THE ROLE OF MATERIALS AND STRUCTURES TECHNOLOGY IN DEFENSE–PART I

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Good morning, ladies and gentlemen. It is a pleasure to have the opportunity to be here this afternoon to discuss with you what I believe are some very important actions that the Department of Defense (DOD), materials and structures research and development community must take if we are to fulfill our mission. Hopefully, your deliberations at this conference will provide some guidance for these actions. Indeed, I could almost entitle this talk "Requirements Versus Realities."

The growing sophistication of DOD structural systems is requiring a much deeper understanding of the fundamental physics involved in evaluating the structural response of more complex materials and complicated geometrical configurations subjected to an ever-widening range of mechanical, thermal, and environmental loadings. When these thoughts are superimposed upon our technical and management philosophy which now emphasizes "design-to-cost" as well as reduced operation and maintenance, while at the same time insisting on some performance improvements, it is not difficult to realize that the demands on construction materials are becoming more and more severe and are placing both a premium on more extensive materials characterization and a deeper understanding of structural response and prevention of failure.

This situation is the primary motivation for the trend towards having to learn more and more about state-of-the art materials at the expense of developing new materials of construction. This is a fine philosophy as long as materials are available to do the required job. The basic problem is that an ever increasing number of situations are arising in which for one reason or another the materials we know about are not satisfactory. What I mean is that many applications are emerging where we are "up against the stops," or a required military capability cannot be satisfied because materials of construction either do not exist or have not been developed to do the job that is needed.

I will discuss some of these problem areas as I go along, but one fact is very clear: inflation and other factors over the past few years have steadily contributed to an erosion of the DOD materials and structures technology base. In the 1960s, the DOD technology base was able to provide support to the near-term needs of the military departments, while at the same time building a technological reserve for the future. Over the past few years that reserve has been used to important advantage, but it has not been replenished because of the pressing needs of increasing military capability. The realities of the fiscal situation are such that if we are to attain necessary military capabilities very deliberate management actions will have to be initiated to take better advantage of the U.S. national technology base.

I propose, therefore, to outline for you some personal perceptions of “technology requirements” and point out some areas where much work, including new ideas, is very badly needed in the light of present “realities,” Figure 1 broadly illustrates the range of problem areas that we must address in the DOD technology base programs, I do not intend to address in detail all of the technologies listed here, but merely highlight a few which are of particular significance.

