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8th Annual Disruptive Technologies Conference

"DoD Science & Technology Priority Roadmaps to Address Emerging Military Challenges"

Washington, DC

8-9 November 2011

Agenda

Tuesday, November 8, 2011

Some Challenges for Global Military Operations

- Dr. Thomas Allen, Deputy Director, Studies and Analysis, Joint Staff, J8

Process Used to Develop the DoD Science & Technology Priorities and Roadmaps

- Mr. Robert Baker, Deputy Director, Plans & Programs, Office of the Assistant Secretary of Defense, Research & Engineering

Data to Decisions

- Dr. Carey Schwartz, Program Officer, Office of Naval Research

Autonomy

- Dr. Morley Stone, Chief Scientist, 711th Human Performance Wing, Air Force Research Laboratory

Human Systems

- Dr. John Tangney, Director, Human & Bioengineered Systems Division, Office of Naval Research

Engineered Resilient Systems

- Dr. Robert Neches, Director, Advanced Engineering Initiatives, Office of the Assistant Secretary of Defense, Research & Engineering

Cyber Science and Technology

- Dr. Steven King, Deputy Director, Cyber Security Technology, Office of the Assistant Secretary of Defense, Research & Engineering

Counter Weapons of Mass Destruction (WMD)

- Dr. Gregory Simonson, Science Advisor, Office of the Assistant Secretary of Defense for Nuclear, Chemical and Biological Defense Programs

Wednesday, November 9, 2011

Army Science & Technology Program: Areas for Industry Participation

- Ms. Nancy Harned, Executive Director, Strategic Plans and Program Planning, Office of the Deputy Assistant Secretary of the Army, Research and Technology

Naval Science & Technology Program: Areas for Industry Participation

Dr. Walter Jones, Technical Director, Office of Naval Research

Basic Science, MURIs and Their Disruptive Qualities

- Dr. Robin Staffin, Director, Basic Sciences, Office of the Assistant Secretary of Defense, Research & Engineering
  - **1. The First MURIs: 1986**

MURIs and What They Lead To

- Dr. George Whitesides, Woodford L. and Ann A. Flowers University Professor, Harvard University

MURI-Funded Scientific and Technological Blockbusters from Northwestern University

- Dr. Chad Mirkin, George B. Rathmann Professor of Chemistry, Northwestern University

From Optical Atomic Clocks to Chemistry Near Absolute Zero—How MURI has Transformed Precision

Measurement and Quantum Control

- Dr. Jun Ye, Fellow of JILA and NIST, Professor Adjoint, Department of Physics, University of Colorado

The Excitement of the MURIs

- Dr. Peter Reynolds, Chief Scientist, Physical Sciences Directorate, Army Research Office

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8*th* ANNUAL DISRUPTIVE TECHNOLOGIES CONFERENCE

"DoD Science & Technology Priority Roadmaps to Address Emerging Military Challenges"

CONFERENCE HIGHLIGHTS:

- Identify game changing disruptive technology that will overmatch hybrid threats
- In depth basis and challenges associated with Top 7 DoD S&T Priorities
- Areas of need — specifically military capabilities to defeat hybrid and provide anti-access to threats of U.S. military operations

THE CONFERENCE WILL BE HELD AT THE CLASSIFIED SECRET LEVEL

FEDERAL GATEWAY ▸ NAVY YARD METRO ▸ WASHINGTON, D.C.

NOVEMBER 8-9, 2011

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EVENT #2920

TUESDAY, NOVEMBER 8, 2011

7:00 am - 5:00 pm **Registration Open**

7:00 am - 8:00 am **Continental Breakfast**

8:00 am - 8:15 am **Welcome Remarks & Introductions**
- Dr. Steve Kimmel, *Senior Vice President, Alion Science & Technology, NDIA C4ISR Division Chairman*

8:15 am - 10:00 am **Session I: "The Character and Impact of Hybrid Threats and Anti-Access/Area Denial Capabilities on U.S. National Interests" (CLASSIFIED)**

8:15 am - 9:15 am **The Hybrid Threat—Challenges and Areas of Concern**
- Mr. Paul Scharre, *Office of Force Development, Office of the Under Secretary of Defense for Policy*

9:15 am - 10:00 am **Some Challenges for Global Military Operations**
- Dr. Thomas Allen, *Deputy Director, Studies and Analysis, Joint Staff, J8*

10:00 am - 10:30 am **Break**

10:30 am - 5:00 pm **Session II: "The DoD S&T Priority Roadmaps" (CLASSIFIED)**

10:30 am - 11:30 am **Keynote Address: "Focus of the DoD Science & Technology Program"**
- Honorable Zachary Lemnios, *Assistant Secretary of Defense for Research & Engineering*

11:30 am - 12:00 pm **Process Used to Develop the DoD Science & Technology Priorities and Roadmaps**
- Mr. Robert Baker, *Deputy Director, Plans & Programs, Office of the Assistant Secretary of Defense, Research & Engineering*

12:00 pm - 1:00 pm **Lunch**

1:00 pm - 1:30 pm **Data to Decisions**
- Dr. Carey Schwartz, *Program Officer, Office of Naval Research*

1:30 pm - 2:00 pm **Autonomy**
- Dr. Morley Stone, *Chief Scientist, 711th Human Performance Wing, Air Force Research Laboratory*

2:00 pm - 2:30 pm **Human Systems**
- Dr. John Tangney, *Director, Human & Bioengineered Systems Division, Office of Naval Research*

2:30 pm - 3:00 pm **Engineered Resilient Systems**
- Dr. Robert Neches, *Director, Advanced Engineering Initiatives, Office of the Assistant Secretary of Defense, Research & Engineering*

3:00 pm - 3:30 pm **Break**

3:30 pm - 4:00 pm **Cyber Science and Technology**
- Dr. Steven King, *Deputy Director, Cyber Security Technology, Office of the Assistant Secretary of Defense, Research & Engineering*

4:00 pm - 4:30 pm **Counter Weapons of Mass Destruction (WMD)**
- Dr. Gregory Simonson, *Science Advisor, Office of the Assistant Secretary of Defense for Nuclear, Chemical and Biological Defense Programs*

4:30 pm - 5:00 pm **Electronic Warfare/Electronic Protection**
- Dr. Jay Kistler, *Director, Electronic Warfare and Countermeasure Technologies, Office of the Assistant Secretary of Defense, Research & Engineering*

5:00 pm - 6:00 pm **Networking Reception**

WEDNESDAY, NOVEMBER 9, 2011

7:00 am - 3:00 pm **Registration Open**

7:00 am - 8:00 am **Continental Breakfast**

8:00 am - 12:00 pm **Session III: "Service and DARPA Science & Technology Programs: Areas of Increasing Emphasis and Investment" (Classified)**

8:00 am - 8:45 am **Army Science & Technology Program: Areas for Industry Participation**
- Ms. Nancy Harned, *Executive Director, Strategic Plans and Program Planning, Office of the Deputy Assistant Secretary of the Army, Research and Technology*

8:45 am - 9:30 am **Naval Science & Technology Program: Areas for Industry Participation**
- Dr. Walter Jones, *Technical Director, Office of Naval Research*

9:30 am - 10:00 am **Break**

10:00 am - 10:45 am **Air Force Science & Technology Program: Areas for Industry Participation**
- Dr. Steven Walker, *Deputy Assistant Secretary of the Air Force for Science, Technology & Engineering*

10:45 am - 12:00 pm **DARPA Science & Technology Program: Areas for Industry Participation**
- Dr. Kaigham (Ken) Gabriel, *Deputy Director, Defense Advanced Research Agency*

12:00 pm - 1:00 pm **Lunch**

1:00 pm - 3:10 pm **Session IV: "DoD Multidisciplinary University Research Initiative: 25 Years of Success" (UNCLASSIFIED)**

1:00 pm - 1:20 pm **Basic Science, MURIs and Their Disruptive Qualities**
- Dr. Robin Staffin, *Director, Basic Sciences, Office of the Assistant Secretary of Defense, Research & Engineering*

1:20 pm - 1:45 pm **MURIs and What They Lead To**
- Dr. George Whitesides, *Woodford L. and Ann A. Flowers University Professor, Harvard University*

1:45 pm - 2:10 pm **MURI-Funded Scientific and Technological Blockbusters from Northwestern University**
- Dr. Chad Mirkin, *George B. Rathmann Professor of Chemistry, Northwestern University*

2:10 pm - 2:35 pm **From Optical Atomic Clocks to Chemistry Near Absolute Zero—How MURI has Transformed Precision Measurement and Quantum Control**
- Dr. Jun Ye, *Fellow of JILA and NIST, Professor Adjoint, Department of Physics, University of Colorado*

2:35 pm - 3:00 pm **The Excitement of the MURIs**
- Dr. Peter Reynolds, *Chief Scientist, Physical Sciences Directorate, Army Research Office*

3:00 pm - 3:20 pm **Closing Remarks: "Sharing MURI Activities to Ensure the Nation's Future Technological Strength"**
- Dr. Robin Staffin, *Director, Basic Sciences, Office of the Assistant Secretary of Defense, Research & Engineering*

3:20 pm **Adjourn**

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8TH ANNUAL DISRUPTIVE TECHNOLOGIES CONFERENCE

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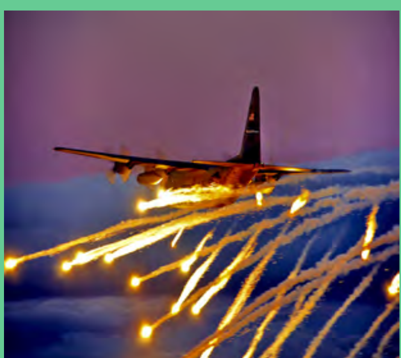

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"Challenges for Global Military Operations"

Presentation by Dr. Tom Allen,
Deputy Director, Studies and Analysis, Joint Staff J-8

to

8th Annual Disruptive Technologies Conference

November 8, 2011

Federal Gateway
Washington, DC

Thank you Dr. Kimmel. I appreciate your kind introduction and inviting me to speak this morning at the 8th Annual Disruptive Technologies Conference. As one of the first presentations of the morning, I have the opportunity to provide you with some context regarding the challenges facing the Defense Department in the coming years. I also appreciate speaking early in the lineup of presentations since it minimizes the chance that I will contradict something you have already heard. My plan this morning is to describe some of the fiscal, strategic and operational challenges facing global military operations, building on the challenges presented by Mr. Scharre, such as anti-access/area denial threats and capabilities, cyber challenges, and hybrid threats, to set the stage for thinking through how the United States can best respond. Most of that will be left to you, both at this conference and in the years to come. I would also like to share some of my ideas about how the Defense Department can address these threats by crafting responses and evaluating them through modeling and simulation prior to fully committing to detailed solutions in our future budgets. Those detailed solutions will require close coordination between the government and industry and must be undertaken with a better understanding of how to effectively transition S&T concepts to real military capability. Secretary Lemnios will talk more about that in his presentation, but aligning your research, to include IRAD, more closely to the challenges confronting the military will facilitate early access to Department research capabilities and will certainly help meet both the fiscal challenges that I will talk about this morning and better align concepts for transition. In a time of shrinking budgets, we can ill afford to divert funding to explore solutions that our research tells us up front that we will be unable to transition.

One of my responsibilities in J8 is to work with the Offices of the Under Secretary of Defense for Policy and the Cost Assessment and Program Evaluation to develop force planning scenario constructs for the Department. These scenario constructs are built to represent multiple military operations or "demand signals" that must be integrated into a time-phased response. Before getting to the specific challenges, I'd like to describe one integrated defense scenario construct for you. First, imagine that the U.S. military is fully engaged in two simultaneous conflicts—these combat operations do not involve all U.S. ground forces but they are geographically separated and place a heavy burden on our logistics supply chain. Now, in the midst of these combat operations, suppose the United States becomes involved in a third military operation. Imagine that this operation includes a multi-national coalition built to enforce United Nations Security Council resolutions and protect innocent civilians. Assume that this third military operation involves kinetic force and requires substantial support from American aerial refueling and reconnaissance platforms. Finally, to make things even more interesting, imagine a last piece of this scenario construct involves a natural disaster which creates the need for a massive humanitarian response to help the victims of the catastrophe, much of this provided by the US military. Remember, in this scenario construct, all of these events are occurring with some degree of simultaneity, meaning they overlap to some extent in time, requiring our military response to be integrated to avoid mission failure. At this point I need to admit that this demanding situation was not a planning scenario cooked up by the Joint Staff to be used for future planning by the Department of Defense. I am sure most of you have already realized I am describing the real-world events from March of this year when the United States military continued combat operations in Iraq and Afghanistan, supported Operation Unified Protector in Libya, and responded to the terrible tragedy in Japan from the earthquake and tsunami. The point of relating this "real world" scenario is to emphasize that the Department of Defense cannot predict with precision the specifics of any future challenge. However, our goal is to ensure that when the real challenges occur, the Department and the nation have enough military capability and capacity to respond to multiple overlapping challenges, such as those we experienced earlier this year, with minimal risk to the security of our nation.

Maintaining military capability and capacity for global military operations will become an ever-increasing challenge in the years ahead due to the current state of the U.S. economy and the requirement articulated at the national level to reduce government spending. As mentioned earlier, I work in J-8, which is the Joint Staff's Force Structure, Resources, and Assessments Directorate. As a result, I can't leave here this morning without conveying to you the serious fiscal challenges facing the Defense Department and the nation. General Dempsey, our current Chairman of the Joint Chiefs, has inherited a situation where it is clear that the budget for the Department of Defense will be reduced over the next several years and he is working closely with the Secretary and other members of the National Security Community to ensure that the available budget will be sufficient to allow the military to execute the National Military Strategy. As you are aware, the final size of the reduction is undetermined, but the President has already agreed to reduce defense spending by $450 Billion over the next 10 years. This reality matches the well-documented United States historical pattern of reducing defense spending at the conclusion of combat operations. For example, after funding reaching a peak in 1968, the post-Vietnam defense budget, adjusted for inflation, came down by over 30% by 1975. After the successful conclusion of the Cold War, there was a nearly identical reduction of 30% in defense spending in the 1990s. We followed similar patterns after the Korean War and World War II. Thus, following the conclusion of combat operations in Iraq this year and Afghanistan by 2014, we should anticipate and plan for a significant reduction in the defense budget.

The reduction in defense spending will affect almost every portfolio within the Defense Department. Secretary of Defense Panetta has already stated that the Department must look at “all areas of the budget” for potential savings. However, the search for more efficient ways to conduct the same business will yield only a limited amount of savings, and it’s clear that the total amount we might save from just cutting overhead costs will not meet the current target. Thus, other elements of the budget, from force structure and procurement to research and development, will undergo a vigorous review. During the most recent drawdown in defense spending, in the period from 1991 until 2001, funding for procurement was reduced by about 50% while the Department managed to maintain investment for RDT&E at about the same level over that period of time. In this coming period of reductions, it is unlikely that a single portion of budget will absorb the bulk of the cuts or that any portion of the budget will be exempt. And because we know that a “peanut butter spread” of cuts across all portfolio areas, across all Services, across all capabilities, will result in a force that may not be able to conduct the highest priority missions we’re going to have to think hard about how we approach this. A peanut butter spread would include force elements that are developed piece meal and without the necessary integration with other elements of the force. So we’ll need to carefully asses our force structure, basing, posture, modernization, readiness level, and R&D options against sets of scenarios that represent the kinds of challenges we are likely to face; only in this way can we hope to make informed decisions that will allow us to measure the tradeoff between incurred risks and fiscal resourcing decisions. This may lead us to adjust our national strategic objectives to ensure we continue to operate within acceptable risk boundaries. In testimony to Congress last month, Secretary Panetta explicitly stated that “we must avoid a hollow force” and “maintain a military that, even if smaller, will be ready, agile and deployable.”

It is within the context of these fiscal realities that we'll need to address some of the strategic security challenges facing the Defense Department. Over the last year, the new SecDef and Chairman, along with the Combatant Commanders, have been clear in articulating the threats and associated strategic/operational challenges they present in today's environment. We continue to confront the threat of terrorism. Regardless of what we've been able to achieve -- and we have achieved a great deal -- there remain real threats out there, not only in Pakistan but also in Somalia, Yemen, North Africa, the Philippines and other places – places where terrorists continue to plan attacks against our deployed forces and allies and, in some cases, against our homeland. In addition to terrorism that threatens our citizens and institutions, the United States will continue to have to deal with the potential proliferation and use of weapons of mass destruction, a specific goal articulated by some hostile organizations. WMD in the hands of terrorists threaten death and destruction on a scope that used to be associated only with a state enterprise. And the allure of nuclear weapons may cause small states to seek such a capability in order to give their desires for power and influence disproportionate influence, one reason why the US continues to oppose any attempts at nuclear proliferation. In the cyber world, technical capability within reach of a single individual has put at risk the information and process requirements of entire organizations and enterprises. DoD for one continues to confront both cyber attacks and an increasing number of those attacks on a daily basis, from individuals and from organizations. More specifically, as we move beyond combat operations in Iraq and Afghanistan, the Department of Defense will need to address a litany of strategic security challenges, such as:

- The threat to the United States and its allies posed by North Korean nuclear and missile capabilities, its proliferation of weapons of mass destruction and associated technologies, and its potential for instability
- Transnational violent extremist organizations (VEOs) undermine stability and threaten traditional Allies and emerging partners. We see this today along the southern border of the United States, but need to be alert for any symbiosis between extremist groups and other factions that, in the aggregate, tend to strengthen each other and which, if left unchecked, could threaten wider areas of territory and the stability of civilian governments.
- China's significant military modernization.
- Territorial disputes, and the increasingly assertive actions needed to resolve them, across a wide range of national borders, something that continues to generate conflict and instability. In fact, a few years ago I visited the UN and was reminded by some of my hosts that virtually every country in the world has some question with at least one of their neighbors regarding the true provenance of a specific piece of their current territorial structure.
- Increasingly persistent and sophisticated cyber threats that challenge unencumbered operations.

State and non-state actors operating with malign intent can readily exploit the conditions noted above, with the most dangerous scenarios involving a mix of insufficient governance, weapons proliferation – especially Weapons of Mass Destruction, the influence of hostile states, and the free flow of extremist elements across national borders as well as the ready accessibility of cyberspace to anyone who would use it for hostile purposes. As I noted earlier, an individual actor in cyberspace can affect our national economy and security on a scale previously reserved only for nation states. The asymmetric nature of cyber warfare makes it difficult to apply traditional deterrence strategies and conventional doctrine to its exploitation. Other strategic challenges include:

- Transnational criminal activity - to include piracy and trafficking in narcotics and persons that reject the rule of law and challenge international order
- Humanitarian crises such as pandemics and famines, as well as natural disasters such as tsunamis, earthquakes, and volcanoes
- Environmental degradation caused by poor resource management, the pillaging of natural resources, and disputes over resource sovereignty

In addition to the "strategic" challenges that I've just enumerated, there are a number of operational challenges that currently face the Department; these are challenges that must be addressed within the overarching strategic context of fiscal constraints and preservation of appropriate military capability, but these operational challenges could prove to be so fundamental to what the military does that not addressing them could result in strategic failure.

Your conference is meant to tackle one such challenge head-on. Our military forces continue to transform to meet the hybrid threat we face in conflicts today and expect to face for the foreseeable future. By hybrid threats, I mean those that cut across conventional warfare, irregular warfare and cyber warfare. These may include attacks by nuclear, biological and chemical weapons, improvised explosive devices and information warfare. Basically, I'm talking about those potent, complex variations of warfare elements and the complex dynamics of the battlespace that requires a highly adaptable and resilient response. We have made huge strides in adapting our doctrine, tactics, techniques, and procedures to become more effective against irregular forces and the asymmetric capabilities they attempt to employ to marginalize our conventional strengths. I applaud your purpose here today, as you seek to identify and promote the development of game changing technologies and the deployment of follow-on operational capabilities that will overmatch hybrid threats to U.S. military operations. One of the issues that "keeps me up at night" is that we as a military and a nation still do not have a theory explaining how fundamental factors drive insurgencies and instability in social systems, and so cannot rigorously assess the impact that existing or new capabilities across the spectrum of national power will have when applied in a particular way, in a particular situation, under specific conditions. Without such an understanding, we run the risk of misaligning scarce fiscal resources in the development of capabilities that could have marginal utility in situations we might face on a regular basis in the future. Luckily there may be some help on the horizon; more on that later.

Another operational challenge confronting the Department is the increasing ability of various state and non-state actors to deny us the freedom to operate in an area of operations, thereby denying us the opportunity to even attempt to achieve our objectives. To my mind, these actors are following the very path that you at this conference hope to follow: they look to leverage "disruptive technologies" to either deny us entry into the area of operations (referred to as Anti-Access), or to constrain our ability to operate within the area (known as Area Denial). Although in many cases we well understand the individual effects of these technologies that could be arrayed against us, in general we don't do a good job at looking at the big picture using the system-of-systems view that is necessary to fully capture the synergies the adversary hopes to leverage and potential cascading consequences on our own integrated capability that the adversary hopes to exploit. Without the capability to perform this holistic analysis, we are ill-prepared to make capability development and resource allocations decisions that will be the key to posturing our forces to defeat Anti-Access/Area Denial threats in the future. Again, there is hope on the horizon here as well.

A third operational challenge, which also confronts us at the strategic level, is the threat posed by adversaries who have the capability to attack us through the cyber domain. As we look to leverage technology to gain an asymmetric advantage over our adversaries, we have come to rely more and more on our dominance in the realm of information technology. However, as we are frequently discovering, our doctrine and technology in this area are not yet on a par with our capability in the physical domains to defend ourselves from attack and retaliate to an attack if necessary. One might suppose that, since the cyber domain is composed of the various information technology systems, components, and connections that span the globe, it would be most amenable to analysis by computer modeling and simulation. However, similar to the problem we face in the Anti-Access/Area Denial challenge area, we currently have limited comprehensive means of holistically assessing red or blue capabilities and their interactions in the cyber domain. However, the Department is also taking steps in this area to rectify the shortfall.

I recognize that I have just touched on several challenges facing the Department, some of which we are only beginning to recognize as having the capacity to negate current military capability. Fortunately, the Department and its partners in industry and academia are looking at a broad array of potential actions and responses. If you remember nothing else from my presentation today, I hope that you'll keep in mind the underlying challenge we face: pursuing all options and then picking the winner after all the results are in is no longer possible. We need to develop a methodology that not only helps us to identify which of a number of threats are the most probable and most dangerous, but also helps to determine which of an array of solutions will address a threat most appropriately—before the threat itself is fully manifested. We know that, in order to support strategic decisions that balance limited fiscal resources with acceptable risk, the Department has developed several different methodologies and processes. I'll describe two existing processes, and propose a third that I'd like to see adopted.

The first process, and the primary activity the Department uses to inform capability development, force sizing, and force shaping decisions for the mid-to-long-term -- in other words for that period that exists beyond the Fiscal Years' Defense Plan -- is our Support to Strategic Analysis effort, or SSA for short. The Department's force planning community has worked hard to lay the analytic foundations to support strategic analysis necessary for the decision support our institutions need in order to manage these challenges. Based on challenges raised in the last Quadrennial Defense Review, this effort has generated three integrated security constructs, or ISCs. The first ISC focuses on the emergence of a near peer competitor; the second addresses the challenges faced during two overlapping regional conflicts; the third looks at the requirements associated with maintaining a rotational force engagement capability, much as we have for the last decade in Afghanistan and Iraq. While these challenges are giving way to a newly articulated national security strategy, by understanding the requirements for a force that could be called upon to prevail in any one of these three challenge spaces, we have developed a sound basis for examining aspects of the emerging strategy. Our current scenario library addresses these challenges under a number of different conditions – objectives, constraints, limitations and assumptions. Moreover, we have invested time and resources into creating an initial set of operational solutions (CONOPS/Force Requirements) against these ISCs which serve as starting points or baselines for DoD strategic analyses and assessments. Coming out of the last Quadrennial Defense Review, we have also created detailed, model-based integrated data sets to enable the community to engage in more robust analyses to understand the implications and phenomena behind some of the challenges I have outlined. As you work with specific military customers to develop capability and plan for its transition, you need to take advantage of the existence of these scenarios and products, which are available to the planners and programmers of the community, in order to help advance the body of knowledge regarding policy and force planning analyses. Your contribution to advancing that body of knowledge is essential, for we are just beginning to understand these challenges well enough to adequately model and emulate their affects for planning purposes.

