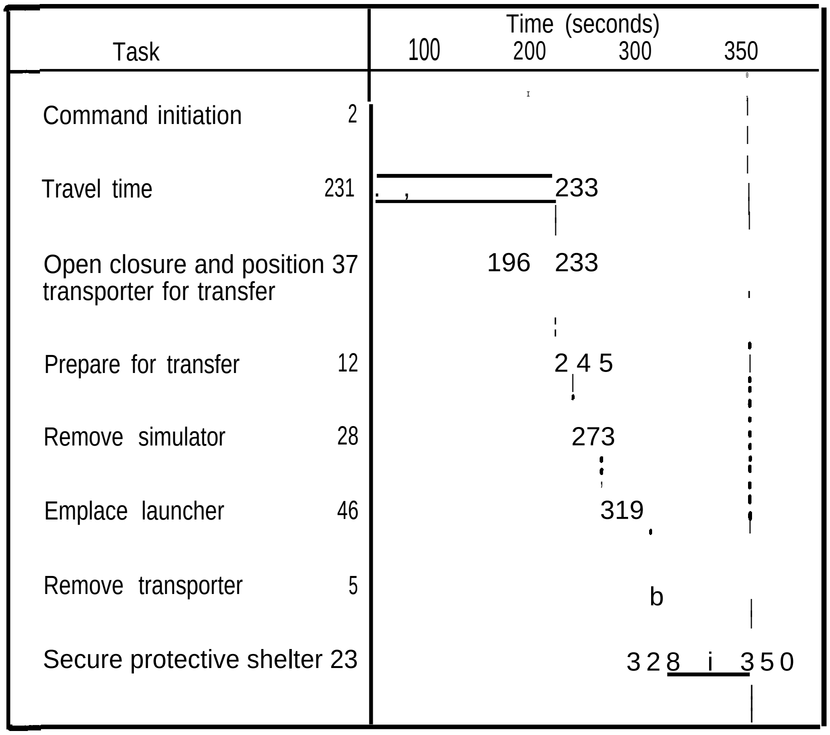
The total construction costs of 4,600 vertical and horizontal shelters are $5.1 billion and $6.3 billion respectively (in fiscal year 1980 dollars), a difference of $1.2 billion. These costs were derived from the application of the Air Force DISPYIC model and cost inputs applicable to the horizontal shelter program (materials costs). Horizontal shelter costs were taken from material furnished by the Air Force.

The major differences between horizontal and vertical shelter costs result from different material requirements and construction costs. The following characteristics of the two types of shelters illustrate the reasons for the differences:

	Horizontal	Vertical
Length	171 ft	122 ft (deep)
Inside diameter	145 ft	131 ft
Wall thickness	21.0 inches	101 inches
Concrete .	934 yd	254 yd '
Rebarsteel	35 tons	15 tons
Liner steel	62 tons	16 tons
Miscellaneous steel	21 tons	4 tons

Thus, 4,600 horizontal shelters would require about 3. I million cubic yards more con-

Figure 49.— Dash Timeline for Horizontal Shelter



SOURCE U S ir Force

rete than vertical shelters and about 380,000 tons more steel.

The transporter required for the vertical mode could be smaller than for the horizontal shelter (according to previous Air Force designs). This difference would result in a reduction in cost of about $250 million to $500 m i l l ion for the **200** transporters required.

The horizontal shelter program is estimated to cost about $43.5 billion to the year 2000. This estimate includes $9.2 billion in development, $28 billion for investment, and $6.3 billion for operating and support costs. A vertical shelter program would be about $1.5 billion less expensive, or a total of about $42 billion for the lifecycle covering the deployment years (IOC to FOC) and 10 years of full-scale operations. Table 18 shows a breakdown of horizontal and vertical shelter lifecycle costs.

Arms Control

There are few differences, in principal, between verifying an arms control agreement for a Vertical or horizontal MPS deployment, if the basing mode has been designed with arms control agreement verification measures. The key arms control agreement verification tasks associated with the basing mode include counting the number of missiles deployed and monitoring vertical shelter construct ion to ensure that the shelters are not actually new ICBM launchers.

So long as, at a minimum, the MX missile and its associated equipment are assembled in the open and left exposed for a period of days to permit accurate counting, the number of missiles and associated vehicles could be adequately verified. Deployment of the missiles and associated vehicles along a dedicated

Table 18.— Lifecycle Costs for Horizontal and Vertical Shelters Deployed in Nevada-Utah
(billions of fiscal year 1980 dollars)

	Horizontal	Vertical
Number of missiles deployed	200	200
Number of shelters	4,600	4,600
costs		
Development		
Missile	$ 5.0	$ 5.0
Basing	2.9	2.9
Other	1.3	1.3
Total	$ 9.2	$ 9.2
Investment		
Missile/cannister/launcher	$ 5.2	$ 5.2
Transport/vehicles	1.6	1.3
c'.	0,9	0.9
Other equipment	5,5	5.5
Construction	10.6	9.4
A&CO	2.0	2.0
Other	2.2	2.2
Total investment	$ 28,0	$ 26.5
Operating and support		
Procurement	$ 0.9	$ 0.9
O&M	1.8	1.8
Personnel	2.5	2.5
Training	0.2	0.2
Other	0.9	0.9
Total O&S	$ 6.3	$ 6.3
Lifecycle costs	$ 43.5	$ 42.0

SOURCE Off Ice of Technology Assessment

transportation network to the deployment area would also permit counting of the missiles. These assembly and transportation procedures are common to the horizontal and vertical shelter deployments, indicating that these arms control monitoring aspects would appear to be the same.

However, the horizontal basing mode appears to some analysts to be a more desirable basing mode because it facilitates confirmation through direct observation that those missile shelters said to be empty of missiles do not in fact contain missiles. The Air Force baseline system relies on removable plugs in the shelters to permit such direct observation. The incremental value of such observation to arms control agreement verification is controversial.

