Preliminary Proposal No. 03-7542
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A proposal for

IMPROVING EFFECTIVENESS OF CONCRETE BARRIER SYSTEMS (OUTLINES OF ALTERNATIVE TASKS AND PROGRAMS)

for

Office of Research and Development
U.S. Department of Transportati
Federal Highways Administratio

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FOREWORD

This document contains proposed programs to improve the safety, economy, and utility of concrete traffic barriers. Its purpose is to outline technology improvement requirements and the related scopes of work for advanced budgetary and administrative planning. The subsequent preparation of a formal proposal containing more precisely defined specific levels of efforts, schedules and estimated costs is anticipated.

Basically, each of the proposed programs involves concepts to increase the effectiveness of concrete traffic barriers. Upon completion of analytical and/or experimental evaluations, performance and application feasibility will be demonstrated by conducting fullscale vehicle impact tests under carefully controlled conditions.

A summary of the proposed program plans is presented in Section 1. Concrete barrier technology and related problem areas are critiqued in Section 2. Tasks directed toward restricted objectives are outlined in Section 3. In Section 4, several multi-task programs are presented. Scheduling, budgetary and contractual information, and project management and staff data are contained in Sections 5 and 6 respectively. A description of SwRI selected facilities is presented in Appendix A; Institute organizational and personnel record sheets are included in Appendix B and C, respectively. Contractual information is presented in Appendix D.

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1. PROPOSAL BRIEF

- Concrete barriers exhibit attributes that are not inherent in other traffic barrier systems. A potential exists for more extensive applications, provided certain deficiencies are eliminated. Some require an expansion of current practice; others need technological breakthroughs to upgrade procedures.

- Depending on available funds, a number of productive programs are identifiable; but decisions regarding appropriations depend on priorities. Since these priorities are based on diverse requirements and are subject to abrupt changes, planning flexibility is essential.

- Accordingly, the Institute has elected to submit a preliminary proposal comprised of alternative, multi-task Programs.

- Forecasts of required concrete barrier improvements (Section 2) are transformed into eight, specifically-oriented Tasks (Section 3)· each Task is self-contained, and therefore can be considered as a candidate for a sponsored project. Section 4 contains the four Programs: with one exception, each Program is comprised of three or four of the aforementioned Tasks.

- Interconnections between require improvements, Tasks and Programs are depicted in Figure 1. 1.

- Preliminary project budgets involve estimates that range from $25,000 to $30,000 (Task C) to $250,000 to $300,000 (Program I). Recommended performance periods are from six to thirty months. If deemed necessary, the Institute can prepare proposals for several, first-stage investigations, each of whose required funding is less than $10,000.

- Pending the FHWA review of this proposal and upon receipt of its recommendations, it is anticipated that the Institute will be invited to submit a formal proposal containing the technical and financial details necessary for precontractual evaluations.

- Southwest Research Institute has the experienced professional and technical-support staff, as well as the facilities and equipment to perform any of the proposed concrete barrier studies presented herein. Its policies and operations are conducive to implementing studies specifically tailored to the objectives of the Federal Highway Administration.

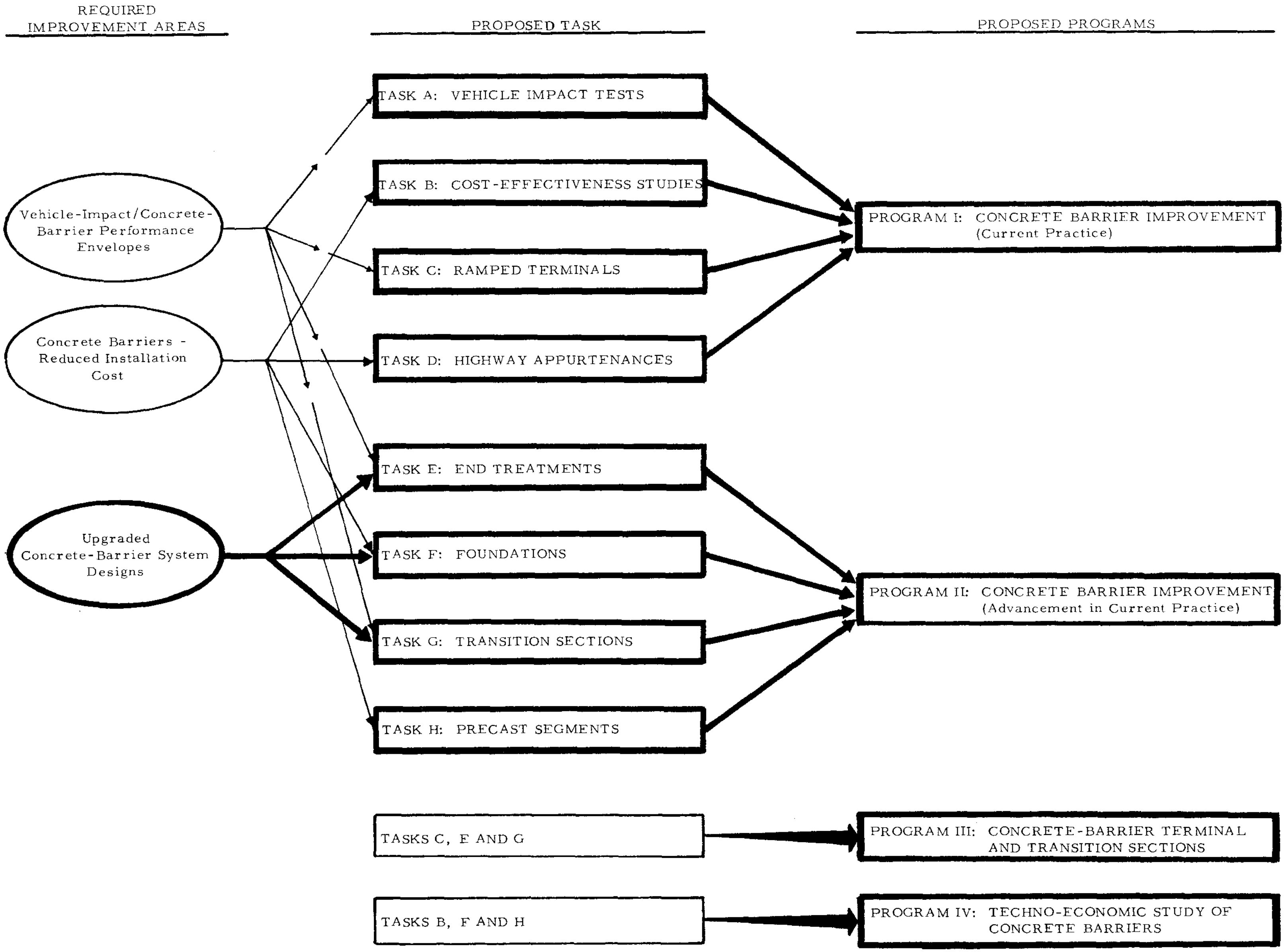

FIGURE 1.1 SwRI PROPOSED TASKS AND PROGRAMS FOR CONCRETE BARRIER SYSTEMS (Preliminary)

2. CONCRETE BARRIER TECHNOLOGY - AN OVERVIEW

2.1. STATUS AND POTENTIAL FOR DIVERSE APPLICATIONS

Within the past fifteen years, two concrete barrier designs have evolved for use in medians between divided highways. The basic function of such barriers is to prevent the across-the-median penetration of vehicles into opposing traffic lanes, thereby avoiding the head-on collision. Subsequent designs have incorporated capabilities to redirect errant vehicles so as to minimize occupant injuries and property damage, and to avoid involvement with following and adjacent traffic.

In 1955, the state of New Jersey began to study several types of median barrier; one of the designs was an 18-inch high concrete curb with a parabolic face. On the basis of in-service experience, the design height was subsequently increased to 32 inches. Accident statistics acquired from the early concrete median barrier sites clearly indicated to New Jersey highway officials that this type barrier was effective in reducing highway fatalities. Accordingly, New Jersey accelerated the barrier construction program to the extent that presently, over 200 miles of the concrete barrier are in service within the state.

In 1963 General Motors Proving Grounds* conducted a series of 21 full-scale tests on a concrete bridge parapet adapted from the New Jersey

*Lundstrom, L.C., Skeels, P.C., Englund, B.R., and Rogers, P.A., "A Bridge Parapet Designed for Safety - General Motors Proving Ground Circular Test Track Project," Highway Research Record No. 83, pp 169-187 (1965).

median barrier design for test speeds less than 50 mph and at impact angles of 12 degrees or less. This design proved to be entirely adequate in preventing penetration, in safely redirecting an impacting vehicle and in limiting damage to both the barrier and the vehicle.

In 1967, the California Division of Highways* performed four crash tests on the New Jersey design concrete barrier. Vehicle impact speeds were approximately 65 mph. Results from three tests indicated that at impact angles of less than 10 degrees, vehicle redirection did not expose occupants to unduly severe hazards; damage to vehicle and barrier was comparatively minor. For one test, with an impact angle of 25 degrees, redirection of the vehicle was severe resulting in major damage to the vehicle and an increased probability of causing serious injury to passengers.

Both the GM and NJ concrete barriers were recognized in the NCHRP Report 54 (published in August 1968) as being an adequate, median-barrier system. Including planned construction, a total of between 400 and 450 miles of concrete traffic barriers will have been installed along highways in 35 States. Based on an estimated nationwide average cost of $14 per foot, this represents an investment of more than 40 million dollars. Moreover, there are indications that the relatively low maintenance and damage repair costs, the positive vehicle containment characteristics and the aesthetics combine to make the concrete barrier an installation that is particularly

*Nordlin, E. F. and Field, N. F., "Dynamic Tests of Steel Box Beam and Concrete Median Barriers," State of California Division of Highways, Research Report No. M&R 636392-3, January 1968.

attractive to the highway industry. On the other hand, it is evident that the design and construction of such barriers has not reached the optimum. Technical and economic improvements are needed if highway designers are to be encouraged to use concrete barriers more extensively.

2.2 THE NEED FOR IMPROVEMENT

If it is valid to assume that concrete traffic barriers have the potential for improved dynamic performance and more diverse application, it follows that research effort directed toward developing these more effective designs and construction techniques must take into account a more comprehensive group of parameters and unique requirements necessitated by a variety of installation sites. Because of this multifacet need for improvement, available development resources must be carefully allocated in such a manner as to provide maximum cost benefits.

Using the preceding guideline, there are a number of barrier improvements that qualify as suitable candidates. Such improvements can be grouped according to technical and economic improvements, but the interdependency is clear. Any improvement in the ability of a barrier to effectively redirect an errant vehicle must be cost-effective. Conversely, cost reductions are valid only when they can be demonstrated that changes in design or construction techniques do not adversely affect performance.

Contacts with cognizant personnel in government and industry indicate that bonafide interests exist in advancing the technology for concrete barriers. But there are diverse opinions as to relative importance of specific needs. Such agreement as exists reflects the need to eliminate inadequacies which limit applicability. But these range from the inefficient use of barrier materials to questionable end treatments and transitions between various types of barriers. The former is cost-oriented whereas the latter reflects a trend to develop fully integrated traffic barrier systems.

In synthesizing the types of improvements for concrete barriers deemed necessary by prospective users, two salient requirements emerge; there is need to

- Eliminate those design, construction or installation characteristics which tend to restrict the use of concrete barriers to only those portions of a highway where the geometry and traffic flow patterns leave no other choice

- Acquire basic engineering data to characterize the crash-impact behavior of concrete barriers. This is necessary if cost-reduction measures and/or increased utilization are to be developed on a rational basis

There are several aspects of concrete barrier design, construction and performance that appear to be most important and amenable to carefully structured program planning. These aspects are discussed in the following paragraphs.

2.2.1 DESIGNS FOR IMPROVED PERFORMANCE: Vehicle Impact Angles, End Treatments and Transition Sections

Both the NJ and GM barriers have demonstrated excellent vehicle-redirection characteristics for impact angles of less than 10 to 15 degrees. On the basis of the vehicle acceleration forces produced during redirection and by the amount of damage sustained by the vehicle as well as the barrier, such experimental evidence as exists indicates that the NJ and GM profiles are quite satisfactory. However, for impact angles greater than 15 degrees, vehicle redirection may be abrupt, occupants may be vulnerable to severe crash injuries, and vehicles may sustain excessive damage. Developers of the GM barrier readily concur that the shape of the profile is probably not optimized for these high-angle impacts. By increasing the recessment of the upper portion of the profile away from the traveled way, it is conjectured that the concrete barrier performance can accommodate the higher-angle impacts. But it is not known whether this type of a change actually constitutes an improvement; it may detract from the low angle vehicle-redirect properties or be infeasible when technoeconomic considerations are introduced.

Although NJ and GM barriers have been in service for some years, a complete definition of their ability to control errant vehicles has not been established. There are not sufficient experimental data to take into account the variables introduced by different vehicle weights, impact velocities, or intermediate impact angles (i.e., between 10 and 20 degrees) to develop a complete performance envelope. In addition to vehicle acceleration forces and property damage, barrier effectiveness must also be evaluated in terms of vehicle post-impact trajectories. Such information would be of immediate value in the selection of those highway locations where concrete barriers can be considered as a candidate traffic barrier system.

Of particular concern to highway designers are the head-on collision hazards associated with the upstream ends of traffic barriers. As a massive, rigid structure, the ends of concrete barriers constitute obstacles normally located very close to the traveled way, and therefore conducive to those types of accidents that result in fatalities. Several end treatment designs have evolved; one concept involves the use of ramps. But based on test experience with other barrier systems, the effectiveness of this (as well as other) end treatment concepts is open to serious doubt. It becomes a question of whether the fatalities are produced by excessive decelerations, or the launching and rollovers of the vehicle.

Transition from flexible to a rigid barrier is another instance where an appurtenance intended to improve highway safety becomes a formidable hazard. If concrete barriers serve as a part of an integrated traffic barrier system, the dynamic response of both the upstream and downstream installations must be compatible. Heretofore, it has been assumed that the dynamic characteristics of a concrete barrier were unchangeable; any attempt to effect compatible transitions had to be incorporated in the design of the more flexible types of adjacent barrier systems. The reverse approach is not infeasible. Variations in geometry, size, reinforcement and/or foundation attachment appear to offer the opportunity to effect designs that are less than absolutely rigid.

Both end treatments and transition sections (as well as vehicle-redirect requirements) are amenable to the classical RDT&E investigations. The development of conceptual designs, followed by iterative cycles of dynamic analyses and laboratory experiments, should yield prototypes with a better than average chance of demonstrating acceptable capabilities during full-scale, vehicle crash tests.

2.2.2 DESIGNS FOR COST EFFECTIVENESS: Materials, Barrier Foundations and Precast Construction Techniques

The prices for concrete barriers vary from less than $6 to more than $40 per linear foot. In some instances, the higher unit costs can be attributed directly to such factors as a builder's lack of construction experience with the system, or his inability to use efficient construction techniques and procedures. On the other hand, there is reason to believe that a portion of the initial cost for concrete barriers is the result of the inappropriate use of materials. For example, the quantity of steel reinforcement is conjectured to be excessive in many typical sections. Special high-strength concrete has been specified for reasons that are not readily apparent; concrete foundations with dowels spaced at extremely close intervals are not uncommon. In other instances, white cement, a very costly item, has been specified apparently to improve the delineation characteristics and appearance of the barrier.

For short lengths, overdesign and highway aesthetics may be economically tolerable. But where an installation extends for several miles, even a modest unit cost reduction can yield substantial savings. The excessive use of reinforcing steel, the specifying of special concrete and the overdesign of foundations reflect a basic conservatism resulting from a lack of understanding of the manner in which vehicle impact loads are transmitted and distributed. If highway designers were provided with experimentally verified methods of design and analysis, and more conclusive performance and design criteria, it is believed that the specifications could be relaxed without adversely affecting the structural integrity of a concrete barrier. For certain locations and installations, it may develop that once the spatial and temporal distribution of the impact loads are determined, the need for reinforcing steel may be governed primarily by thermal and erection stresses.

Extremes in foundation designs have ranged from a barrier established on compacted base materials to one that is keyed by closely spaced dowels in massive, heavily reinforced, grade beams. A properly compacted base material may provide an adequate foundation; however, a better understanding of vehicle impact forces and the mechanisms by which they are transferred through the structure and into the soil is needed before this concept is verified. Several other barrier improvement options appear to be feasible - provided the forces and displacements at the interface between the barrier and its foundation are known. Among these are those design concepts wherein barrier-foundation hardware is preprogrammed to serve as an energy-absorbing device for certain infrequent but severe vehicle impact forces. Others are based on the premise that horizontal displacement and/or some degree of rotation (or uplifting) may be permissible when the mass-acceleration forces of vehicle and the barrier are coupled.

Precast techniques (where the above-grade barrier and/or foundation segments are built at central casting yards and then transported to the highway site and erected) appear to offer significant cost advantages. Heretofore, concrete barriers have been constructed primarily by cast-in-place methods. Part of the designer's reluctance to use the precast technique can be attributed to a lack of information pertaining to the interacting forces at the barrier-to-foundation and barrier-segment interfaces, and the resulting uncertainties regarding connections. In addition to the cost advantages of precast construction methods, there are other attributes that are particularly applicable to concrete barriers. For example, the possibility of implementing quality control procedures provides the means whereby realistic and universally-applied standards and specifications can be developed. Quantity production also affords the opportunity for detailed refinement to smoothly vary the properties of the barrier to more effectively reflect variations in crash-impact dynamics. For long concrete barriers, changes in highway geometry, relative locations and/or traffic flow patterns could be accommodated by, say, four or five different, standardized precast barrier segments.

2.2.3 DESIGNS FOR SECONDARY FUNCTIONS

Due to their customary location (at the center of divided highways), concrete traffic barriers are frequently required to serve as a base for sign supports, lighting standards and headlight glare screens. Several states have devised schemes whereby a light pole base is incorporated in a widened section of the barrier. In at least one state, the height of the barrier (as recommended in NCHRP Report 54) has been increased to serve as a headlight glare screen.

The effects of these changes on the performance of concrete barriers have not been adequately examined. These and other post-construction modifications (e.g., storm drainage holes, conduits for power cables, etc.) need to be systematically evaluated so that standards can be developed. If the use of concrete barriers is extended to include roadside installations along heavily traveled portions of a highway, the need to accommodate a variety of highway appurtenances and to make provisions for adequate drainage will increase accordingly.

3. PROPOSED APPROACH FOR PROGRAM PLANNING

3.1 A CONCEPT FOR SELECTIVE PROGRAMMING

Translating needs for improved concrete traffic barriers into a program plan involves several considerations. Foremost among these is the stipulation that any improvement must be of immediate and discernible value to the highway industry. This suggests that the potential users' requirements for each type of concrete barrier improvement need to be taken into account. But the diverse responsibilities of various agencies within each of the fifth State Highway Departments would result in a set of requirements that are well beyond the available resources. Comparative evaluations including commonalities, spinoff benefits, and elimination of duplications can be used to reduce the spectrum of requirements. Additionally, by using relative merit indices, a synthesized, priority listing could form a basis for differentiating between, say, broad-scope/long-term and limited-efforts/urgently-required programs.

