DSO Office-wide BAA Proposers Day

21–22 JULY 2015 • DARPA CONFERENCE CENTER

Tuesday, July 21, 2015

8:45–9:30	**DSO Overview** *Dr. Stefanie Tompkins, Director, DSO*
9:30–10:30	**Program Manager Introductions** *Dr. Tyler McQuade* *Dr. Prem Kumar* *Dr. Predrag Milojkovic* *Dr. Jim Gimlett* *Mr. Mick Maher* *Dr. John Paschkewitz* *Dr. Vincent Tang*
10:30–10:50	*Break*
10:50–11:45	**Program Manager Introductions Continued** *Dr. Fariba Fahroo* *Dr. Reza Ghanadan* *Dr. Jan Vandenbrande* *Dr. John Main* *Dr. Mark Micire* *Dr. Adam Russell*
11:45–1:05	*Lunch (pick-up lunch boxes)*

Tuesday, July 21, 2015

12:05–12:50 **How to build a DARPA program**
(Optional/Concurrent with Lunch)
Dr. Bill Regli, Deputy Director, DSO

12:50–1:05 **Top 10 Ways to Prepare to Engage with DARPA**
(Optional/Concurrent with Lunch)
Dr. Tyler McQuade, DSO

*****Reminder: submit Questions by 2:00 pm*****

1:10–2:10 **Case Studies**
Program at beginning stages
Program ending and transitioning

2:15–3:00 **Welcome to DARPA**
Dr. Arati Prabhakar, Director, DARPA

3:00-3:30 *Break*

Tuesday, July 21, 2015

3:30–3:50	**Q&A** *Dr. Stefanie Tompkins, Director, DSO*
3:50–4:20	**Doing Business with DARPA** ***(Optional/Concurrent with sidebars)*** *Ms. Kristen Fuller, ADPM, DSO*
4:20–4:35	**Security Instructions for Working with DARPA** ***(Optional/Concurrent with sidebars)*** *Mr. James Persons, Program Security Representative, DSO*
4:00–5:15	***Sidebars***
5:15	*Adjourn*

Defense Sciences Office

Dr. Stefanie Tompkins

July 21, 2015

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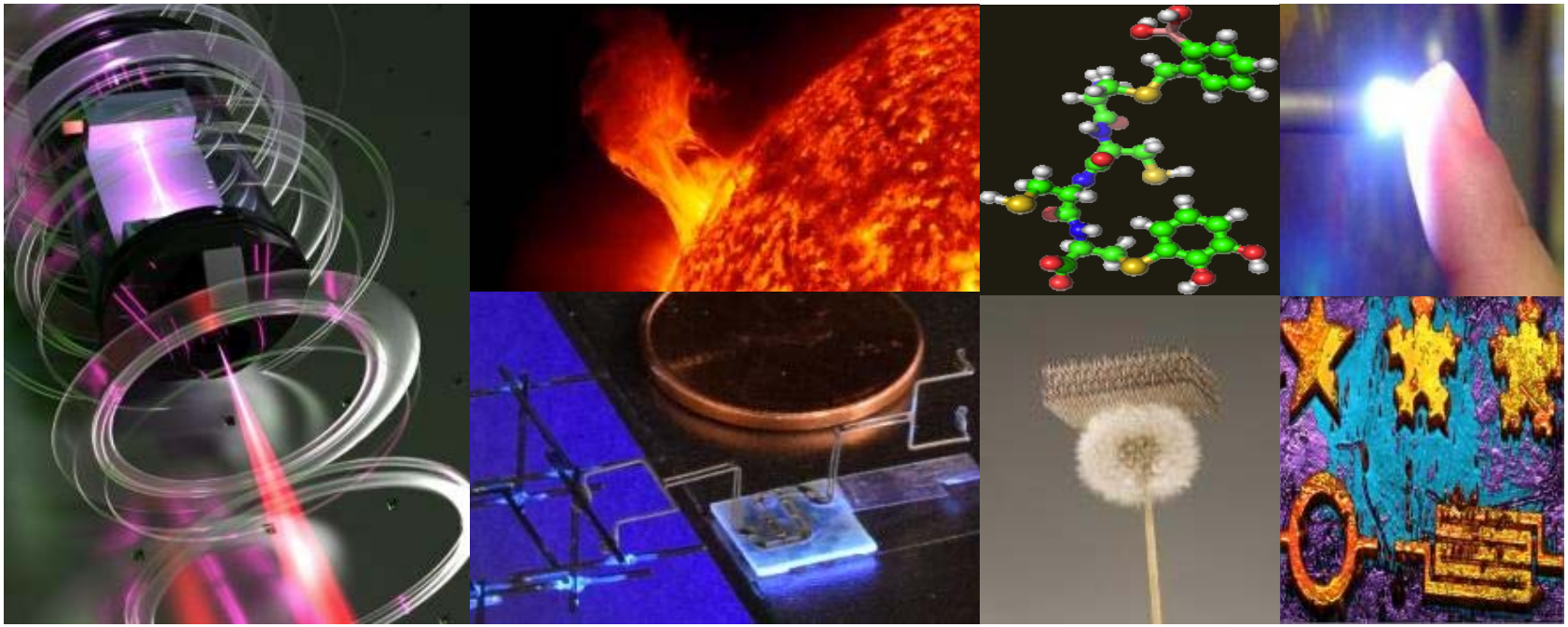
DSO is “DARPA’s DARPA”



Accelerating breakthrough discoveries to create new enabling technologies for national security

DARPA Technical Offices

BTO — BIOLOGICAL TECHNOLOGY OFFICE

- Biological Complexity at Scale
- Neurotechnologies
- Engineering Biology
- Restore, Maintain and Improve Warfighter Abilities

DSO — DEFENSE SCIENCE OFFICE

- Math, Modeling & Design
- Physical Systems
- Human-Machine Systems

I2O — INFORMATION INNOVATION OFFICE

- Empower the Human within the Information Ecosystem
- Guarantee Trustworthy Computing and Information

MTO — MICROSYSTEMS TECHNOLOGY OFFICE

- Electromagnetic Spectrum
- Tactical Information Extraction
- Globalization

STO — STRATEGIC TECHNOLOGY OFFICE

- System of Systems (SoS)
- Battle Management/Comm and and Control (BMC2)
- Communications and Networks (C&N)
- Electronic Warfare (EW)
- Intelligence Surveillance, and Reconnaissance (ISR)
- Positioning, Navigation, and Timing (PNT)

TTO — TACTICAL TECHNOLOGY OFFICE

System Focus Areas:
- Ground
- Maritime
- Air
- Space

Crosscutting Themes:
- Agile development
- Cooperative Autonomy
- Unmanned Systems
- Power and Propulsion

Factors Shaping DARPA Investments Today

Wide range of national security challenges: evolving nation states, shifting networks

Powerful, globally available technologies set a fast pace

Military systems' cost, pace, and inflexibility limit our operational capabilities

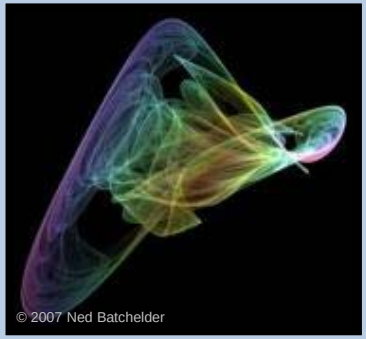
DSO's Approach (This Year)

Accelerate discovery and development

Enable rapid, customized production of (nearly) everything

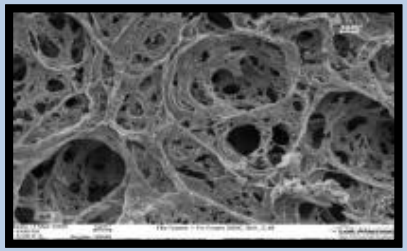
Harness complexity through modeling and design

Focus Areas



Math, Modeling & Design

Physical Systems



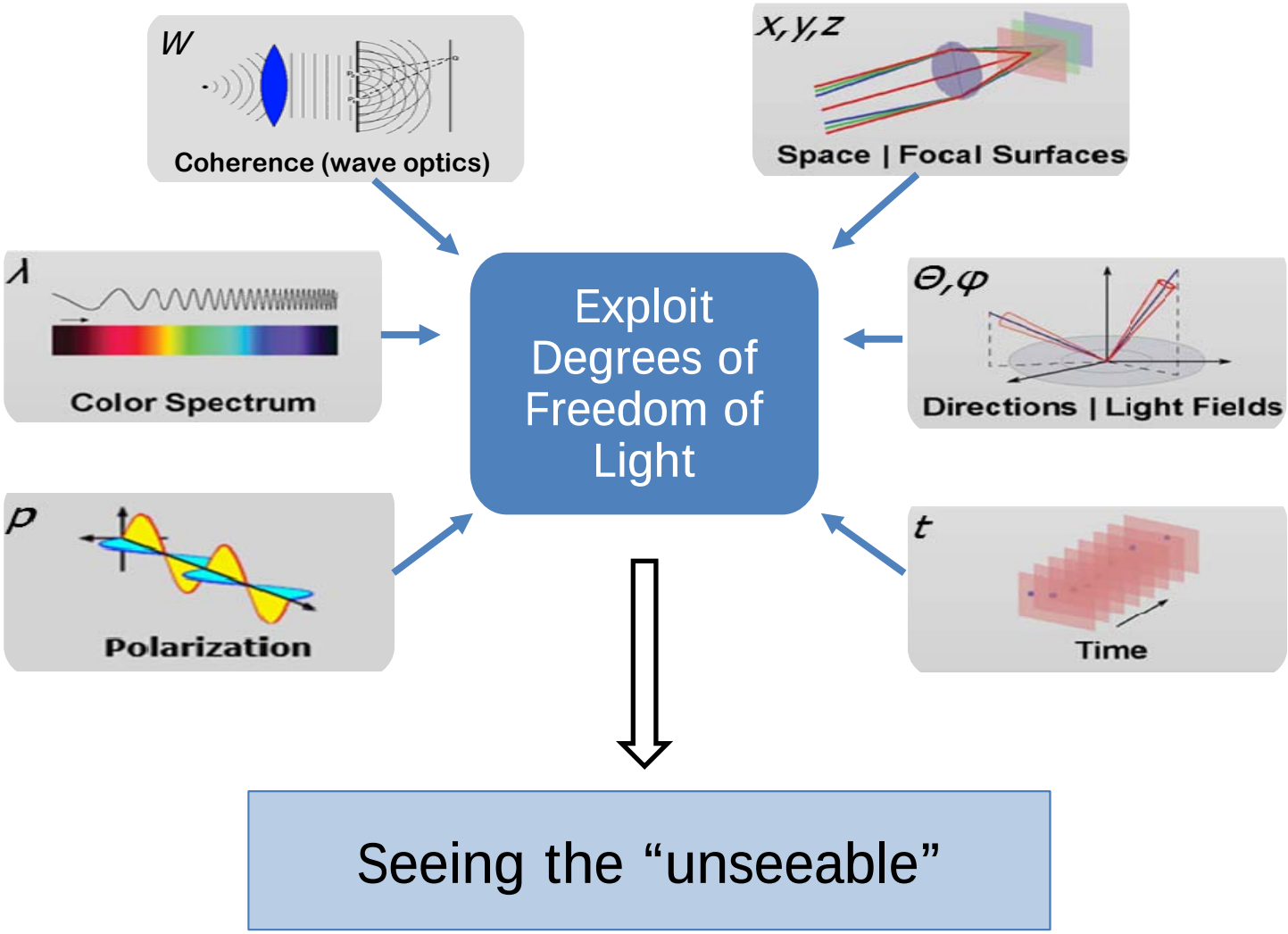
Human-Machine Systems

Social Systems

Types of Programs

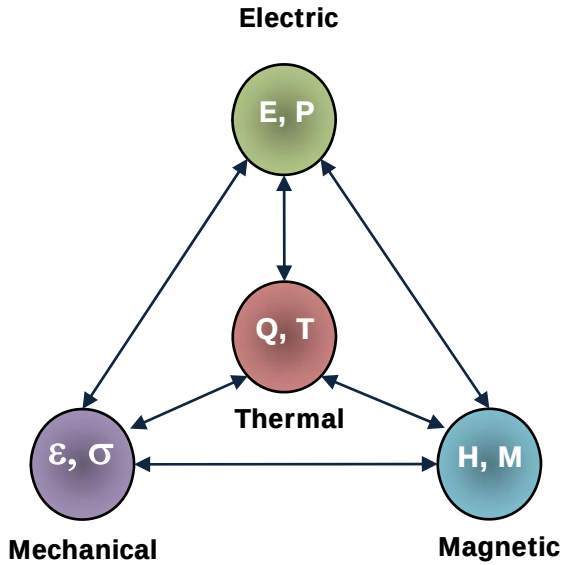
Foundations	Tools	Integrated Demonstrations
• Monitor and explore scientific frontiers across multiple disciplines to create new communities and capabilities • Mostly measurement and theory	• Exploit discoveries to develop tools • Translate capability from within a research community to outsiders • Increased focus on use cases and potential CONOPS	• Bring together multiple lines of research into a new capability, outside the laboratory • Often opportunistic, and/or driven by specific DoD needs

Revolutionary Enhancement of Visibility by Exploiting Active Light-fields (REVEAL)



Materials for Transduction (MATRIX)

Energy Transduction Diagram



Examples of Transductional Materials

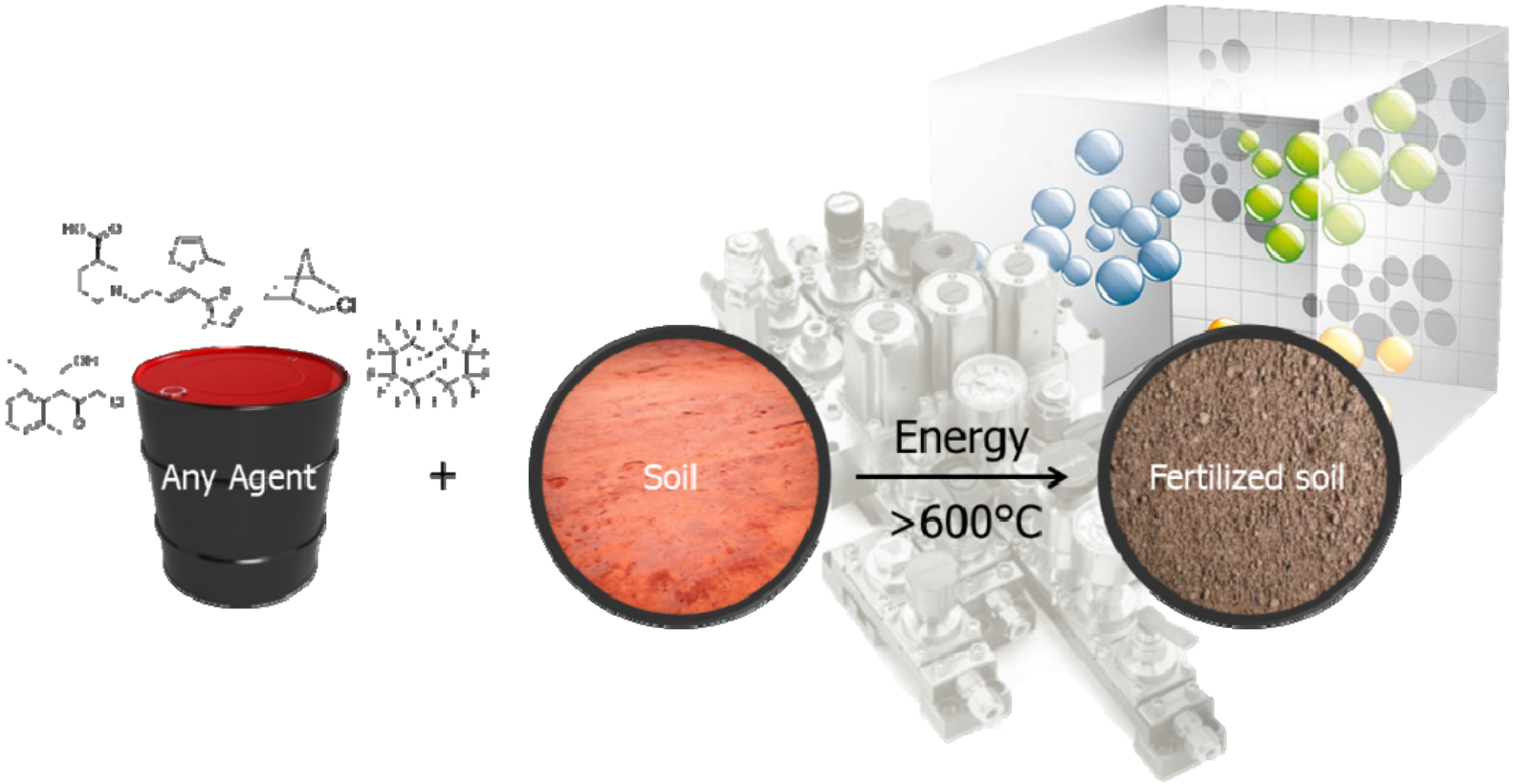
Thermoelectrics
Thermal ⇔ Electric

Multiferroics
Magnetic ⇔ Electric

Phase Change Materials & Others
Utilizing multiple modes (phononic, optical, etc.)

Integrate transduction modeling, design and validation into unified R&D approach with applications focus

Agnostic Compact Demilitarization of Chemical Agents (ACDC)

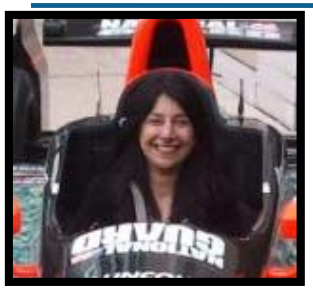


On-site agnostic chemical destruction capability using local resources to convert harmful agents with no hazardous output

Heilmeier Catechism

- What are we trying to do?
- How does this get done, at present?
- What is new about our approach?
- If we succeed, what difference do we think it will make?
- How long do we think it will take?
- Can we transition?
- How much will it cost?

