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An Overview of Operation Breakthrough Guide Criteria

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An Overview of Operation Breakthrough Guide Criteria

Edward O. Pfrang
Building Research Division
Institute for Applied Technology
National Bureau of Standards

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ABSTRACT

A discussion of the reasons for the Operation BREAKTHROUGH team's development of performance criteria; an elaboration of the philosophical basis upon which the BREAKTHROUGH Guide Criteria were developed; and a discussion of the background which led to their establishment. Also discussed are the general format used for the criteria and an example of how the criteria can be implemented in the evaluation process leading to certification.

Operation BREAKTHROUGH is a program sponsored by the Department of Housing and Urban Development designed to overcome the nation's acute housing shortage and to stimulate industrialized housing as a means of meeting this goal. The initial phase of Operation BREAKTHROUGH has now been completed. Housing System Producers have been selected; and the criteria which they must follow in developing and constructing their housing systems have been developed. These criteria - largely performance in nature - were developed by a team of experts from the National Bureau of Standards (NBS) in cooperation with specialists from the Department of Housing and Urban Development (HUD) along with a special committee of the National Academies of Science and Engineering. This report is concerned with the process and philosophical basis for the development of the BREAKTHROUGH Guide Criteria and outlines their organization and content.

If all the housing systems proposed under Operation BREAKTHROUGH had been conventional in nature, it is doubtful that the BREAKTHROUGH team would have bothered to develop performance criteria at all. However, many of the solutions which were proposed involved significant innovations which could not readily be evaluated on the basis of existing codes and standards. Thus, at the very beginning of the program it became evident that a performance basis would be required for the evaluation of these systems.

Codes are generally prescriptive in nature and component oriented. For example, they might require that 2" x 4" wood studs be spaced 16 inches on center. The BREAKTHROUGH Criteria, on the other hand, are, so far as the present state of the art permits, performance based and systems oriented. For example, BREAKTHROUGH criteria require that the total building system be capable of resisting a wind load of 90 mph. Of course, the wind speed is a site-dependent variable. Another factor which distinguishes BREAKTHROUGH criteria from present codes is that codes are concerned primarily with the areas of health and safety. However, since Operation BREAKTHROUGH aims at the production of housing which is not only safe but also of improved quality, the criteria must be considerably broader in scope - i.e., they cover not only health and safety, but also liveability and durability. A second reason for this is the innovative nature of the solutions which are being considered under BREAKTHROUGH. Conventional solutions automatically provide certain levels of liveability and durability. But, with innovative systems, there is no implicit, time-proven guarantee that these same levels of liveability and durability will be obtained. Thus the Guide Criteria specifically address themselves to a much broader range of requirements than do codes and attempts to make explicit the acceptability of quality performance.

Let us now examine the philosophical basis which was used in developing the BREAKTHROUGH criteria. In the area of health and safety, we aimed at achieving at least that level which is <u>intended</u> in present codes. Note that the emphasis is placed on intended. In many cases, code writers intend certain kinds of performance, but in the translation to prescription language, this desired performance is not necessarily achieved. Since the BREAKTHROUGH criteria were written directly in performance language, it was possible to review the state of the art and to call for the kind of performance that was intended rather than that which is generally achieved in practice. Throughout we tried to establish the best balance of performance possible, if it was reasonable to make trade-offs from one attribute of a system to another, we took advantage of these opportunities.

Where there were targets of opportunities which could be achieved both technically and economically, these were incorporated. One such opportunity was in the area of smoke detectors. BREAKTHROUGH criteria call for the introduction of smoke detectors on a much broader base than is presently called for in most code jurisdictions.

We also tried to establish a greater emphasis on life safety. All too frequently in the past, there has not been sufficient emphasis placed upon the lives of the inhabitants of housing. In this area we introduced requirements concerning flame spread and smoke generation.

Finally, our criteria are characterized by the translation to quantification of many items not explicitly present in many codes. In any conventional solution, certain levels of performance are automatically achieved, even though these are not specifically called for in the codes and standards pertaining to housing. This is a safe policy when only conventional solutions are being considered; however, Operation BREAKTHROUGH covers innovative as well as conventional solutions. Since we wanted to make sure that the housing to be delivered under Operation BREAKTHROUGH was at least as good as that obtained by conventional solutions, we found it necessary to quantify many of the attributes which automatically derive from conventional solutions. One such example is the fire endurance of floors over crawl spaces in single family housing. Codes generally place no fire endurance requirement on such floors; however, all conventional solutions achieve at least 10 minutes of resistance. Therefore, this level of performance is called for until evidence becomes available which shows that such fire resistance is not needed.

In the areas of liveability and durability we set as our base that level which would be obtained through a conscientious execution of moderate-level conventional construction. Again, where targets of opportunity were within economic reach, we incorporated these. An example of such a target was in the area of acoustical isolation between dwelling units - where there is frequent complaint about the level of performance provided by conventional construction. The BREAKTHROUGH criteria provide specific performance levels for interdwelling walls. These are dependent upon the functions of the spaces involved. For example, between bathrooms a sound transmission class of 50 is required.

In the process of generating these criteria, every effort was made to avoid working in a vacuum. Our first priority was to study in detail the various codes and standards which were in use within the United States. We reviewed research reports, called upon consultants, brought in people from other laboratories, and in general, brought ourselves up as high on the learning curve as was possible within the present state of the art and within the time frame which was available. To further quantify the state of the art, we implemented laboratory and field tests to determine those levels of performance which one could expect from conventional construction.