However, specific scopes of work, schedules and estimated costs are necessary rational decisions regarding appropriations. Based on the information acquired from various sources, the Institute could submit a program plan encompassing the concrete traffic barrier improvements outlined in Section 2; but, such an approach is restrictive in that it fails to allow for the fact that both the technology and user requirements change rapidly. Moreover, it would not provide the readjustment flexibility that is necessary to accommodate new developments.

Accordingly, the Institute believes it appropriate to recommend limited scope Tasks which can be combined to formulate two or more program plans. In that each Task involves technical advancements and cost-effectiveness evaluations, there is a degree of commonality. However, the feature that distinguishes one Task from another is the level of effort devoted to either technical or economic objectives.

In formulating program plans involving various Tasks, the Institute's rationale included the following governing conditions:

- From the viewpoint of budgets that are compatible with funding constraints, and in recognition of the need to provide conclusive results in the shortest length of time, a single Task should not attempt to encompass all of the concrete barrier improvement requirements

- For a maximum return per development dollar, and a minimum contract performance period, each Task should yield

    - Definitive information suitable for reasonable predictions of concrete barrier performance for typical vehicle-highway accident conditions

    - Tentative performance criteria (based on an adequate amount of experimental evidence) for developing rational design and analysis methods

    - Operational experience with new conceptual designs sufficient to demonstrate diverse applicability

- Newly acquired information and experience from each Task should relate directly to barrier requirements, and should result in definitive, and immediately useful techno-economic payoffs

- Since the primary function of a concrete traffic barrier is to improve highway safety, the cost-effective results obtained in each Task must demonstrate conclusively that this characteristic is not diminished

3.2 DESCRIPTION OF TASKS

Several proposed Tasks are summarized and presented at the end of this section. The scopes of work incorporate one or more of the improvements discussed in Section 2. One Task is distinguished from another primarily in the degree to which technical or economic factors are emphasized. For convenience in program planning, a Task is considered to be self-contained; however, the degree of interdependence it shares with other Tasks makes it apparent that programs involving two or more Tasks provide the opportunity to conduct a more efficient investigation.

In general, the order of presentation is based on the following criteria: (a) the urgency of an improvement as measured by estimates of the highway industry's existing needs; (b) the immediate utility of returns from incremental investments of development resources, and (c) the relevancy of concrete barrier behavioral data that will serve as a firm foundation for subsequent technical and economic advancements.

Basically, the purpose of the proposed Tasks is to acquire concrete barrier performance information for vehicle impact conditions, and to use such information for the development of safer, less costly and more functional traffic barriers. More specifically, the efforts are directed toward:

- Extending the technology of concrete barrier (including the methodology for full-scale crash testing) to encompass a wider range of accident conditions

- Acquiring the data necessary to evaluate effects of potential profile modifications. Involved are comparisons of the dynamic performance of errant vehicles as related to NJ and GM barriers, and those design modifications that may provide improved capabilities for high-angle impacts

- Determining the magnitude, direction and distribution of vehicle impact forces and the manner in which such phenomena are transferred from the point of impact to surrounding soil

- Evaluating barrier-terminal and transition treatments, including development of design and analysis methods, the use of experimental techniques to verify analytical predictions, and the design and construction of prototypes for full-scale, demonstrative crash testing

- Development of experimentally verified, rational design and analysis methods for incorporating highway appurtenances (e.g., lighting support base, drainage, glare screening, etc.) in a manner that will not degrade highway safety capabilities of a barrier

- Determining material design specifications to reduce installation costs while maintaining optimum, barrier dynamic performance characteristics

In Section 4, selected Tasks are combined and arranged to form several recommended Program Plans.

TASK A

VEHICLE IMPACT TESTS OF CONCRETE BARRIERS

Type of Improvement: Increased application potential at various highway traffic barrier sites.

Objective: Acquire vehicle-performance data adequate to verify crash injury reduction capabilities of NJ, GM or comparable concrete barriers.

Payoff Potential: Information conducive to encouraging highway designers to consider concrete barriers as potential alternates.

Study Requirements: Compare effectiveness in terms of occupant vulnerability of barrier profiles for simulated vehicle-barrier accidents.

Technical Scope:

Subtask A. 1: Prepare designs for test barriers. Include two foundations* and alternate profile with a wider base (see Fig. A. 1) to lessen severity of vehicle redirections and post-impact trajectories for high speed, high impact angle accidents. Prepare preliminary estimates of any additional costs.

Subtask A. 2: Perform a series of impact tests using 4,000-pound vehicles impacting at speeds of 60 mph. A sample test matrix is presented in Table A. 1. For purposes of test control and economy, each barrier installation to consist of three, 20-foot precast sections** specially designed for crash testing.

Subtask A. 3:

Option 1: If one or more barrier design(s) prove to be adequate for selected vehicle impact conditions, then construct reduced-cost sections, and conduct selective, demonstrative tests.

Option 2: If the test data are inconclusive (in terms of defining performance envelope or requirement) then revise test matrix. Subject to FHWA approval fabricate test sections and conduct vehicle impact tests.

Option 3: If barrier performance is found to be unsatisfactory for one or more test conditions, then revise designs and prepare a demonstrative-test matrix. Pending FHWA approval, construct test prototypes and conduct crash tests.

Estimated Performance Period/Level of Effort: Four (4) months/one professional manyear.

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*For low impact angles, vehicles may be redirected without contacting upper vertical surface. For impact angles of 25° to 30°, vehicle bumper and body could contact upper surface (before inboard front wheel reaches lower inclined surface), and introduce large horizontal forces and overturning moments into foundation.

**These are not intended to represent a production prototype for precast concepts in Task H.

TABLE A.1

TEST MATRIX FOR SUBTASK A.1[1]

Test Number	Barrier Profile	Vehicle Weight (lbs)	Vehicle Speed (mph)	Angle of Approach (deg)
1	New Jersey	4000	60	7°*
2	New Jersey	4000	60	15°*
3	New Jersey	4000	60	25°*
4	General Motors	4000	60	7°*
5	General Motors	4000	60	15°*
6	General Motors	4000	60	25°*
7	SwRI[2]	4000	60	7°
8	SwRI[2]	4000	60	15°
9	SwRI[2]	4000	60	25°
10	SwRI[2]	4000	60	30°

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(1) Proposed data retrieval systems:
- High-speed photography (computerized analysis for vehicle impact and post impact dynamics).
- On board accelerometers.
- Instrumented and restrained driver dummy.

(2) Alternate: NJ and/or GM barrier with modified foundations.

*Comparisonwith existing test data.

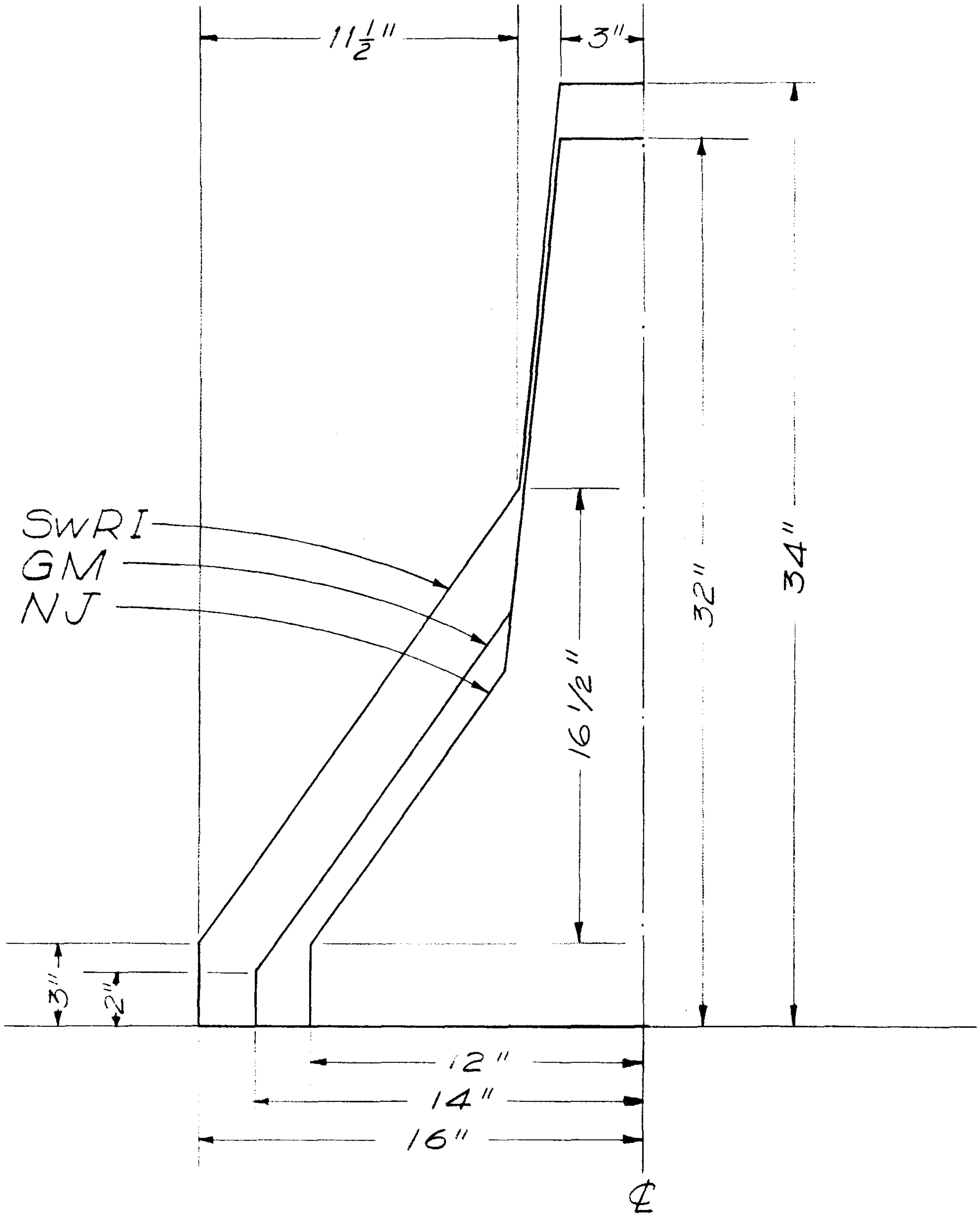

FIGURE A.1 COMPARISON OF BARRIER PROFILES

TASK B

COST-EFFECTIVENESS STUDY FOR CONCRETE BARRIERS

Type of Improvement: Increased incentive to consider concrete barriers as a price-competitive concept.

Objective: To develop designs incorporating the more efficient use of construction materials, and those most amenable to advanced fabrication and installation techniques.

Payoff Potential: In-place unit prices (reflecting local warrants) suitable for comparisons of system costs by highway designers.

Study Requirements: Use analytical model(s) for parametric evaluations to establish relative importance of cost factors, and to conduct quantitative tradeoffs between labor/material costs and performance criteria.

Technical Scope:

Subtask B.1: Prepare cost-analysis model (containing material, in-place construction, delineation and aesthetic parameters) for: (a) above-grade structure, (b) foundation and (c) adjacent soil. Combine aforementioned major model elements by including attachment hardware parameters, barrier-foundation and foundation-soil interfaces, and parameters for attachment or inclusion of highway appurtenances. Use model to conduct parametric analysis. Establish relative importance of cost factors, and correlate with performance parameters.

Subtask B.2: Using existing allowables and criteria, and design methods in accord with current practice, prepare conceptual minimum-cost barrier designs. Obtain appraisals from at least three but no more than five contractors with experience in concrete barrier construction; select geographical locations to represent extremes in labor, material and/or construction costs.

Subtask B.3: Revise designs to incorporate results of contractor survey. Construct and instrument 20-foot long prototypes for the three to five optimum, minimum-cost designs. Perform impact experiments using SwRI pendulum facility (see Appendix A) to verify predicted dynamic performance capabilities.

Subtask B.4: Based on preceding experimental results,* select not more than two minimum cost/maximum structural integrity designs. Construct prototype barriers and place on test foundation.** Conduct three to five tests to demonstrate performance under selected vehicle-impact conditions. Prepare sample specifications for cost-reduction design and construction procedures.

Estimated Performance Period/Level of Effort: Six (6) months/one professional manyear.

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* If experimental data indicate structural inadequacies that are independent of test article size, prepare revised designs and repeat Subtask B.3 experiments.

**Reference Task A.

TASK C

RAMPED TERMINALS FOR CONCRETE BARRIERS

Type of Improvement: Reduce or eliminate rigid-obstacle hazards of upstream ends.

Objective: Demonstrate effectiveness (or limitations) of ramped terminals for median and/or shoulder installations.

Payoff Potential: Test information sufficient to validate use of ramped terminals for specified (or unrestricted) highway locations.

Technical Scope:

Subtask C. 1: Design and construct ramps as described in NCHRP Report 54 (i. e., 80-foot long, tapered sections*. Conduct minimum of five (5) crash tests are proposed; sample matrix presented in Table C. 1**.

Subtask C. 2:

Option 1: If ramp used in Subtask C. 1 proves to be satisfactory, expand test matrix to include additional vehicle parameters, and to include reduced cost ramp configurations. Conduct full scale, vehicle impact tests.

Option 2: If test results demonstrate marginal and/or limited performance capabilities, prepare design modifications, and repeat all or selected from Subtask C. 1, test conditions. If possible, increase confidence level by repeating most critical (i. e., least conclusive) tests.

Estimated Performance Period/Level of Effort: Four (4) months/one half professional manyear.

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*While ramps do not improve safety for metal beam guardrail systems, their performance for concrete barriers may be different; any extrapolations could be misleading.

**Test 1: A low speed, ran-off-the-road accident. Test 2: Investigate launching tendencies for a direct, end-on impact. Test 3: Similar to Test 1 except for vehicle impact velocity. Test 4: A high velocity/impact angle accident. Test 5: Most adverse ramp qualifying requirements.

TABLE C.1

TEST CONDITION FOR TASK B

Test Number	Barrier System[1]	Vehicle Weight (lbs)	Vehicle Speed (mph)	Impact Angle[2]	Impact Point[3]
1	General Motors	4000	40	15°	A
2	General Motors	4000	40	0°	B
3	General Motors	4000	60	15°	A
4	General Motors	4000	60	25°	A
5	General Motors	4000	60	0°	B

NOTES:

(1) System MB6 of NCHRP Report 54.

(2) Angle measured between direction of travel of vehicle and centerline of highway.

(3) Point A is midway along 80-foot terminal section; Point B is at end of terminal section.

TASK D

CONCRETE-BARRIER SEGMENTS FOR HIGHWAY APPURTENANCES

Type of Improvements: Enhance ability to serve as a support for lighting and sign structures, headlight screens, and/or method for drainage control.

Objective: To develop design(s) for new installations or post-construction modifications for attachment of inclusion of most predominate highway appurtenances.

Payoff Potential: Standards and specifications for optimum compromise between appurtenance and concrete-barrier accident control requirements.

Study Requirements: Conduct investigative engineering study to evaluate existing and/or new modifications to enhance concrete-barrier utility without decreasing crash impact effectiveness

Technical Scope:

Subtask D. 1: Prepare relative-importance matrix based on concrete-barrier, usage frequency; include storm drainage, lighting and sign positioning, headlight glare screening, adjustments for elevation differences between adjacent highways, outside of sharp curves, etc.*

Subtask D. 2: Analytically evaluate techno-economic feasibility of existing and conceptual designs.

Subtask D. 3: Select optimum designs based on relative merit indices denoting application feasibility and cost. Conduct laboratory experiments to verify retention of structural integrity under simulated impact conditions.

Subtask D. 4: Based on preceding experimental results**, conduct demonstrative crash tests using selected components incorporating two or more, attached or integrally formed, concrete-barrier modifications.

Estimated Performance Period/Level of Effort: Six (6) months/one professional man-year.

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*A concept for light or sign support in a median barrier is shown in Figure C. 1. Two concepts for headlight glare screening are shown in Figure C. 2. Concepts for storm drainage includes use of integral longitudinal drain lines, or small cross-channels that provide adequate flow capacity. Note: For precast barriers, subsurface channels can be easily introduced.