Program Managers



Fariba Fahroo
Mathematics

Mark Micire
Robotics

James Gimlett
Physics

Prem Kumar
Quantum & Nonlinear Optics

Judah Goldwasser
Structural Materials

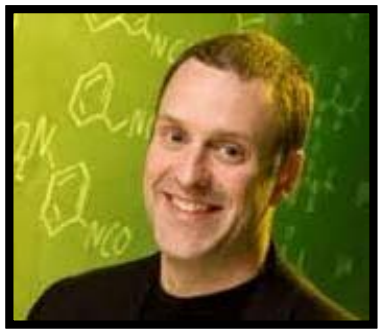
John Paschkewitz
Systems, Design, & Materials

Michael Maher
Materials & Manufacturing

Jan Vandebrande
Math, Design, & Production Automation

Adam Russell
Behavioral/Social Sciences

Gill Pratt
Robotics & Neuromorphic Systems



Tyler McQuade
Chemistry

Predrag Milojkovic
Imaging & Optics

Reza Ghanadan
Complexity Science

John Main
Material System Innovation

Vincent Tang
Applied Physics

Bubbling Technology Opportunities

???

(Tell us what you think they are)

Three Ways to Engage with DSO

Talk to a Program Manager (PM)

- PM sidebars today and tomorrow
- Email/phone/face to face throughout the year

Submit ideas to the DSO Office-Wide BAA (BAA-15-39)

Respond to DSO program BAAs

Concepts → New Ideas

Seedlings: Disbelief → "Mere" Doubt

Programs: Possibility → Capability

We look forward to your ideas.

Tyler McQuade

Tyler McQuade

- B.S. in Chemistry
- B.S. in Biology
- Ph.D in Chemistry

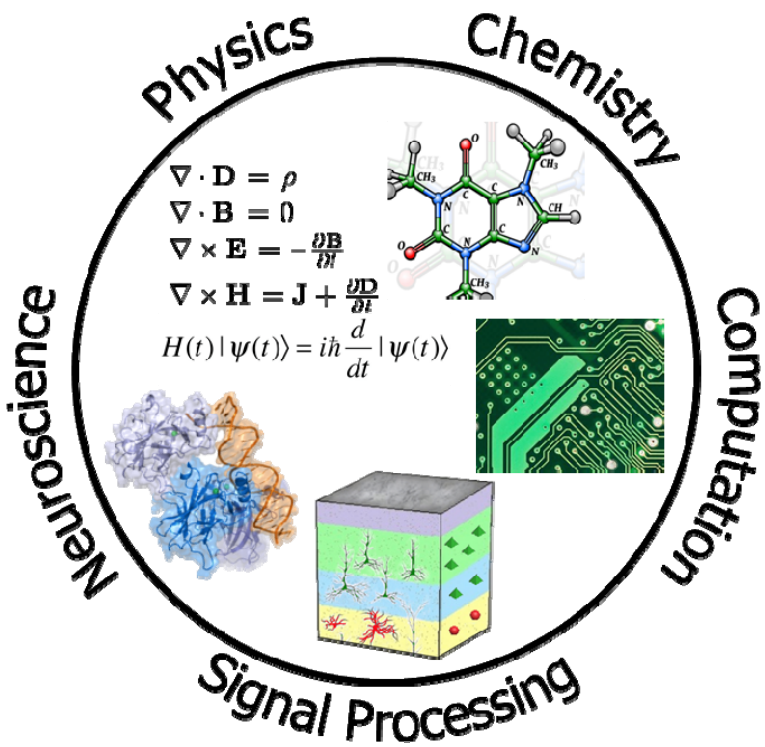
Interests: Molecular Science

- Redefining how molecules are made and synthetic methods shared
- Creating non-natural chemical systems that exhibit emergent behavior/properties
- Complex composites that exhibit emergent behavior
- New approaches to surface modification
- New concepts in switchable interfaces

Prem Kumar

Prem Kumar

Prem Kumar



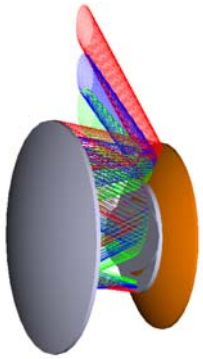
Merging of scientific and technological disciplines

- Ph.D. in Physics
  - Atomic, Molecular, Optical Science
- IPA from Northwestern University
  - Professor of EECS & Physics
- Expert in Optics & Photonics
  - Quantum Optics, Quantum Information Science, Quantum Processing/Computing
  - Lasers, Optical Communications, Photonic Imaging & Sensing

- Asking questions at the intersection of basic sciences (physics, chemistry, biology, math) with engineering, signal processing & computation
  - Can photon detection be time stamped with precision of the most accurate clocks of today?
  - Can we see through fog with the resolution of visible light?
  - Can we understand neuronal circuits from first principles?

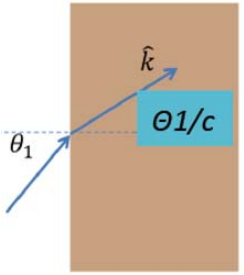
Predrag Milojkovic

Predrag Milojkovic

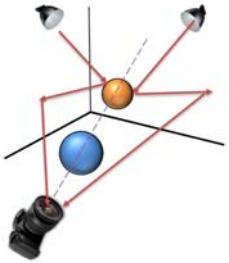


- Ph.D. in Electrical and Computer Engineering
- From Army Research Lab, joined DSO in 11/2014
- Background in optics, optical design, photonics, computer science...

Interests:



- **Extreme challenges in optics and imaging**
  - Full hemispherical FOV reflecting telescope
  - Extremely wide FOV refractive singlet
  - Reconfigurable multi-functional optics
  - Generation of arbitrary 3D light fields (spatial, temporal, spectral)
  - Near field effects in the far field



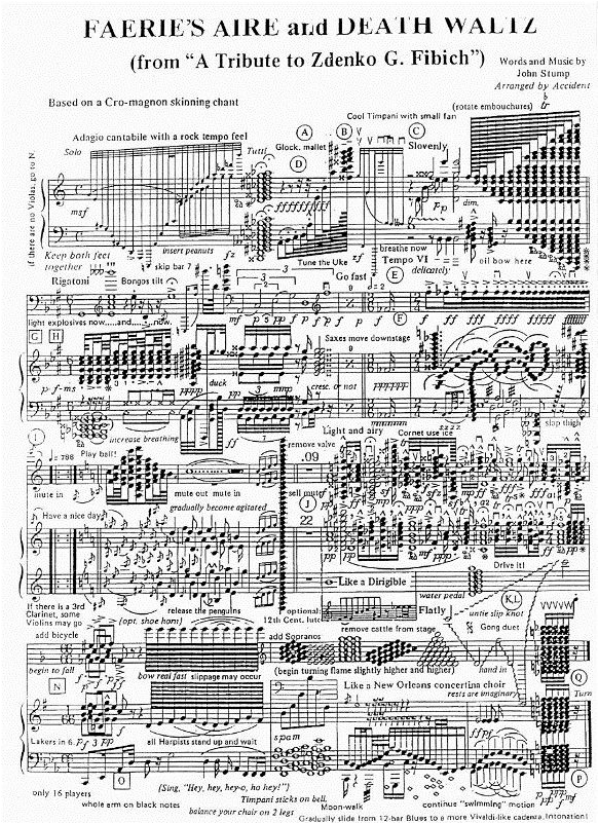
- **Extreme imaging architectures**
  - Imagers for adaptive multi-dimensional information capture
  - Micro-cameras in a swarm – “the sum is greater than its parts”
  - Extremes: zero power, floating, invisible, flexible, 1D/2D...
- **“Seeing the unseeable”**
  - Seeing scene details invisible to optics (super resolution)
  - Maximum scene information extraction from all photons (direct and indirect)

Jim Gimlett

Jim Gimlett

Background:

Basic Research	Applied Research	Commercialization	DARPA	? AD (After DARPA)
PhD Physics Caltech (Time Reversal Symmetry) Nuclear Spectroscopy Neutrino Physics	Optoelectronics Video Networks Optical Networks	Network Elements Inc.	Quantum Sensing (QuASAR) Biochronicity Transductional Materials (MATRIX) NPSW (Next Program. Suggestions Welcome) …..	

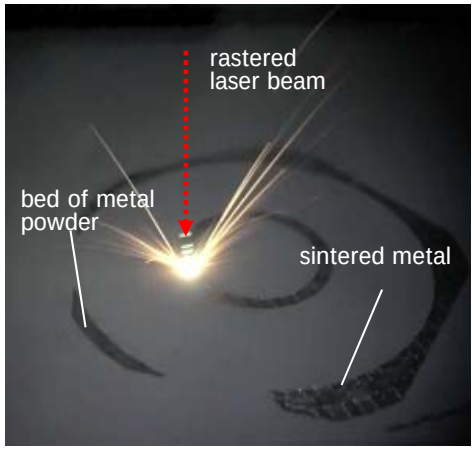


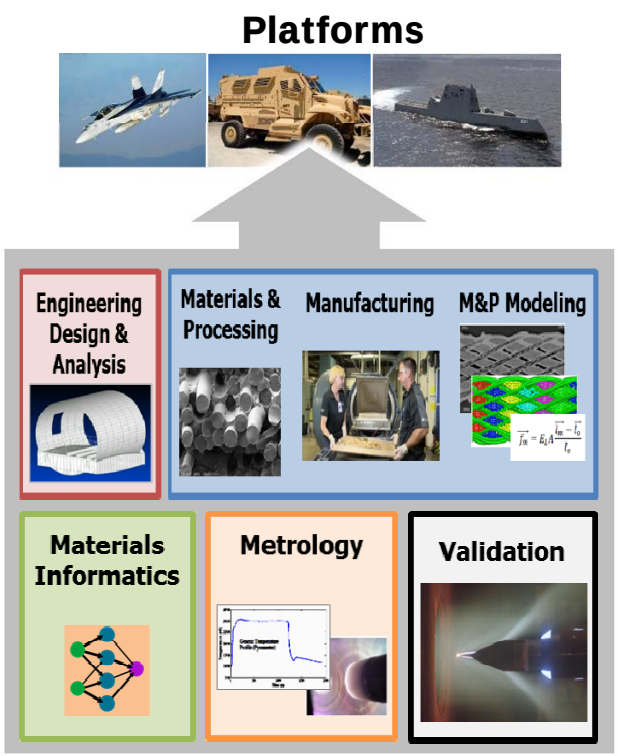
Interests:

- New physics for sensing & transduction
- Understand, model, adapt, build: complex, nonlinear, self-organizing, dynamic, multiscale systems
  - Materials
  - Earth sciences
  - Biological
  - Human-machine interactive systems
- Connect top-down and bottom-up approaches
  - Using every trick in the book, plus a few new ones, from physics, information science, control theory, mathematics

Mick Maher

Mick Maher





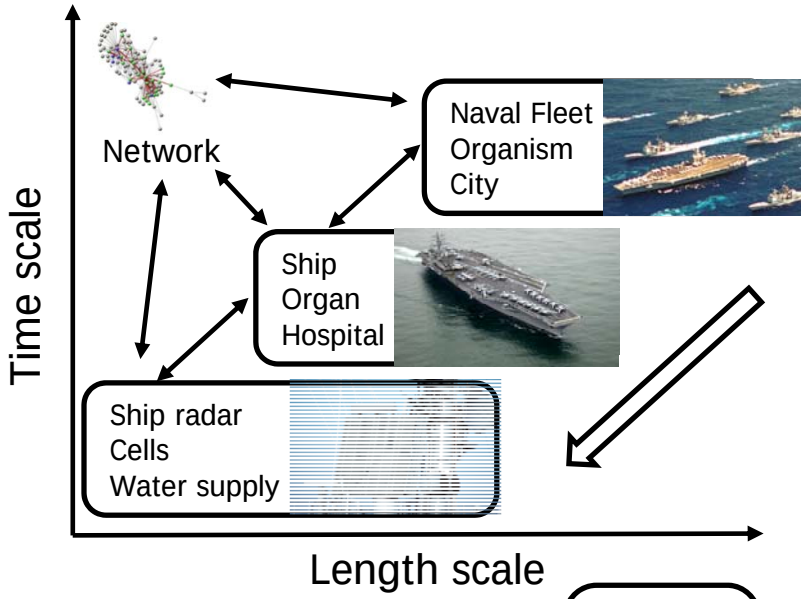
- BS, Chemistry
- Managing:
  - Open Manufacturing
  - Materials Development for Platforms

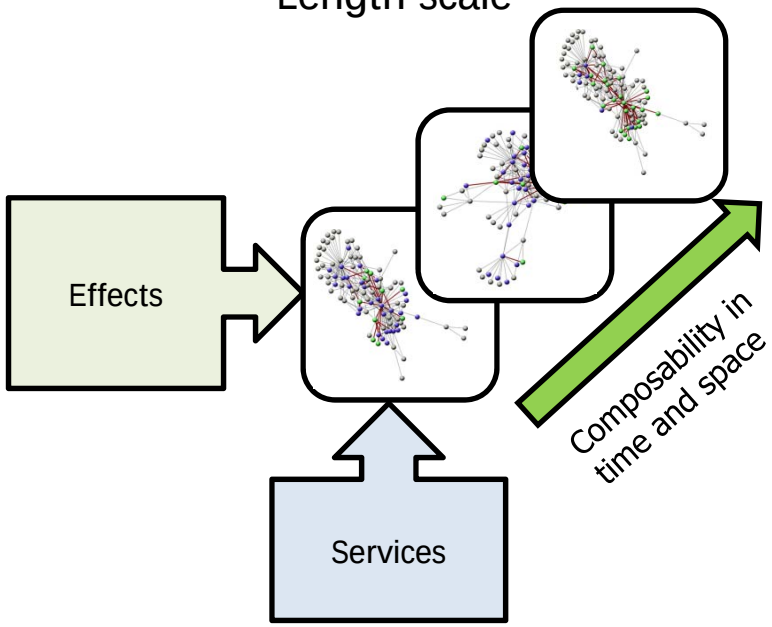
Interests: Materials and Manufacturing

- Impact the materials and manufacturing communities with new approaches to accelerate development and technology acceptance
- Address issues that impact:
- Rapid Qualification
- Accelerated development
- Reducing complexity in systems

John Paschkewitz

John Paschkewitz





- S.B., S.M. Chemical Engineering, MIT
- Ph.D. Chemical Engineering, Stanford

- Experience in multi-scale, multi-disciplinary modeling and systems design (AFRL, LLNL, Caliper, PARC)

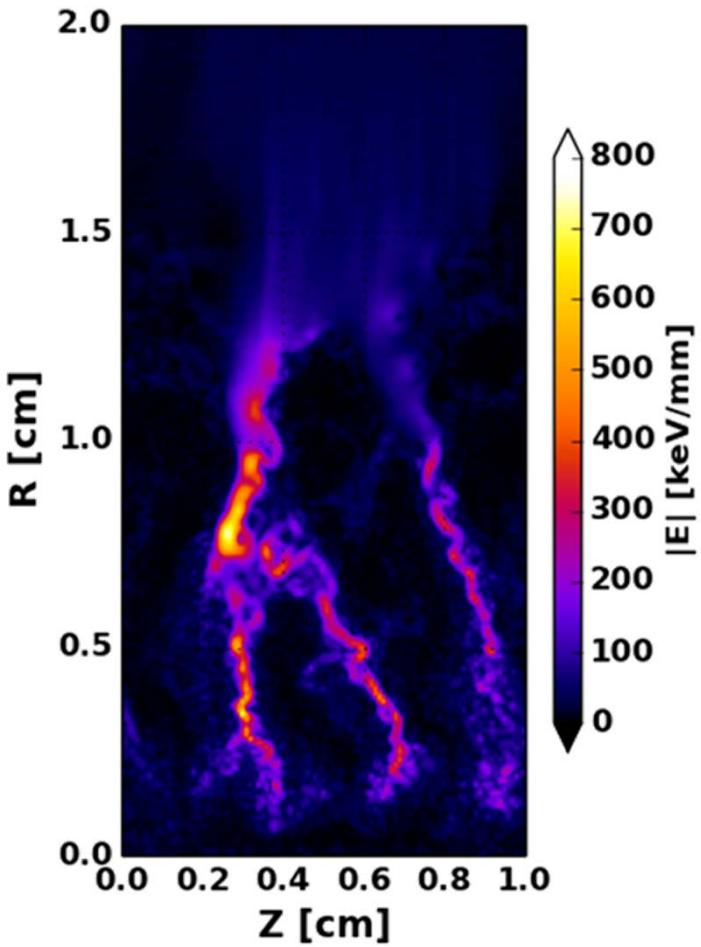
Interests:

- "Architecture aware" systems-of-systems (SoS) design tools, particularly for dynamic inverse problems
- "Composable" systems design – how to build from interfaces out and maximize flexibility while maintaining low weight, power, & cost?
- Man-machine teaming to catalyze revolutionary hardware design for SoS application and to maximize SoS performance

Graphs from Sinan Aral et al. PNAS 2009, all images from Wikipedia

Vincent Tang

Vincent Tang



Intense E fields in a dense z-pinch plasma column from a large plasma simulation

- UCB: B.S. Nuclear & Chemical Engineering
- MIT: M.S. Nuclear Engineering
  PhD. Applied Plasma Physics
- LLNL: Staff Physicist

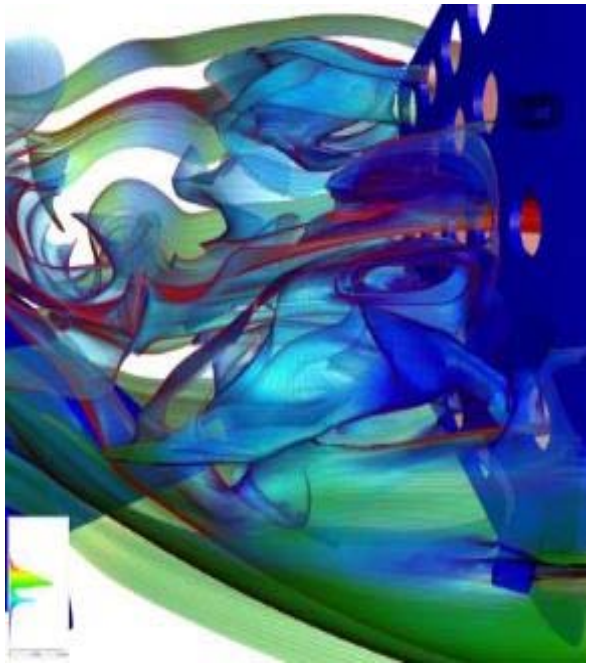
- Nuclear science, applications, and security
  - SIGMA: Continuous, cost-effective, city- and state-scale nuclear and radiological WMD detection capability
  - ICONS: In-the-field neutron radiography through new intense and human portable sources
  - Novel computers enabling petaflops-scale scientific simulations on desktops for revolutionary design tools