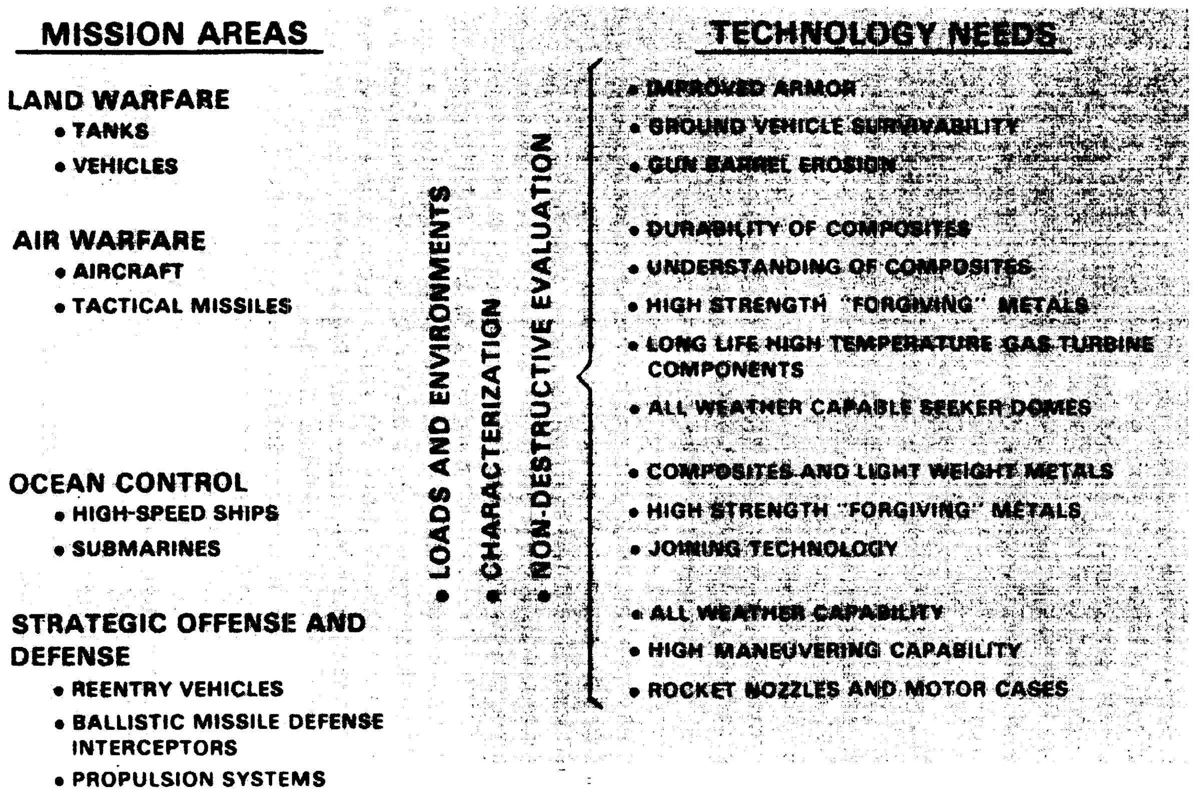
Technology

Before getting into the individual mission areas, however, I should point out that my intent in showing the loads and environment, materials characterization, and non-destructive evaluation as major program needs applicable across-the-board is very deliberate, I do not mean to imply that each of the mission areas suffers a major deficiency in these areas, but if there were any single set of program needs common to all mission areas, these are the ones. Without accurate definition of the structural and environmental loading on any given system, the designer must take a conservative route which leads to an over-designed or inefficient structure. Similarly for material characterization, if the measured properties scatter because of reproducibility problems, for example, the designer has no choice but to use the lower-most curve, These types of situations arise time and time again.

Now let me discuss the individual mission areas,

In the land warfare mission area one of our critical problems is that of survivability, The development of a materials solution to defeat the high velocity/high density penetrators is a very definite program need, This is a very complex problem involving not only materials development but also very extensive calculation schemes. This mission area also has very important program needs which address the problem of survivability of all types of ground vehicles, especially to mine field situations, The gun barrel erosion problem is one which has been with us a long time and will probably continue that way. As the need to increase projective velocity and accuracy increases, so do our gun barrel ero-.

FIGURE 1.—DOD Materials and Structures Techno ogy Requiremen s



sion problems. Materials and structures solutions to these problems, such as appropriate trade-offs between base materials and special coatings, are really not clear at this time.

The air warfare mission area also has many problem areas for which satisfactory solutions appear distant. All of the military departments are working on composite materials for use in aircraft. These materials are most promising for all types of aircraft structural components, particularly in areas where weight and size reductions are critical. When used effectively, they can result in structural weight savings up to 50 percent which can be traded for increased performance, combat survivability, or maintainability. But as with all things, we do not get something for nothing. Design with composite materials is a very difficult undertaking, as is meaningful, non-destructive evaluation during structural integrity investigations, Furthermore, they are not the solution to all problems. Military aircraft of the future will continue to depend on metallic materials for a variety of specific applications, The trend for the future will undoubtedly be towards the most effective use of each category of material.

Gas turbines perhaps provide a very good example to illustrate many of the points I have made so far. Before moving much further toward advancing this application, we need a better insight into the loads and environment inside military high-performance engines. We need a much better definition of the mechanical and the thermal loadings, especially in the very hot sections, While we seem to be moving in the direction of metal-matrix composites in the lower temperature compressor regions, the drive towards ever-increasing turbine inlet temperatures is putting severe demands on the high-temperature superalloy used in these regions. As a matter of fact, the evolutionary point has been reached where, for safety reasons, we must refurbish the hot sections of military aircraft gas turbines long before their estimated lifetime has been reached. This is a very expensive proposition from many points of view and reflects the quality of our materials and structures technology base.

The air warfare mission area also includes tactical missiles. A very important need is all-weather capability, While we have fairly large materials development programs addressing this need, I believe we are still a long way from providing the materials which will fully satisfy systems requirements.

