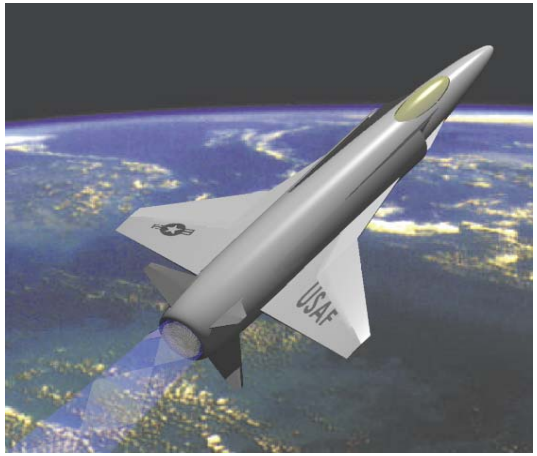
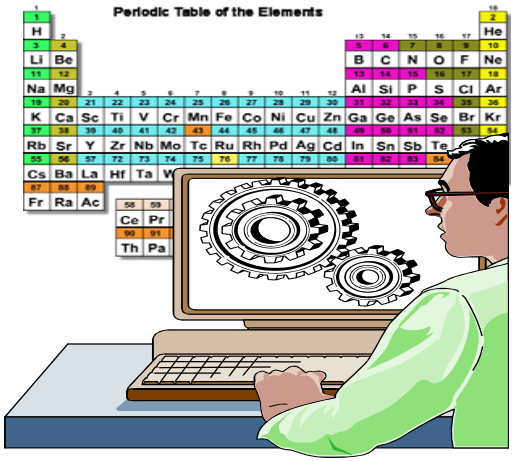
MEANS2

A Revolutionary Approach to Materials in the Design Process

MATERIALS ENGINEERING FOR AFFORDABLE NEW SYSTEMS



THEME OBJECTIVE: To develop a global design methodology employing materials modeling and strategic experimentation that spans length and time scales from individual atoms to engineering structures, emphasizing compatibility between models at adjacent scales, interoperability with existing design software, lifetime prediction and uncertainty modeling.



The Issue

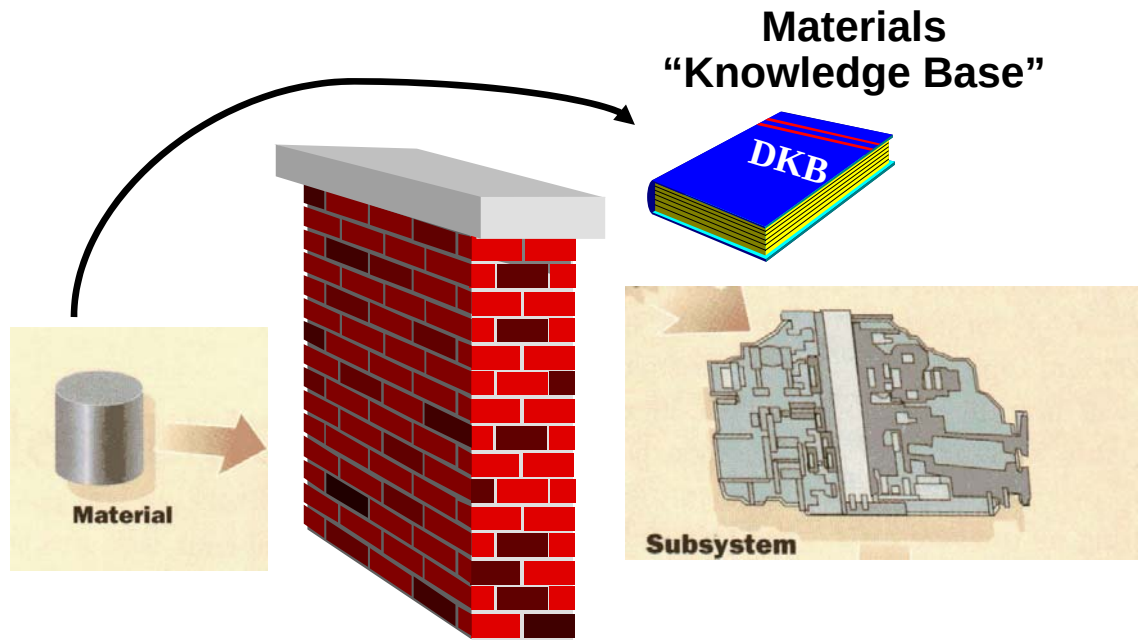
- Materials Science and Engineering has not progressed as rapidly as other disciplines in contributing to the reduction in the product cycle during the last decade.
- New developments in materials are not being exploited as rapidly as desirable because of the time and cost necessary to obtain information on material properties and characteristics.
- Products are being designed and fabricated with existing materials having verified design properties, resulting in the use of less than optimal materials for many applications.