BREAK

Return by 10:50 AM

Fariba Fahroo

Fariba Fahroo



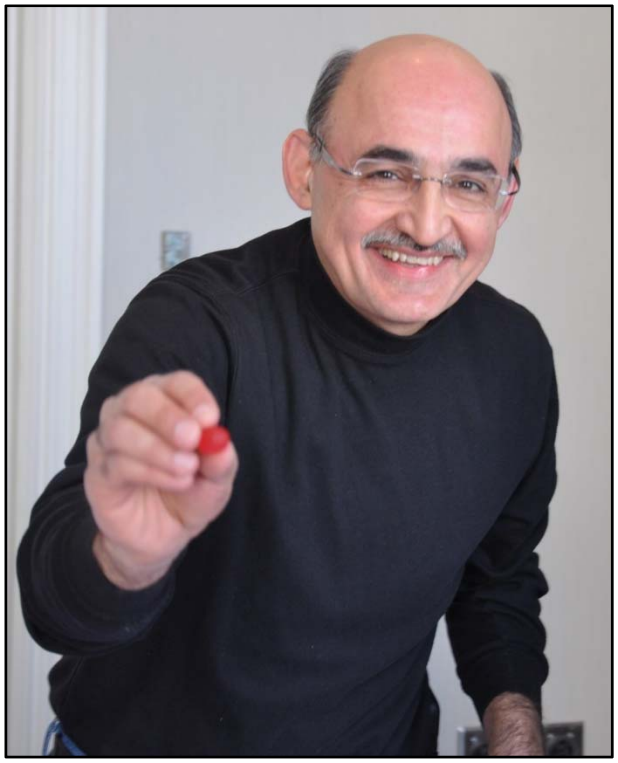
Dr. Ben Evans, College of Engineering, Swansea University

- A.B. in Physics and Applied Mathematics
- M.A. in Mathematics
- Ph.D. in Applied Mathematics

Interests:

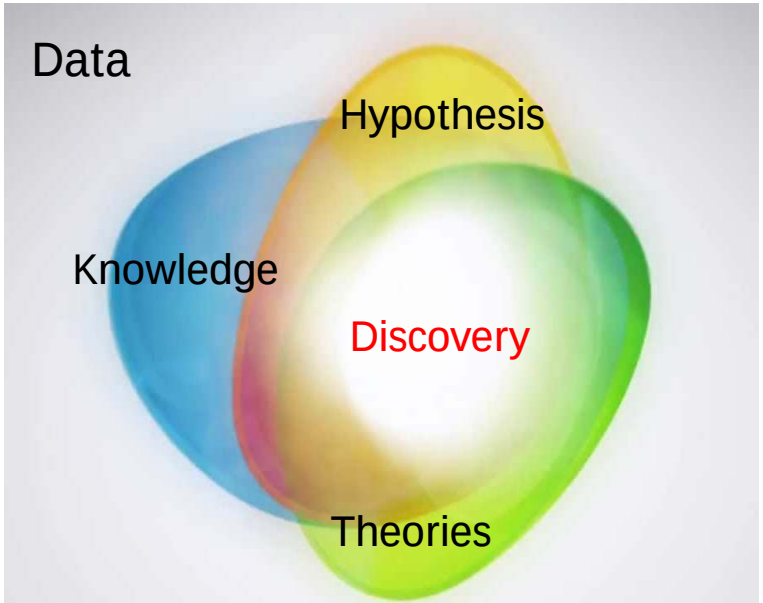
- Exploring the role of mathematics for analysis of **high-dimensional, complex systems** in the age of big data and computing
  - Uncertainty Quantification for complex physical systems (EQUiPS program)
  - Novel mathematical approaches for dynamic data sets
    - Geometry
    - Topology
    - Machine learning
    - Statistics
    - Dynamical systems

Reza Ghanadan



Reza Ghanadan

- B.S. in Physics & Electrical Engineering
- M.S. and Ph.D. in Electrical Engineering
- MBA Management and Finance



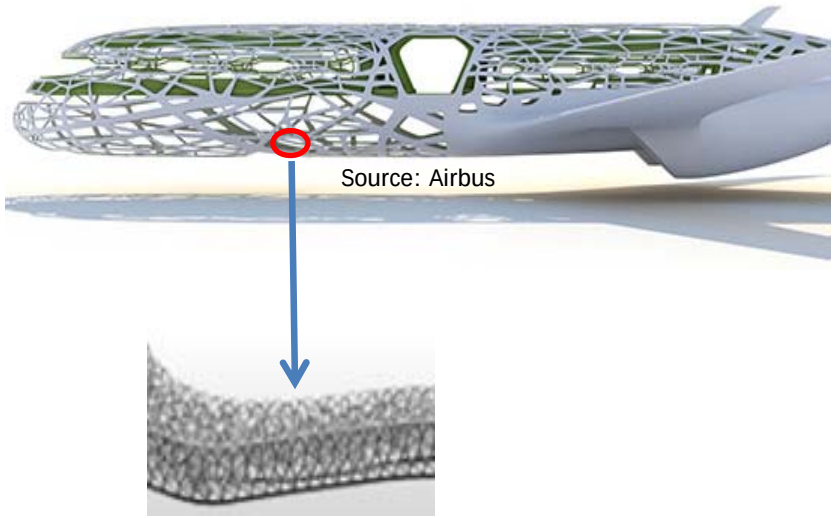
Invent the Future via Automated Synthesis and Symbiotic Learning

Interests:

- Ongoing Programs: MSEE, GRAPHS, SIMPLEX
- Create automated tools to accelerate scientific discovery and technology innovation
- Build adaptive systems and intelligent machines that understand and help with what people want
- Problems I want to solve include:
  - Automated synthesis and hypothesis generation
  - Effective human-machine systems, seamless teaming and collaboration
  - Human-machine symbiotic learning
  - Robust information access everywhere anytime

Jan Vandenbrande

Jan Vandenbrande

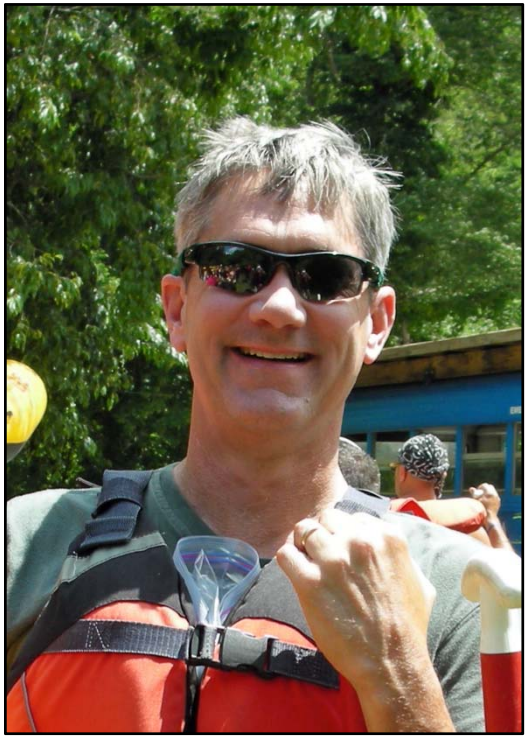


- Ph.D. Electrical Engineering
- Started with EE, then mechanical & metal
- Geometric modeling & reasoning
- Optimization, composite fabrication
- Architect systems to design & build faster, better
- Practical & pragmatic

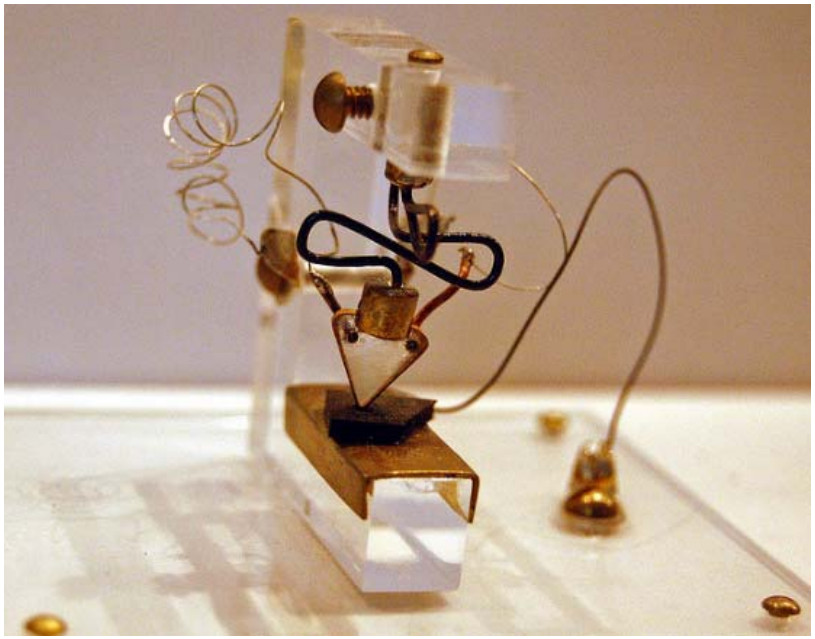
Interests: Rethink design

- Change how we design mechanical products
- Maximally leverage new materials & fabrication processes
- Amplify design discovery, optimization everywhere
- Identify necessary representations, math and computational tools
- Span 6 orders of magnitude in scale
- Leverage massive computing power

John Main



John Main



- Mechanical Engineer by training
- Interested in everything new to me
- Not interested in things in the weeds (Most people think they are not in the weeds; most are)

Interests right now:

- Identifying surprises by accelerating innovation
- Understanding human-technology systems

Interests next week:

- ?

Mark Micire

Mark Micire

- BS, MS, PhD, Computer Science - Robotics
- University of South Florida
- University of Massachusetts at Lowell

- Nationally certified fire fighter
- FEMA search & rescue team member
- Underwater vehicle operator and instructor
- Programmer, tinkerer and maker

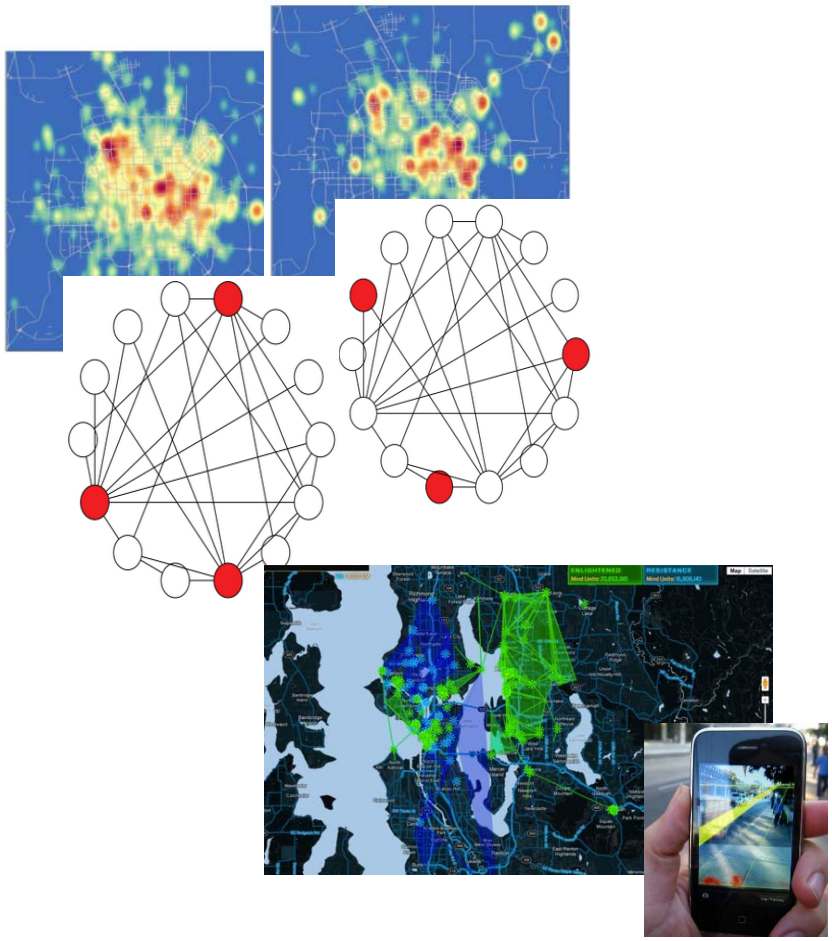
Interests include:

- Scalability of autonomous systems
- Human-robot interaction
- High speed sensing, perception, and autonomy

How do we change the human-robot interaction dynamic so that robots are viewed as teammates and not just tools?

Adam Russell

Adam Russell



- B.A. in Cultural Anthropology
- Ph.D. in Social Anthropology

Interests: The "Hardest" Science

- Exploring new tools and platforms to experimentally test and validate fundamental measures in social and behavioral sciences
  - New research capabilities to go from Big Data (observation and correlation) to Big Validation (causation and prediction)
  - Address current methodological challenges that limit our ability to measure, quantify and predict the causal impact of multi-level, complex variables on human behavior and performance

"Imagine how much harder physics would be if electrons could think." - Murray Gell-Mann
"Imagine how much harder physics would be if electrons had feelings." - Richard Feynman

Images from: http://www.technologyreview.com/view/528216/the-emerging-science-of-computational-anthropology/; http://www.technologyreview.com/view/538866/the-social-network-illusion-that-tricks-your-mind/; https://en.wikipedia.org/wiki/Ingress_%28game%29; https://en.wikipedia.org/wiki/Augmented_reality#/media/File:MediatedReality_on_iPhone2009_07_13_21_33_39.jpg

PICK-UP LUNCH & RETURN BY 12:05 PM

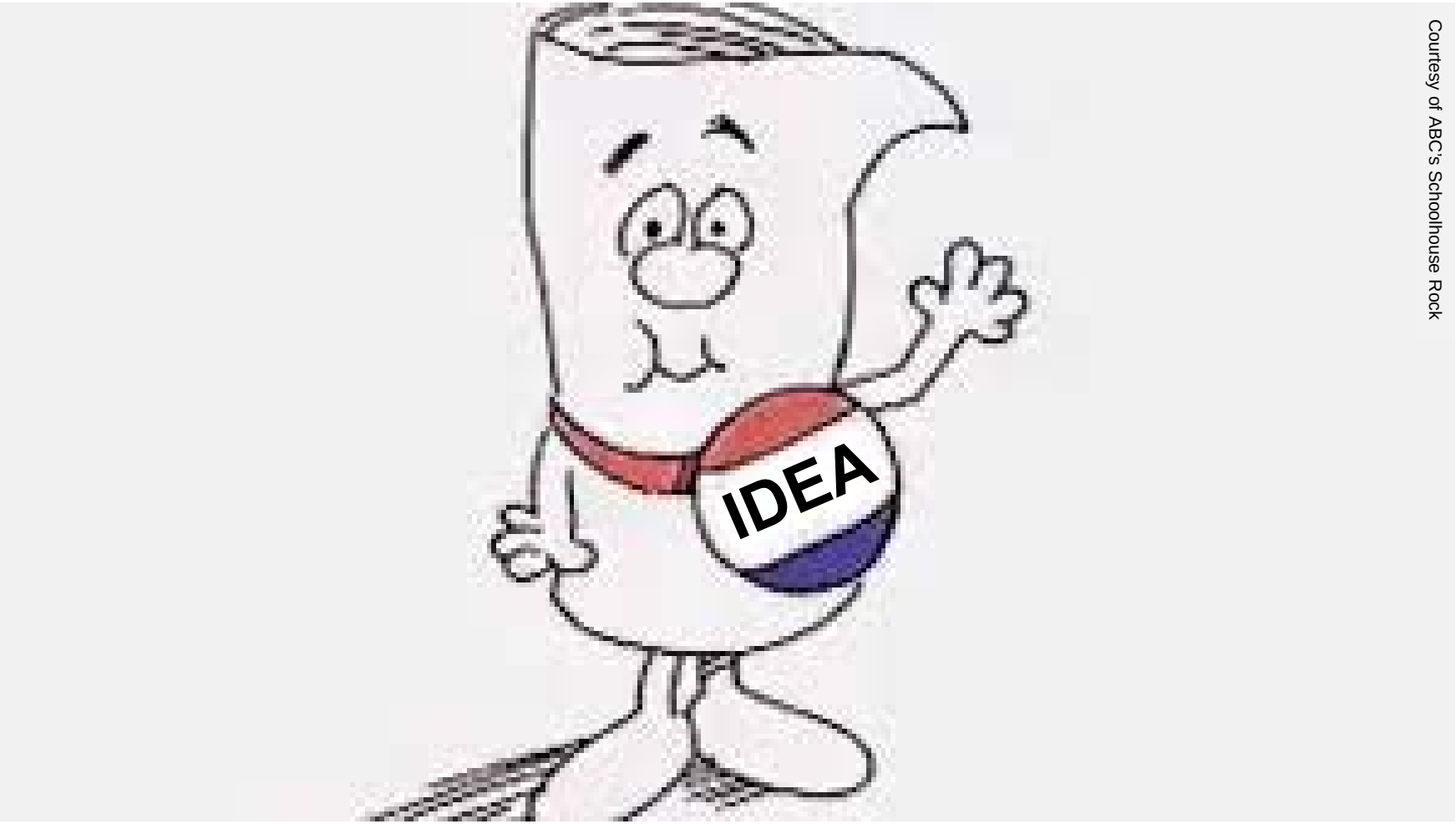
(Optional/Concurrent with Lunch)

The Making of a DARPA Program: What Goes on Behind the Curtain

William Regli
Deputy Director
Defense Sciences Office

DSO Proposers Day

July 21, 2015



Courtesy of ABC's Schoolhouse Rock

The Program Life Cycle

- **Concept**
- **Seedling**
- **Evaluation**
- **Presentation**
- **Acquisition**
- **Execution**
- **Reporting**
- **Completion**

All program phases are led by one or more DARPA Program Managers.
(typically one)

Program Managers:

They Make it Happen!!

