INNOVATION RESEARCH INTERCHANGE
Accelerating Value Creation

A division of the National Association of Manufacturers

IRI 2025 | INNOVATORS SUMMIT

May 19–21 / Chicago, IL

DARPA's Breakthrough R&D in Materials and Manufacturing

Andrew Detor, Ph.D.
Program Manager
Defense Sciences Office

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Innovation Research Interchange (IRI) – Innovators Summit

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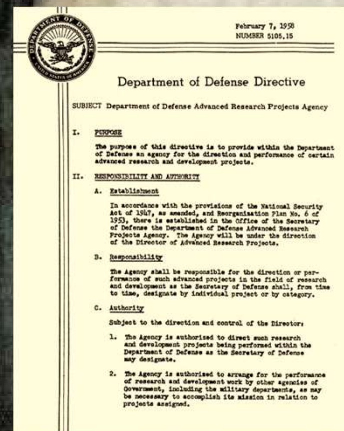
DARPA Origins

October 4, 1957

Soviets beat U.S. to space with Sputnik

U.S. should never again be surprised by technology.



February 7, 1958
NUMBER 5105.15

Department of Defense Directive

SUBJECT Department of Defense Advanced Research Projects Agency

I. PURPOSE

The purpose of this directive is to provide within the Department of Defense an agency for the direction and performance of certain advanced research and development projects.

II. RESPONSIBILITY AND AUTHORITY

A. Establishment

In accordance with the provisions of the National Security Act of 1947, as amended, and Reorganization Plan No. 6 of 1953, there is established in the Office of the Secretary of Defense the Department of Defense Advanced Research Projects Agency. The Agency will be under the direction of the Director of Advanced Research Projects.

B. Responsibility

The Agency shall be responsible for the direction or performance of such advanced projects in the field of research and development as the Secretary of Defense shall, from time to time, designate by individual project or by category.

C. Authority

Subject to the direction and control of the Director:

1. The Agency is authorized to direct such research and development projects being performed within the Department of Defense as the Secretary of Defense may designate.

2. The Agency is authorized to arrange for the performance of research and development work by other agencies of Government, including the military departments, as may be necessary to accomplish its mission in relation to projects assigned.

February 7, 1958

"The purpose of this directive is to provide within the Department of Defense an agency for the direction and performance of certain advanced research and development projects."

Defense Advanced Research Projects Agency

DARPA

The Independent Science and Technology
Agency of the Department of Defense

Prevent and Create Strategic Surprise by Making
Pivotal Investments in Disruptive Technologies

DARPA's Culture Persists and the Agency Delivers

PEOPLE

Strong technologists
Limited tenure
Autonomy

PROCESS

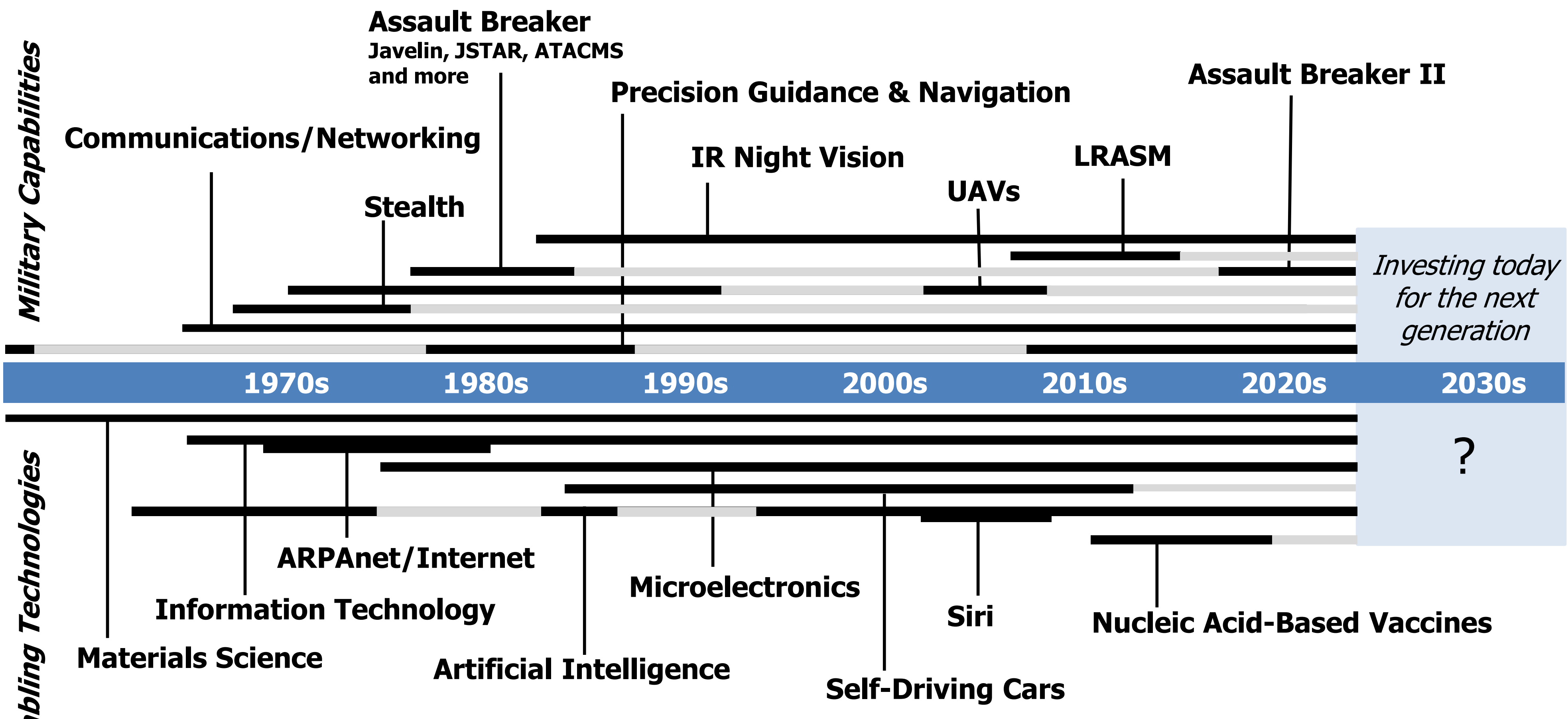
No in-house labs
Metrics-based
Active management

