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IMPROVING THE MUTUAL GUIDANCE AND SUPPORT BETWEEN THE FIELDS OF MATERIALS AND DESIGN

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Introduction

We have all heard a great deal about the need for increased interaction between materials people and design people, and it has often been said that what is really needed is "better communication" between materials people and designers. However, it has not always been clear just what this better communication should consist of, or how it would be accomplished.

What I will try to do here is to give some possible answers to this question by describing a few of the primary functions that interaction between the two fields might perform, and to indicate some possible mechanisms for helping to accomplish this. And let me hasten to add that the problem is by no means solved; there is still a great deal yet to be learned.

To begin, I do not conceive of the subject of design as being separate from the subject of materials, but rather as an extension of the same subject at a different level of abstraction. You could not take materials out of design any more than you could take the gold out of a solid gold ring.

Both the materials specialist and the designer work with materials, but with different sets of ground rules and objectives. In one sense, the designer's function regarding materials might be thought of as managerial, where he is attempting to manage the materials in such a way as to achieve a certain overall objective. To do this he needs both information and substance from the materials area — information in the form of materials characteristics and behavior, and substance in the form of the materials themselves. However, there are certain contributions he himself must make to the process of bringing the information and the materials into existence, and this is what I will concentrate on in this discussion.

The Problem of Developing Materials Information for the Designer

Let us consider first the interaction between the materials and design areas on the subject of obtaining materials information for use by the designer. This is an area that is important to technological accomplishment and one on which a great deal of time and money is expended.

Since the designer is the user of the information, it is of course up to him to say what information he needs. However, those of you who have had experience in asking the designer what he needs have undoubtedly observed that in those cases where he is able to be specific, he frequently requests a great deal more information than can be reasonably furnished.

Because it costs money and man-hours to get experimental information, there has to be a balance between what one wants and what one is able or willing to pay. If we look

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back for a moment at the analogy of the designer as a manager of materials, we could say that as part of his managerial responsibility he should consider carefully the expenditures that inevitably are associated with the acquisition of the information he requests.

We have to recognize that there are uncertainties that sometimes prevent the designer from knowing exactly what information to ask for. On the other hand, however, it is incumbent upon the designer to restrain himself from requesting everything for which he thinks there might conceivably arise a need. This is invariably too much.

Many of you undoubtedly are familiar with past attempts on the part of certain committee groups, representing the materials research community, to determine from structural designers what information was needed on the newer alloys that were then under development.

In one of these exercises, because the variables of temperature and time were involved in addition to the usual strength parameters, the list of "properties" that were requested by the structural design community was of such a magnitude that it was out of the question. There were not enough people or dollars to carry out the program, even if it had been thought desirable.

Undoubtedly one of the reasons for the magnitude of this particular list was that the designers were not sure at this time exactly which information they would eventually need for the final design. However, I think another major factor behind the tendency to ask for too much too soon is the failure to distinguish between the information required for exploratory or advanced design and the information required for detail design of hardware. This also raises a point concerning this hypothetical "designer" we talk about. It must be recognized that he is not one person with a single function, but rather is several people with several different functions in the design spectrum.

Exploratory design studies are continually being conducted in order to develop and evaluate new design concepts. These studies must of course use materials, which in many cases are new or projected materials; in order to design with a material, certain information must be obtained for design use.

However, the amount of materials information required for an exploratory design is much less than that required for a detail hardware design. And yet it seems to me that the mistake is often made of asking for detail design information on laboratory materials. Of course, even if it were possible to obtain this information it would not be useful for detail design because detail hardware design must in nearly all cases be based on production materials — not laboratory materials.

When the materials people are faced with, what to them appears to be an impossibly large request, they must pare it down somehow, and by this process they take on the function of deciding which parts of the total request are most important to the designer. Of course this is not a desirable situation. I am sure we would all agree that this function is the responsibility of the designer rather than the materials specialist.

