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A MODULE FOR NATIONAL SURVIVAL

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June 5, 1961 [redacted]

Engineering Research Report

CONVAIR SAN DIEGO CONVAIR DIVISION GENERAL DYNAMICS CORPORATION

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Convair Division of General Dynamics Corporation

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CONTENTS

FOREWORD

This document contains the thoughts of the authors with respect to an important national problem. Much of the work represented has been carried out on the authors' own initiative and time. The detailed design of the survival module represented here has been carried out with Convair sponsorship under REA 8701. The authors wish to acknowledge the extensive contribution of Mr. A. Mattia in performing the detail design of the survival module described in this report.

Insofar as we know, no classified information is represented in the document. We are, however, maintaining very strict control of the distribution so that a high classification can be established if this is deemed to be wise.

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ABSTRACT

A plan is proposed for ensuring the survival of the American population in the event of an all-out nuclear war. The plan involves the large-scale use of survival modules, each unit capable of handling six persons. Each module consists of three components, (1) a low cost blast and radiation resistant survival hole, (2) a segmented survival capsule which when assembled is like the body of a camping trailer, (3) a trailer frame. Design features of the survival hole include cylindrical-spherical geometry for blast resistance, a minimum of 4 feet of earth cover for radiation attenuation. The arrangement would provide good probability of survival to within 1-1/2 miles from a multimegaton blast. Support facilities for the capsule provide for two or more weeks of continuous habitation. Design features of the capsule include provisions for simple disassembly to permit passage through a 3-ft x 7-ft opening and assembly for outdoor recreational purposes as a camping trailer. Various alternative modes for using the modules are discussed. A module when produced to take fullest advantage of America's mass production technology can be fabricated for less than $2,000 per module. In view of the possibility of utilization as a recreational device it is likely that the unit will have wide appeal and that the public will be willing to bear a large portion of the cost of the units on a voluntary basis.

Consideration is given to the alternative modes of utilizing the elements of a complete module. By inserting additional segments a module can be expanded to serve as an element in a community shelter program. The fact that the technological strength of the country could then be brought to bear on the problem would be an advantageous feature of this type of program compared to conventional community shelter programs.

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From a political standpoint, this is probably not the best moment for initiating the large-scale production of such survival units. Possibly international affairs will take such a favorbale turn that the moment will never arise. However, taking cognizance of the fact that human affairs oft go in unwanted directions, a proposal is made which would make it possible to quickly implement this survival plan in the event circumstances warrant. The implementation of the survival plan is broken down into the following phases:

Phase 1. Preliminary and subsequent detailed design of survival modules. Construction of several prototypes. Preliminary design of machinery for the mass production of survival units. Analysis of utilization and impact of survival system as well as utilization and impact of its recreational features. (approximate cost $200,000)

Phase 2. Final design and test of basic module. Construction of prototypes of machine tools for mass production of the modules ($2,000,000)

Phase 3. Large-scale production of specialized machinery and adaptors for fabricating survival units (estimate requirement, 2,000 units at $50,000 each).

Phase 4. In the event the political situation warrants, full-scale production and installation of survival modules by utilizing the entire technological resources of the nation. (estimated cost, 50 million units, $2,000 each)

Political, psychological, and economic ramifications of the proposed program are discussed. It is believed that the possible short-run hazard that the program would unstabilize the present precarious deterrence balance, is avoidable, and that the long-range impact of the proposed system will be toward ensuring world stability and the control of armaments.

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1. INTRODUCTION AND STATEMENT OF PROBLEM

In the event of an all-out nuclear attack on the continental United States, a large portion of the American population would become casualties unless an adequate shelter program had previously been instituted. The casualties will be of two types: (1) those due to the prompt effects of blast, heat, and radiation, primarily among the urban population in close proximity to the nuclear detonations, and (2) those due to residual radioactive fallout among the suburban and rural population. The residual radiation would reach an approximately uniform level over the entire nation within a day and endanger all who have not taken precautionary measures. The consensus of opinion of the military and civil authorities who have studied this problem, is that protection can be afforded a family from excess radiation exposure by living in a shielded area until the radiation levels have declined to physiologically acceptable values. An adequately shielded area cannot normally be found in the average home. Hence, for protection in the event of an attack, a radiation shelter must be provided in advance.

While much has been written and said about the importance of shelters, relatively little has yet been accomplished toward the protection of the American population. Until the present time, the primary encouragement toward building radiation shelters has been through the medium of information pamphlets distributed by the Office of Civil Defense Mobilization. These pamphlets point out the danger and show how these dangers can be mitigated, particularly for regions outside the blast, heat, and instantaneous radiation zones. The pamphlets include diagrams which illustrate how radiation shelters may be constructed in basements of buildings and underground with wood, brick, cinders, concrete block, poured concrete, and dirt. While some of the more primitive shelters can be constructed by the average homeowner, the most effective types would require the assistance of a general contractor. Despite the fact that the costs of the shelters are relatively modest, the response to the encouragement of the OCDM and other federal agencies has been, unfortunately, quite small. Currently, the average family does not regard the investment as essential at this time, and very few shelters are being built or planned. The difficulty is probably due, in considerable part, to the great reluctance of the American population, as a whole, to think of such unpleasant possibilities as nuclear war. Furthermore, there appears to be a reluctance on the part of top officials in the government to very aggressively and openly pursue an all-out civil defense program, despite the generally conceded importance of such a program to the survival of the country in the event of an attack. The reasons behind this reluctance will be discussed later and in the context of current affairs; we will agree that it is probably justifiable. On the other hand, in the long run, it would appear that an adequate national system of shelters is an absolute necessity, and hence the questions arise: "What kind of shelter designs will best serve the nation's needs from the broadest aspects? How should we go about instituting such a shelter program?"

To answer the question of what is an optimum design, one must know the relative importance of each of the casualty-producing effects associated with a nuclear detonation. Extensive studies by the RAND Corporation and other agencies indicate that with no warning, the initial salvo of nuclear warheads would cause the death of 3% of the population. On succeeding salvoes, with 30 to 60 minutes of warning, the fatalities will build up to 90% if no precautionary measures have been taken; to 50% if a system of fallout shelters with arrangements for tactical evacuation has been instituted; to 22% if strategic evacuation has been accomplished and a system of fallout shelters exists; to 15% if a system of blast and fallout shelters exists; and 3% fatalities if strategic evacuation has been accomplished and a system of blast and fallout shelters exists. These studies indicate that 40% of the population would be fallout victims, and 35% of the population would be victims of initial blast who could be saved by a national system of blast-fallout shelters.

Since the greatest portion of our urban population would fall victim to the initial blast, any shelter design for urban use must not only protect against fallout, but also be highly blast resistant. In addition, there will be a need in most instances for mobility to escape from areas of lethal radiation densities to areas of lower fallout concentration to permit long-term habitation after a nuclear war. In this report, we present a design for a shelter module which satisfies a number of important design requirements:

1. medium or high blast resistance,
2. adequate radiation attenuation, even in areas of highest expected fallout concentration,
3. habitability for a two-week period,
4. low cost,
5. an important means of mobility following an attack, and
6. an attractive secondary purpose for the survival unit.

The proposed survival unit might not represent the least expensive module, but it is believed to represent a module that

1. will have a broad appeal,
2. will handle most possible situations,
3. can best be handled by American technology, and
4. can be instituted in a manner which will not upset current delicate negotiations on armaments control.