**If experimental data indicate structural inadequacies, prepare revised designs and repeat Subtask D. 3 experiments.

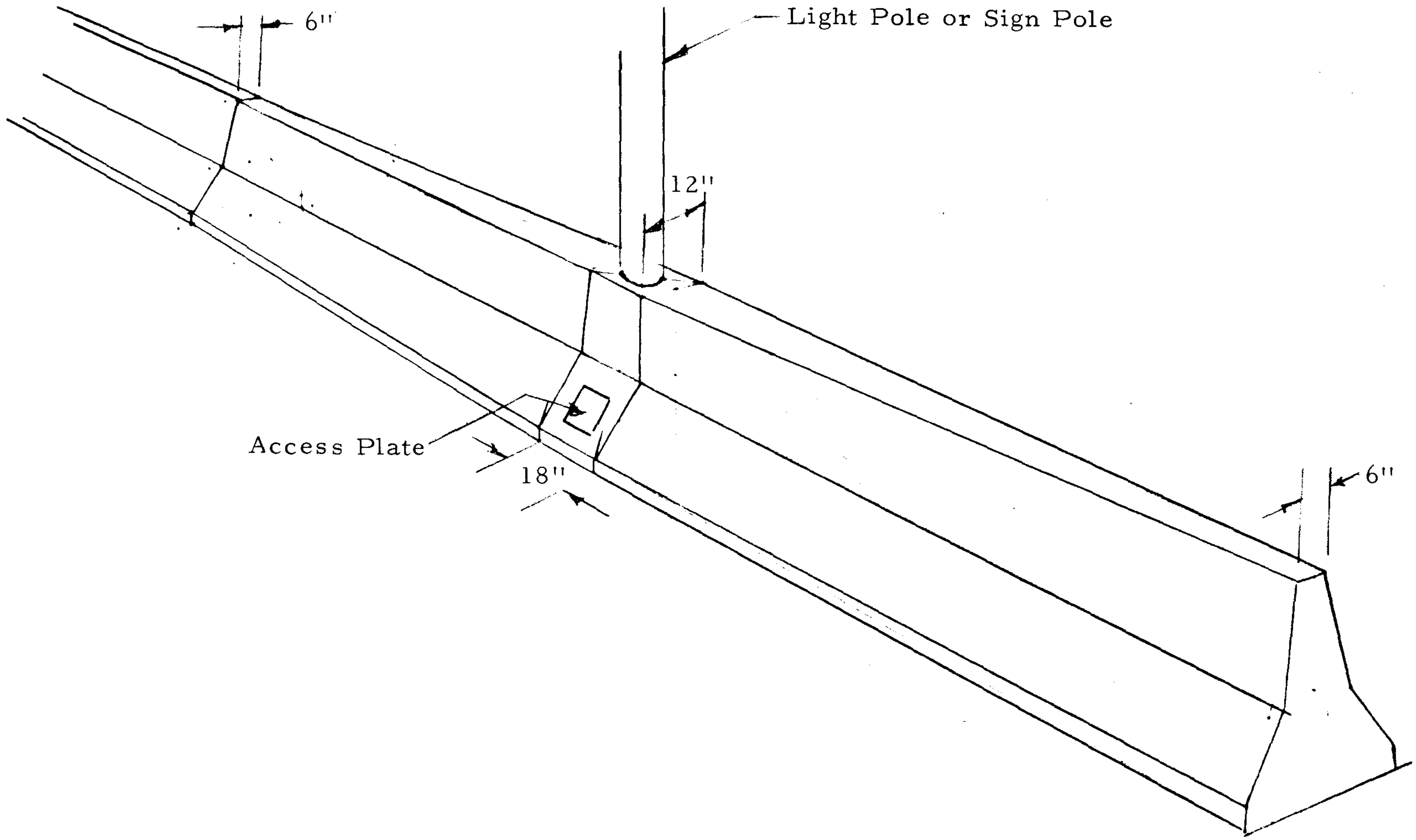

FIGURE D. 1 MEDIAN CONCRETE BARRIER SUPPORT

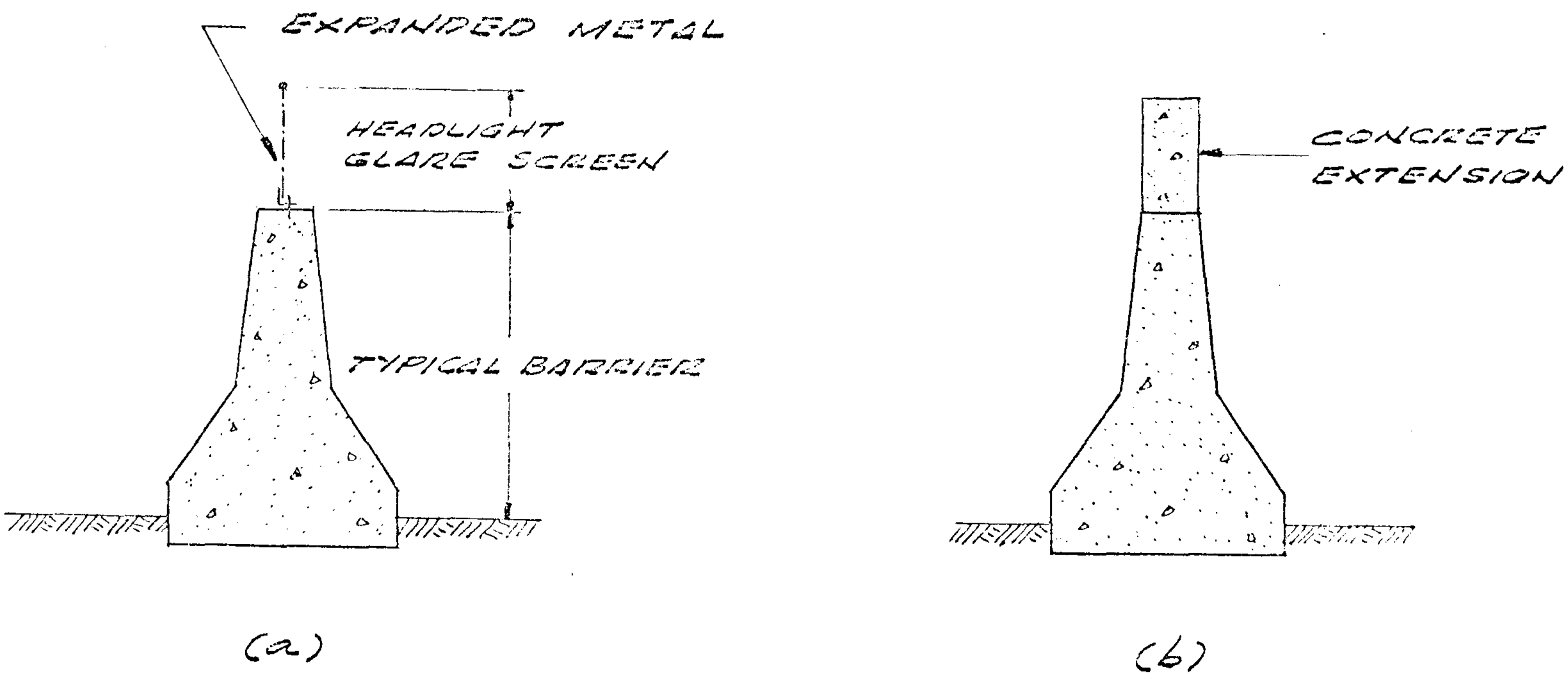

FIGURE D.2 USE OF CONCRETE BARRIER FOR GLARE SCREENING

TASK E

CONCRETE BARRIER END TREATMENTS (OTHER THAN RAMPS)

Type of Improvement: Nonhazardous, cost-effective, versatile designs for upstream ends.

Objective: To demonstrate feasibility of two or more concepts as more effective replacements for ramps.

Payoff Potential: Preliminary designs, cost analysis and specifications in sufficient detail to allow designers to conduct comparative evaluation

Study Requirements: In an iterative procedure, prepare basic and preliminary designs and cost estimates, conduct combined analytical-experimental studies and perform demonstrative vehicle-impact tests.

Technical Scope:

Subtask E. 1: Develop basic design and cost data for no less than three (3) and no more than five (5) concepts. Include feasibility of precast* sections. Following are examples.

Concept A: Flared Terminal - As depicted in Figure E. 1, a shoulder barrier (warranted by either a fixed object, steep embankment, or bridge approach) is extended beyond the point-of-need**. In absence of requirement to prevent vehicle penetration, cross-sections are reduced to redirect vehicles traveling at moderate speeds and impacting angles. Vehicles impacting barrier at high speeds and/or large angles are allowed to penetrate Primary attribute is the preprogrammed penetration capability compatible with occupant deceleration tolerances.

Concept B: Energy Attenuator - Shown in Figure E. 2, concept employs low density, high-energy absorbing material(s); section length determined by coupled vehicle-barrier energy absorption requirements. Vehicles striking ends near 0 degree impact angles progressively crush terminal section inducing deceleration forces tolerable to vehicle occupants. For errant vehicles impacting at moderate speeds and small angles, barrier would have transverse strength comparable to standard barrier section. In the more severe side-on impacts, the vehicles would be allowed to penetrate. Figure E. 3 illustrates a vermiculite concrete terminal section with large, preformed voids.

Subtask E. 2: Prepare mathematical models capable of predicting energy absorption and/or penetration capabilities. Prepare designs and construct prototypes suitable for verification experiments.

Subtask E. 3: Conduct full-scale crash tests; a sample test matrix is presented in Table E. 1.

Subtask E. 4: Select most promising candidate. Refine design details and cost estimate; perform one or more demonstrative full-scale crash tests.

Estimated Performance Period/Level of Effort: Twelve (12) months/one (1) professional manyear.

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*As relatively light weight components these sections could be economically transported, handled and installed.

**Point-of-need is the nearest point on the upstream edge of pavement measured from the warranting condition where errant vehicles can safely leave the pavement at an assumed angle and speed.

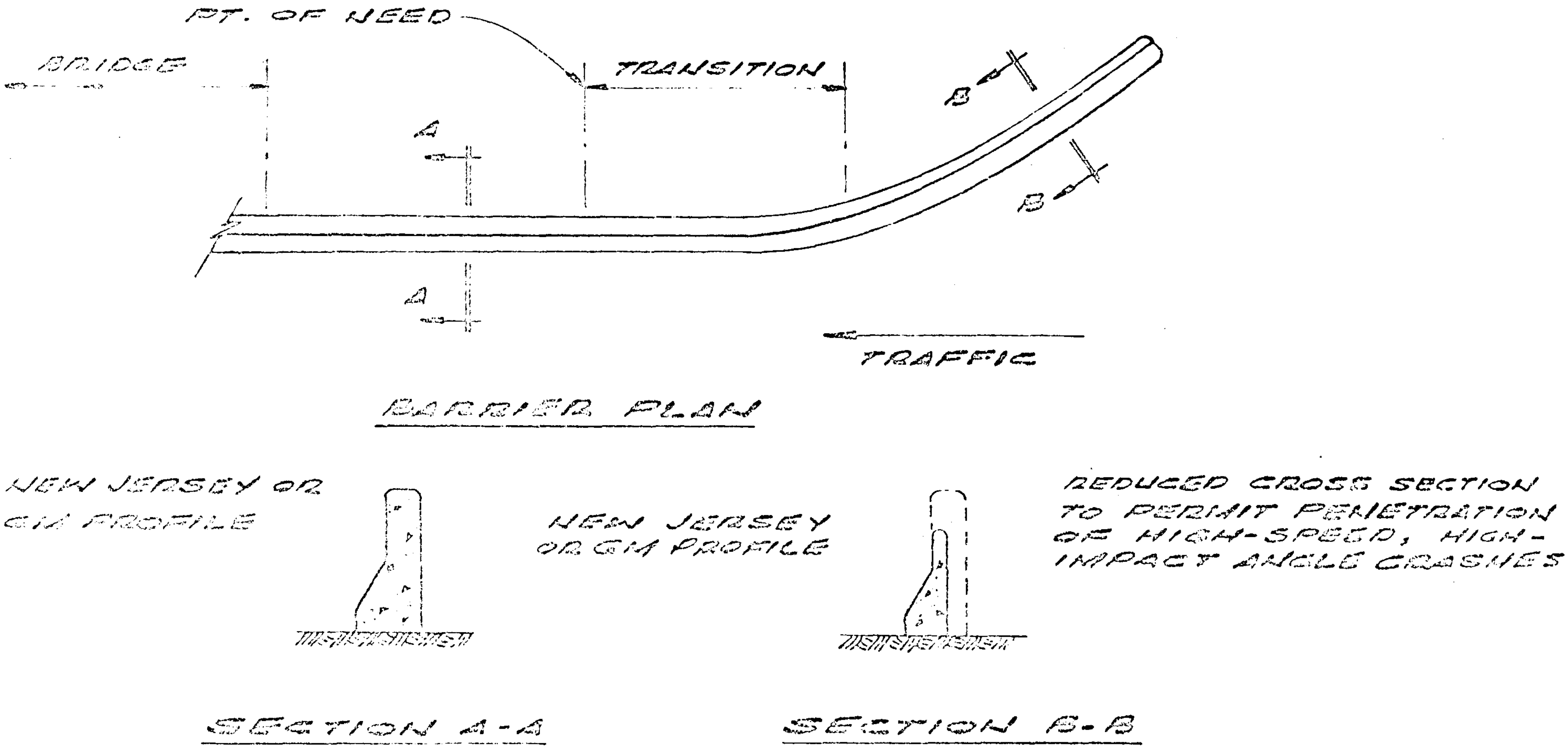


FIGURE E.1 CONCRETE BARRIER END TREATMENT: CONCEPT A

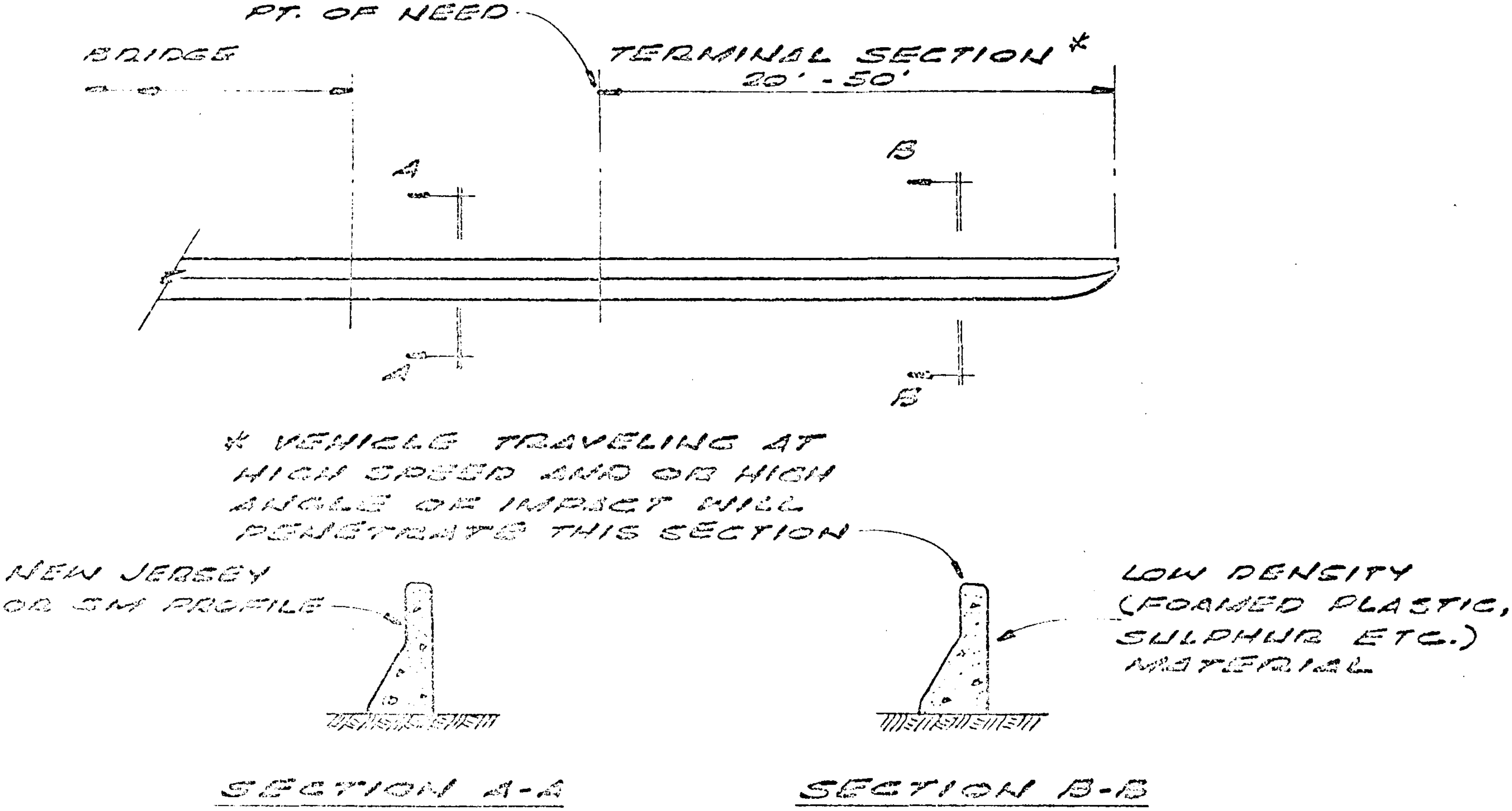


FIGURE E.2 CONCRETE BARRIER END TREATMENT: CONCEPT B

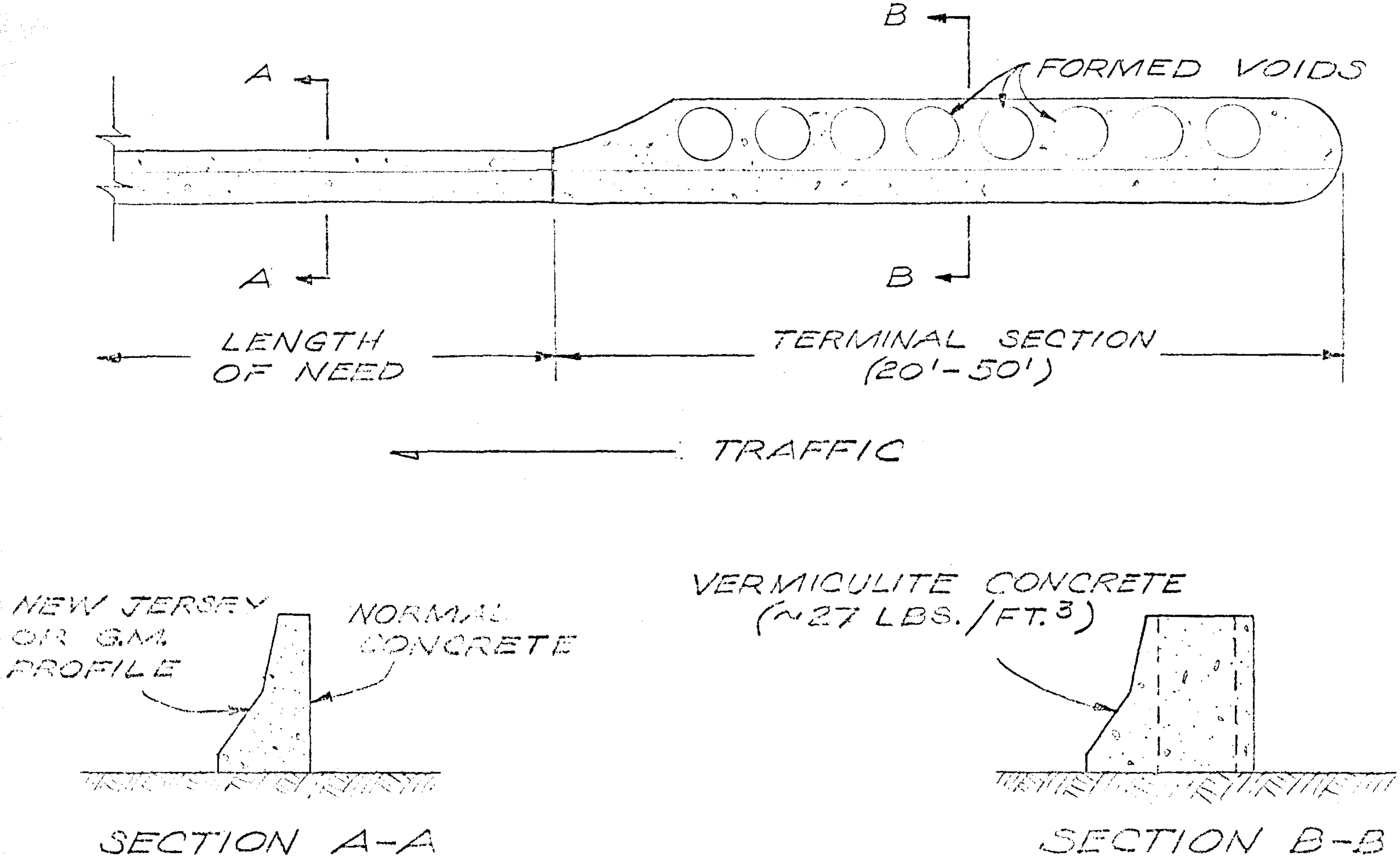


FIGURE E.3 CONCRETE BARRIER END TREATMENT: CONCEPT C

TABLE E.1

SAMPLE CRASH TEST MATRIX FOR SUBTASK E.4

Test Number	Terminal Concept*	Vehicle Parameters		
		Weight (lbs)	Speed (mph)	Angle of Impact (deg)
1	A	4000	60	25
2	A	4000	40	15
3	B	4000	60	0
4	B	4000	60	25
5	C	4000	60	0
6	C	4000	60	25

*See Figures E.1-E.3.

TASK F

CONCRETE BARRIER FOUNDATIONS

Type of Improvements: Rational design conducive to cost reductions and improved barrier performance.

Objective: To develop design and analysis methods wherein the foundation is considered as an integral subsystem between the soil and above-grade structure.

Payoff Potential: Cost-effective foundation designs reflecting specific barrier performance requirements and representative soil conditions at installation site.

Study Requirements: Perform iterative design/analysis/experimentation/testing studies to establish structural design and dynamic performance parameters leading to allowables and criteria suitable for standard and specification.

Technical Scope:

Subtask F. 1: Syntheses and analyses of prevalent designs, including evaluation of material usage efficiencies, grade preparation requirements, and force characterization due to vehicle impact loads.