Figure 1 shows the execution of a laboratory test

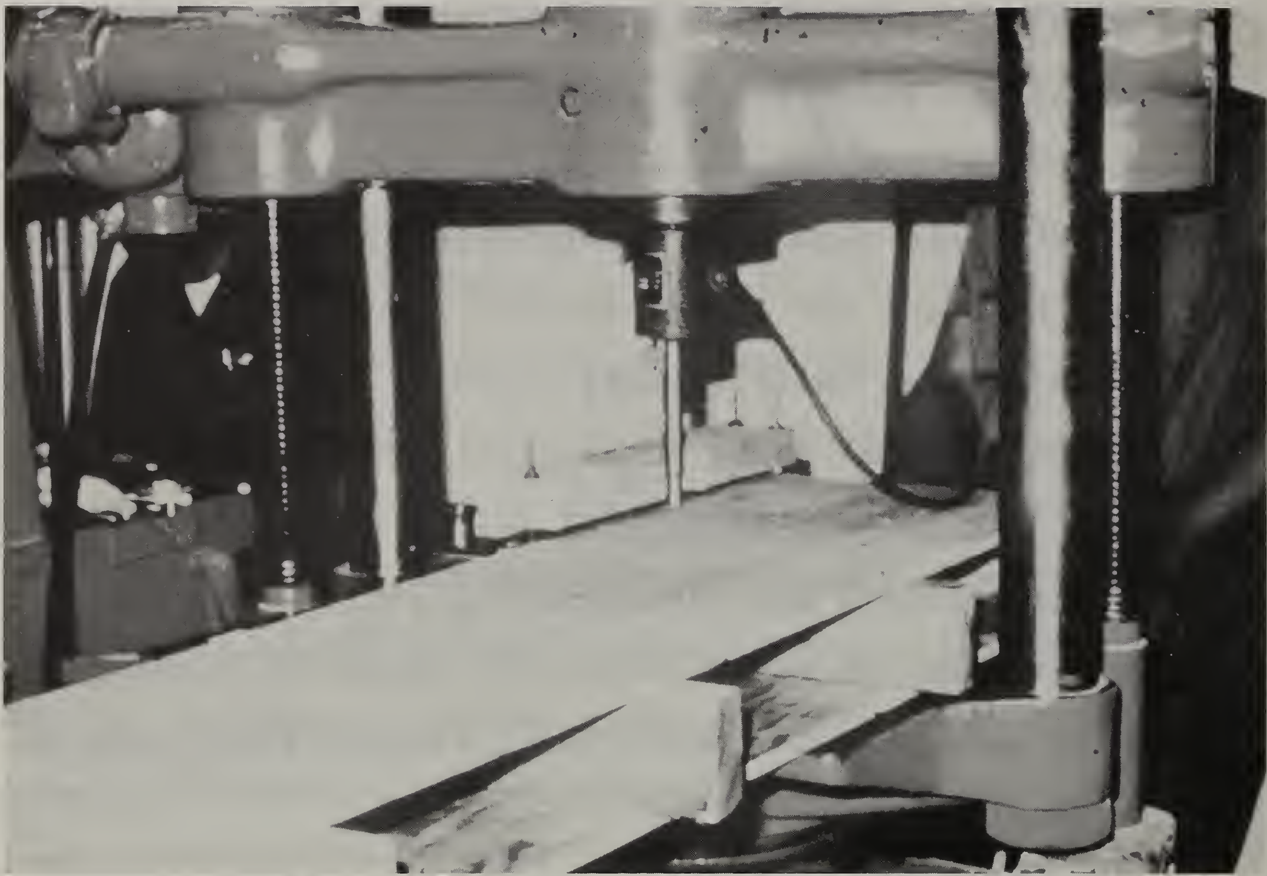

FIGURE 1 - Concentrated Load Test, Conventional Subflooring

concerning the ability of conventional subflooring material to resist the effect of concentrated loads. And, Figure 2 depicts a housing project not far from the Gaithersburg, Maryland, site of the National Bureau of Standards where we carried out some impact tests to determine the dynamic response characteristics of conventional floors. Figure 3 illustrates the test set-up for carrying out a dynamic response test in a furnished apartment.

While we at NBS were very much concerned with the quality of the BREAKTHROUGH criteria from a technical standpoint, HUD, recognizing that success of the program

FIGURE 2 - Townhouses, Montgomery Village, Gaithersburg, Maryland

FIGURE 3 - Dynamic Response Test of Conventional Floor

depends on acceptance of the certification process by responsible building officials, was carefully designing a process for the validation of the criteria. This process is depicted in Figure 4. In developing the criteria, NBS

