# Outlook

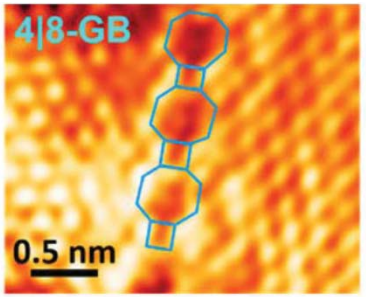
## U.S. Army Research Office

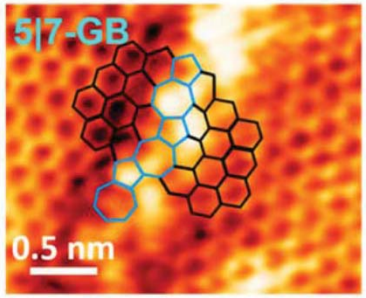
18 May 2017

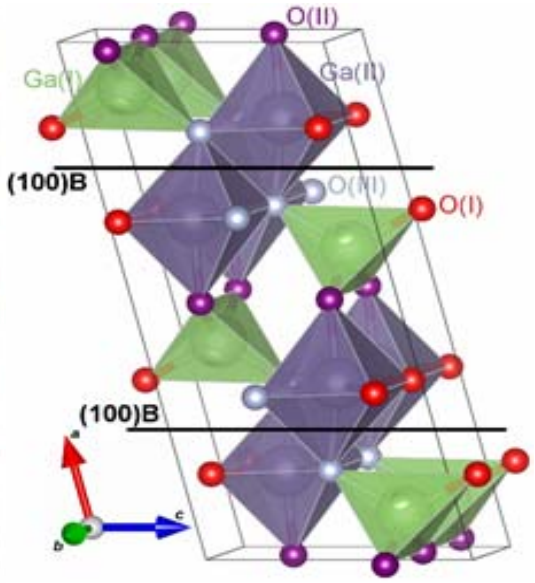
**Dr. David M. Stepp**
Director, Engineering Sciences
Division Chief, Materials Science
U.S. Army Research Office
david.m.stepp.civ@mail.mil
919-549-4329

# Materials Science Division Vision

To realize ***unprecedented material properties*** by embracing long-term, high risk, high-payoff opportunities for the US Army with special emphasis on: Materials by Design, Mechanical Behavior of Materials, Physical Properties of Materials, and Synthesis and Processing of Materials




# Materials Science Division
# "Unprecedented Material Properties"

## Materials by Design

Dr. John Prater
john.t.prater.civ@mail.mil

## Mechanical Behavior of Materials

Dr. David Stepp
david.m.stepp.civ@mail.mil

## Physical Properties of Materials

Dr. Pani Varanasi
chakrapani.v.varanasi.civ@mail.mil

## Synthesis and Processing of Materials

Dr. Michael Bakas
michael.p.bakas.civ@mail.mil

**http://www.arl.army.mil/www/pages/8/W911NF-17-S-0002.pdf**

US Army Research Office
Complementary Materials Research in Other Divisions

## Mechanical Sciences Division
- Complex Dynamics & Systems
- Fluid Dynamics
- Propulsion and Energetics
- Solid Mechanics

## Electronics Division
- Electromagnetics
- Nano- and Bio- Electronics
- Optoelectronics
- Electronic Sensing

## Physics Division
- Atomic and Molecular Physics
- Condensed Matter Physics
- Optics and Fields
- Quantum Information Science

## Chemical Sciences Division
- Electrochemistry
- Molecular Structure & Dynamics
- Reactive Chemical Systems
- Polymer Chemistry