The proposed unit consists of a survival hole made of a corrugated steel culvert pipe capped by two hemispheres of formed sheet metal buried to a minimum depth of four feet. A segmented survival capsule containing most of the expensive living accommodations associated with the shelter is placed within the basic steel underground structure. This survival capsule is designed so that it can be disassembled and raised above the ground and reassembled on a trailer base. In this form it would serve as an efficient camping trailer and would look, in many respects, like a typical recreational trailer which now markets in the neighborhood of $1000. The additional components of a survival unit would be a trailer bed and a lift mechanism. A number of optional arrangements of the

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components of the unit are possible. These will be discussed later. We will now describe in more detail the components of the survival module.

2. THE SURVIVAL HOLE

Since initial blast effects would be responsible for a large portion of the expected casualties, any system of shelters must include maximum protection from blast effects as well as radiation effects. A shelter incorporating the structural advantages of ellipsoidal or spheroidal geometry provides the maximum blast protection for a given wall thickness. Unfortunately, the problem of efficiently utilizing the enclosed volume of an ellipsoid or spheroid is difficult and as a compromise, a cylindrical-spherical geometry in which the basic structure is a cylinder and is capped with hemispherical ends is suggested. This geometry provides great strength in all directions, except longitudinally. In this direction the shelter is somewhat weaker, but the component of blast pressure in this direction will be small unless the shelter is very close to ground zero and has its horizontal axis pointed toward ground zero. The proposed design makes survival possible almost to the crater lip in the event of a surface burst. The proposed design could withstand any overpressures which did not produce excessive plastic deformation of the ground itself. The prompt neutron and gamma radiation will determine the minimum survival distance for an air burst. Table 1 contains the values of expected distances from ground zero within which personnel and vehicles could be expected to survive for various warhead yields. The table includes both surface- and air-burst conditions, tabulating the more stringent case in each instance. Table 1 also contains data pertaining to the distance within which an automobile can survive as a function of warhead yield. This factor is of importance if the family automobile is to be used in conjunction with the trailer for evacuation.

In the first detailed design configuration the survival hole is constructed of a corrugated 8-gauge steel cylinder, 17-1/2 ft long and 8-1/2 ft in diameter such as is used in culvert construction. The cylinder is capped by two specially fabricated spherical ends. Two vertical

TABLE 1. PARAMETERS ASSOCIATED WITH MEGATON BURSTS*

Warhead Yield (megaton)	1	5	10	20
Maximum Fireball Radius (mile)	0.7	1.0	1.4	1.9
Maximum Lip Crater Radius	0.4	0.7	0.88	1.1
Total Radiation Dose (Initial and First 2 Weeks Residual) with 4-foot Earth Shield	30 Rem at 1 mi	40 Rem at 1 mi	30 Rem at 1.2 mi	30 Rem at 1.5 mi
Distance at which some Personnel can be Expected to Survive in Proposed Shelter	< 1 mi	1 mi	1.2 mi	1.5 mi
Thermal Hazard to Auto (5 cal/cm^2)	10 mi	16 mi	28 mi	40 mi
Minimum Radius at which Auto can Survive Blast Damage (if no fire)	3-1/2 mi	6 mi	8 mi	11 mi
Minimum Radius at which Frame Garage can Survive Blast	6 mi	10 mi	13 mi	16 mi

*Table based on data from "The Effects of Nuclear Weapons," U.S. Armed Forces Special Weapons Project (1957).

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columns intersect the metallic structure, one near each end. One column is a 30 in. diameter, corrugated steel tube which is used as an emergency escape hatch in the event that the main entrance becomes blocked. This access tube is filled with sand for radiation protection and is capped by a concrete blast door. Egress could be accomplished by draining the sand into the shelter and lifting the blast door by utilizing a counter-balanced lever system. The main entrance is an oval-shaped concrete structure large enough to permit an opening of 7 ft x 3 ft at the top through which the sections of the survival capsule are passed. The opening is protected by a sliding, reinforced, high-density concrete blast door, 5 ft x 9 ft with a minimum thickness of 1 ft. The main horizontal cylinder is buried to a minimum depth of 4 ft to provide adequate radiation attenuation. Bins are provided in the culvert for the storage of water and food. The particular design shown represents a structure which is believed adequate for most conceivable situations.

An alternate shelter design provides a completely sealed atmosphere for a period starting at the time the shelter is entered and ending approximately 48 hours after the detonation of the warhead. At that time, a ventilation pipe is forced up to the surface through 6 in. of earth by means of a hand-powered jack. Ventilation of the shelter through filters to prevent contamination by radioactive, biological, or chemical agents is then accomplished. Alternatively and at additional cost, sufficient oxygen regeneration chemicals could be stored to provide a sealed atmosphere for a period of two weeks.

A standard shelter unit would require a hole 13 ft deep, 9 ft wide and 22 ft long. To expand the shelter capacity for families larger than the norm, one simply adds additional center sections. Sections interlock and the entire structure is coated with a rust inhibitor and the seams waterproofed. The structure can be enlarged at any time by separating one end from the center section and by inserting additional center sections. Top and end views of the survival hole are shown in Sketch 1 with the outline of the survival capsule in place. Also shown is the winch structure used for lowering and lifting the segmented survival capsule.

3. THE SURVIVAL CAPSULE

The survival hole, as depicted thus far, represents the bare minimum of structure necessary to achieve the desired blast and radiation resistance to ensure survival. In addition, a complete shelter must embody life support functions for extended periods. The novel feature of the proposed shelter design is the possibility of utilizing the major portions of the life support structure as a removable unit which can be made to serve recreational purposes by conversion into a camping trailer. The small camping trailer probably represents the highest achievement in compactness and economy in the engineering of living quarters. Therefore, a modern, efficiently designed camping trailer is used as a prototype for the proposed survival capsule. Such trailers are currently available on the market in the price range from $850 to $1500. They are designed to accommodate a family of two adults and three to four children. However, in view of the dual purpose of the proposed unit, several significant departures from ordinary trailer construction must be made.

In the first place, the capsule must be of segmented construction so that it can be inserted through the comparatively small blast door. In the form first visualized, the capsule is segmented into four 3-ft sections. These sections can easily be inserted into the survival hole by lowering one section at a time, with the aid of a collapsible winch, through the blast door. In the design shown in Sketch 2, each section would weigh approximately [illegible] lb, with the exception of the aft section which would weigh approximately 4[illegible] lb. The sections latch together easily and when assembled are water tight. Construction techniques utilize Fiberglas walls for strength, lightness and durability, aluminum beams for window and door frames, and steel locking pins, latches, and roller assemblies for maximum wear resistance. Doors are provided at both ends to permit access to the outer survival hole and to the storage area, chemical toilet, air conditioning system, and power source. Access to the storage bin in the floor of the shell is made by separating the capsule at any of its joints and exposing the floor at that joint. This

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is possible because the survival shell is longer than the capsule and permits a 3-ft separation of the capsule segments.

To insert a trailer into the survival opening, the tension latches are released, and a segment of the trailer body is rolled off the trailer frame and lowered with the winch. It would probably be necessary for a second person to be within the shelter to guide the capsule segment down into the hole. The segment would then be rolled to the rear of the hole and the next section lowered. The completely assembled unit would be relatively airtight. Installation of an air-conditioning system would maintain a slightly positive pressure in the capsule with respect to the outer survival hole to forestall the possibility of any odors or contaminants reaching the living area.