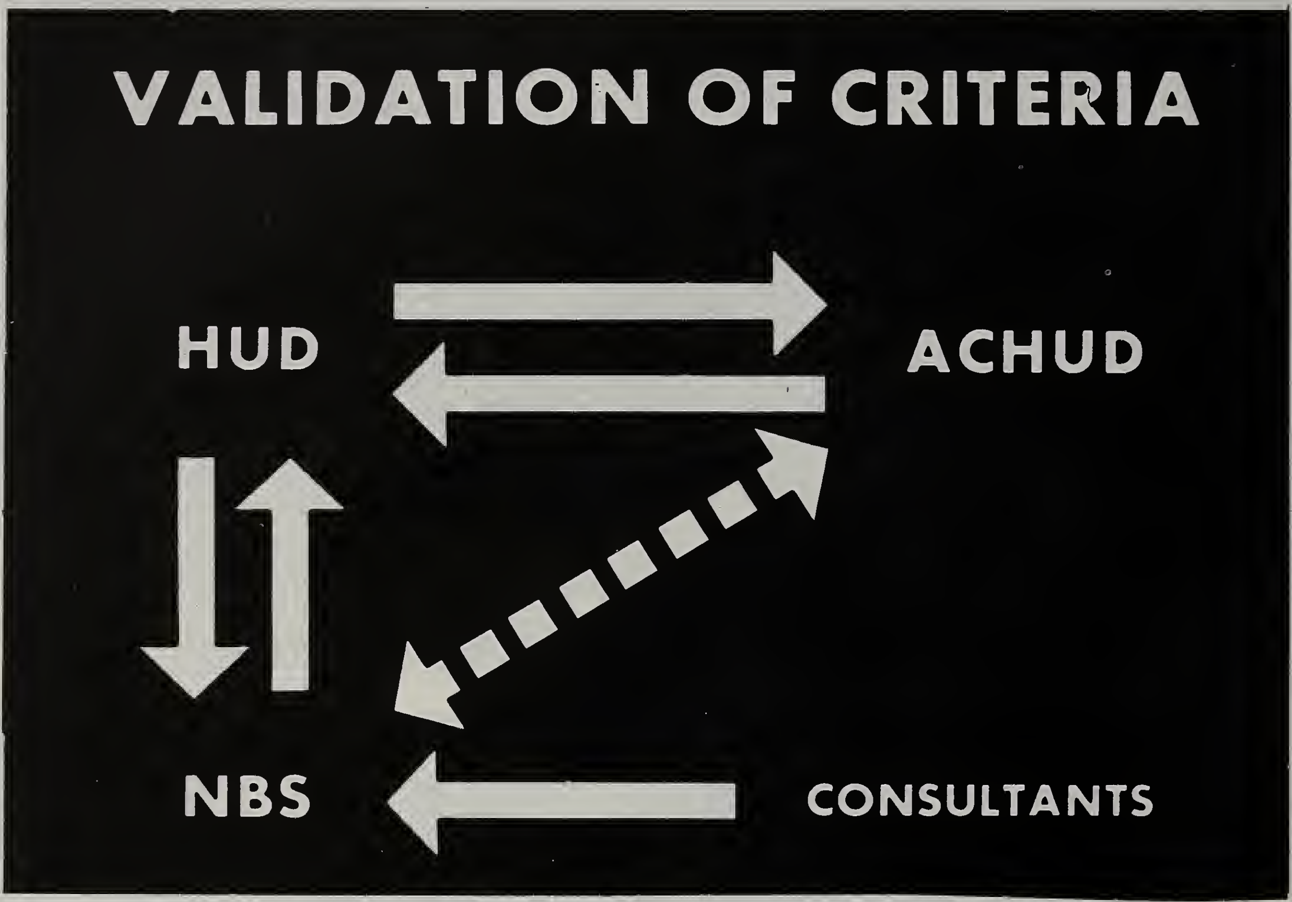

FIGURE 4 - Validation of Criteria

employed a number of consultants - representatives from other Federal laboratories and persons having expert knowledge of the voluntary standards process or with expertise in special areas. In order to assist in the validation process, HUD requested that the National Academies of Science and Engineering establish a special advisory committee. Such an advisory committee was established; it is generally known as ACHUD, or Advisory Committee to HUD of the National Academies of Science and Engineering. This committee was originally chaired by General Bernard Schriever and is currently chaired by Ambassador George C. McGhee. Under the Advisory Committee, there is a technical panel of distinguished experts chaired by Professor J. Neils Thompson of the University of Texas. The formal route established for the validation process was for NBS to generate criteria; transmit these to HUD for review; and finally, for HUD to transmit them to ACHUD for validation. In practice, however, an informal line of communication between ACHUD and NBS has developed and has been encouraged by HUD. While establishing the criteria, we found ourselves working in almost continual contact with the ACHUD Technical Panel. This relationship has permitted the expeditious development of the criteria and has resulted in a superior set of criteria. At this point in time (Feb. 1971), NBS has recommended to HUD certain criteria. These have officially been sent to ACHUD, and ACHUD in turn has validated them and recommended their use by HUD for Operation BREAKTHROUGH.

In developing the criteria, we found it advantageous to put together four separate volumes (Figure 5). Volume I covers Multifamily High-Rise; Volume II covers Multifamily Low-Rise; Volume III, Single Family Attached; and Volume IV, Single Family Detached. We felt that this four-volume format was the best way to accommodate the needs of the Housing System Producers and others who would be using the