## Life Sciences Division
- Biochemistry
- Microbiology
- Neurophysiology of Cognition
- Genetics

## Mathematical Sciences Division
- Probability & Statistics
- Computational Mathematics
- Modeling of Complex Systems

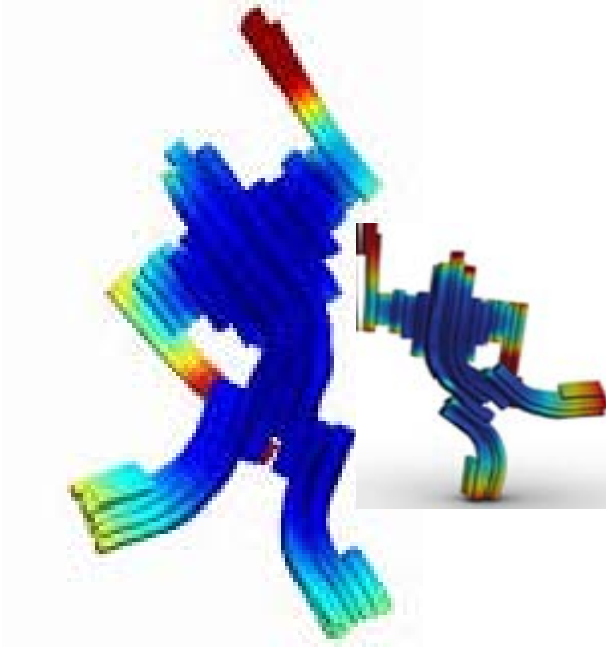
# Materials by Design

*john.t.prater.civ@mail.mil*

**Vision:** Establish the experimental techniques and theoretical foundations needed to facilitate the hierarchical design and bottoms-up assembly of reconfigurable materials that will enable the implementation of advanced materials concepts including transformational optics, biomimetics and smart materials.

## Research Thrusts

- Directed 3D Self-Assembly of Reconfigurable Nanomaterials
- Functional Materials Integration



*john.t.prater.civ@mail.mil*

## Scientific Objectives:

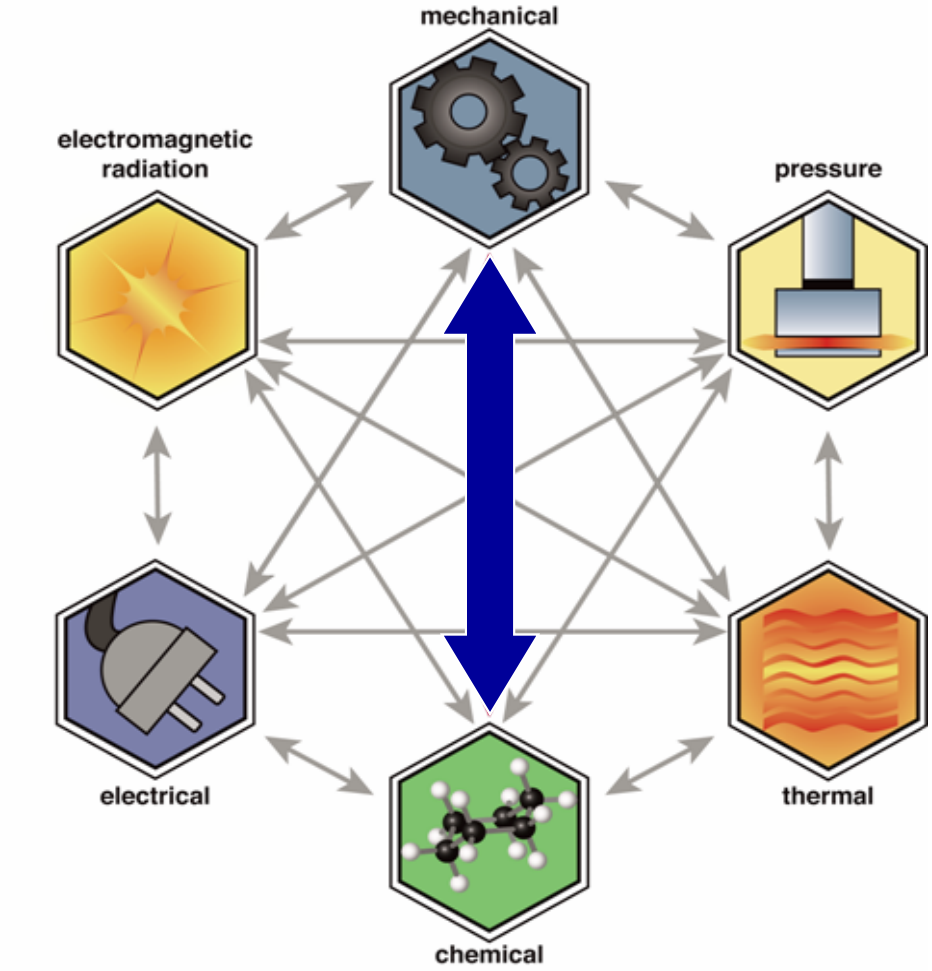
- Enable the directed bottoms-up 3D assembly of reconfigurable colloidal materials that afford high levels of functional integration, complexity and hierarchy
- Develop the theoretical/experimental foundations needed to design, assemble, and analyze biochemical pathways translated to non-cellular environments
- Enable the predictive design and integration of functional materials into complex multi-component, smart or tunable systems
- Development of functional materials with engineered properties (e.g. low hysteresis losses)