The Motivation

Major disconnect between materials development & components/systems engineering design

- **Known alloy to reliable part ~36 months**
- **Steels for navy landing gear 15+ yrs**
- **Lightweight composites for army vehicles 15+ yrs**
- **Gamma titanium aluminides ~30yrs and counting**
- **Ceramics for engines - 30+++ ? yrs**
- **Evolutionary alloy changes (ship steels, superalloys, etc) ~7-10 years**

Adapted from Wax, 1999



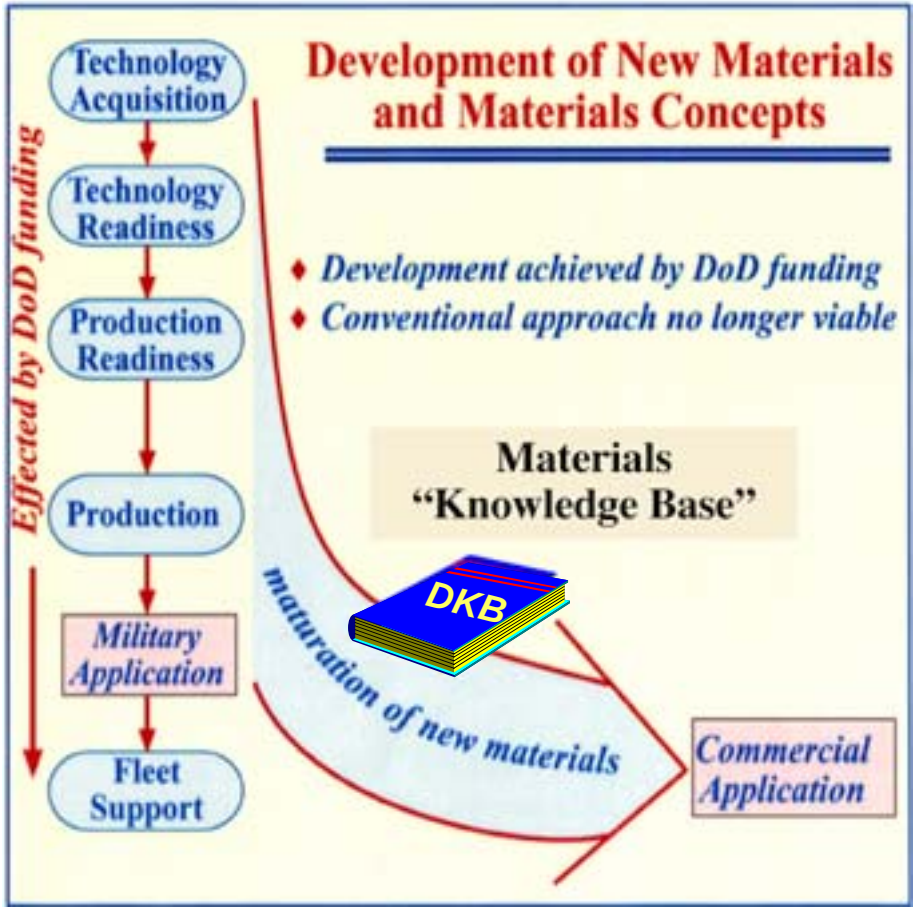
Materials Development

- **Highly Empirical**
- **Testing Independent of Use**
- **Existing Models Unlinked**