A second process which actually forms the basis for a more focused effort that we are engaged in is the development of what the US Transportation Command and the Defense Logistics Agency are calling the Comprehensive Materiel Response Plan or CMRP. In this era of decreasing defense budgets the Department must more thoroughly examine how it does "business" across the spectrum of military operations. One of the legacy constructs that is being examined is the forward positioning of material to support combat operations, known as Pre-positioned Materiel, or "PREPO". At the direction of the Vice Chairman and supported by the Secretary of Defense's Efficiencies Task Force, TRANSCOM and DLA, together with the Joint Staff, the Combatant Commands, and the Services, are developing a new construct intended to transform how the Department approaches Material Distribution. The goal for the CMRP is to achieve the integration of materiel posture and distribution management to support the full range of military activities. To do this the CMRP must provide agile, flexible, and responsive solutions across the full range of military activities. Solutions must be capable of effectively supporting the War fight and also efficiently supporting the rest of military operations encompassing everything from partnership exercises to major disaster relief efforts. The CMRP must also leverage shared capabilities and common materiel to create joint solutions. This mean we must examine what we deploy, how we deploy it, and how often we deploy it Basically, CMRP will answer the question, “What do we need to routinely move when we deploy, support an exercise, or provide disaster relief?” and then achieve synchronized planning, effective sourcing, and optimized positioning through enterprise management. A long range goal of the CMRP is to gain total asset visibility of what is required for the most dangerous situations we might face, in addition to determining what is routinely deployed to address the most likely situation. With this knowledge the CMRP will provide efficiencies by developing an enterprise management structure that will more efficiently manage the materiel distribution system.

The goals for CMRP are challenging but necessary to posture the Department’s materiel response program to effectively and efficiently support the nation during this time of decreased resources and ever-present challenges. I see modeling and simulation as a way to better evaluate the challenges of this specific effort as well as to test the options available for meeting those challenges. The analysis team is currently in the process of developing an appropriate M&S environment to better inform the Department on understanding and meeting the CMRP challenges.

While Support to Strategic Analysis and the CMRP processes provide specific responses to a range of challenges confronting the United States, a third, possible, response to the strategic challenges we face is to develop an approach that takes a systematic, rigorous, analytic approach to investment across the entire spectrum of military capability requirements. Our British allies are already embarked upon just such an initiative, which they refer to as their Strategic Balance of Investment, or “Strat BOI” process. We currently have in place multiple processes, key expertise, and data sets that would be vital in the creation of such a process here in the United States. However, our scenario sets and the data that accompanies them are not nearly robust enough yet to support such a comprehensive attempt; and currently, the Department is finishing up specific scenario sets to support time-sensitive decisions for the upcoming FY14 POM, so Departmental decisions needed to “fill in” the scenarios required to span the entire decision space is still a ways off. Assuming the Department did decide to embark on a Strategic Balance of Investment initiative, we would also need to create the rule-sets for combining scenarios as well as for quantifying risk, and we’d have to adapt analytic methodologies to generate outcomes in the desired form. The latter issue is much less problematic than it might have been a decade ago, since there are a number of capable linear and nonlinear program applications in existence that are well-suited to this kind of optimization problem, using fiscal constraints to inform the objective function. The former issue of creating appropriate rule sets is thornier. As anyone who has spent time working around the Department of Defense knows, reaching consensus on business rules is often the biggest challenge one faces when attempting to conduct analyses with far-reaching implications. And we still find the quantification of risk to be one of the most challenging aspects of any capability analysis. Nevertheless, I strongly feel that unless we move aggressively to develop this kind of overarching capability to provide our senior leaders the kind of decision support they need and deserve, we’ll have missed a major opportunity when we attempt to allocate our resources wisely to cover the situations we could face in the future without incurring unacceptable risk.

I mentioned before that I am concerned about investments to meet the challenges of hybrid adversaries or irregular warfare without sufficient information about the fundamental driving factors in these conflicts. Lack of this information prevents us from creating models to represent system behavior, which in turn makes the creation of simulations of the full Irregular Warfare operational environment impossible. I firmly believe that we need these kinds of simulations to enable us to explore the potential impacts of new technologies and doctrine, and application of whole-of-government approaches that leverage all the instruments of national power. While we are currently pursuing the knowledge and gathering the necessary data needed to develop useful models and simulations in the hybrid threat arena, our lack of understanding about the populations that are the focus of most hybrid warfare operations makes it impossible to reasonably test alternative approaches to the problem. How will our presence influence the success of specific actions or projects in the area? Are these projects or the reality of US armed presence in a region the reason for the observed effects? What will happen when the projects continue and US soldiers are no longer visible? I have found that there is no universal answer to any of these questions, but knowing the right framework for a specific situation will help planners and commanders develop successful operational plans and concepts of operation for the situations that they face. Knowing when the conditions exist for appropriately applying the requisite tools or simulations is as important as developing those tools and simulations to move our cause forward in this area.

This means that we technologists, analysts and engineers will need to pay more attention to the human dimension of any issue involving the use of the nation’s military forces. In order to understand these dimensions, the Department has at least three initiatives in place: the Human, Social, Culture, and Behavior (HSCB) Modeling Program sponsored by the Assistant Secretary of Defense for Research and Engineering; the Irregular Warfare Modeling & Simulation High Level Task, an effort sponsored by the M&S Steering Committee led by AT&L; and the Minerva Initiative. All of these are all good examples of the Department’s efforts to better understand and model human behavior. And we need to understand human behavior in the context of a specific threat in order to understand when a specific military option will be appropriate. The HSCB invests in research to generate capability through the development of a knowledge base, building models, and creating training capacity in order to understand, predict, and shape human behavior cross-culturally. This is the starting point for generating appropriate human behavior representation in our operational tools.

The IW M&S High Level Task promotes the development of tools, models, methods, and data to support irregular warfare practitioners in areas including data collection and management, relevant theory, validation and standards, collaboration, and the establishment of a modeling and simulation as-is baseline. While neither the HSCB nor the IW M&S High Level Task has been long in existence, in theory, the High Level Task should provide the baseline insight and information for not only developing more useful tools to support operators confronting hybrid threats, it should also provide the sweet spot in which HSCB efforts can thrive.

The Minerva Initiative is a Department-sponsored, university-based social science research initiative launched by the Secretary of Defense in 2008 focusing on areas of strategic importance to U.S. national security policy. The goal of Minerva is to improve DoD's basic understanding of the social, cultural, behavioral, and political forces that shape regions of the world of strategic importance to the U.S.. The research program provides basic information by leveraging and focusing the resources of the Nation's top universities, analogous to the Cold War development of Kremlinology and game theory. And while it seeks to define and develop foundational knowledge about sources of present and future conflict with an eye toward better understanding of the political trajectories of key regions of the world, it also should provide basic information that the HSCB program, the IW M&S High Level task, and DoD's partners can use to generate more useful tools for planners and operators confronting the hybrid threat.

The second operational problem I mentioned, that of Anti-Access/Area Denial, has senior DoD leaders rightfully concerned. Because of our inability to realistically simulate, and hence come to a holistic understanding of this kind of environment, we do not know how an adversary might leverage multiple capabilities to magnify our operational obstacles or how we might be able to overcome those obstacles with the right application of technology and doctrine. That in turn means we do not fully understand the implications of critical, costly resourcing decisions, nor can we provide the comprehensive analytical insights needed to fully inform those decisions. To address this shortfall, the Department plans to integrate current disparate "system-on-system" simulation architectures into single integrating "systems-of-systems" architecture transitioning away from many stand-alone simulations to a single integrated threat simulation which covers all war fighting domains. This Integrated Threat System Modeling & Simulation (ITSMS) will:

- Represent the variety of integrated threat systems in A2/AD environment
- Develop authoritative analysis of threat "systems-of-systems" for use across DoD
- Improve fidelity and scalability of current threat analytic capabilities
- Integrate architectures from across IPCs to produce threat "systems-of-systems" analysis
- Integrate existing and emerging M&S architectures to perform integrated kill chain analysis
- Produce a common threat system architecture to foster re-use; support threat and blue analysis
- Support live, virtual and constructive stand-alone and distributed simulations Authoritative threat representations to support the communities enabled by M&S

- Develop a capability to analyze threat Systems-of-Systems in an A2/AD environment
- Develop architecture to enable both Red and Blue analysis

We are also moving aggressively to develop a virtual cyber environment that will enable multiple simulations to interact within a common context to enable system-of-systems analysis of both blue and red capabilities, their interactions, and the impact of new technologies and doctrines. The Cyber Operations Research & Network Analysis or CORONA is an M&S research effort that if successful will enable the user to ascertain cyber effects of an attack and the resulting impact on a mission; create a cyber operations assessment environment; enable heterogeneous, scalable assessments; portray advanced cyber threats and representative environments; and integrate with other live virtual constructive (or LVC) components, in order to obtain operational "so what?" answers.

My goal this morning was to present some of the challenges facing the Defense Department in order to give you context for the presentations and discussions over the remainder of your conference. In the Department, we are wrestling with a range of challenges starting with the constrained budget environment, but including the strategic and operational challenges we face in this environment such as anti-access/area-denial, hybrid warfare and cyber threats. I have described some of the ways the Defense Department is working to address these challenges. This audience, more than most, understands that we do not have all the answers and we must continue to leverage the creative genius and innovation of both those in the National Security Sector and our partners in Academia and Industry to help us meet these challenges. In fact, we need to work closely not only on solutions, but on determining early which solutions will have the broadest impact and start near the beginning of their life cycle to figure out the most efficient pathway for transition. As I stated at the start of my comments, we cannot predict where exactly the future challenges will come from, but we know they are coming. With your assistance, we will continue to identify the key challenges and ensure the military maintains the capability and capacity to preserve and protect our nation's security in the face of these challenges.

Thank you.

I am prepared to take questions from the audience and, although my prepared remarks are not classified, I can respond to your questions up to the SECRET level as required.

Process Used to Develop the DoD Science &Technology Priorities November 8, 2011

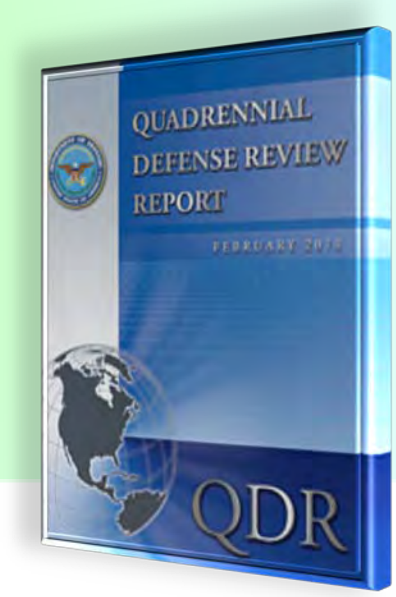
Mr. Bob Baker
Deputy Director, Plans & Programs
Assistant Secretary of Defense (Research & Engineering)

Process Began With the 2010 QDR

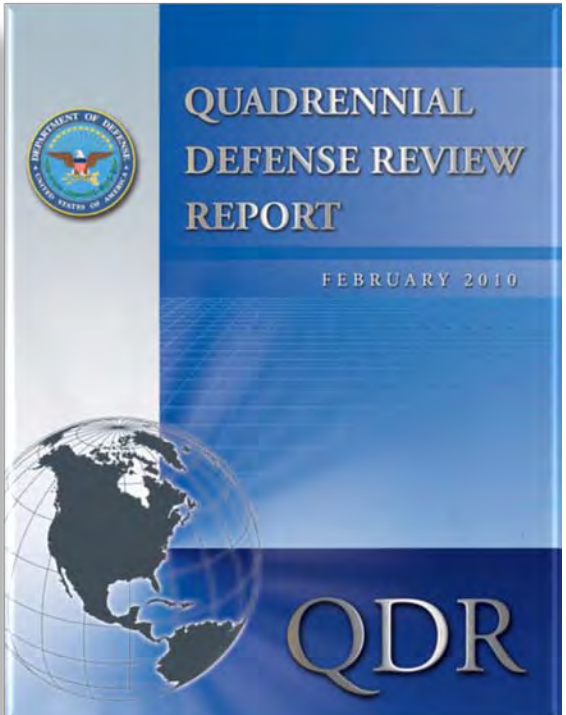
-- February 2010 --

❑ **The 2010 QDR identified 6 Key Mission Areas (KMAs) that DoD should build capability capacity to be successful in the future global security environment**

- ***Defend the United States and Support Civil Authorities at Home***
- ***Succeed in Counterinsurgency, Stability, and Counterterrorist Operations***
- ***Build the Security Capacity of Partner States***
- ***Deter and Defeat Aggression in Anti-Access Environments***
- ***Prevent Proliferation and Counter Weapons of Mass Destruction***
- ***Operate Effectively in Cyberspace.***



QDR Key Mission Areas and Department Planning and Programming Guidance (DPPG) Tasking

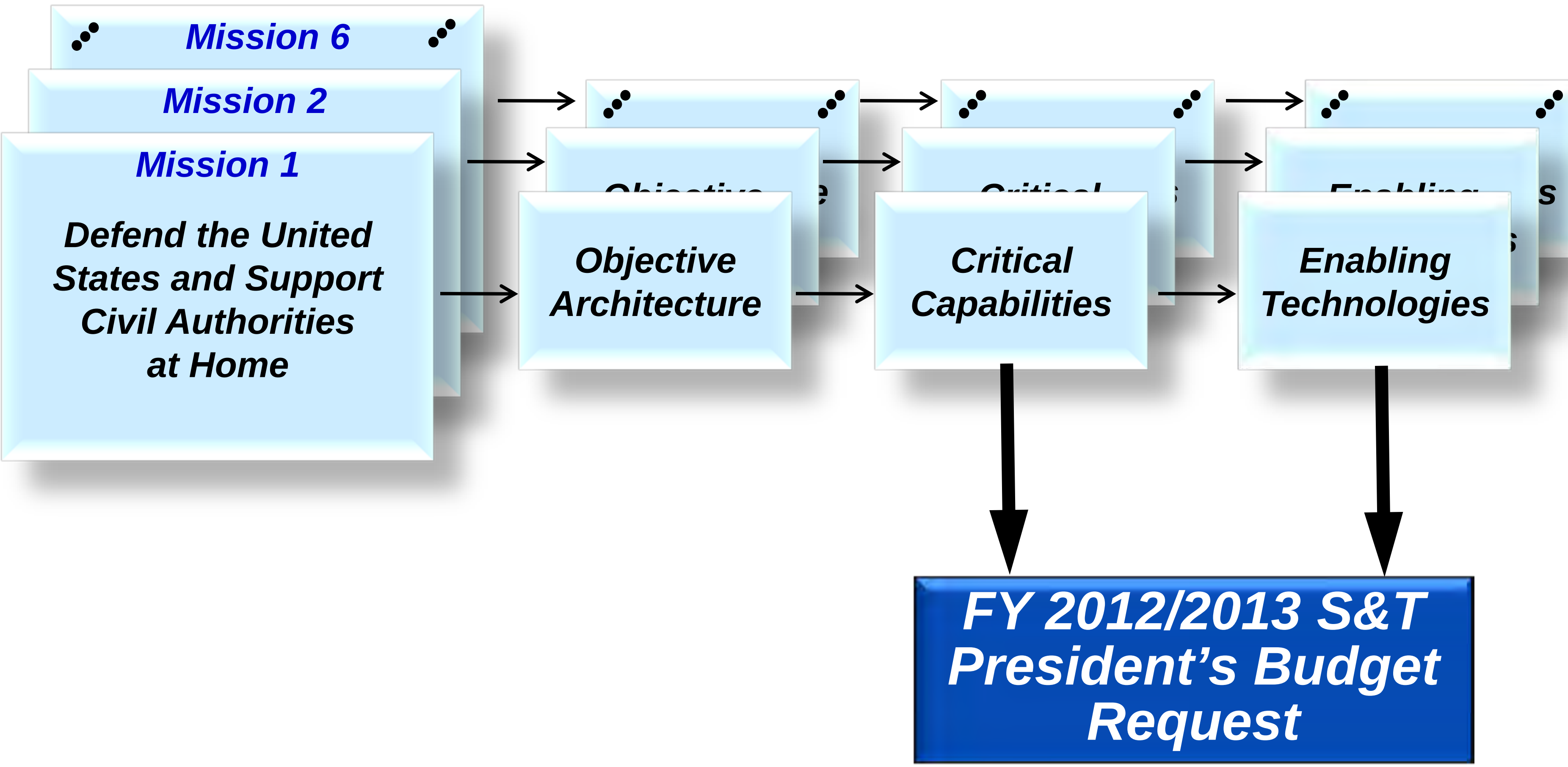


Key Mission Areas
Defend U.S. and Support Civil Authorities at Home
Succeed in COIN/Stability/CT Ops
Build Partner Security Capacity
Deter and Defeat Aggression in Anti-Access Environments
Prevent Proliferation and Counter WMD
Operate Effectively in Cyberspace

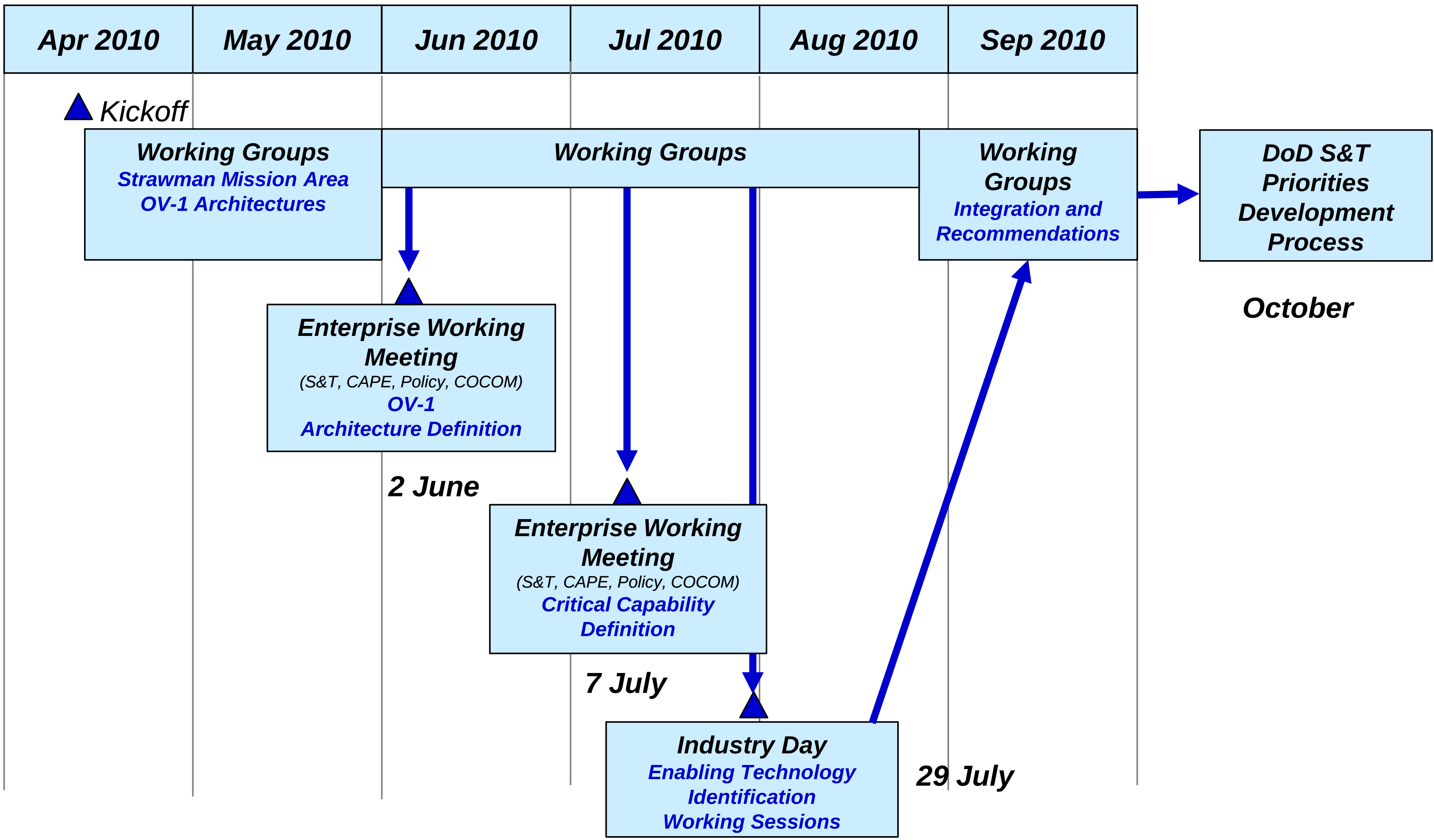
***DPPG Task*: "The DDR&E, with the support of the Secretaries of the Military Departments, Directors of the Defense Agencies, and CJCS will lead an effort across the Department to identify the core capabilities and enabling technologies for each of the six QDR key mission areas."**

-- July 12, 2010 --

QDR KMA Study Approach



QDR KMA Study Timeline



Single-Service Led S&T Priorities

- **Army**
  - Immersive Training
- **Navy**
  - Undersea Warfare
- **Air Force**
  - Long Range Strike
  - Affordable Space Access

Note: The QDR KMAs are additive to core military missions and competencies assigned to the Armed Forces

Initial S&T Priorities - 54 Total
- Reduced to 7 -

- **QDR KMA DPPG Study:**
  - Data to Decisions
  - Systems 2020
  - Immersive Training
  - Autonomy for Standoff, Speed & Scale
  - Human Terrain Preparation
  - CBRN Standoff Detection, Locate, Monitor & Track
  - Cyber Mission Assurance/Dominance -Includes Trust & Attribution
  - Rapidly Tailored Effects
  - EM Spectrum Management
  - Knowledge and Information Management / Architecture
  - Ubiquitous Observation
  - Access and Sharing of DoD Information/Databases
  - Alternatives to GPS for providing PNT
  - Contextual Exploitation
- **TFTs and COIs:**
  - High Speed / Hypersonics

Initial S&T Priorities - 54 Total - Reduced to 7 (contd.) -

- TFTs and COIs (contd.)
  – Highly Adaptive Turbine Engines
  – Multi Role Vertical Lift
  – Reasoning Machines
  – Teaming Large Numbers of Autonomous Hetero. Systems
  – Developing Materials Underpinning Electronics Technologies
  – Force Protection
  – Mobility
  – Integrated Computational Materials Science and Engineering (ICMSE)
  – Complex Engineered Materials
  – Improved Kinetic Weapons
- Service and Agency Priorities
  – Autonomy
  – Power & Energy
  – Total Ownership Cost
  – Directed Energy
  – Educational Outreach/STEM

Initial S&T Priorities - 54 Total
- Reduced to 7 (contd.) -

- **Service and Agency Priorities (contd.)**
  - Irregular Warfare/Counter IED
  - Undersea Warfare
  - Electronic Warfare/Electronic Protection
  - Improved Situation Awareness, Persistent ISR
  - Climate Change and the Arctic
  - Long-Range Strike
  - Medical PTSD/TBI, Blast/Trauma
  - Enhanced Cognitive Performance
  - Software Assurance
  - Rare Earth Element Technologies
  - Small Engines/Alternate Propulsion
  - Military-Unique Fixed-Wing and Rotary-Wing Technologies
  - Human System
  - Affordable Space Access
  - Precision lethality
  - Counter-WMD Technologies (9 total that were consolidated to 1)

FY 2013 S&T Priorities Timeline

Nov 8-12	Nov 15-19	Nov 22-26	Nov 29-Dec 3	Dec 6-10	Dec 13-17

S&T Deputies Council Working Group

Nov 8-12

Service Priorities
QDR KMA Study
DPPG Studies
OSTP Priorities
TFT/COI Priorities

3 Nov

S&T Deputies Council Meeting
- Gather Inputs and organize data

10 Nov

S&T Deputies Council Meeting
- Priorities spreadsheet discussion

17 Nov

S&T Deputies Council Meeting
- Discuss which priorities make it into DDR&E Guidance Memo
- QDR KMA Study Team 1 Brief)

23 Nov

S&T Deputies Council Meeting
- Reviewed voting on top 6-8 S&T Priorities

30 Nov

S&T Deputies Council Meeting
- POC briefings on S&T Priorities

8 Dec

S&T Deputies Council Meeting
- Review DDR&E Guidance Memo
-- Dry run S&T Priorities Briefing

15 Dec

S&T EXCOM
- S&T Priorities Briefing

Roadmap Development

Process for Developing S&T Priorities

S&T Investment Drivers

Warfighters
- *IPLs/STIPLs*
- *RDA Task Force*

Strategic Guidance
- *QDR KMA Studies*
- *DPPG Studies*
- *OSTP Priorities*

Technology Push
- *TFT Priorities*
- *COI Priorities*

Service Priorities
- *Immersive Training*
- *Undersea Warfare*
- *Affordable Space Access*

→

Comprehensive List of S&T Priorities

-
-
-
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-
-
-
- ***(54 Total)***
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-
-
-

→

Identify Cross-cutting & Single Service Priorities

→

S&T EXCOM Review

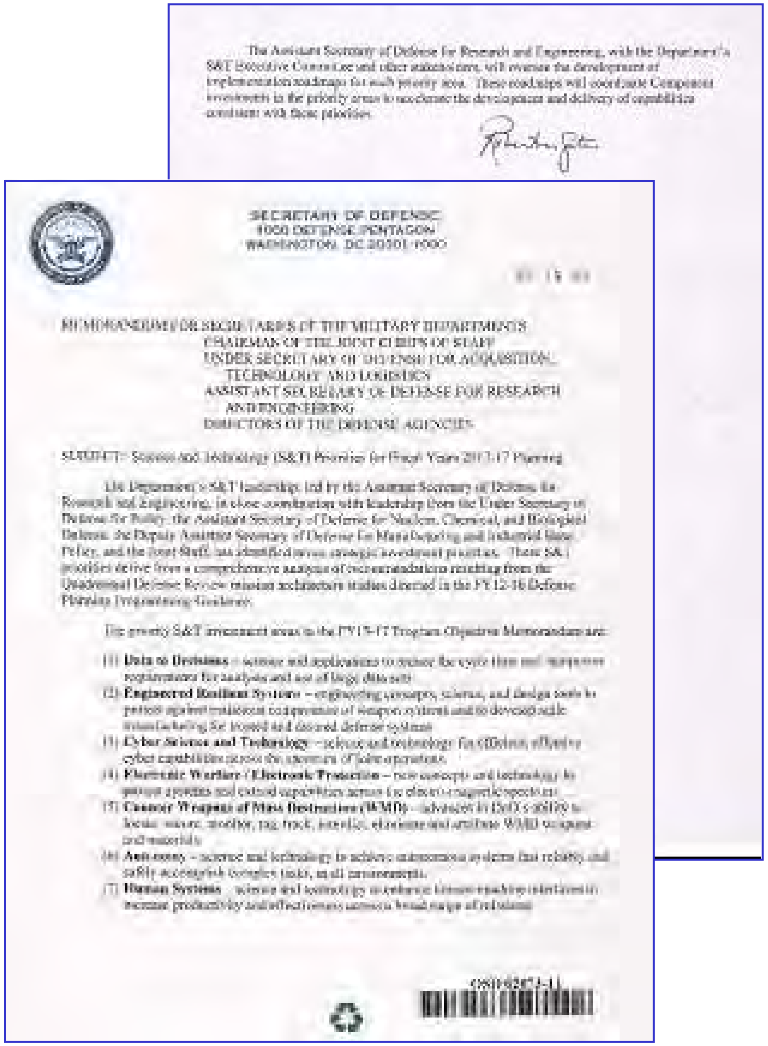
High Level Review of Existing Priorities

(7 Identified)

→

SECDEF S&T Priorities Memo Apr 19. 2011

Secretary of Defense
S&T Priorities Memo – Apr 19, 2011


SECRETARY OF DEFENSE
1000 DEFENSE PENTAGON
WASHINGTON, DC 20301-1000

S&T Priorities

- *Data-to-Decisions*
- *Engineered Resilient Systems*
- *Cyber Science and Technology*
- *Electronic Warfare / Electronic Protection*
- *Counter Weapons of Mass Destruction*
- *Autonomy*
- *Human Systems*

"The Assistant Secretary of Defense for Research and Engineering, with the Department's S&T Executive Committee and other stakeholders, will oversee the development of implementation roadmaps for each priority. These roadmaps will coordinate Component investments in the priority areas to accelerate the development and delivery of capabilities consistent with these priorities."