SOME PREVIOUS MX/MPS BASING MODES

The Roadable Transporter-Erector- Launcher (TEL)

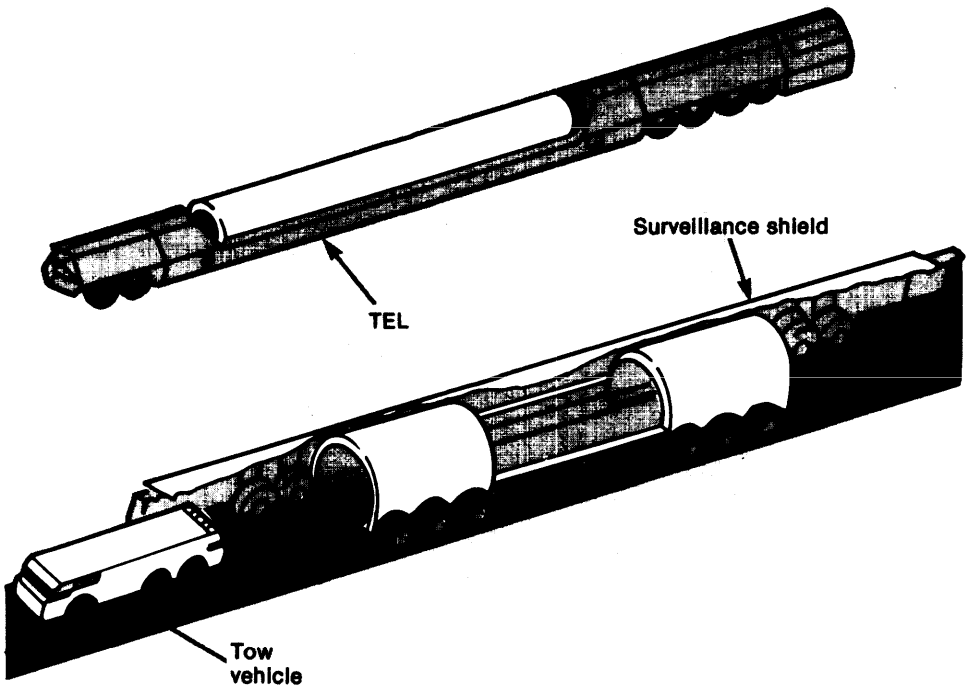
In the period between the start of full-scale engineering development in September 1979, through the spring of 1980, the missile and launcher were designed to be structurally integrated with the transporter, into a roadable vehicle called the T E L, for transporter-erector-launcher. (See fig. 50.) The entire TEL unit was to be placed in the protective shelter. On command to launch, the shelter door would open, the TEL would plow through any debris, erect the missile to a near vertical position, and launch the missile,

The TEL could exercise several mobility options. One mode, used for maintenance and rapid relocation, would have the TEL transported, and shielded under a towed, wheeled vehicle called the mobile surveillance shield. The surveillance shield would visit every shelter, simulating a TEL insertion at each one except for the shelter where it actually deposits the TEL. This operation would be manned. Travel to all shelters was estimated to be about 12 hours, as in the current design.

A second mobility mode would permit a portion of the force to be on the road, under the surveillance shield. This manned hide-on-warning operation would respond to SLBM attack warning, and secure the TEL at the nearest shelter before the attacking warheads arrived. Like the first mode, this is similar to the presently designed capability,

The third mode of missile mobility was called the dash. Dash was to be an unmanned operation. Upon receipt of warning of an ICBM attack, the TEL would leave its shelter, unconcealed, and dash to another shelter

Figure 50.–Roadable Transporter- Erector.Launcher (TEL)



SOURCE U S Air Force

within the cluster. To be successful, this would have to be done within the 30-minute flight time of attacking ICBMS. Arranging the shelters in a closed loop would facilitate dashing into any other shelter in the cluster, This closed shelter arrangement with the dash operation led to the colloquial term, "MX Racetrack. " This last mobile option could not be retained in the present "loading dock" design.

The most serious shortcoming of the TEL design is the difficulty of maintaining PLU, according to Air Force analysis. The TEL shelter is larger than the present shelter design by 2 ft in diameter, and in order to have the possibility of satisfying PLU, the shelter needed to be even further expanded to be able to house a credible TEL simulator and still support the dash capability. With the 16.5-ft inner diameter shelter of the TEL design as a constraint, al I decoys studied by the Air Force had a poor signature match to the TEL. One design used two rods inserted between the inner and outer diameters of the shelter to act as a Inissile simulator. However, it was learned that the different vibration modes of the rods, as well as other d instinctive signatures, would be evident during transit, simulator insertion, and removal. These arguments are quantitatively plausible.

Concerning the three mobility options discussed above, the first two are similar to the loading dock arrangement. For the third mobility option, unmanned dash, transferring the TEL during an ICBM flight time would leave it exposed during its transit to a coordinated SLBM attack, since the TEL unit is not designed to survive such an attack. Typical hardness for such a vehicle would be in the range of 5 to 10 psi, which lies approximately at the 1 to 2 mile contour for an exploding SLBM warhead. If, as suspected, PLU had been broken and the enemy knew the shelter location of the

TEL, then it could be vulnerable to an SLBM attack during the dash operation.