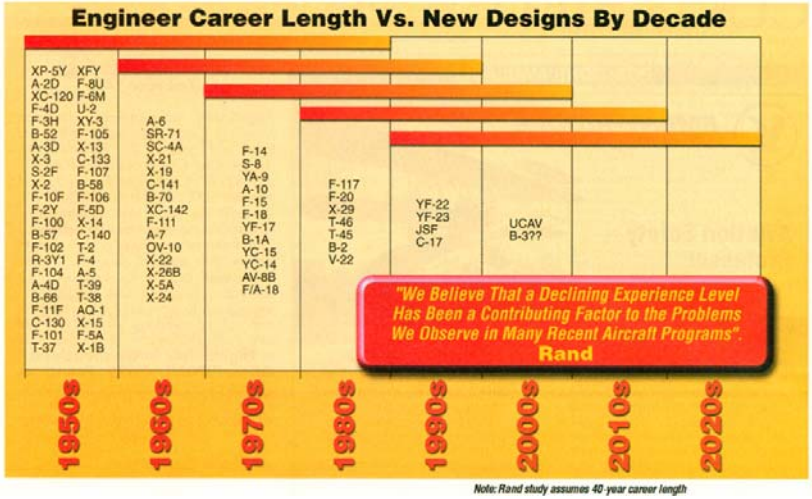
Engineering Design

- **Materials Input from "Knowledge Base" of Data (Data Sheets, Graphs, Heuristics, Experience, etc.)**
- **System/Sub-System Design is Heavily Computational and Rapid**
- **Well Established Testing Protocols**

Aerospace Structural Materials Development: How It Happened



Adapted from Fraser, 1998; Wax, 1999



- DoD materials transition opportunities (systems) have drastically reduced
- Material development time far exceeds the modern short product cycle
  - iterative, empirical development of "Knowledge Base" is lengthy, data intensive, and expensive

21st Century Reality <u>Demands</u> that the Paradigm Change!

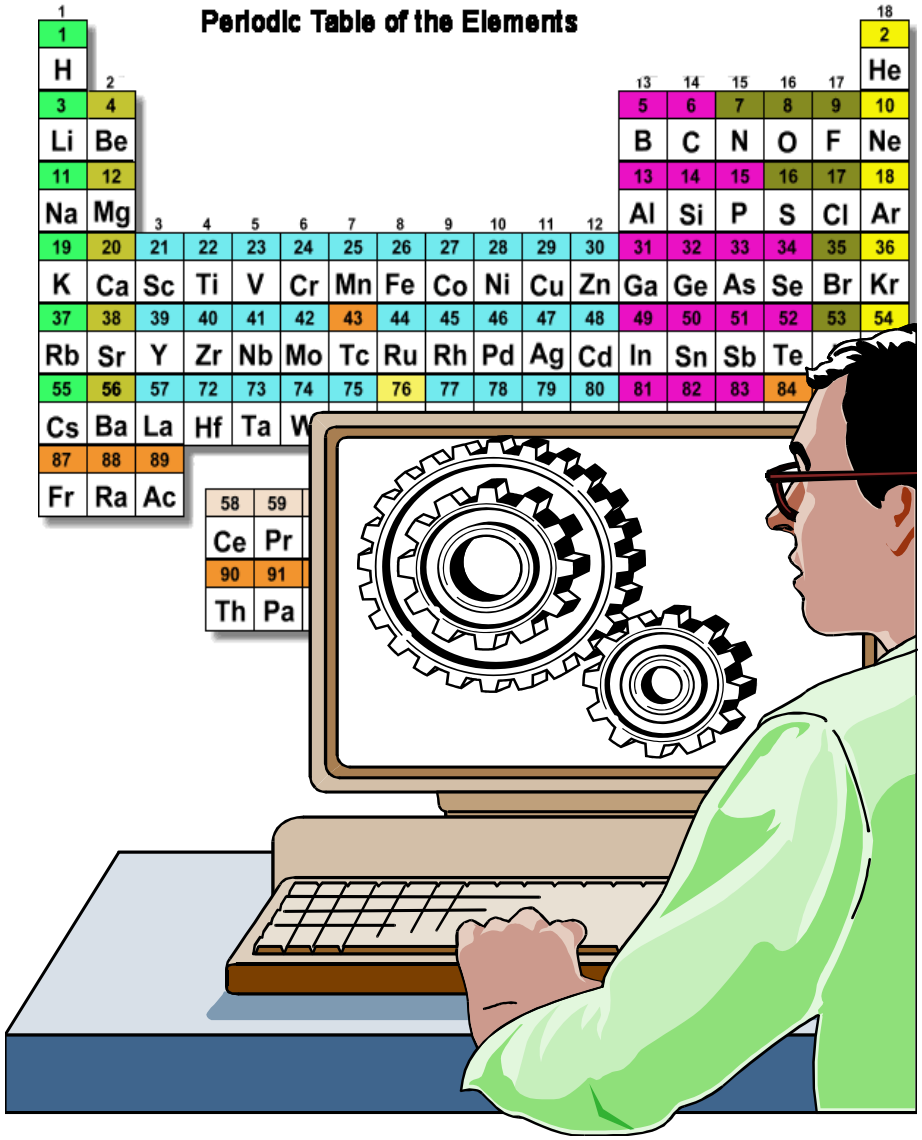
The MEANS to a Desireable End

Materials Engineering for Affordable New Systems

Exploit computational Materials Science and Engineering to develop a design methodology that incorporates models of structure-process-property relationships of materials into engineering design software, enabling materials design to be an integral part of the global design process.