What can be done to improve this situation? First, the materials people responsible for materials research planning should recognize that all designers do not wear the same color hats, and that the kind of information requested by a designer will likely be influenced by his particular area of the design spectrum. The list of required properties a detail designer would submit might be quite different from that submitted by a designer working on advanced design.

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So we should try to make sure that the design inputs to the formulation of each kind of materials research program comes from the appropriate design area. Further, when the designer requests materials information we should try to make certain that the final program decided upon accurately reflects his real needs. In this later regard, I do not see any substitute for the designer and the materials specialist sitting down together and discussing what is needed and what it is to be used for.

Need for New Materials

Next we might look at the question of the designer's needs and desires (I hesitate to use the word "requirements") for new and improved materials and at the question of how the designer identifies these needs and communicates them to the materials community.

Guidance from the design area on this subject is usually somewhat more vague than on the subject of materials information; valid conclusions are harder to come by, and the uncertainties are greater, both in the full identification of needs and in the probability of satisfying the needs. Obtaining test information on materials is a fairly straightforward process, and one in which results are pretty well assured. However, you cannot be certain that the time and money expended in materials research will necessarily yield the material you would like to have.

There are two primary dimensions to the guidance needed here from the designer: first, what does he need, and second, how important is the need? It seems to me that we do quite well on the first of these and not nearly so well on the second.

I think the designers do pretty well on identifying future materials needs and problems; relatively few of these are missed for very long. The place where improvement is needed is the area of determining relative values or importance among the various needs.

It is seldom that one sees recommendations that call for less research, or cancellation of research in some particular area. I think nearly all the recommendations I have seen call for new research or for an increased level of effort in some area.

However, since the materials research manager has a finite budget and finite man-power resources, he must make the decision as to which research programs to implement, and at what relative levels of effort. (And of course this is not a decision he makes once and for all, but he must be continually reviewing and adjusting the programs.) This boils down to the fact that some research programs are implemented and some are not. Now we come to the question of the role that information from the design area could and should play in this decision process.

Role of Generalized or Parametric Design Studies

One of the most important resources the designer has for generating information for materials research guidance is the properly-structured generalized design study, and I would like now to discuss some aspects of its use. Because there are several different kinds of generalized studies, we will illustrate the type we mean by use of a simplified example.

By use of parametric or generalized design techniques, we could, for example, design a generic family of glide-rockets and we could determine the total vehicle weights associated with various combinations of payload and range, as illustrated in figure 1.

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It is important to keep in mind that the vehicle, corresponding to any point on any of the lines of figure 1, has been optimized with respect to the design variables. The lines represent families of optimized vehicles. This is quite different from the optimization of a single vehicle for a specified mission.

One of the important parameters in our glide-rocket study is the maximum-allowable temperature of the leading-edge structure. If we want to study separately the problem of leading-edge materials, we can design a family of glide-rockets for a spectrum of (maximum) leading-edge temperatures, and thus isolate the effect of this parameter. This can give us information about the following:

1. What are the temperature-time ranges associated with this vehicle and what are the corresponding materials of interest?
2. How sensitive is the vehicle capability to the temperature capability of the leading-edge material?
3. How much must the material capability be improved (over current capability) in order to achieve a significant improvement in vehicle performance or efficiency?

By performing a similar exercise for various other important vehicle components, we can add a fourth item to the list:

4. In what areas is the capability of the vehicle most sensitive to changes in materials capability?

Each of the four items above has information of value to the question of planning materials research. If properly structured to answer these four questions, each vehicle design study that is carried out can furnish information not only about the feasibility and capability of the particular vehicle in question but also can furnish information of great value to the research function.

Taking the items in reverse order, Item 4 obviously helps to locate the areas where an improvement in materials will give the largest payoff. This is certainly relevant to the question raised previously concerning relative importance.

Item 3 is useful in setting minimum research goals, by showing what must be accomplished in materials research in order to achieve a specified level of improvement in the end item; this also helps in deciding which research program to undertake.

Item 2 is a special case of Item 3, and the type of information in Item 1 also helps to focus the area of inquiry in materials research by showing what ranges of parameters are of interest.