To be used as a camping trailer, the segments would be raised in the reverse order from their insertion into the shelter and would be latched together on the trailer frame which is stored above ground. Assembled on the trailer frame, the capsule appears in most respects like a modern camping trailer and can be used for the same purposes. The fact that the survival hole would serve to store the camping trailer between periods of use would be a decided advantage to middle-class people living in restricted residential areas where the storing of a camping trailer above ground is generally frowned upon or restricted by local ordinances. Storing the trailer below ground and out of sight could create no objections from neighbors.

An alternate purpose for the survival capsule would be as a part of a houseboat. In the simplest form one might have a set of pontoons to which the trailer frame could be attached, and on which the survival capsule could be mounted. This type of houseboat would be very useful in lake country for vacation periods. Alternatively, one might insert the capsule into a large hull to provide the carefully engineered accommodations usually associated with a very expensive boat.

The over-all concept in the embodiment in the survival capsule of the maximum degree of expensive life support features is an attempt to move the most attractive features of the shelter module into a unit which has an alternative recreational use. This might be appealing to many people who have resisted the family shelter concept for psychological reasons. The survival shelter has not been accepted widely in America, probably because most people dislike thinking about the horrors of nuclear war. In view of these horrors, as they have been portrayed, people are dubious as to whether they really would wish to survive in the post-attack period. At least they are dubious enough to be unwilling to invest money which could be spent on other comforts. By attempting to embody as much of the cost of the shelter into a unit that has a very desirable purpose in itself, we feel that the public might ultimately accept the unit and bear an appreciable fraction of its cost.

The proposed design in Sketch 1 represents an initial effort. Much further study is needed before deciding upon one or two designs for consideration as a prototype for mass production. One alternate possibility would be to use five segments, each small enough to permit access through a standard doorway. This would further reduce the size of the blast door and would also permit the assembly of the survival capsule in house basements far removed from target areas; in this case the capsule might be used primarily as a protection against radioactive fallout with relatively minor modifications to the home. This might greatly extend the sales appeal to many persons. We should also give consideration to the possibility of disassembling the capsule into panels. If a design could be evolved which had the requisite strength and fluid sealant properties and which could be assembled with relative speed, then many aspects of the survival hole could be simplified. The blast door could then be made much smaller and the winch would be unnecessary for raising and lowering the panels. The feasibility of such a design should be considered in any future study of this type. While such a design might not be the simplest, it might well be the most attractive variation of the segmented capsule technique and should be examined from this point of view. Details of the sealing and latching mechanisms and the entire unit assembled in the survival hole are shown in Sketches 3 and 4. The estimated weights and materials used in the survival unit are listed in Table 2; also included are estimated weights and materials for a supplementary 3-ft section which would provide food storage space and sleeping space for additional persons at a cost of approximately $200.

TABLE 2. WEIGHT BREAKDOWN OF SURVIVAL MODULE

Trailer Hull and Equipment (Total weight without additional sections-1498)	Material	Forward Section	Center Forward	Center Aft	Aft Section	Additional 3-ft Section
4 Longitudinal Beams - 8 x 36 x 0.125 in.	Aluminum	12	12	12	12	12
Roller Assemblies 3 lb ea.	Steel	12	12	12	12	12
Floor tension latch 4 lb ea.	Steel	8	8	8	8	8
Wall tension latch 2 lb ea.	Steel	6	6	6	6	6
2 Lateral beams - 4 x 70 x 0.1 in.	Aluminum	6	6	6	6	6
Plywood floor panel	3/4 in. Plywood	30	36	36	30	36
Station frames - 240 x 4 x 0.1 in.	Aluminum	10	20	20	10	20
Door frames - 160 x 4 x 0.1 x 2 in.	Aluminum	12	12		12	
Window frames (1/4 door)	Aluminum	6(2)		3		
Fiberglas and Foam Sandwich Shell	Fiberglas and Foam 1.5 lb/ft.	160	90	90	160	90
	Glass	--	--	--	--	--
Range, Refrigerator, Cabinet, Sink	Apt. size		150			
Cabinets, built-in 3/8	3/8 in. Plywood		15	80	25	
Couch/bed	3/4 in. Plywood				110	
Mattress	2.5 lb Polyfoam				30	
Hammocks and channel supports	Tubes and fabric			(2)20	(2)20	(3)30
Hammock Mattresses	Polyfoam			15	15	22
Dinette Structure (including table)	3/4 in. Plywood	70				
Dinette cushions	Polyfoam	20				
Totals		352	367	323	456	242

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Trailer Frame and Running Gear		Material	Weight-lb	Additional 3 ft Section
2 Longitudinal Hatsections		Steel	200	None
2 Longitudinal Roller Tubes		Steel	80	
5 Lateral Channel Area		Steel	135	
2 Wheel Ass'y (wheels, tires, etc.)		Steel, Rubber	80	
Axles and spindles		Steel	45	
Jack (at Hitch)		Steel	15	
	Total		555	
Underground Shell Installation				
Corrugated Drum				
Cylinder		Steel	4750	855
Ends		Steel	730	--
End Ribs		Steel	235	
End Flanges		Steel	450	
Floor				
Plywood		Plywood	90	30
Lengthwise Angles		Steel	116	19
Crosswise channels		Steel	190	27
Pipe tracks		Steel	150	30
Escape Hatch				
Cylinder		Steel	380	
Upper and lower flanges		Steel	75	
Lower Door		Steel	100	
Upper door and Recess		Reinforced Concrete	1200	
Main Entrance				
Support I beams		Steel	430	
Walls		Steel	1500	
Roller beams		Steel	360	
Door		Reinforced Concrete	6150	
Door rails		Steel	180	
Ladder		Steel	10	
Rollers, crank drive, etc.		Steel	150	
Miscellaneous				
Water tank		Steel	170	
Air inlet pipe		Steel	33	
Blower		Steel	40	
Filter (blast proof)		Steel, Concrete	50	
Exhaust Duct		Steel	30	
Exhaust head		Steel	5	
Toilet		Wood	4	
		Steel	20	
Hoisting Equipment				
Collapsible Structure		Aluminum	40	
Misc. brackets, pulley, etc.		Steel	20	
Winch, Cables, etc.		Steel	20	
	Totals	Steel	10,100	931
		Wood	94	30
		Concrete	7,400	
		Aluminum	40	
			17,640	961

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4. TRAILER FRAME, LIFT MECHANISM AND OTHER ACCESSORIES

In the form now visualized, the trailer frame utilizes two longitudinal tubes as a support for the capsule segments. Roller mechanisms in the capsule sections mate with these tubes and permit positioning of the section overlocking pins. These prevent lateral or longitudinal movements of the sections with respect to the frame when the capsule and frame are used as a trailer. Extensions to the longitudinal tubes permit positioning of the segments over the shelter access hole for lowering without necessitating parking the trailer over the hole. The trailer will be designed to permit it to serve other functions such as moving a boat, furniture etc.

The lift mechanism consists of a collapsible aluminum framework which, stored neatly on the ground, is anchored to concrete blocks. A hand winch permits easy raising and lowering of the sections. If smaller capsule assemblies are used, then the possibility of simple jack lifts or a simple elevator device can be considered. The construction of a prototype would be extremely helpful in determining an optimum design for the purpose envisioned.

As mentioned previously, an additional accessory which might have great appeal in certain regions, would be a pontoon structure onto which the trailer could be assembled for use as a houseboat on relatively calm bodies of water.