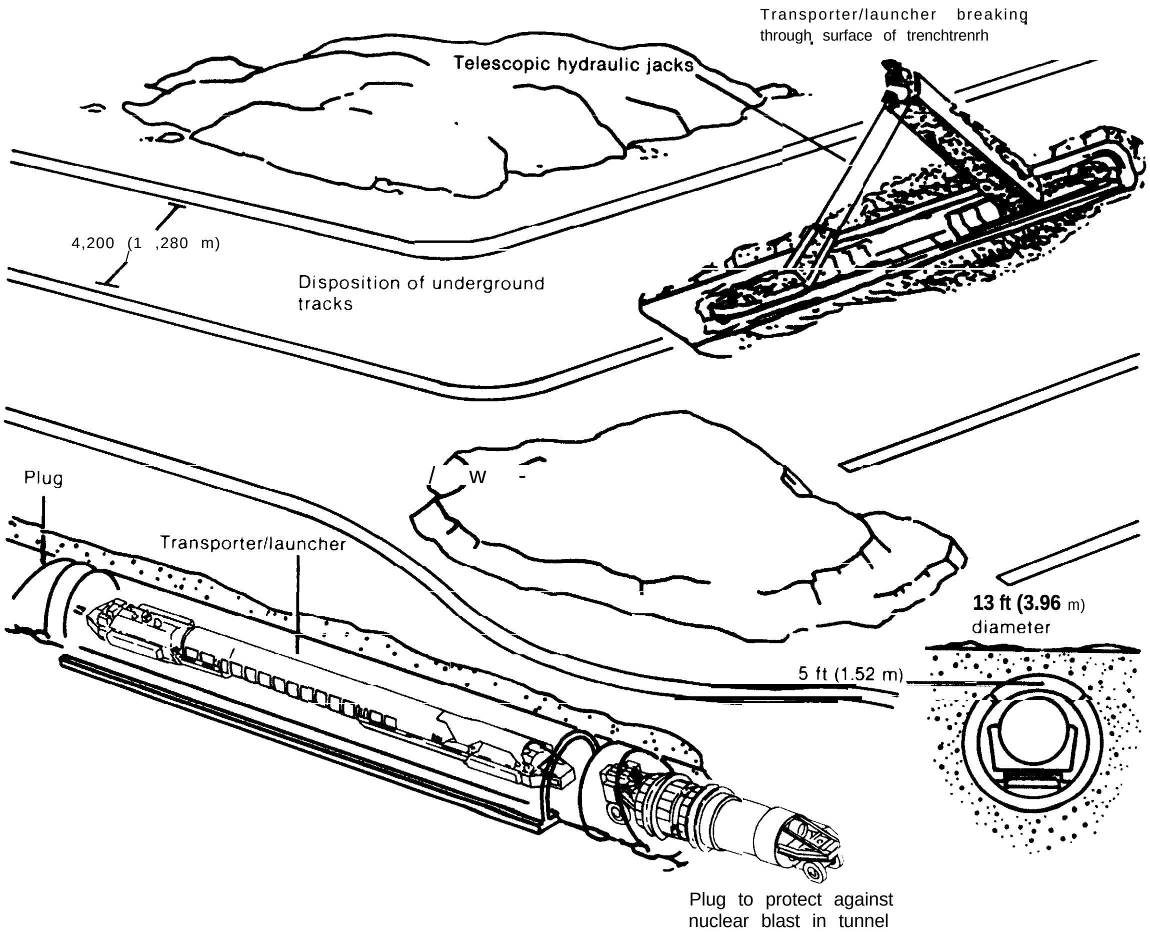
Other than the transporter design, dash, the larger shelter, and the closed cluster layout, this MPS design is the same as the present baseline system

The Trench

The trench was an even earlier design for basing the MX missile, before MX entered full-scale engineering development In this mode, the missile, housed on an unmanned transporter and launcher, would reside in an underground concrete tunnel, out of public view, (see fig. 51), As in multiple shelters, trench-basing the MX relied on keeping the missile location in the trench unknown to the attacker. The missile could randomly move in the trench as an additional PLU measure In order to launch the missile, the transporter would break through the roof and erect the missile, preparatory to launching.

Several trenches have been designed for MX basing. Some trenches were continuously hardened, others were hardened in sections. Some trenches had single spurs in which the missile resided, and others had double spurs. Most trenches were designed with inside ribs to

Figure 51 .—Trench Layout



SOURCE Off Ice of Technology Assessment

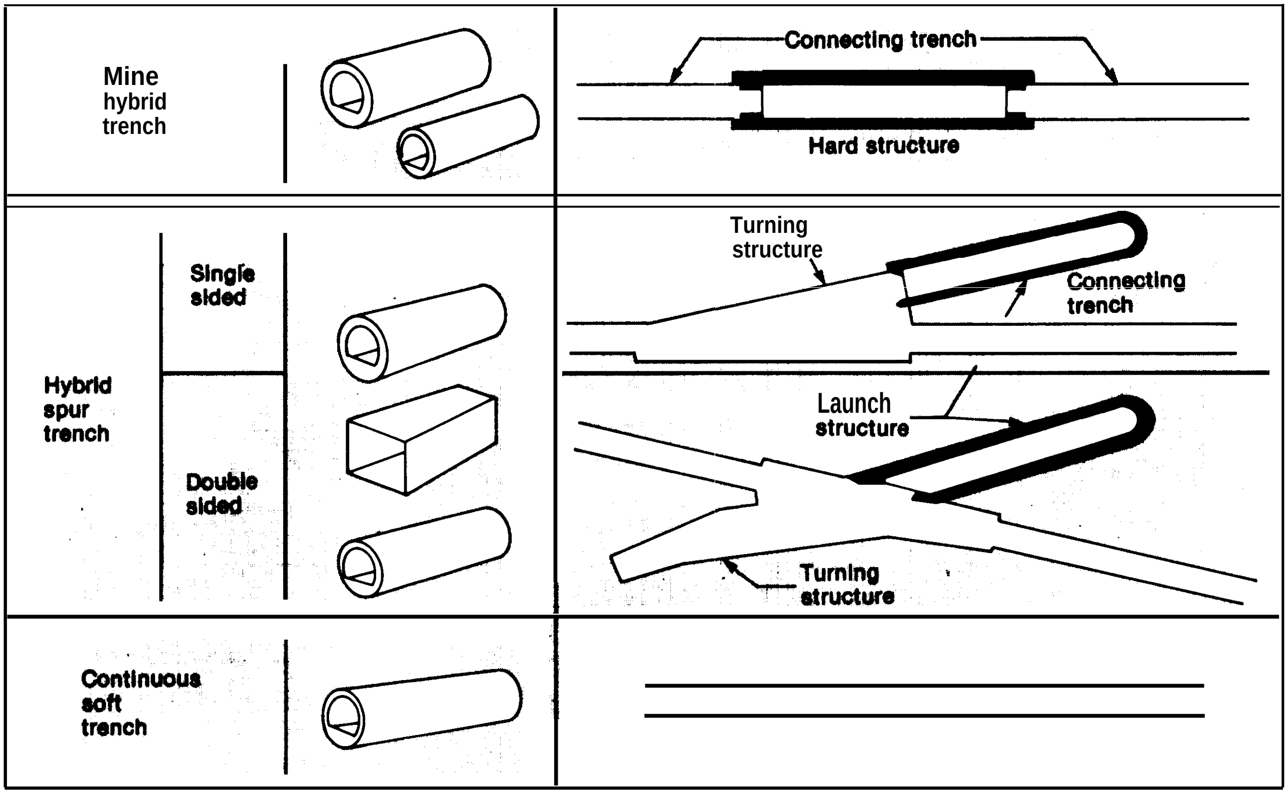
accommodate blast plugs, designed to protect the missile (see fig. 52).