Priority S&T Investment Areas for FY 2013-2017

- **Data-to-Decisions**
  - **Science and applications to reduce the cycle time and manpower requirements for analyses and use of large data sets.**
- **Engineered Resilient Systems**
  - **Engineering concepts, science, and design tools to protect against malicious compromise of weapon systems, and to develop agile manufacturing for trusted and assured defense systems.**
- **Cyber Science and Technology**
  - **Science and technology for efficient, effective cyber capabilities across the spectrum of joint operations.**
- **Electronic warfare / Electronic protection**
  - **New concepts and technology to protect systems and extend capabilities across the electro-magnetic spectrum.**
- **Counter Weapons of Mass Destruction (WMD)**
  - **Advances in DoD's ability to locate, secure, monitor, tag, track, interdict, eliminate, and attribute WMD weapons and materials.**
- **Autonomy**
  - **Science and technology to achieve autonomous systems that reliably and safely accomplish complex tasks in all environments.**
- **Human Systems**
  - **Science and technology to enhance human-machine interfaces to increase productivity and effectiveness across a broad range of missions.**

Army Science & Technology

NDIA 8th Annual Disruptive Technologies Conference

Army S&T Strategic Direction:

Areas for Industry Participation

Ms. Nancy Harned
Office of the Deputy Assistant Secretary of the Armyfor Research and Technology

November 9, 2011

Purpose

- **To provide you with an update of the new processes we are implementing in Army S&T**
  - **Reflects Senior Leadership's priorities and synchronized to budget process**

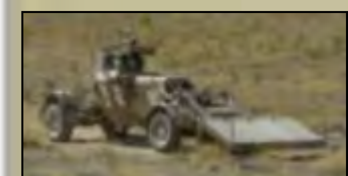
- **To walk you through our S&T path forward and highlight opportunities for you to participate**

Army S&T Mission

Foster invention, innovation, maturation, and demonstration of technologies to enable Future Force capabilities while exploiting opportunities to transition technology enabled capabilities to the Current Force

Current Force

Modular Protective Systems



IED/Mine Detection Ground Penetrating Radar

Unattended Transient Acoustic MASINT System

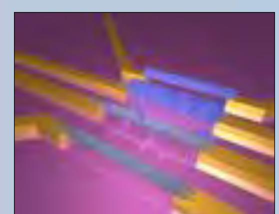
MRAP Expedient Armor Program

Enabling the Future Force

Enhancing the Current Force

Future Force

Immersive Training



Virus-based Self-Assembling Electrodes

Regenerative Medicine

Autonomous Materiel Handling System

Army Science & Technology Vision

Vision

Provide ***Technology Enabling Capabilities*** that Empower, Unburden and Protect our Soldiers and Warfighters in an environment of Persistent Conflict

Our Challenge

Deliver these technologies through effective partnerships in synchronization with Army Force Generation (ARFORGEN) and fiscal processes

Respond Rapidly to Technological Evolution

Strategic Goals for Army S&T

FY11 Focus

"World Class" Science & Technology

Timely Transition of the Right Technologies

Recognized Leader in Defense Development and Engineering

Strong Internal & External Partnerships

High Quality, Relevant Facilities and Capabilities

A Balanced Investment Portfolio

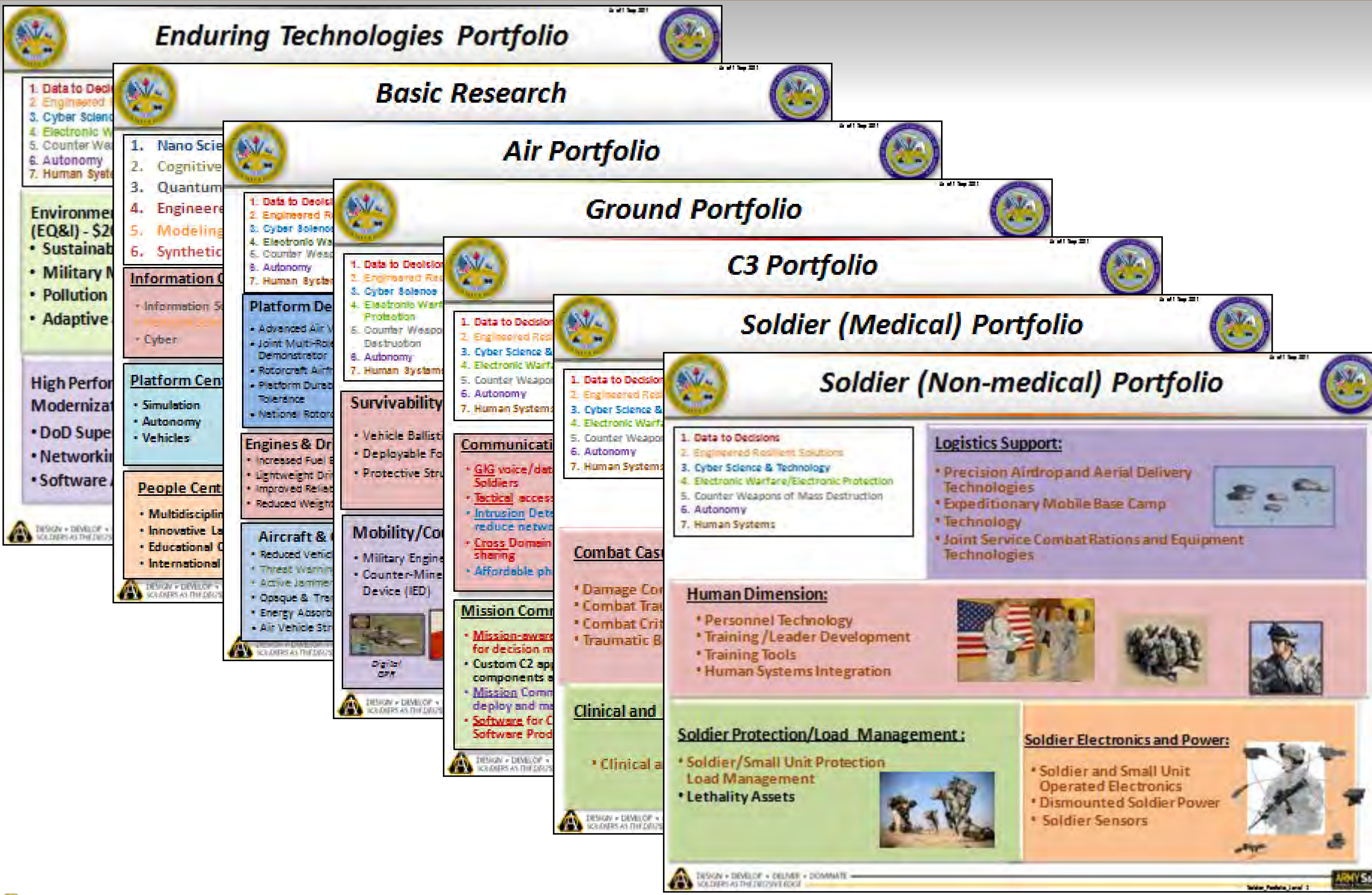
Highly Skilled, Motivated Workforce that Exemplifies our Core Values

Effective, Efficient, & Adaptable Processes

Government and Public Understanding of Our Value

FY11 focus was on setting conditions for success

S&T Portfolios



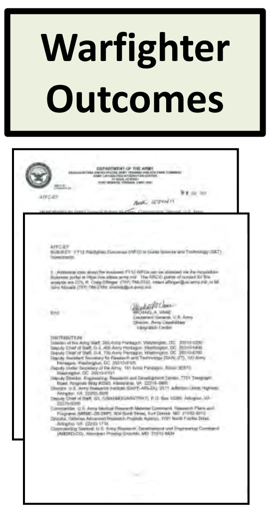
Moving from ATOs to TECDs

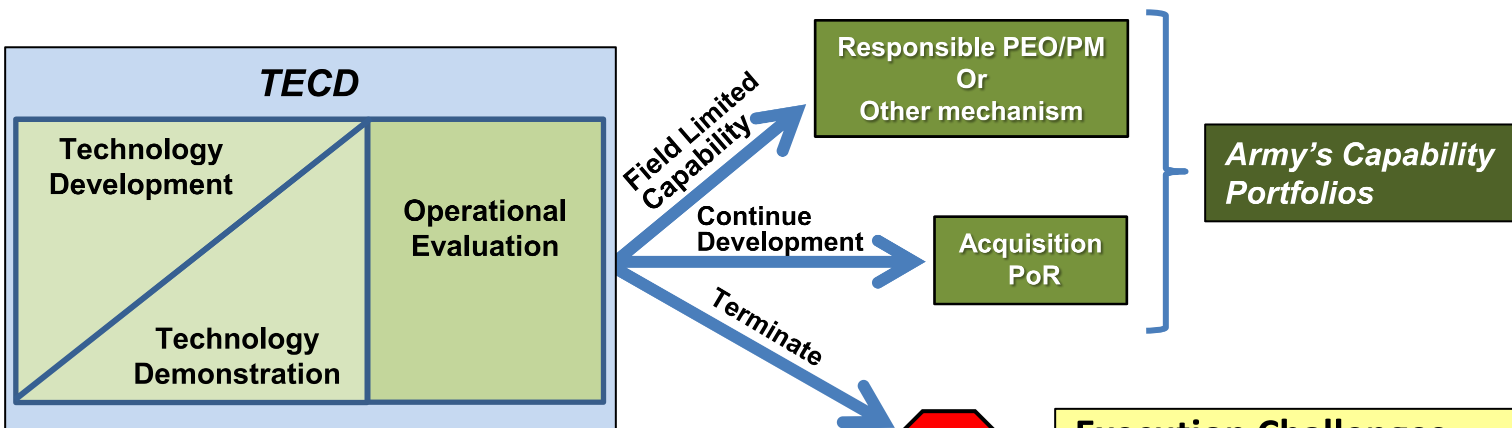
Characteristics of ATOs

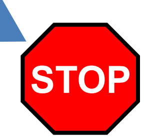
- Three types of ATOs: ATO-R, ATO-D, ATO-M
- Bench-level initiatives generated from the bottom up
- Focused on individual technical objectives, not capabilities
- Mapped to Warfighter Outcomes and *endorsed* early by TRADOC schools
- Needed to be combined after S&T to provide an operational capability
- Difficulty transitioning
- Difficult for Senior leadership to understand the value of individual ATO products

Execution Challenges
- Cooperation
- Transition
- Adaptability/ Responsiveness
- Visibility & Oversight

Characteristics of Technology Enabled Capabilities Demonstration (TECD)







- Integrated programs across all S&T
- Integrated solutions/multiple systems
- Output is a full capability
- High-level oversight, including TRADOC involvement

Execution Challenges
- Cooperation
- Synchronization
- Moving funding
- Program Management

Big Army Problems that S&T Must Help Solve
Current focus: "Soldier as the Decisive Edge"

1. There is insufficient **FORCE PROTECTION** to ensure highest degree of survivability across the spectrum of operations.

2. Soldiers in Small Units (squads/fire teams/crews) are **OVERBURDENED** (physically and cognitively); this degrades performance and may result in immediate, as well as, long term consequences.

3. U.S. Army squads are too often **SURPRISED** in tactical situations. Soldiers in Small Units lack sufficient timely **MISSION COMMAND & TACTICAL INTELLIGENCE** to understand where their assets are, who and where the enemy is, who and where non-combatants are and to document and communicate this information to each other and higher echelons.

4. We spend too much time and money on **STORING**, **TRANSPORTING**, **DISTRIBUTING** and **WASTE HANDLING** of consumables (water, fuel, power, ammo and food) to field elements, creating exposure risks and opportunities for operational disruption.

5. Soldiers in Small Units have limited capability to integrate maneuver and fires in all environments to create **TACTICAL OVERMATCH** necessary to achieve mission objectives.

6. Operational **MANEUVERABILITY** (dismounted & mounted) is difficult to achieve in complex, austere, and harsh terrains and at high OPTEMPO.

7. We do not understand **WHAT MAKES THE HUMAN TICK** in a way that can lead to assured ability to perform operational, high OPTEMPO missions effectively and without secondary negative effects.

Problems listed in no particular order—validated by Senior Army Leadership

24 Army S&T Challenges

	Challenge #	Challenge Title
Top 5	1b	Force Protection – Soldier & Small Unit
	1c	Force Protection – Occupant Centric Platform
	2a	Overburdened – Physical Burden
	3a	Surprise/Tactical Intelligence – Mission Command
	7d	Human – Medical Assessment & Treatment
Next 5	1a	Force Protection – Basing
	7b	Human – Individual Training to Tactical Tasks
	3b	Surprise/Tactical Intelligence – Actionable Intelligence
	4a	Sustainability/Logistics – Basing
	4b	Sustainability/Logistics – Transport, Distribute & Dispose
Remaining 14	1d	Force Protection – On the Move (Ground)
	2b	Overburdened – Cognitive Burden
	3c	Surprise/Tactical Intelligence – Cultural / Linguistic
	3d	Surprise/Tactical Intelligence – Organic Combat ID
	3e	Surprise/Tactical Intelligence – Overwatch Persistent Surveillance
	3f	Surprise/Tactical Intelligence – METT-TC Data/Information/Knowledge
	3g	Surprise/Tactical Intelligence – Network
	5a	Tactical Overmatch – Deliver Decisive Effects
	5b	Tactical Overmatch – Targeting/Hand-off
	6a	Maneuverability – On the Move (Air)
	6b	Maneuverability – Degraded Visual Environment (brown-out)
	7a	Human – Strength-based Soldier Characteristic Assessments & Readiness
	7c	Human – Collective Training for Tactical Operations
	7e	Human – Trauma Management

Force Protection – Soldier and Small Unit

1.b Top 5

<u>Problem Statement</u>: The spectrum of threats encountered by Soldiers in Small Units is varied and complex; current equipment, clothing, and other protective measures do not provide adequate protection without adding significant mobility challenges.

<u>Challenge</u>: Formulate a S&T program to increase the level of individual protection for male and female Soldiers at reduced total weight and volume while enabling increased physical and mental agility, particularly over extended periods. The goal is to reduce the number and severity of injuries and casualties (including TBI and PTSD causes).

<u>Challenge Boundary Conditions</u>:

Who: Individual Soldiers

What: Develop technologies to increase protective gear performance while reducing weight and volume – protection from weapon threats, blast, fire, insect-borne diseases, weather conditions including excessive heat/cold, and CB threats.

How: Establish baselines 2010/2011 field collection data, injury, and use other data sources to clearly define the focus.

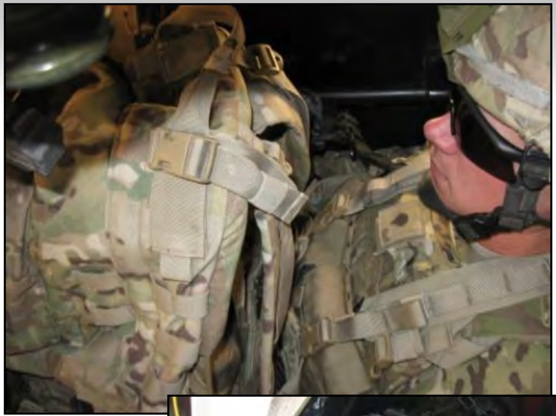
<u>Objectives</u>:

Near term (FY17): Identify trade space to enable holistic protection design and implementation on the individual Soldier and in Small Unit; optimize level and area of protection against threats while reducing total weight of individual protective gear/equipment by 50% and total volume by 30% from baseline; improve clothing, helmet, MOPP gear, fire retardancy, insect repellant, etc.

Force Protection – Occupant Centric Platform

1.c Top 5

Problem Statement: We design vehicles to put Soldiers in rather than designing vehicles around Soldiers. Increasing protection levels of the platforms impacts interior volumes reducing mobility, maneuverability, and freedom of movement for occupants and leads to heavier platforms.



Challenge: Formulate a S&T program to make improvements to existing platforms or develop new platforms that provide appropriate increased protection from current and emerging threats and optimal space allocation for Soldiers and their gear, while decreasing platform weight and maintaining or increasing maneuverability during full spectrum operations. Goal is to reduce overall platform weight by 25% and reduce casualties and WIAs by 50% across each mission role with scalable protection levels to defeat a wide range of threats, enhance mobility, and maintain freedom of action during full spectrum operations.

Challenge Boundary Conditions:

Who: TBD – for Small Unit transport and convoys

What: TBD – specify mission, vignettes, scenarios, conditions of the 2011 representative baseline

How: Establish baselines using 2010/2011 field collection data, injury, and other data sources.

Objectives:

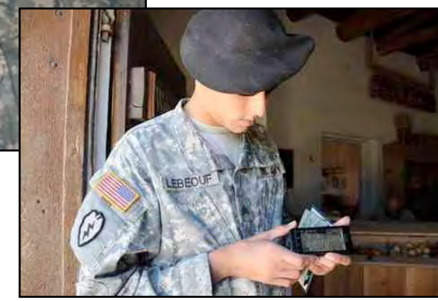
Near term (FY17): Establish baselines; develop occupant protective standards; mature interior and exterior occupant protection technologies; increase lab testing capability; improve confidence in M&S predictions

Surprise/Tactical Intelligence – Mission Command

3.a Top 5

Problem Statement: The Small Unit lacks tools and ability to execute mission command on the move (air or ground) to synchronize action, seize the initiative and maintain situational awareness.

Challenge : Formulate a S&T program to provide an integrated data structure for intelligence and mission command systems that can feed automated processing and analysis tools to reduce time to decision; provide interactive tools to provide relevant, timely information to support decisions; and reduce the timeline needed to develop, accredit and field intuitive, useful, effective mission command and battlefield awareness software applications.



Challenge Boundary Conditions:

Who: Small Units operating in decentralized locations

What: Focus on TOC/COIST capability

How: Assess consolidation of Intel and Battle command decision support and analysis tools by 2015 to inform and shape Science and Technology to shorten/improve the decision cycle to figure out HOW to measure success.

Objectives:

Near term (FY17): Identify how to reduce development time for BFA software applications to 6 months, for all environments,

Overburdened – Physical Burden

2.a Top 5

Problem Statement: Soldiers in Small Units (squads/fire teams/crews) are physically overburdened, often carrying up to 130lbs; this degrades performance and may result in immediate, as well as, long term consequences.

Challenge: Formulate a S&T program to significantly reduce the weight and volume of all items that individual Soldiers in a Small Unit must physically carry to accomplish their missions while maintaining or increasing the ability of the Unit to perform tasks, whether operating as dismounted or in vehicles.

Challenge Boundary Conditions:

Who: Soldiers and Small Units operating in Afghanistan-like environments

What: Reduce physical burden within the squad so that no individual Soldier load exceeds 30% of their body weight.

How: Establish 2011 baseline for various operations and for Afghanistan-like engagement conditions. Measure impact on load (weight, volume, cube) relative to Soldier's body weight and related impacts on Small Units distribution/supply handling against baseline

Objectives:

Near term (FY17): Reduce physical burden of Soldier and Small Unit so that grenadier, SAW gunner and attached combat medic does not exceed 50% of individual's body weight without a reduction in operational capability.

Human – Medical Assessment and Treatment

7.d Top 5

Problem Statement: Traumatic brain injury (TBI) continues to be a significant issue due to IEDs and other hazards. The Army medical community is not able to promptly assess, diagnose, treat and rehabilitate Soldiers who have been exposed to ballistic and blast events or other insults.

Challenge: Formulate a S&T program to rapidly conduct in-the -field screening, assessment and mitigating treatment to improve short and long term adverse outcomes of mTBI and TBI.

Challenge Boundary Conditions:

Who: Individual Soldier and combat medic

What: Selected Operational Mission Scenarios

How: Measure the number of Soldiers correctly identified and diagnosed with mTBI/TBI without significant false positives; reduce number of evacuations due to suspected against 2011 baseline

Objectives:

Near term (FY17): Develop tools that accurately and objectively assess Soldiers with mild to moderate TBI in less than 1 hour following Soldier's return to COP/PD without increasing personnel or administrative burden.

Force Protection - Basing

1.a Next 5

Problem Statement: It takes too long and too much manpower to deploy, set up, protect, sustain and relocate Combat Outposts (COPs) and Patrol Bases (PBs).

Challenge: Formulate a S&T program to reduce the percentage of Soldiers needed to set-up a COP/PB and protect against threats (including small arms, indirect fires, air delivered weapons, and CBRNE) in austere, restricted terrains.

Challenge Boundary Conditions:

Who: Focus on Combat Outposts and Patrol Bases in Afghanistan-like conditions

What: Representative 2011 COP/PBs baseline indicates that it takes 60-90 days using 70% of the manpower assets (i.e., 70% not available for mission tasks)

How: Measure impact on Soldier availability and set-up time

Objectives:

Near term (FY17): Increase Soldier availability for mission tasks vs. set-up and security tasks to 50% in 30 days with increased force protection; decrease tear-down time to no more than 4 days and increase the percentage of material reusable at next COP within 100 miles.

Human –
Individual Training to Tactical Tasks

7.b Next 5

Problem Statement: The Soldier today has a larger number and more complex weapons, protective systems and communications devices with which to perform more complex missions. The Army needs a highly adaptable, versatile, easy-to-access learner –centric system of training skills and tasks that is tailored to the individual's developmental needs through timing, content, delivery, and duration.

Challenge: Formulate a S&T program to develop self-training mechanisms which can supplement or replace trainers to monitor and track Soldier learning needs, assess and diagnose problems, and guide Soldiers through training events, provide effective performance feedback, select appropriate instructional strategies, anticipate and seek out information and learning content tailored to the learner's needs, and provide interventions of other assistance as needed.

Challenge Boundary Conditions:

Who: Selected specific tasks (vehicle driving, maintenance mechanic, weapon operations)

What: Baseline of FY11 learning tools and methods of instruction

How: Measures of Soldier comprehension, retention and skill proficiency; determine how this changes requirements for frequency of training/retraining.