CULTURE

Off-scale impact
Risk required
Public service

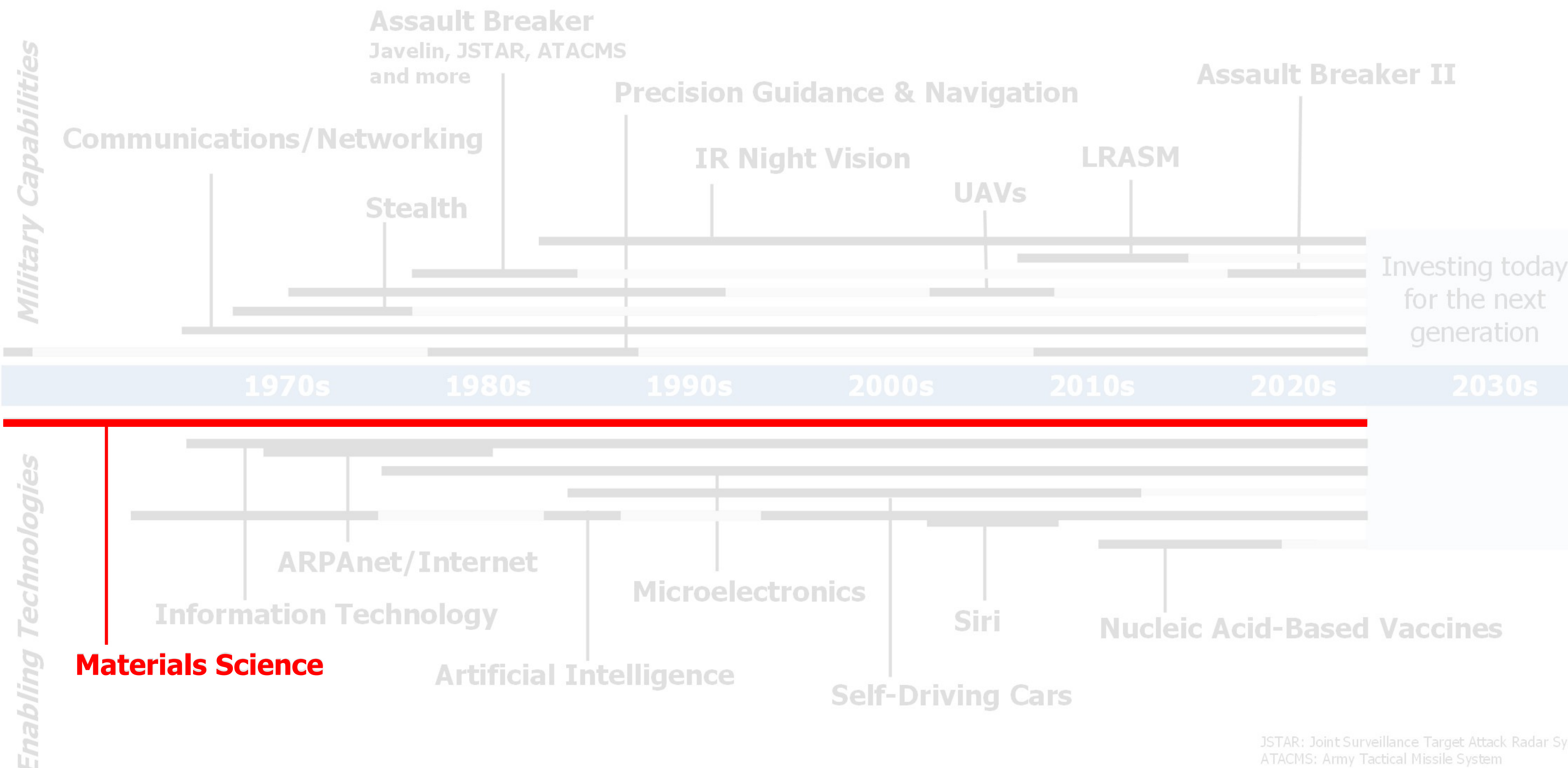
YEARS	GOV EMPLOYEES	FY24 BUDGET	NEW PROGRAMS A YEAR	PM TENURE (yrs)
66	283	$4.1B	~50	3-5