# Mechanical Behavior of Materials

*david.m.stepp.civ@mail.mil*

## Program Vision

To establish precise manipulation of molecular-scale mechanical environments and exploit design strategies for amplifying the mechanical response of bulk materials from atomic-scale features and assemblies to enable new materials paradigms for protection and sustainment.




## Research Thrusts

- Force-Activated Materials
- Mechanical Complements in Materials

complement (n): something that completes, makes up a whole, or brings to perfection

*david.m.stepp.civ@mail.mil*

## Scientific Objectives:

- Create, design, and optimize a broad range of robust mechanochemically adaptive materials, based on exquisite control of force-activated molecules and force-activated reactions
- Tailor the deformation and failure mechanisms in materials to mitigate the propagation of intense stress-waves and control energy dissipation
- Create materials with the ability to facilitate extraordinary electrochemical reactions through an interdependent optimization of mechanical properties
- Catalyze the creation and demonstration of unique fiber precursors, tailored for lateral and axial interactions, to generate new paradigms for revolutionary structural fibers
- Establish and optimize new atomic-scale strengthening mechanisms governing bulk mechanical behavior

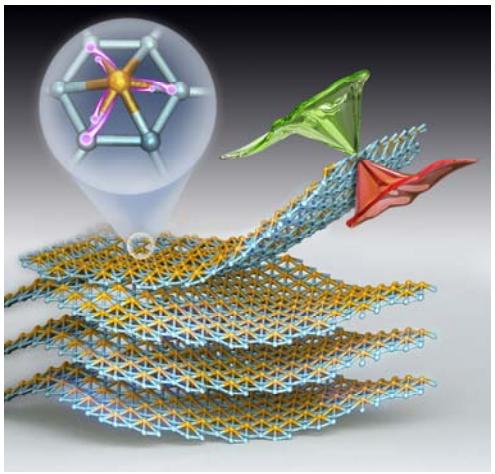
*chakrapani.v.varanasi.civ@mail.mil*

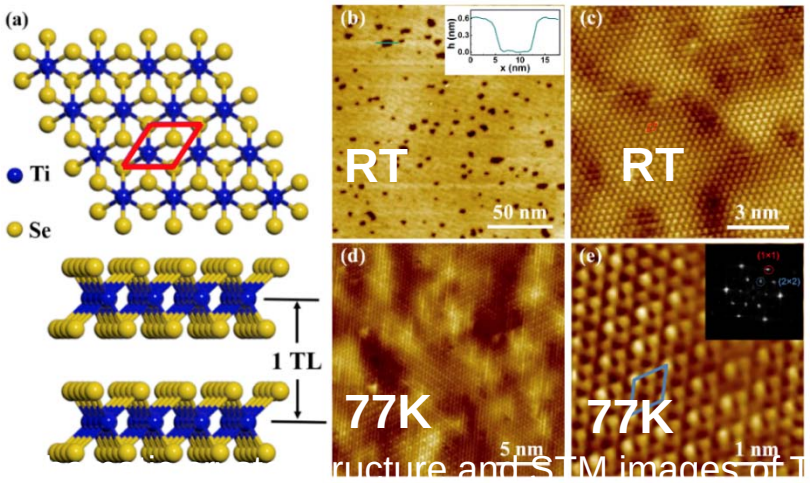
## Program Vision

To discover novel functional materials with extraordinary *electronic*, *photonic*, *magnetic* and *thermal* properties and establish underlying processing parameter-defect-property relationships to empower the future Army with superior capabilities in electronics, sensors, power & energy.