The mission area of ocean control is primarily the responsibility of the Navy, We divide this mission area into high-speed surface ships and submarines. Each has its own particular combat environment, general performance envelope, design philosophy, and geometric configuration, For example, there is a major effort along a broad front to provide the Navy with higher speed ships, A common denominator of the various new types under consideration is the necessity to keep the weight low. Thus, the structural design and materials selection for high-speed ships approaches that of the aerospace vehicles. But the environment and loading are vastly different, leading one to inquire as to just how far it is possible to go in transferring aerospace technology to ocean control.

This brings me to the strategic offensive and defensive missile mission area. It is in this mission area where probably our most demanding program needs exist. Meeting existing requirements for all-weather capability, accuracy, reliability, and cost reduction all depend heavily upon our materials and structures technology. This mission area is in need of a great deal of emphasis.

Funding and Performers

Figure 2 shows the current and following fiscal years funding segregated by mission area. The recent Federal Council on Science and Technology Committee on Materials (COMAT) task force on the inventory and analysis of federally supported materials research and development revealed that the DOD materials R&D budget is less than 14 percent of the total supported by the US. Government. Because of the broad applicability of this technology area, it is not unreasonable to expect that a sizeable fraction of the work supported by other Federal agencies should, in some measure, be applicable to DOD needs. The question is “how do we take advantage of that work ?“

As far as military department performers involved in DOD materials and structures R&D, figure 3 indicates generally where and by whom the work is being done. The industrial and academic organizations listed are intended only to be representative and are by no means inclusive. The distribution of the funding shown at the bottom of the figure indicates that while the Army tends to do much of its work at in-house laboratories, the Air Force has a heavy contract program. The Navy is about 50 percent in-house and 50 percent on contract. An effort is being made to increase the amount of contract work of the Army and Navy over the next few years. This is an important step towards bringing in a broader range of new ideas into the DOD technology base.

Management

I would now like to discuss some aspects of what I term technology program management. Figure 4 illustrates some factors

FIGURE 2,—Funding Summary
DOD Materials and Structures Technology Base

&l+ 6.2+ 6.3A
MILITARY DEPARTMENTS +DARPA +DNA

MISSION AREA	FY 1976		FY 1977	
	MATERIALS	STRUCTURES	MATERIALS	STRUCTURES
RESEARCH	48.6	9.6	52.8	10.6
AIRCRAFT	36.8	31.4	34.9	28.9
MISSILES	23.2	4.5	19.5	5.4
ASTRONAUTICS	1.2	–	1.3	–
SHIPS, CRAFT, SUBMARINES	10.0	9.5	13.1	12.1
ORDNANCE, COMBAT VEHICLES	12.1	4.6	13.1	2.4
FACILITIES, OTHER EQUIPMENT	9.3	7.8	7.9	25.5
SUB-TOTALS	141.2	67.4	142.6	84.9
TOTALS	208.6		227.5	

which are having increasing influence on how we go about our business.

Over the past 3 to 4 years, there has been a steady growth of DOD/tri-service coordination for those mission areas having common materials/structures requirements. For example, there are formal and casual working groups in such areas as laser hardened materials and structures, tactical missiles, aircraft engines, reentry technology, and armor and penetrators. The military departments recognize that they must get together to exchange current information and to prepare integrated planning for future efforts if they are to keep up with requirements. In some cases workshops are called for, sometimes with industrial participants, to obtain additional ideas and inputs for future planning. These meetings prevent unwanted and unacceptable duplication of effort. They also focus more brainpower and experience to help solve existing technical problems. In addition to these specialized

FIGURE 3.—Implementation of the Military Department Materials and Structures Programs