Pivotal Early Investments that Change What's Possible



JSTAR: Joint Surveillance Target Attack Radar System
ATACMS: Army Tactical Missile System
LRASM: Long Range Anti-Ship Missile

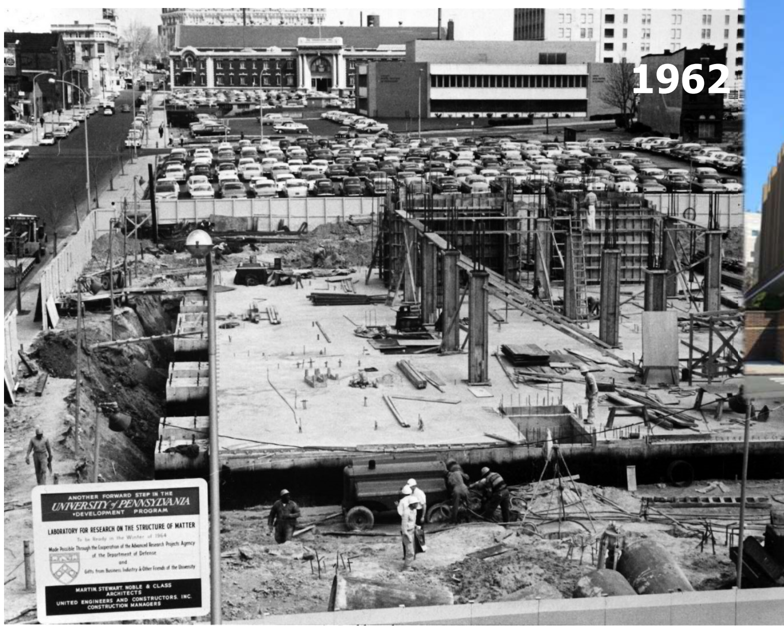
Pivotal Early Investments that Change What's Possible



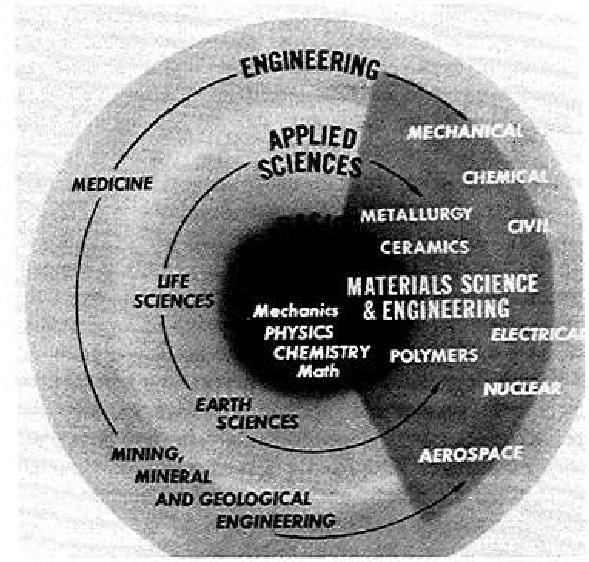
JSTAR: Joint Surveillance Target Attack Radar System
ATACMS: Army Tactical Missile System
LRASM: Long Range Anti-Ship Missile

Founding of the Materials Science Field

Laboratory for Research on the Structure of Matter (LRSM)



Materials Science and Engineering (1969)