Subtask F. 2: Prepare basic designs and analyses for representative vehicle impact conditions. Fabricate specimens (fully instrumented, full-scale test articles). Conduct crash test experiments to verify predictive capabilities of analytical procedures.

Subtask F. 3: Modify analytical methods to improve designs and/or cost-effectiveness of two optimum foundations. Perform relative-merit analyses; include cost, performance and installation site parameters.

Subtask F. 4: Using refined methods of analysis for structural response and cost-effectiveness, design and construct prototype foundations. Conduct selective vehicle-impact tests to demonstrate feasibility.

Estimated Performance Period/Level of Effort: Twelve (12) months/one and a half professional manyears.

TASK G

CONCRETE BARRIER TRANSITION SECTION

Type of Improvement: Nonhazardous designs to joint concrete barrier to semirigid and flexible traffic barrier systems.

Objective: To develop and demonstrate feasibility of two or more transition concepts.

Payoff Potential: Preliminary designs, cost analysis and specifications in sufficient detail to allow designers to incorporate as variation of basic concrete barrier system design.

Study Requirements: In an iterative procedure, prepare basic and preliminary designs and cost estimates, conduct combinaed analytical/experimental studies and perform demonstrative vehicle-impact tests.

Technical Scope:

Subtask E. 1: Develop basic design and cost data for no less than three (3) and no more than five (5) concepts. Include feasibility of precast section. Following are examples.

Concept A: Box Beam to Concrete Barrier Transistions As depicted in Figure G. 1, box beam approaches concrete barrier approximately 2 ft outboard to allow for lateral deflection. If impacted in the transition zone, the box beam deflects inward and upward due to post offset, and hence, banks vehicle away from barrier. This banking behavior is compatible to typical concrete barrier performance. Transitions from rigid to more flexible systems are generally nonhazardous (i.e., traffic in opposite direction).

Concept B: W-Beam to Concrete Barrier Transition - Shown in Figure G. 2, a low density concrete (i.e., Vermiculite, etc.) is used to offset the approach W-beam from the concrete barrier line; a "rub rail" is also provided in the transition zone to minimize tendency of vehicle to wedge under the main rail. A significant quantity of kinetic energy of vehicle impacting within the transition zone is absorbed in crushing the low-density concrete. It is conjectured that spare precast transition sections could be available at local storage points, facilitating repairs to damaged installations.

Subtask G. 2: Prepare mathematical model capable of predicting energy absorption and redirection capabilities. Prepare designs and construct prototype suitable for verification.

Subtask G. 3: Conduct full-scale crash tests on selected transitions. A sample matrix is presented in Table G. 1.

Subtask G. 4: Select most promising candidate. Refine design details and perform one or more demonstration crash tests.

Estimated Performance Period/Level of Effort: Twelve (12) months/one (1) professional manyear.

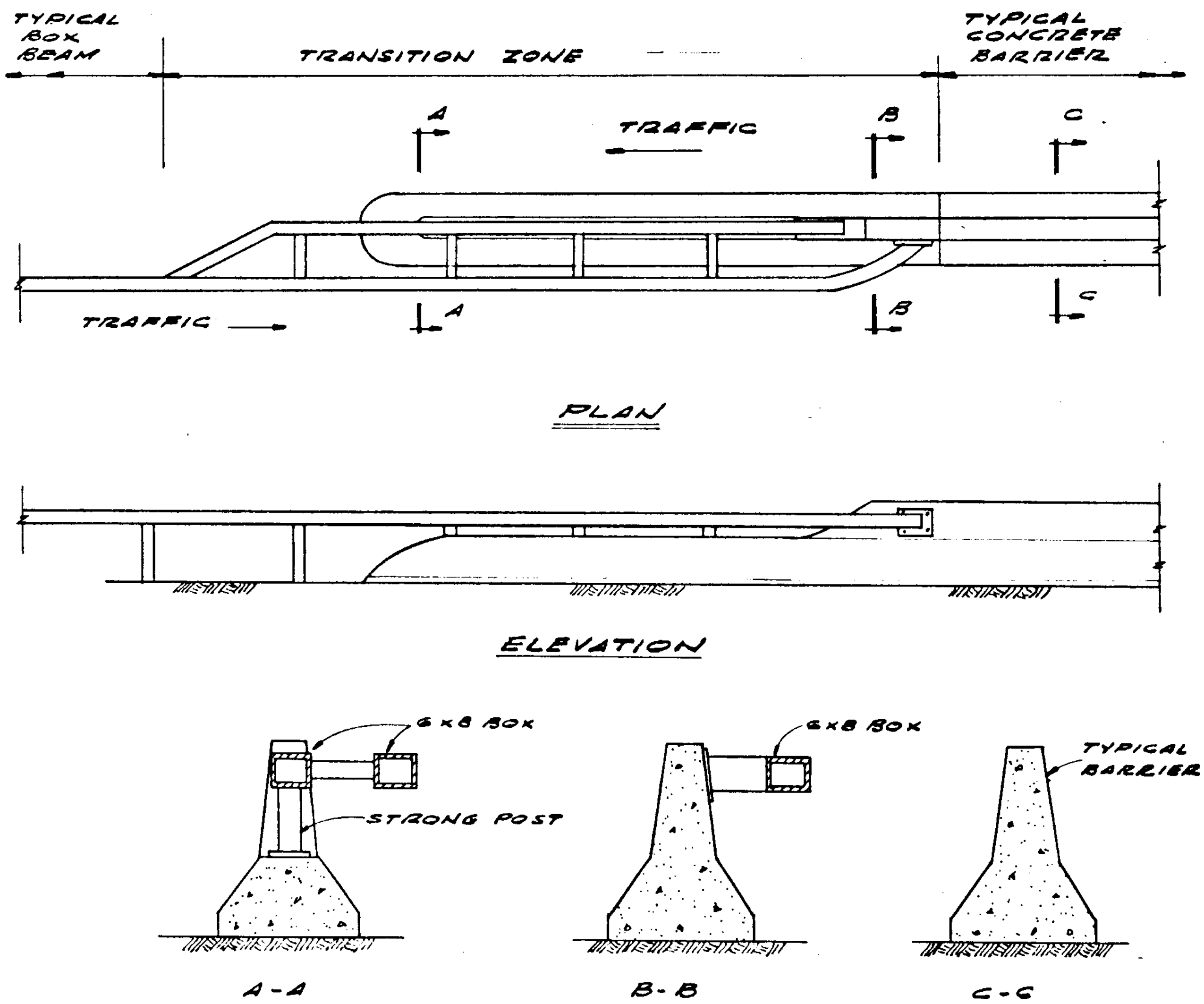


FIGURE G.1 BOX BEAM TO CONCRETE BARRIER TRANSITION (CONCEPT A)

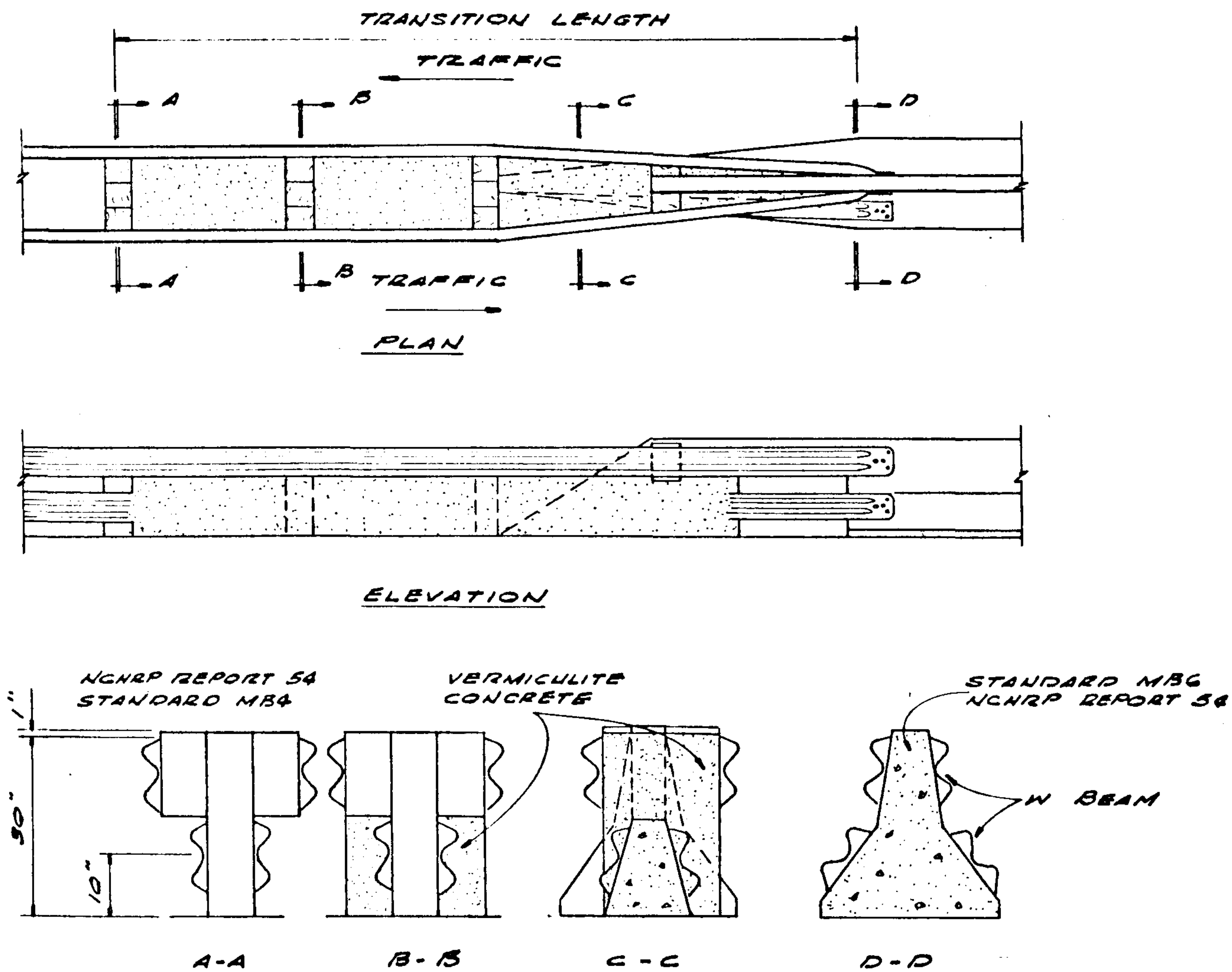


FIGURE G.2 W-BEAM TO CONCRETE BARRIER TRANSITION (CONCEPT B)

TABLE G.1

SAMPLE CRASH TEST MATRIX FOR SUBTASK G.3

Test Number	Transition Concept	Vehicle Parameters		
		Weight (lbs)	Speed (mph)	Angle of Impact (deg)
1	A[1]	4,500	60	15
2	A[2]	4,500	60	15
3	B[1]	4,500	60	15
4	B[2]	4,500	60	15
5	C[1]	4,500	60	15
6	C[2]	4,500	60	15

(1)Point of impact at transition center.

(2)Point of impact midway between transition center and beginning of typical concrete barrier profile.

TASK H

PRECAST CONCRETE-BARRIER SEGMENTS

Type of Improvement: Cost-effective and standardized concrete barrier systems.

Objectives: To develop designs for precast barrier segments; include attachments for boundaries and foundations.

Payoff Potential: Unit prices, installation procedures and ability to vary dynamic structural properties along warranted site comparable to other systems.

Study Requirements: Conduct an iterative design-analysis-experimental studies. Demonstrate feasibility of integrated system compromised of two or more types of precast segments by vehicle impact tests.

Technical Scope:

Subtask H. 1: Analytically characterize transient forces and deformations due to vehicle impacts; include three-dimensional, time-dependent predictions of magnitudes and distributions along barrier, and at barrier/foundation and foundation/soil interfaces.

Subtask H. 2: Select optimum segment length(s) based on lengthwise force-deformation distributions, as well as fabrication, transportation handling, installation and segment interface attachment requirements.

Subtask H. 3: Design, fabricate and instrument experimental prototypes. Conduct experimental analyses to verify analytically predicted structural response and integrity of segments, and of attachment devices between segments and foundation.

Subtask H. 4: Design and construct preproduction prototypes. Conduct preliminary crash tests. Foundation forces and deformations to be acquired from instrumented, test-control section (Fig. H.1) supported at the middle and four feet in front each end. Vertical forces required to resist overturning moment to be measured by strain-gaged rods extending vertically through barrier and anchored to foundation beam. A steel plate (restrained in the horizontal plane by a strain-gaged column bearing against beam support to be used to measure side thrust.

Subtask H. 5: Upgrade designs for performance and/or cost-effectiveness. Conduct final demonstration tests. Prepare tentative specifications.

Estimated Performance Period/Level of Effort: Twelve (12) months/two (2) professional manyears.

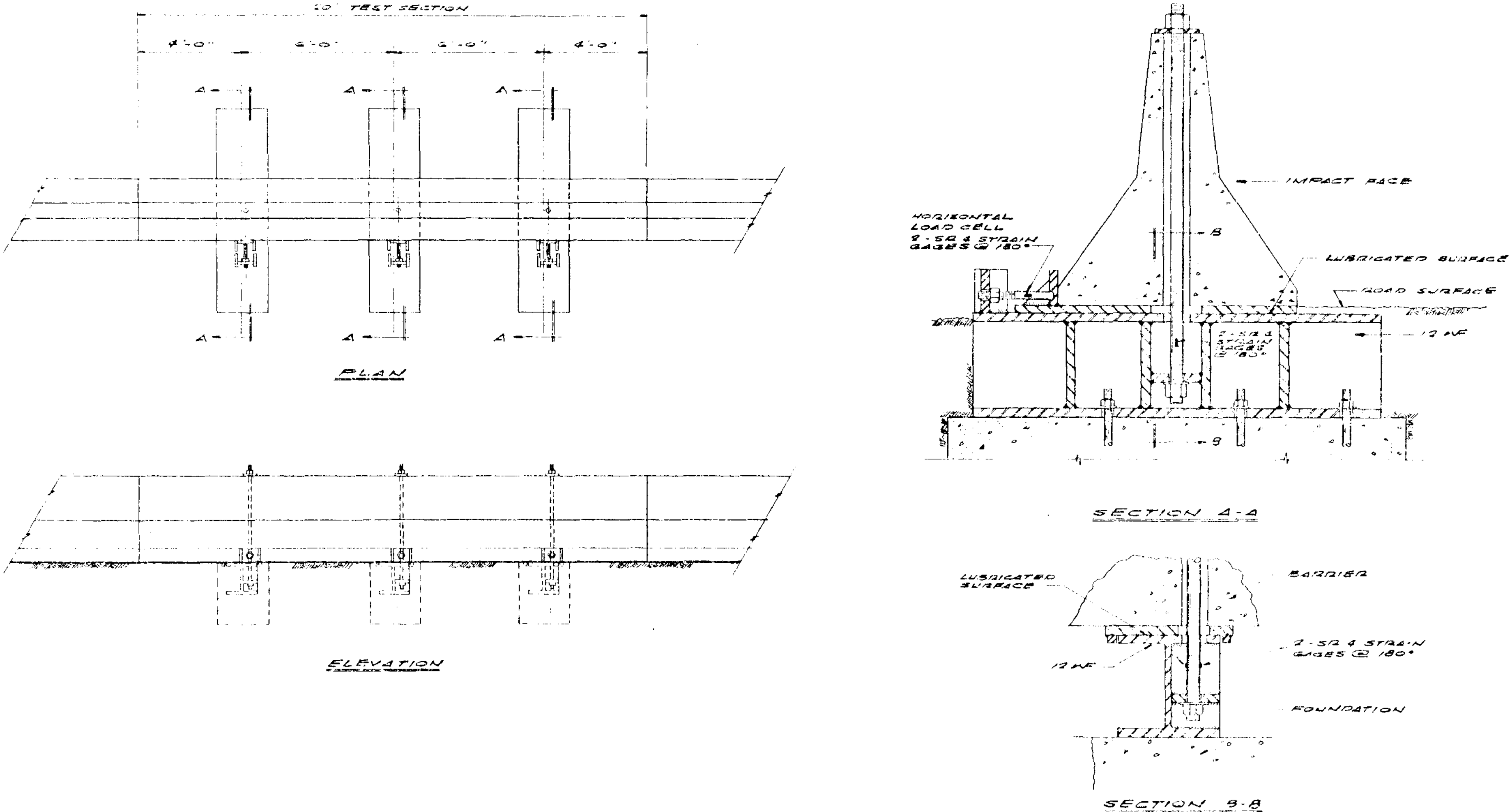


FIGURE H.1 EXPERIMENT DESIGN TO ACQUIRE VEHICLE FORCES ON CONCRETE BARRIER

4. PROPOSED TECHNICAL PROGRAM PLANS

Despite a limited scope, each Task outlined in Section 3 is self contained and constitutes a program within itself. However, combinations of two or more Tasks have obvious functional advantages. Certain multi-Task programs emphasize the aspects of basic engineering while others relate to application feasibility or state-of-the-art improvement studies. Economic considerations prevail but the importance of cost reductions increases as a program tends to satisfy short-term objectives. In presenting several program plans in this section, the Institute intends to provide examples of multi-Tasks combinations in sufficient detail for FHWA evaluations and recommendations.

For the technology of concrete barrier systems, current and future requirements suggest that available development resources could be productively invested for several different types of programs. Since existing and contemplated installations will exceed 500 miles, application-oriented studies are needed in order to more fully exploit the potential of concrete barriers. Factors pertaining to application feasibility would appear to be of prime importance. These include,

- Elimination or alleviation of existing technical and/or economic deficiencies which limit the diverse utilization of concrete barriers.
- Full exploitation of growth potential within current design and construction practice.
- Expansion of design and/or construction capabilities (for the next generation of concrete barriers) without requiring excessive upgrading of either current design or construction practice.
- Assuming that all possible improvements within the state-of-the-art are exhausted, additional advancements acquired through research.

In Table 4.1, the Tasks outlined in Section 3 are listed accordingly. Tasks A through D emphasize immediate or near-future improvements. Task E through H require varying degrees of technological advancements, and more refined engineering procedures. The first and second set of four Tasks have been used to create, respectively:

- Program I: Concrete Barrier Improvements (Current Practice)
- Program II: Concrete Barrier Improvements (Advancements in Current Practice).

Also of importance is the interplay between Tasks within a program. Spinoffs and feedback information tend to eliminate duplications, increase reliability and confidence, provide continuity that enhances efficiency and thus reduce project costs. While Programs I and II exhibit a degree of interaction, they do not take full advantage of other Task commonalities.

From the viewpoint of related problem areas, Task C (Ramped Terminals), Task E (End Treatments) and Task G (Transition Segments) exhibit readily apparent interdependencies that justify consideration of

- Program III: Study of Concrete Barrier Terminal and Transition Sections

Similarly, there are interactions between Task F (Concrete Barrier Foundation) and Task H (Precast Concrete Barrier Segments) in terms of design, fabrication and construction. Moreover, the efforts and results for both Tasks have a direct influence on cost-effectiveness (Task B). Thus Program IV represents a coordinated, techno-economic study with a substantial amount of crossflow information

A synopsis of the four Programs (I, II, III and IV) is presented in Figure 1.1 of Section 1.