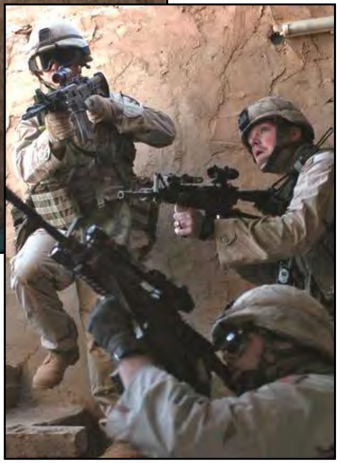
Objectives:

Near term (FY17): Develop more effective fieldable simulators and apps-based training modules for key skills and tasks that can be used whenever and wherever Soldiers need to be trained/retrained/certified; develop a mechanism to automatically collect and document proficiency levels that are accessible to leaders.

Surprise/Tactical Intelligence – Actionable Intelligence

3.b Next 5

Problem Statement: Small Units do not have capability to send/receive critical tactical intelligence; the tools or training to help them recognize/identify friends or foes, to know where IEDs are, to see inside buildings and around corners or over hills; or awareness of cultural patterns that might indicate imminent danger.



Challenge: Formulate a S&T program to provide Small Units with tools and training to efficiently collect, process, exploit, and disseminate data to support situational awareness and decision making without adding more Soldiers or significantly increasing weight or number of devices.

Challenge Boundary Conditions:

Who: Small Units operating COIN/Stability Operations in Afghanistan-like conditions

What: Goal is to provide the ground unit a common operational picture in real time to identify friendly forces in a given AO with 90% accuracy and maintain 90% probability of determining threat interdiction.

How: Measure reduction in unanticipated threat encounters, reduction in loss of equipment and loss of life (friendly/non-combatant) against 2011 baseline.

Objectives:

Near term (FY17): Provide timely accurate/actionable info/intel to obtain in 25% reduction in unanticipated threat encounters at the squad level and increase mission accomplishment (%) measured against loss of life and equipment by 50%

Sustainability/Logistics – Basing

4.a Next 5

Problem Statement: The Army needs improved capability to enable sustainment independence/“self-sufficiency” and to reduce sustainment demands at expeditionary basing levels. It is too costly, too unpredictable, and too labor intensive for a Small Unit to carry all required consumables to last for weeks or months at a COP/PB, storage facilities and systems do not meet needs of these small bases, and resupply efforts are highly unpredictable.

Challenge: Formulate a S&T program to increase self-sufficiency, reduce supply demands, and reduce waste at COPs/PBs and improve the ability to sustain the Small Unit for the duration of the mission at lower cost and lower risk to suppliers without adversely impacting primary mission Soldier availability.

Challenge Boundary Conditions:

Who: Small Units in Afghanistan-like environments

What: Identify tools, tactics, and techniques to achieve demand reduction.

How: Measure demands for power, water and fuel; waste generated and/or waste-to-energy power; weight/volume of food; time to resupply.

Objectives:

Near term (FY17): reduce need for fuel resupply by 20%, reduce need for water resupply by 75% and decrease waste by XX% while increasing quality of life over 2011 COPs/PBs in Afghanistan

Sustainability/Logistics – Transport, Distribute & Dispose

4.b Next 5

Problem Statement: The Army needs improved capability to tactically transport and reliably deliver consumables to Forward Operating Bases (FOBs) and smaller satellite bases in remote, dispersed, austere locations with reduced supplier and equipment risk, including improved efficient and safe methods for disposing waste.

Challenge: Formulate a S&T program to leverage all available conveyance modes to ensure supply delivery, to increase the reliability and timeliness of supplies delivery, and to be able to predict when and where all classes of supplies will be needed. In addition, the program will devise methods to reduce waste and use it to provide power.

Challenge Boundary Conditions:

Who: For Forward Operating Bases with applications to expeditionary bases (Small Units in COPs and PBs)

What: Rapidly deliver significant quantities (volume, weight, etc) of supplies. Air drop and convoy operations - develop ability to conduct rapid movement of emergency, planned, or critical logistics support that enables precise delivery of supplies and repair parts to forward battlefield locations, medical evacuation operations and relief operations

How: Representative 2011 Afghanistan-like environment baseline

Objectives:

Near term (FY17): Develop tools that efficiently manage, track, redirect, account for and distribute supplies to support forced entry, early entry, and non-contiguous operations

New S&T Investment Strategy

Studies, Tech Planning Activities

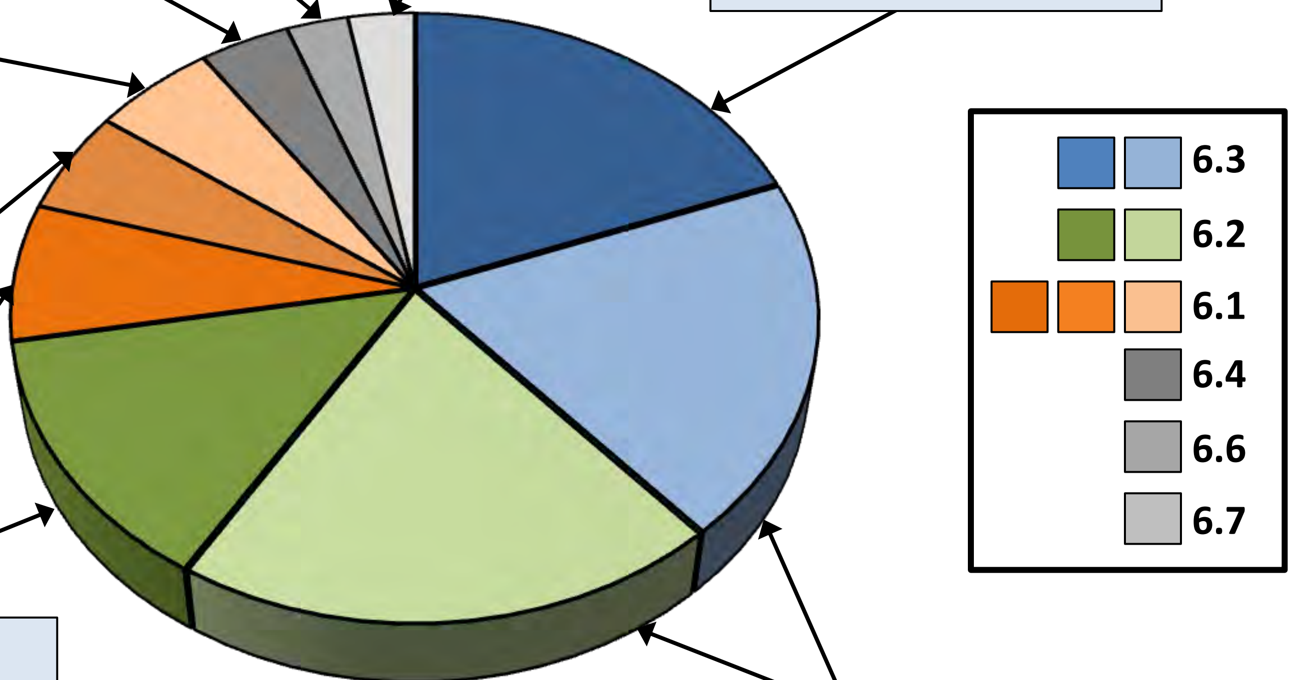
Manufacturing Technology

TECDs—Near-term integrated capability demonstrations—predominately 6.3, may have some 6.2

Competitive prototyping Greater than TRL6

Long Term Exploration Invention, discovery, future gazing, technology trends

Long-term Game-Changing (Disruptive) Technology



Long-term Enabling Technology Development—Innovation, invention, technology exploitation to create sub-system opportunities

Mid-term—Innovation*, maturation, technology demonstration; reducing technological risk; predominately supporting planned Programs of Record

* Includes Rapid Innovation Funding

Defense Contractors with IRAD Investments
(how can you play?)

- We are interested in learning about your Industry IRAD efforts if you believe they are relevant to our solution set
- We offer you an opportunity to come talk with us about these efforts and how you can contribute to solutions for high priority challenges.
- We look forward to fostering opportunities to collaborate/partner with to develop concrete S&T programs to address Army capability challenges
- As appropriate, we will also provide opportunities for you to meet with our Portfolio Managers

Small Business and don't have IRAD
(how can you play?)

- **We are interested in learning about your technologies if you believe they are relevant to our solution set**
- **We offer Small Business priority consideration for participation in the Army Rapid Innovation Fund**
- **We look forward to fostering opportunities to collaborate/partner with you to develop concrete S&T programs to address Army capability challenges**
- **As appropriate, we will also provide opportunities for you to meet with our Portfolio Managers**

In addition to the Small Business Innovative Research program

Opportunities

- **Army Rapid Innovation Fund (RIF)**
  - Status
    - BAA released the September 30
  - Guidelines
    - Executed under Broad Agency Announcements for candidate proposals in direct support of major acquisition and priority programs
    - The total amount of funding provided to any project under the program shall not exceed $3,000,000, unless the Secretary, or the Secretary's designee, approves a larger amount of funding for the project.
    - No project shall be funded under the program for more than two years, unless the Secretary, or the Secretary's designee, approves funding for any additional year.
    - Selection criteria includes:
      - Meeting Army Top 10 Challenge areas
      - Meeting critical national security needs
      - Reduced acquisition or life cycle costs
      - Likelihood of fielding within 3 years
      - Clarity of goals and metrics
      - Innovation

If you are in Academia
(how can you play?)

- **We are interested in learning about your technologies if you believe they are relevant to our solution set**
- **We offer you an opportunity to participate independently or as a team member in the Rapid Innovation Fund**
- **We look forward to fostering opportunities to collaborate/partner with you to develop concrete S&T programs to address Army capability challenges**
- **As appropriate, we will also provide opportunities for you to meet with our Portfolio Managers**

Contact info

Office of the Assistant Secretary of the Army
(Acquisition, Logistics and Technology)

Army Research & Technology

asaaltaie.wordpress.com | **ArmyIndustry@conus.army.mil**

Army Science & Technology

Providing Soldiers Technology Enabled Capabilities

ARMY S&T
SCIENCE & TECHNOLOGY

Backup

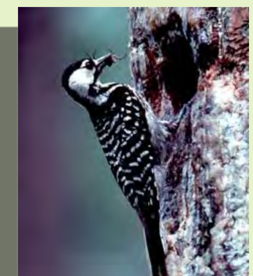
Enduring Technologies Portfolio

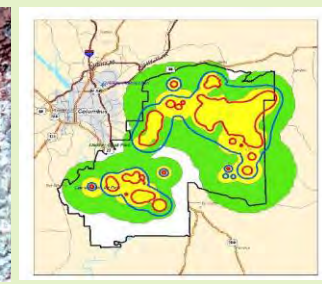
1. Data to Decisions
2. Engineered Resilient Solutions
3. Cyber Science & Technology
4. Electronic Warfare/Electronic Protection
5. Counter Weapons of Mass Destruction
6. Autonomy
7. Human Systems

Environmental Quality & Installations (EQ&I)

- Sustainable Ranges and Lands
- Military Materials in the Environment
- Pollution Prevention
- Adaptive and Resilient Installations


Pyrotechnic Simulator


Endangered Species

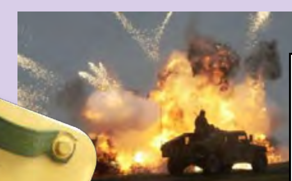

Noise Assessment Model Output

High Performance Computing Modernization Program (HPCMP)

Supports PSC Areas

- DoD Supercomputing Resource Centers
- Networking
- Software Applications


FRAG6 and MRAP


Vehicle Blast


CH47 Advanced Rotor Assessment

*does not include procurement $

Basic Research

1. Nano Science and Engineering
2. Cognitive Neuroscience
3. Quantum Systems
4. Engineered Materials
5. Modeling of Human Behavior
6. Synthetic Biology

Human Centric

- Life Science
- Cultural and Behavioral
- Training
- Neuroscience
- Medical

Information Centric:

- Information Science
- Network Science
- Cyber

Platform Centric:

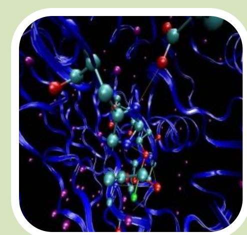
- Simulation
- Autonomy
- Vehicles

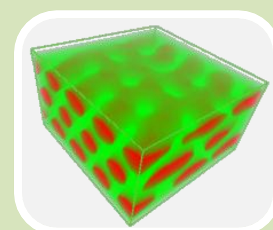
People Centric:

- Multidisciplinary Research Initiatives
- Innovative Lab Research
- Educational Outreach Activities
- International Technology Watch

Material Centric:

- Environmental, Chemical, Physics, Electronics, Photonics, Mechanical, Materials, and Quantum Sciences
- Materials Modeling
- Biotechnology
- Nanotechnology
- Environmental





Air Portfolio

1. Data to Decisions
2. Engineered Resilient Solutions
3. Cyber Science & Technology
4. Electronic Warfare/Electronic Protection
5. Counter Weapons of Mass Destruction
6. Autonomy
7. Human Systems

Maintainability & Sustainability

- Reduced Maintenance Actions
- Improved Reliability
- Improved Mission Readiness
- Reduced Spares Logistics

Platform Design & Structures

- Advanced Air Vehicle System Concepts
- Joint Multi-Role Technology Demonstrator
- Rotorcraft Airframe Technology
- Platform Durability and Damage Tolerance
- National Rotorcraft Technology Center

Rotors & Vehicle Management

- Improved Vehicle Performance
- Reduced Vibrations
- Reduced Acoustic Signature
- Adaptive Vehicle Management

Engines & Drive Trains

- Increased Fuel Efficiency Engines
- Lightweight Drive Trains
- Improved Reliability and Durability
- Reduced Weight/Vibration

Aircraft Weapons & Sensors

- Aviation Weapons and Integration
- Pilotage Sensors and Displays

Aircraft & Occupant Survivability

- Reduced Vehicle Signatures
- Threat Warning Sensors
- Active Jammers & Decoys
- Opaque & Transparent Armor
- Energy Absorbing Seats & Landing Gear
- Air Vehicle Structures & Dynamics Technology

Unmanned & Optionally Manned Systems

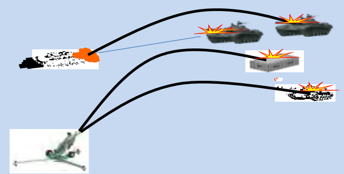
- Common Human Machine Interface
- Sensor Payloads
- Increased Levels of Autonomy
- Manned-Unmanned Intelligent Teaming

Ground Portfolio

1. Data to Decisions
2. Engineered Resilient Solutions
3. Cyber Science & Technology
4. Electronic Warfare/Electronic Protection
5. Counter Weapons of Mass Destruction
6. Autonomy
7. Human Systems

Weapons

- Fire Support
- Close Combat
- Protective Fires
- High Energy Lasers & High Power Microwaves
- Munitions / Warheads / Enablers



MEMS Inertial Navigation

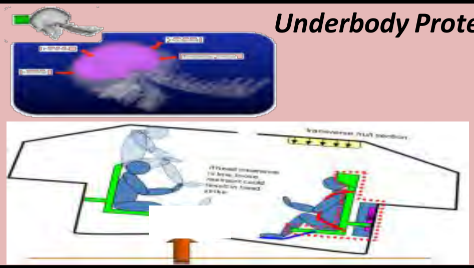
High Energy Laser

Multi-Purpose Warhead

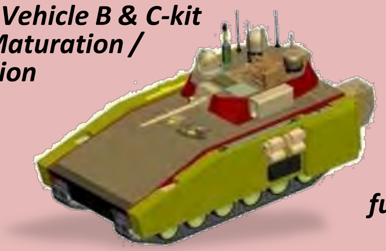
Survivability

- Vehicle Ballistic & Blast Protection
- Deployable Force Protection
- Protective Structures

Underbody Protection



Combat Vehicle B & C-kit Armor Maturation / Integration

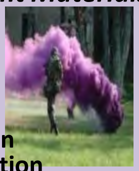


Multi-functional Armor

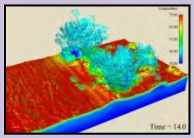
Mobility/Countermobility

- Military Engineering & Obscurants
- Counter-Mine/Improvised Explosive Device (IED)

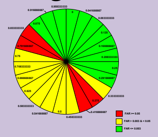
Obscurant Materials



Digital GPR



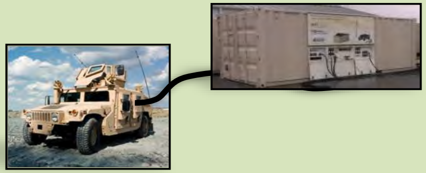
Sensor Scene Generation: Best Times for Target ID



Precision Neutralization

Ground Platforms

- Power & Mobility
- Unmanned Systems
- Logistics



Microgrids

Autonomous Platform Demonstrator

Alternative Fuels

C3 Portfolio

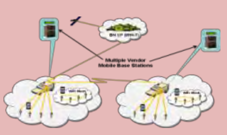
1. Data to Decisions
2. Engineered Resilient Solutions
3. Cyber Science & Technology
4. Electronic Warfare/Electronic Protection
5. Counter Weapons of Mass Destruction
6. Autonomy
7. Human Systems

Intelligence & Electronic Warfare:

- Fusion for timely, accurate SA
- Networked EW assets for simultaneous and autonomous detection, classification, and geo-location of modern emitters/threats in all terrains
- Surgical disruption and/or neutralization of C4ISR nodes and RCIEDs

Communications:

- GIG voice/data connectivity for dismounted Soldiers
- Tactical access to military Smartphone applications
- Intrusion Detection Systems to detect/protect and reduce network downtime from cyber threats
- Cross Domain Solution for bi-directional info sharing
- Affordable phased-array antennas for OTM Satcom

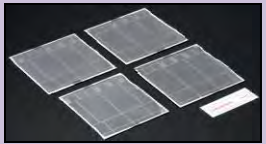


Mission Command:

- Mission-aware data mining and reasoning software agents for decision making and communications utilization
- Custom C2 applications from existing software components and services
- Mission Command software services – able to plan, deploy and manage unmanned missions
- Software for Collaboration Services and Decision Support Software Products

Sensors:

- New growth methods and structures enabling lower cost, large format IR FPAs:
  - Superlattice & Barrier ("nBn") detectors
  - Novel digital readout integrated circuit (ROIC) technology
- Radar technologies for 360 Degree Hemispherical Coverage
- Standoff capability to characterize urban structures



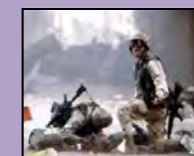
As of 1 Sep 2011

Soldier (Medical) Portfolio

1. Data to Decisions
2. Engineered Resilient Solutions
3. Cyber Science & Technology
4. Electronic Warfare/Electronic Protection
5. Counter Weapons of Mass Destruction
6. Autonomy
7. Human Systems

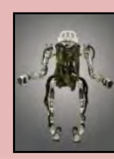
Infectious Disease Research

- Drugs to Prevent/Treat Parasitic Diseases
- Vaccines for Prevention of Malaria
- Viral Threat Research
- Bacterial Threats
- Diagnostics and Disease Transmission Control



Combat Casualty Care:

- Damage Control Resuscitation
- Combat Trauma Therapies
- Combat Critical Care Engineering
- Traumatic Brain Injury



Military Operational Medicine

- Environmental Health and Protection
- Injury Prevention and Reduction
- Psychological Health

Clinical and Rehabilitative Medicine

- Clinical and Rehabilitative Medicine

Soldier (Non-medical) Portfolio

1. Data to Decisions
2. Engineered Resilient Solutions
3. Cyber Science & Technology
4. Electronic Warfare/Electronic Protection
5. Counter Weapons of Mass Destruction
6. Autonomy
7. Human Systems

Logistics Support:

- Precision Airdrop and Aerial Delivery Technologies
- Expeditionary Mobile Base Camp
- Technology
- Joint Service Combat Rations and Equipment Technologies

Human Dimension:

- Personnel Technology
- Training /Leader Development
- Training Tools
- Human Systems Integration

Soldier Protection/Load Management :

- Soldier/Small Unit Protection Load Management
- Lethality Assets

Soldier Electronics and Power:

- Soldier and Small Unit Operated Electronics
- Dismounted Soldier Power
- Soldier Sensors

Disruptive Technologies Conference 2011

Dr. Walter F. Jones

Executive Director

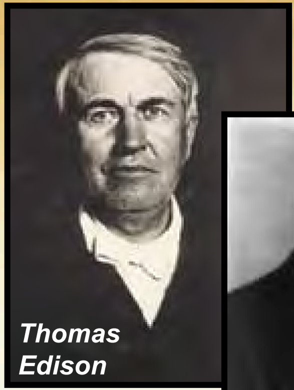
Revolutionary Research . . . Relevant Results

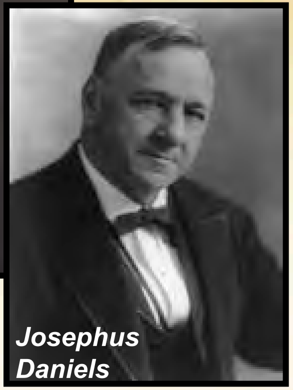
OFFICE OF NAVAL RESEARCH

The Office of Naval Research

Revolutionary Research . . . Relevant Results

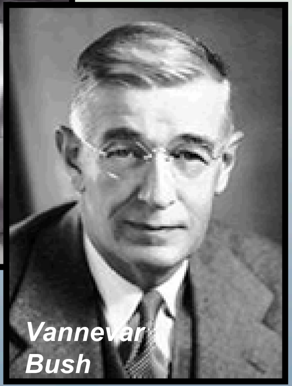
Naval Research Laboratory *(Appropriations Act, 1916)*
"[Conduct] exploratory and research work…necessary …for the benefit of Government service, including the construction, equipment, and operation of a laboratory…."


Thomas Edison


Josephus Daniels

Office of Naval Research *(Public Law 588, 1946)*
"…plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future of naval power, and the preservation of national security…"


Harry S. Truman


Vannevar Bush

Office of Naval Research - London Office *(1946)*
"…reporting on the latest developments and to assist visiting American scientists to make contact with their colleagues in Europe…"

Transitioning S&T *(Defense Authorization Act, 2001)*
"…manage the Navy's basic, applied, and advanced research to foster transition from science and technology to higher levels of research, development, test, and evaluation."