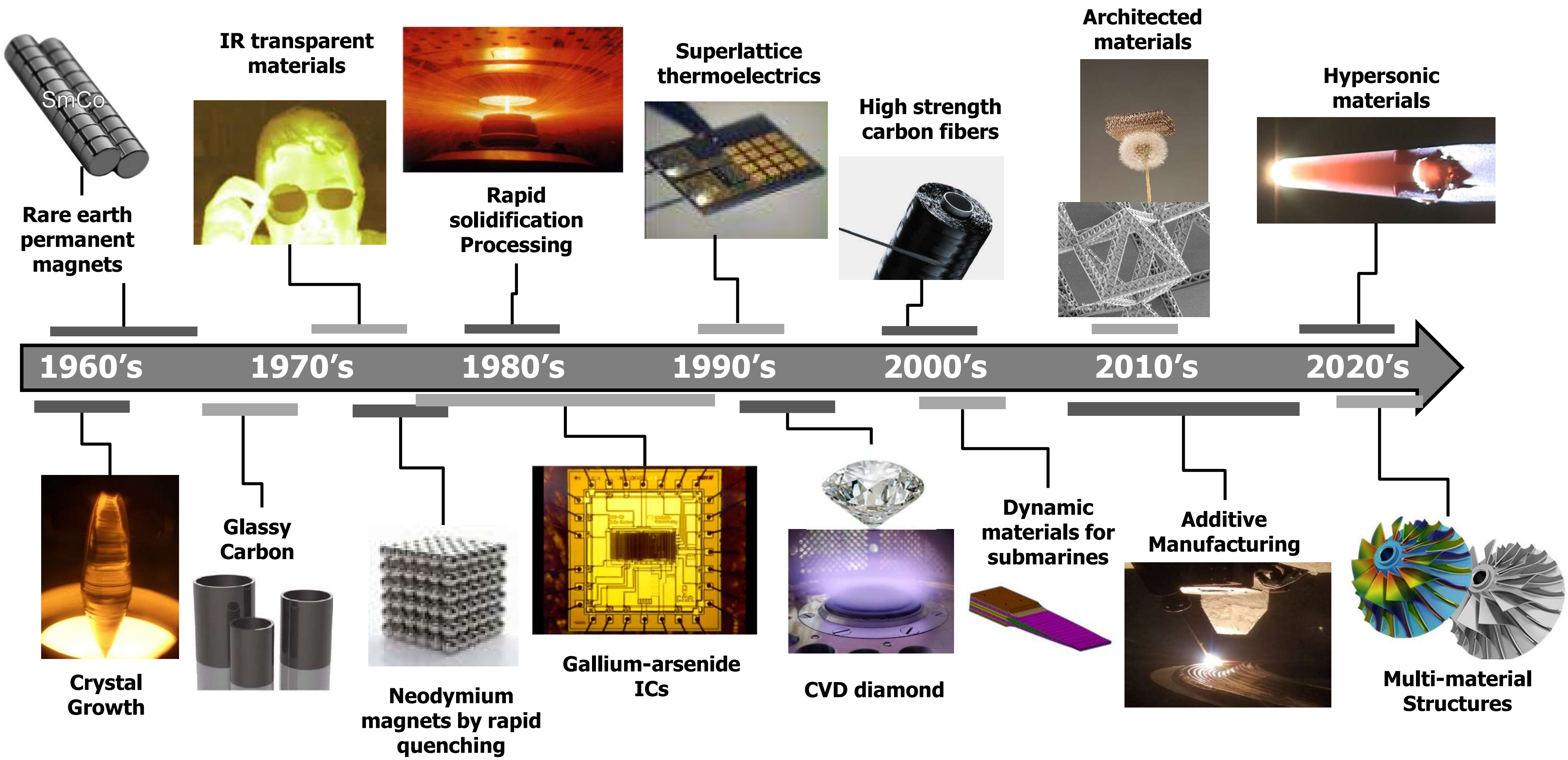


1960
DARPA Interdisciplinary Laboratory (IDL) program: U. Penn, Cornell, and Northwestern

1969 IDL Program
- $18.7M funding
- 600 faculty members
- 2400 graduate students
- 360 PhD's awarded

1972
IDL program transitioned to NSF and renamed Materials Research Laboratories (MRL)

DARPA's Contributions in Materials & Manufacturing



Future Vision for Structural Materials

	Discovery	Design	Manufacturing	Deployment
Today	5-10 years for new material development	Material is a fixed design input	Lead times measured in months	10:1 maintenance to use ratio
Future	Material tailored for application in <1mo.	Material as a continuous variable	Delivery of qualified hardware in days	2x+ uptime through health monitoring

Acceleration through Integration

Key Challenge Areas in Structural Materials

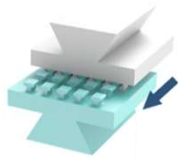
Data Strategy
Materials Informatics Bottleneck

Perspective

FAIR data enabling new horizons for materials research

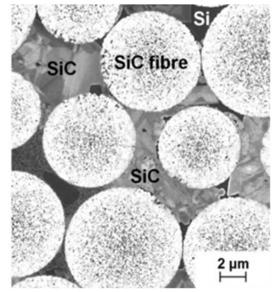
Scheffler, et al., Nature, 2022

Joining Technology
Multifunctional architectures



Young, et al., Mat. & Design, 2023

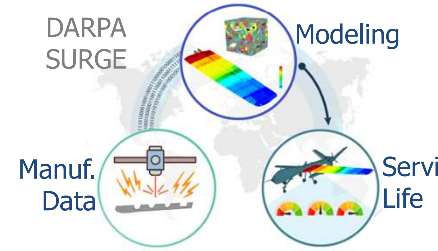
Slashing Lead Times



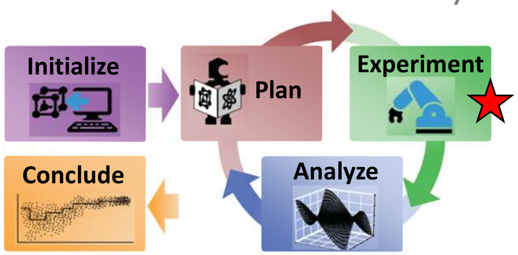
~6 mos. for CMC's

Mainzer, et al., J. Eur. Cer. Soc., 2016

Rapid Part Qualification
<12hr after production



Autonomous Materials Research
1000x research acceleration by 2040



Stach, et al., Matter, 2021

Multi-Material Structures
50% mass savings

Raytheon DARPA METALS Team

Manufacturing Workforce
2.1M jobs unfilled by 2030

National Association of Manufacturers (NAM)