The possibility of providing a small engine and drive system which could move the trailer in the event the family car is destroyed should also be considered. Perhaps the engine utilized in the air-conditioning and power generating system could double for this purpose. A small prime mover in disassembled form could be stored in the shelter to insure its survival.

5. ALTERNATE MODES OF USE

Having designed and engineered a basic survival module for six people, consisting of a survival hole, a survival capsule, and a trailer body, we might consider simple variations which would enable the fundamental elements of the design to be utilized for broader purposes. One possibility that warrants further study is that of using extended versions of this shelter for community shelters. There must be an optimum size for a community shelter, dictated to a certain extent by the number of people that can be supported by such basic facilities as a sink, a toilet, air-conditioner, etc. Since these basic supporting units are available in a family shelter, the principal modification to a module for community shelter would involve a simple extension of the length of the shelter with the insertion of additional segments, both to the basic shell and to the capsule. Since such a module for a community shelter would be built by mass production techniques, it is quite possible that its cost would come within the cost realm of specially designed community shelters. From the psychological standpoint, it would appear that control of the population in the event of an attack would be more simple if people were subdivided into smaller groups. Every school could have a battery of underground units matching the capability of the classrooms. Factories and industry could have such units underground matching the organizational structure of the working establishment. With the cost of the door, the lift mechanism, the toilet, sink, and other basic life support units amortized over a larger group of people, it is quite possible that protection could be provided at a cost of about $200 per person.

In many areas of the United States the blast resistant feature of this survival module might not be a significant asset. Furthermore, there might be natural shielding arrangements which could possibly be completed for much less cost than the module proposed here (e.g., basements, caves, etc). In this case one might, nevertheless, wish to adapt the unit to permit installation of the survival capsule and other auxiliary gear. With mass production, this might be an inexpensive method of achieving a reasonably comfortable shelter by taking advantage of the careful engineering which will go into the fundamental survival capsule and support equipment.

The basic shelter itself, can serve most of the functions of blast and radiation protection. Should funding be a problem, one might establish a system in which families who have the type of gear utilized in camping might simply purchase the basic survival hole. This could save approximately $1,000 for the typical family or permit them to postpone the purchase of the complete installation for a later time. Of course the capsule would be a highly desirable augmentation to the basic shelter and would, in the post-attack period, have a variety of possible uses in addition to that of rendering survival within the basic shelter more comfortable. For example, following the attack, after radiation levels have declined, one might wish to use the survival capsule as a home above ground should one's home be destroyed by fire or blast. Thus, by bringing the capsule outside the shelter, one effectively has a two-room, two-story, living accomodation instead of a single underground room. To minimize the cumulative burden of radiation, one might, for example, use the outside capsule for daily living and working, but sleep in the survival hole, at least until the radiation levels decrease to approximately normal levels. Alternatively, it might be necessary to evacuate an area of extremely high radioactive contamination to a more physiologically acceptable area; use of the trailer and capsule combination would provide a means of transporting the personal effects and the living quarters of the family unit.

To transport the capsule to a remote location one must have access to some prime mover, such as a family car. This means that some attention must be paid to the problem of increasing the probability of survival of the family car. Several approaches are possible in view of the automobile's intrinsic resistance to disabling blast damage. One could extensively alter the family garage so that it in itself has a certain degree of blast resistance. A number of possibilities of this type have been explored. While these appear quite feasible they seem to be, for the most part, quite costly. A simpler system would be to simply reinforce the garage structure with tubular steel braces. The garage, itself, would serve as a shield against thermal radiation from the detonation, which is the principal danger to an automobile at distances up to three times that at which the blast would disable the vehicle. The overpressure might then destroy the garage, but leave the tubular framework intact. This might permit one to enter the vehicle through the rubble of the garage and attempt to drive it out. Where the principal danger to the family automobile is contamination, a protective plastic covering could be utilized. Decontamination of the automobile would then merely involve the removal of the covering. The survival of the family automobile is important for many reasons. An all-out attack undoubtedly will destroy all means of mass transportation. Accordingly, the automobile might well represent the one major mode of transportation which remains intact. The automobile is also, in itself, a life supporting unit capable of providing many services through its battery, lights, radio, generator, air filter, and tools. For this reason it is believed that the survival module should be built in close proximity to the storage position of the family automobile wherever possible.

For areas close to possible target complexes where neither surface structures nor vehicles could survive (a distance of about 12 miles from a 20-megaton blast) it will be necessary to transport survival trailers with transport from outside the damaged area. In the national survival plan, provision must be made for special survival teams to move into such areas to evacuate families and to provide them with basic necessities, should their stores be exhausted.

An interesting mode of use for the survival module would be in connection with space exploration. In effect, the proposed survival module is a means of providing life support in a very hostile environment, hostile from the point of view of radiation levels, as well as possible blast and thermal stress. The unit proposed in many respects is like a complete self-contained life support system although it does have a few communicating links to the external world, e.g., the air intake and the toilet drain. Apart from these connections with the external world, the survival unit is almost a closed life support system. To convert it into a completely closed system would require some process for taking the exhausted air and returning it to the intake after purification and also for taking the body waste and returning it to the storage tanks for reuse after purification and reconversion.

Now let us assume we wish to establish a colony on the moon. While in the later stages of such a colony one might run into community arrangements, nevertheless, for the initial establishment of colonies and for initial exploration a unit quite akin to the survival module might be quite close to ideal. One could, for example, place on the moon many survival shells buried under an appropriate amount of earth (or rather moon dirt). The explorers would spend many of their hours in their survival capsules, particularly during the solar flares when the radiation intensities might be expected to become excessive. Furthermore, this type of insulation might protect them from the intense heat of the sun, since the moon lacks a protective atmosphere. If one wished to journey from capsule to capsule, one might raise the survival unit onto a trailer base provided with its own motive power. This unit could then convey the explorer, his personal effects, and the scientific instrumentation associated with his measuring program to any desired position. This possible use of the survival unit may justifiably be regarded as quite fanciful but it does serve to illustrate the possible extensive versatility of the module concept in the space exploration context.

6. INCORPORATION IN A NATIONAL SURVIVAL PLAN

A national system of family shelters would be only one facet of a total national survival plan. To be effective such a plan must of necessity include survival shelters for personnel at work, protection for industries vital to the recuperation of the economy and provisions for stockpiling of food stuffs, machinery, and essential material which would expedite national recovery in the post-attack period.

In the event of total nuclear warfare, it is quite likely that at least a full year's agricultural output will be unfit for consumption because of contamination. To overcome this obstacle, one must plan the utilization of the surplus stocks of commodities now owned by the federal government. A national shelter program must provide a means for nationwide disbursal of such food stocks. First, surpluses should be converted into packaged form and into a form capable of direct consumption. The complete provisioning of the entire national survival system could absorb say, one month's national supply. The remaining surplus stock of commodities now owned by the government must be protected against contamination and cached to be accessible to various population centers.

Having established a system of shelter modules for personnel protection it might be well to disburse useful, but possibly outmoded, machinery throughout the country for use in rebuilding the economy following an attack. Perhaps, and where feasible, entire factories could be built in mines to ensure survival of the most critical industries. Possibly the very machinery to be manufactured for building shelters should be installed in areas which would ensure its survival. This machinery would be quite versatile and could be designed to have alternate manufacturing functions. Since a survival module is a small home, the machinery for its manufacture would be typical of machinery used to support the current economy; hence, in the very process of planning a shelter program, one might keep in mind the alternative uses to which the machinery might be put to ensure the recovery of the nation following the attack.