An example of the way in which one of the tradeoffs might appear is shown in figure 2, which plots vehicle gross weight as a function of allowable leading-edge temperature. For example, this curve shows the region of greatest sensitivity and also the level of achievement beyond which increasing leading-edge temperatures have very little payoff.

Obviously we cannot base our whole materials research program on only a few studies of this type; we must have many of these and on a continuing basis. At the present time there are large numbers of advanced design studies being carried on, but unfortunately for the materials research planner, few if any, of these studies are structured to give the kind of information discussed above.

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The reason that most advanced vehicle design studies do not now furnish this kind of information is that they are usually conducted with a different purpose in mind. They are generally asking the question "What is the best vehicle that can be designed to meet a specified set of performance requirements (assuming some level of the state of the art)?"

What happens here is that the system is designed and optimized for the specified performance or mission requirements. In a section called "Material Requirements" may be listed the materials capabilities required by this system. In essence, however, such a list is merely a restatement of the optimistic (called advanced state of the art) assumptions made in the study. I submit that this kind of information is of doubtful value in guiding materials research and development. Besides being misleadingly disguised as proper research goals, such a list of requirements may introduce an additional risk if the system performance depends critically on the achievement of these goals. This risk is that the more optimism we put into the assumptions, the greater the lead-time, the greater the uncertainty, and the greater the research and development costs we are likely to be automatically building into the system. These quantities should not be the result of assumptions concerning the state of the art— they should be the cause of these assumptions. Otherwise we have the cart before the horse.

The relationship of research goals to their corresponding cost, time, and uncertainty of attainment should be examined as carefully as possible; these quantities should be inputs into the decision process of what research to undertake and what state of the art to design a particular system for.

I am not saying that we shouldn't design advanced systems with advanced materials. We should conduct these design studies using a spectrum of materials capabilities (some of which are beyond the current state of the art). Then we have the basis for including, in our subsequent decisions relative to procurement of a particular vehicle, a proper consideration of the factors of lead-time, research and development costs, and the effects of achieving less than the full research goals. We can then see what the tradeoffs are and make the decisions accordingly. And consequently, by the way in which we design the vehicle, we can buy some insurance against the uncertainties of achieving certain research goals.

Overall Interactions

In conclusion I would like to show you a chart (figure 3), admittedly over-simplified, that illustrates some of the functions of the materials/design interplay that have been mentioned and their relationships to one another. This chart has been drawn to show particularly the role of generalized design studies in the materials/design interaction.

The contributions of the design area are depicted here in the blocks beginning with the advanced design studies and proceeding to the formulation of candidate research programs, which should be a joint function as indicated. The materials functions begin at this same block and proceed to the function of materials testing for advanced design information, which is also a joint function.

Although this chart separates the area of design function and materials function, this separation applies only to the question of primary responsibility for the various functions, not to the activities involved in the functions. For example, the design study is shown here as a design function, yet it certainly should have materials specialists on the design team. Likewise, there should be people from both areas participating in each of the activities shown in the various blocks.

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I think this chart is self-explanatory but there are two things I want to point out. One is the separation of testing for advanced design and testing for detail design that was discussed earlier.

The other thing I want to call attention to is the step going from the design studies to the formulation of candidate research programs for the materials research planner to consider. At the present time this is one of our major areas of inexperience. I think two things should be done to improve our handling of this area and to exploit an untapped potential that exists here.

First, there should be a few study activities conducted whose primary objective is to develop a methodology of structuring design studies to give the desired outputs discussed earlier and to explore and develop processes of converting these outputs into complete outlines of corresponding research programs. (The Air Force has recently given some attention to this subject and I would certainly encourage further action in this area.)

Second, when the methodology above has been developed to a point where it can be helpful, the Air Force should require wherever possible that funded design studies include, as an integral part of the study, the type of input-output relations discussed above that furnish the information needed for materials research planning.