Revolutionary Research . . . Relevant Results

88 Years of Naval Research

Leadership for S&T

RADM Nevin Carr Jr.
Chief of Naval Research

Dr. Walter Jones
Executive Director

BGen Mark R. Wise
Vice CNR

Guidance Comes From…

Assistant Secretary of the Navy (Research, Development and Acquisition)

Vice Chief of Naval Operations

Assistant Commandant for the Marine Corps

Assistant Secretary of Defense for Research & Engineering

Aligning to Strategic Guidance

Revolutionary Research . . . Relevant Results

CNO Priorities

- Build the Future Force
- Maintain Warfighting Readiness
- Develop & Support Our Sailors, Civilians and Families

SECNAV Priorities

- Taking care of our Sailors, Marines, Civilians, and their families
- Treating energy in DON as an issue of national security
- Creating acquisition excellence
- Optimizing unmanned systems

Commandant Guidance

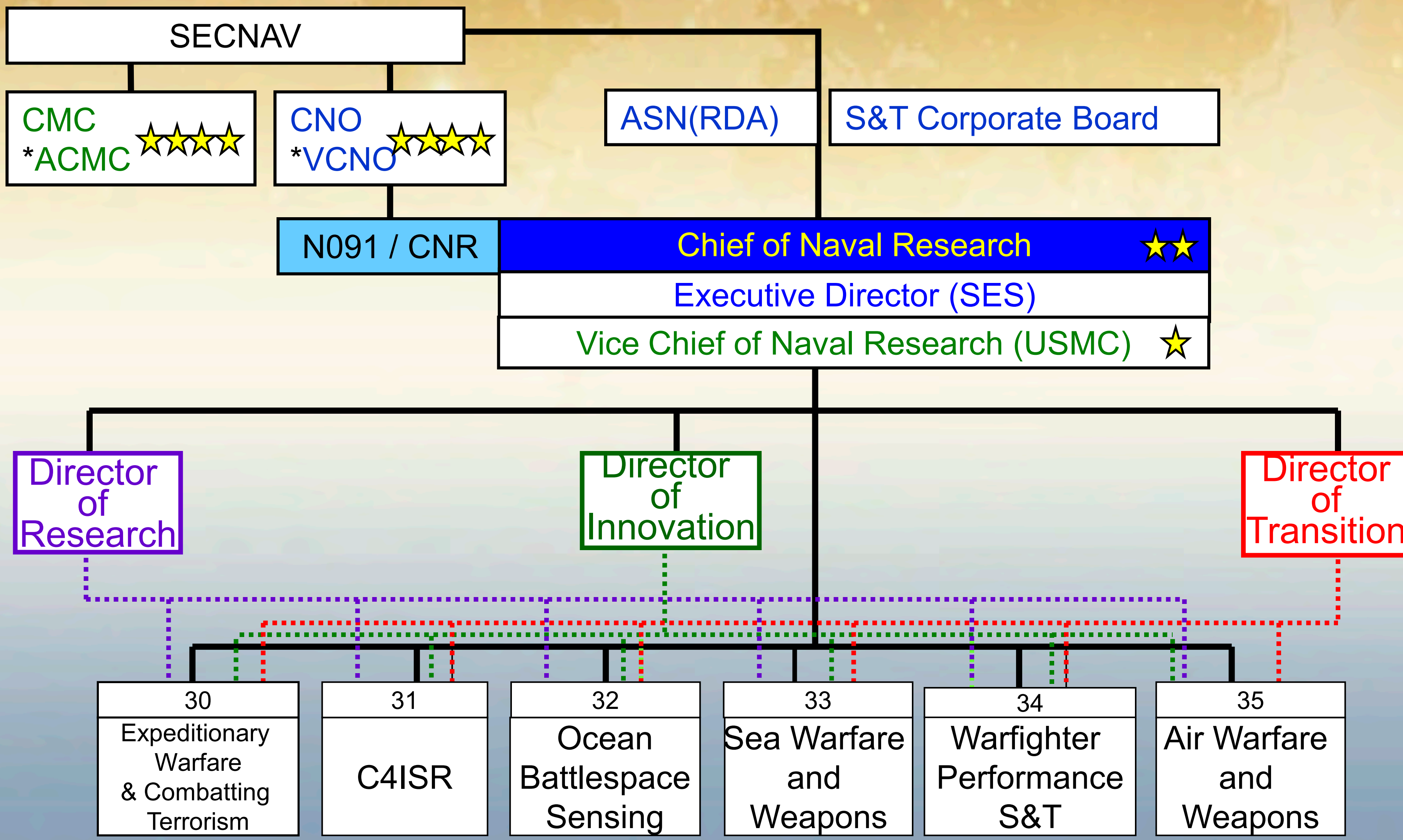
- Provide the best trained and equipped Marines to Afghanistan
- Rebalance USMC for the future
- Better educate and train Marines
- Keep faith with our Marines, Sailors and families

CNR Priorities

- Focus on S&T areas that provide the biggest payoff for our future
- Be innovative in our thinking and business processes
- Improve our ability to transition S&T into acquisition programs
- *Improve strategic communication and engagement with stakeholders*

Office of Naval Research

Revolutionary Research . . . Relevant Results



Unique Structure

- **All three S&T funding lines under one roof**
- **Program Officer can see a program through D&I → Applied Science → Transition**

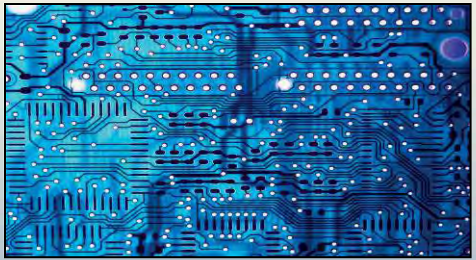
Basic Research
6.1

Applied research
6.2

Advanced Tech Development
6.3

From new materials

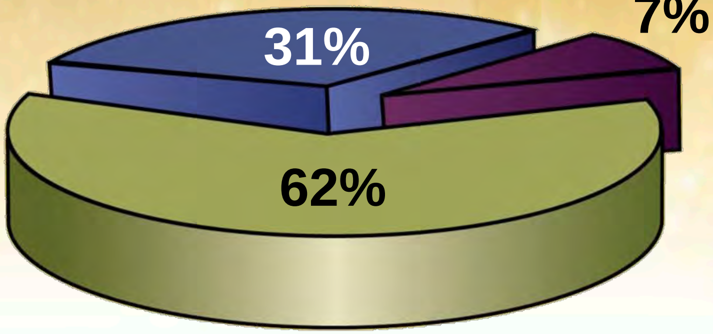
To advanced electronics



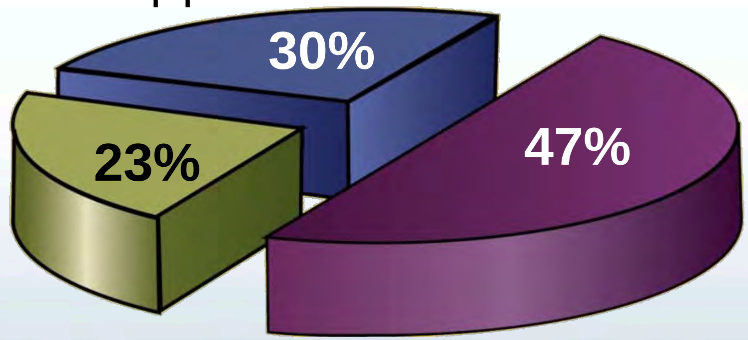
To cutting edge radar

Investment Balance

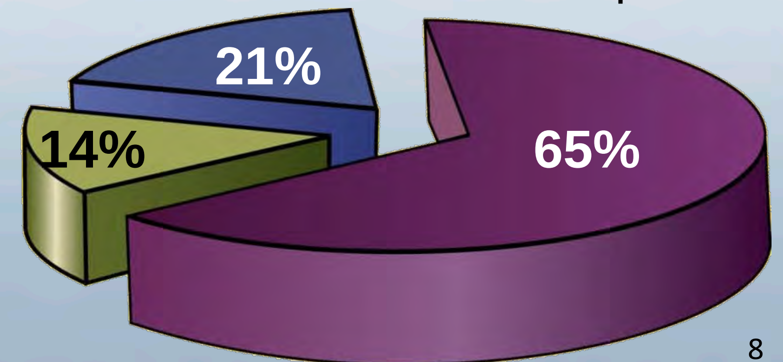
6.1: Basic Research



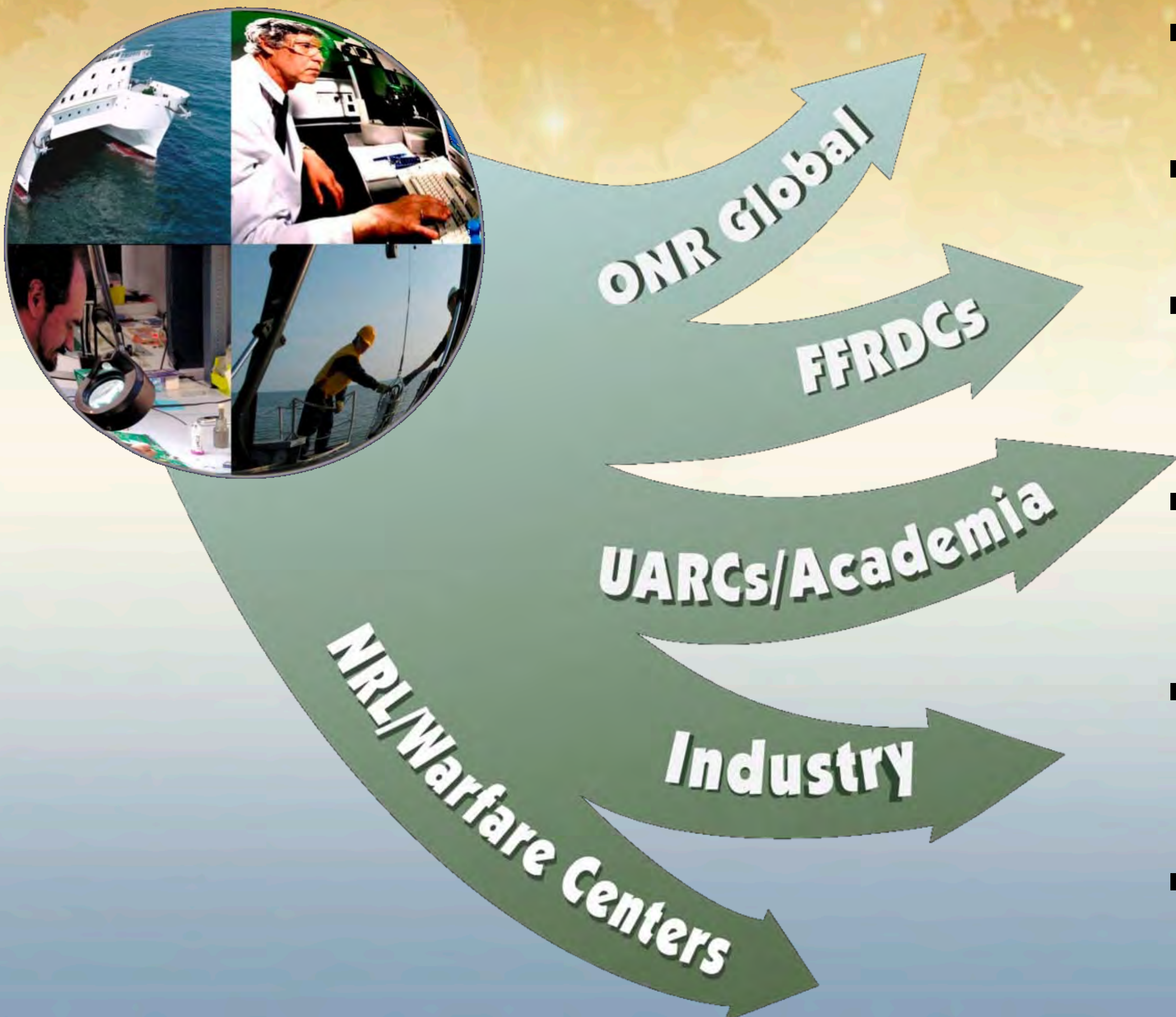
6.2: Applied Research



6.3: Advanced Tech Development

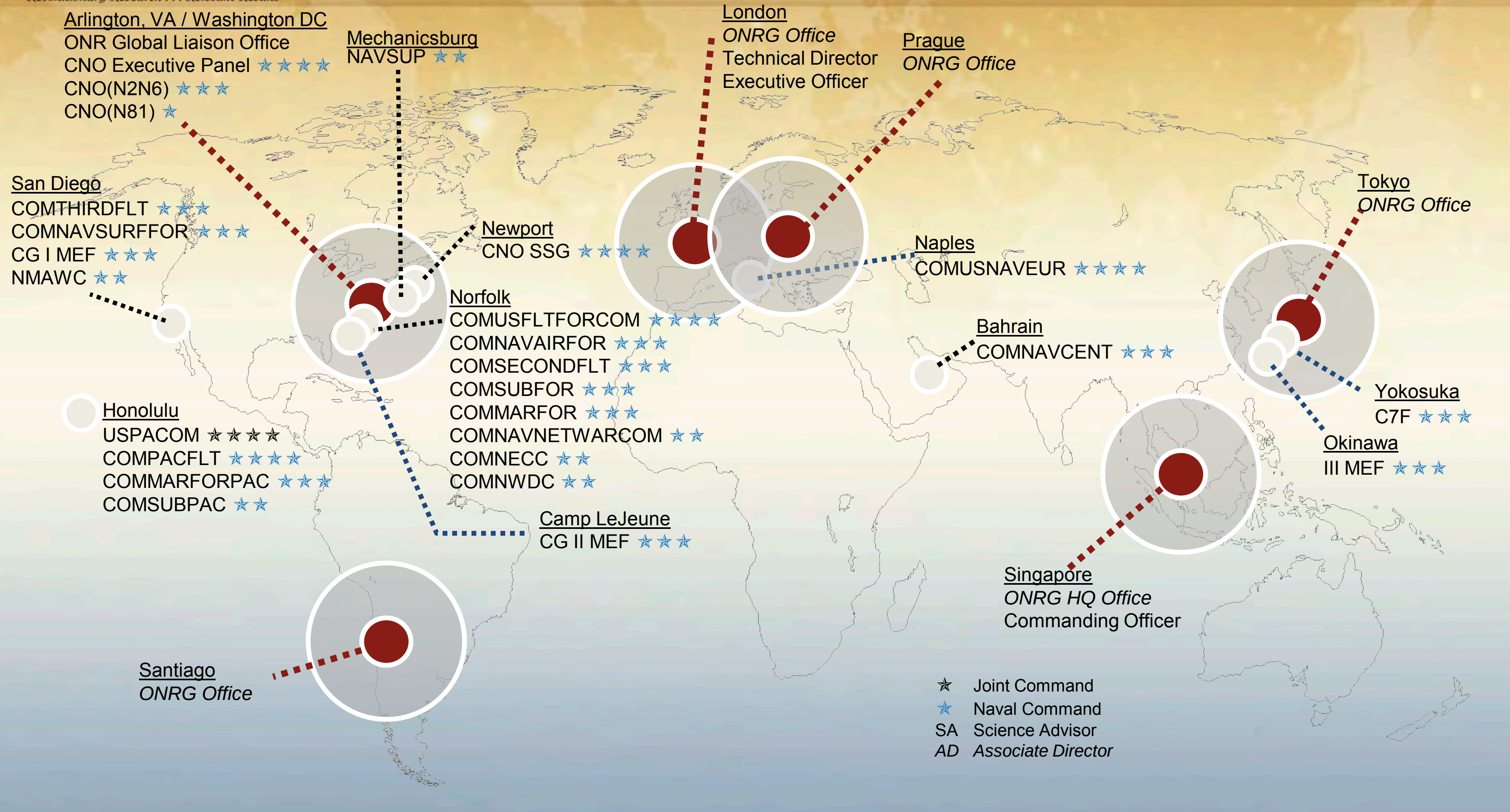


How We Execute



- **30 Countries**
- **50 States**
- **983 Companies**
  - **- 744 small business**
- **412 Universities & Nonprofit Entities**
- **3,340 Principal Investigators**
- **3,000 Grad Students**

ONR Global Footprint



ONR Global is an Echelon 2 Command under the CNR

Naval Science and Technology

Revolutionary Research . . . Relevant Results

"…plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future of naval power, and the preservation of national security…" *(Public Law 588, 1946)*

Focus Areas:

- **Assure Access to Maritime Battlespace**
- **Autonomy & Unmanned Systems**
- **Expeditionary & Irregular Warfare**
- **Information Dominance**
- **Platform Design & Survivability**
- **Power & Energy**
- **Strike & Integrated Defense**
- **Total Ownership Cost**
- **Warfighter Performance**

Science, Technology, Engineering & Math (STEM)

Quick Reaction

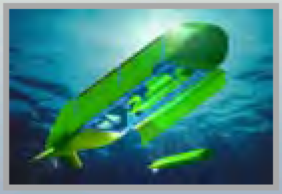
Fleet Driven
Material Solutions

1-2 yrs

Acquisition Enablers

Evolutionary POR
component improvements

3-5 yrs



Leap Ahead Innovations

Disruptive
Technologies

5-7 yrs

Discovery & Invention

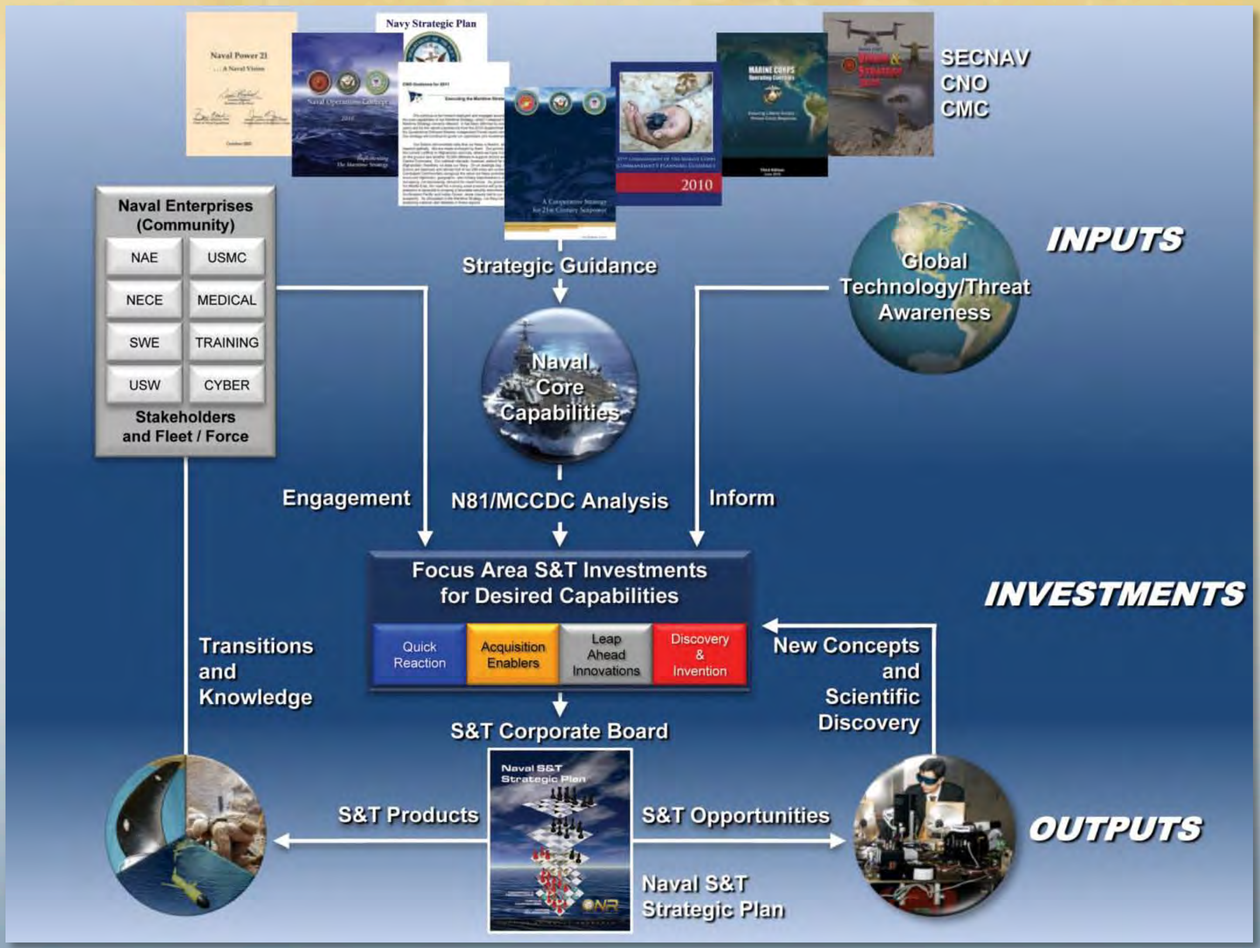
Fundamental Science focused
on naval problems

5-20 yrs

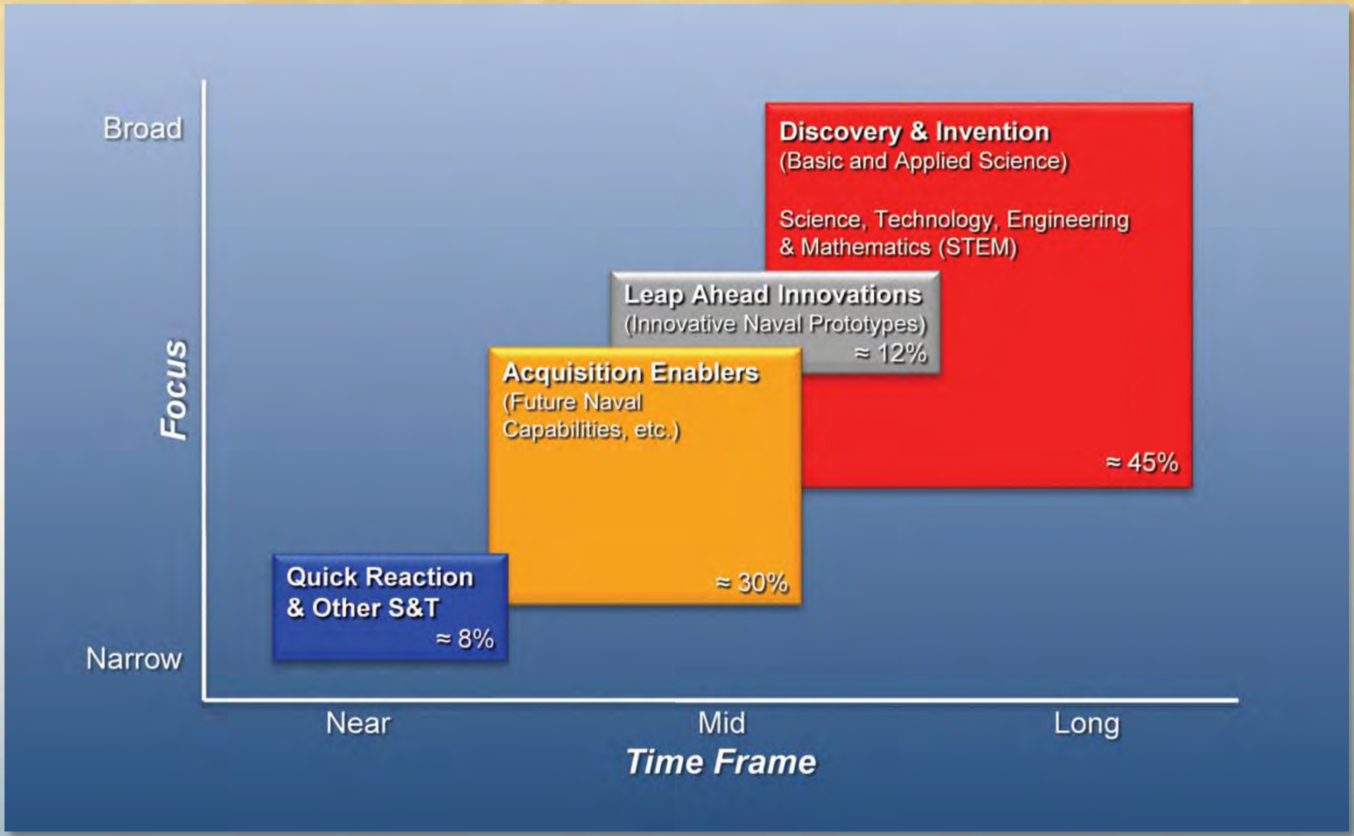
Naval S&T Strategic Plan

- Second update of the original Naval S&T Strategic Plan
- Focused on top-down guidance, informed by fiscal realities of POM13
- Strategic Context – development guided by Cooperative Strategy for the 21st Century, SECNAV Guidance, Naval Strategic Plan, and Vision and Strategy 2025
- Focus Areas consolidated from 13 to 9; includes addition of one new area on Autonomy and Unmanned Systems

Naval S&T Strategic Process



ONR S&T Investment Portfolio



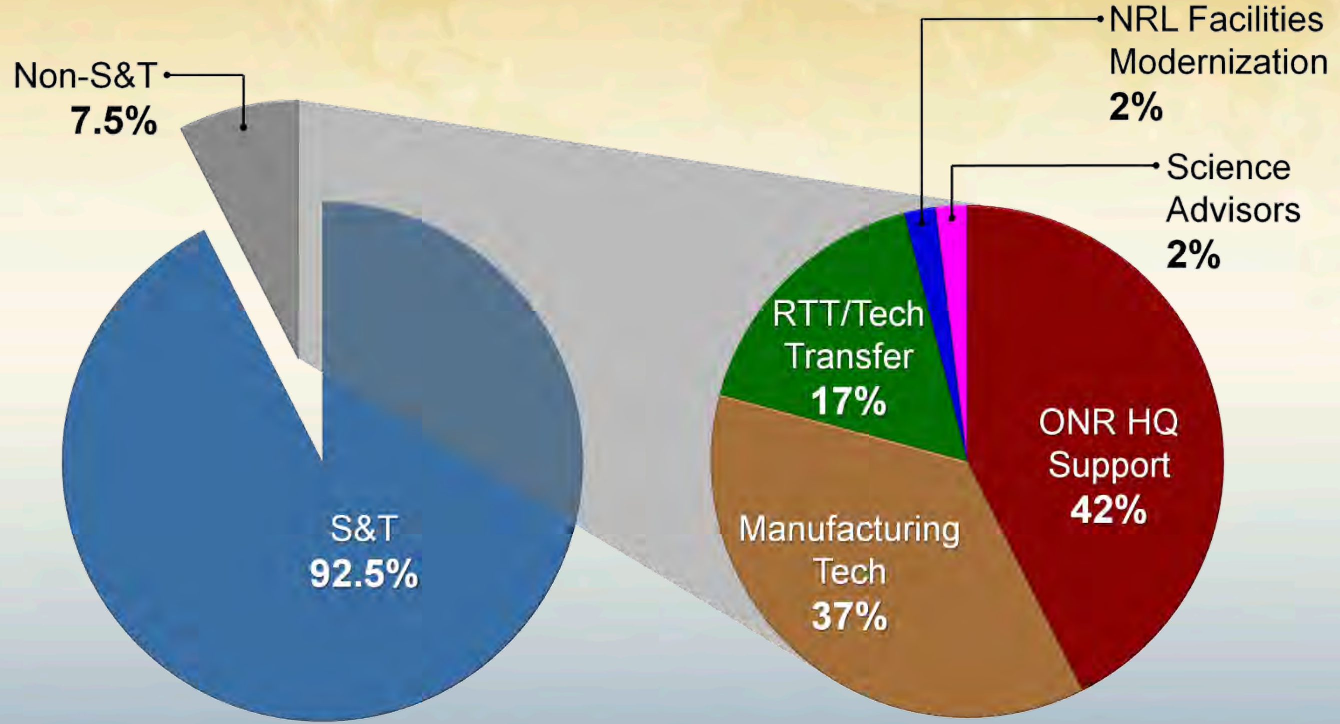
Quick Reaction S&T
- Tech Solutions
- Experimentation
- All MCWL, %JNLW 6.3
- % Code 30 6.3
- RTT, UUNS Response

Acquisition Enablers
- Future Naval Capabilities
- Warfighter Protection
- Capable Manpower
- % LO/CLO
- % Code 30 6.3 /JNLW 6.3

Leap-ahead Innovations
- Innovative Naval Prototypes
- % SwampWorks

Discovery & Invention
- Basic & Early Applied Research
- National Naval Responsibilities
- Education Outreach HBCU/MI

S&T and Non-S&T Investments



ONR Investment Portfolio *ONR Non-S&T Funding*

Naval S&T Focus Areas

STEM is a critical enabler across all Focus Areas

16

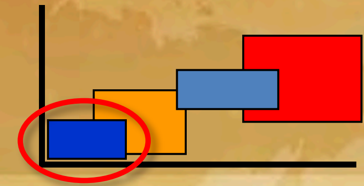
Naval S&T Strategic Plan

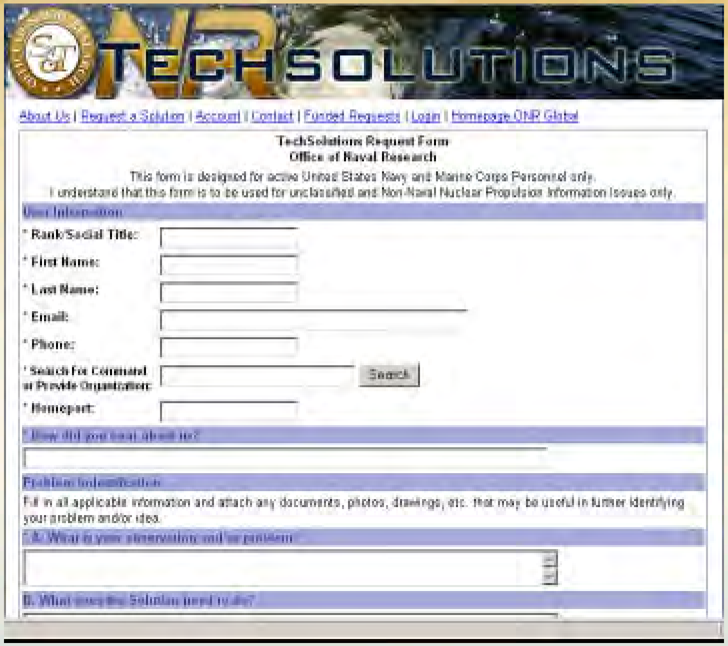
- Addresses DON top down guidance, considers global S&T trends, accounts for future security environments, and includes close and continuous engagement with Enterprises and Stakeholders
- Aligns with articulated long term Naval needs and missions
- Balances broad strategic research topics, high risk disruptive/game changing technologies, prioritized nearer term acquisition enablers via FNCs, and quick reaction efforts
- Communicates the way ahead to decision makers and our partners in industry and academia
- Reduces risk and provides options for acquisition
- S&T Investments over time provide the foundation for the essential capabilities that ensure the continued technological superiority of our Naval Forces

Naval S&T Strategic Plan located at:

www.onr.navy.mil/en/About-ONR/science-technology-strategic-plan.aspx

Quick Reaction S&T





TECHSOLUTIONS

About Us | Request a Solution | Account | Contact | Funded Requests | Login | Homepage ONR Global

TechSolutions Request Form
Office of Naval Research

This form is designed for active United States Navy and Marine Corps Personnel only.
I understand that this form is to be used for unclassified and Non-Naval Nuclear Propulsion Information Issues only.