If the political situation took a serious turn for the worse, it would be reasonable to direct the entire economy toward non-military defense. The difference between 97% survival when adequate protection is afforded, and 1[illegible]% survival with the present state of civilian defense in the case of an all-out nuclear attack, is sufficient reason to warrant the complete mobilization of the American economy towards this goal.

Naturally, the shelter program (particularly if it advances to Phase 4) would have a tremendous impact upon our economy. While we are planning for this facet, we should give consideration to the economically stimulating influence of such a shelter program and possibly use it to alleviate certain unemployment or dislocation problems as was done under the CCC and WPA programs. Presently over [illegible]% of the labor force is unemployed. With the gross national product now running into about five hundred billion dollars this idle labor force represents a loss of tens of [illegible] dollars annually. Furthermore, the nation's economy is presently functioning well below its capacity. Thus, the family shelter system proposed here can readily be handled by the national economy, particularly if the final phase of the program were spread out over several years. Indeed, if the construction of family shelters for the entire national population were spread out over several years, the cost of the program could be balanced out by the added productivity of the labor force employed.

The entire program of national survival after a nuclear war might utilize surplus labor and productive capacity alone (unless conditions warrant a crash program). Thus the program could serve as a work reservoir to maintain a steady level of employment. Since the plan proposed involves the distribution of machinery for producing survival shelters throughout the country, one might utilize this productive capacity to balance seasonal drops in the output of a particular community. Large machine-tool industries could utilize surplus labor periods to produce machinery for stock piling in blastproof locations for use in national recovery after a nuclear war. Sales of shelters could be encouraged by various means such as requiring the incorporation of a federally approved blast-fallout shelter in any new home construction for which an FHA loan is required. The tremendous boost to recreational activities afforded by the trailers and houseboats could serve as a tremendous stimulus to the economy. With a well-thought out national program the impact of the program could be one of stabilizing the economy rather than disrupting it. While the utilization of surplus labor forces might help get the program started, it would be possible to order maximum production of shelters should it be felt a crash program is indicated. The production and prior use of shelter-production machinery by industry all over the country would enable a smooth transition from normal products to shelters to take place virtually overnight.

7. COST ESTIMATES

The cost of a complete module, including the shelter capsule, trailer and installation might be estimated on various assumptions. Let us assume that mass production techniques are used and that a tremendous number of units are to be built. In this case the principal cost would be that of materials. An estimate of the material and fabrication cost in a typical unit is contained in Table 3. From the table we see that our estimate of $2000 is quite reasonable. It is possible that with a stimulated production of materials occasioned by a nationwide shelter program that the cost of materials themselves would be reduced appreciably and the cost of a survival unit correspondingly reduced. With mass production techniques, the additional cost of assembly is expected to be a relatively small fraction of the total cost. It is anticpated that the cost of design and tooling for the program will be borne initially by the federal government. Later on, should it be passed on to the purchaser in a full-scale program, this cost would be very small. As to the program itself, it is estimated roughly that the entire program should be phased in the following approximate manner.

Phase 1. Preliminary Design and Advanced Design of survival modules, construction of prototypes, analysis of utilization and impact of the survival system, preliminary design of machinery for mass production of survival units.

Phase 2. Final design and test of the basic modules, construction of prototypes of machinery for mass production of the modules.

Phase 3. Large scale production of machinery for fabricating survival units, estimated requirements, 2,000 units.

Phase 4. Full-scale production and installation of survival modules.

In Table 4 we list some estimated costs of the various phases. Note that no substantial investment of government funds is necessary until the third phase is reached. Under reasonable circumstances we might expect this to be by mid 1963 or 1964. Perhaps by then the world situation will have taken such an extremely favorable turn that we might dismiss Phase 3 and 4 as unnecessary. In this case only a minute fraction of the potential cost of the full scale program would have been wasted. On the other hand

TABLE 3. COST ESTIMATES

Item	Material	Weight(lb)	Total Cost
Corrugated Steel Shell	Steel	10,200	$400.
Trailer-frame	Steel	500	20.
Miscellaneous	Steel	300	20.
Lift Mechanism	Aluminum	40	40.
Capsule Fittings	Aluminum	180	180.
Sliding door, well, etc.	Concrete	3 cu. yd.	50.
Capsule Shell	Fiberglas, foam	500	500.
Tires, wheels			50.
Furnishings:			
Range, icebox, sink,			100.
mattresses, cushions, latches,			80.
beds, cabinets, floors, etc.	Plywood	560	30.
Excavation and placement of shelter			200.
Life Support Facilities (Chemical toilet, air-conditioning, etc.)			200.
		Total	$1870.

TABLE 4. COST AND ESTIMATED TIME REQUIREMENTS FOR THE NATIONAL SURVIVAL SHELTER PROGRAM

Phase	Estimated Cost	Estimated Time for Execution
1	$200,000	1 year
2	$2,000,000	1 year
3	$100,000,000	2 years
4	$100,000,000,000	1 - 4 years

should the world situation still look ominous, we could then embark upon Phase 3 which still represents but a small fraction of the total defense budget. Only when Phase 4 is reached are we involved with an investment which would have an important impact upon the economy. Even in Phase 4 we are discussing funding which still represents but a fraction of our gross national product. Should the need for the full-scale shelter program clearly be evident, say by late 1963 or 1964, then the small investment in research and development would lead to tremendous savings in time and money necessary to implement an effective full-scale program.

As to the final procurement of shelters, it would be expected that the government would subsidize such procurement by various means. Perhaps a federal mortgage system can be instituted which will permit the family to pay off the costs over a ten-year period. Two hundred dollars per year is not an unreasonable price to pay for the insurance provided by such a survival module. Of course the cost of the unit should be tax free and possibly tax deductible as well. Whether some cost sharing program should be instituted with the government sharing the cost of the survival hole and the family bearing the cost of the survival capsule and trailer (because of its alternate use) must be investigated further for its economic implications.

8. SHELTER PROGRAMS AND AICBM SYSTEMS

The government is currently spending hundreds of millions of dollars on research and development of AICBM systems and is considering launching one particular system, the Nike-Zeus system, which should cost billions of dollars. No comparable funds have yet been allocated to shelters. If one is to take the potentialities of AICBM systems seriously (and our level of investment in the possibilities suggests that we do) then it is inescapable that we in corresponding fashion take seriously the institution of a shelter program. Active and passive defense can scarcely be separated, since they are both modes for protecting the country against missile attacks. Furthermore, there is a very strong interaction between the two systems and a shelter program would, indeed, complement an active AICBM system, and perhaps convert it from one of marginal usefulness into one of considerable usefulness. For example, experienced persons in the AICBM field recognize that none of the proposed AICBM systems are sure-fire. The difficulty of the problem in large measure is associated with the galaxy of decoys and countermeasures to the AICBM systems which can be thrown aloft along with the missiles themselves. In view of the broad spectrum of decoys and other countermeasures which the enemy can use, it does appear that active systems, whether they be active in the launch, midcourse, or re-entry phase will at best serve as a filter or attenuator rather than a complete obstacle to a missile attack. A shelter system probably represents as effective a final obstacle to the killing of populations as any of the active elements that could be put in a total defense system. Furthermore, a shelter program should go hand in hand with terminal defense systems and thus permit the defender to continue his attempts to destroy the missile to the final phase of re-entry. It furthermore might permit the defender to utilize more severe kill mechanisms which to an unsheltered population might also have a marginal deadliness. A number of suggestions have been made on defensive uses of nuclear blasts which would inflict some damage to the general area of defense; however, such damage would be less severe than that which a missile, if it comes to its final burst point, would achieve. Accordingly, one might accept this less severe defensive damage if the bulk of the population is insulated by a shelter system from possible destructive action of the defensive measures. Thus the shelter program does broaden the scope of defensive measures that could be sensibly utilized in an attack.