## Research Thrusts

- Discover (design, synthesize & characterize) novel materials with exceptional functional properties
- Defect science & engineering of functional materials



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chakrapani.v.varanasi.civ@mail.mil

## Scientific Objectives

- Create materials of novel compositions and structures with unique physical properties through developing fundamental understanding of nucleation/growth mechanisms
- Invent unique characterization techniques and discover novel functional properties (*electronic, photonic, magnetic and thermal*) of materials through establishing composition/structure- property correlations
- Determine the specific *influences of defects* on the physical properties of functional materials through establishing defect type- density-property relationships
- Develop *innovative defect characterization techniques* to detect the type and the density of various types of defects in functional materials during the growth/post growth processing stages e.g. atomic scale characterization

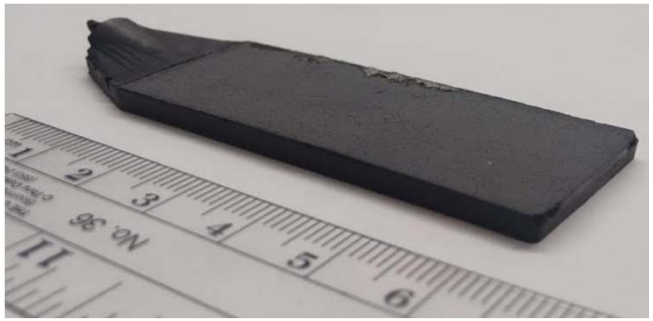
*michael.p.bakas.civ@mail.mil*

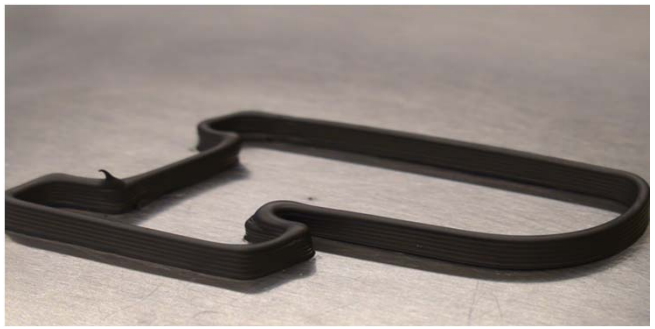
## Program Vision

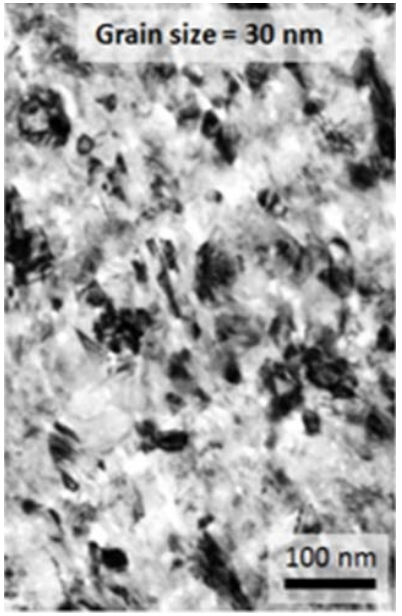
Define and demonstrate the underlying processing-property-microstructure relationships, and their controlled manipulation under dynamic conditions, to create the next generation of bulk alloys, ceramics and composites for unmatched performance, lightweighting and readiness capabilities.

## Research Thrusts

- Stability of Nanostructured Materials
- Manufacturing Process Science







*michael.p.bakas.civ@mail.mil*

## Scientific Objectives

- Creation of thermally-stable, ultrahigh strength nanocrystalline materials through interfacial grain boundary engineering
- Realization of high strength, nanostructured alloys via pinning nanoprecipitates and internal coherent boundaries
- Establish advanced processing methods by discovering the governing thermodynamic and physical laws that control the microstructural evolution of a material
- Exploitation of unique phenomena under metastable and complex conditions for the creation of new material phases and morphologies