The Vision

- Imagine that the periodic table is the ultimate data base.
- Construct a design space that extends from the periodic table to input into current design software.
- Conduct research to fill the gaps in this space.



Following the Vision

Elements of MEANS

SOME OF THE THINGS WE WILL NEED FOR SUCCESS:

- **Models and simulations that include not only values of design parameters based on structure-property relationships but also estimates of reliability and lifetime prediction**

- **Strategies that link models at various length and time scales**

- **Validated and verified modeling, simulation and experimentation technologies that reduce the time required to construct an acceptable Designer Knowledge Base for use by designers**

- **A collaborative, interactive design environment in which engineering designers and materials designers can interact simultaneously to develop a robust approach to including materials and process design in the engineering and systems design process.**

MEANS1 Research Projects FY 00-04

NOVEL SiCN CERAMICS FOR HEALTH MONITORING OF HIGH TEMPERATURE SYSTEMS; PI-R. Raj, U. Colo.

MULTIFUNCTIONAL STRUCTURAL CERAMICS WITH FERROELASTIC AND MARTENSITIC TRANSFORMATIONS; PI-A. Sayir, CWRU and NASA Glenn.

MULTISCALE MODELING AND EXPERIMENTS FOR DESIGN OF SELF-HEALING STRUCTURAL COMPOSITE MATERIALS;PI- S. White, UIUC and J. Kieffer, U. Mich. (2 Grants)

INFLUENCE OF PREPREG MICROSTRUCTURE OF STRUCTURAL PERFORMANCE OF POLYMER MATRIX COMPOSITES; PI-G. Dillon, U. Pa.

MODEL-BASED DESIGN FOR COMPOSITE MATERIALS FOR LIFE MANAGEMENT; PI-G. Schoeppner, AFRL/ML

CURING OF COMPOSITES: AN INTEGRATED MULTISCALE PROCESS DESCRIPTION TOWARD TAILORED STRUCTURES AND PROPERTIES; PI-R. Pitchumani, U. Conn.

COMPUTATONAL DESIGN OF ADVANCED AEROTURBINE MATERIALS: PI – G. Olson, Northwestern U.

MICROSTRUCTURE-BASED MODELING FOR LIFE-LIMITED COMPONENTS: PI – H. Fraser, Ohio State U.

DEVELOPMENT OF A PHYSICALLY BASED METHODOLOGY FOR PREDICTING MATERIAL VARIABILITY IN FATIGUE CRACK INITIATION AND GROWTH: PI – K. Chan, SWRI

DEVELOPMENT OF AN ACCELERATED METHODOLOGY FOR THE EVALUATION OF CRITICAL MECHANICAL PROPERTIES OF POLYPHASE ALLOYS: PI – P. Dawson & M. Miller, Cornell U.