TABLE 4.1

APPLICATION-ORIENTED RATING OF TASKS

TASK A:	Vehicle-Impact Tests of Concrete Barriers	Eliminate/Alleviate Existing Deficiencies (Technical)
TASK B:	Cost-Effectiveness Studies of Concrete Barriers	Eliminate/Alleviate Existing Deficiencies (Economic)
TASK C:	Ramped Terminals for Concrete Barriers	Growth within Current Practice
TASK D:	Concrete-Barrier Segments for Highway Appurtenances	Growth within Current Practice
TASK E:	Concrete Barrier End Treatment(s) (Other than Ramps)	Expansion with Upgrading of Current Practice
TASK F:	Concrete Barrier Foundations	Expansion with Upgrading of Current Practice
TASK G:	Concrete Barrier Transition Segments	Basic Engineering (Systems Development)
TASK H:	Precast Concrete-Barrier Segments	Basic Engineering (Product Development)

5. SCHEDULING, BUDGETARY PLANNING AND CONTRACTUAL INFORMATION

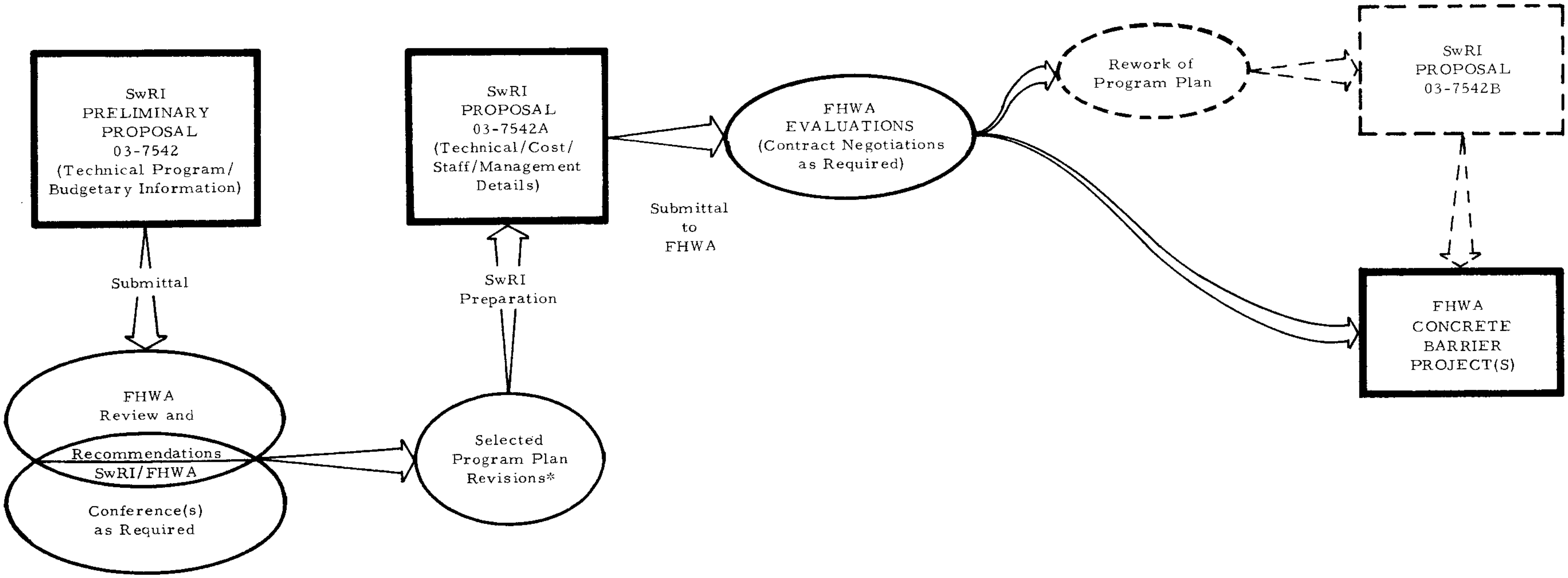
A degree of programming flexibility is essential. While SwRI can appraise current requirements, it cannot presume to anticipate the administrative, funding and coordination considerations that govern the objectives and policies of FWHA and other agencies concerned with highway traffic barriers. Therefore, Southwest Research Institute respectfully requests that the Federal Highway Administration view the alternate Program Plans outlined in Section 4, and/or the individual Task outlined in Section 3 as preliminary. The Institute anticipates that the process culminating in a concrete barrier Project will, as a minimum, require the sequence of events depicted in Figure 5. 1. It is assumed that this proposal will be superceded by Proposal 03-7542-(1) which will contain more specific technical, scheduling, manpower, project manage, ment and cost information in accord with FHWA recommendations.

Since the state-of-the-art for both traffic barrier systems and highway safety changes rapidly, the Institute recommends that the selected Program Plan include provisions to accommodate new developments (or revised requirements and priorities) and be amenable to work scope and effort adjustments. Accordingly, projects based on Programs I thru IV (or other comparable study plans) are to be divided into the following Phases:

<u>PHASE ONE</u> <u>FINALIZE TECHNICAL SCOPE</u>

- Conduct survey of State Highway Departments to delineate requirements, and to establish priorities.

- Prepare and submit detailed work plan; to include technical, scheduling details for Tasks and Subtasks.



*Includes additions to or deletions from Tasks or Programs as contained herein, or a different program plan as requested by FHWA.

FIGURE 5.1 ANTICIPATED SwRI PROPOSAL/FHWA CONTRACT SEQUENCE OF EVENTS

PHASE TWO CONDUCT INITIAL TECHNICAL EFFORTS

PHASE THREE PERFORM IN-PROGRESS EVALUATION

- Prescheduled appraisal of prior accomplishments (including those of other studies) to identify changes in requirements and priorities, and the need (if any) to revise followon efforts.

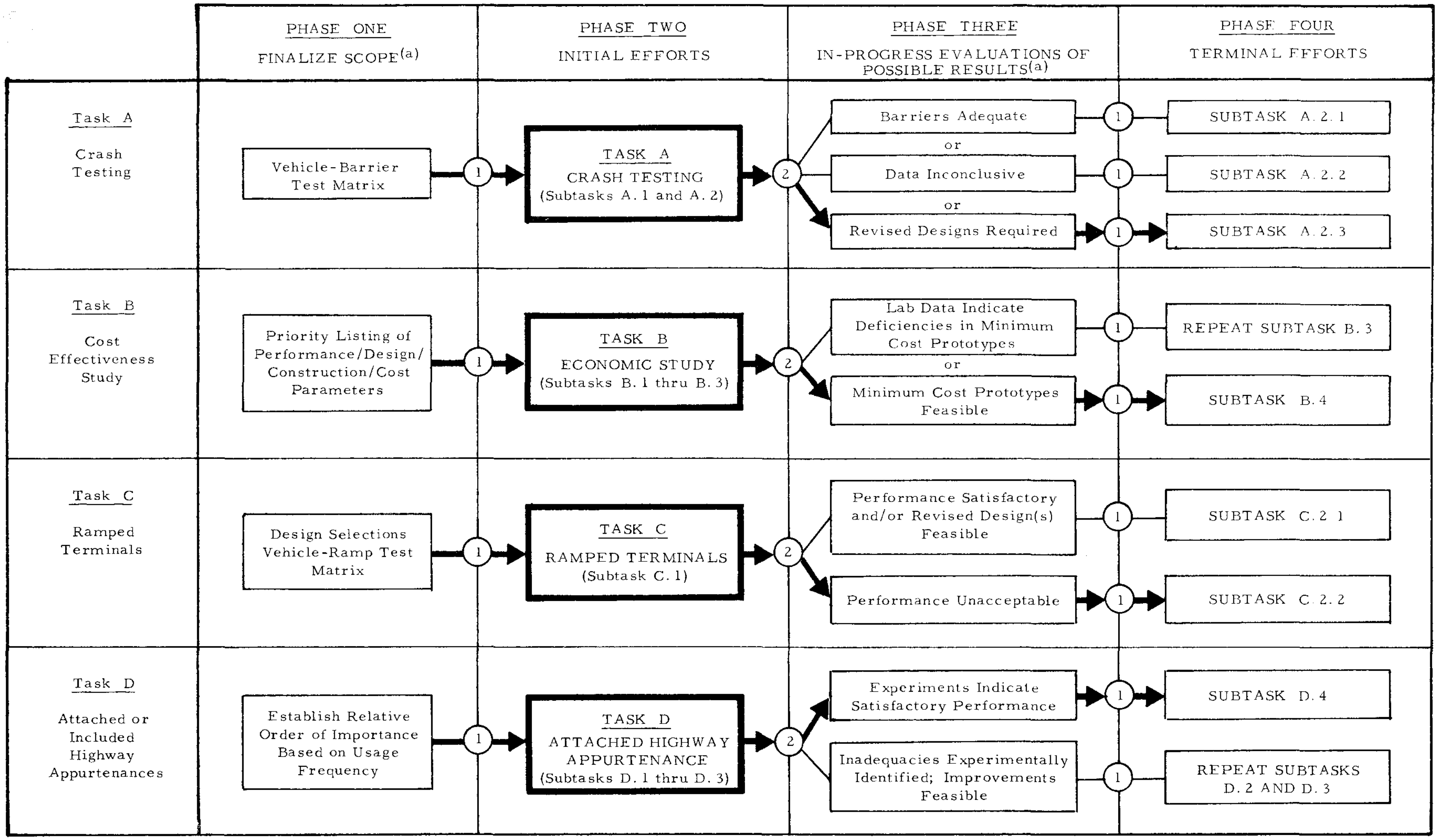
PHASE FOUR CONDUCT TERMINAL TECHNICAL EFFORTS

The initial efforts in each Task within Program I thru IV are directed toward delineating technical objectives and requirements. The iteration process depicted in Figure 5.1 also involves similar delineations. Nevertheless, the Institute recommends that Phase One of the resulting Project be included to insure that the objectives of FHWA and/or the needs of the highway community are firmly crystallized at the outset.

Phase Three is based on the premise that the selected numbered and type of Tasks will result in a program whose level of effort and contract performance period warrant a mid-project analysis of prior accomplishments, and a confirmation of the original forecasts. In addition, Phase Three is intended to provide an opportunity to make project decisions related to changes in emphasis as well as abrupt changes in direction The basic aspect of the aforementioned project-phase concept is depicted in Figure 5.2.

For convenient reference, Figure 5.3 lists the proposed multi-Task Programs; included are estimates of the anticipated performance period and levels of effort and budgetary forecasts. Several aspects are noteworthy:

- The sequence of presentation is not intended to convey the Institute's preference As discussed previously, the order reflects a decreasing order of application feasibility.



(a)FHWA/SwRI Conference.
(1) FHWA approval for go-ahead.
(2) Interim Task Report.
NOTE: Heavy lines indicate anticipated events used for scheduling and budget estimates.

FIGURE 5.2 PROGRAM PLAN I: CONCRETE BARRIER IMPROVEMENTS: CURRENT PRACTICE
(Task/Phase Sequence)

	Proposed Program	Program Tasks (Reference Section 3)	Estimated Performance Period (Calendar Months)	Estimated Level of Effort (Professional Manyears)	Budgetary Estimates ($1,000)
I	CONCRETE BARRIER IMPROVEMENTS (Current Practice)	A: Vehicle Impact Tests B: Cost Effectiveness C: Ramped Terminals D: Highway Appurtenances	12	2-1/2 - 3	125 - 150
II	CONCRETE BARRIER IMPROVEMENTS (Advanced Practice)	E: End Treatments F: Foundations G: Transition Sections H: Precast Segments	30	3-1/2 - 4	180 - 200
III	CONCRETE BARRIER TERMINALS AND TRANSITION SECTIONS	C: Ramped Terminals E: End Treatments F: Transition Sections	18	2 - 2-1/2	100 - 125
IV	CONCRETE BARRIER TECHNO-ECONOMIC STUDY	B: Cost Effectiveness F: Foundations H: Precast Sections	24	3 - 4	150 - 175

FIGURE 5.3 SUMMARY OF SwRI PROPOSED PROGRAMS FOR CONCRETE BARRIERS

- Both the performance period and the level of effort for a Program are less than the totals obtained from the Task outlines presented in 3. This denotes the advantages of concurrent, coordinated, interdependent efforts.

- The preliminary cost estimated is intended to provide FHWA with an indication of funding for budget-planning purposes. Similarly, the SwRI contractual information in Appendix C conveys the salient features of a recommended CPFF type of contract*. In the subsequent SwRI Proposal(s), the cost estimate (constituting a firm offer) will contain itemized unit and composite price data.

The cost range (from $100,000 to $300,000) reflects not only the differences between programs but also portions of the effort that were devoted to testing, experimental or analytical studies. It is to be noted that vehicle-impact tests are expensive, expecially if the results are to provide data other than go/no-go information and documentary films. On the other hand, maximum returns are realized only when the data from integrated instrumentation systems are totally analyzed and interpreted to provide indication of trends and more definitive guidelines for future work.

If deemed advisable by FHWA, the Institute would be most willing to prepare a formal proposal for: (a) any one of the Tasks A thru H, (b) a program composied of all the initial Subtasks in Tasks A thru H, (c) a program with no vehicle-impact testing or (d) a program involving only crash testing.

*Contractual information is presented in Appendix D.

6. PROJECT MANAGEMENT AND PERSONNEL

Technical and administrative responsibilities will be assigned to the Department of Structural Research under the direction of Dr. Robert C. DeHart. Leonard U. Rastrelli, Assistant Director, will set policy to ensure the accomplishment of program objectives. Coordination of project activities, technical performance and contract supervision will be provided by a Project Manager who will also serve as one of the Principal Investigators.

The exact Project Management/Staff structure will, of course, depend on the particular characteristics of the proposed study. There are, however, certain members of the Institute's staff whose experience is directly related to two or more of the proposed Programs and/or Tasks. Mr. Jarvis Michie, for example, could serve as the Project Manager. Depending on the scope and level of effort, he would be supported by senior personnel who would perform as Principal Investigators and if required, as Assistant Project Managers. Since the proposed programs are amenable to speciality-oriented efforts, major functional studies will be assigned to scientists and/or engineers who, together with the forementioned technical administrative personnel, constitute the Institute's team. Other direct and temporary assignments of professional personnel will be made in accord with specified requirements. Table 6.1 contains a partial listing of the potential Institute participants.

The professional resumes of Institute staff members available to serve as principal investigators or in an advisory capacity on specific problems are presented in Appendix C. Their technical experiences (as they pertain to the proposed study) are summarized in the following:

TABLE 6.1

PROJECT PERSONNEL

Name	Title	Primary Field	Project Function	Time Available (%)
R. C. DeHart	Director, Department of Structural Research	Structural Dynamics	General Supervision and Consultation	As required
L. U. Rastrelli	Assistant Director, Department of Structural Research	Systems Analysis	Technical Administrator	10
J. D. Michie	Group Leader	Structural/Highway	Program Manager/Principal Investigator	60
M. E. Bronstad	Senior Research Engineer	Highway/Bridge Structures	Crash Test Program	30
G. K. Wolfe	Research Engineer	Systems Development	Crash Test Program	20
T. E. Hawkins	Senior Research Analyst	Cost Analysis	Cost Effectiveness Studies	20
T. Wah	Staff Scientist	Structural Dynamic	Theoretical Considerations	As required
G. J. Overby	Research Engineer	Structural Design	Preliminary/Final Designs	30
C. R. Ursell	Group Leader	Vehicle Dynamics	Crash Test Evaluation	20

Dr. R. C. DeHart's experience includes the effects of dynamic loads on bearing performance. As a research-executive, his extensive background in directing the accomplishment of unique investigations will contribute directly to the achievement of program objectives.

Mr. L. U. Rastrelli has assembled experience concerned with the behavior of highway structures. His recent association with programs concerned with accumulative fatigue damage, thermal effects, the structural integrity of composite structures, and dynamic strains in structures provide a broad background.

Mr. J. D. Michie is presently serving as Project Manager for NCHRP Program 15-1(2) Design and Performance of Highway Guardrail. In this capacity he is directing both the theoretical and experimental phases of this most comprehensive study. Mr. Michie has considerable experience in the utilization of laboratory equipment to effectively accomplish unique structural research programs.

Mr. M. E. Bronstad, Senior Research Engineer, will be the engineer-in-charge of performing full scale impact tests. He has acquired considerable design experience on bridges and other highway related structures. Recently, Mr. Bronstad designed and developed the Institute's Vehicle Impact Test Facility.

Mr. G. K. Wolfe, Research Engineer, will assist Mr. Bronstad in conducting full-scale crash testing and other laboratory experimentation as needed.

Mr. T. E. Hawkins, Senior Research Analyst, will have responsibility for performing cost analysis and cost effectiveness studies required in the various program Tasks.

Dr. T. Wah, Staff Scientist, will be responsible for theoretical considerations and computer simulation for the vehicle-barrier interactions.

Mr. G. J. Overby, Research Engineer, will have charge of design, modification and fabrication of the various test articles.

The forementioned project engineering staff will be supported by other Institute engineers and scientists as required, and by experienced machinists, mechanics and instrumentation technicians.

APPENDIX A

SwRI VEHICLE CRASH AND PENDULUM IMPACT FACILITIES

APPENDIX A

SwRI VEHICLE CRASH AND PENDULUM IMPACT FACILITIES

A.1 CAPABILITY

SwRI Vehicle Crash Facility is designed to permit experimental study of vehicle dynamic behavior during impact with another vehicle or with highway appurtenances (i.e., guardrail, sign post, bridge pier, etc.) or natural roadside features (i.e., embankment, ditch, water hazard, etc.). Unmanned test vehicles, traveling at speeds up to and in excess of 60 mph, are guided into various type barriers. Impact events are documented by high speed photography and on-board instrumentation. Data from these carefully controlled experiments are analyzed and correlated with other tests and theoretical predictions.

A.2 FACILITY DESCRIPTION

Location of the facility is at the SwRI San Antonio campus adjacent to Culebra Road. A 12-foot wide, 1500-foot long paved run-up strip provides adequate acceleration distance for standard cars with six-cylinder engines to attain speeds of 60 mph; cars with eight-cylinder engines can accelerate to 60 mph in less distance. Grade variation of the acceleration strip is less than 0.5 percent.

Vehicle impact and recovery area is located at the end of the run-up strip. Space is available to investigate either confined impacts (as when a vehicle strikes a bridge pier) or redirected impact where a vehicle impinges a guardrail at a shallow angle. Features of crash facility are illustrated in

Figure A.1.

A control building is located adjacent the run-up strip and 600 feet from vehicle impact area. Vehicle speed monitoring instruments, vehicle test abort controls (ignition, brakes), data and documentary camera controls and test data recorder are situated at this site.

A.3 TEST VEHICLE

Self-powered vehicles are generally utilized in tests, although in special cases towed vehicles are used. Vehicles, less than 10 years old, are procured from Federal government surplus or purchased from commercial dealers. Vehicles are carefully inspected, and the engines adjusted for peak performance. After being steam-cleaned, the test cars are painted white and marked with reference decals to aid in high-speed photography data analysis.