ARMY			NAVY			AIR FORCE		
DARCOM		Army Research Office. Durham	Navy Commands (Sea, Air)		Office of Naval Research	Air Form Systems Command (AFSC)		Office of Scientific Research
DOD Labs	Industry	Univ.	DOD Labs	Industry	Univ.	DOD Labs	Industry	Univ.
AMMRC	U.S. Steel	Northwestern	NSRDC	Int'1 Nickel	Webb Inst.	AFML	Hughes	MIT
AVRADCOM	AVCO	Case Western		Union Carbide	Gee. Wash.	AFFDL	Boeing	Brooklyn Poly
HDDC	Norton	Lehigh	Annapolis	Whittaker	U. Florida	AFWL	Gen'1 Dynamics	
ECOM	Philco-Ford	U. Calif.	Carderock	Sikorsky	Penn State	AFAL	Northrop	U. Calif.
MIRADCOM	TRW	Illinois		Grumman	Ohio State	CRL	Lockheed	Texas
ARRADCOM	Corning	MIT	NRL	Lockheed	Georgia Tech		Fansteel	Yale
BR L	Raytheon		NSWC	Battelle			Dow Corning	Wisconsin
Watervliet	Honeywell		NWC				Crucible	USC
Frankford	G.E.	Others	NADC	Others	Others		Celanese	
Rodman Labs	Whittaker						Carborundum	Others
	Others						Others	

Army: In-House / Out-of-House = 1.30

Navy: In-House / Out-of-House = 1.00

Air Force: In-House / Out-of-House = .40

OVERALL In-House / Out-of-House = 0.90 “

FIGURE 4.—Materials and Structures Technology Program Management Trends

- **PLANNING AND COORDINATION**
  - **INCREASING ODDR&E/MILITARY DEPARTMENT PLANNING AND COORDINATION**
    - **LASER HARDENED MATERIALS AND STRUCTURES**
    - **TACTICAL MISSILES**
    - **REENTRY VEHICLE TECHNOLOGY**
    - **ARMOR AND PENETRATORS**
  - **INCREASING COORDINATION BETWEEN TECHNOLOGY BASE PROGRAMS AND MANUFACTURING TECHNOLOGY**
  - **INCREASING EMPHASIS ON [illegible]**
    - **IF TECHNOLOGY FULLY ACHIEVED WHAT ARE CAPABILITY/COST BENEFITS**
- **LIFE CYCLE COSTS WITH ACCEPTABLE MILITARY PERFORMANCE**
    - **ACQUISITION**
    - **O&M**
- **MATERIALS AVAILABILITY, CONSERVATION AND ENERGY REQUIREMENTS**
  - **INCREASING COORDINATION WITH OTHER FEDERAL AGENCIES**

working groups, formal materials and structures Technology Coordinating Papers (TCPS) have been and will continue to be prepared. The formality of these TCPS puts a necessary discipline in the system since they must be approved by high authorities responsible for materials and structure technology in defense.

These documents are prepared as a coordinated effort of the Army, Navy, Air Force, the Defense Advanced Research Projects Agency (DARPA), Defense Intelligence Agency (DIA), and Office of the Director of Defense Research and Engineering (ODDR& E). They describe and predict, in detail, the technical developments which the materials and structures technological communities who support the DOD must achieve in order that advanced weapon systems can be developed which will assure a credible U.S. military posture in the late 1970's and early and middle 1980's. These documents also identify areas where the greatest strengths and inadequacies lie, establish those categories in which critical materials and structures technology is needed, and recommend the level of effort to achieve required capabilities.

Unlike traditional descriptions of materials and structures technology programs, TCPS are organized in terms of military vehicles, weapons, and mission areas with each services' needs and objectives clearly identified, Each of these areas is analyzed with respect to principal systems, subsystems, and components to define and establish the pacing problems in materials and structures technology associated with each piece of hardware. In these documents we have tried to provide systems planners with the best judgments of the DOD materials and structures technology communities as to current technological status. The documents also address whether a specific technological area can be advanced at a faster rate than currently planned and, if so, at what cost.

As I am sure you can appreciate, these TCPS must be treated as internal Government documents because they contain financial and planning projections. Because of our sincere desire to share our assessment of the technology base with the industrial and academic sectors and thus develop a further, improved assessment, we have sponsored technology conferences which are based on the information contained in the TCPS. In the past, we have held separate conferences for materials and structures. The next one will be a structures TCP conference which will be held on November 16-18, 1976, at the Institute of Defense Analyses (IDA). This conference will update the information presented in 1974 at the last structures TCP conference.

We hope from these conferences that the industry sector will maintain a continuing insight into our many specific problem areas. An intangible, but most important, element of these conferences is the opportunity for representatives of those industrial and university organizations who have not been engaged in DOD research and development to meet Army, Navy, and Air Force officials and discuss mutual interests. The same opportunity would also exist for companies whose engineers and scientists have been involved in one or more segments of defense technology but have not participated in other related or unrelated areas. By this mechanism we hope that these conferences stimulate a continuing dialogue, After all, nobody has a monopoly on good ideas which can be stimulated by open discussion in an appropriate environment.