User Information

* Rank/Social Title:
* First Name:
* Last Name:
* Email:
* Phone:
* Search For Command or Provide Organization: [Search]
* Homeport:

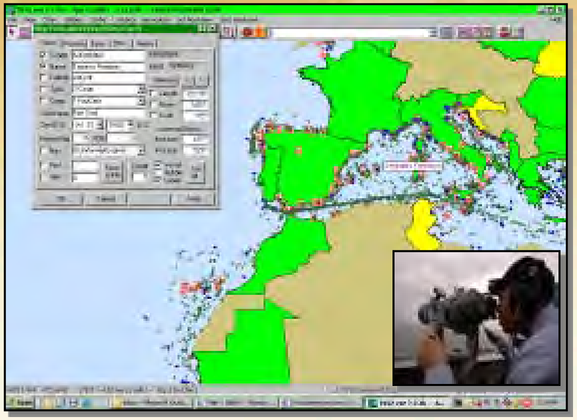
* How did you hear about us?

Problem Identification

Fill in all applicable information and attach any documents, photos, drawings, etc. that may be useful in further identifying your problem and/or idea.

B. What does the Solution need to do?

- Ship Identification
- Solid State Lighting
- HCO Trainer
- Food Service Software
- Automated Weather Prediction system



- **Rapid solutions to problems identified by deckplate Sailors and Marines**
- **1 year turnaround time**
- **Video: www.youtube.com/usnavyresearch**
- **Requests submitted online**
  www.onr.navy.mil/techsolutions

Revolutionary Research . . . Relevant Results

Future Naval Capabilities

(3-5 Year) Component Technologies

Revolutionary Research . . . Relevant Results

Future Naval Capability Program

Initiated in FY02

- Focus S&T Critical Mass on Highest Priority capabilities
- Facilitate Flexible, Responsive, and Consistent Prioritization
- Ensure focused Transition to Acquisition and Naval Forces

Align Requirements, Acquisition, Fleet, and S&T Community

The FNC program is composed of Enabling Capabilities (ECs) that develop and deliver quantifiable products (i.e., prototype systems, knowledge products, and technology improvements) in response to validated requirements (Naval S&T Gaps), approved by Pillar IPTs and the Technology Oversight Group (TOG), for insertion into acquisition programs of record, after meeting agreed upon exit criteria, within five years.

Impact of S&T Investment Increased

Revolutionary Research . . . Relevant Results

Technology Oversight Group

- Co-Chairs: N8 / MCCDC
- Permanent Members: PMD ASN (RDA), DCOM USFF, N091/CNR, N2/N6
- Equity Members: N1, N093, Deputy CNOs and Deputy Commandants

N8F – Executive Secretary

TOG Working Group

- 0-6/GS-15 Level Representatives of Each TOG Member
- Interacts with IPTs and makes recommendations to TOG

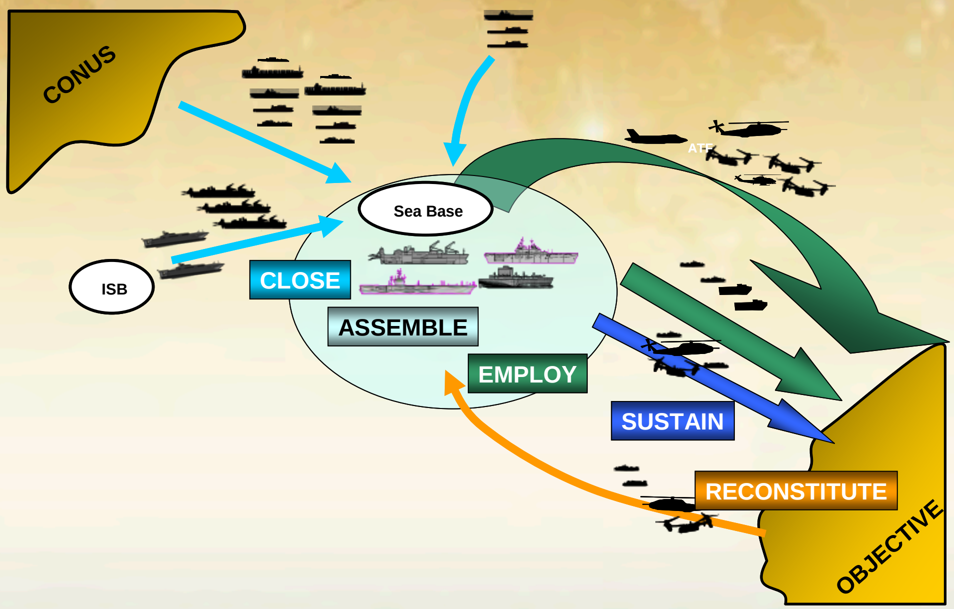
FNC IPTs

Sea Shield	Sea Strike	Naval Expeditionary Maneuver Warfare	Sea Basing	Power & Energy
*17 ECs, $347M	*10 ECs, $197M	*9 ECs, $78M	*4 ECs, $89M	*4ECs, $64M
• OPNAV N86 • MCCDC • USFF N803 • PEO LMW • ONR 32	• OPNAV N87 • HQMC Aviation • USFF N8 • PEO U&W • ONR 35	• OPNAV N85B • HQMC PP&O • USFF N8 • MCSC • ONR 30	• OPNAV N85B • Dep. CG MCCDC • USFF N804 • PEO Ships • ONR 33	• OPNAV N45 • USMC HQ E20 • USFF N8 • NAVSEA 05 • ONR 03T

FORCEnet	Enterprise & Platform Enablers	Force Health Protection	Capable Manpower
*15 ECs, $331M	*12 ECs, $204M	*6 ECs, $71M	*8 ECs,$98M
• OPNAV N6F • Dir HQMC C4 • NETWARCOM • SPAWAR 05 • ONR 31	• OPNAV N8F • HQMC I&L • USFF N433 • NAVSEA 05 • ONR 33	• OPNAV N931 • TMO, USMC • FFC N02H • NMSC • ONR 34	• N15 • USMC Training/Ed. • USFF N1D • NAVAIR TSD • ONR 34

* FY11-15

Example S&T Gap



Gap No. FY13-XX: At Sea Arrival and Assembly, Adaptive Force Packaging.

Operational Need: The joint sea base requires the capability to rapidly receive and assemble forces vessel-to-vessel at sea without reliance on land bases within the Joint Operating Area.

Metrics:

- Assemble an expeditionary brigade-sized force within 72 hours through SS4.
- Ship-to-ship lift of TEUs and equipment (<=30 STONs, 5 moves/hr, SS4) among selected military and commercial shipping.
- Interface and transfer tracked and wheeled equipment, personnel, and logistics
  - between military and commercial shipping and with sea based platforms and surface connectors through SS4.
  - Including ramps with 80 STON capacity.
- Selective offload through SS4.

Technology Transition Programs

DoN Program	Purpose				
	Proposal Accepted Form	Project Duration	Project Funding	Approx. # Projects Funded per Year	Proposals Due to ONR
Rapid Technology Transition (RTT)	Rapidly transition technology into DoN programs of record (PoRs) to meet emergent/urgent Naval Needs.				
	CTOs	Up to 2 years	Up to $2M	15	January
Technology Insertion Program for Savings (TIPS)	Rapidly transition technology from any source into PoRs to significantly reduce operations and support cots.				
	CTOs	Up to 2 years	Up to $2M	6	January
Rapid Development & Deployment (RDD)	Rapidly develops and fields prototype solutions to meet validated urgent operational Naval needs.				
	CNO N8 or CG, MCCDC	Up to 1 year	As required	2	Rolling submission

Navy SBIR/STTR: Delivering R&D To the Warfighter

Revolutionary Research . . . Relevant Results

- **Two main goals of Navy SBIR/STTR Program**:
  - Use small business to develop innovative R&D addressing Navy needs
  - Commercialize that technology into a Navy Platform or Weapon System
- **~$395M in FY2010 funds** - 1,200+ Phase I and II awards
  - Quarterly solicitations (3 SBIR, 1 STTR)
  - 6-month Phase I award typically $150K
  - 2-year Phase II award typically $1M
- **Acquisition driven, technology pull**
  - 283 SBIR/STTR Topics in FY10, over 80% address a specific need from a PEO/PM/FNC (i.e. military application) – list of PEO SBIR POCs found at www.navysbir.com
  - Topics and awards based on PEO/PM/FNC R&D priorities and SBIR/STTR funding
  - Many contracts awarded/monitored by lab employees with Acquisition Office POC involved
  - Dedicated outreach to industry and government through annual Navy Opportunity Forum, seen at www.navyopportunityforum.com
  - Unique concept-based search engine at www.navysbirsearch.com supports efficient mining of Navy SBIR/STTR inventory, other DoD resources

Navy SBIR/STTR: Transitioning Innovation

Revolutionary Research . . . Relevant Results

- **Transition Assistance Program (TAP)**
  - Available to all Navy Phase II companies, provides Business Consultant who helps with DoD customer marketing and Phase III strategies
  - TAP-linked *Navy Opportunity Forum (June 6-8, 2011)* provides annual look at mature Phase II projects, previewed in depth at www.VirtualAcquisitionShowcase.com
- **Commercialization Pilot Program (CPP)**
  - Congressional mandate to align DoD R&D capability with priority warfighter needs
  - 1% of SBIR funds used by Navy for internal transition help to SBIR/STTR firms (no funding to firms)
- **Phase II.5**
  - Provides SBIR funding, above normal < $1M Phase II levels, to firms with high Phase III and insertion potential

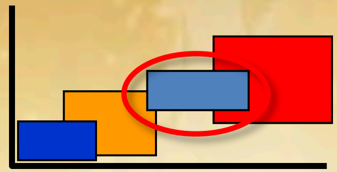
Why is Navy SBIR Successful with Phase III Awards?

- Strong SYSCOM SBIR Offices provide assistance all along the way
- PEO involvement/pull key, as they control much Phase III funding
- Navy engagement with Prime contractors, since they control technology insertion decisions
- Navy SBIR/STTR FY2010 Phase III investment = $565M, more than all other DoD agencies combined

Innovative Naval Prototypes

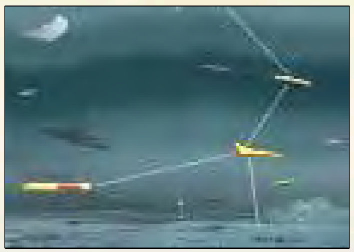
(5-10 Year) Disruptive Technologies

- **High Risk / High Payoff**
- **Innovative and game-changing**
- **Approved by Corporate Board**
- **Delivers prototype**



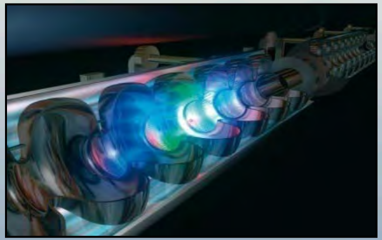
Tactical Satellite

EM Railgun

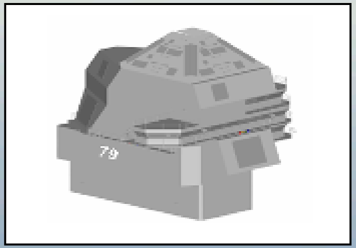


Persistent Littoral Undersea Surveillance

Sea Base Enablers



Free Electron Laser



Integrated Topside

Large Displacement UUV

AACUS

INP Programs

Revolutionary Research . . . Relevant Results

- **Determined by DoN guidance, INPs are funded at ~10% of ONR Total Obligation Authority**
- **Purpose:**
  - Explore high-risk, game-changing technologies and to advance the capabilities of the warfighter
  - Reduce the acquisition risk of disruptive technologies and capabilities
  - Deliver “The Next Big Thing”
- **Approved by VCNO, ASN (RDA) and ACMC**
- **FY10 Innovative Naval Prototypes:**
  - Tactical Satellite (TACSAT)
- **Current Innovative Naval Prototypes:**
  - Persistent Littoral Undersea Surveillance (PLUS)
  - Sea Base Enablers (SBE)
  - Electromagentic Railgun (EMRG)
  - Free Electron Laser (FEL)
  - Integrated Topside (INTOP)
- **FY12 Innovative Naval Prototypes:**
  - Autonomous Aerial Cargo Utility System (AACUS)
  - Large Displacement Underwater Unmanned Vehicle (LDUUV)

Free Electron Laser

Electromagnetic Railgun

INP Business Process

Solicit Ideas from Innovation Community

Ideas Evaluated by Technical Community

Ideas Receive Advocacy from Warfighter Community

Enterprises
SYSCOMS
PEOs
Fleet/Force
Flag/SES

DoN Leadership Prioritizes & Decides *

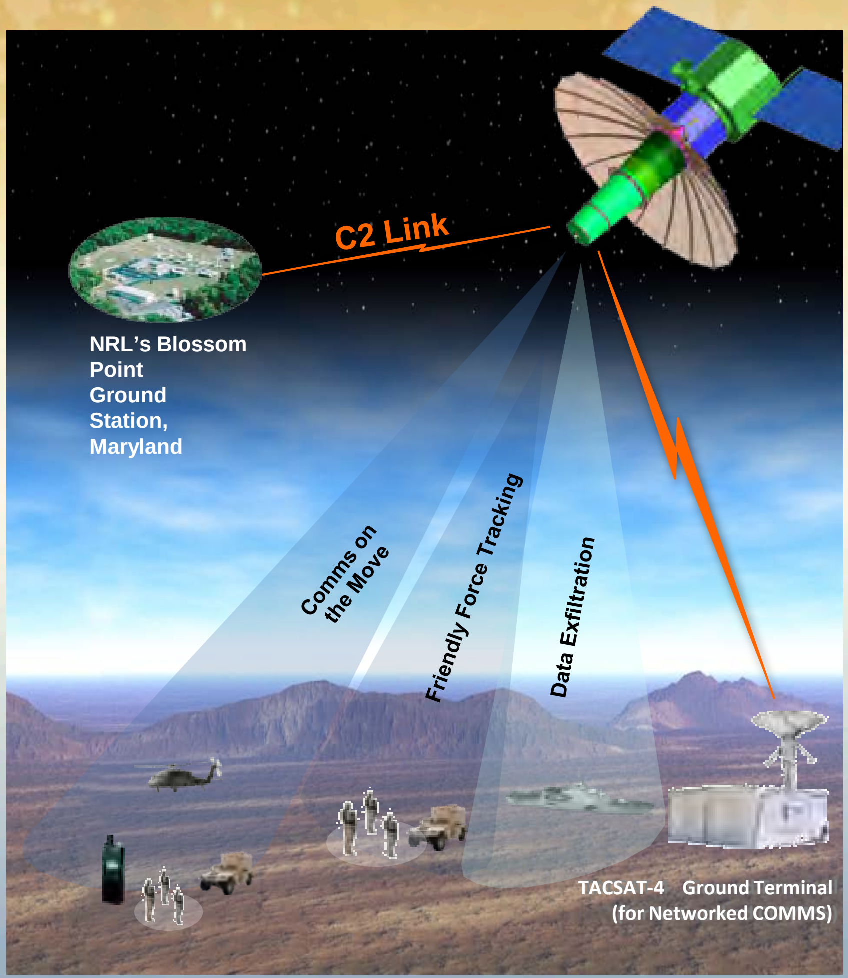
* *CNO Futures Group*
DoN S&T Corporate Board

Tactical Satellite (TACSAT)

Why TACSAT: TACSAT developed payloads to fly on microsatellites demonstrating new technologies to help close existing OPNAV N8 Naval Warfighting gaps. The program does so by using quick and responsive access to space, substantially lowering costs, and providing easy access to the tactical commander

Partnerships: NRL, OPNAV N2 and N6, SPAWAR, DoD's Operationally Responsive Space Office and Office of Force Transformation, STRATCOM, NRO, JHU Applied Physics Laboratory

Why is TACSAT Hard: TACSAT is using unconventional and innovative commercial off the shelf technologies, and providing unprecedented access via SIPRNET through a newly developed Virtual Mission Operations Center



Accomplishments:

- Ocean Data Telemetry Microsatellite Link (ODTM) was launched on TACSAT 3 and STPSat-2 to provide world-wide data exfiltration.
- Ship tracking, cross platform precision geolocation, specific emitter identification, and AIS on TACSAT 2
- Maritime Hyperspectral Imaging of the Coastal Oceans (HICO) and the Remote Atmospheric and Ionospheric Detection System (RAIDS) payloads were installed on the International Space Station

Upcoming Major Milestones:

- TACSAT-4 Spacecraft to be launched May 2011 from Kodiak Alaska to provide Comms on the Move, Friendly Force Tracking, and Data Exfiltration
- Trident Warrior 11 Exercise
- Joint Military Utility Assessment

Electromagnetic Railgun (EMRG)

Revolutionary Research . . . Relevant Results

Why EMRG: EMRG is a revolutionary long range gun with multi-mission potential including ballistic and cruise missile defense, long range land attack, and anti-surface warfare against small boats and ships. It uses electricity instead of gun propellant s enabling MACH 7 launch velocities and 200+ NM ranges

Partnerships: NSWC, PEO Ships, IWS, MCCDC, NRL, Charles Draper Labs, Sandia National Lab, Lawrence Livermore Labs, BAE Systems, Boeing, General Atomics

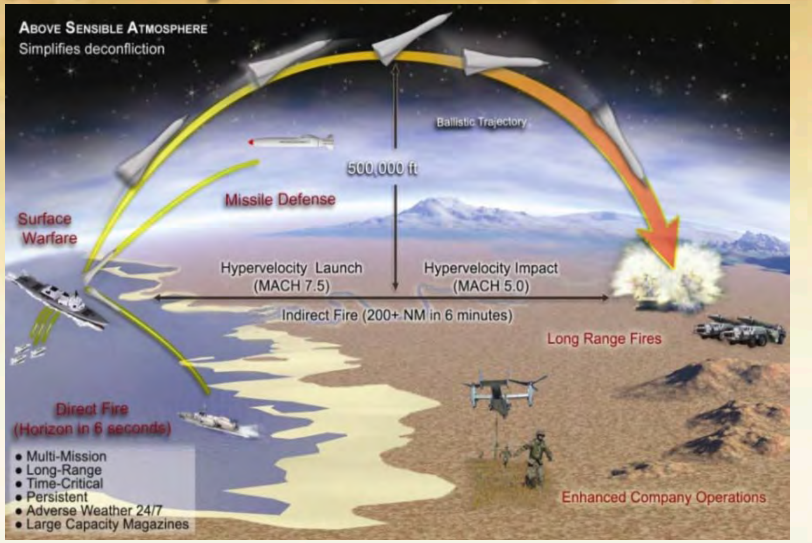
Why is EMRG Hard: EMRG requires development of composite barrels with extended barrel life, advanced pulsed power, high speed low drag projectile, and system thermal management

Accomplishments:

- World record 32 MJ launch energy
- Developed extended rail bore life enabling over 100 shots from 1 set of rails with multiple configurations
- Improved pulsed power design to deliver multiple shot versus single shot capability
- Conducted open range projectile sabot discard tests
- Evaluated EMRG utility in support of Special Forces and Surface Warfare

Upcoming Major Milestones:

- Demonstrate structural integrity of industry developed launchers at multiple energy levels
- Quantify acceleration load limits of critical projectile components
- Demonstrate repetitive shot-rate capability
- Increase understanding of bore life physics to improve overall performance



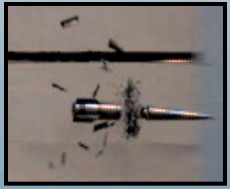
Recent Progress

BAE Half-Length Advanced Composite Prototype

32MJ Muzzle Energy World Record

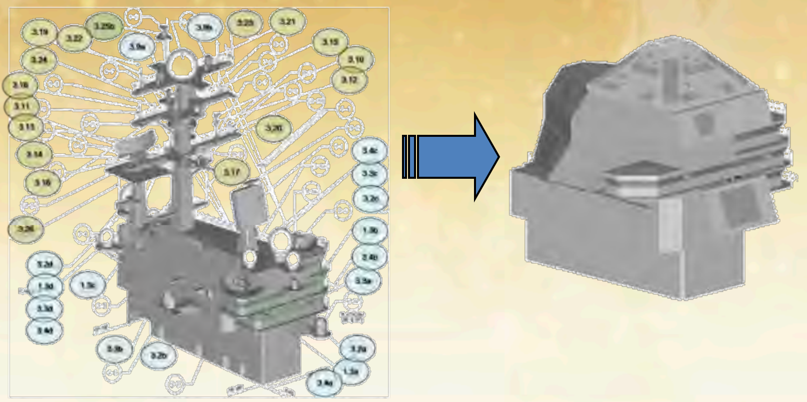
General Atomics Med-Cal Blitzer (IRAD)

Actively Cooled Rep-Rate Pulsed Power Module



Projectile Pellet Dispense Demo

Integrated Topside (INTOP)



Why INTOP: INTOP will develop a scalable family of multi-function apertures and electronics that provides a leap ahead capability to utilize the electromagnetic spectrum for electronic warfare, radar, communications and SIGINT on multiple classes of ships and other Navy platforms

Partnerships: NSWC, PEOs IWS, C4I, Subs, Ships, Carriers, NRL, SSC, Northrop Grumman, Raytheon, Lockheed Martin

Why is InTop Hard: INTOP requires adoption of shared RF resources across sensor, weapon & communication domains and the ability to perform dynamic resource and spectrum allocation in real time