Counterfeit Hardware
2% of aerospace parts

Courtesy RTX

Discovery
Identifying early potential

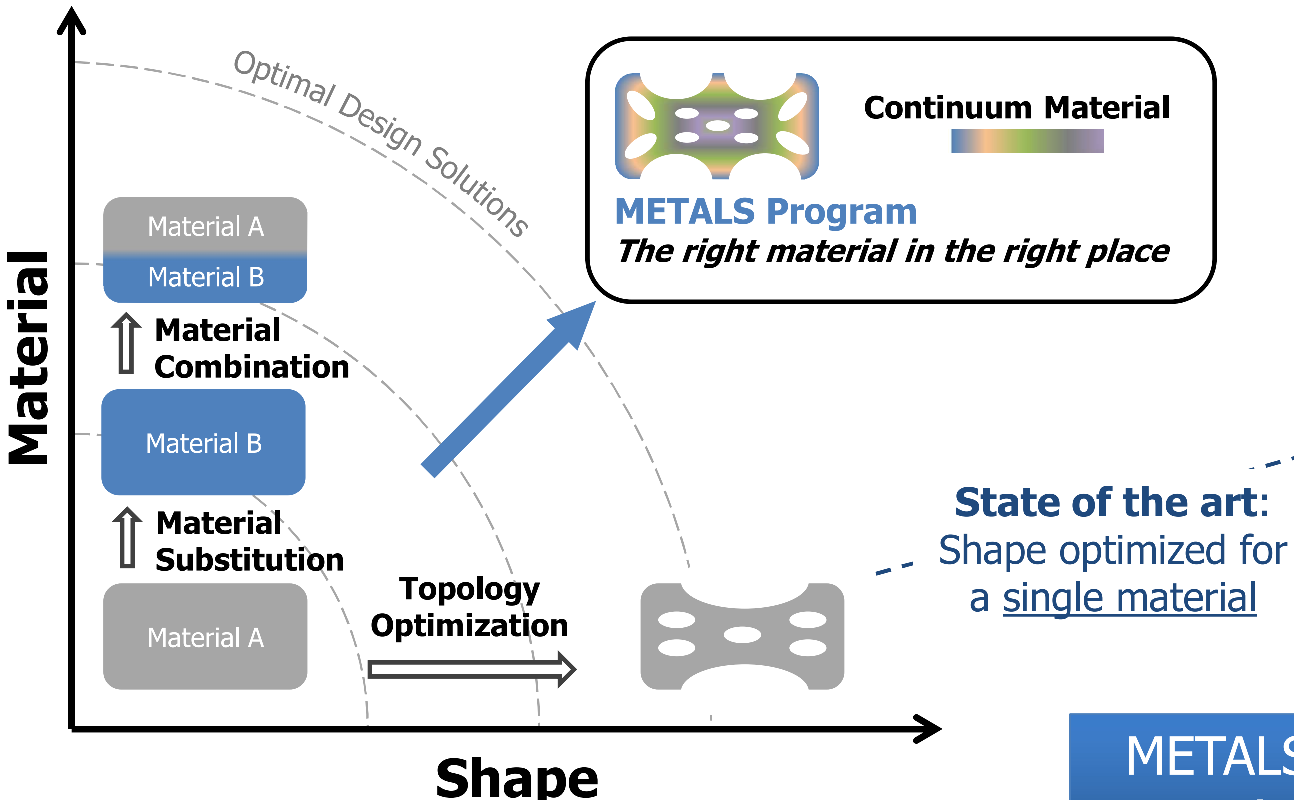
Design
Optimizing functionality

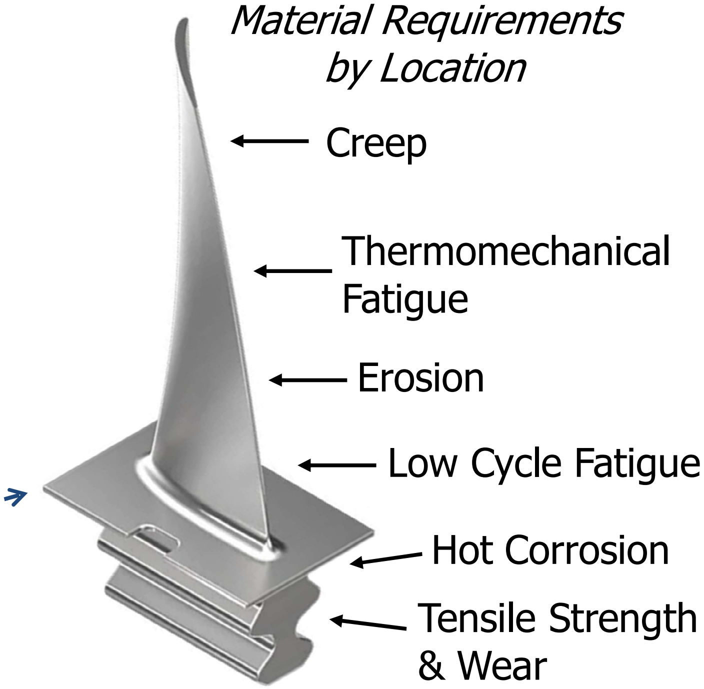
Manufacturing
Producing hardware at scale

Deployment
Fielding for use

DARPA METALS Program

Multiobjective Engineering and Testing of ALloy Structures (METALS)