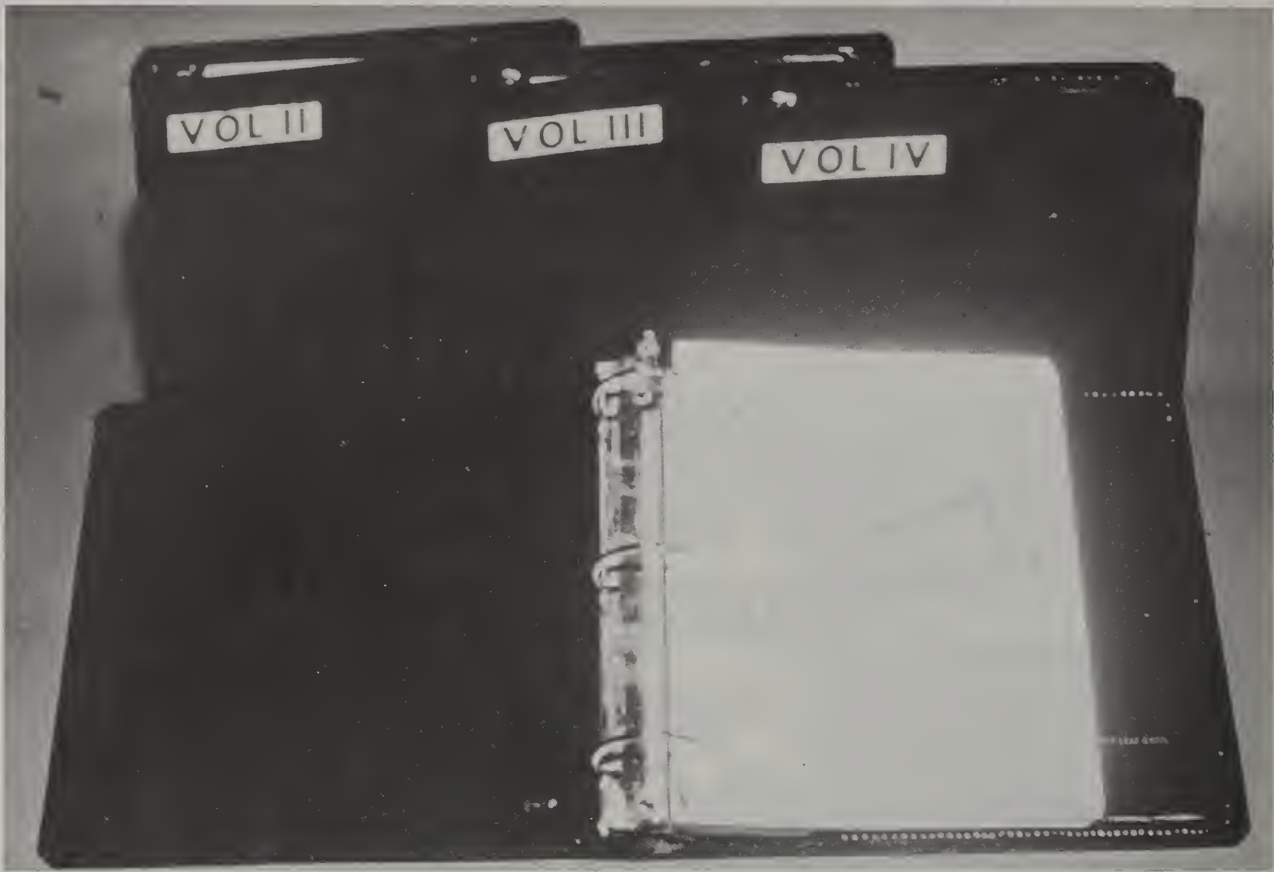

FIGURE 5 - Operation BREAKTHROUGH Guide Criteria

criteria. Thus far, these volumes have been left in loose-leaf form. The criteria are by no means final; they represent the best performance statements which are possible given the present state of the art. As better information becomes available, they will be continually expanded and improved. Several addenda have already been issued and others are in the process of generation.

One problem we encountered in the development of the criteria was that of formating or assembling. We studied the various model codes and found that, since they did not cover a range as wide as ours, the formating arrangement used therein did not lend itself particularly well to the accommodation of our needs. Thus we arrived at the use of the two-dimensional matrix as a convenient means of organization (see Figure 6). We found that by organizing the matrix in terms of built elements of the housing system versus attributes, we were able to index all the criteria conveniently. The built elements are lettered, and the attributes are numbered. Thus, for example, under Section H-5 of the criteria, one would expect to find all requirements and criteria relating to noise generated by plumbing.

Figure 7 shows a typical performance statement found in the BREAKTHROUGH criteria. Under Section A-1, which is structure and structural serviceability, we have a requirement which is a quantitative statement of what the user wants from the housing system. This particular requirement is that occupants should not experience discomfort as a result of horizontal movement under service wind load. The criterion, on the other hand, is a quantitative statement written in technical terms. Basically, this criterion states that at 9/10 service dead load and full service wind load, the horizontal movement of the building should not exceed 1/500 of its height. The criterion thus is a statement which permits one to make a determination as to the performance of the housing system.

The next item to be considered in the development of a performance statement concerns what tests are acceptable. The term "test" is used in its broadest sense to connotate

Continued on page 14

Built Elements			Attributes: 1 Structural Serviceability	2 Structural Safety	3 Health and Safety	4 Fire Safety	5 Acoustic Environment	6 Illuminated Environment	7 Atmospheric Environment	8 Durability/Time Reliability (Function)	9 Spatial Characteristics and Arrangement
	Structure	A									
Interior Space Dividers	Walls and Doors, Inter-Dwelling	B									
Interior Space Dividers	Walls and Doors, Intra-Dwelling	C									
Interior Space Dividers	Floor-Ceiling	D									
Exterior Envelope	Walls, Doors and Windows	E									
Exterior Envelope	Roof-Ceiling, Ground Floor	F									
	Fixtures and Hardware	G									
	Plumbing	H									
	Mechanical Equipment, Appliances	I									
	Power, Electrical Distribution, Communications	J									
	Lighting Elements	K									
	Enclosed Spaces	L									

For criteria relating to noise generated by plumbing refer to Section H5

FIGURE 6 - Guide Criteria Matrix

A. STRUCTURE

1. Structural Serviceability

Requirement. Occupants should not experience discomfort as a result of horizontal movement caused by story drift under service[1] wind load.

Criterion. At a load level of 0.9 service[1] dead load and 1 service wind load (0.9D + 1W), the horizontal drift due to the superimposed load of 1W is not to exceed the following limits: dh - 0.002h, in which h is the height above finished grade (ground outside building) or the interface between the building system and a separately-built basement, whichever is higher; dh is the lateral displacement at a story level (story drift).

Test. Analysis and/or physical simulation.

Commentary. Generally, a structure will experience its most severe lateral deflections under a condition of minimum gravity load and maximum lateral load and this criterion is designed to prevent excessive drift under such loading. There has been limited experience with high-rise apartment structures which indicates that when such structures are designed to permit lateral drift in excess of h/400 to h/500 under maximum service wind loads, discomfort is felt by some of the occupants during severe wind conditions. Even though human discomfort is probably related to motion, and therefore to the acceleration and the natural frequency of the building as well as to drift, this conservative criterion should be used until additional research is done in this field. In practice, many steel buildings are designed for a lateral drift of h/400 based on the bare structural frame. It is assumed that the stiffening effect of walls, partitions, cladding and other built elements will reduce the actual drift of these buildings to less than h/500.