Accomplishments:

- Completed Navy-Industry open RF architecture study
- Established Indefinite Delivery Indefinite Quantity 5-year $800M contract with 18 awardees
- Completed 6 EW/IO/Comms studies
- Awarded Submarine SATCOM contract for design with build option to Lockheed Martin
- Awarded contracts for EW/IO/COMMs ADM design with build option to Northrop Grumman & Raytheon

Upcoming Major Milestones:

- Complete Submarine SATCOM design to include prototype and award build option
- Complete EW/IO/COMMs ADM design and down select for build option to single contractor
- Issue RFP and award contract to continue Resource Allocation Manager development
- Hold Flag-level summit for prototype selection and transition path development

Revolutionary Research . . . Relevant Results

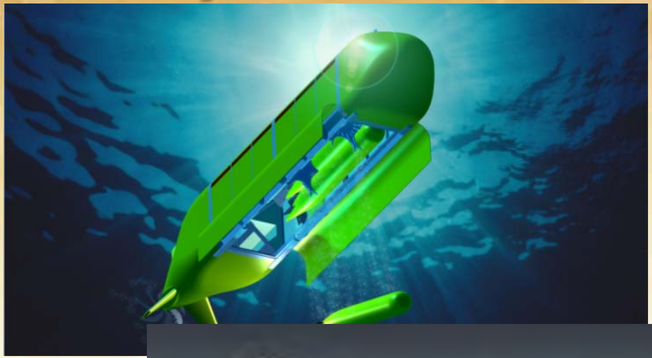
Large Displacement UUV (LDUUV)

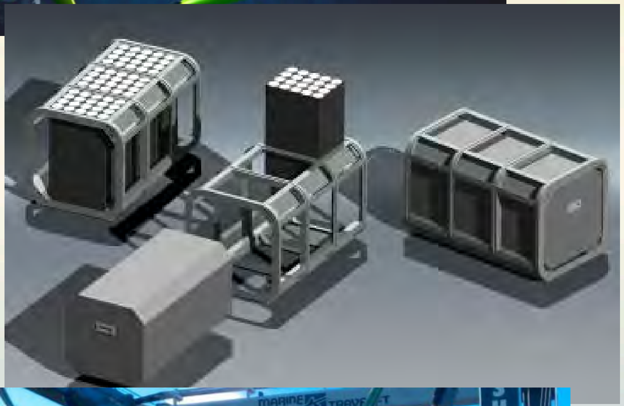
Why LD UUV: Develop fully autonomous long endurance land-launched UUVs capable of operating near shore, extend and multiply the current Navy platform's capability
- Ability to extend the reach of the Navy into the denied littorals
- Significant endurance

Partnerships: NRL, NUWC, PSU ARL, N2 and N6, OPNAV and PEO LMW to develop a technology that meets the Navy's needs and quickly transition to fleet operations

Why is LDUUV Hard: LDUUV will operate in complex littoral environments that change significantly over relatively short periods of time

Solution Attributes:
- Development of advanced air independent UUV energy systems to provide months of operations
- Focus on technologies that enable full autonomy in a cluttered littoral environment
- Conduct pier to pier fully autonomous operations to demonstrate increased mission flexibility
- Defined interfaces and standards will allow for cost effective quick insertions of payload and autonomy capability
- Leverage technologies from Navy Enterprises

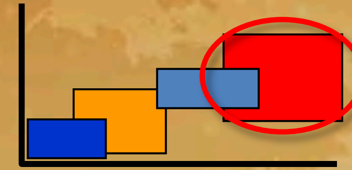




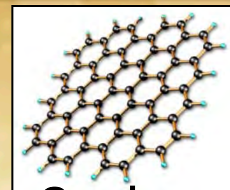
Revolutionary Research . . . Relevant Results

Basic Research

Seed corn for disruptive technologies



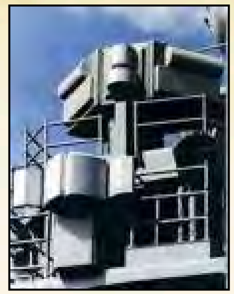
- Diverse portfolio
- Fosters innovation
- Long-term
- Investment in people
  *60+ Nobel laureates



Graphene

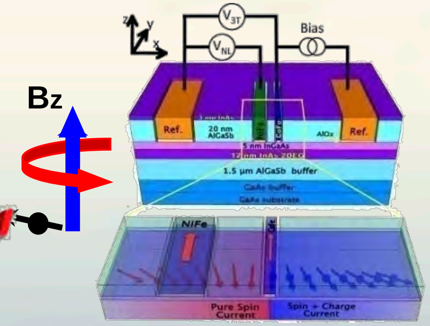
1st U.S. Intel satellite
GRAB

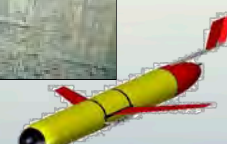
Semiconductors
GaAs, GaN, SiC



EW

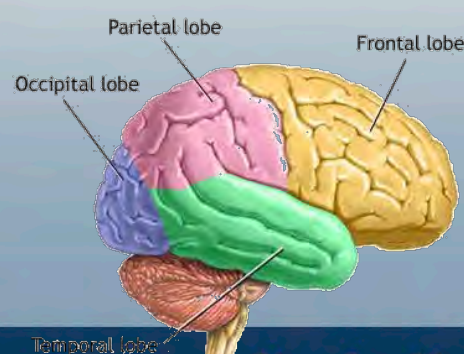
Spintronics



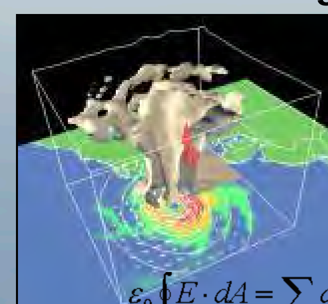


Arctic Research

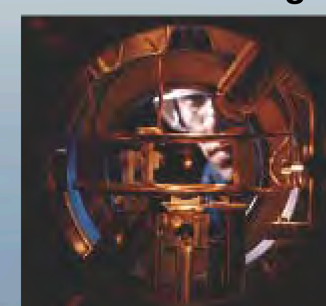
GPS



Weather Modeling



Laser Cooling



Discovery and Invention Vision

KNOWLEDGE

Develop Naval-relevant fundamental knowledge

- Expand the boundaries in traditional Naval interest research areas
- Examine new research directions for future Naval needs
- Encourage risk-taking to seek scientific breakthroughs

TRANSITIONS

Provide the basis for future Navy and Marine Corps systems

- Ensure research relevancy to Naval S&T strategy
- Transition promising Basic Research to applications
- Use knowledge (even failures) to reduce risk in acquisition

PEOPLE

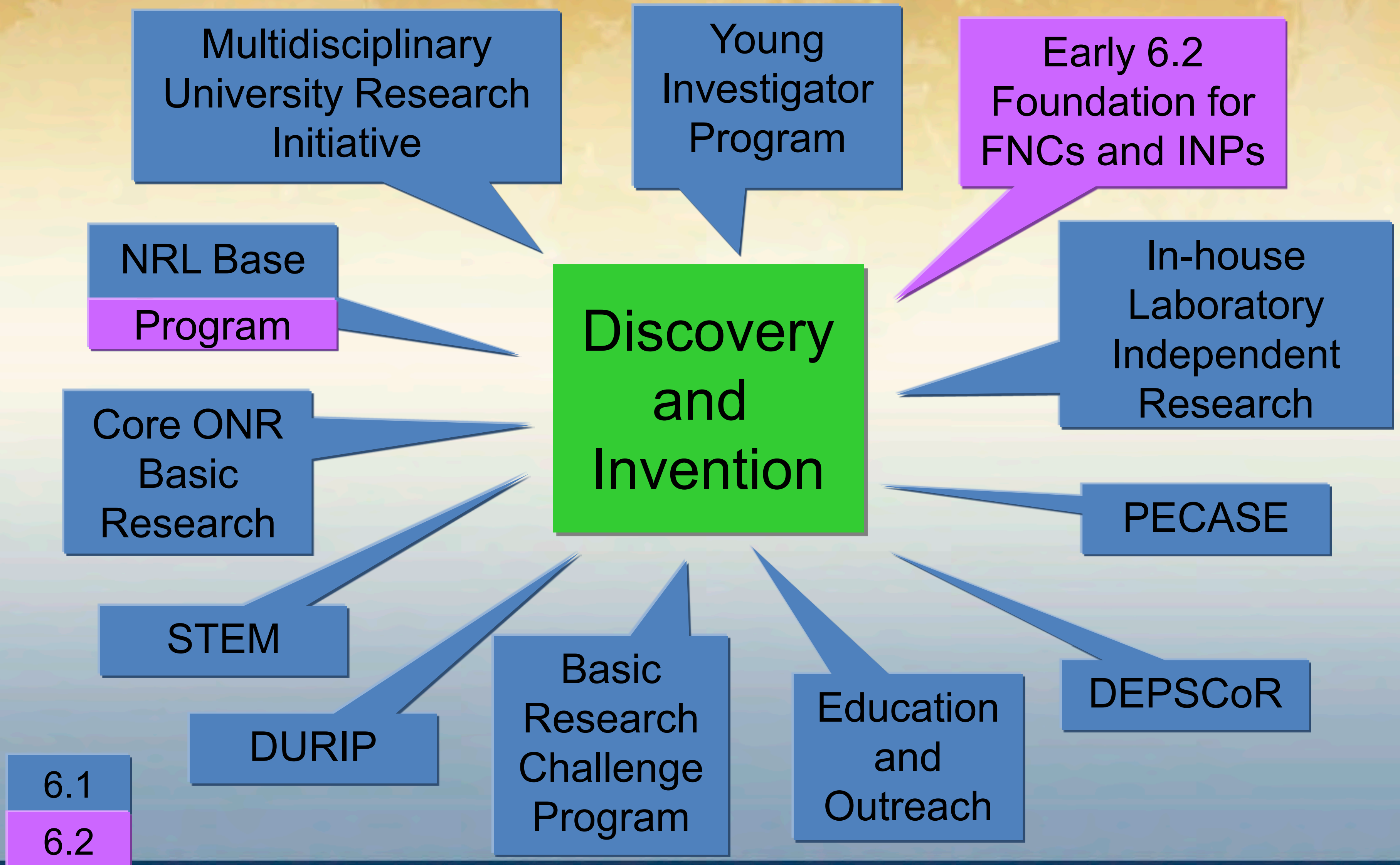
Maintain the health of the Defense Scientist and Engineer workforce

Develop and nurture future generation of DoD researchers and engineers

Ensure continued U.S. advantage in intellectual capital

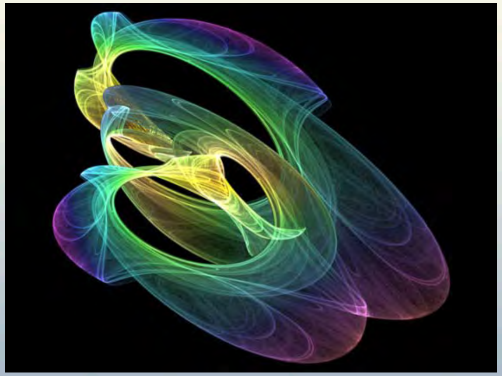
Maintain unique/essential research infrastructure

Discovery and Invention Program Content

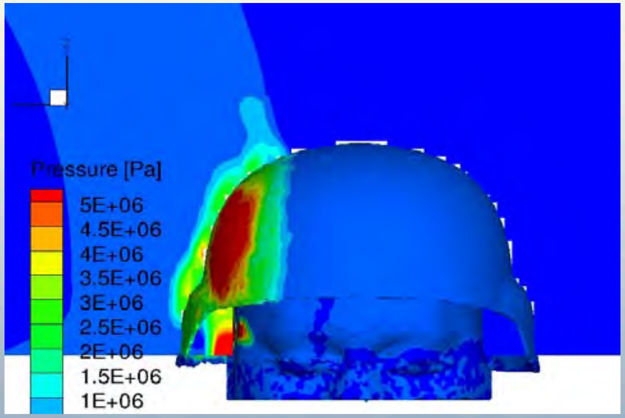


Basic Research Challenge Program

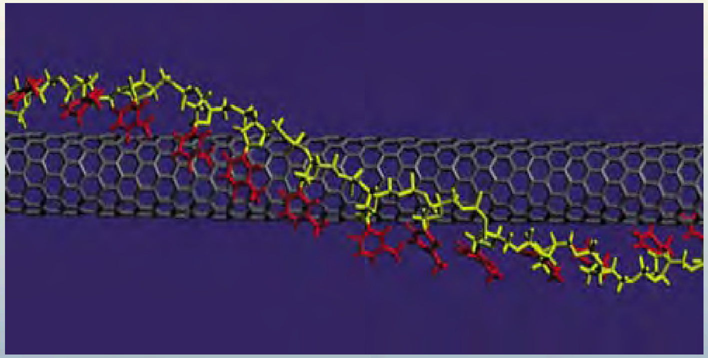
Competitively funds promising Basic Research programs in new areas not currently addressed by the Basic Research program. Stimulates new, high-risk Basic Research projects in multi-disciplinary and Departmental collaborative efforts.



Irreducible Uncertainty *



Elastomeric Polymer by Design *

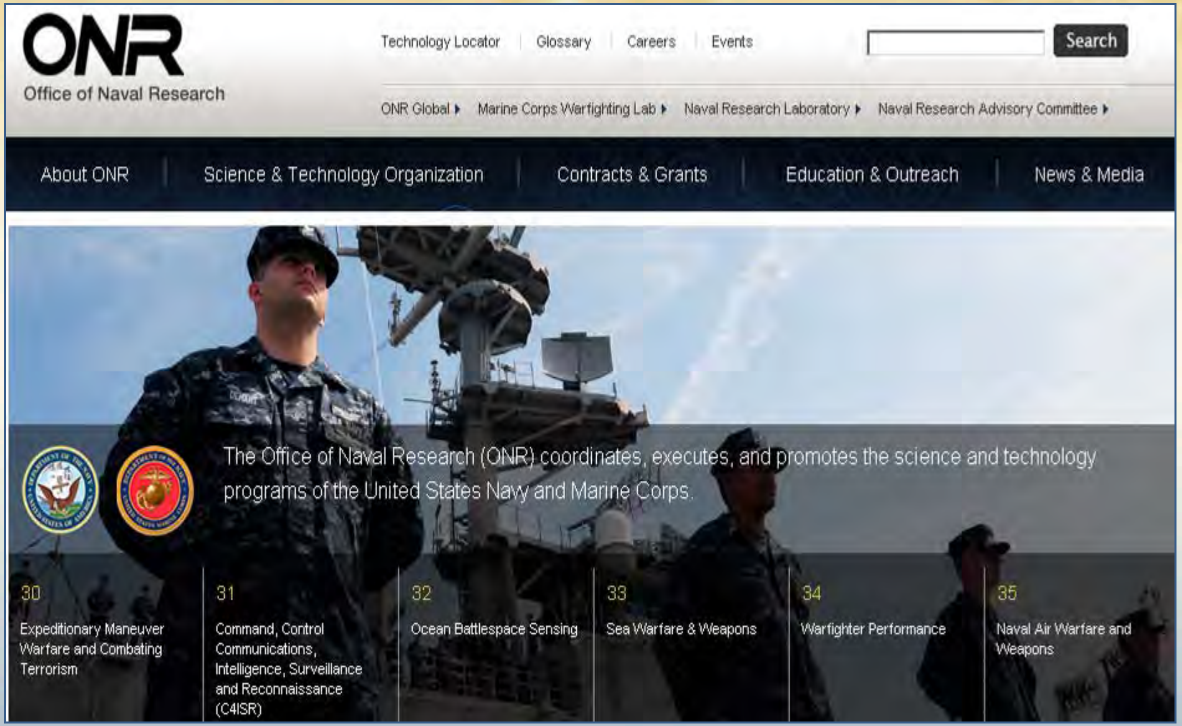


DNA-Based Nanoelectronic Fabrication *

* FY09 BRC Program Selections

Revolutionary Research . . . Relevant Results

Where to Find Us Online

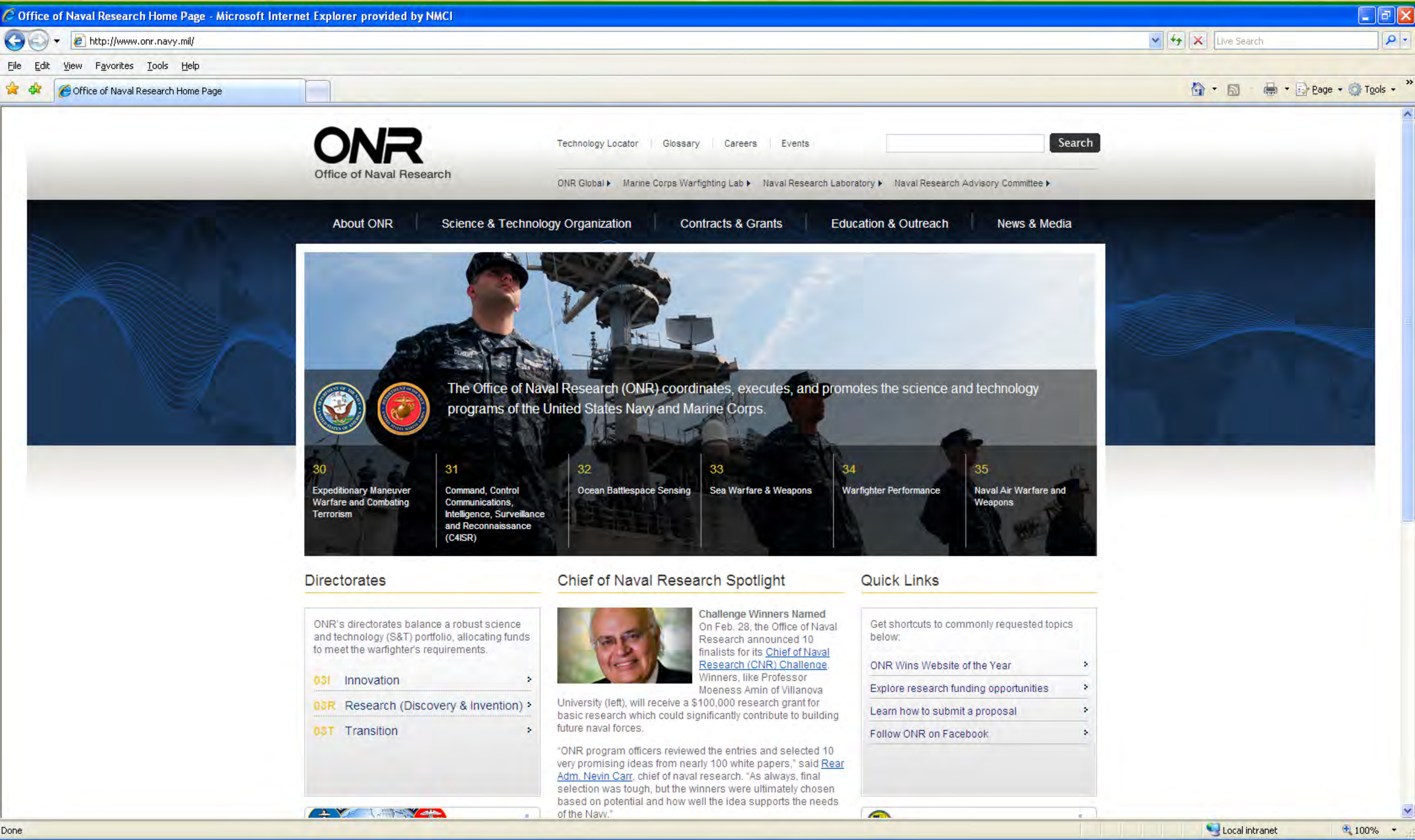


www.onr.navy.mil

YouTube Broadcast Yourself™

Revolutionary Research . . . Relevant Results

www.onr.navy.mil



Cyber S&T Priority Steering Council Research Roadmap

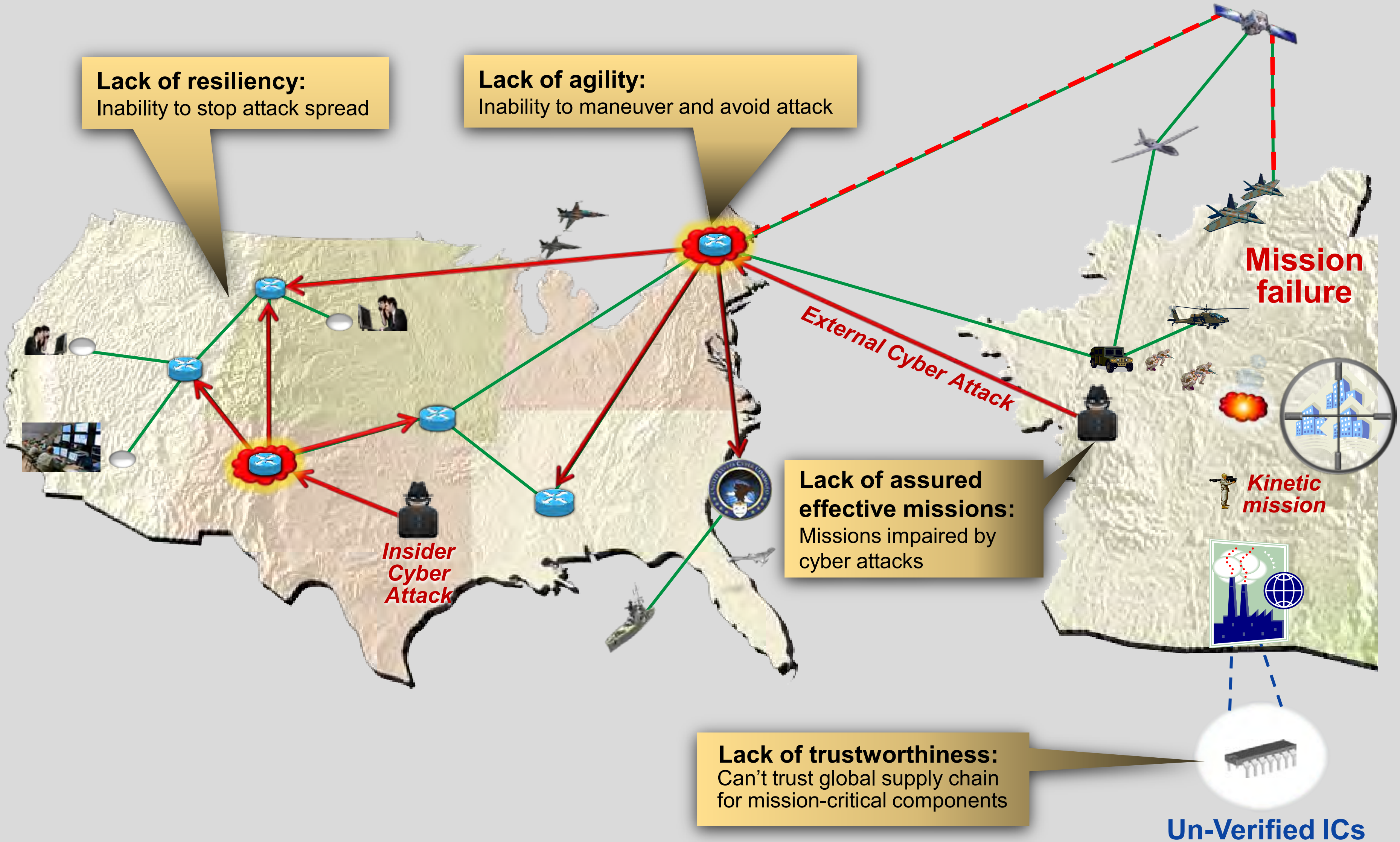
for the

National Defense Industrial Association Disruptive Technologies Conference

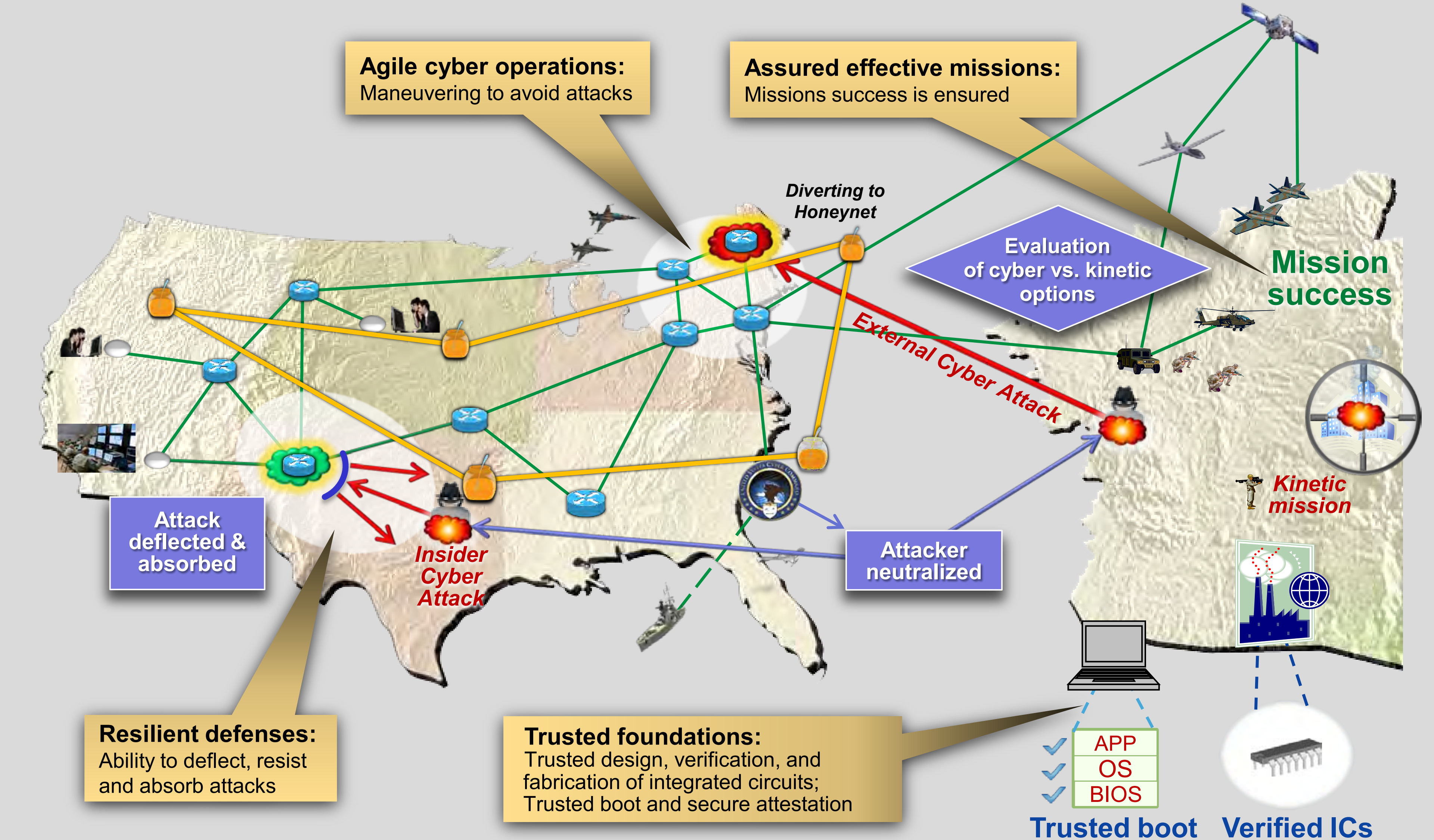
8 November 2011

Steven E. King, Ph.D.