I think this latter requirement would have a two-fold payoff: 1) it would furnish much-needed information for materials research, and 2) the increased attention to materials vs vehicle performance tradeoffs would result in a better vehicle design than one would obtain otherwise.

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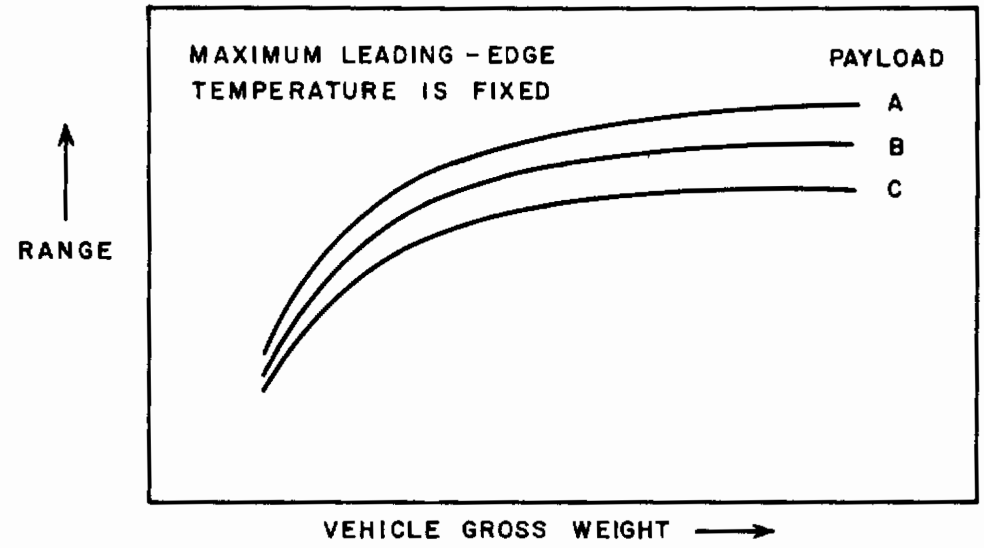

Fig. I — Generalized glide — rocket design

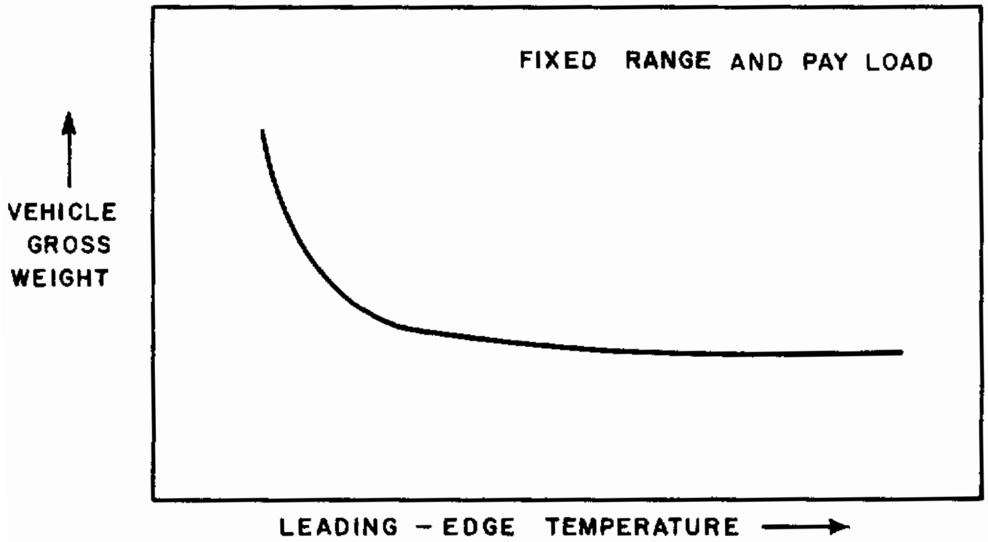

Fig. 2 — Influence of allowable leading — edge temperature on glide — rocket weight