# ARO Broad Agency Announcement (BAA) Awards

## The "Core" ARO Program

Single Investigator awards
- $135 K/year for 3–5 years

Conference / symposium / workshop grants
- $5–30K

Short Term Innovative Research (STIR)
- $60K for 9 months

Young Investigator Program (YIP)
- $120K/year for 3 years

**http://www.arl.army.mil/www/pages/8/W911NF-17-S-0002.pdf**

# Other Awards Based on ARO BAA

Presidential Early Career Award for Scientists and Engineers (PECASE)

- $200K/year for 5 years

Defense University Research Instrumentation Program (DURIP & RI)

- $150K for 12 months (avg)

High School / Undergraduate Research Apprenticeship Programs (HSAP/ URAP)

- $3K/student for 3 months

Programs for Minority Institutions (MI)

- Historically Black College/University and Minority Institutions (HBCU/MI)
  - Up to $350K total for 3 years
- DoD Research and Educational Program (REP) for HBCU/MI
  - Up to $500K total for 3 years

**http://www.arl.army.mil/www/pages/8/W911NF-17-S-0002.pdf**

# Other Non-ARO BAA Awards

Multidisciplinary University Research Initiative (MURI)

$1.25M/year for 3 years plus options for 2 years

Small Business Innovation Research (SBIR)

$100K for 6 months (Phase I) → $50 K option for 3 months → $1M total for 2 years (Phase II)

Small Business Technology Transfer (STTR)

$150K for 6 months (Phase I) → $1M total for 2 years (Phase II)

**http://www.arl.army.mil/www/default.cfm?page=8**

# Perennial Rule

## Study the solicitations

*Corollary:* Contact the program managers personally

*Should go without saying:* Extend the frontiers of materials science

# Specific Current Research Interests

## Materials By Design – Dr. John Prater

Development of hierarchically organized materials with life-like capabilities for enabling materials that can alter their properties to respond to their surroundings

## Mechanical Properties of Materials- Dr. David Stepp

Force-activated materials, biologically-inspired force-activated mechanisms and materials, unique network architectures for structural composites

## Physical Properties of Materials- Dr. Pani Varanasi

Organic- inorganic hybrids (2D materials) with novel functional properties, basic material issues for quantum sciences

## Synthesis and Processing- Dr. Michael Bakas

Basic insight into advanced processing methods like SPS and flash sintering, novel processing methods for structural materials, use of plasmas for processing of structural materials

# ARO International Strategy

Strategic Tools

## Discover

- DoD/Army S&T priorities
- Conference participation
- Exploratory visits
- Unique scientific breakthroughs

## Engage

- Face-to-face meetings
- Networking
- Conference support
- Research Funding

## Partner

- Program reviews
- Research facilities
- Joint publications
- Lasting partnerships

- New ARO PMs stationed at key regions across the globe
- International Programs organized within existing ARO Divisions
- ARO International BAA component published in March 2017
  - International PMs will present planned program strategies at this year's Division Reviews

**2. INTERNATIONAL RESEARCH INTERESTS**

The U.S. Army Research Office has international research programs which are focused in specific research areas supporting the 10 scientific divisions. These research areas and information provided in the following are opportunities for foreign organizations and foreign

**e. Innovations in Materials**

As one of the ARO International Programs and part of the ARO Materials Science Division portfolio, the Innovation in Materials is focused on supporting multidisciplinary research at