No data from full-scale tests of conventional wood-frame construction are available at this time. Approximate analysis indicates that the combined stiffening effect of all walls, partitions, connections and cladding causes these structures to meet this criterion. The adequacy of this type of construction is confirmed by a history of satisfactory performance.

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[1]Service load is maximum load which has a recurrence interval equal to the useful life of the structure. In the absence of detailed statistical information, service loads are assumed to be equal to currently accepted "design loads."

FIGURE 7 - Example Performance Statement

the means for demonstrating compliance and can thus refer to engineering computation and analysis, prior documented experience or physical simulation. If there are ASTM or other standard tests which are applicable, these are referenced. However, for horizontal movement of buildings, there is no standard test. Thus we call for analysis and/ or physical simulation - either of which would be acceptable.

The final item which makes up a complete performance statement in the BREAKTHROUGH criteria is a commentary. Strictly speaking, this is not a necessary component of the performance statement. However, since Operation BREAKTHROUGH is an experimental program and since these criteria represent a translation of the most advanced state of the art, we found it desirable to state clearly the origin of the criterion and our degree of confidence in the performance levels or test methods specified.

It may be well now to look at what we consider to be the life cycle of these Guide Criteria (see Figure 8). The criteria were originally developed by NBS. They went to ACHUD, and ACHUD has since recommended the criteria to HUD for use in Operation BREAKTHROUGH. HUD has issued the criteria to the Housing System Producers (HSP's) for their guidance during the design and development portion of the program. During this process we have been working very closely with the HSP's. We have received valuable input in the way of feedback from them, and we are continually

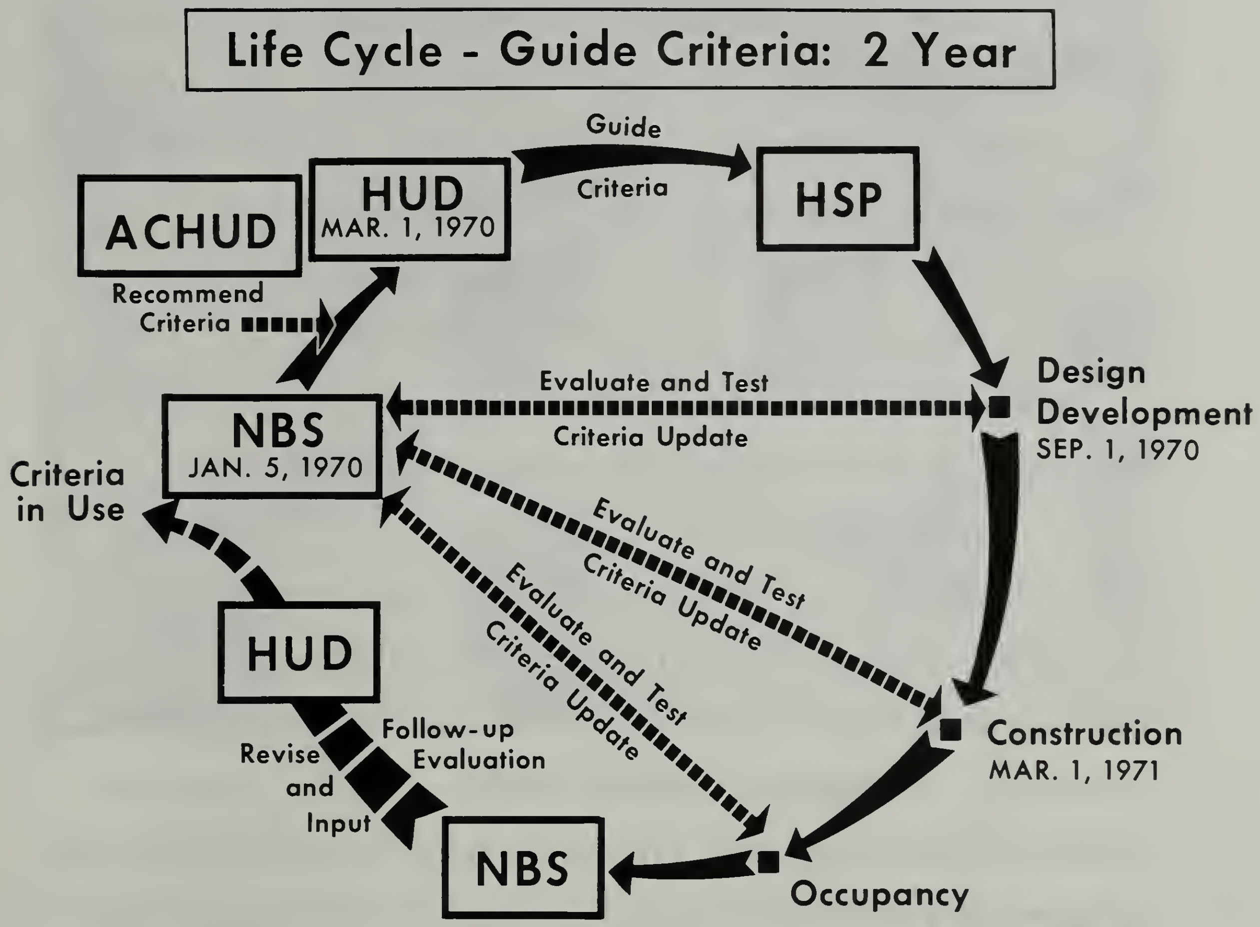

FIGURE 8 - Life Cycle - Guide Criteria

updating and improving the criteria on the basis of this feedback. We expect the same procedure to take place during the construction process. And, finally, during occupancy we expect a major feedback from a detailed documentation program of the performance of the housing systems. We expect to have very significant input as a result of this program, and we feel that, by the end of this period, we will have a set of Guide Criteria which will have received more study and examination than any performance document ever has in the building industry.