In a number of instances, we have found it necessary to engage in formal and informal coordination between ourselves and many other U.S. Government agencies and foreign countries. Figure 5 displays the coordination activities that are on-going between DOD and other Federal agencies. This, in a way, is a possible response to the first question posed to the panel; "How can DOD materials and structures research and development be made more productive in a world of declining real dollar funding?" The approach we have taken is less than satisfactory in that most of the relationships have been established in a specific known area and therefore relate to a specific problem. It would appear to be more beneficial if a realistically structured, Federal Government-wide coordination mechanism could be implemented so that all U.S. materials and structures technology areas are covered by an across-the-board formal organizational entity.

The question for the task group here then resolves itself to:

> Is greater coordination and interaction between the Department of Defense materials and structures technology base community and those participating in other Federal agency programs a feasible mechanism to increase productivity? If so, how should we go about achieving this?

An example of our cooperation with free-world, English-speaking foreign countries is the technical cooperation program (TCP) between the defense agencies of the United States, United Kingdom, Canada, Australia, and New Zealand. This is an extremely important aspect of our programs because, while their technology budgets are, in the absolute sense, less than those of the United States, they do provide an important different perspective on many problems.

FIGURE S.—coordination

WITHIN DOD

- **DOD Materials Shortages Steering Committee**

  All Services, DARPA, Department of Commerce, Federal Preparedness Agency, NASA, General Services Administration, National Commission on Supplies and Shortages, Department of Interior, Office of Technology Assessment, etc.

- **National Commission on Supplies and Shortages**
- **Henniker IV Conference on Materials Policies**

FOREIGN

- **The Technical Cooperation Program (TTCP) Subgroup P (Materials Technology)**

  All Sarvices and DIA

- **AGARD**

Materials Shortages

The possible shortage of critical materials is becoming more and more of a real problem. It forces DOD and contractors to examine carefully the question of materials substitution, redesign, recycling, or other alternatives at all stages of a given development. A great deal of attention is now being given to the question of shortages, and the situation may lead to some changes in DOD procurement techniques. To deal with this problem, the DOD Materials Shortages Steering Committee has been organized. Because the causes, effects, and resolution of potential problems extend much broader than the DOD, membership includes representatives from other Government departments and agencies. Figure 6 shows the current membership of this group. To date, the steering committee has held two major workshops involving representatives of Government and the materials industries (both producers and users). These workshops have contributed in defining and clarifying many very complex problems which could seriously impact DOD mission responsibilities. To assist in the deliberations of this conference, we have provided for each conference participant copies of the papers given at the workshop held in February 1976. We do not yet have any clear answers to the many problems we have encountered, but before that can happen we recognize that we must first have an understanding of the overall problem.

FIGURE 6.—Coordination

BETWEEN DOD AND OTHER FEDERAL AGENCIES AND ORGANIZATIONS

- **National Academy of Sciences (NAS)/National Materials Advisory Board (NMAB)**
  All Services, DARPA and NASA contribute to support
- **DOD/NASA Aeronautics and Astronautics Coordinating Board (AACB)/Supporting Research and Technology (SRT)**
  Materials and Structures Subpanel
- **Defense Materiel Standards and Specifications Board (DMSSB) – Materials Panel**
  All Services, DSA, Dept. of Commerce, Energy Research and Development Administration (ERDA), NASA, ANSI, ASTM, SAE participate
- **Federal Council on Science and Technology (FCST) – Committee on Materials (COMAT)**
  All Services, ARPA, Dept. of Commerce, Dept. of Interior, Energy Research and Development Administration (ERDA), Dept. of Transportation, HUD and HEW participate
- **Materials Intelligence Seminar (MIS) - Structures Intelligence Seminar (S1S)**
  All Services, DIA, and CIA participate
- **Industry Conferences**
  Jointly sponsored with Dept. of Commerce and Interior
  "Health of Industry," "Titanium, " "Technology Transfer"
- **ERDA Ceramic Gas Turbine Review Committee**

NASA

- **Carbon/Carbon Re-entry Shields**
- **Carbon/Carbon Rocket Nozzles**

Innovation

I would like now to discuss some aspects of creativity and the goals of materials and structures technology development. Admittedly, calling out the need for creative or innovative ideas is a little like renewing one's faith in motherhood. Such ideas are always good and desirable. Nevertheless, because of the technological barriers that are confronting us in so many areas, we must reexamine our technical approaches. Is there a better way to approach a given problem? Are we solving the right problem or are we overlooking something? Are there possible new concepts which could eliminate the problem altogether?