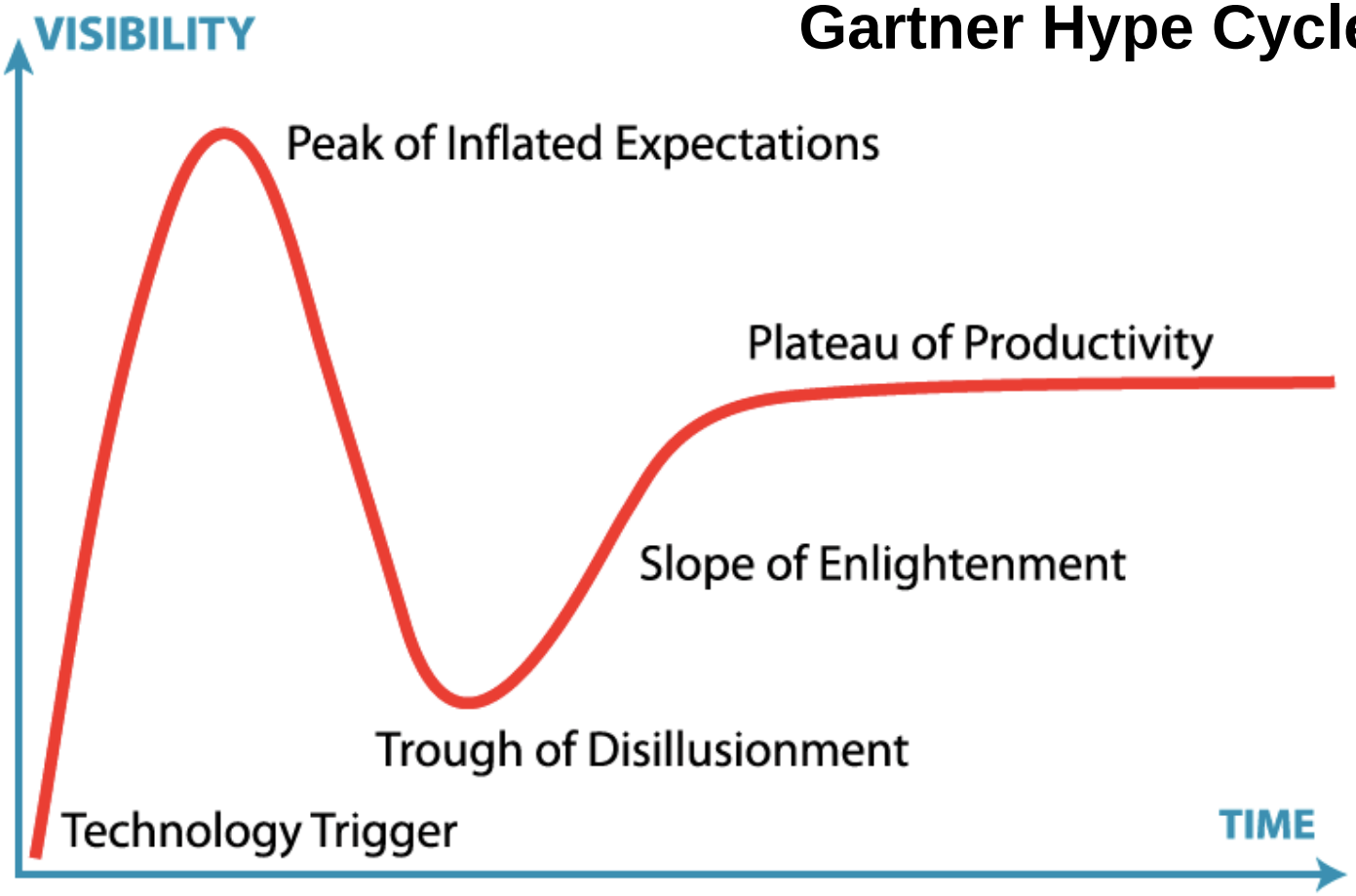
**ARMY RESEARCH OFFICE**

**BROAD AGENCY ANNOUNCEMENT FOR**

**BASIC AND APPLIED SCIENTIFIC RESEARCH**

**W911NF-17-S-0002**
**01 April 2017 – 31 March 2022**

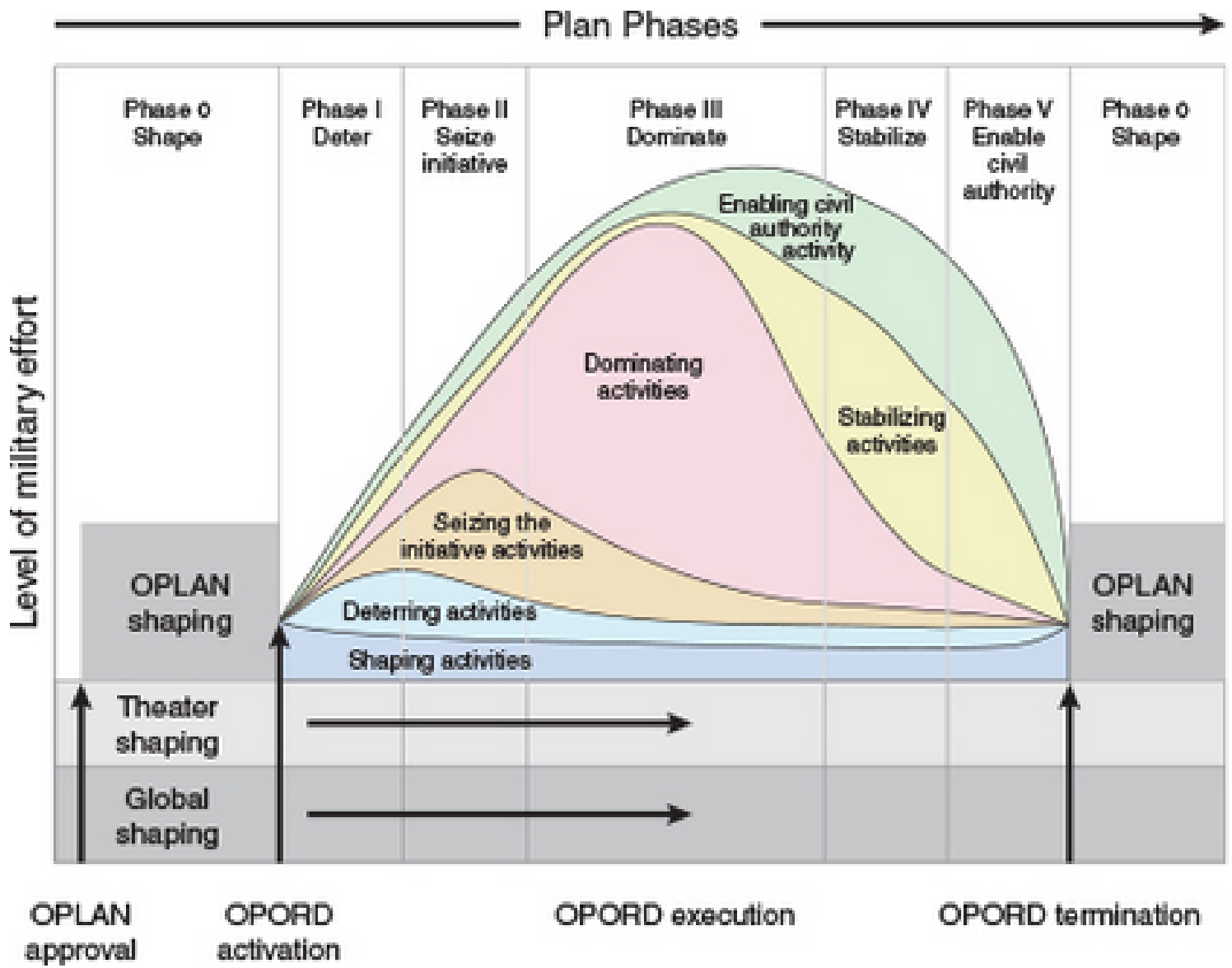

## Gartner Hype Cycle




# Impactful Research Suggestions

- **Collaborative small teams**
  - Mutually-interdependent with multiple disciplines
  - Predictive-modeling to lead design
- **Identify key basic areas of research that should be worked on <u>now</u> rather than <u>10 years</u> from now**
  - Beware non-falsifiable hypotheses
- **Balance of basic and applied research investments**
  - Find the right partners, technology pull
- **Periodic workshops to critically evaluate the future directions**
  - More tutorial sessions to cover basics and overviews
  - Sharing failures or methods that did not work (does not exist now)

# Materials for Phases IV and V?



# ARL S&T Campaigns:
## Integration of Extramural and In-house Research

# Final (Candid) Thoughts

**Uncertainty**

Rumors (*pay attention to the dollars*) and Initiatives

Contrary to popular opinion, OSTP does not run the world

**The questions I wish you would ask** (*impactful research*)

Why do people think _____ is fundamental materials science?

When is collaboration / data analytics valuable, and when it is not?

Don't you realize that this (materials science) "emperor" has no clothes on?

Where is the next "unprecedented" breakthrough at the frontier of materials science?

What should we be doing, strategically, during this time of uncertainty?