An early concern for trench basing was the possibility that the trench tube would serve as a shock wave guide. Specifically, the fear was that in an attack on the trench, the shock wave propagating down the tube (largely unattenuated due to the trench's one-dimensional geometry) would result in conditions capable of breaching the blast plug and destroying the missile beyond a range where it presumably would survive the internal airblast. Steps were taken in trench design to protect the missile from the in-trench shock wave propagation. This design included stationing the missile in tunnel spurs, so that the plug would experience the side-on overpressure and not the direct reflected shock.

A series of high-explosive blast tests on the trench was performed at Luke-Yuma in 1977-78 (HAVE HOST, T-series), to investigate the above concepts for missile protection in the trench. Results of the tests indeed validated the blast plug concept on a half-scale trench test, and vividly showed the reflected shock venting at the plug. Even more significant, analyses by the Defense Nuclear Agency showed that even in the absence of blast plugs, hot air ablation of the tunnel walls (as well as other mechanisms) would attenuate the wave, such that the pressure impulse transferred to the plug would be approximately the same as if the trench were not even present.

A far more serious problem for the trench would have been PLU. Even though the missile would not be visible, its motion on the transporter, 5 ft underground, would not be difficult to detect. A large number of signatures would enable an observer to establish its location. (For a general discussion of these sig-

Figure 52. —MX Trench Concepts



SOURCE U S Air Force

natures, see the earlier section "Theory of MPS. ") Therefore, missile-transporter simulators would be necessary to install, at which point system cost would be a deterring factor. Moreover, security along the entire trench length probably also would be necessary, which would make the system less acceptable to the deployment region.

MINUTEMAN MPS AND NORTHERN PLAINS BASING

One means proposed to protect the survivability of the Minuteman I I I component of the present land-based missile force is to redeploy these 550 missiles in an MPS system similar to that proposed for the MX deployment in Utah and Nevada, For this case, vertical shelters would be constructed in the existing Minuteman base areas, The existing Minuteman missiles would be modified so that they could be moved more easily among existing silos and the new ones. Like the MX/MPS basing mode, survivability would be sought by constructing more shelters than the Soviets had warheads available to target them. As a weapon, the Minuteman I I I could be improved to achieve MX design accuracy by backfitting the MX guidance unit, Such a force could use the existing Minuteman bases, public roads, and support infrastructure.

Missile Modifications

A number of minor modifications would need to be made to the present Minuteman missile, To facilitate the increased handling of the missile, it would be placed in a cannister. Attachment tabs, or their equivalent, would be instal led on the stages to accommodate cannisterization. The entire missile would be transported, unlike the present Minuteman missile, which moves the first three stages and the fourth stage, separately, ı n addition, several attachments in the missile that were originally built to accommodate vertical orientation of the missile, might need strengthening to support horizontal motion of the missile during transport. The Minuteman guidance unit would also need modification, None of the modifications to the Minuteman missile appears infeasible,

Most technical risks associated with an MX/MPS deployment would also be a factor for a Minuteman MPS deployment. Most notably, PLU would be likely to be as formidable a task as for MX. Also, demands on system expansion due to an increased Soviet threat would be similar to the case with MX,

Since the Minuteman missiles, roads, and infrastructure are already available it might seem possible that the cost and time needed to proceed with such a deployment could be significantly less than for MX baseline. To examine this hypothesis, Minuteman deployments, corresponding to the baseline MX/MPS deployment and for expanded threats were observed, and estimates were formed for cost and schedule. The cases are the following:

- **Case 1, Baseline.** Encapsulate existing 550 deployed Minuteman Ill missiles and 117 MM Ill currently in storage and modify for MPS and cold launch. Modify the existing 550 silos to accept the encapsulated missile. Build 5,250 new shelters, for a total deployment of 5,800 shelters, spaced a minimum of l-mile apart. Deploy 5,250 decoys, and one transport for every two missiles. Reopen the MM I I I production line to replace missiles taken from storage. This mix of missiles and shelters would retain the same number of surviving Mark 12A warheads after a Soviet attack as the baseline MX/MPS system when deployed in conjunction with a planned Minuteman force of 350 MMIIIs and 450 MM IIS,
- **Case** 2, **Expanded 1990 Threat.** Deploy a cost optimum mix of Minuteman missiles and shelters, determined to be approximately 900 missiles and 10,400 shelters.

Case 3, **Expanded 1995 Threat.** Deploy a cost optimum mix of Minuteman missiles and shelters, determined to be approximately 1,1 ()() missiles and 15,500 shelters for this threat level

Cost and Schedule

Cost estimates are given for these three cases and the A i r Force baseline system i n table 19.

I n case 1, it is estimated that 5,800 shelters with 667 MM I I I missiles could be constructed in the Northern Minuteman Wings for about $7 billion (fiscal year 80 dollars) less than the AF baseline system.

In case 2, corresponding to a 1990 Soviet threat level of 7,000 RV'S the cost estimate is $534 billion for a system of 900 MMIII missiles and 10,400 shelters.

In case 3, corresponding to a 1995 Soviet threat level of 12,000 RV'S, the cost estimate is $724 billion for a system of 1,100 MMIII missiles and 15,500 shelters.

The major cost drivers for these cases are mechanical systems (transporters and decoys, primarily), construction, and assembly and checkout in the investment phase, Operations and maintenance and personnel costs drive the operating and support phase. MMIII missile R&D effort is minimal in relation to MX, assuming a maximum dependence on the existing Minuteman road network and C network, There would still need to be a substantial upgrading of the existing roads and new roads to the new shelters would be required.