Similar remarks can be made about potential future midcourse defensive systems, should a breakthrough be made in the development of such systems. In this instance, the destruction of a missile during the midcourse of its trajectory would lead to re-entry of the object in a form unable to withstand re-entry. The material will ablate off and will probably re-enter in a very dispersed fashion. Should an effective midcourse system be developed which destroys multitudes of nuclear missiles, the wide spread fallout might be a nation-wide or world-wide problem. Shelters might assist in survival in the face of this problem. Finally, it is

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conceivable that a launch phase system will eventually be moderately effective. If this possibility exists for the United States, it undoubtedly will exist for Russia, and accordingly in the retaliatory measures by the United States (i.e., its second strike) we might anticipate that many of our missiles will be destroyed in the launch phase. Whether or not the missiles are fail-safe, they would disperse either plutonium or U^{235} over the local area, and a radiation problem which could be mitigated by shelters might ensue.

In summary, the AICBM problem and shelter problem are a part and parcel of the problem of defense. An unbalanced approach to defense against ICBM which overlooks this simple fact undoubtedly will represent a more costly way of buying protection than might be achieved with a balanced viewpoint.

The concept of "counterforce," which may be defined as the ability to sustain a nuclear attack and still retain the means to achieve victory, loses its validity if applied only to military hardware and personnel. There is little motivation and less reason for our military to bring an opponent to his knees if we have lost the bulk of our population. To attain the position of counterforce, our nation must of necessity develop the means to protect the civil population, the essential element of any possible recovery program in the post-attack period. The Soviets apparently realize this obvious fact and have implemented a civil defense program which encompasses the dispersal of new industries as well as a vigorous civil shelter program. If we maintain our current level of civil defense, we may realize at some future date that our adversaries have attained a position of counterforce so much stronger than our own that a threatened trade of nuclear strikes would be obviated by the defenseless position of our population in comparison to that of the Soviet Union.

9. POLITICAL, ECONOMIC AND PSYCHOLOGICAL IMPACT

Judging from the articles of many leading scientists, the foremost political-scientific issue of the day is the question of arms control. Certainly the problem of controlling armament is approaching tremendous urgency, and unless some successful strides are made the future looks glum indeed. It would appear that the popular trend in scientific-political circles is to view a large-scale shelter program now as a provocative move. The argument on this goes as follows: At present the United States and Russia are at a stalemate by virtue of the effective deterrent nature of the nuclear-missile threat. This comes about when both sides maintain a second strike capability, which is rapidly being acquired by means of hardened missile bases, mobile solid propellant missiles, as well as Polaris missiles. Then neither side will trigger a war by virtue of the other side's recognition of the dire consequences of the destruction which would follow from the retaliatory strike. Should, at this "stable" juncture, Side A embark upon a full-scale shelter program whose payoffs in terms of survival of the population are well recognized, Side B would view this as an indication of an intention of Side A to launch an attack. This might induce Side B to strike before the A population is hardened.

On a short time scale the above logic undoubtedly has a degree of cogency and must be taken seriously. On the other hand, this logic must be recognized to be diametrically opposite to common sense in that a purely passive defense system now becomes a symbol of aggression, whereas offensive capability in the form of missiles and other strategic striking power is a symbol of defense. The weight of human experience suggests that in the long run the logic of common sense will probably lie closer to the truth than the rather sophisticated logic now used against embarking upon a shelter program. Indeed the anti-shelter logic bears an amazingly close resemblance to the logic of a school of thought which in 1950 argued that the United States should not develop the H-bomb because, presumably, the Russians would not if we did not. History has shown that the decision of the United States to pursue the H-bomb had relatively little influence on the Russian's decision to go ahead in this direction.

With regard to stability vis-a-vis the USSR, it is possible that deterrence will provide a long-term immunity to catastrophic war if both countries maintain highly responsible leadership. On the other hand, the following hazards which would be greatly mitigated by a nationwide shelter program exist at all times.

1. Whereas Kruschev, the present Russian leader, now seems sufficiently hard-headed to recognize the dire consequences of nuclear war, there is no certainty that he will not deteriorate mentally as he gets older. Such a deterioration afflicted Stalin, and particularly Hitler, whose megalomania increased drastically with age and stress. In a dictatorial society, with insufficient checks and balances, the singular characteristics of the leader has a major influence on the course of events which in consequence cannot always be predicted. It would be wishful thinking indeed, to believe that succession in the Russian dictatorship will follow a logical and responsible course.

2. Even with the existing government, there are certain signs which suggest that the Russians are not talking peace entirely in good faith. The stalemate in attempts to achieve agreement on a nuclear test ban must be a very significant index of the Russian position on the much larger issue of Arms Control.

3. Even in the two nation deterrence situation, there is a great danger of accidental war occasioned by the rapid response time needed for missile warfare.

4. Should an AICBM system be invented by the Russians it is quite possible that they would initiate a pre-emptive attack.

5. When one considers not the two-nation problem, but rather the many-nation problem, the prospects for long-term stability become extremely bleak. Here, the possibilities for the deterioration of one nation's leadership, the possibilities for expansion of a local war, the possibilities of an accidental war, all increase approximately as the number of two nation interactions [i.e., $n(n-1)/2$]. The recent discovery of an inexpensive method for separating U^{235} might soon place fissionable materials within the reach of even smaller nations, or nations of less advanced technologies. Furthermore, the direct development

of solid propellant missiles might enable small countries to develop a missile capability without going through a long and expensive developmental stage.

These foregoing reasons must be coupled with the facts that wars have occurred throughout the course of history, and that whereas technology has changed drastically, man has not. It would thus seem to be the height of optimism, indeed, to ignore the possibility of an all-out nuclear war. We therefore conclude that some form of survival insurance is needed in the dire event that nuclear war is triggered by one means or another. A large-scale shelter program is a very reasonable form of insurance with major payoffs in the event disaster strikes.

Now the launching of a large-scale shelter program, even though its sole purpose is to preserve populations, might appear in the context of the immediate times to be a provocative act. However, the proposed plan, if carried out with caution, need not have much of an influence on political events, since Phases I and II and possibly III could be carried out with a very minimum of public involvement. It would only be Phase IV which would involve large-scale production and will have a psychological impact on the people. If, at any point during Phases I, II, and III, the matter, through a leak in security, does become a factor in international relations, then the simple gesture of offering to disclose the plan to the Russians and to make it a part of a disarmament plan would readily counter all possible adverse influences of the shelter problem. In actuality, no great harm would be done should we sell the manufacturing equipment to be developed to other nations including Russia. Indeed, in many respects an international shelter program would have a great psychological impact in favor of Arms Control.