Braking of the vehicle is possible through a remotely actuated solenoid valve which permits air from a pressurized accumulator (760 psig) to enter the brake lines. This package mounted in the trunk of the test vehicle permits the test engineer to pulse or lock the brakes. A small, pressurized and heavy duty gasoline tank is installed in the trunk and plumbed to the carburetor in order to greatly lessen a fire hazard during the experiment; the regular gasoline tank is either removed or filled with water. An electronic unit (containing on-board instrumentation, signal conditioning and amplifying systems) is securely attached in the trunk or rear seat space.

Vehicle test speed is achieved by means of an automatic speed controller attached to the engine distributor. After the car accelerates to the predeter-

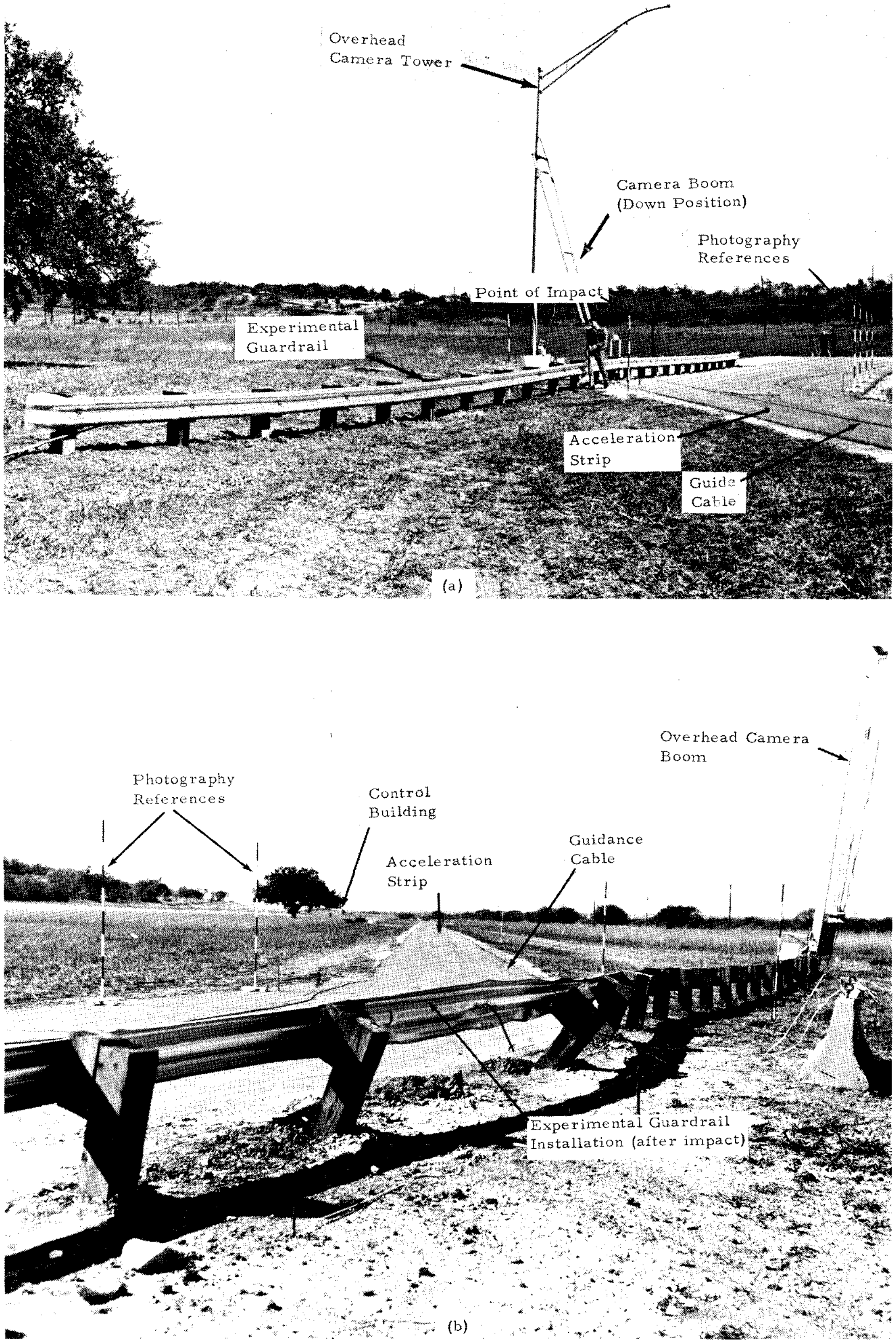


FIGURE A.1 FEATURES OF VEHICLE CRASH FACILITY mined test speed, the controller pulses the ignition and maintains the car at a constant velocity. Engine speed is also monitored in the control building. In the event the test vehicle does not achieve desired speed, the test can be aborted by the test engineer by cutting the ignition and pulsing or locking the vehicle brakes.

A 1/4-inch steel cable, 1500 feet long pretensioned along the left side of the run-up strip provides means of vehicle guidance. A bracket attached to the vehicle left front wheel guides on the cable. Just prior to impact, the bracket is sheared off. A typical crash test vehicle is shown in Figure A.2 just prior to an experiment.

Vehicle ignition and brake controls and on-board data signals are fed to the control building by means of a tether line which trails the test vehicle. The tether line is fastened to the car with a weak link. In case the tether is inadvertently severed during a test, the ignition is automatically cut and the brakes locked.

A.4 DATA ACQUISITION

On-Board Systems

Lateral and longitudinal accelerometers are attached to the vehicle frame at the right rear seat floor panel 9 feet from front of vehicle. Transverse, longitudinal and vertical peak "g" meters are attached in the same vicinity and serve as a back-up system. Critical vehicle components are monitored during a test by means of strain gages, load cells and/or deflection sensitive devices. Special instrumentation, pecular to the crash tests, is designed and built at SwRI.

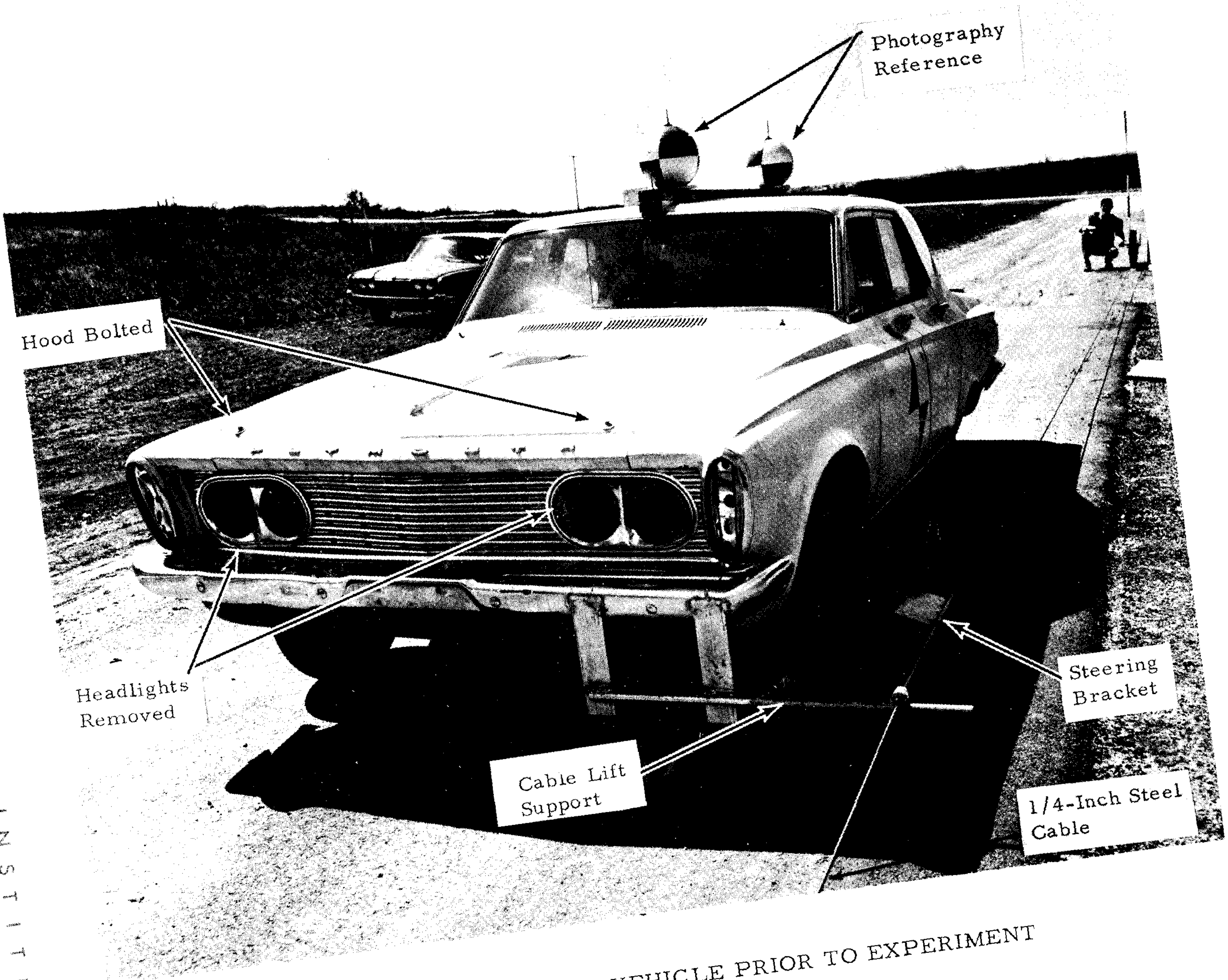


FIGURE A.2 TEST VEHICLE PRIOR TO EXPERIMENT

An anthropomorphic dummy is secured in the driver's position with lap belt and chest strap (Figure A.3). Lateral, vertical, and longitudinal accelerometers are contained in the dummy chest cavity. A high speed movie camera with "fish eye" lens is positioned in the vehicle to the dummy's right and slightly aft. Load cells are attached to the lap belt and chest strap and measure forces during impact environment.

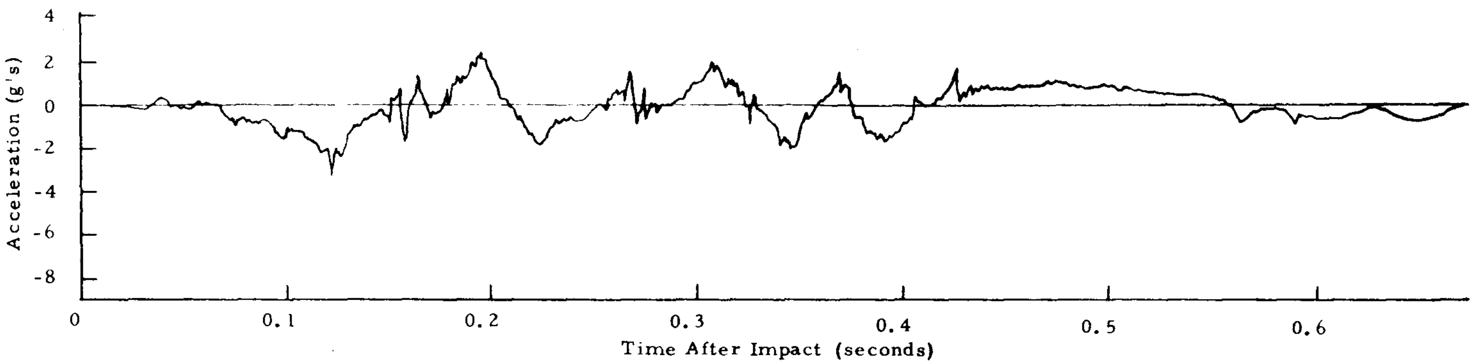
On-board signals are fed by means of a tether line to a high speed magnetic tape recorder located in the control building. A typical example of accelerometer data is depicted in Figure A.4.

Impact Site Systems

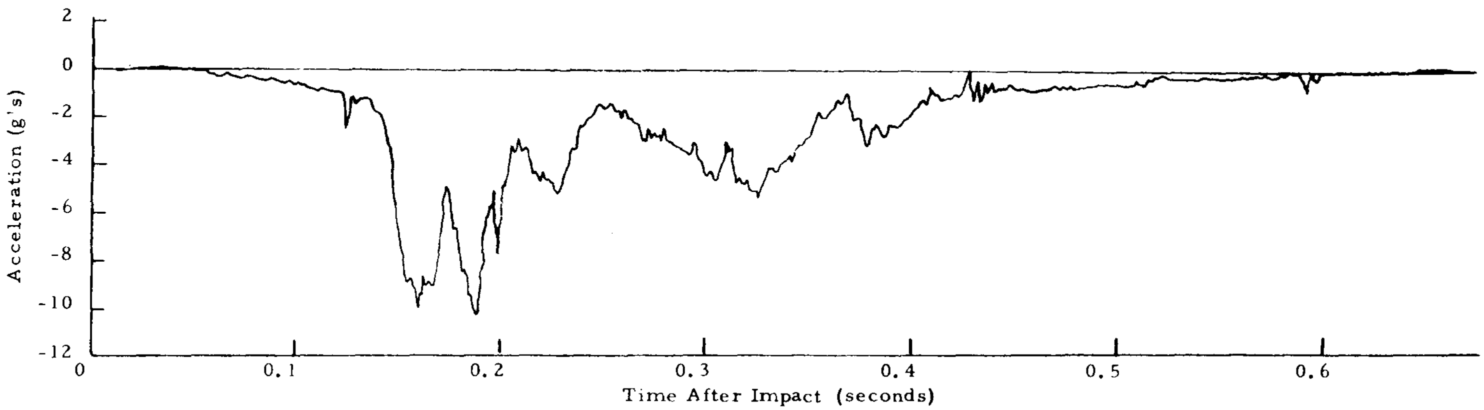
Camera coverage varies among tests; however, for the more extensively monitored experiments as many as six high-speed motion picture cameras are used. A typical camera layout is shown in Figure A.5. Impact events are recorded from three directions: along guardrail, normal to guardrail and overhead. Data camera speeds are usually set for 500 to 1000 fps. Real-time, documentary camera coverage is also provided for most tests. Before and after testing, still photographs are taken of the more significant test details, and the damage sustained by the vehicle and test object. Example of photography taken after a test is shown in Figure A.6.

Test articles (e.g., guardrail components, sign posts, etc.) are instrumented with strain and deflection measuring devices. Signals from these gages are fed to the magnetic tape recorder in control building and integrated with signals from the vehicle.

FIGURE A.3 ANTHROPOMORPHIC DUMMY SECURED IN CRASH VEHICLE PRIOR TO TEST

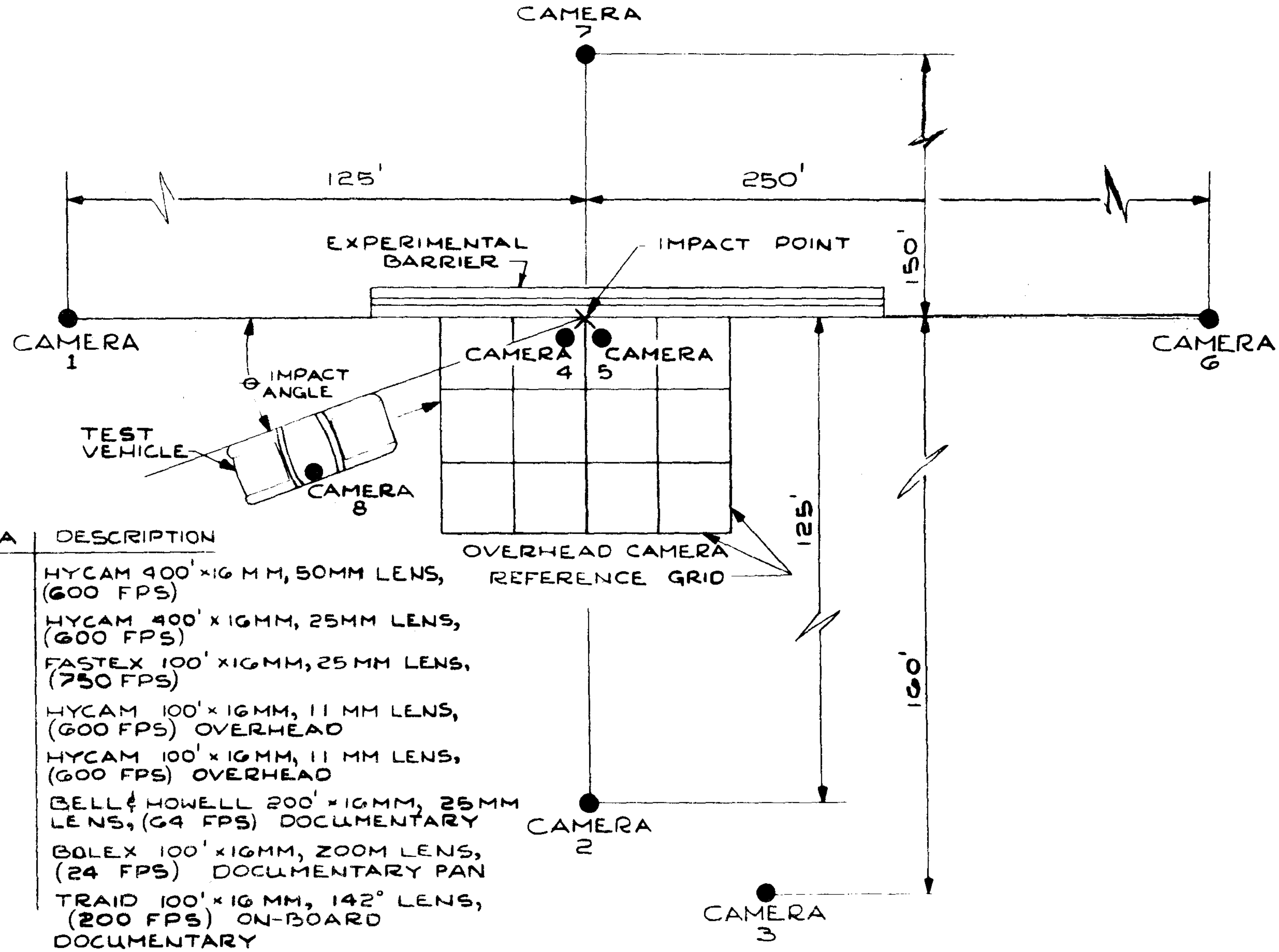


(a) Trace of Vertical Accelerometer in Dummy Chest Cavity



(b) Trace of Transverse Accelerometer in Dummy Chest Cavity

FIGURE A.4 TYPICAL ACCELEROMETER DATA FROM GUARDRAIL TEST

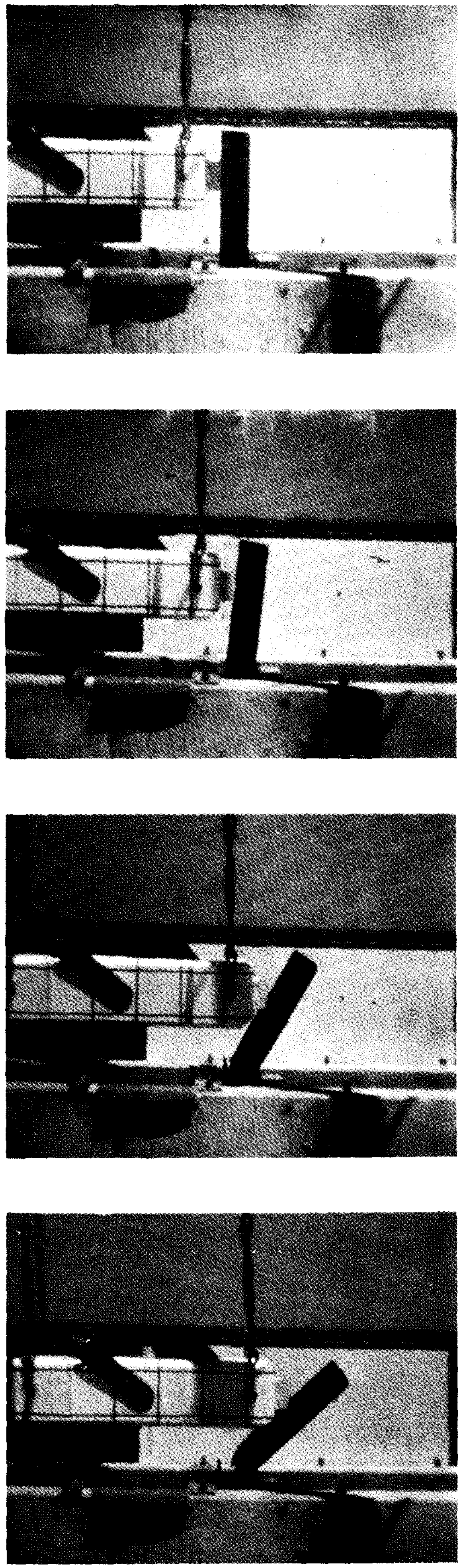


CAMERA	DESCRIPTION
1	HYCAM 400' × 16 MM, 50MM LENS, (600 FPS)
2	HYCAM 400' × 16MM, 25MM LENS, (600 FPS)
3	FASTEX 100' × 16MM, 25 MM LENS, (750 FPS)
4	HYCAM 100' × 16MM, 11 MM LENS, (600 FPS) OVERHEAD
5	HYCAM 100' × 16MM, 11 MM LENS, (600 FPS) OVERHEAD
6	BELL & HOWELL 200' × 16MM, 25MM LENS, (64 FPS) DOCUMENTARY
7	BOLEX 100' × 16MM, ZOOM LENS, (24 FPS) DOCUMENTARY PAN
8	TRAID 100' × 16 MM, 142° LENS, (200 FPS) ON-BOARD DOCUMENTARY