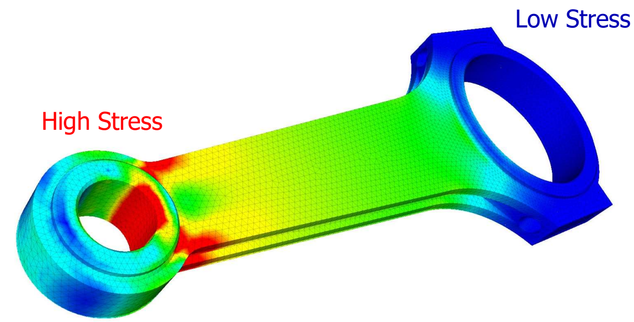


https://tungaloy.com/industries/aerospace_turbine-blade/

METALS is exploring simultaneous co-optimization of shape & material

Materials Informatics Will Enable Explicit Design Integration

Discipline	Surrogate Model
Structures	Finite element analysis (FEA) *Static equilibrium*
Fluid mechanics & aerodynamics	Computational fluid dynamics *Navier-Stokes*
Heat Transfer	Finite element analysis *Fourier, Stefan-Boltzmann*
Controls	Equations of motion *Newton*
…	…
Materials	



FEA analysis of the stress distribution in a piston rod
https://www.simscale.com/docs/simwiki/fea-finite-element-analysis/what-is-fea-finite-element-analysis/

Materials has never had an adequate surrogate model…**materials informatics** is a key enabler

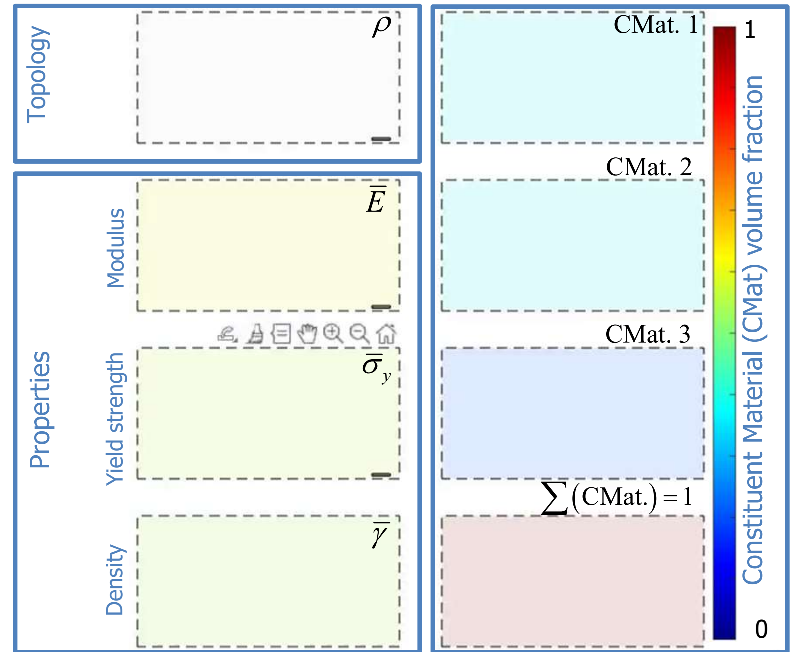
METALS is developing design optimization architectures incorporating material *explicitly* using a materials informatics approach

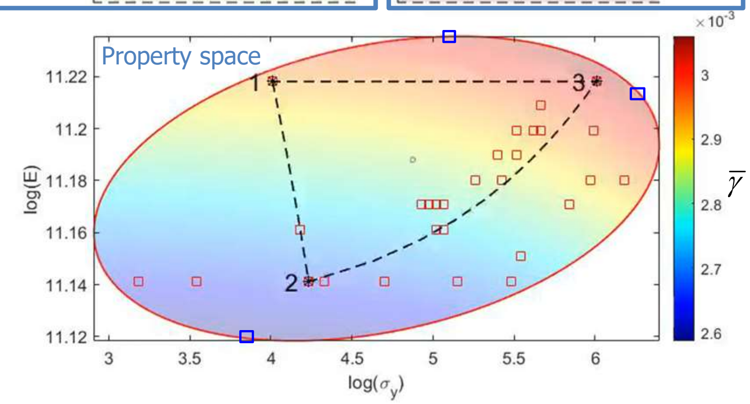
METALS Early Results

RTX Technology Research Center (RTRC),
Raytheon, Johns Hopkins University

- Simple cantilever beam demonstration
- Simultaneous optimization of shape and material distribution to minimize mass and deflection
- 50% weight savings realized in multi-material design

Team is building out material testing and optimization frameworks to demonstrate on a generic propeller design