Courtesy of ABC's Schoolhouse Rock

The Program Life Cycle

- **Concept**
- Seedling
- Evaluation
- Presentation
- Acquisition
- Execution
- Reporting
- Completion

- **PM originated**
- **Other internal**
  - Office Director
  - DIRO
- **Other DoD**
  - Urgent user needs
  - Identified long-term gaps
  - OSD, DSB, etc
- **Other external**
  - Industry, Academia, Community
  - Workshops, RFIs

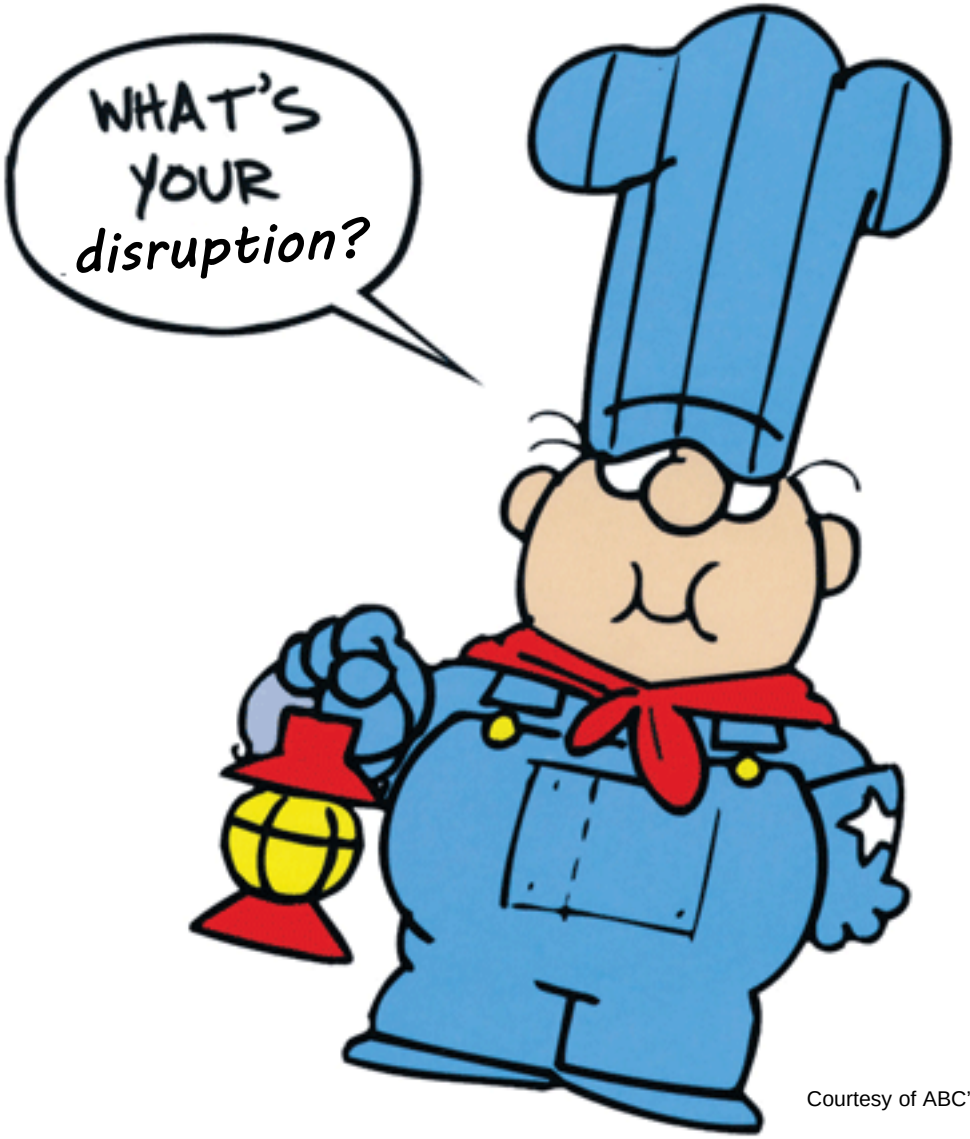
Engage the community

Courtesy of ABC's Schoolhouse Rock

The Program Life Cycle

- Concept
- **Seedling**
  - **Prove that key concepts have merit**
  - **Generally 3 to 9 months**
  - **Generally 1 to 2 FTEs**
- Evaluation
- Presentation
- Acquisition
- Execution
- Reporting
- Completion

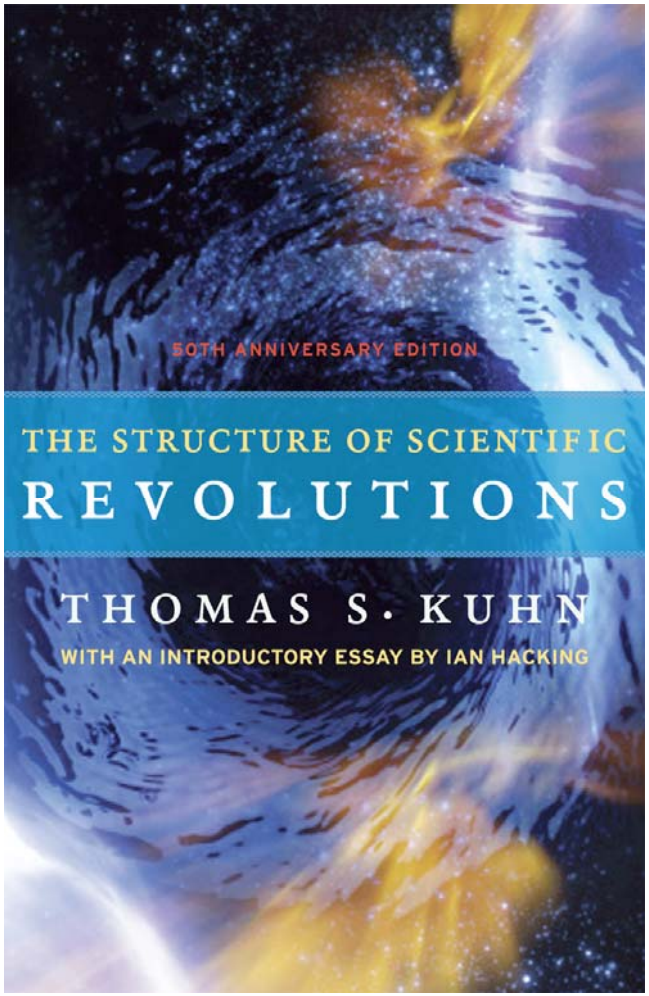
What are you trying to do: Designing Disruption

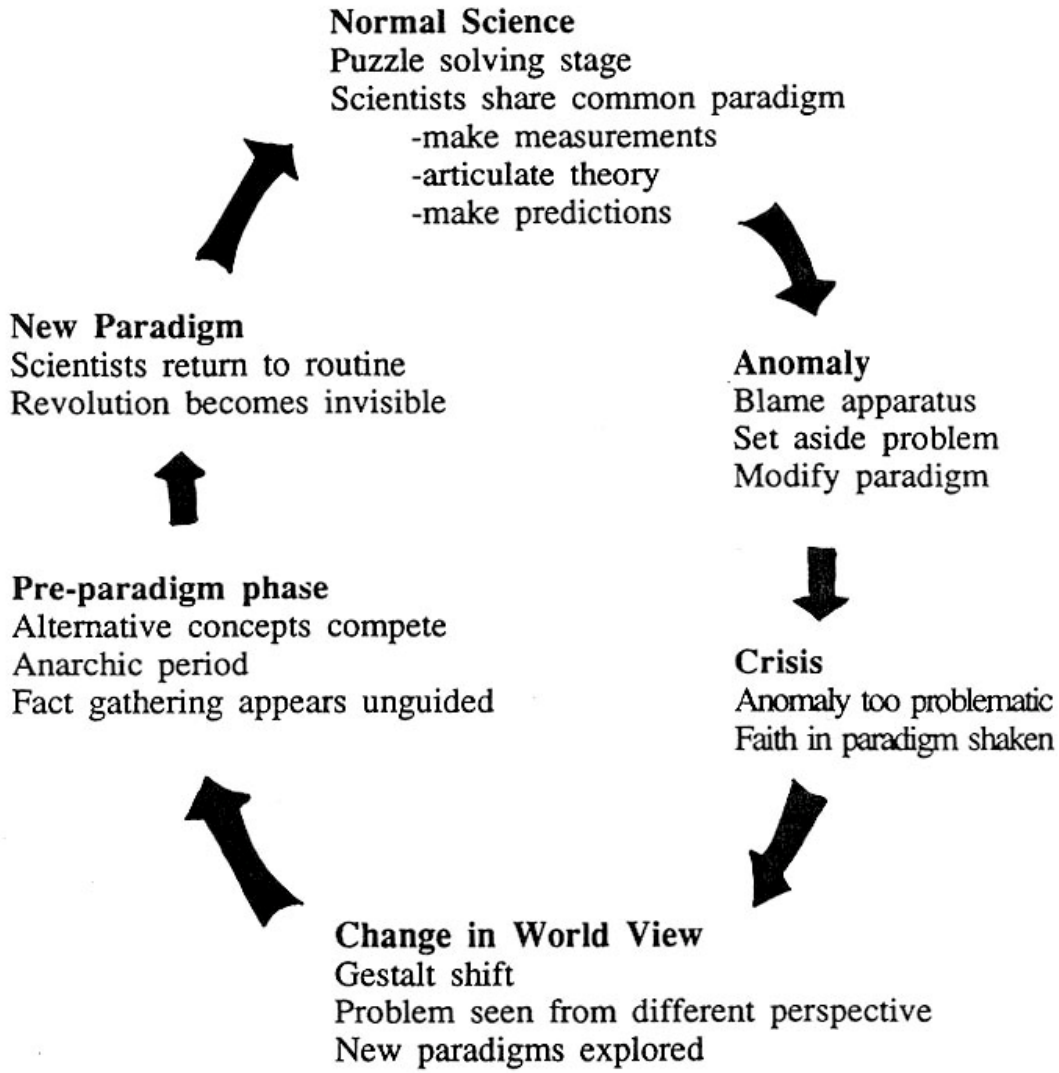


Courtesy of ABC's Schoolhouse Rock

Courtesy of ABC's Schoolhouse Rock

The DSO ideal

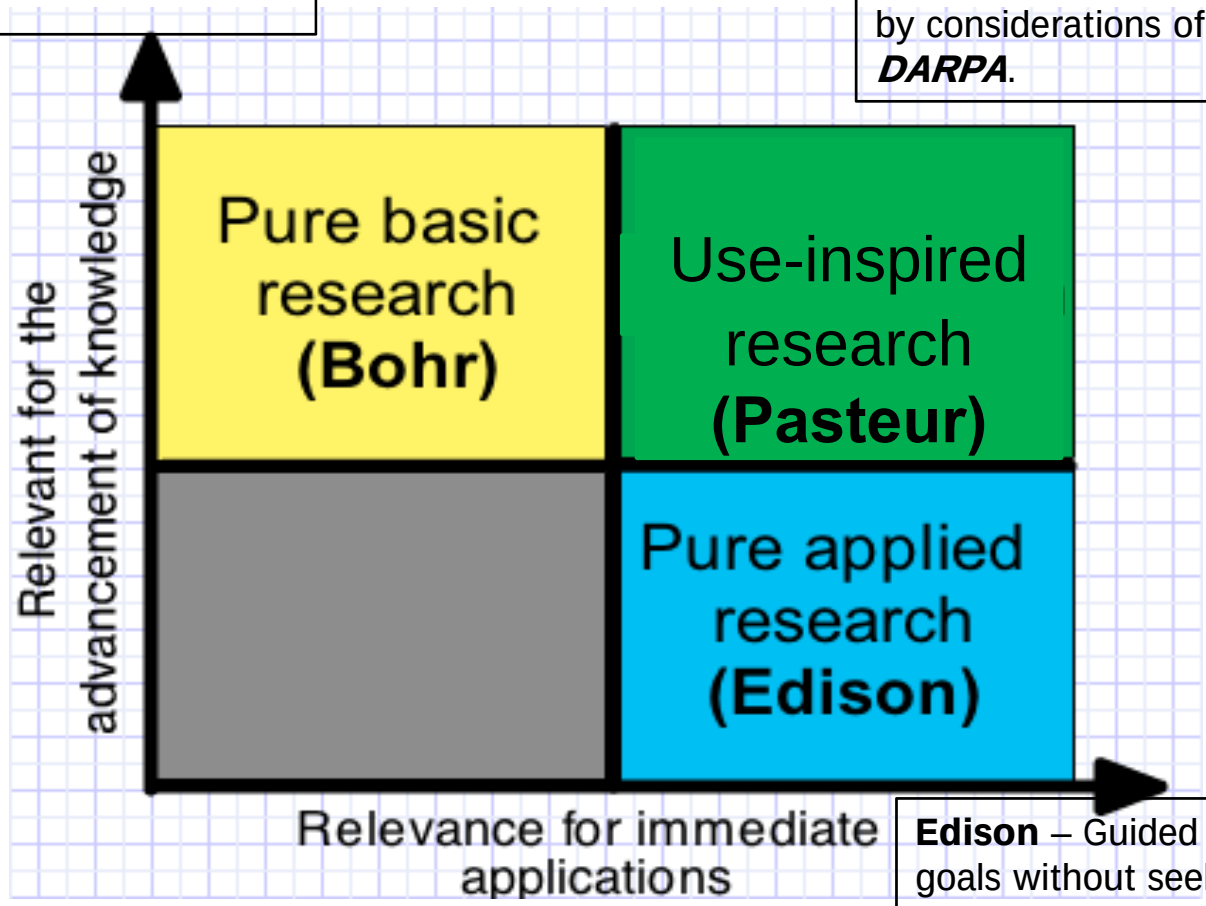




Pasteur's Quadrant: DARPA's Power Lane

Bohr – Guided solely by the quest for understanding without thought of practical use.

Pasteur – Includes research that seeks to explain the frontiers of understanding, but is also inspired by considerations of use. ***This is DARPA***.



Edison – Guided solely by applied goals without seeking a more general understanding of the phenomena of a scientific field.

Think like a PM: What are we reading?

- The Second Machine Age, E. Brynjolfsson and A. McAfee (2012)
- Antifragile: Things That Gain from Disorder, N. N. Taleb (2012)
- Superintelligence: Paths, Dangers, Strategies, N. Bostrom (2014)
- The Origin of Wealth, E. Beinhocker (2006)
- The Swerve: How the World Became Modern, S. Greenblatt (2012)
- Endless Forms Most Beautiful: The New Science of Evo Devo, S. Carroll (2006)
- On Intelligence, J. Hawkins (2005)

- Quadrennial Defense Review
- Driving in the Dark: Ten Propositions About Prediction and National Security, R. Danzig (2011)
- Various reports from the NAS & NAE and DSB

- Some classics
  - Pasteur's Quadrant: Basic Science and Technological Innovation, D. Stokes (1997)
  - The Sciences of the Artificial, H. Simon (1996)
  - The Structure of Scientific Revolutions, T. Khun (1970)

The Program Life Cycle

- Concept
- Seedling
- **Evaluation**
- Presentation
- Acquisition
- Execution
- Reporting
- Completion

- **Assess concepts / ideas:**
  - Does the idea have merit?
  - How much will it cost?
  - How long will it take?
  - How much risk is involved?
  - Is the program ***suitable for DARPA?***
- **Evaluations are typically performed at the "Office" level**

Courtesy of ABC's Schoolhouse Rock

There are lots of worthy ideas

Courtesy of ABC's Schoolhouse Rock

The Program Life Cycle

- Concept
- Seedling
- Evaluation
- **Presentation**
- Acquisition
- Execution
- Reporting
- Completion

- **The Program Manager briefs the concept at the Director DARPA level to the "Tech Council"**
- **Must answer the "Heilmeier" questions…**

The Heilmeier Catechism

To help bring rigor and formality to the program-development process, DARPA Director George Heilmeier developed a set of questions that every program manager was required to address when formulating or proposing a new program.

Dr. George H. Heilmeier
Director DARPA 1975-1977

- **What are you trying to do?** *Articulate your objectives using absolutely no jargon.*
- **How is it done today, and what are the limits of current practice?**
- **What's new in your approach and why do you think it will be successful?**
- **Who cares?**
- **If you're successful, what difference will it make?**
- **What are the risks and the payoffs?**
- **How much will it cost?**
- **How long will it take?**
- **What are the midterm and final "exams" to check for success?**

This formalism has become known as “The Heilmeier Catechism.”
It is the program-definition formalism still in use at DARPA today.

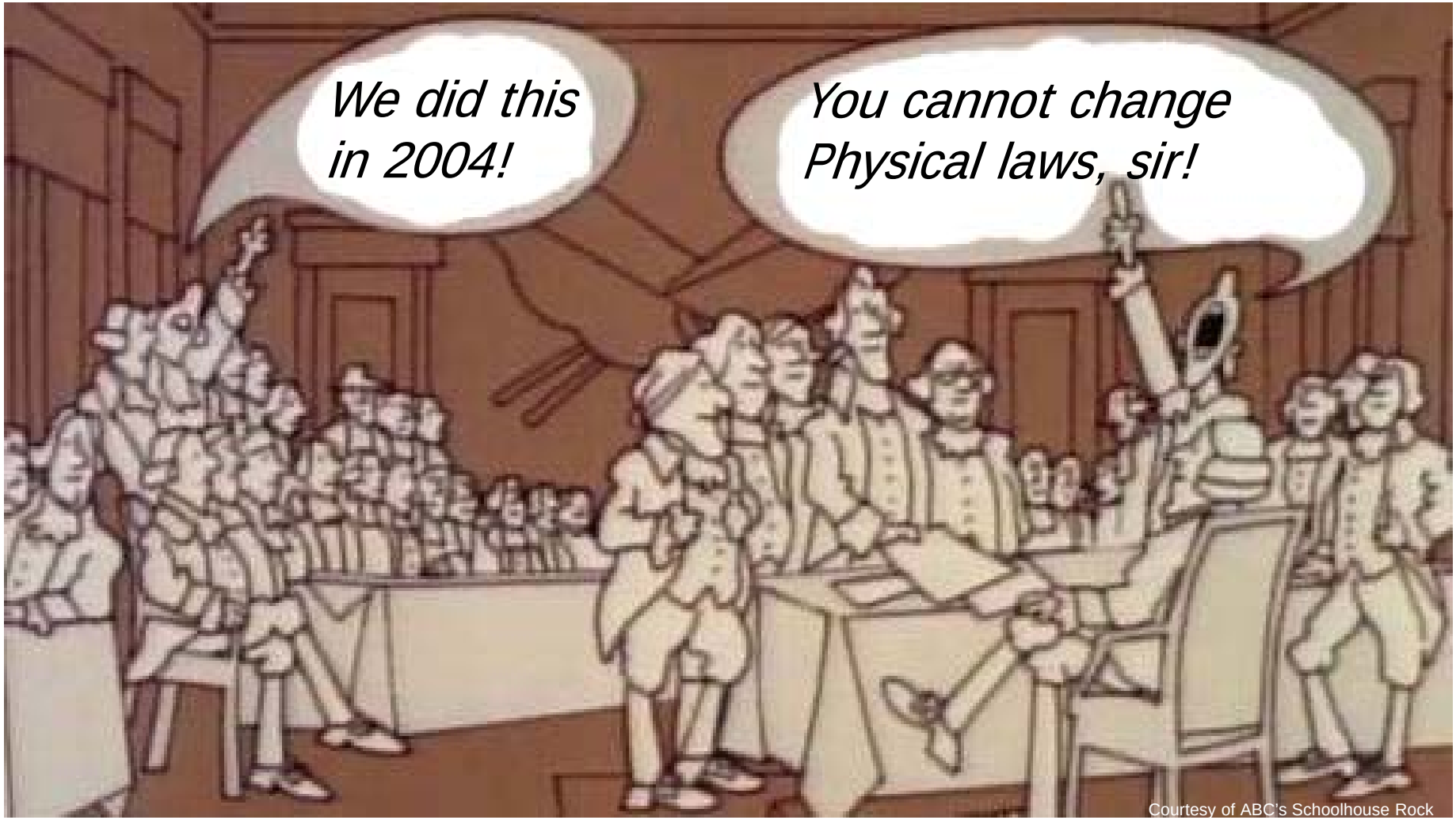
Courtesy of ABC's Schoolhouse Rock
IDEA
Tech
Council
or Bust!