Table 19.—Minuteman MPS Costs
(billions of fiscal year 1980 dollars)

	Baseline	Expanded 1990 Threat	Expanded 1995 Threat
Missiles . . .	667	900	1,100
Shelters	5,800	10,400	15,500
cost			
R&D	$ 2.5	$ 2.5	$ 2,5
Investment			
Nonrecurring .	1.4	1.4	1.4
Missile	2.7	5.3	7.4
Equipment	9.7	14.8	21,7
Aircraft	0.5	0.5	0.5
Engineering change orders	0.6	1,1	1.5
Construction	10.4	15.7	21.7
Assembly and checkout. .	2.4	**4.1**	**5.9**
Other.	0.3	***0.3***	***0.3***
Total investment	28.0	***43.2***	***60.4***
O&S to year 2,000.	5.9	***7.7***	***9.5***
Lifecycle cost. .	36.4	***53.4***	***72,4***

SOURCE Office of Technology Assessment

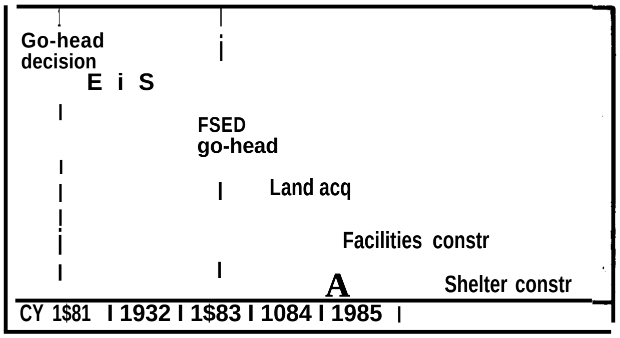
If a decision to deploy Minuteman/MPS were made in the summer of 1981 it is still unlikely that IOC could be achieved before 1987.

Assuming a period of 18-30 months for site selection and land acquisition (including E IS preparation), it could be possible to start construction on new silos in late 1984 or early 1985 (see fig. 53) with a resultant IOC date of late 1986 or early 1987. At the same time other activities that would have to proceed in parallel would include:

- development of a missile decoy and PLU,
- development of a transporter,
- cold launch development,
- definition of additional C requirements,
- upgrading of existing roads and construction of new roads to withstand the weight and length of a new transporter.

Schedule for FOC depends, in part, on peak construction rate. Assuming a peak construction rate of 2,000 shelters per year, by October 1986, FOC for Case 1 is projected to be 1989 or

Figure 53.— Minuteman/MPS Schedule



SOURCE Off Ice of Technology Assessment

1990 Case 2 and Case 3 FOCs are projected by 1991 and 1994, respectively

An additional question which could be significant, but which has not been analyzed, regards the cost associated with upgrading roads to accommodate a deployment of MX missiles in the Northern Minuteman fields In contrast to the Minuteman transporter, which would weigh approximately 2 15,()()() I b loaded, the loaded MX transporter would weigh close to 1 6 million I b Modification and opgrading of roads to accommodate this transporter could affect cost, schedule, and socioeconomic impacts

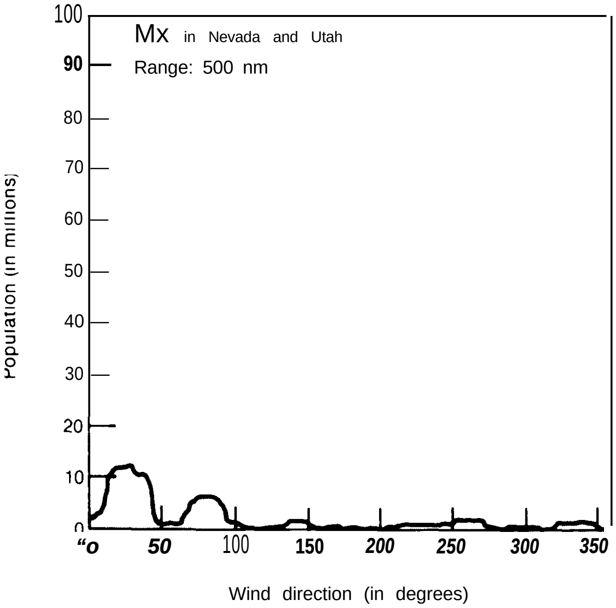
CIVILIAN FATALITIES FROM A COUNTERFORCE MPS STRIKE

Interest has been expressed concerning the level of civilian fatalities resulting from a Soviet nuclear attack on an MPS-based MX deployment. Specifically, because the number of nuclear detonations in such an attack would run into the many thousands of megatons, there is concern that civilian deaths resulting from radiation fat lout would be so large that it might be questionable if such a n attack could in any sense be considered a " limited counterforce" strike.

I n order to approach this problem, OTA obtained a series of calculations on resultant radiation doses over populated areas for a number of cases involving a nuclear strike on an MPS field. These computations are regarded only as representative and approximate at best. It is customary for such calculations to yield a wide range of results, and these are no different, The reason for this range is that resu lts are strongly sensitive to a number of factors, including wind speed and direction, wind shear, burst height of the weapon, and the weapon's fission fraction, It is not unusual to see variations in calculated fatality levels of at least an order of magnitude for differing wind speeds. Furthermore, different computer codes for the same *physical circumstances* (winds, etc) customarily yield results differing by a factor of 2 or 3. We have not attempted to resolve these differences, but have used a set of runs using the Weapons System Evaluation Group (WSEG) code as typical among different codes. I n addition to these caveats, there are some additional l imitations to these particular calculations. First, these computations rely on an urban-only population data base, consisting of 140 million people Therefore, total fatal i ties will be underestimated because fatalities in rural areas will not have been counted. Second, because the number of nuclear detonations would run into the many thousands, significant total doses depend on very small dose levels from the individual weapons. Because data at these small doses is scant, the value of any of these fallout models should be suspect