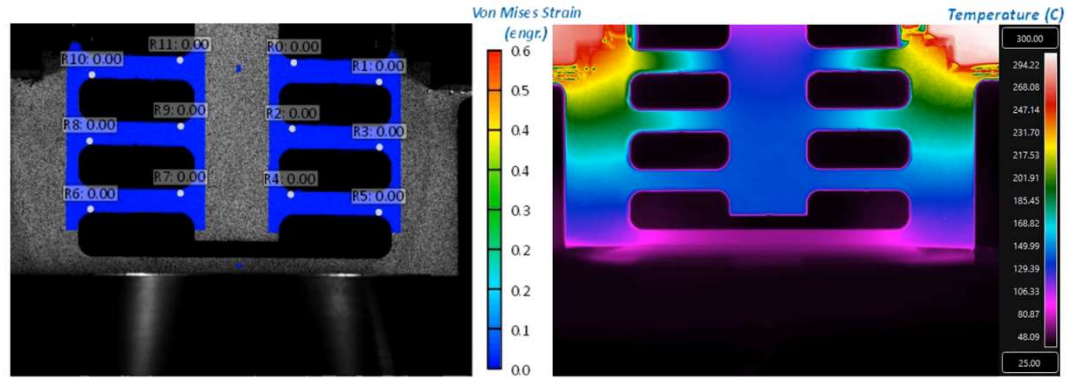


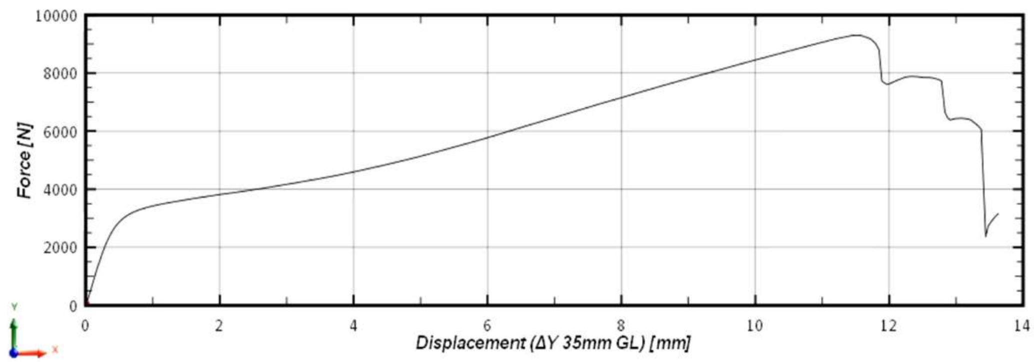


METALS Early Results

Teledyne Scientific Company, U. Wisconsin, U. Colorado – Boulder, U. Miami

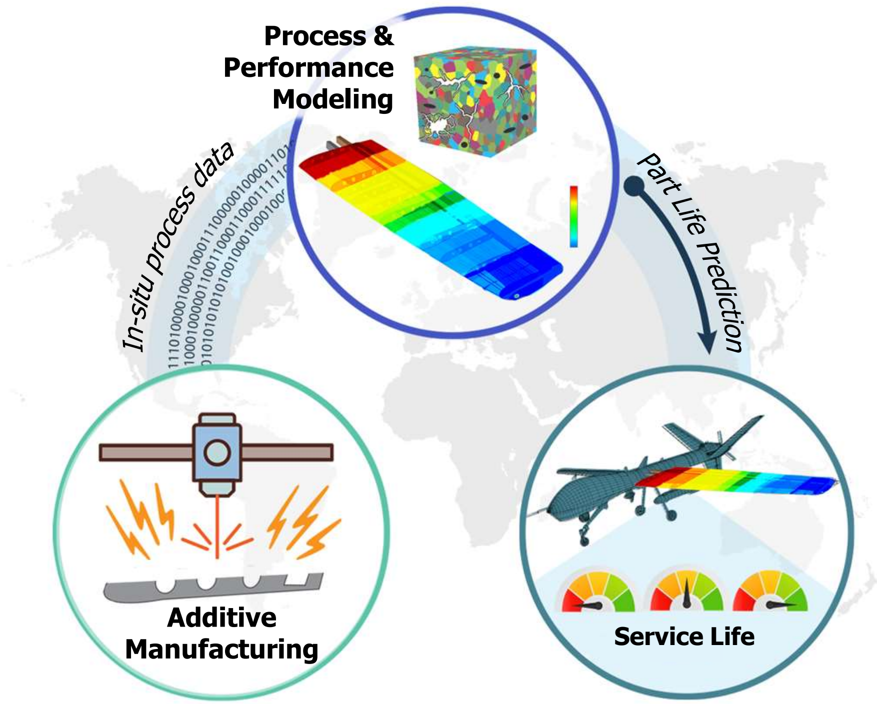
- Novel specimen design to access multiple temperatures and strain states in a single test
- Leveraging digital image correlation and domain-transfer neural network to extract material properties





High-throughout testing approach to feed design optimization data needs

Structures Uniquely Resolved to Guarantee Endurance (SURGE)



Core hypothesis: Part life can be predicted on the fly based on data collected during manufacturing

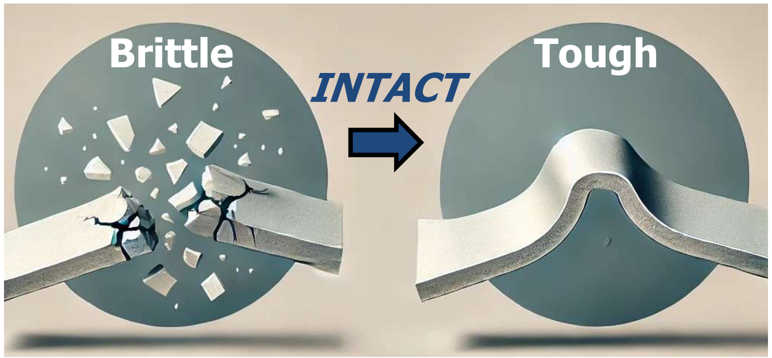
Objective: Enable distributed additive manufacturing for point-of-need and surge production demand

Approach:

- Generate a digital twin of part microstructure and defect distribution based on data collected during manufacturing
- Apply microstructure-based lifing methods to predict part life under specified usage scenarios

SURGE will demonstrate an alternative path to part qualification to realize the full potential of additive manufacturing

Intrinsically Tough and Affordable Ceramics Today (INTACT)



