Navy's Research Arm Prepares "Science and Technology Grand Challenges"

The Office of Naval Research (ONR) is attempting a long-term research and development (R&D) strategy intended to enhance the future capabilities of the Navy and Marine Corps. ONR calls the strategy its Science and Technology Grand Challenges, which would affect R&D efforts for at least the next 20 years. The challenges call for vastly improved communication and coordination within the research community in order to compress the normal time frames for technological advances.

ONR has chosen four Grand Challenges, including one of particular interest to the materials research community: Naval Materials by Design. The others are Multifunctional Electronics, Naval Battlespace Awareness, and Electric Power Sources for the Navy and Marine Corps. The four challenges were chosen by ONR from 165 original possibilities. According to naval research officials, these areas represent "the greatest combination of impact and opportunity."

The basic premise of the challenges is to use advances in information technology to improve communication and information-sharing among research groups that normally have little or no contact. In the materials area, ONR wants to develop a continuous link in information from first principles research to prototype experimentation, including each research phase in between. "It's a bridging of length scales," one official said.

As ONR officials explained, since the various materials research groups tend to work independently, a great deal of potentially useful information remains uncirculated. Researchers working at macroscopic scales do not have access to available calculations and therefore must obtain the same results via lengthy experimentation.

At the same time, if the Navy—or any agency or institution—develops a need for a material with certain properties, it either must choose from commercially available products or conduct the R&D process from the beginning. The materials chosen might approach desired specifications, but naval engineers usually are forced to work around technical limitations. Those limitations sometimes can cause problems in the complex naval operational environment. For example, steels having tensile strengths of the order of 350 ksi (known as maraging steels) were developed by industry in the 1960s, which were capable of providing phenomenally high strength-to-weight ratios for military systems. Unfortunately their susceptibility to hydrogen embrittlement in environments such as seawater forced Navy architects to use steels of strength levels of the order of 120 ksi to avoid these types of failure. Engineers are forced to accept tradeoffs between desired properties and the real properties of commercially available materials. The process of developing new materials capable of performing in that environment usually takes up to 20 years and often is too costly to meet the needs of a limited number of naval platforms.

Under the new concept envisioned in ONR's Grand Challenges, available information—from theoretical calculations to computer simulations to nonproprietary experimental results—would be added to a database accessible to materials researchers in the various fields. The improved data sharing and networking could yield new materials with exact composition, synthesis, and processing requirements for naval applications, accomplished in a significantly shorter time frame.

Once the database is operational, future naval architects and systems integrators could access a range of materials properties, from the atomic level to finished bulk components. ONR believes it will become much easier to develop customized materials with user-specified critical properties. "This will allow new alloy formulation, microstructure optimization, and processing development to occur" much more quickly, according to officials, perhaps well in advance of the current 20-year development threshold.

As envisioned by ONR, the naval materials Grand Challenge would proceed as follows:

- ONR would establish "a hierarchy of computational techniques" for calculating materials properties, spanning the range of length and time scales, from microscopic to macroscopic. The techniques would employ the latest supercomputer capabilities, such as first-principles atomic scale techniques, parameter-based molecular dynamics techniques, kinetic/phase equilibrium simulations, and parameter-based continuum mechanics models.
- Links would be forged between the techniques operating at different scales so that the output from one provides the input to the calculation at the next scale. ONR wants the links to be "based on relevant models that relate materials phenomena to fundamental rules or principles."
- Experimental activities would be targeted to determine or verify the computer models.
- The computer techniques would be applied simultaneously to an ensemble of desired or required properties in new naval materials.

ONR officials said the materials aspect of Grand Challenge would likely begin with structural materials and would encompass both metals and composites. Eventually, the effort will be extended to include electronics, sensors, propulsion components, transducers, and other special purpose materials.

If the materials Grand Challenge succeeds, officials said, it could greatly improve the Navy's ability to meet its emerging materials needs. Urgent design changes and mid-deployment upgrades would become feasible. Materials development costs would be reduced, and processing would be optimized, making superior materials more affordable.

The other three Grand Challenges are:

- *Multifunctional Electronics for Intelligent Naval Sensors.* The challenge here would be to advance these devices to their ultimate limits of speed, size, and power. The goal is to combine sensing, image processing, computation, signal processing, and communication functions to produce a real-time adaptive response, on-site, for Navy missions.
- *Naval Battlespace Awareness.* The challenge is to isolate the locations of friendly and enemy forces with space, the atmosphere, the ocean, and nearby land masses, with as much detail, accuracy, and timeliness as possible to meet evolving Navy and Marine Corps mission requirements.
- *Electric Power Sources for the Navy and Marine Corps.* The challenge is to develop new, safe, efficient, environmentally friendly, nonpetroleum-based sources of power and power generation. In particular, ONR wants portable, long-lived power sources for all future Marine equipment, as well as electric power sources for all-electric ships and other Naval warfighting platforms.

ONR officials caution that the Grand Challenges are meant chiefly to provide long-term focus and program guidance for the Navy's Science and Technology Program. "They are designed as rallying points to establish long-term goals," according to an ONR official involved in developing the challenges. "No specific funding is involved."

The Grand Challenges will be reviewed periodically by ONR's Chief Scientist, Craig Dorman, who will determine whether any adjustments are necessary in the overall strategy. Meanwhile, ONR is planning to invite members of the research community to discuss the Grand Challenges at a workshop on the subject this fall. For updated information about the Grand Challenges, refer to website www.onr.navy.mil/sci_tech/chief/GrandChal.htm

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