FIGURE A.5 TYPICAL CAMERA POSITIONS FOR CRASH TEST

FIGURE A.6 DAMAGE TO TEST VEHICLE AND GUARDRAIL

PENDULUM IMPACT TEST FACILITY



SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO HOUSTON

FACILITY DESCRIPTION

The SwRI Pendulum Impact Test Facility is designed especially for large-scale impact tests of materials, structures, and vehicular components. The facility will accommodate pendulum weights up to 10,000 pounds. Impact velocities range up to 40 feet per second at accuracy within one percent of the programmed value.

Data acquisition sensors include strain gage and piezoelectric accelerometers, a photocell-operated "speed trap," and high-speed movie cameras capable of framing rates up to 11,000 frames per second. A control station immediately adjacent to the pendulum structure houses a full range of data retrieval and storage equipment, including a CEC VR-3300 Data Tape Recorder and a Honeywell 906 C Visicorder. For experiments requiring the simultaneous recording of signals from an array of sensors, two Leach MTR-3200 Recorders are available with a capacity of 22 analog and 225 multiplex channels of data.

Facility software includes a unique computer program for reducing data from high-speed movies to complete time-displacement, velocity, and acceleration histories of an impacted test article. In addition, a computer program is available to process the multiplexed data through (a) analog to digital conversion, (b) demultiplex, (c) scaling, (d) data reduction, (e) strain gage rosette analysis, and (f) plotting of results.

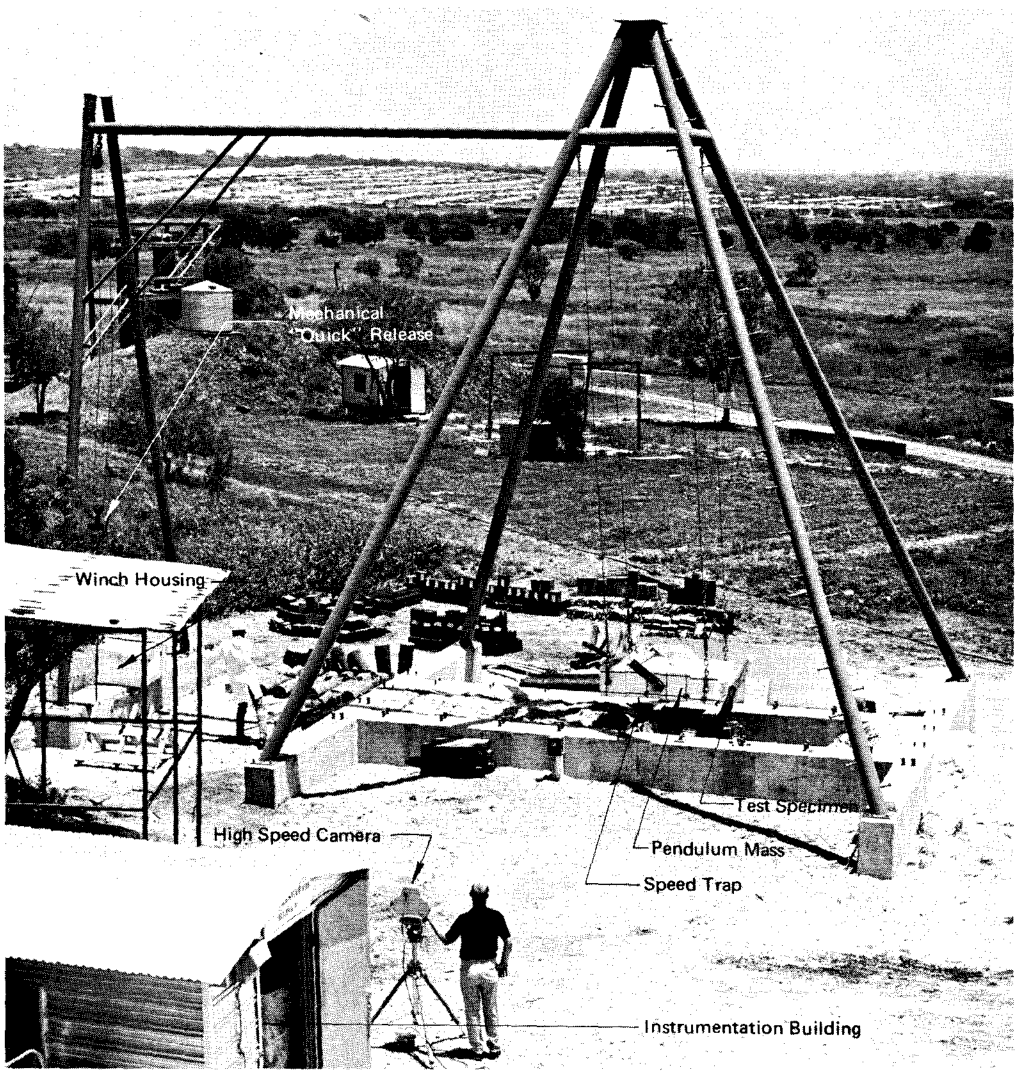
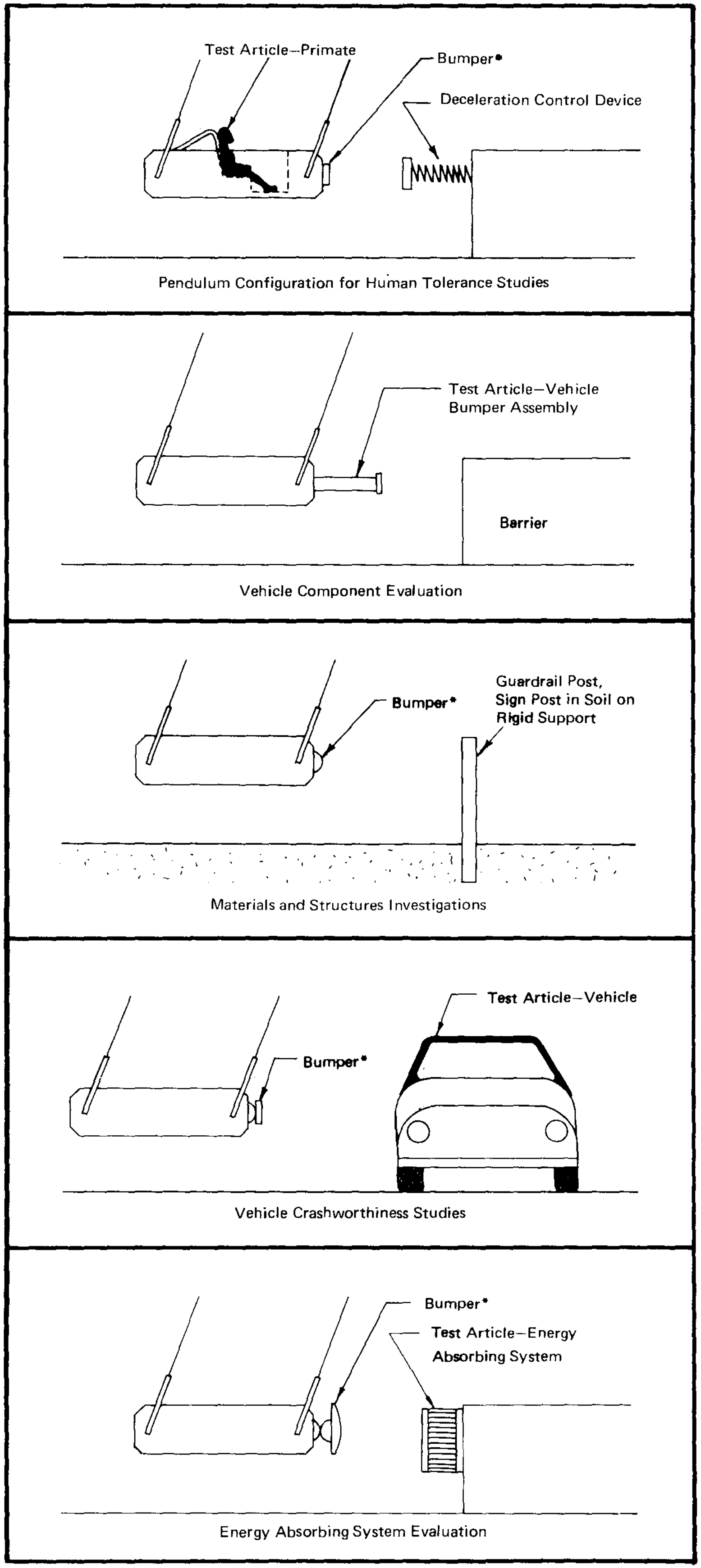


Figure 1–SwRI pendulum impact tester



*Bumper configuration determined by application.

Figure 2–Example applications

CAPABILITIES

The SwRI Pendulum Impact Test Facility provides a precise and repeatable dynamic energy source that is adjustable to specific test requirements. Fundamental simplicity of the Facility and its operation result in an efficient device that can provide experiment capabilities for research experiments and "proof-testing" studies. Typical applications include:

- Investigative experiments for highway appurtenances such as guardrail posts, breakaway lighting and sign supports, and impact absorbing devices.
- Developmental studies for testing of automotive components such as bumpers, energy absorbing systems for bumpers, doors, roof structures, head and torso restraint systems, safety glazing materials, etc.
- Experimental analyses concerned with the dynamic response of structures and materials to large impulsive loads.
- Studies of soil dynamics; for example, embedded posts subjected to lateral dynamic loads.
- Performance evaluation testing of packaging materials.
- Data acquisition tests for establishing or verifying human tolerances to crash environments.

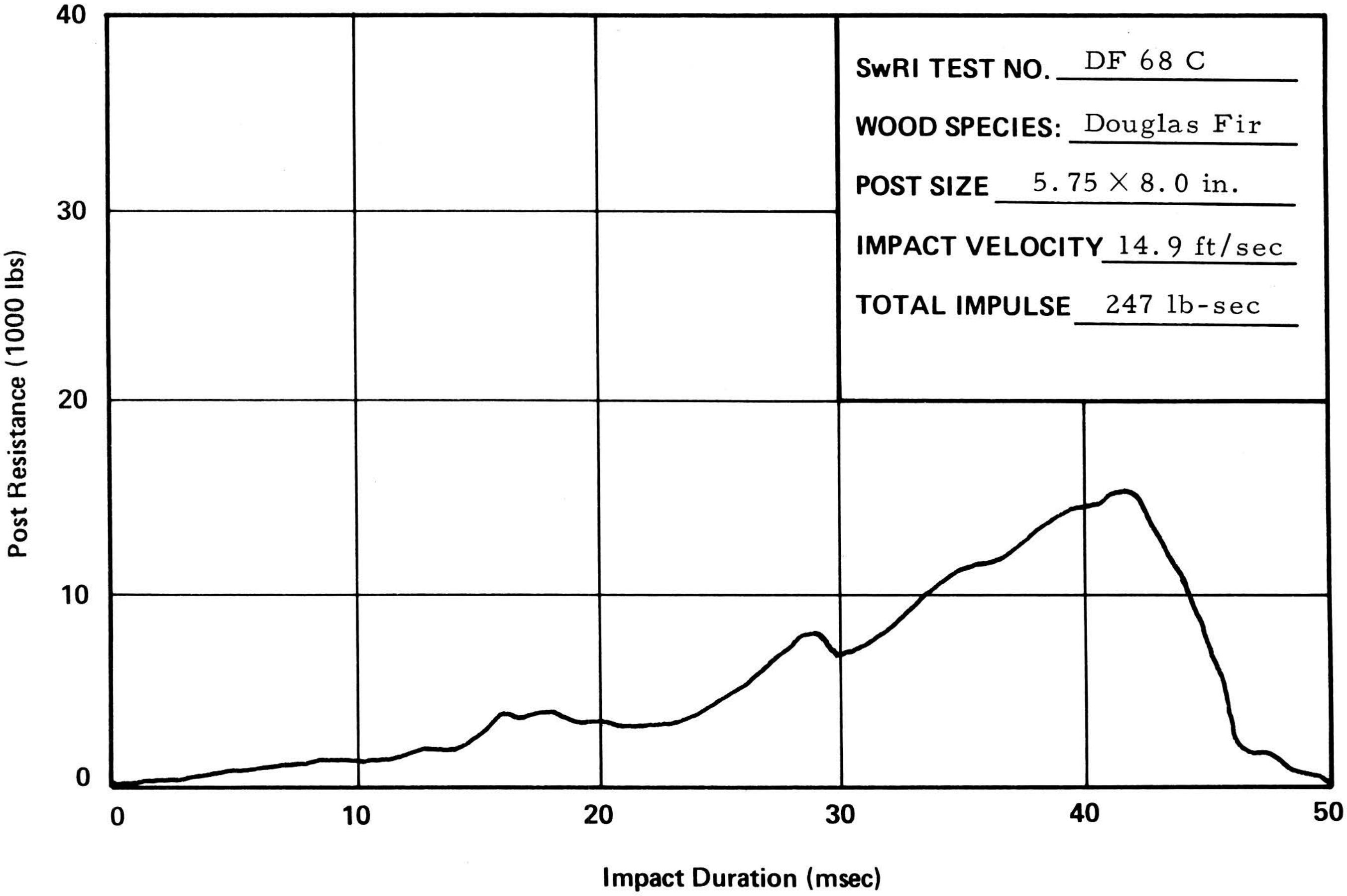


Figure 3–Typical impact trace

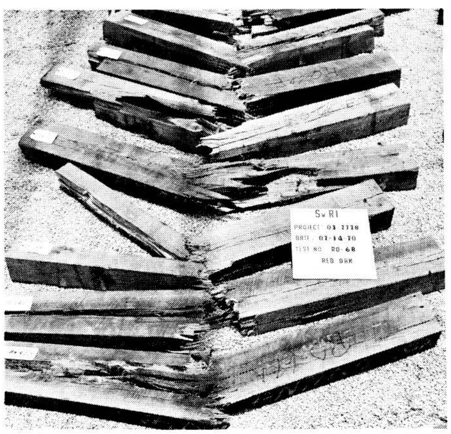


Figure 4–Wood post test sequence

Figure 5–Steel post test specimen

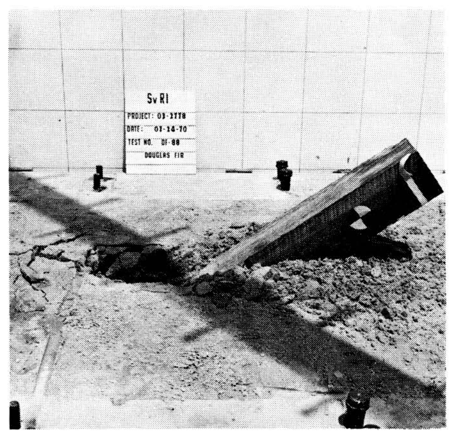


Figure 6–Wood post in soil

For information, please write or call:

J. D. Michie, Group Leader
M. E. Bronstad, Senior Research Engineer
L. U. Rastrelli, Assistant Director
Department of Structural Research
Southwest Research Institute
8500 Culebra • Area Code 512, 684-2000
San Antonio, Texas 78228

APPENDIX B

SOUTHWEST RESEARCH INSTITUTE
RELATED ORGANIZATIONAL AND EXPERIENCE INFORMATION

B.1 INSTITUTE ORGANIZATION

Southwest Research Institute is a nonprofit corporation organized under the laws of the State of Texas to serve government, industry, and individuals in the fields of applied research, development, and engineering. Present employment exceeds 1000, of whom approximately one-third are professional scientists and engineers involved in direct technical work. The professional staff have degrees from more than one hundred colleges and universities, including a number of doctorates in special fields of science and engineering.

The Institute does not engage in production manufacturing, although it is particularly well qualified to perform development work and provide one of a kind or prototype quantities of various type devices, instruments and systems. Because of its inherent lack of dependence on production type contracts, the Institute is able to provide totally unbiased services with respect to the analysis, evaluation, selection and recommendations of various techniques and equipments.

Southwest Research Institute performs research and development in a wide variety of technical fields. This is partially illustrated by the titles of the various research departments. These include:

Aerospace Propulsion Research
Applied Economics
Applied Physics
Automotive Products and Equipment Research
Chemistry and Chemical Engineering
Electronics and Electrical Engineering
Engines, Fuels and Lubricants Evaluation
Materials Engineering
Mechanical Sciences
Ordnance, Fuels and Lubricants Research
Physical and Biological Sciences
Structural Research

A research team selected to attach a specific problem will be assembled to include professional personnel from several departments and from outside sources as required. All of the Institute's professional personnel are available for consultation on any program, although direct assignment to a program must be coordinated with other work in progress. Outside consultants in special areas are also under contract and can be used to supplement the Institute's capabilities.

Although the personnel from a number of the Institute's departments have backgrounds of experience related to the technical program, the technical activities most closely allied with these requirements are primarily concentrated in the Department of Structural Research. For this reason, a detailed description of the technical activities within this department is presented in the following section.