The Program Life Cycle

- Concept
- Seedling
- Evaluation
- **Presentation**
- Acquisition
- Execution
- Reporting
- Completion

- **The Program Manager briefs the concept at the Director DARPA level to the "Tech Council"**
- **Must answer the "Heilmeier" questions…**
- **Decision is often quick**

Rigorous scientific and policy debate occurs...



Courtesy of ABC's Schoolhouse Rock

The Program Life Cycle

- Concept
- Seedling
- Evaluation
- Presentation
- **Acquisition**
- Execution
- Reporting
- Completion

- **Solicitation is released**
- **Often, the PM will hold an "Industry Day" meeting**
- **"Scientific review" process is used for proposals**
- **Outbrief to Scientific Review Official**
- **Acquisition package goes to Contracting Officer (CO) and Contracting Officer Representative (COR) for award**

Building the program out of the submissions...

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The Program Life Cycle

- Concept
- Seedling
- Evaluation
- Presentation
- Acquisition
- **Execution**
- Reporting
- Completion

- **Program kickoff**
- **Periodic internal program reviews**
- **Periodic meetings with prospective transition partners and other stakeholders**

Program Managers:

We Actively Manage Programs

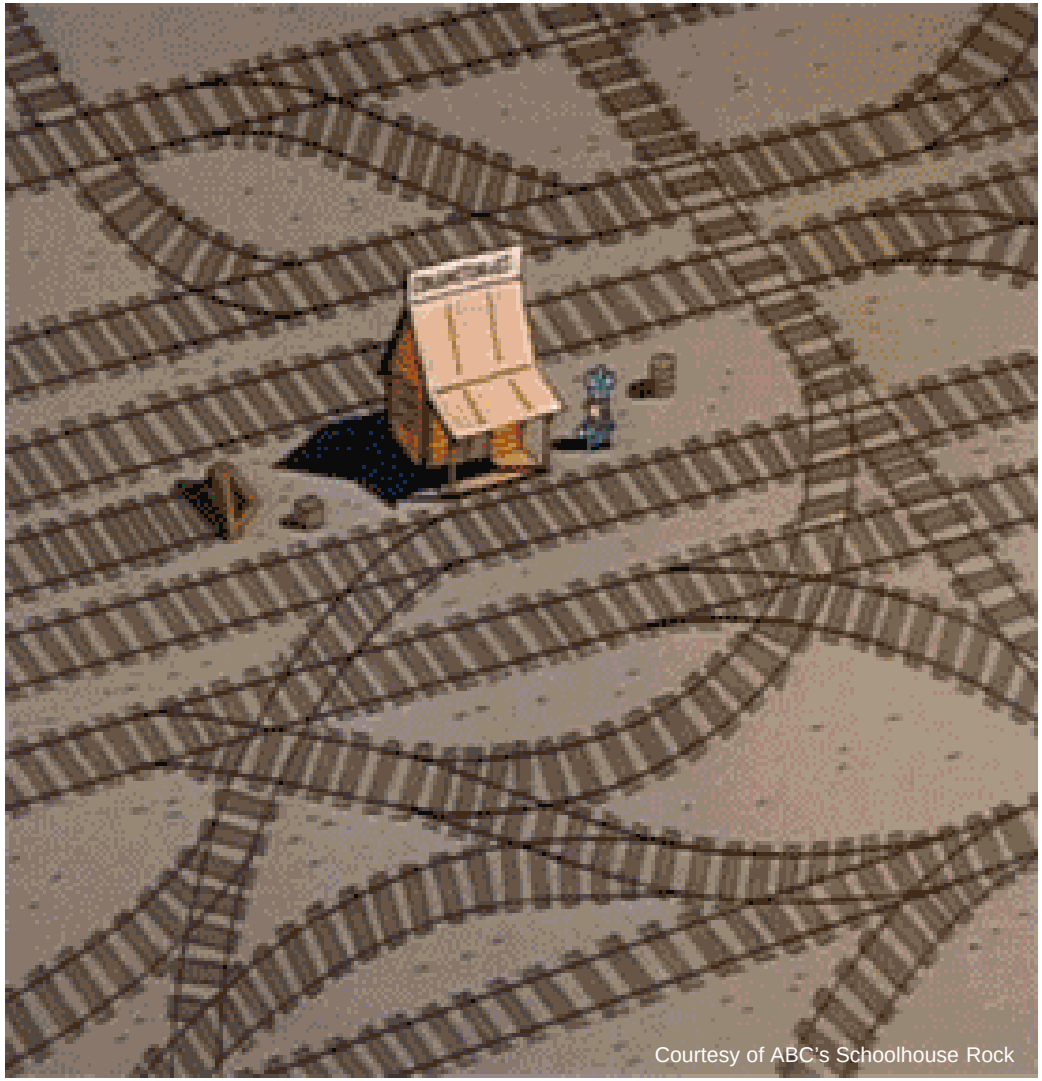
Courtesy of ABC's Schoolhouse Rock

The Program Life Cycle

- Concept
- Seedling
- Evaluation
- Presentation
- Acquisition
- Execution
- **Reporting**
- Completion

- **Periodic briefings / updates for the Office Director**
- **Annual briefing / update to the DARPA Director**

Smoothly running DARPA program…



The Program Life Cycle

- Concept
- Seedling
- Evaluation
- Presentation
- Acquisition
- Execution
- Reporting
- **Completion**

- **Transition (if applicable) to key stakeholder(s) for employment and continued support/development**
- **Contract closeout**
- **Program completion report**

Courtesy of ABC's Schoolhouse Rock

END

Top 10 Ways to Prepare to Engage with DARPA

(Optional/Concurrent with Lunch)

Dr. Tyler McQuade

Defense Sciences Office

DSO Proposers Day

July 21, 2015

Top Ten Ways to Prepare to Engage DARPA

1. **Go beyond state of the art.**

2. **Share, but don't over sell.**

3. **Plan your visit.**

4. **Interaction is a two way street.**

5. **Understand the role of a PM.**

6. **Understand our mission.**

7. **Understand our process.**

8. **Recognize that DARPA evolves fast.**

9. **Know thy audience.**

10. **Know thyself.**

Steven George

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Case Study: Working with DARPA on "Local Control of Materials Synthesis"

Steven M. George
Depts. of Chemistry & Mechanical Engineering
University of Colorado, Boulder, Colorado 80309

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The Formulation: DARPA Workshop

Workshop for Proposed Local Control of Materials Synthesis (LoCo) Program (May 2010):

Goal: Growing films at dramatically lower temperatures

$$1000°C \rightarrow 100°C$$

Workshop tried to answer if thin film field was ready for this program. "Are we ready to summit?"

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The Challenge: DARPA Broad Agency Announcement

BAA for Local Control of Materials Synthesis (LoCo) (May 2012):

Objective was to seek novel processes for:

- Higher reactant flux
- Enhanced surface mobility
- Overcoming activation barriers

Lower film growth temperatures using non-thermal methods

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The Thought Process: Meeting the BAA Challenge

Sounds impossible – but if not me, then who?

Build on entire skill set

Start fresh: What is best approach?

Assume resources are available

Develop new paradigms

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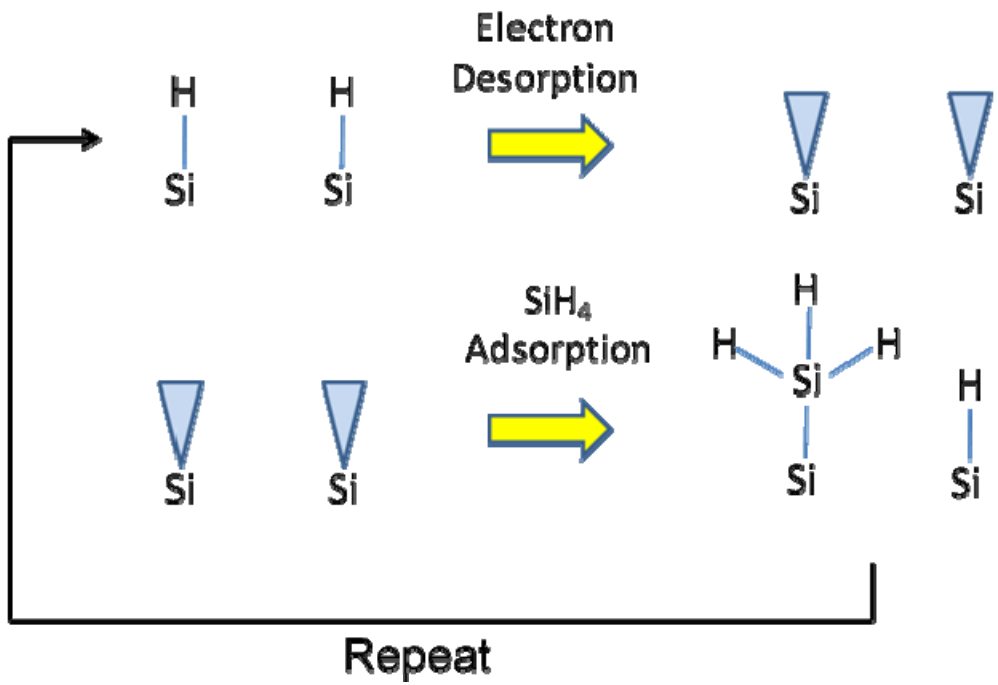
The Proposal: Electron Stimulated Desorption (ESD) to Facilitate Reactions

Proposal "Stepwise Sequence of Surface Reactions for Diamond and GaN Surfaces" (July 2012)



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The Beginning: Kickoff Meeting

Many participants and projects during Kickoff Meeting (February 2013)

DARPA Hard: "One step back from impossible."

Goal: Integrate new techniques at supersite to achieve goal

"Play nice together"

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The First Impossible: Base Period

Build new reactor for low temperature growth using ESD

Required to demonstrate working system in nine months

Revised initial plans & built reactor with no *in situ* probes

Key is getting results in the required time

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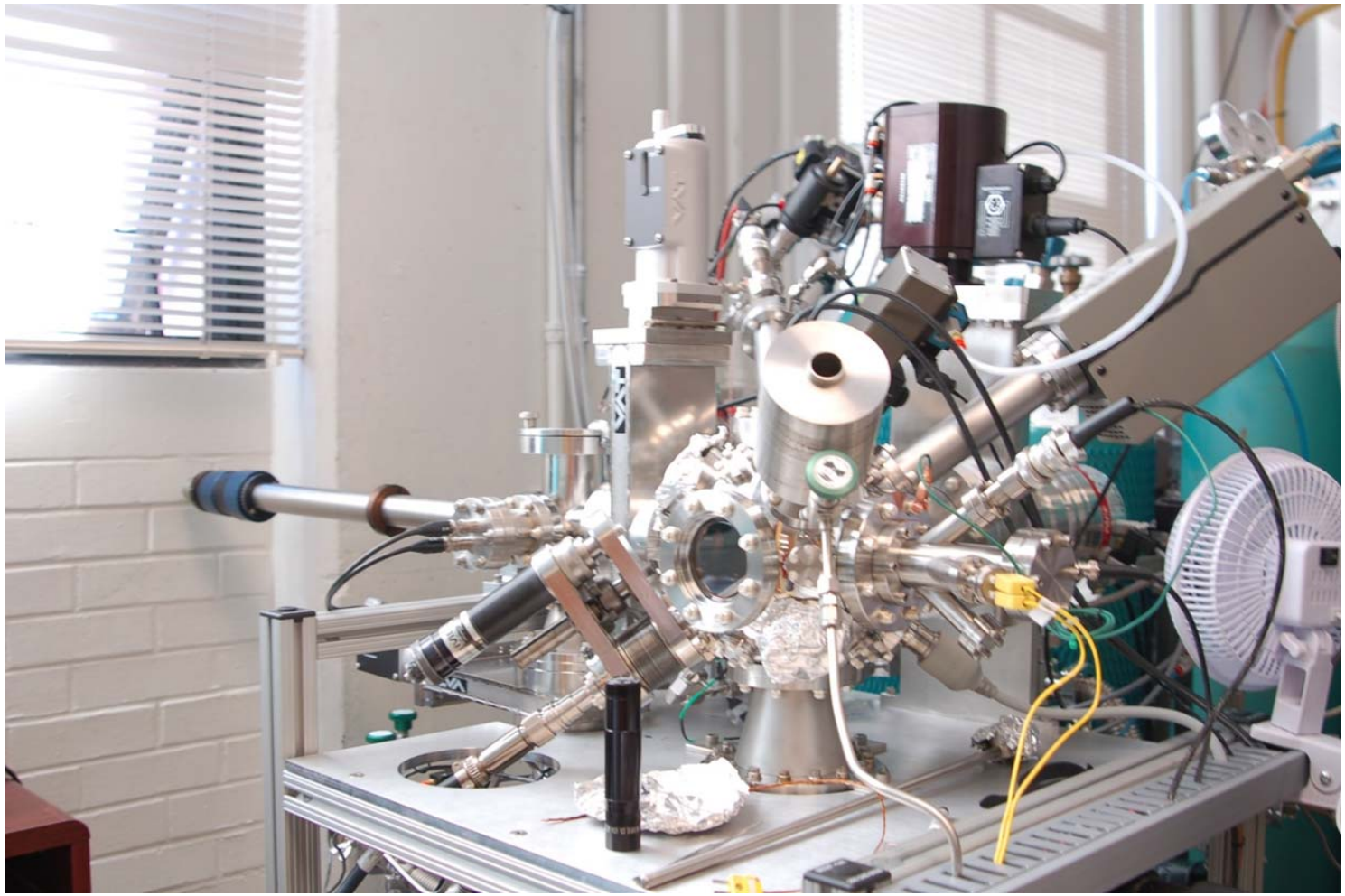
The First Go/No Go: Reactor is Built



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The Second Impossible: Option 1

Next milestone was obtaining low temperature growth in 6 months (starting October 2013)

Focus on GaN because worried about diamond instability

"Swimming against the stream" because most participants focused on diamond

First GaN film deposited at 100°C (January 2014)

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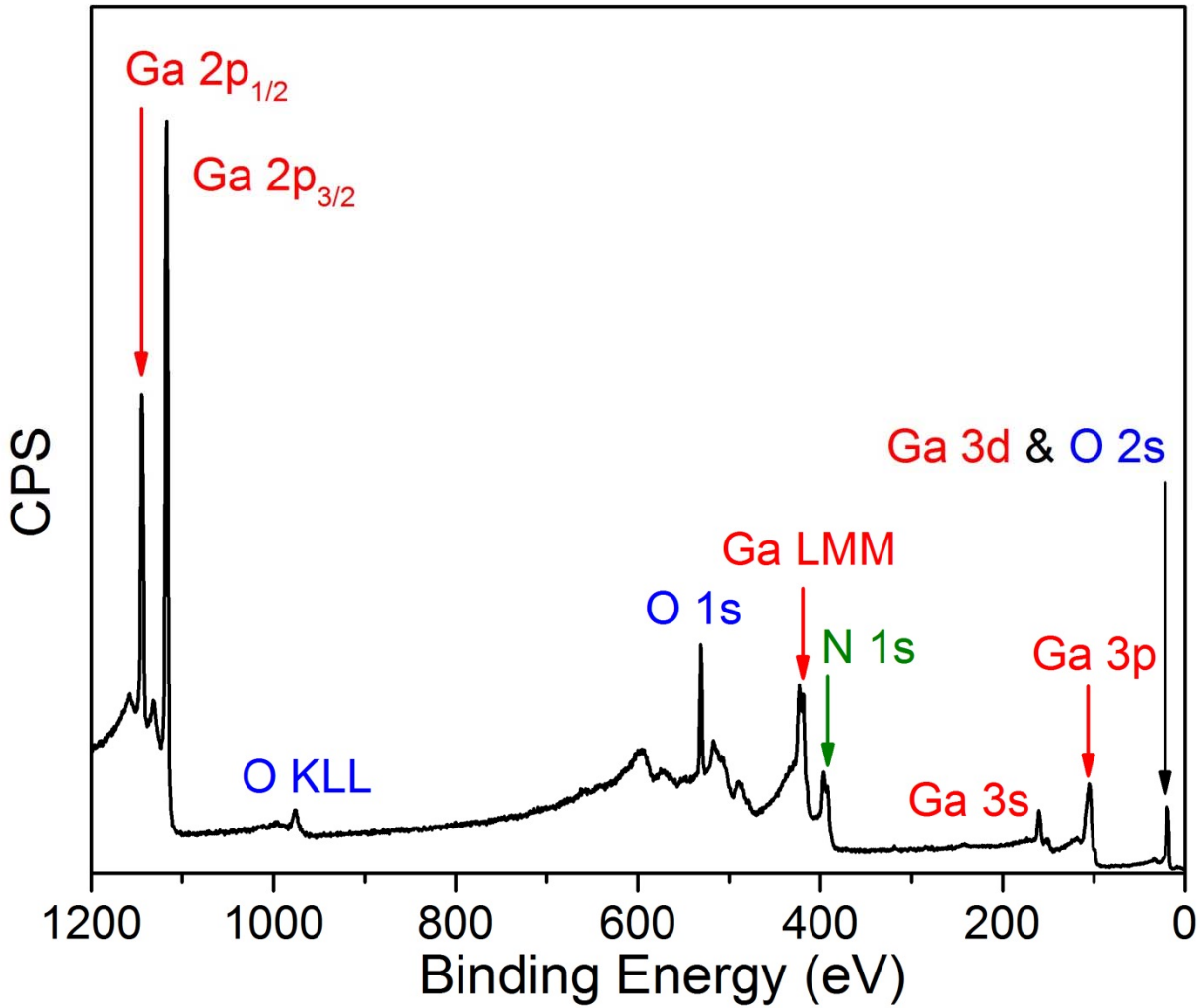
The Second Go/No Go: GaN Deposition at Low Temperature of 100°C