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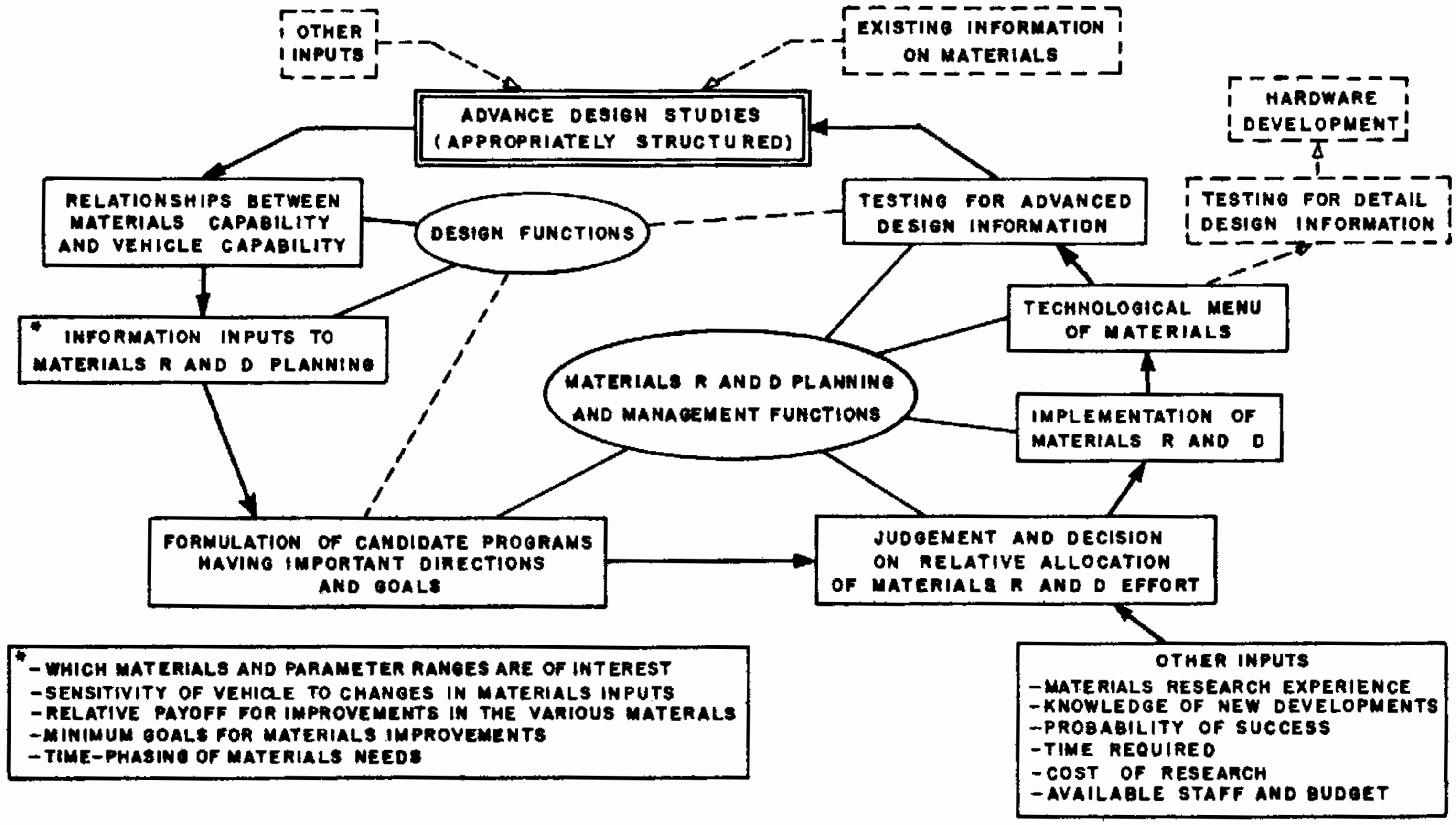

Fig 3 —Role of advanced design studies in the design / materials interaction

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