B.2 DEPARTMENT OF STRUCTURAL RESEARCH

The Department consists of structural designers and engineers, materials engineers, scientists and architects who specialize in structural theory and analysis. This staff conducts studies, surveys, investigations, evaluations, and tests and, from techniques of fundamental theory and analysis, develops basic criteria and designs of both a general and specific nature related to structural systems, equipment, and buildings. The general scope of endeavor includes regional and architectural planning analysis; construction criteria and design analysis; structural system and building design and evaluation; space and equipment criteria development and evaluation; and fire technology.

The experience and capabilities of the Department cover the entire theoretical, analytical, design, and experimental spectrum of structural research and development. The training and experience of its engineers and scientists provide a well-rounded capability in the utilization of mathematical theories, computational and analytical procedures, and the experimental techniques required for the solution of structural problems.

Past and current programs concerned with the behavior of structures that are subjected to repetitious and/or transient, mechanical and thermal loads account for a large portion of the Department's activities. Studies where the material's characterizations are employed to mathematically define the manner in which structural elements deform, are demaged and eventually fail as the result of impulse or cyclic loads, thermal shock, sustained elevated temperature environments and/or cyclic temperatures are currently being accomplished.

The Department has achieved a position of special competence in the field of structural dynamics. Its experience includes the development of new theories and methods of analysis, the application of these and other analytical procedures to design problems and the undertaking of unique experimental investigations. Extensive experience has been acquired in analytical and experimental studies of transient pressures on various types of aerospace structures. Methods have been developed for predicting the vulnerability and the hardening requirements for aircraft, helicopters, boost-glide vehicles, and a variety of tactical missiles together with their ground support equipment.

In the field of structural mechanics, studies are being undertaken in such areas as dynamic response of elastoplastic and plastic plates and shells. In other analytical and experimental programs, the failure susceptibility of aerospace structures is being investigated. The effects of environments and time-dependent loads on submarines and surface vessels (hulls, superstructures and equipment) and on high-performance, nuclear power plant pressure vessels, piping and equipment are also being studied.

Other studies have been concerned with the development of realistic failure and damage criteria for a variety of structural configurations and materials. Investigations were conducted to quantitatively define the possible modes of failures, the permissible degree of damage a structure can sustain (without negating its future serviceability, repairability and/or recovery) and the catastrophic or critical failure criteria.

Qualified personnel, experienced in all commonly used, as well as the infrequently used, techniques of experimental stress analysis are available. Electric resistance and mechanical types of strain gages are commonly used experimental tools. The birefringent coating techniques are used for dynamic or static analyses. Closely associated with birefringent coating analysis are the photoelastic techniques. The brittle coating method is commonly used to determine the isoentatics, the principal stress trajectories, and to qualitatively determine the individual principal stress.

The Department is particularly well qualified and experienced in conducting programs requiring the experimental acquisition of structural response data. This includes the design of instrumentation systems to effectively measure transient pressures, forces, temperatures, strains, and displacements.

The design, fabrication, and experimental analysis of structural models are other areas in which the Department is proficient. Accordingly, considerable knowledge and experience has been gained in ascertaining the limitations and capabilities of model systems.

APPENDIX C

SOUTHWEST RESEARCH INSTITUTE PROFESSIONAL RECORD SHEETS

ROBERT C. DEHART
Director, Structural Research

B.S. in Civil Engineering, University of Wyoming, 1938
M.S. in Civil Engineering, Illinois Institute of Technology, 1940
Ph.D. in Civil Engineering, Illinois Institute of Technology, 1955

Dr. DeHart is a former member of and consultant for several Department of Defense committees. He is the author of approximately 40 papers on structural mechanics, pressure vessels, piping, and fatigue. Dr. DeHart is a research executive, specializing in applied mechanics, pressure vessel research and development, and underwater and air shock phenomena. He has been active in submersible research and development and has participated in various phases of the design and development of vehicles such as the Aluminaut, Deep Jeep, Alvin, Deep Quest, Beaver, DSSV, DOWB, and Deep View.

PROFESSIONAL CHRONOLOGY: Design engineer, Standard Oil Company of Indiana, 1950-6; associate professor of civil engineering, Montana State College, 1946-51; research engineer, Illinois Institute of Technology, 1951-2 (on leave from Montana State); Armed Forces Special Weapons Project, 1953-8 (structural analyst, 1953-5; aeronautical research engineer, 1955-8); Southwest Research Institute, 1958-(manager, structural mechanics section, 1958-9; department director, 1959-).

Memberships: Sigma Xi, American Society of Civil Engineers, Tau Beta Pi, Sigma Tau, and Phi Kappa Phi.

Rev Sep/69

LEONARD U. RASTRELLI
Assistant Director
Department of Structural Research

B.S. in Civil Engineering, University of Illinois, 1947
M.S. in Civil Engineering, University of Illinois, 1948

Since joining the Institute staff, Mr. Rastrelli has been involved in the planning and directing of basic and applied engineering programs concerned with aerospace and land-based structural systems and components, and the more effective utilization of advanced materials. His experience includes the structural application of fiber-reinforced, sandwich construction and plastic concrete materials from the viewpoint of design and analysis methodologies for technically and economically effective operational systems. Such programs are concerned with the behavior of structures under service loads and environments including, for example, the effects of accumulative fatigue, cyclic and blast loadings and elevated temperatures, and appraisals of structural integrity for such elements as solid propellant grains, aircraft and highway vehicle tires, landing gears as well as highway joints, guardrails and structural appurtenances. Most of Mr. Rastrelli's programs are characterized by an iterative process involving design and analyses, laboratory model-simulation experiments, and full-scale field test verifications. As a co-inventor, he has several patents and patents pending in the general area of internal strain measuring methods for rubberlike materials. His special field is structural mechanics and structural system analyses.

PROFESSIONAL CHRONOLOGY: Inspection engineer, Standard Oil Company, Indiana, 1948-50, University of Wichita, 1950-8 (assistant professor and acting head, Department of Civil Engineering, 1950-3; associate professor and head, 1953-8; consultant to Office of Naval Research, Beech Aircraft Corporation, Boeing Airplane Company, and R. S. Delameter, consulting engineer); Southwest Research Institute, 1958-(senior research engineer, 1958-61; manager, special projects section, department of structural research, 1961-7; assistant director, 1967-).

Memberships: American Society of Civil Engineers, National Society of Professional Engineers, American Society of Engineering Educators, and American Institute of Aeronautics and Astronautics.

Rev Jan/68

JARVIS D. MICHIE
Senior Research Engineer (Group Leader)
Department of Structural Research

B.S. in Civil Engineering, University of Texas, 1955
M.S. in Civil Engineering, Louisiana State University, 1961
Graduate Work in Mathematics, St. Mary's University, 1963-

Mr. Michie's professional experience includes the structural design and analysis of large industrial, commercial and public buildings, structural foundation design and soil mechanics, as related to slope stability of highway embankments and settlement prediction of structures founded on unconsolidated soils.

At Southwest Research Institute, he has managed programs involving material properties at elevated temperatures and the study of viscoelastic behavior of solid propellant grains; in the latter program, an elastomer strain gage was developed and patented. He has performed research on new high-strength plastic concrete materials, and has developed and experimentally verified a system for constructing deep underground structural chambers. In the transportation field, he has managed an indepth study of the design and performance of highway guardrails; the program involved theoretical characterization of vehicle-guardrail interactions and the performance of full-scale crash tests. Mr. Michie coordinated the writing of a guardrail and median barrier design manual (NCHRP Report 54) which received extensive distribution in the United States.

PROFESSIONAL CHRONOLOGY: Research assistant, hydraulic group, civil engineering department, University of Texas, 1954-5; commissioned officer, U. S. Navy, 1955-7; design engineer, structural design group, Ethyl Corporation, 1957-61; design engineer, Ezra Meir and Associates, 1962; Southwest Research Institute, 1962-(associate research engineer, department of structural research, 1962-3; senior research engineer, 1963-9; group leader, 1969-).

Memberships: American Society of Civil Engineers, National Society of Professional Engineers, Tau Beta Phi, Chi Epsilon.

Rev Feb/70

MAURICE E. BRONSTAD
Senior Research Engineer
Department of Structural Research

B. S. in Architectural Engineering, University of Texas, 1961
Graduate Studies in Engineering Mechanics, University of Texas

With experience in both aerospace and civil engineering applications, Mr. Bronstad has been practicing in the field of structural engineering since 1961. His responsibilities have included the structural design of highway bridge structures, using a variety of materials and concepts. As a stress engineer, he was responsible for load derivations and stress analyses on both commercial and military rotary wing aircraft, radar antenna systems, aircraft ground support equipment, precision camera mounts, and armament systems. Experience at the Institute includes participation in experimental and aircraft flight test programs and preparation of design guides for both aerospace and civil engineering applications. His recent experience in the highway safety field included the design of new structures and the performance of full-scale vehicle crash tests of highway guardrail systems.

PROFESSIONAL CHRONOLOGY: Engineer, bridge division, Texas Highway Department, 1961-3; stress engineer, electronics and space division, Emerson Electric Company, 1963-5; structures engineer, Bell Helicopter Company, 1965-7; Southwest Research Institute, 1967-(research engineer, department of structural research, 1967-9; senior research engineer, 1969-).

Rev Feb/70

GEORGE K. WOLFE
Research Engineer
Department of Structural Research

B.S. in Aeronautical Engineering, California State Polytechnic College, 1966

Mr. Wolfe has acquired varied experience in aerospace hardware design and development in the areas of preliminary and detail designs, structural analyses and developmental testing. He has performed design and research studies in such areas as rotating machinery, automated production machinery, liquid and gaseous oxygen tanks for Ramjet engines and inlet control systems for supersonic fighter aircraft. While at SwRI, Mr. Wolfe has assisted in the performance of full-scale vehicle crash tests of highway guardrail systems, with particular emphasis in data and film analysis.

PROFESSIONAL CHRONOLOGY: Engineering draftsman, Douglas Missile and Space Systems Division, 1965-6; member of technical staff, The Marquardt Corporation, 1966-7; member of advanced technical staff, The Marquardt Corporation 1967-70; Southwest Research Institute, 1970-(research engineer, department of structural research, 1970-).

Rev Mar/70

THOMAS E. HAWKINS
Senior Research Analyst
Department of Electronic Systems Research

B.S. in Engineering, U.S. Coast Guard Academy, 1949
M.A. in Government, George Washington University, 1964
Graduate Study in Public Administration,
George Washington University, 1965-

Mr. Hawkins is an experienced systems analyst with academic training in both engineering and administration and has held the rank of Commander in the U.S. Coast Guard. Twenty years of experience as an active commissioned officer has provided Mr. Hawkins with a broad background in systems analysis, including specialized experience in program planning and control, system requirements and effectiveness analysis, operations research, and management information systems. His major fields of graduate study are administrative theory and practice, financial management, computer technology, and political science. Mr. Hawkins is currently a dissertation candidate for the professional degree of Doctor of Public Administration. At Southwest Research Institute, Mr. Hawkins will be involved in the application of quantitative techniques and computer technology to the solution of complex problems of government and industry.

PROFESSIONAL CHRONOLOGY: Commissioned officer, U.S. Coast Guard, 1949-69 (junior officer assigned to duties entailing oceanographic and meteorlogical data collection, maritime safety, and aids to navigation, 1949-58; electronic aids to navigation, 1958-62; commanding officer, 1962-3; full-time graduate student, 1963-4; long range planning and program analysis, 1964-9); Southwest Research Institute, 1969-(senior research analyst, department of electronic systems research, 1969-).

Memberships: Operations Research Society of America; American Society for Public Administration.

Sep/69

THEIN WAH
Staff Scientist
Department of Structural Research

B.S. in Civil Engineering, Rangoon University (Burma), 1941
M.S. (C.E. - Structures), University of Utah, 1948
M.S. (C.E. - Applied Mechanics), Harvard University, 1949
Ph.D. (Engineering), University of Illinois, 1953

A former faculty member of Lehigh University and the University of Connecticut, Dr. Wah is recognized in the field of structural theory. He is a specialist in elasticity and structural design and analysis. His experience has included construction, design, analysis, teaching and research, thus encompassing several facets of engineering activity. He is the author of numerous theoretical papers in the special areas of linear and nonlinear vibrations, thermal stress, creep, and the analysis of discrete field problems. His articles have appeared in the Journal of Applied Mechanics, Journal of Aerospace Sciences, Aeronautical Quarterly, ASCE Proceedings, Journal of the Society for Industrial and Applied Mathematics, Journal of Ship Research, International Journal of Mechanical Sciences, Journal of the Acoustical Society of America, Journal of the Mechanics and Physics of Solids, International Association for Bridge and Structural Engineering, International Journal of Solids and Structures, Journal of the Franklin Institute and others.

Dr. Wah is a citizen of the United States and is listed in American Men of Science.

PROFESSIONAL CHRONOLOGY: Assistant engineer, Burma Railways, 1941-7; graduate research assistant, University of Illinois, 1950-1; designer, Bureau of Bridges, Illinois Division of Highways, 1952-3; assistant professor of civil engineering and mechanics, Lehigh University, 1953-4; assistant professor of civil engineering (promoted to associate professor, 1957), University of Connecticut, 1954-7; Southwest Research Institute, senior structures research engineer, department of structural research, 1957-61; visiting professor, Indian Institute of Technology, 1961-2; Southwest Research Institute, 1962-(staff scientist, department of structural research, 1962-).

Memberships: American Society of Civil Engineers, American Society of Mechanical Engineers, American Society of Engineering Education, American Association for the Advancement of Science, Society of Engineering Science and RESA.

Rev Jul/65

GERALD J. OVERBY
Research Engineer
Department of Structural Research

B.S. in Civil Engineering, University of Texas, 1968

Mr. Overby has had experience in manufacturing processes, job cost estimation and scheduling, and profit planning. This includes manufacturing knowledge of nuclear instrumentation, electromechanical components, and marine industry hardware. Since coming to Southwest Research Institute, his experience includes airframe structural analysis, studies of the mechanical properties of composite materials, and determination of automobile structural response to restraint systems.

PROFESSIONAL CHRONOLOGY: Production manager, Nuclearay Inc., 1968-9; manufacturing manager, Nuclearay Inc., 1969; Southwest Research Institute, 1969-(research engineer, department of structural research, 1969-).

Mar/70

APPENDIX D

CONTRACTUAL DATA

SOUTHWEST RESEARCH INSTITUTE
CONTRACTUAL INFORMATION
COST-PLUS-FIXED-FEE PROPOSAL

SwRI Proposal No. __________
Purchase Request No. ____________________

Southwest Research Institute is a nonprofit corporation organized in the public interest and existing under the laws of the State of Texas, with its general offices at 8500 Culebra Road, San Antonio, Texas 78228. Laboratories are maintained at San Antonio, 3600 Yoakum Boulevard, Houston, Texas 77006, and 406 Belden, Corpus Christi, Texas 78403. The Institute presently employs approximately 1100 full-time scientists, engineers, technicians, and service personnel.

The Defense Supply Agency, Defense Contract Administration Services Office, 7071B San Pedro, San Antonio, Texas 78216 has been assigned responsibility for administration of Department of Defense contracts. The agency having cost cognizance on all Government contracts awarded this Contractor is the Defense Contract Audit Agency, San Antonio, 7077 San Pedro, San Antonio, Texas 78216.

Contractor's current financial statements are filed quarterly with the Defense Supply Agency, the audit agency, and the Directorate of Procurement, Headquarters, Air Force Systems Command, Andrews Air Force Base, Washington, D. C. 20331, who has been assigned cognizance under the program for the coordinated negotiation of overhead rates.

The accounting policies and procedures of the Institute and employee salary rates and ranges are reviewed and approved on a current basis as acceptable for Government cost-type contracts.

It is desired that a cost-plus-fixed-fee contract be provided with costs determined in accordance with the Armed Services Procurement Regulations, Section XV, Part 2. In accordance with current approved procedures, direct labor cost includes provision for vacation, holiday, and sickness costs at 12% of the cost of direct salaries and wages. A final negotiated overhead rate of 100.28% of regular staff direct labor cost has been established for fiscal year ended September 30, 1967 on the basis of actual cost by the cognizant audit agency. The overhead rate for fiscal year ended September 28, 1968 has not been established. The Government approved provisional overhead billing rate based on audit of current cost incurred and projections is 110% of direct labor cost. However, cost projections are made by the Institute on a periodic basis, and any expected variation from the approved provisional rate is reflected in the cost estimate.

The approved policy of the Institute with regard to reimbursement for transportation and other travel expenses is limited to the actual reasonable cost incurred. Subsistence expenses are limited to the actual cost of lodging and related tips plus the actual cost, not to exceed an average of $12.00 per day, for meals, related tips and other subsistence expenses. Transportation by personal and/or Institute-owned automobiles is reimbursed at $0.10 per mile as representing the actual cost of such transportation.

Government financing to the extent of current payments on account of allowable costs as provided in the clause entitled "Allowable Cost, Fee and Payment" in accordance with Paragraph 203.4 of Section VII of the Armed Services Procurement Regulations is requested.

The fixed fee, in the case of the Institute is paid not only for the "know-how," which it is in a position to furnish, but for the growth and expansion of the organization which has been set up primarily for the public good through scientific progress and as a specific service to the Government, industry, and the public generally. The Institute, a nonprofit organization, does not have the capital structure to provide for expansion outside of the fee received for work performed, and nominal contributions from interested individuals and organizations. Experience has proven that funds must be available to expand facilities, and also procure new and replace obsolete equipment, in order for the Institute to keep abreast with the latest in scientific development. The fixed fee proposed in this instance has been determined with due consideration given to factors set forth in ASPR, Section III, Par. 808.

This proposal shall remain in effect not longer than ____________ days from date of presentation. This proposal constitutes an offer and, if accepted by a Notice of Award placed in the mail addressed to Southwest Research Institute, will form a binding contract on the terms covered by this proposal. It is agreed that any such Notice of Award will be replaced at a later date by a definitive contract bearing the same date as the Notice of Award and containing the details of the agreement between the parties.

Personnel to be contacted for any negotiations required on this procurement:

Contractual:

Mr. S. H. Birgel, Sr. Contract Administrator, Area Code 512, 684-2000, Ext. 755,
Mr. D. D. Belto, Assistant Treasurer, Area Code 512, 684-2000, Ext. 231,
Mr. Andrew Khourie, Treasurer, Area Code 512, 684-2000, Ext. 307

Technical:

Contractual Information - Continued
Cost-Plus-Fixed-Proposal

Contingent Fee Statement

Bidder represents: (a) That he has not employed or retained any company or person (other than a full-time bona fide employee working solely for the bidder) to solicit or secure this contract, and (b) that he has not paid or agreed to pay to any company or person (other than a full-time bona fide employee working solely for the bidder) any fee, commission, percentage or brokerage fee, contingent upon or resulting from the award of this contract, and agrees to furnish information relating to (a) and (b) above as requested by the Contracting Officer. (For interpretation of the representation, including the term "bona fide employee," see Code of Federal Regulations, Title 41, subpart 1-1.5 (April 1966)(August 1967).

SOUTHWEST RESEARCH INSTITUTE

By ______________________________

Title ____________________________

Date ____________________________