A point which should be made is that even at the end of the 2-year life cycle, the criteria will not be final or frozen. The criteria must be the subject of continual refinement and upgrading. However, we feel that after this 2-year development cycle, the criteria can function as:

(1) The basis for a continuing system for evaluating innovative housing solutions; and

(2) Major technical input for the development of future performance-based housing and other building codes.

In conclusion, the process which has been described herein can best be illustrated by an actual case history of how a system can and has been evaluated against performance criteria. The housing system shown in Figure 9 was proposed for erection in a large U.S. city several years ago as part of a HUD experimental program. The project was held up for over a year because the local building official did not have sufficient evidence upon which to base the issuance of a building permit. The building system in question used a lightweight precast, mechanically connected structural frame. It is normal practice for such a frame to be designed so that the frame itself (Figure 10) is capable of resisting all vertical and lateral loads. However, the designer of this particular system - realizing that, for every additional $100 expended for the system, there

FIGURE 9 - Industrialized Housing System

would be some 15,000 Americans who would be priced out of its market - took full advantage of the fact that his system was not merely a bare skeleton; it consisted of the frame plus the partition walls and exterior walls, which went to make up the total building. He relied upon this cladding of the building to provide most of his lateral load's resistant capacity.

The problem which was facing the local building official was whether or not this system was structurally adequate. The system involved the use of new materials and different fabrication techniques - innovations which definitely departed from the code. The National Bureau of

FIGURE 10 - Structural Frame

Standards' Building Research Division was consulted, and we recommended some type of performance evaluation. At first, approaching the problem in terms of an analysis of the system, we found the problem was so complex and the system so innovative that a precise analysis was not possible. An approximate analysis indicated that the structure was probably adequate. However, because there were still a number of unresolved questions relating to its overall behavior, we felt that physical testing was necessary. The structural performance criteria which we needed to evaluate for this particular system were, from a safety standpoint, its reliability against collapse; and from a serviceability standpoint, its static stiffness, its dynamic response and its freedom from distress under load. From the analysis performed on this system, we were confident that by testing a one-story module taken from the structure, we could properly simulate the behavior of an entire three-story construction. Thus, this one-story module depicted in Figure 11 was erected in our laboratory in Gaithersburg, Maryland. We used the actual structural components which

FIGURE 11 - Laboratory Model - Frame Only

were proposed for the system, and we also added the actual cladding materials which were to be used on the prototypes (Figure 12).

FIGURE 12 - Laboratory Model with Walls in Place

After the complete erection of the one-story module, we erected our test frames (Figure 13). Horizontally-acting hydraulic rams simulated the effect of wind loads on the three-story building, while vertically-acting rams simulated the column loads from above. The effect of uniformily distributed floor loads was simulated by using pneumatic air bags. Because the structure was tested in the laboratory, we were able to instrument it in considerable

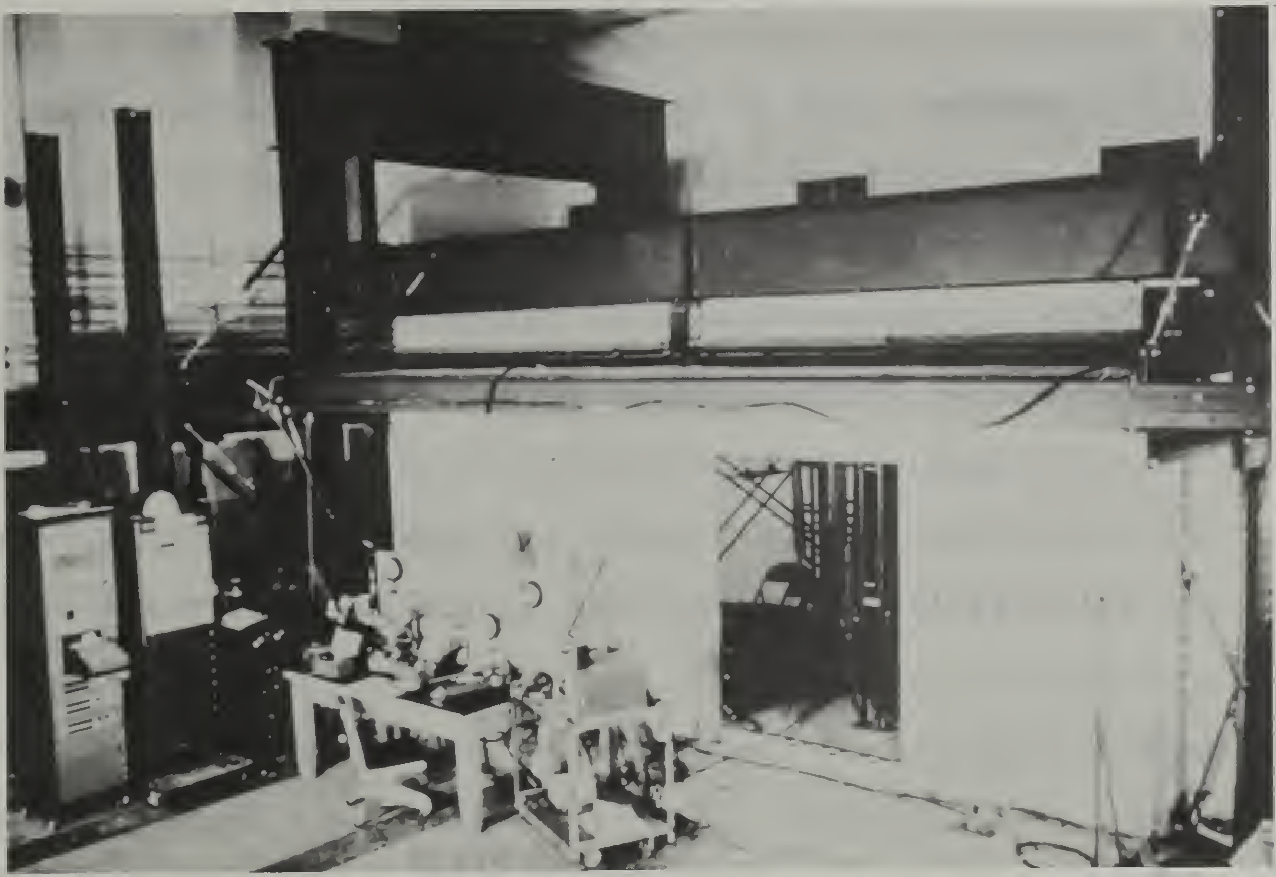

FIGURE 13 - Laboratory Model Ready for Test

detail and to document the total response of the building under a wide range of load conditions.