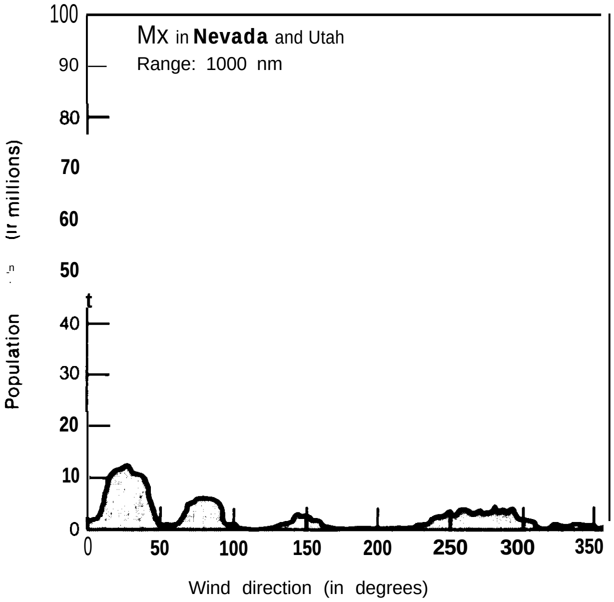
As an illustration of our population data base, we show in figs. 54 A-D the population in

Figure 54A.— Population Subject to Fallout v. Wind Direction



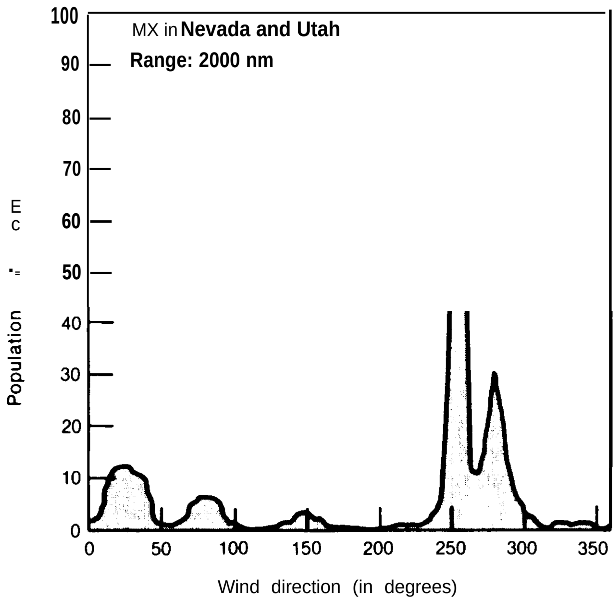
SOURCE Lawrence Livermore Laboratory

Figure 54B.— Population Subject to Fallout v. Wind Direction



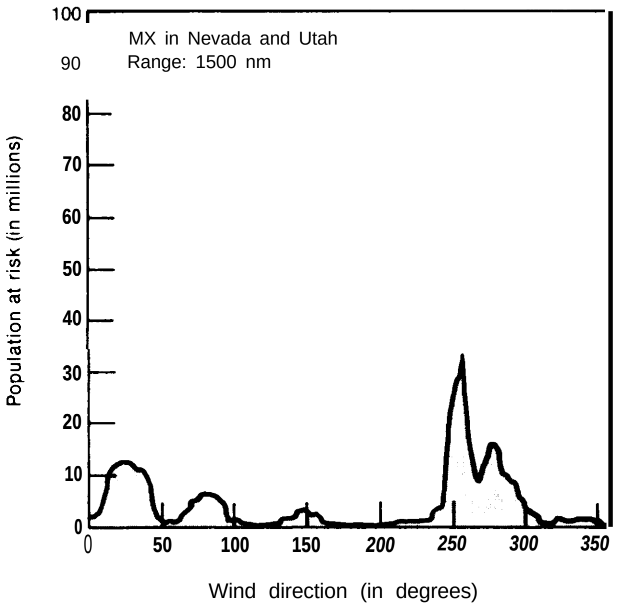
SOURCE Lawrence Livermore Laboratory

Figure 54D. —Population Subject to Fallout v. Wind Direction



SOURCE: Lawrence Livermore Laboratory

Figure 54C.— Population Subject to Fallout v. Wind Direction

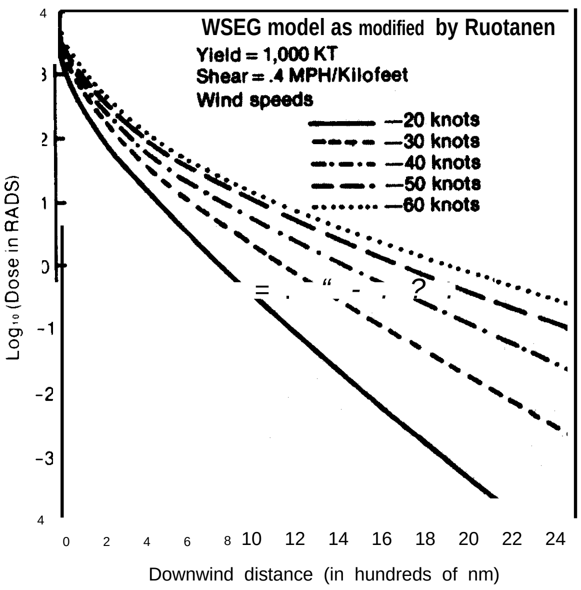


SOURCE Lawrence Livermore Laboratory

the path of radiation fallout versus wind direction, at distances from the MPS fields of 500, 1,000, 1,500, and 2,000 nautical miles. In these charts, a wind direction of 00 is from north to south. Similarly, a wind direction of 1800 is from south to north. A wind direction of 2700 points due east. In fig. 54A, the peak at 250 represents the Los Angeles area, 800 corresponds to the San Francisco Bay area, and so forth.

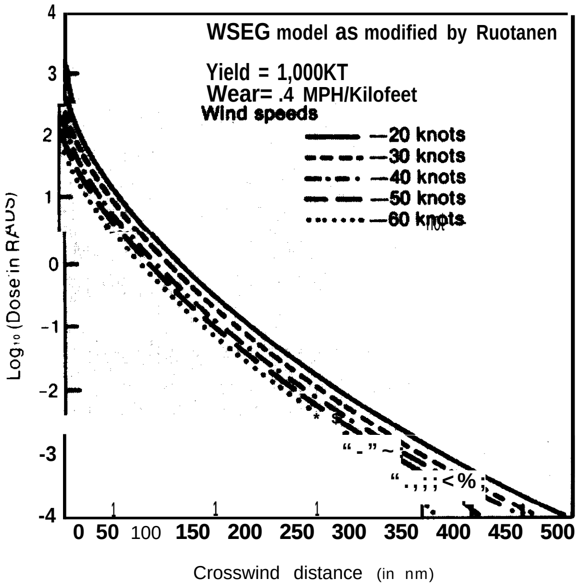
To determine the range of lethal fallout, and therefore the magnitude of civilian radiation fatalities, figure 55 shows the dose, in rads, resulting from the detonation of a 1 -MT weapon with downwind distance. These doses are plotted for a range of possible wind speeds, from 20 knots to 60 knots. For example, with 20 knot winds, the one rad contour would extend to about 800 nautical miles (for a single l-MT weapon). This contour would extend to about 1,400 nautical miles (or 1,600 statute miles) with 40 knot winds, and so forth. The 10- to 20-km altitude is the region where the mushroom cloud stabilizes and carries the bulk of the