XPS Results for GaN Film after 300 Cycles at 50 eV

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The Third Impossible: Option 2

Next milestone was optimizing GaN growth in next 9 months (starting May 2014)

Targeted goal of crystalline GaN by October 2014

Discovered that electrons can promote growth and also cause etching

Crystalline growth at such low temperature may depend on combination of growth/etching

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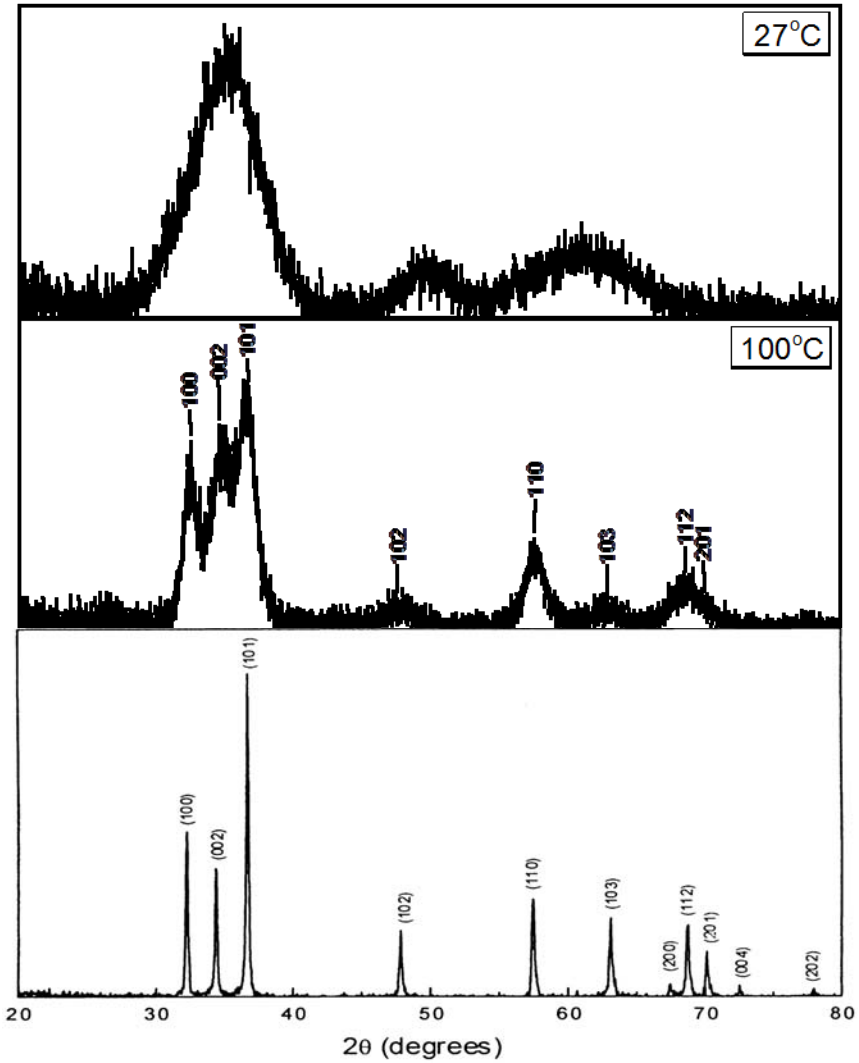
The Third Go/No Go: Crystalline GaN Deposition at Low Temperature



Crystalline GaN with grain sizes ~2-3 nm at room temperature

Crystalline GaN with grain sizes ~5-7 nm at 100°C

Powder XRD pattern for crystalline GaN

M.S. Kumar et al., *Mater. Chem. Phys.* **77**, 341 (2003).

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The Ramp Up: Upgrade Reactor & Build New Scale-up Reactor

New funds added to add *in situ* probing to growth reactor

New funds added for scale-up reactor combining low temperature growth by ESD with spatial ALD

Milestone to have scaleup reactor assembled by May 2015

"Time is more important than money"

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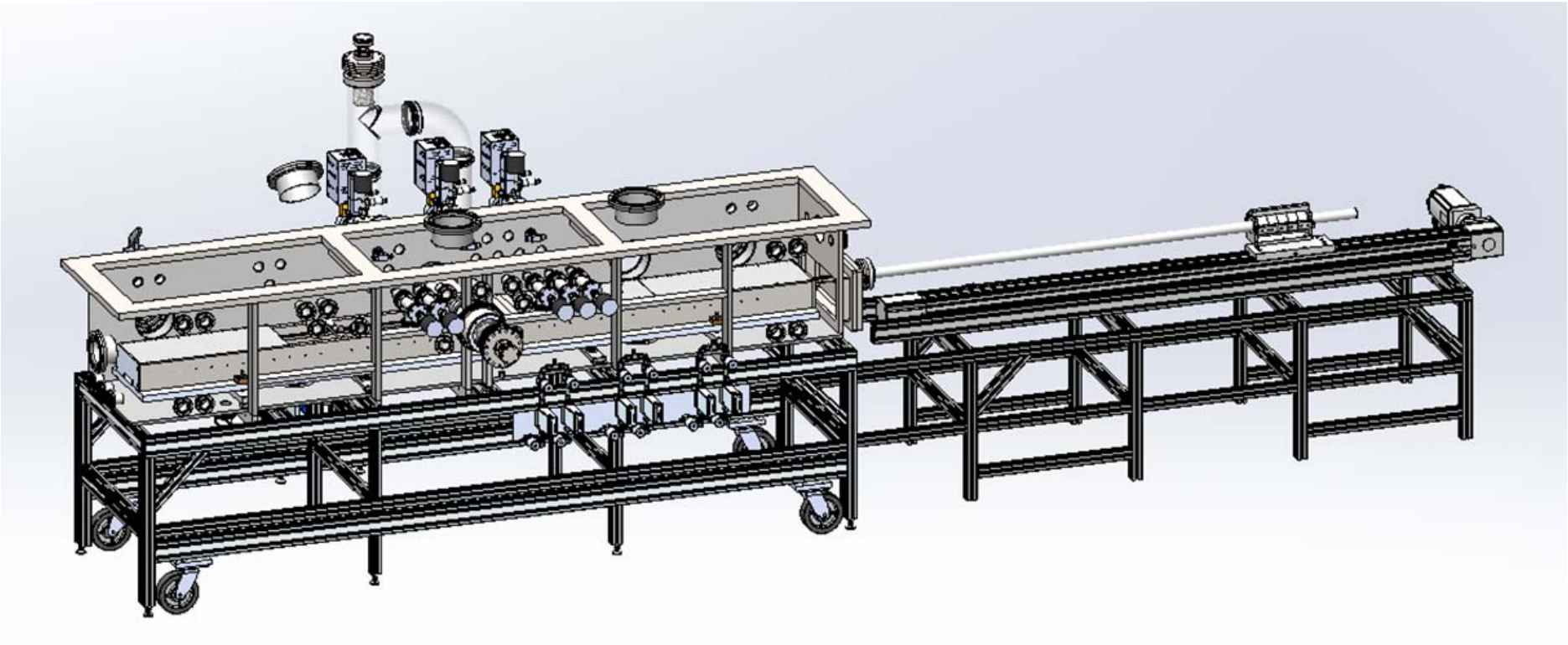
The Fourth Go/No Go: Assembled Scale-up Reactor for Pathway to Commercialization



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The Third Impossible: Option 3

Currently waiting for official notification of Option 3 funding (starting September 2015)

Milestone goal of GaN growth in new scaleup reactor by October 2015

Option 3 will also address new paradigm that crystalline GaN growth at such low temperature may result from combined growth/etching

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The Future: New Possibilities

New method for low temperature film growth

Potential to disrupt current technology

Consistent with DARPA goal to prevent & achieve strategic surprise

New equipment and capabilities are transformative to research group

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The Take Away: Lessons Learned

Take big steps. Take risks

No reward for taking incremental, safe steps

"Show DARPA what is not impossible"

"Do not iterate, but change the reality"

Do what you think is best – provided you can meet the milestones

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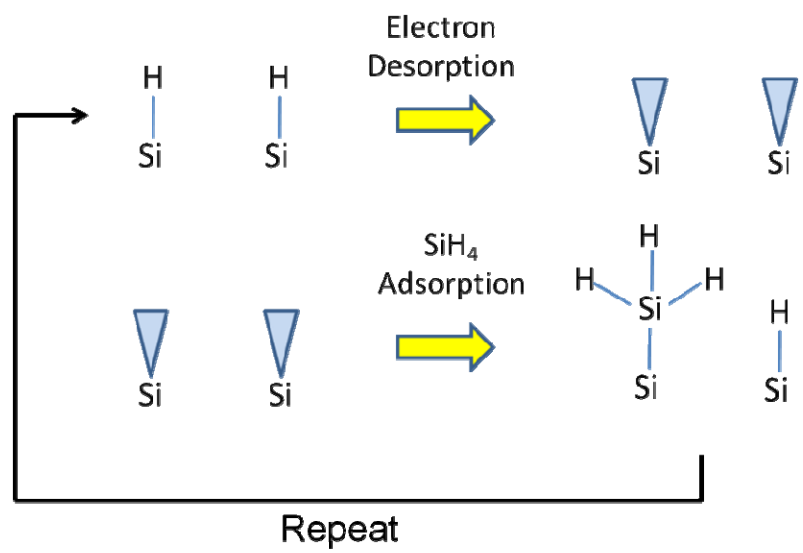
Stepwise Sequence of Surface Reactions for Diamond and GaN Growth

Low temperature growth of thin films can be achieved using a stepwise sequence of surface reactions.

Electron stimulated desorption (ESD) of hydrogen facilitates low temperature thin film growth. ESD of hydrogen produces highly reactive "dangling bond" sites on the surface of the growing film. Hydride precursors for film growth can then adsorb on these "dangling bond" sites.



Silicon Growth using ESD

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David Carter

Case Study: Z-Man

David J. Carter, Draper Laboratory

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Z-Man: Allowing Humans to Climb Like Geckos

Draper Laboratory and the Z-Man Program

More than 80 years applying exquisite engineering solutions to its customers' most difficult challenges.

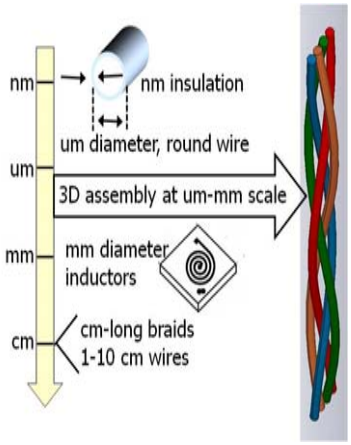
Draper Engineering Capabilities

- Positioning, Navigation & Timing (PNT)
- Autonomous Systems
- Precision Instrumentation
- Microsystems
- Fault Tolerant Systems
- Secure & Assured Systems
- Human Systems Technology
- Image & Data Analytics
- Bioengineering
- Materials Science

Draper's Business with DARPA

- DARPA-funded research from DSO, BTO, MTO, I2O, STO and TTO
- Other S&T funding sources: NSF, ONR, AFOSR, NIH, DHS, NASA, commercial, …

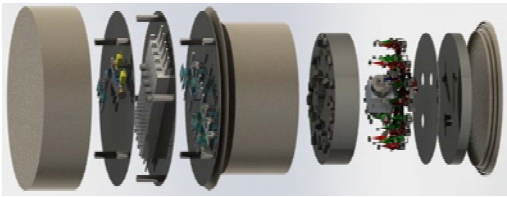
Micro/Nano Assembly
(DARPA DSO: Atoms-to-Products)



- Teamed with Harvard

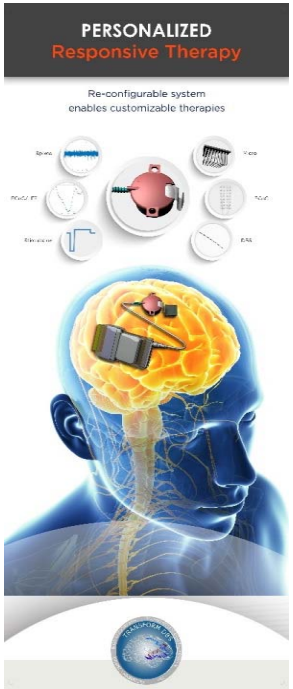
Quantum-Based Sensors
(DARPA MTO: CSCAN)

Cold Atom inertial sensor



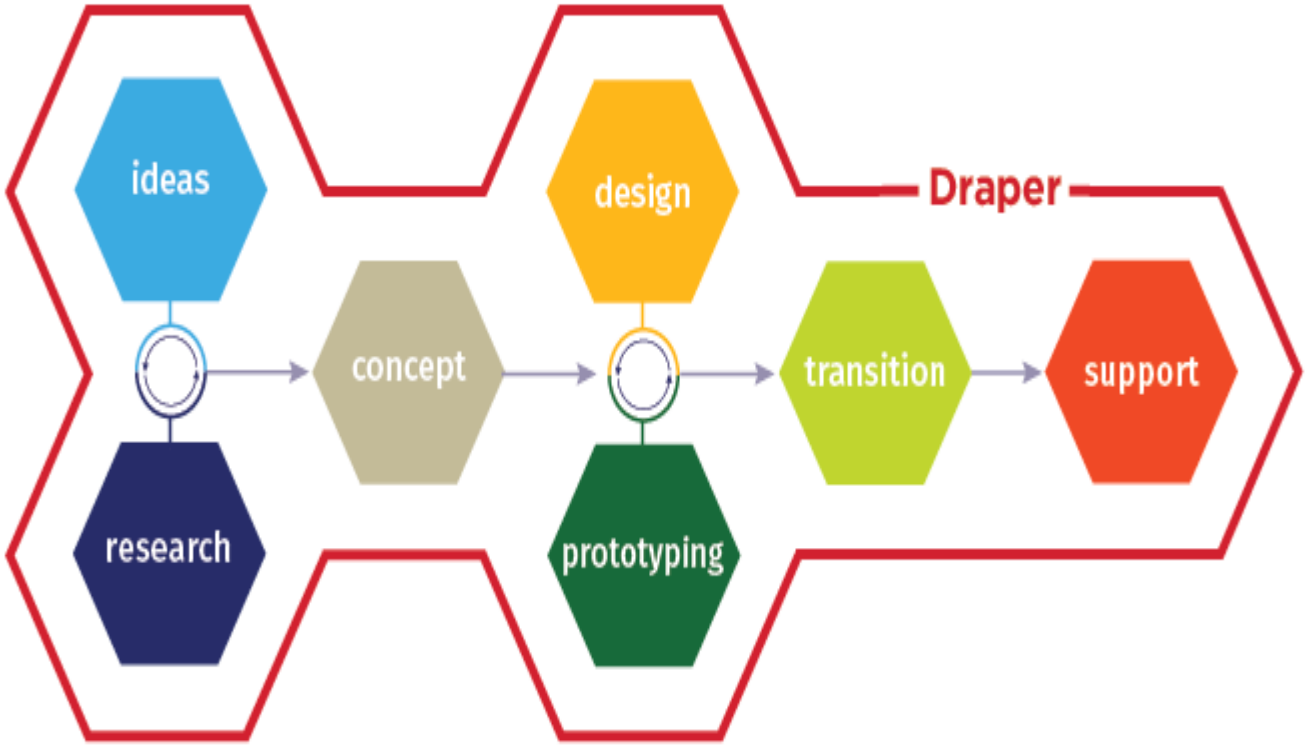
- Teamed with Stanford, MIT, Colorado

Deep Brain Stimulation
(DARPA DSO→ BTO: Subnets)



- Teamed with MGH and MIT

Technology Development Process



TRL1	TRL2	TRL3	TRL4	TRL5	TRL 6	TRL 7	TRL 8	TRL 9
Basic principles observed.	Technology concept formulated.	Analytical and experimental proof of concept.	Component validation in laboratory environment.	Component validation in relevant environment.	Prototype demonstration in a relevant environment.	Prototype demonstration in an operational environment.	System qualified through test and demonstration.	System proven through successful mission operations.