The code in the city in question called for the structure to have a capacity to resist a 90 mile per hour wind load. We tested for a simulated wind load of up to 150 mph, and even at that point, the structure was not exhibiting any signs of major distress. The module which was tested had an area within it of size equivalent to that of a typical living room which was 12 x 20 feet. The code required that a living room of that size, when all the safety factors were taken into account, be capable of resisting an applied load equivalent to 240 average-weight people. In our tests, we reached a load equivalent to 540 people without the structure's failing. One of the major issues concerning this housing system was the effectiveness of the partition walls and exterior cladding of the building in resisting load - primarily in the resistance of lateral loads. The first tests which we carried out were of the total structure with the walls in place; the results of this testing are illustrated by the solid curve in Figure 14. This response was quite satisfactory in terms of the criteria which has

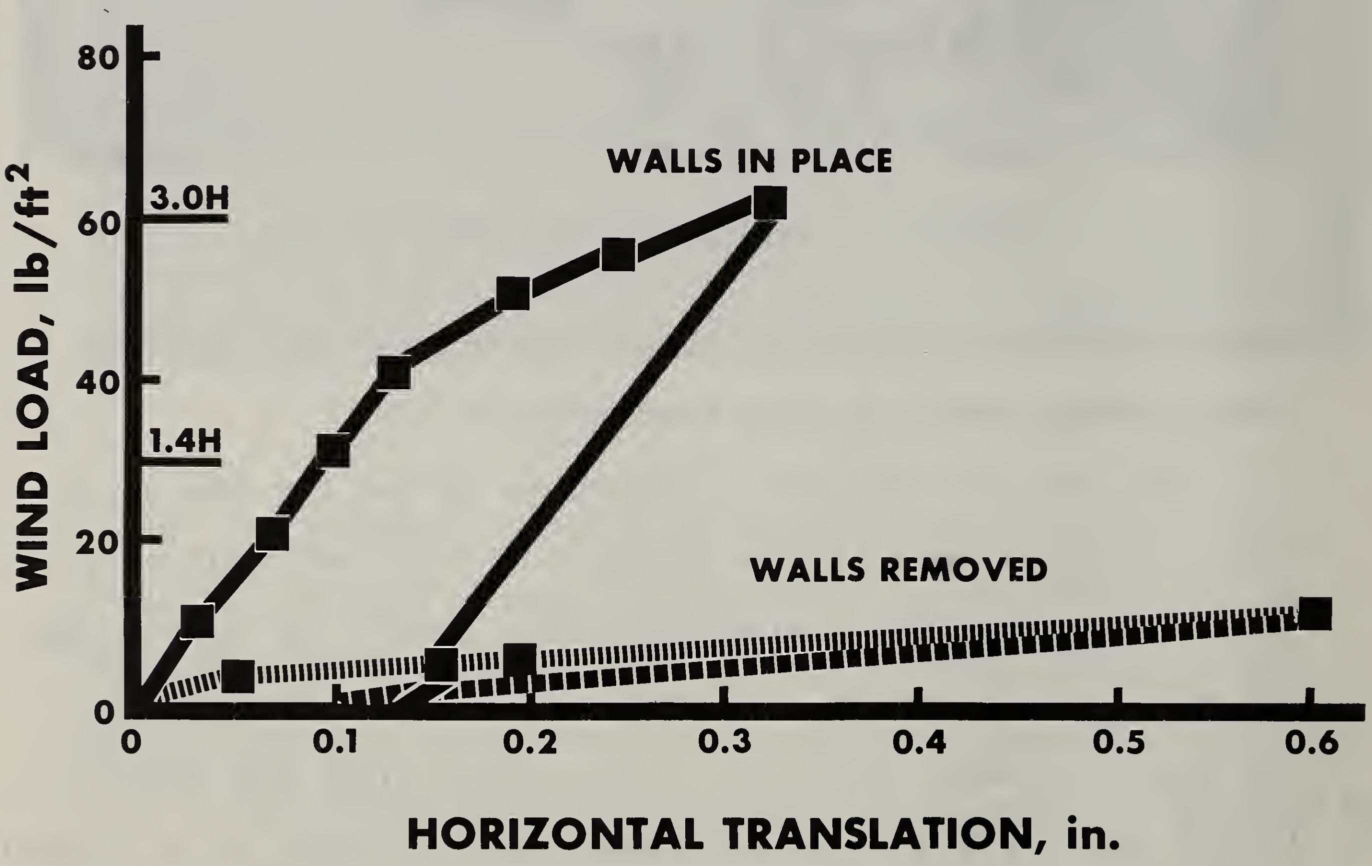

FIGURE 14 - Wind Load vs. Horizontal Translation

been set for evaluating the system. But, we were also interested in the actual influence of these walls and cladding material on the total response of the structure. Thus we removed all the cladding and wall material and tested the structure again. The lower response shown by the dashed curve was totally unsatisfactory. This testing is of special interest in that it shows the massive influence that normally-neglected cladding materials have on total system behavior. And unless one considers the totality of the system's nature of innovative housing solutions, he seriously errs in attempting to evaluate them. The period of time required for this testing was under three weeks, and we were able to deliver our final report concerning the performance evaluation of the system within eight weeks. Because this was the kind of documentation required by the building official in order for him to make his decision, in less than a week he was able to issue a building permit. However, due to certain non-technical factors, the system was never built in the city where it was originally proposed. But it has since been built in two other cities and the performance evaluation which was carried out formed the basis of acceptance in those cities. The obvious conclusion to be drawn from this anecdote is that carefully executed performance evaluation can indeed provide a vehicle of acceptance for the building official.