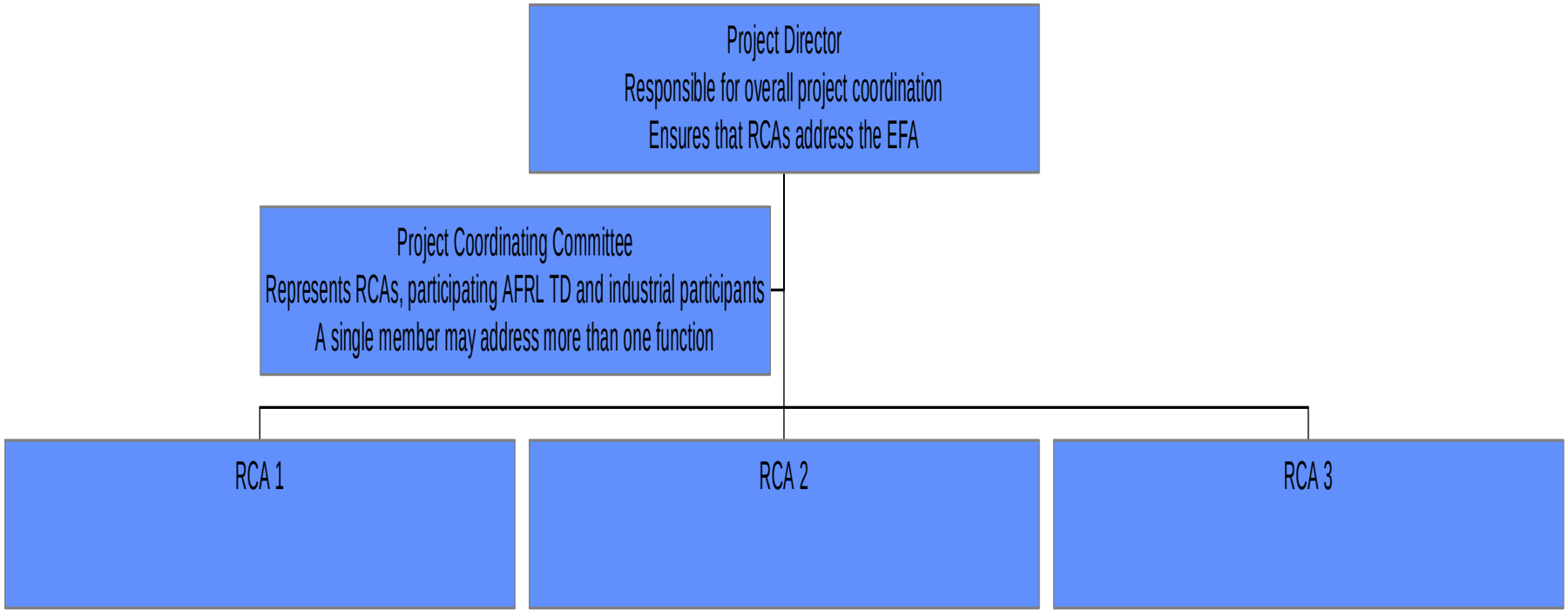
ANNUAL FUNDING $2M+

New Elements of MEANS2

- The Integrated Materials Design Team (IMDT)
  - Materials and process modeling
  - Design methodology and integration
  - Project coordination committee
- Engineering Focus Area (EFA)
  - Defines an application area towards which the research is directed (not the North Star, but the short-term destination)
  - Illustration of a Broad EFA: “thermal protection systems for use in aircraft gas turbine engines”
  - Illustration of a Narrow EFA: “blisk for operation at 1300ºC”
- Research Concentration Areas (RCA)
  - Define specific research areas that will be coupled to address the EFA
  - Each research group that comprises the IMDT will address one or more RCAs