It is possible. even probable, that new ideas will not appear when requested. Creativity cannot be turned on like a faucet; it evolves in the mind. However, unless innovative ideas are invited and welcomed, they may never appear; or, if they do, may not be properly exploited, To be welcome, such ideas need be neither major breakthroughs, nor highly technical.

A case in point related to the non-destructive evaluation (NDE) of high-performance materials. Military requirements are emerging which require that the critical flaw size to be detected is approximately the same size as inherent materials defects. This evolution is placing ever-increasing demands on NDE detection capabilities and is approaching unreality in certain critical structural areas and in certain materials, Inspection costs are rising rapidly for these components as are the costs associated with the higher reject rates, Even more serious is the situation in which an undetected flaw might cause a catastrophic failure of a component because of our marginal ability to detect the smaller and smaIler critical flaws.

We may be traveling down the wrong path in developing high-strength metals which require increasingly higher resolution NDE. We should perhaps consider paying more attention to imparting some “forgiveness“ into the materials of construction. For metals, compositing with high-strength fibers may be a good approach. Extensive work on organic-matrix composites has demonstrated significant flaw tolerance and dramatic increases in fatigue life. If these important attributes can be demonstrated for metal-matrix composites, a very important development for future military equipment could result.

While there is increasing interest in the use of ceramic materials for high-temperature structural use, they are certainly not “forgiving” materials; consequently, the reliability problem is quite severe. Compositing, however, may be one promising approach. Ceramic composites have been used in high-temperature windows but not really as a true load-carrying component. Another, and more basic, approach is to impart more ductility to ceramics.

Impact load characterizations and effects are becoming highly important. Particle impacts, such as the weather effects on all aeronautical vehicles, bird impacts on gas turbine engine fan blades, and ballistic impacts on armor are all phenomena which are only semi-empirically understood. It is vital that we understand, in a much better fashion, both how the loads arise (for example, how are atmospheric water and ice characterized?), and how to determine and simulate the material behavior under such loads,

Many similar problems exist for which more basic understanding is needed, But for the sake of time I will not elaborate upon them.

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Conclusion

Let me conclude these remarks by commenting on a matter of concern to me and my DOD colleagues involved with materials and structures. In many areas the technology base so essential to future systems development is severely depleted. Future military requirements are almost certain to involve even more stringent design conditions. At the same time, high reliability at lower cost will continue to be emphasized. These needs can be met only through a revitalized technology base. Unfortunately, the missions of other Government organizations are such that their technology base is not directly useful to DOD. We do use a great deal of what they develop and depend on them heavily to sustain the overall U.S. technology base, And without it I am sure we would be in even worse trouble. Nevertheless, the DOD has its own special requirements, and it will take special efforts to meet and maintain its needs. The overall question I therefore place before this audience is "How can the DOD do a better job of implementing the transfer of materials and structures technology between Federal agencies, industry, and academia so that it can replenish the technological reserve which has been depleted over the past few years?"

We in the DOD are working very hard to keep ourselves as far up on the "power curve" as we can. We recognize that we are running into "road blocks" in many areas and must work our way around them. I will continue to press for greater creativity and innovation in our programs as the best pathways around these road blocks, Let me emphasize again that dollars cannot produce good ideas. The ideas and thoughts that emerge from other programs could prove extremely valuable, and the military departments will welcome them.

As I said earlier, we cannot by ourselves solve the problems I have outlined. We need the help of other U.S. and free-world programs, The strength of the U.S. national defense effort is very much dependent on the collective, sustained efforts of the overall U.S. materials and structures technology community. My perception of the world situation is that we had better "get on with it" or the technological balance is sure to shift the other way. And we cannot allow this to happen.

Thank you.