Consider, for example, a period ten years in the future, when every family in the world has a survival unit of the type suggested here. The survival unit would serve a recreational purpose and would undoubtedly be a source of considerable pleasure to the family. On the other hand, in practice drills when installed in the hole, the same facility would undoubtedly be quite uncomfortable. Even in practice drills of a day's duration one would become impressed with the madness of modern war. Hence, the very act of using this unit above ground for recreational purposes, coupled with the practice use of the same facility below ground for survival, would bring home to every person in the world the importance of avoiding war if it can be done without sacrificing the freedoms we treasure. Such a conclusion would follow from the sober reflection which might be possible when we are not laboring under the present mass neuroses occasioned by our completely defenseless posture with respect to a nuclear attack. Thus the proposed unit would not be provocative but instead would, in the long run, tend to focus greater attention on the need for Arms Control.

10. CONCLUSION AND SUMMARY

Lest the essential elements in this proposed plan be lost in the lengthy discourse, we would like now to summarize our thoughts. We have proposed a plan involving as its principal component, a survival module which would permit the United States to bring its vast technological strength to bear upon the problem of population survival. In the form presented and explored in some detail, each module consists of three components, (1) a low-cost blast and radiation resistant survival hole, (2) a segmented survival capsule which contains the majority of the life support features, and which can serve an alternate recreational function, and (3) a trailer. In a proposed follow-up study, alternative designs will be considered in detail in an effort to arrive at one or two module final designs which would serve the greatest possible need. By standardizing on the essential elements in a national shelter program, one can quickly provide adaptors to meet new threats as they are identified. For example, special filters and air handling adaptors might be added later in the event chemical or germ warfare becomes a great threat. Standardization when applied to a nationwide problem of this magnitude would have many payoffs both before an attack as well as in the recovery period should the attack occur.

The proposed program does not visualize an immediate launching of shelter construction on a large scale. Instead, it is proposed to proceed through four distinct phases. In Phase I (a one-year study program at the level of about $100,000) the preliminary and detailed design of survival modules will be completed and several prototypes will be constructed. Further, the preliminary design of the special machinery needed for mass production of survival units will be carried out and a complete analysis of the best utilization and impact of the survival system, as well as the utilization and impact of its recreational features will be carried out. Phase I should greatly help to clarify the many points which we have been unable to treat in detail in this preliminary work.

Phase II (a one-year program at the $2,000,000 level) would involve fixing the final design of one or two basic modules, testing these to establish their survival capabilities under various types of stresses and finally building up prototypes of the best specialized machinery necessary for the mass fabrication of the principal elements of a survival module. This machinery, incidentally, since it would have versatile capabilities, might well be designed under the assumption that it will be used subsequent to a nuclear attack to assist in the technological recovery of the country. The Third Phase (a two-year program at the $100,000,000 level) would involve the production of special dies and adapters for existing mass production equipment as well as such special machinery as is shown to be needed in the second Phase. An investment of the order of $100,000,000 (still a minute fraction of our gross national product) is visualized for this phase. Of course, very careful review would have to be given before launching this phase. Should the program be continued after careful review the country could proceed to Phase IV, the large-scale production of survival modules in accord with conceptions and plans evolved during the first three phases. The pace to be utilized in this fourth phase will have to be decided by subsequent political and economic developments. The plan proposed would permit proceeding on the basis of a crash program, should the matter become extremely urgent. Alternatively, a gradual implementation of the program might be made utilizing the surplus productive capacity of the country.

We have considered some social, political, and economic implications of this plan. It is believed that the possible hazard of upsetting the present deterrence balance can be avoided and that in the long run this shelter program would be a force for peace and stability and would assist in the accomplishment of international arms control.

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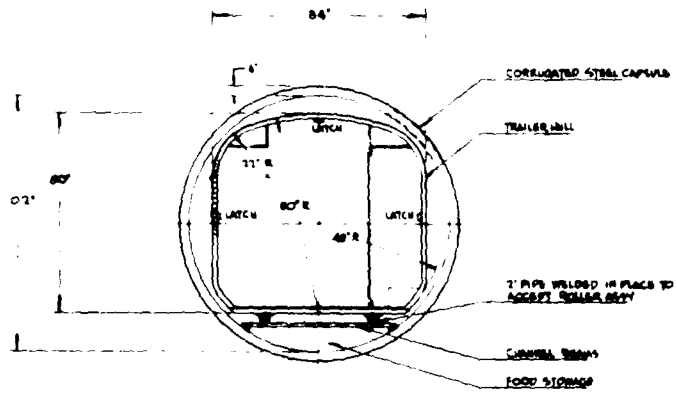

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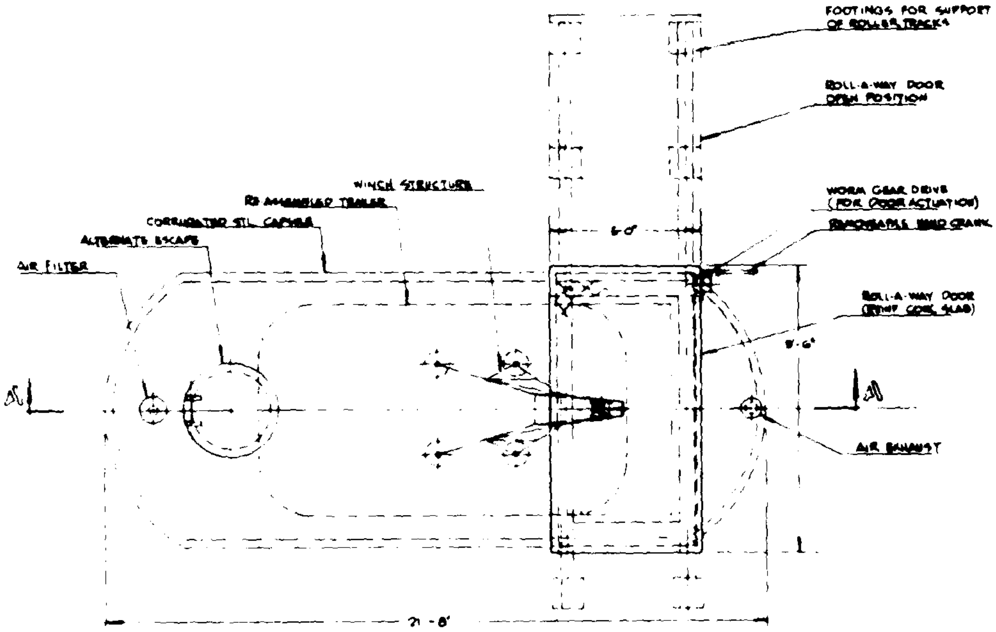

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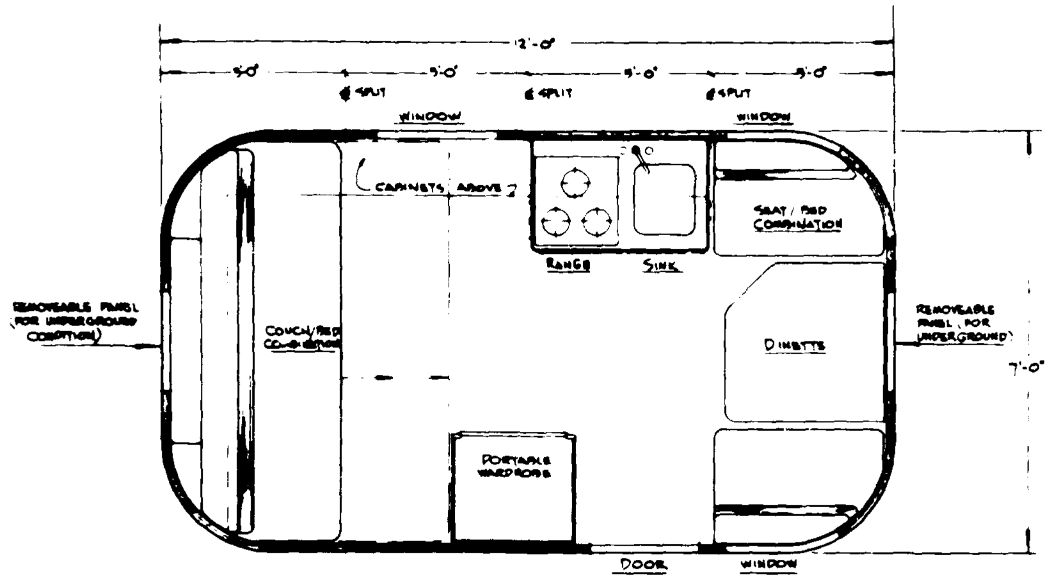