Material Property	Metals	Ceramics
Ductility		INTACT
Fracture Toughness		
Compressive Strength		
Elastic Modulus		
Density		
Max. Use Temperature		
Corrosion Resistance		

Core hypothesis: Intrinsic toughness can be engineered into ceramic materials

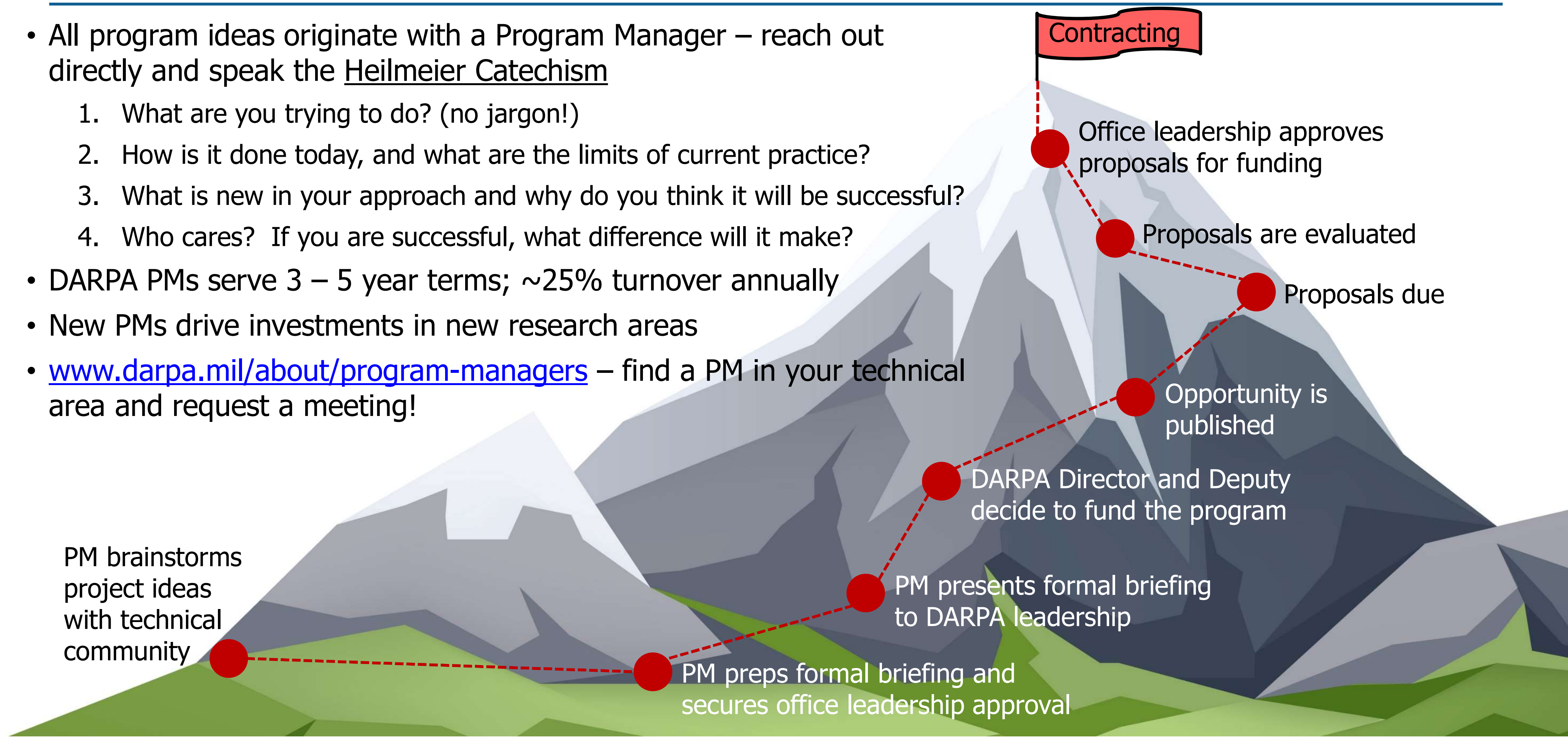
Objective: Explore a range of atomic-scale toughening mechanisms to instill metal-like ductility in structural ceramics

Approach:
- Leverage non-equilibrium processing techniques to access novel microstructures unrealizable via traditional production methods
- Engineer defects in ceramic microstructures to accommodate local plasticity and, in turn, bulk fracture toughness

Addressing the Achilles heel of ceramics to open a new class of structural materials

The Path from Idea to Program & How to Engage

- All program ideas originate with a Program Manager – reach out directly and speak the Heilmeier Catechism
  1. What are you trying to do? (no jargon!)
  2. How is it done today, and what are the limits of current practice?
  3. What is new in your approach and why do you think it will be successful?
  4. Who cares? If you are successful, what difference will it make?
- DARPA PMs serve 3 – 5 year terms; ~25% turnover annually
- New PMs drive investments in new research areas
- www.darpa.mil/about/program-managers – find a PM in your technical area and request a meeting!



Breaking Down Barriers to Entry for Nontraditional Performers

DARPAConnect is designed to broaden DARPA's reach and stimulate **growth and collaboration** between DARPA, industry, and academia.

- Regional and Virtual Events
- Networking Opportunities
- Training and Development
- Customized Support and Mentoring

www.DARPAconnect.us

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