Sample Project Organization

MEANS2 PROJECT ORGANIZATION



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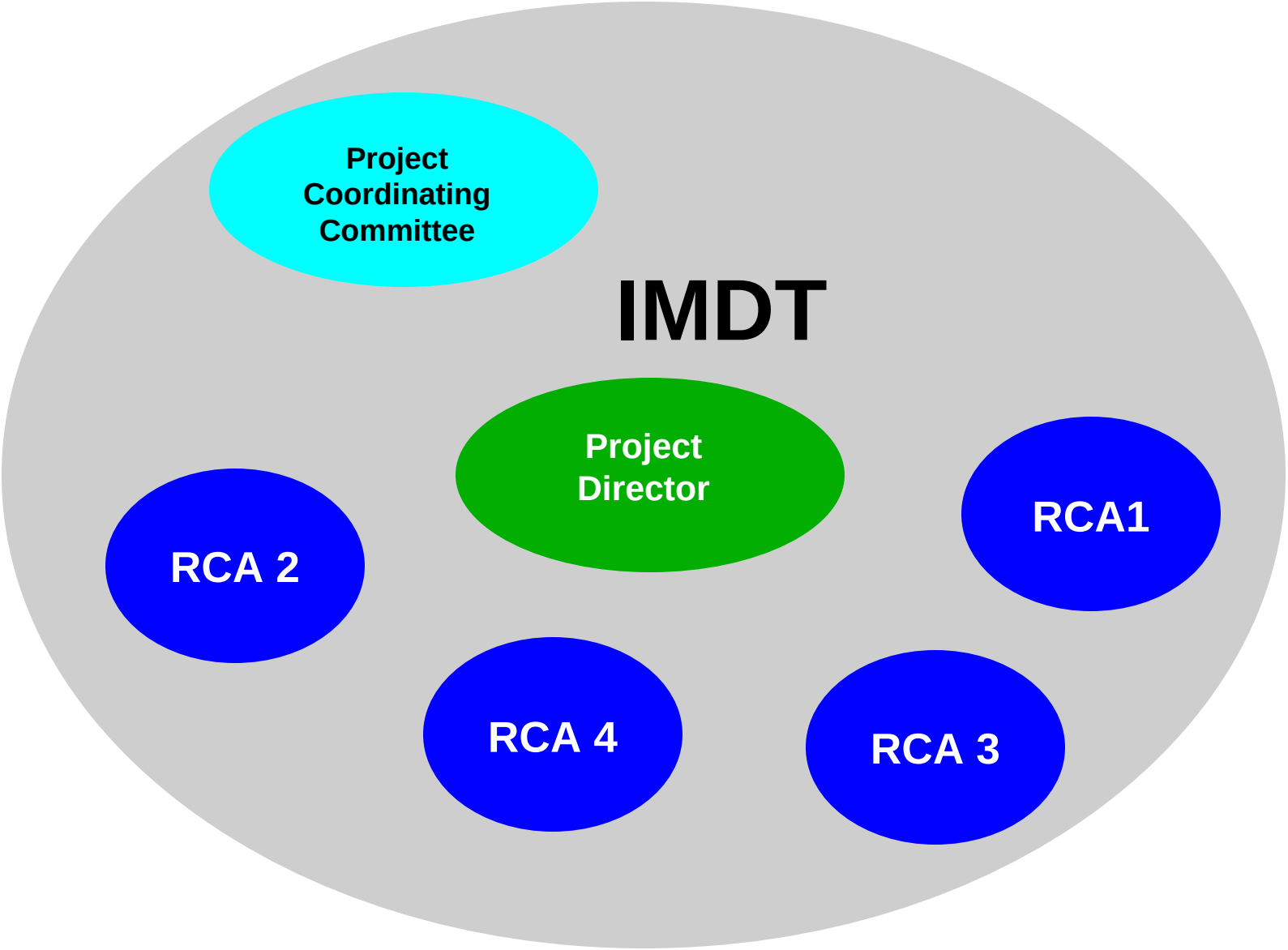

Award Details

- Awards will be grants for one year with two, one-year options – standard for AFOSR
- IMDTs can be organized as a single contractor with subcontracts or a collection of coordinated grants
- AFRL TD participation will be handled through internal AFRL procedures
- Funds directed from AFOSR to an AFRL TD in support of a MEANS2 project will be counted as part of the project cost
- Cost sharing by participants is encouraged, but not required. Where offered, the specific contribution should be documented.

Award Details (cont'd)

- The total amount of funds allocated to this initiative is $2M p.a. for 3 years.
- The maximum amount that will be granted for any one project is $750K p.a. for 3 years.
- Proposal budgets should reflect an appropriate level of effort for the magnitude of the EFA chosen.
- AFOSR reserves the right to make awards of lesser amounts to proposers, subject to negotiation of project objectives and scope.
- AFOSR reserves the right to request teaming of selected proposers both within and across program areas.
- Projects will be administered within AFOSR by Program Managers in Metallic Materials (C.S. Hartley), Ceramic and Nonmetallic Materials (J. Fuller), Mechanics of Materials and Devices(B.-L. Lee) and Organic Matrix Composites (C. Y. Lee)

Review Process

- Letters of intent (LOI) of 2-3 pages that describe a proposed project are due 1 Jun 2004
- LOI should identify the EFA addressed, the number of RCAs proposed, the proposed participants and their functions and include an estimated project cost
- All LOI will be reviewed internally by all participating AFOSR Program Managers with confidential input, at the discretion of the AFOSR PMs, from internal or external parties not involved in any proposal
- Responses to LOI that encourage or discourage full proposals will be sent by 30 Jun 2004
- Proposals are due at AFOSR by COB 12 Aug 2004
- Proposal review will be conducted by participating AFOSR Program Managers with confidential input, at the discretion of the AFOSR PMs, from internal or external parties not involved in any proposal
- Announcements of awards will be made on or before 1 Oct 2004

Summary

- *MEANS is the Basic Research component supporting the paradigm shift initiated by the Accelerated Insertion of Materials program --* pioneering cost- and *time-saving* design tools

- MEANS consists of a *Design-centric* approach establishing *microstructural parameters as design variables* through integrated process-structure-property simulations

- *Academic and national laboratory* links are central

- *Strong industrial link* must be established
  - Realistic near- and mid-term achievements can only occur by industrial involvement
  - Process modeling, microstructural evolution, strength modeling must be linked
  - Experiments needed for model validation must be clearly articulated