TRAILER FLOOR PLAN
1/10 SCALE

SKETCH 2

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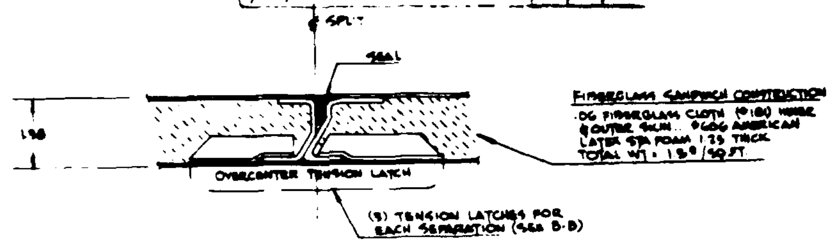

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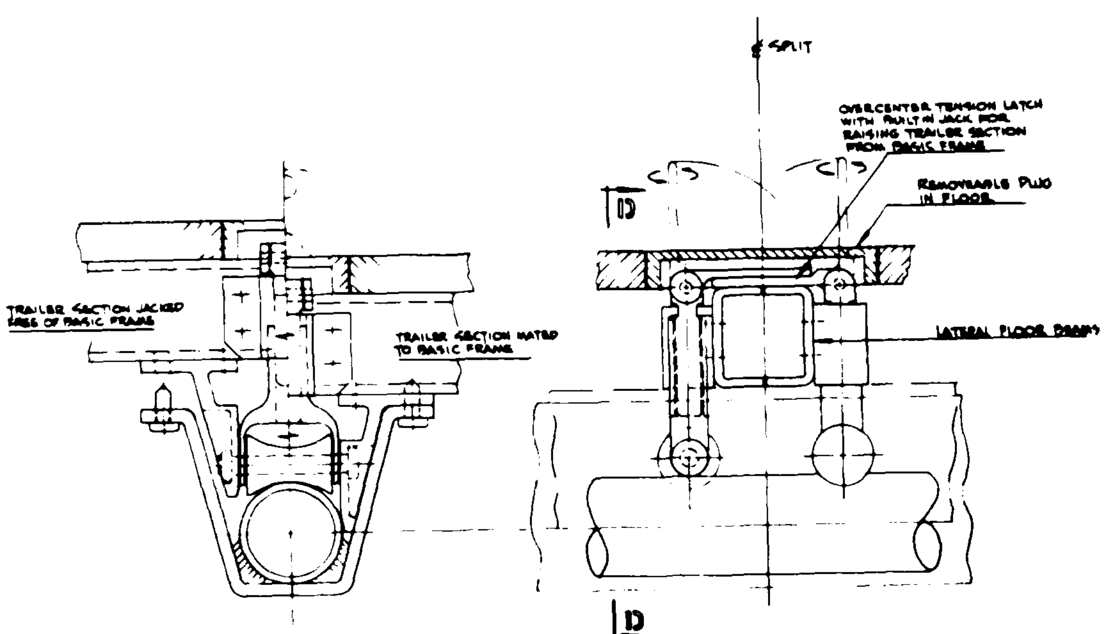

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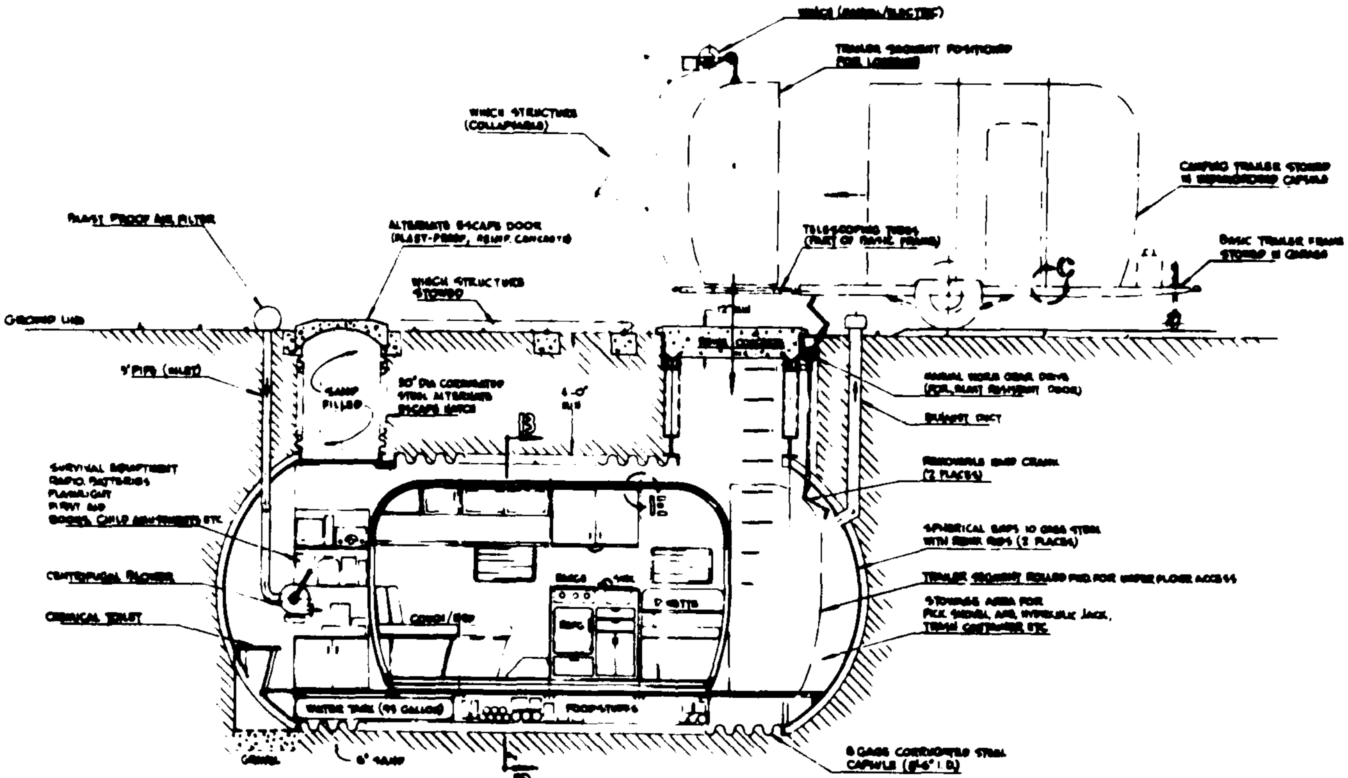

SECTION A-A

SKETCH 4

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