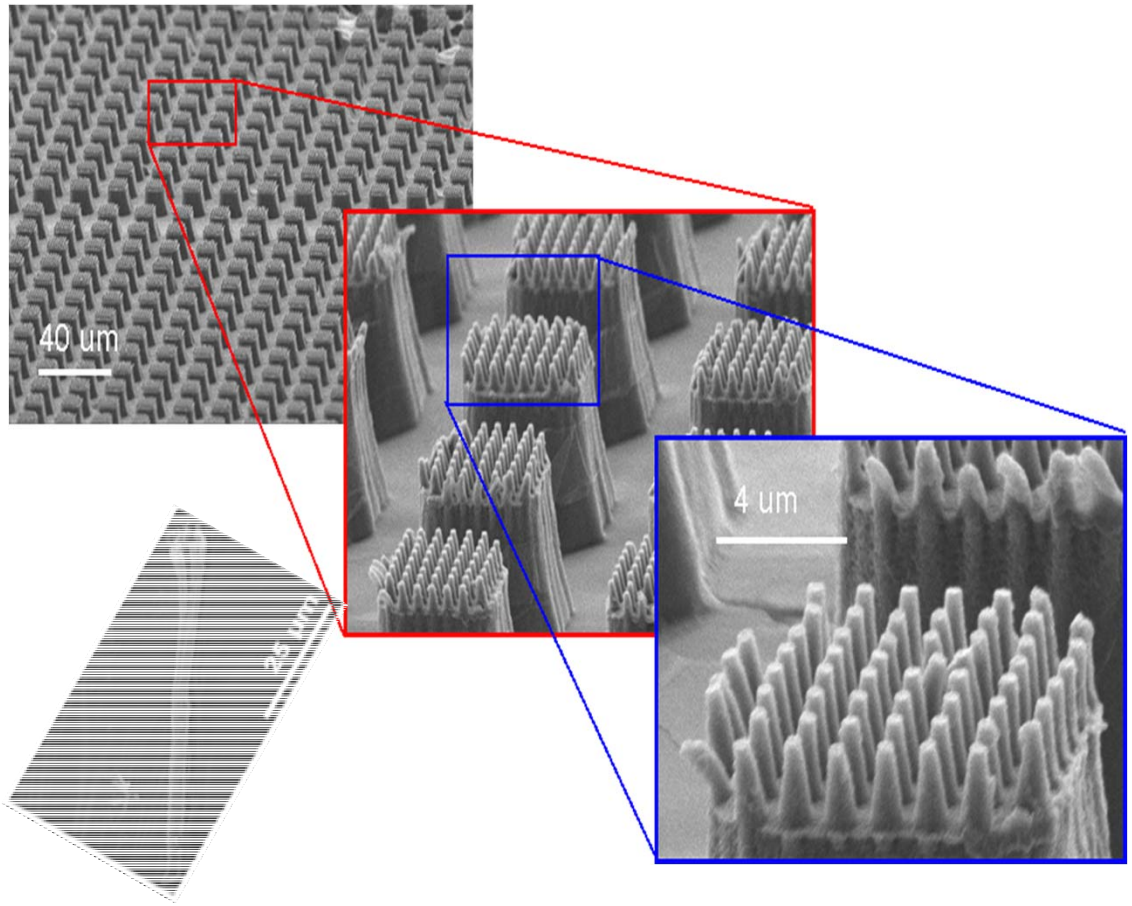
Background – Gecko Adhesion

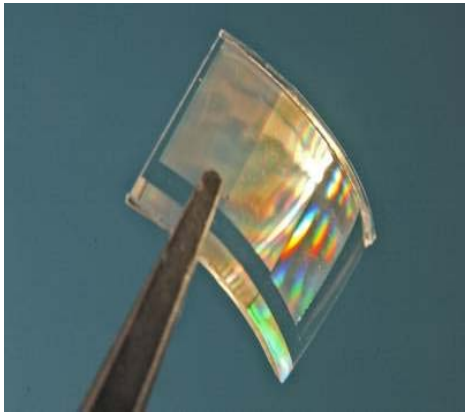
- Geckos have inspired for scientific inquiry for centuries
  - Aristotle (BCE 350): "…run up and down a tree in any way, even with the head downwards, like the gecko-lizard"
  - Autumn et al (*PNAS* AD 2002): "weak molecular attractions called *van der Waals forces* and a *unique geometry* are responsible for geckos' amazing climbing ability"

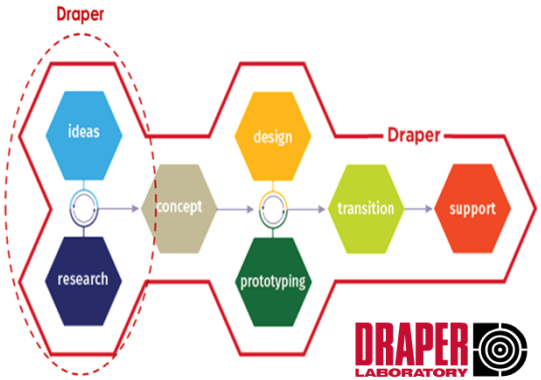
Pre-Zman (Draper)

Draper fabricated hierarchical synthetic gecko structures with MEMS/NEMS techniques

Demonstrated adhesion > gecko over ~cm² area







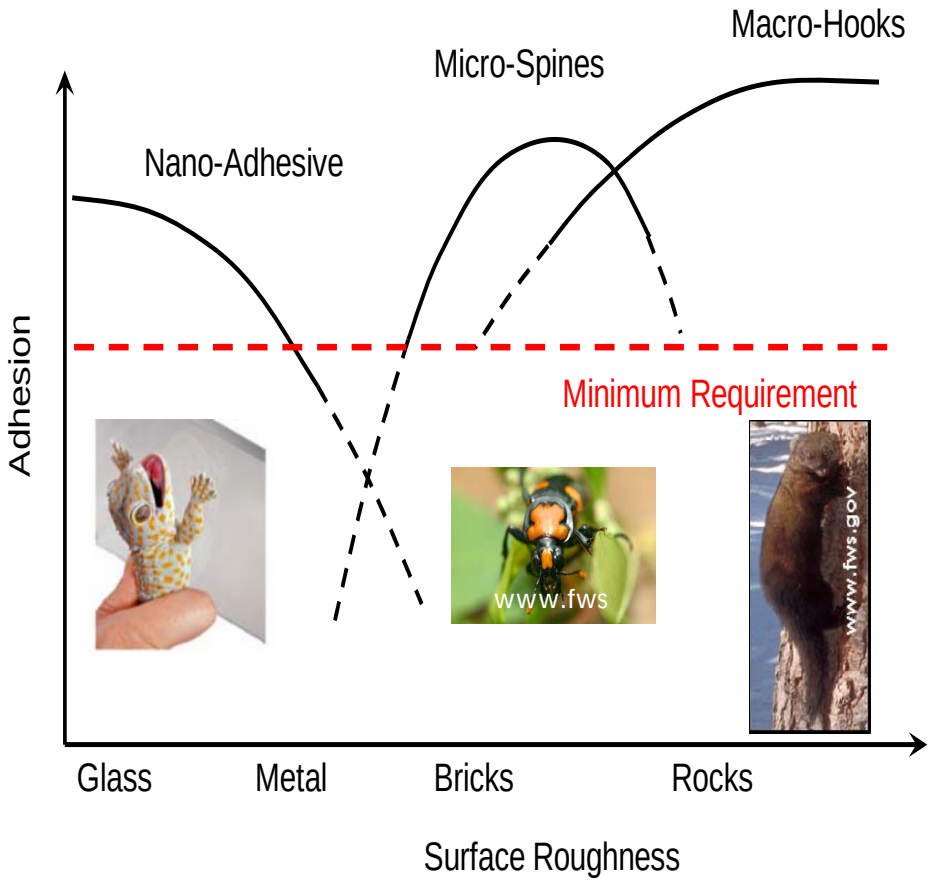
DARPA Zman

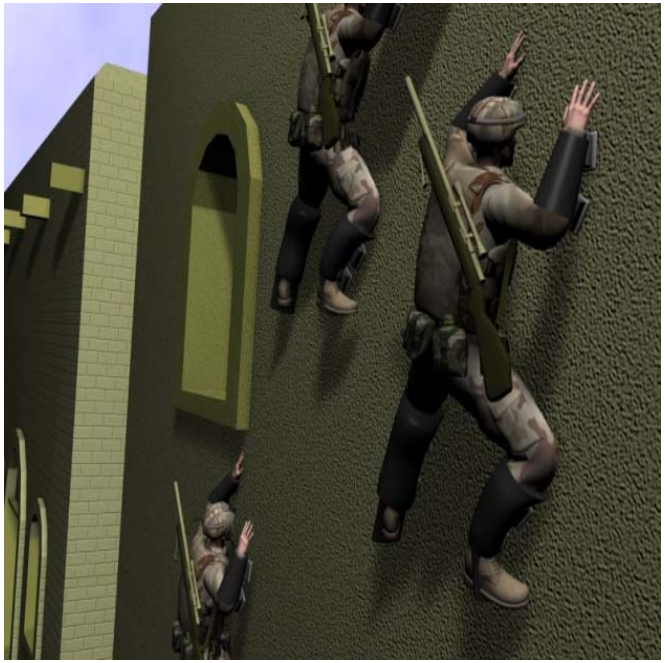
DARPA's challenge: Build a system that will enable humans to climb like geckos, insects, and small animals

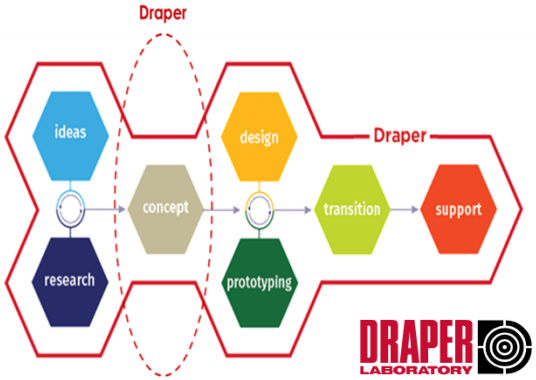
- Loading
  - Shear (down the wall) and normal (away from the wall)
  - Dynamic vs. static
- Climbing system
  - Makes contact easily
  - Releases when desired
- Scale:
  - Tokay gecko 150-300 g
  - Human ~100 kg (~500x larger load than nature!)

Draper Zman Initial Concept

Combine gecko dry adhesion, insect microspines, macro claws into integrated human climbing system

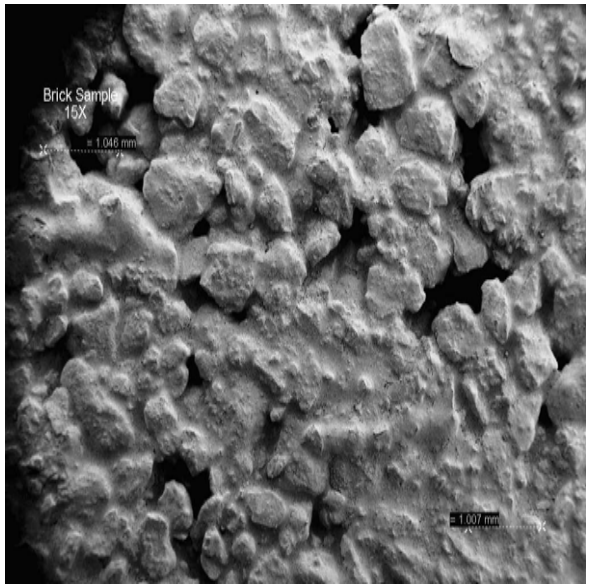


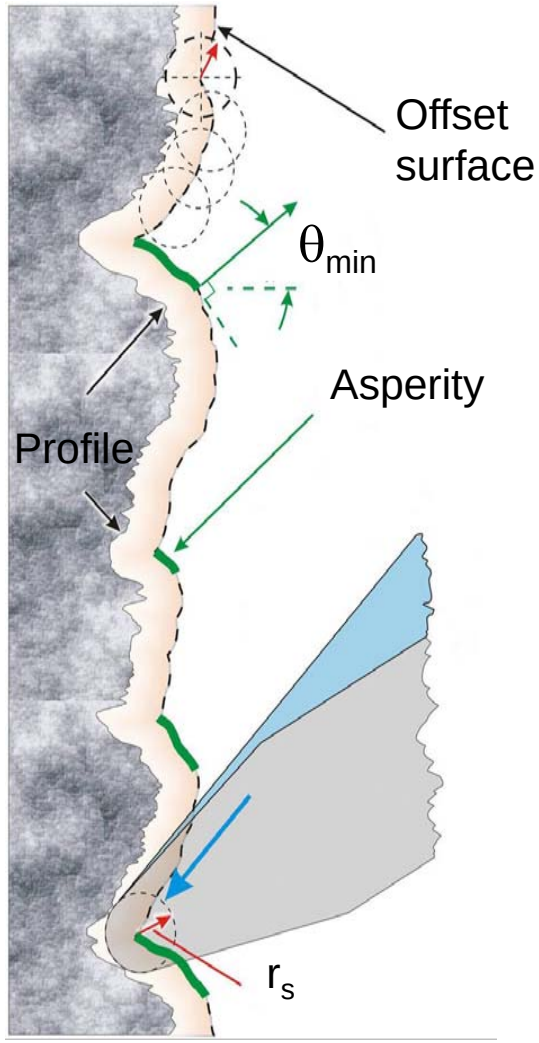




Micro-Spine Principles

- Micro-spines must hook 'asperities' (little crevices in a surface) to support weight
- On any given wall, asperities are randomly distributed
- To catch a spine, an asperity must be large relative to the tip of the spine

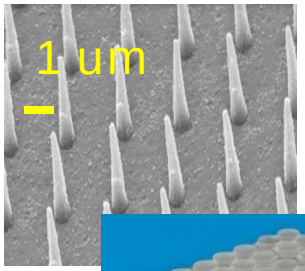


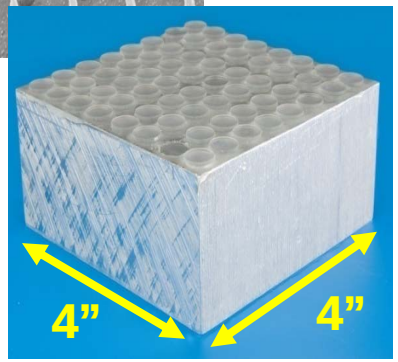


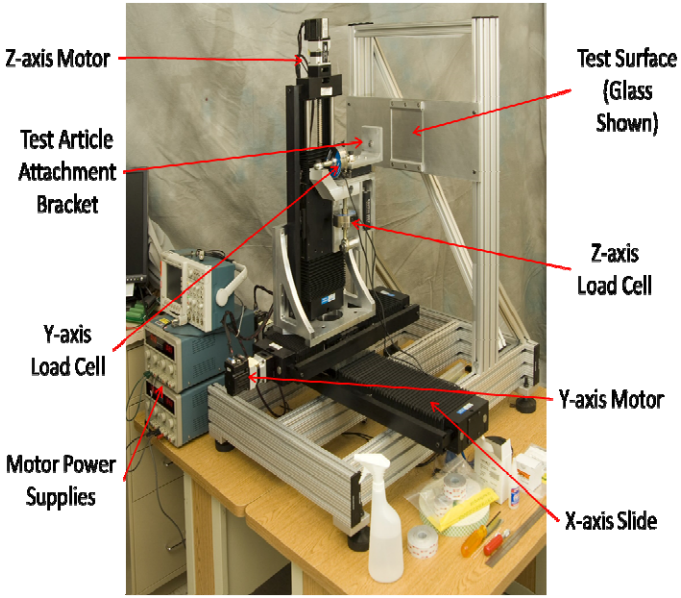
Zman Feasibility Demonstration

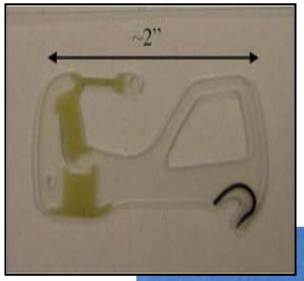
Demonstrate *feasibility of human climbing* with gecko adhesives and insect microspines

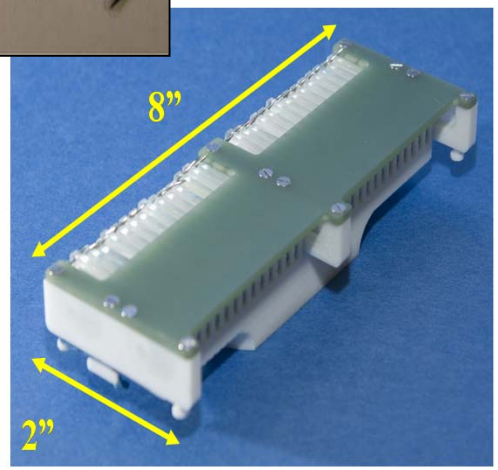
- ***Adequate load/area*** for human-scale system
- ***Reasonable scaling*** (4”x4”)
- ***Durability/repeatability*** (100X)

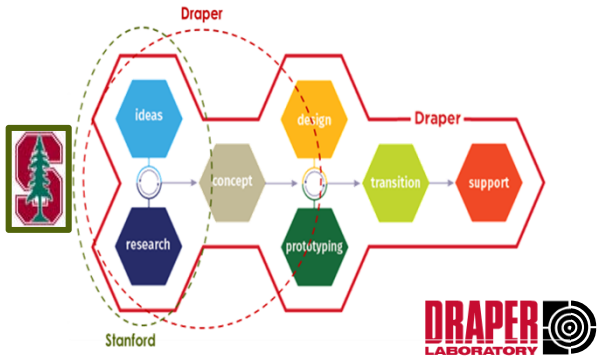






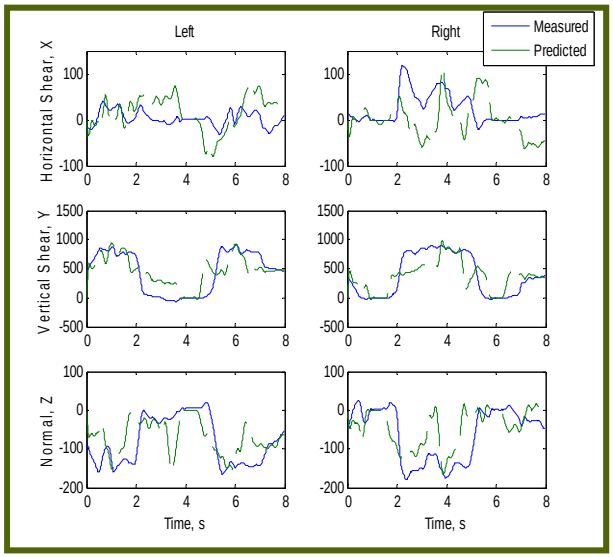


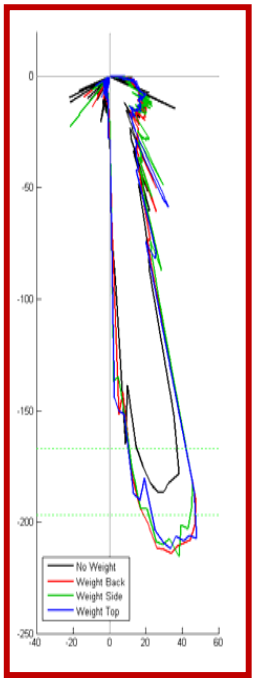


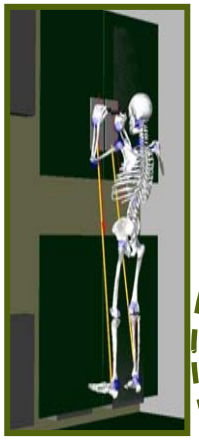


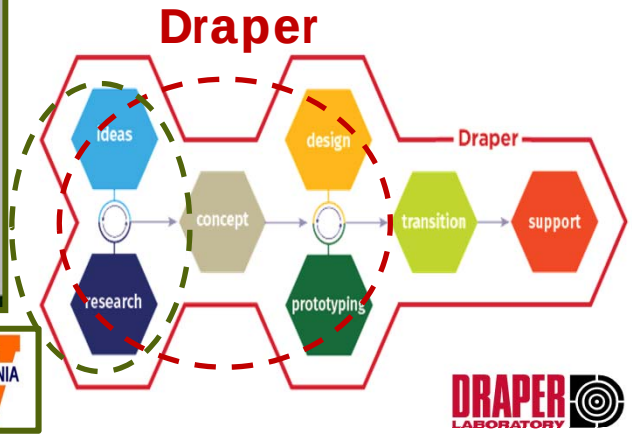
Human climbing studies

- **Draper**: initial work to determine load envelopes, explore dynamics, climbing system topology
- **UVA** brought on to do more complete modeling
  - Inform system design constraints
  - Study fundamentals of human climbing
  - Explore training methodologies (later in program)