Operation BREAKTHROUGH is a phased program. The first step was the preparation of proposals, their evaluation, and the selection of the 22 Housing System Producers and the prototype sites. Phase I of Operation BREAKTHROUGH is the prototype design phase, and we are now reaching the end point of that particular phase. Phase II is prototype construction. Ground has been broken on all 9 BREAKTHROUGH Prototype Sites and site work is underway at this time (Feb 1971). Concurrently with Phases I and II, we are carrying out tests and evaluations of the housing systems. A considerable amount of this evaluation has already taken place, and a limited number of physical tests have been carried out or are underway. Before we recommend to HUD that any system be certified, it will be thoroughly evaluated; and where necessary, it will be adequately tested. In addition to this, the system's performance on the prototype sites will be thoroughly documented. In carrying out the evaluation and testing program on the 22 systems, we are following the lines of communication indicated in Figure 15. NBS is acting as the focal point for all testing and evaluation. We are using other laboratories and consultants as far as is possible. After thorough evaluation of a system, NBS will submit the results to HUD, and after HUD reviews these results, they will be communicated to the ACHUD Panel. There they will be validated and the final recommendation concerning certification will be returned to

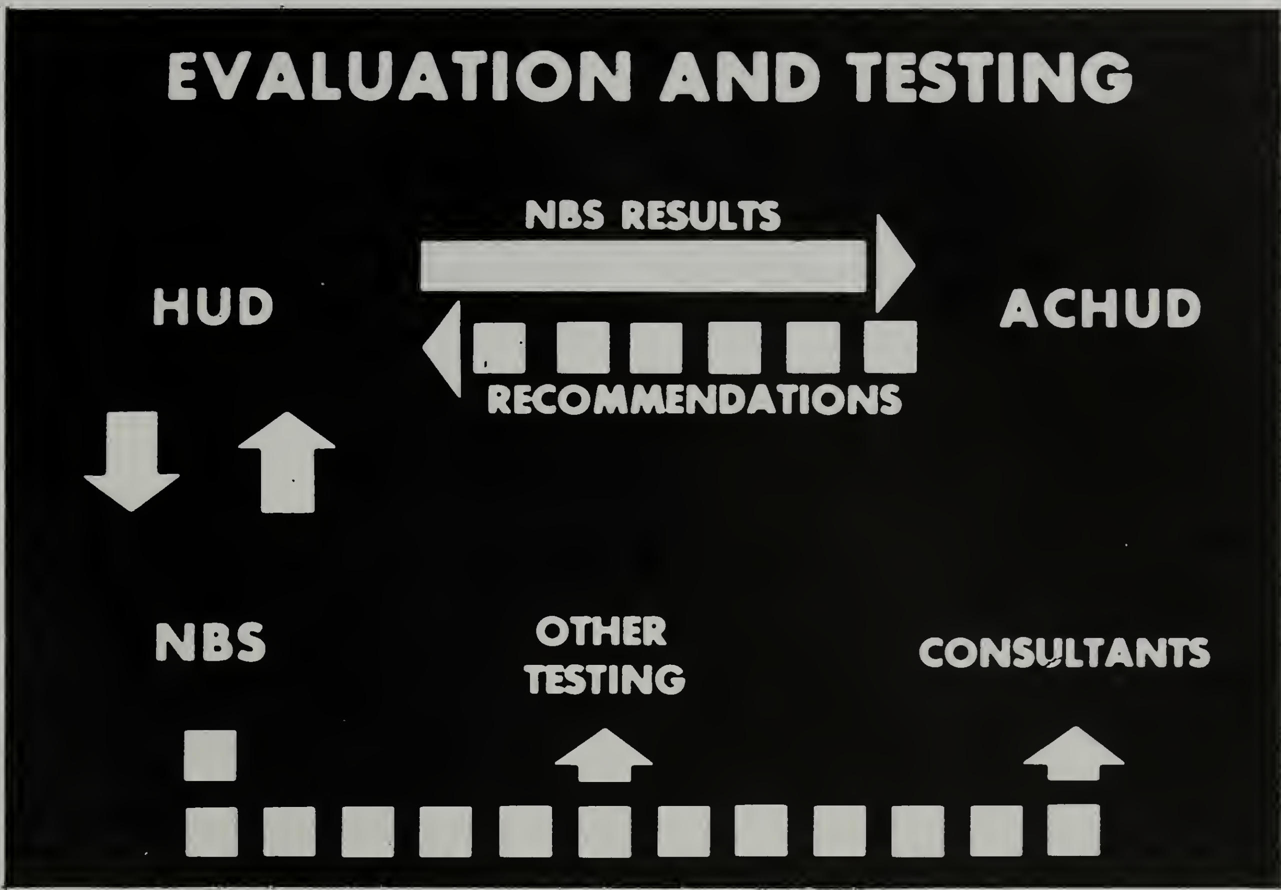

FIGURE 15 - Evaluation and Testing

HUD. At that point, if HUD has received an affirmative response from both NBS and ACHUD, the final certification report concerning the system will be issued. It is the opinion of those of us directly involved in BREAKTHROUGH that, by the time the building official, the consumer, the community and the lender are asked to accept a certified system, it will have been so thoroughly evaluated and documented that there should be little if any question regarding its acceptability.