Figure 55.— Downwind Distance v. Total Dose



SOURCE Lawrence Livermore Laboratory

Figure 56.— Crosswind Distance v. Total Dose



SOURCE Lawrence Livermore Laboratory

radioactive fallout. A survey of wind conditions for the proposed MPS deployment area showed wind speeds at these altitudes that averaged 30 to 40 knots, depending on season, with a typical wind direction of 2500 to 290 i.e., from the west-southwest to west-northwest. Finally, figure 56 shows the maximum width of radiation dose contours with differing windspeed for a given wind shear. (This width occurs at approximately half of the downwind range for a given dose.)

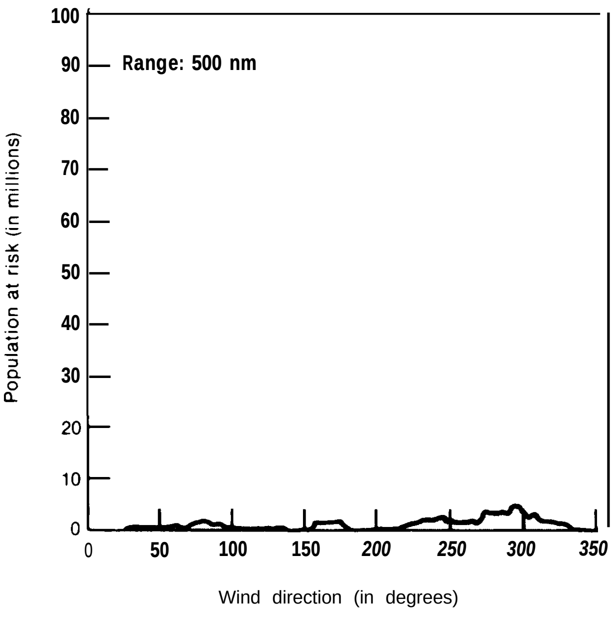
Civilian fatalities will depend on the prevailing winds, as well as the degree of protection taken by the populace. The 50-percent fatality level occurs at about 450 rads and the 90-percent fatality level occurs at about 600 rads. (For our purposes, we use the rad and the rem, for roentgen-equivalent man, itter Changeably.) Second, the relation between exposed radiation dose and the actual absorbed dose depends on the degree of protection afforded the population at the time of attack. This is commonly expressed as a protection factor, which is a direct proportionality between total dose absorbed for a given state of protection (e. g., in the basement of a house) and the dose collected without any protection, such as out in the open. Typical protection factors vary between one and 20 (see The Effects of *Nuclear Weapons, .3rd .,* Samuel Glasstone and Philip Dolan; Table 9.1 20)

An attack on MX in Nevada and Utah might involve the detonations of 4,600 1-MT weapons, spread over about 20,000 mi2. Based on these graphs, total doses of 500 to 2,000 rads for such a nuclear attack, corresponding to fatal doses for a protection factor of 1 to 4, might occur at a range of 500 to perhaps 1,500 nautical miles from the origin of the attack, and depending largely on wind speed. Going back to figures 54 A, B, and C, depending on wind direction as we I I as winds peed and population protection, civilian fatalities could range from less than 1 million to more than 20 million. For typical winds in a west or north-west direction, fatalities run from less than 5 million for a 500 nautical mile lethal range, up to 20 million to 30 million corresponding to our high lethal range of 1,500 nautical miles.

It is important to note that these figures indicate the expected fatalities due to an attack on the MX fields alone. However, it seems probable that a Soviet attack on MX would be likely to include Minuteman and Titan fields, strategic bomber bases and submarines in port. Because these existing targets are distributed over a large area the *added* fallout related fatalities due to the additional targets in the MPS fields would have a likely range from less than 1 million to 5 million. Total fatalities for this limited counterforce attack have been estimated to range from 25 million to 50 million people

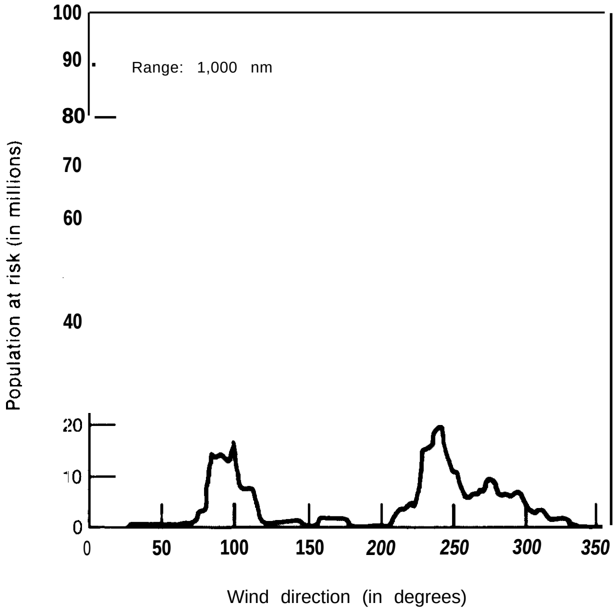
For an MPS deployment in Northern Texas and New Mexico, corresponding graphs of population at risk are shown in figures 57A-D. Windspeed and direction,for this area at relevant altitudes average 35 to 45 knots, and from the west, 2750 - 2800, With these winds, a nuclear attack might result in fatalities of 10 million to 20 million; however even a normal shift of wind direction could result in fatalities of well over 40 million for an attack on MX/MPS alone

Figure 57A.— **MX in Texas and New Mexico: Population Subject to Fallout v. Wind Direction**