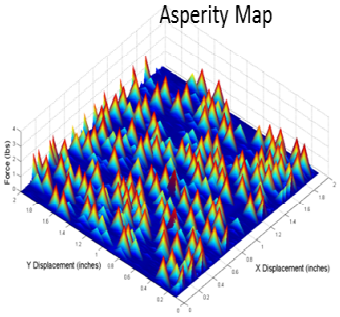
Transition from feasibility to human climbing

- Feasibility phase showed this wasn't impossible
- DARPA's next challenge: *Build spine and gecko climbing devices to enable a Soldier to climb 25 feet on vertical walls of glass, stucco, brick or concrete, painted and unpainted steel, and adobe*
- Apply lessons learned:
  - Single modality is hard enough – develop separate systems for set of target surfaces
  - Scaling is non-trivial – 16 in^2 to ~1-2 ft^2 challenging – mechanisms for load sharing will be critical
  - Fabrication with adequate throughput/low enough cost is programmatic/engineering challenge

Z-Man Microspines: Climbing Like Insects

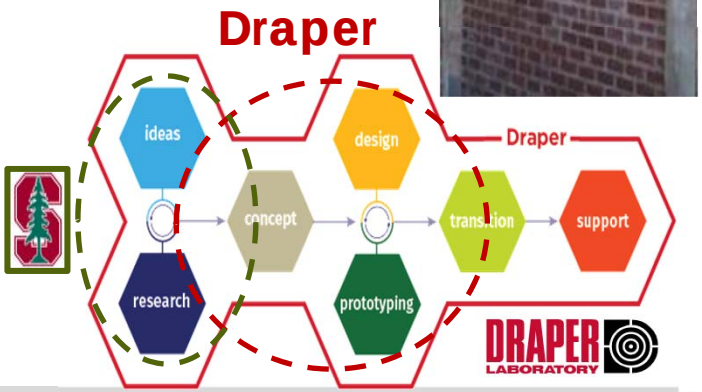
Advance spine fabrication/robustness (injection molded part)

Demonstrated Human Climbing!

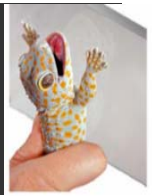


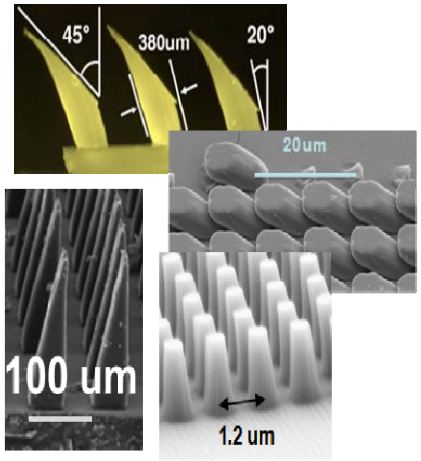
Mapping of surface asperities (inform system design)

Spine climbing system (~2000 spines/paddle)

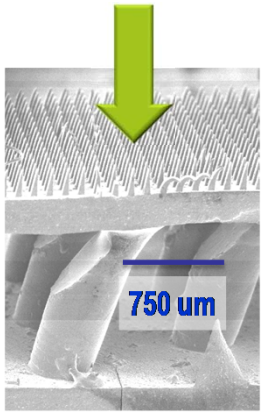


Z-Man Dry Adhesive: (Almost) Climbing Like Geckos





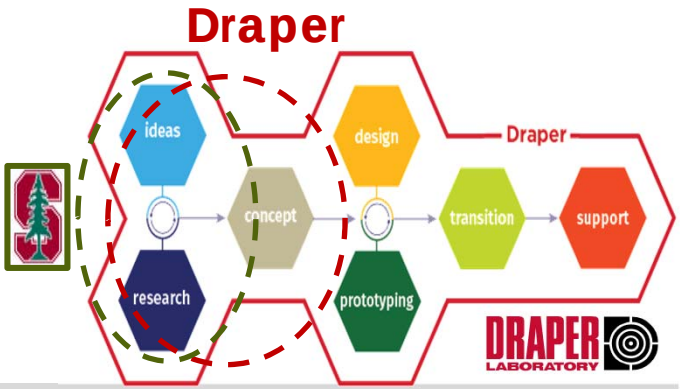
Individual Structures



Hierarchical Structures

Large loads

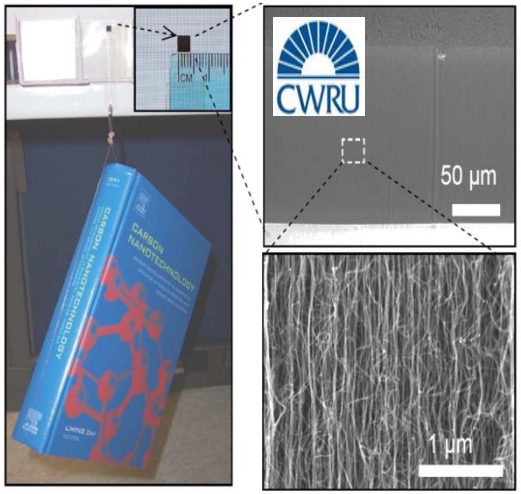
Adhesion to multiple surfaces

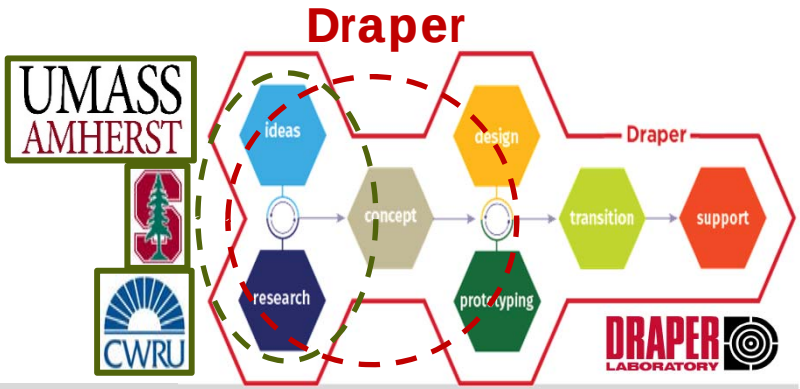


Z-Man Dry Adhesive: (Closer to) Climbing Like Geckos

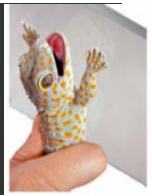
Brought on larger team to more completely explore dry adhesives

- Stanford (dry adhesives – microwedges)
- UMass Amherst (gecko structure)
- Case-Western (CNT-based adhesives)





Z-Man Dry Adhesive: Climbing Like Geckos!



Draper: focused efforts on

- Mechanism design (scaling)
- Dry adhesive performance improvement
- Dry adhesive fabrication (cost/throughput/repeatability)

Result: First time humans have climbed like geckos

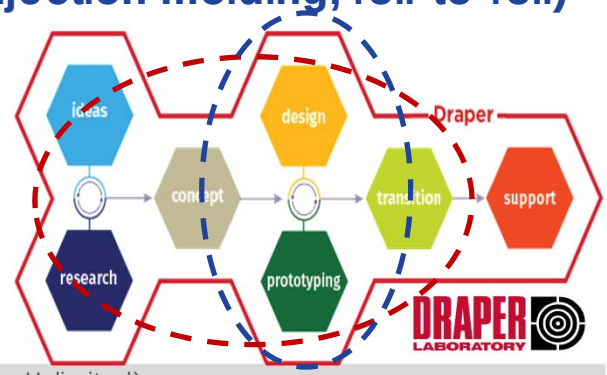
- 218-pound climber ascended and descended 25 feet of glass
- Also climbed successfully with 50-lb load

Where do we go from here?

- Human climbing is hardest thing to do: 100% reliable; large loads
- Other applications may be less demanding
- Cost of dry adhesive high
  - current Z-man phase looking at manufacturing

Manufacturers (injection molding, roll-to-roll)

Draper



Keys to working successfully with DARPA

- DARPA PMs are looking for (1) good ideas for problems they want to solve and (2) new problems to pursue.
  - Talk to them about things you're working on (technology push)
  - Ask them what they're interested in ("market" pull)
- You're on the same team as your PM; you both want to solve the same problem
  - Keep them in the loop as things progress to alert them to good (and bad) news
  - Maybe not a day-to-day update (apply some filtering)…
- Teams can be greater than the sum of their parts
  - DARPA creates communities
    - Sometimes this is multiple performers on a program
    - On Z-man we formed (and re-formed) team to solve problem
  - Be on the lookout even as your program progresses for new approaches/team members to help solve the problem
- "Sponsor" vs. "Customer"

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BREAK

RETURN BY 3:30 PM

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Q&A Session

Doing Business with DSO

Kristen Fuller
Assistant Director, Program Management
Defense Sciences Office

DSO Proposers Day

July 21, 2015

Distribution Statement “A” (Approved for Public Release, Distribution Unlimited)

Doing Business with DSO – Overview

- What is DSO-BAA-15-39?
- Preparing to propose
- Submitting your proposal
- Key Take-Aways

What is DSO-BAA-15-39?

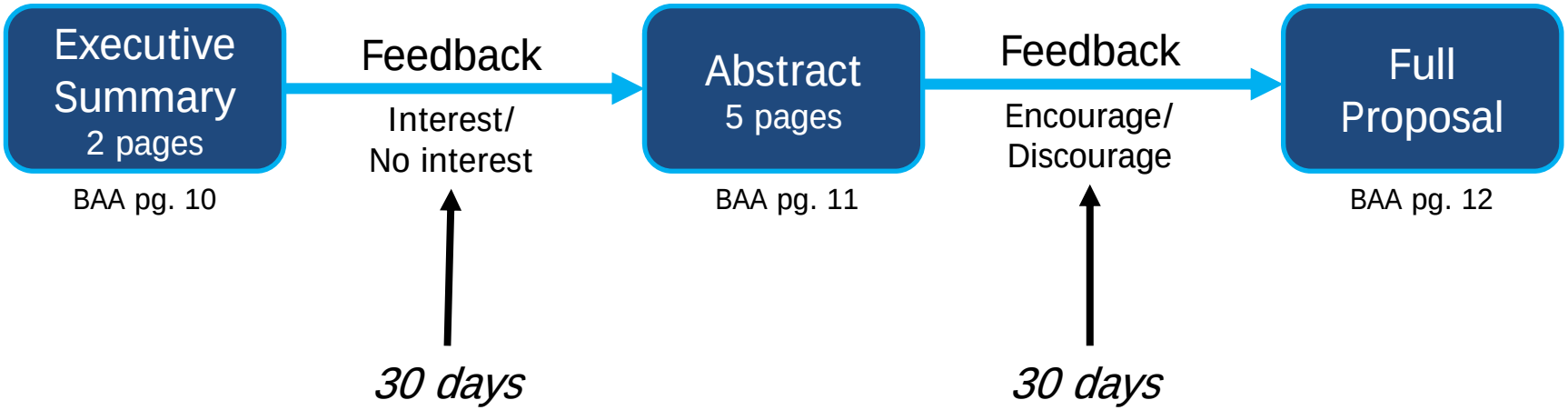
- DSO-BAA-15-39 is DSO's Office-wide BAA
  - Formal access point to communicate new ideas to DSO PMs
  - Means of identifying new ideas that fall within DSO's mission set
  - Open for one year with no interim cut-off dates
  - Encourages submission of Executive Summaries
  - Has no predetermined overall funding level, planned dollar value per award, or anticipated number of awards
  - Used primarily to identify "seedlings"

Seedlings in DSO

- Small, short duration projects or studies
  - 3-9 months
  - 1-2 Full-Time Equivalents
- Move concepts from disbelief to mere doubt
- May lead to the next generation of program ideas

HOWEVER, *not all seedlings become programs*

DSO's Office-wide BAA Proposal Process



May still submit full proposal if you are discouraged, but you should strongly consider Government feedback before expending more resources

NOTE: *Full proposals not encouraged as the result of an executive summary or abstract are rarely selected for negotiation of an award*

Preparing to propose

- Read the BAA and follow the instructions therein
- Communicate with a PM
- Answer the Heilmeier Questions
- Start with an Executive Summary
- Follow up with an Abstract
- Finally, submit a Full Proposal
  - Optional templates
  - Be concise, but include details
  - Ensure proposal is “conforming”

Conforming Proposals

- Proposals are assessed for whether they contribute to DSO's mission
  - Applicability to DSO Technical Areas
  - Important to DSO investment portfolio
  - Revolutionary technical approach
  - There must be an R&D component to the proposal
  - The concept is not already being funded by the Government

- Non-conforming proposals will not receive further review and will not be considered for award

Submitting your proposal

- DSO-BAA-15-39 closing dates:
  - Executive Summaries: May 12, 2016
  - Abstracts: June 2, 2016
  - Full Proposals: June 30, 2016
- Submission portals
  - Contracts and Other Transaction proposals: https://baa.darpa.mil
  - Grants or cooperative agreements: www.grants.gov
- Q&A
  - E-mail questions about the BAA to DARPA-BAA-15-39@darpa.mil
  - FAQs will be posted under the BAA at http://www.darpa.mil/work-with-us/opportunities (filter by "DSO")
  - Find PM bios, program information, and contact PMs at https://www.darpa.mil/about/offices/dso

BAA Evaluation Criteria

- Overall Scientific and Technical Merit
- Potential Contribution and Relevance to the DARPA Mission
- Cost Realism

Key Take-Aways

- Before hitting the “Finalize” button—
  - Read the BAA in its entirety again
  - Take advantage of Executive Summaries and Abstracts before submitting a Full Proposal
  - Ensure your proposal is conforming
  - Include detail necessary to make proposal believable

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Security Instructions for Working with DARPA

James Persons
Defense Sciences Office

DSO Proposers Day

July 21, 2015

Distribution Statement “A” (Approved for Public Release, Distribution Unlimited)

Security Requirements

- For general Security information and guidance:

- Single most important thing you can do—

READ THE BROAD AGENCY ANNOUNCEMENT (BAA)

- Second most important thing you can do—

FOLLOW THE INSTRUCTIONS IN THE BAA

- Now that we've stated the obvious…

Common Security Questions

- Basic/Fundamental Research – Are there security restrictions?
  - No security clearance requirements
  - No publication restrictions
  - No US citizenship requirements
  - Not export controlled
    - International Traffic in Arms Regulations (ITAR)
    - You will be required to identify if your work crosses ITAR thresholds
    - If it does, then publication and citizenship requirements may apply
    - Learn more about ITAR: http://www.cdse.edu/documents/cdse/itar-101.pdf

Common Security Questions

- Can non US citizens work on DARPA contracts?
  - For basic/fundamental research, yes
  - For work that is not ITAR controlled or otherwise sensitive, yes
  - For ITAR or sensitive but unclassified work (i.e., FOUO), you should contact us for instructions
  - For classified work, no
- Does our work require pre-publication review?
  - For basic/fundamental research, no
  - For all other work, yes

Common Security Questions

- I think my work might be classified. What do I do?
  - Specific instructions will be in the BAA
  - Provisionally mark it at the level you believe it will be classified at and protect accordingly
- Our relevant past performance is classified by someone else. Can I include it in my proposal?
  - In order to submit to DARPA you need permission from the data owner
  - If the information contains Special Access Program (SAP) or Sensitive Compartmented Information (SCI), special conditions apply. Please contact us before transmitting for instructions

Security Philosophy

- Our priority is ensuring information is protected at the right level
  - Sometimes that means no protection (i.e., open and releasable without restriction)
  - It can mean the application of ITAR controls to specific information or technology
  - Unclassified sensitive information (e.g. FOUO) that requires handling and protection above that afforded other unclassified information
  - At times it can mean classification, and some programs may have additional caveats associated with them (e.g., SCI or SAP)
  - Protection levels may change as a program matures (up or down)
  - Bottom line: We want to enable performers work to be done while achieving an appropriate protection profile
- We also want to ensure *your* information is protected
  - We understand how important your Intellectual Property is to you
  - DARPA federal employees are automatically bound by statute to protect your IP
  - DARPA SETAs complete legally binding Non-Disclosure Agreements (NDAs)
  - Mark your IP as Proprietary or Intellectual Property. **DO NOT** mark it Confidential – That translates as "Classified" within DoD!

DSO Security Team

- Our Team
  - 1 Government Program Security Officer (PSO) – Dave Stiffler
  - 2 Program Security Representatives (PSR) – James Persons and John Sura
  - 1 Security Administrator (SA) – Kevin McAfee
- PSRs provide dedicated support to each DSO Program Manager
  - They're your first stop for security related issues and questions
- The PSO has great latitude in implementing security for DSO programs
  - Flexibility allows us to find creative solutions
  - It means trying to find a pathway to yes instead of "no!"
- Bottom line – we're here to integrate security (when necessary) into programs in a way that protects what needs to be protected without hindering the program

DSO Security Contact Information

- David Stiffler, PSO
  - Email: david.stiffler@darpa.mil
  - Phone: 703-526-2838
- James Persons, PSR
  - Email: james.persons.ctr@darpa.mil
  - Phone: 703-526-1054
- John Sura, PSR
  - Email: john.sura.ctr@darpa.mil
  - Phone: 703-526-2812
- Kevin McAfee, SA
  - Email: kevin.mcafee.ctr@darpa.mil
  - Phone: 703-526-4775

Questions?

Additional Questions can be sent to the BAA mailbox at

DARPA-BAA-15-39@darpa.mil