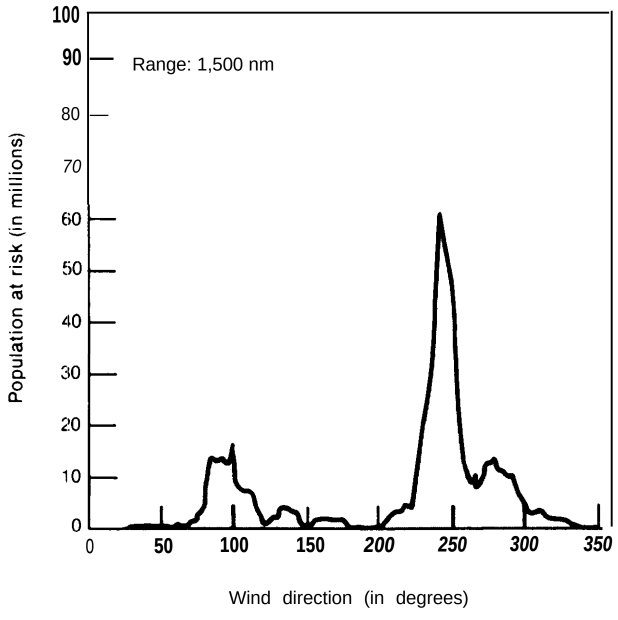
SOURCE Lawrence Livermore Laboratory

Figure 57B. —MX in Texas and New Mexico: Population Subject to Fallout v. Wind Direction



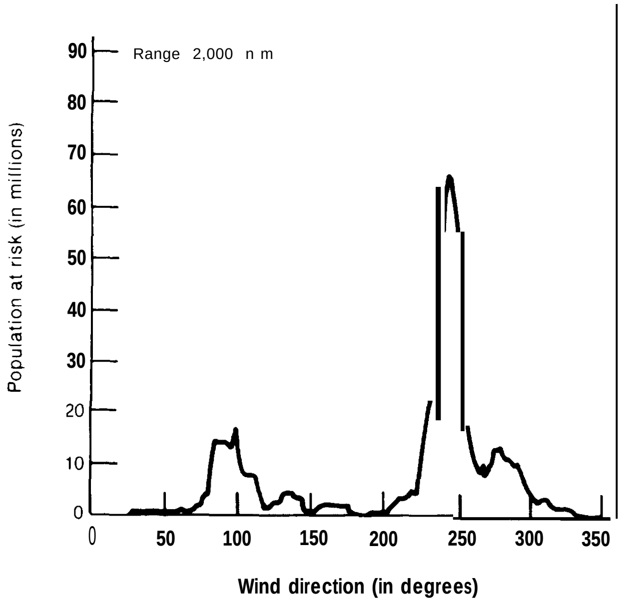
SOURCE Lawrence Livermore Laboratory

Figure 57C.— MX in Texas and New Mexico: Population Subject to Fallout v. Wind Direction



SOURCE Lawrence Livermore Laboratory

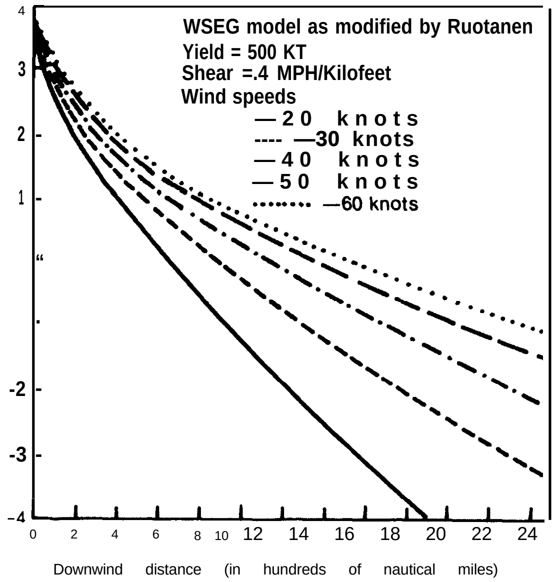
Figure 57D.—MX in Texas and New Mexico: Population Subject to Fallout v. Wind Direction



SOURCE Lawrence Livermore Laboratory

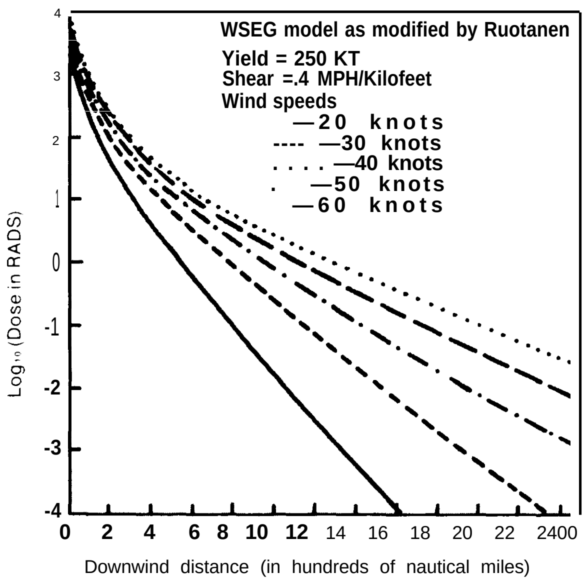
Results on civilian fatalities would also depenal in part on the Soviet responses to MPS If, for example, the Soviets responded by building more missiles, each carrying the same warhead yields as before, then the resulting radiation doses would go up proportionately, If however, the Soviets respond by fractionating their warheads, i.e., increasing the numbers of warheads with diminished individual yields, then total radiation dose would most likely go down, and not up. This decrease occurs for two reasons. First, fractionation customarily reduces total yield, resulting in less radioactive byproduct of the weapon. Secondly, a lower yield weapon results in a slightly lower altitude for the radioactive mushroom cloud, and hence less fallout range, This distinction can be seen quantitatively by comparing the one megaton case in figure 55 with the 500 and 250 kT cases shown in figures 58A&B.

Figure **58A.—Downwind Distance v. Total Dose—500 KT**



SOURCE Lawrence Livermore Laboratory

Figure 58B.—Downwind Distance v. Total Dose—250 KT



SOURCE Lawrence Livermore Laboratory