Problem Statement



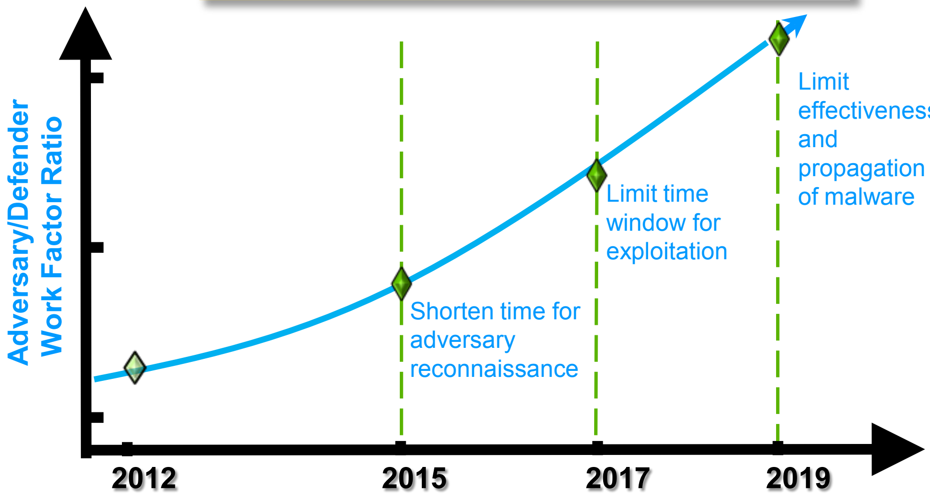
Desired End State



Key Parameter: Work Factor Ratio

- **Missions**
  - Kinetic, cyber, and combined missions will have a cyber dependency
- **Infrastructure**
  - Any element of the cyber infrastructure may be compromised and manipulated
  - DoD will continue to leverage commercial products and services we do not own or control
  - DoD infrastructure defies establishing an all-encompassing static perimeter

Challenge: Increase Adversary / Defender Relative Work Factor Over Time



Perimeter is not well defined

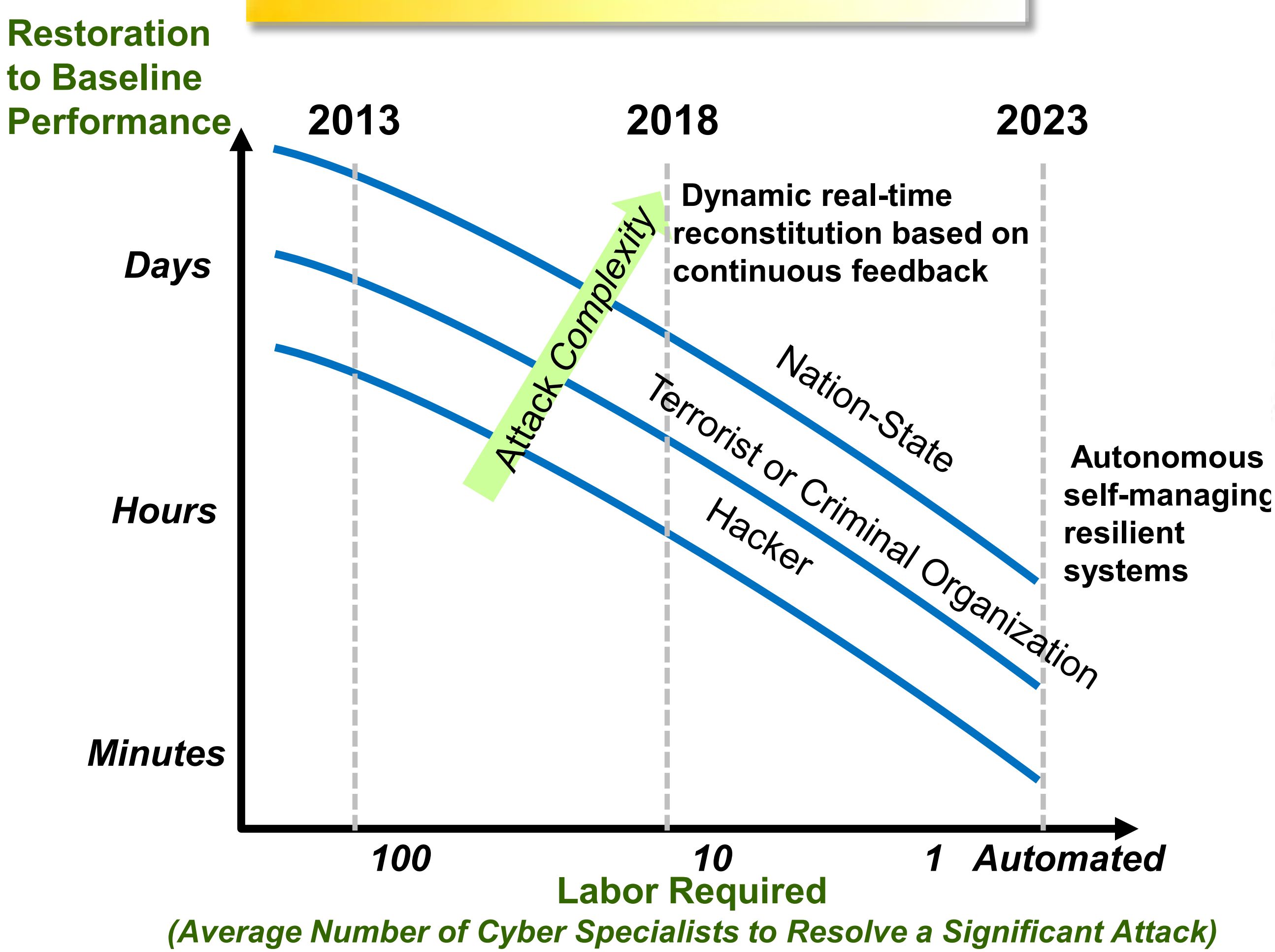
Four Major 10 Year Objectives

Assuring Effective Missions	Assess and control the cyber situation in mission context
Agile Operations	Dynamically reshape cyber systems as conditions/goals change, to escape harm

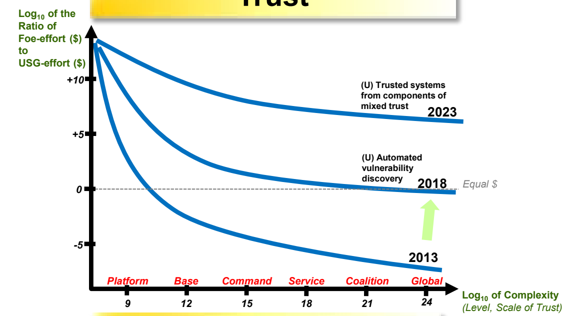
Resilient Infrastructure	Withstand cyber attacks, and sustain or recover critical functions
Trust	Establish known degree of assurance that devices, networks, and cyber-dependent functions perform as expected, despite attack or error

Metrics

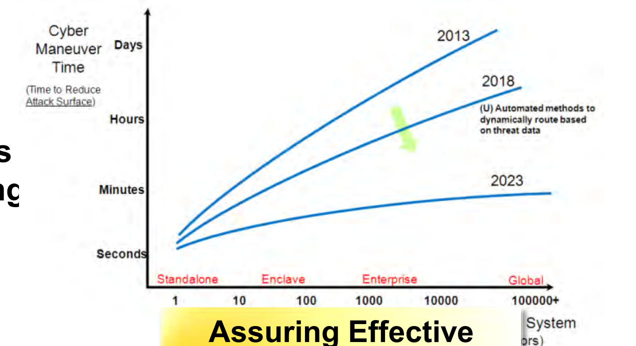
Resilient Infrastructure



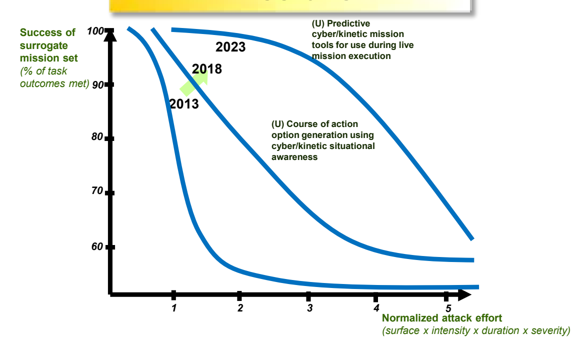
Trust



Operational Agility

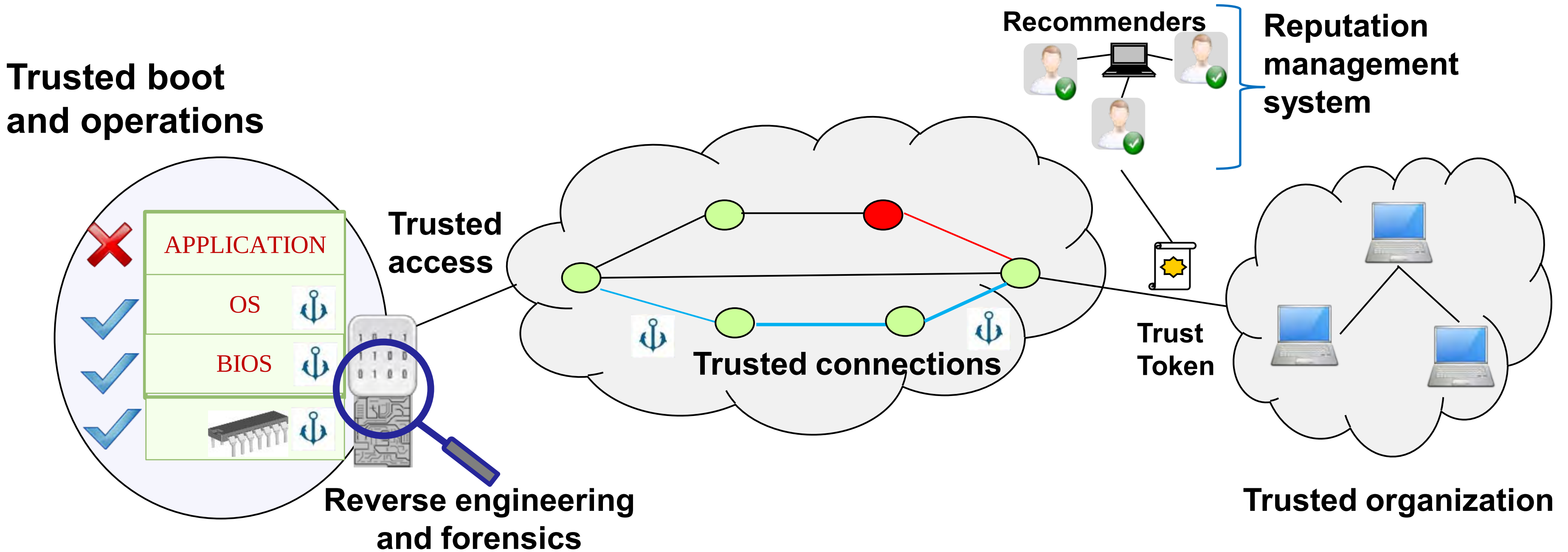


Assuring Effective Missions



Trust

Technical Challenges and Research Opportunities

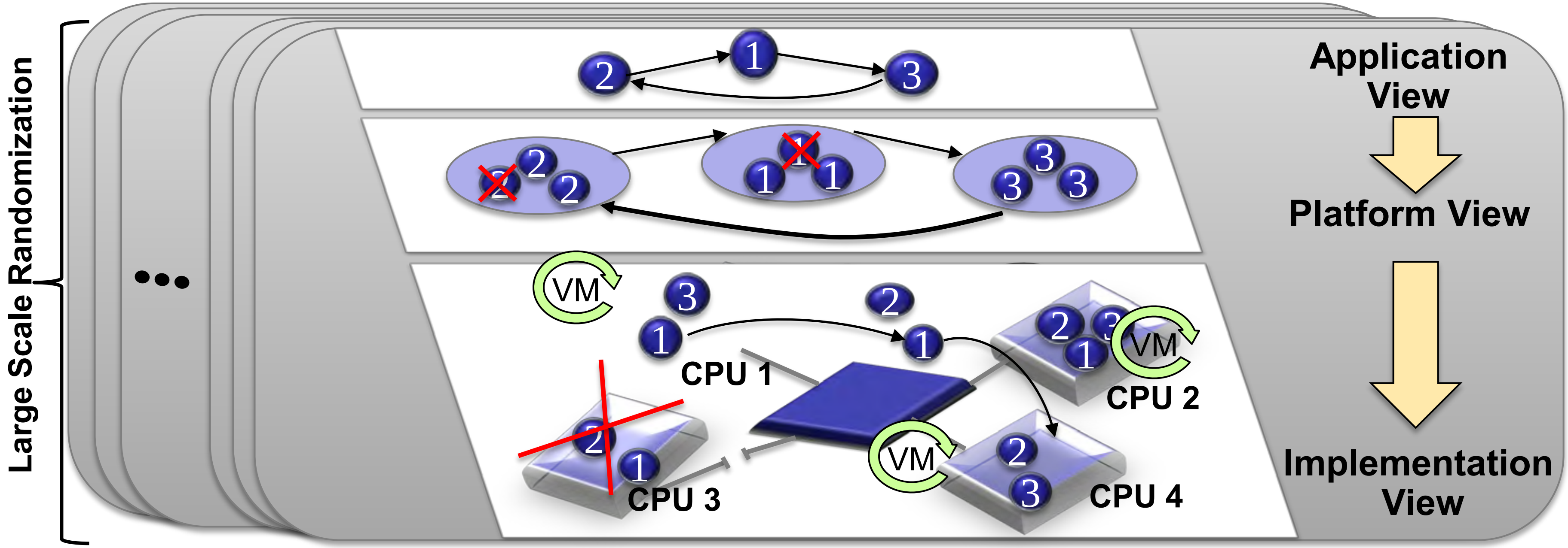


Trust Foundations

- Scalable reverse engineering and analysis
- Trust establishment, propagation, and maintenance techniques
- Measurement of trustworthiness
- Trustworthy architectures and trust composition tools

Resilient Infrastructure

Technical Challenges and Research Opportunities



Resilient Architectures

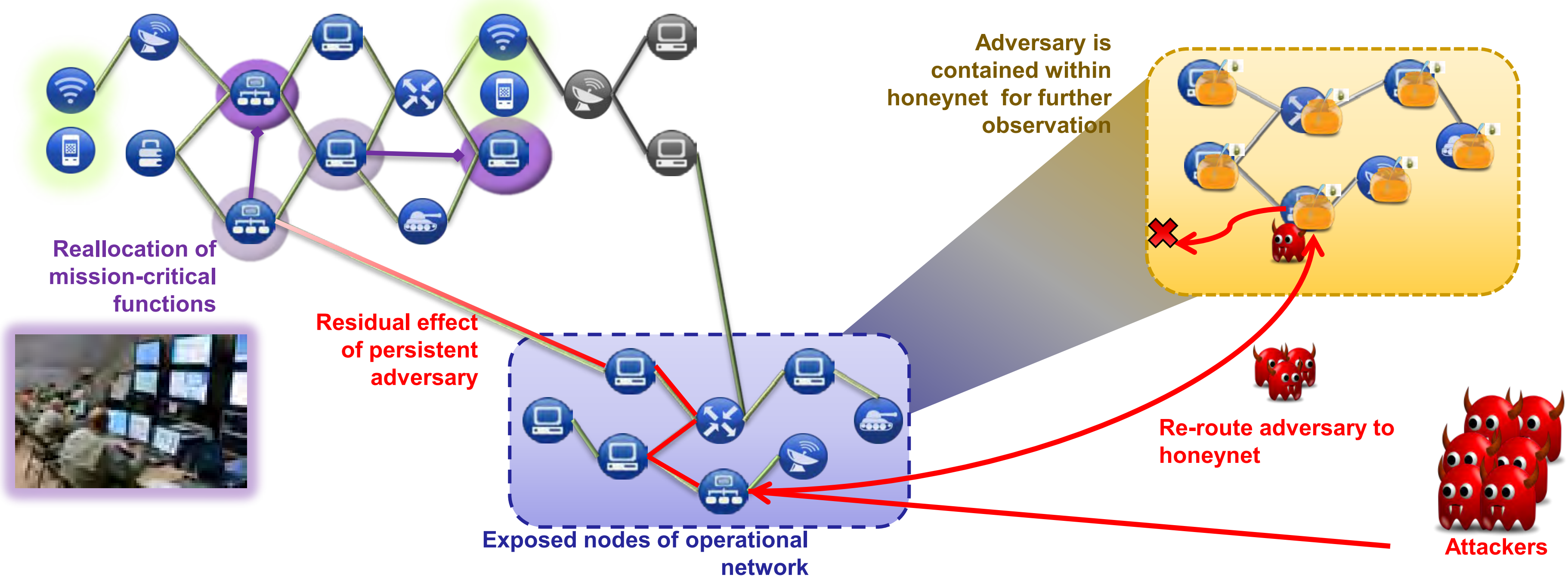
- Resiliency for operational systems
- Mechanisms to compose resilient systems from brittle components
- Integration of sensing, detection, response, and recovery mechanisms
- Secure modularization and virtualization of nodes and networks
- Resiliency-specific modeling and simulation

Resilient Algorithms and Protocols

- Code-level software resiliency
- Network overlays and virtualization
- Network management algorithms
- Mobile computing security

Agile Operations

Technical Challenges and Research Opportunities



Autonomic Cyber Agility

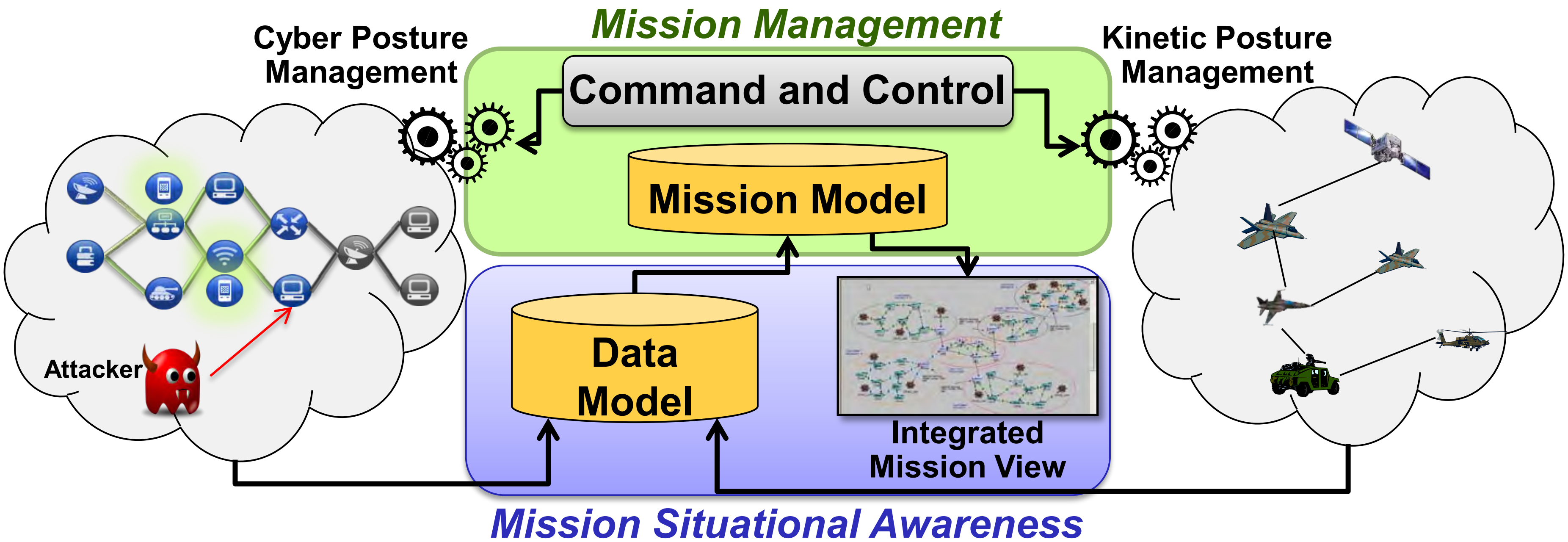
- Techniques for autonomous reprogramming, reconfiguration, and control of cyber components
- Machine intelligence and automated reasoning techniques for executing courses of action

Cyber Maneuver

- Distributed systems architectures and service application polymorphism
- Network composition based on graph theory
- Distributed collaboration and social network theory

Assuring Effective Missions

Technical Challenges and Research Opportunities



Cyber Mission Control

- Techniques for mapping assets and describing dependencies between mission elements and cyber infrastructure
- Techniques for course of action development and analysis
- Cyber effects assessment

Open Broad Agency Announcements

- **Army Research Office (ARO)**
  - Solicitation #:W911NF-07-R-0003-04; BAA for Basic and Applied Research, Section 5.3
- **Army Research Laboratory (ARL)**
  - Solicitation #:W911NF-07-R-0001-05; BAA for Basic and Applied Research, Section 1
- **Communications and Electronics Research, Development, and Engineering Center (CERDEC)**
  - Solicitation #: W15P7T-08-R-P415
- **Office of Naval Research (ONR)**
  - Solicitation #: ONRBAA 12-001, Code 31 Section 1
- **Naval Research Laboratory (NRL)**
  - Solicitation #: BAA-N00173-02, Section 55-11-02 (Mathematical Foundations of Computing)
  - Solicitation #: BAA-N00173-02, Section 55-11-03 (High Assurance Engineering and Computing)
- **Air Force Office of Scientific Research (AFOSR)**
  - Solicitation #: AFOSR-BAA-2010-1, Section c.12
- **Air Force Research Laboratory (AFRL)**
  - Solicitation #: BAA-10-09-RIKA (Cross Domain Innovative Technologies)
  - Solicitation #: BAA-11-01-RIKA (Cyber Assurance Technologies)
- **Defense Advanced Research Projects Agency (DARPA)**
  - Solicitation #: DARPA-BAA-11-63 (Automated Program Analysis for Cyber Security)
  - Solicitation #: DARPA-BAA-10-83 (Strategic Technologies Office BAA)
  - Solicitation #: DARPA-BAA-11-34 (Information Innovation Office BAA)
  - Solicitation #: DARPA-RA-11-52 (Cyber Fast Track)
  - Solicitation #: DARPA-SN-11-55 (Future Directions in Cyber Security)

Small Business Innovation Research Announcements

http://www.dodsbir.net

NSA Contact Information

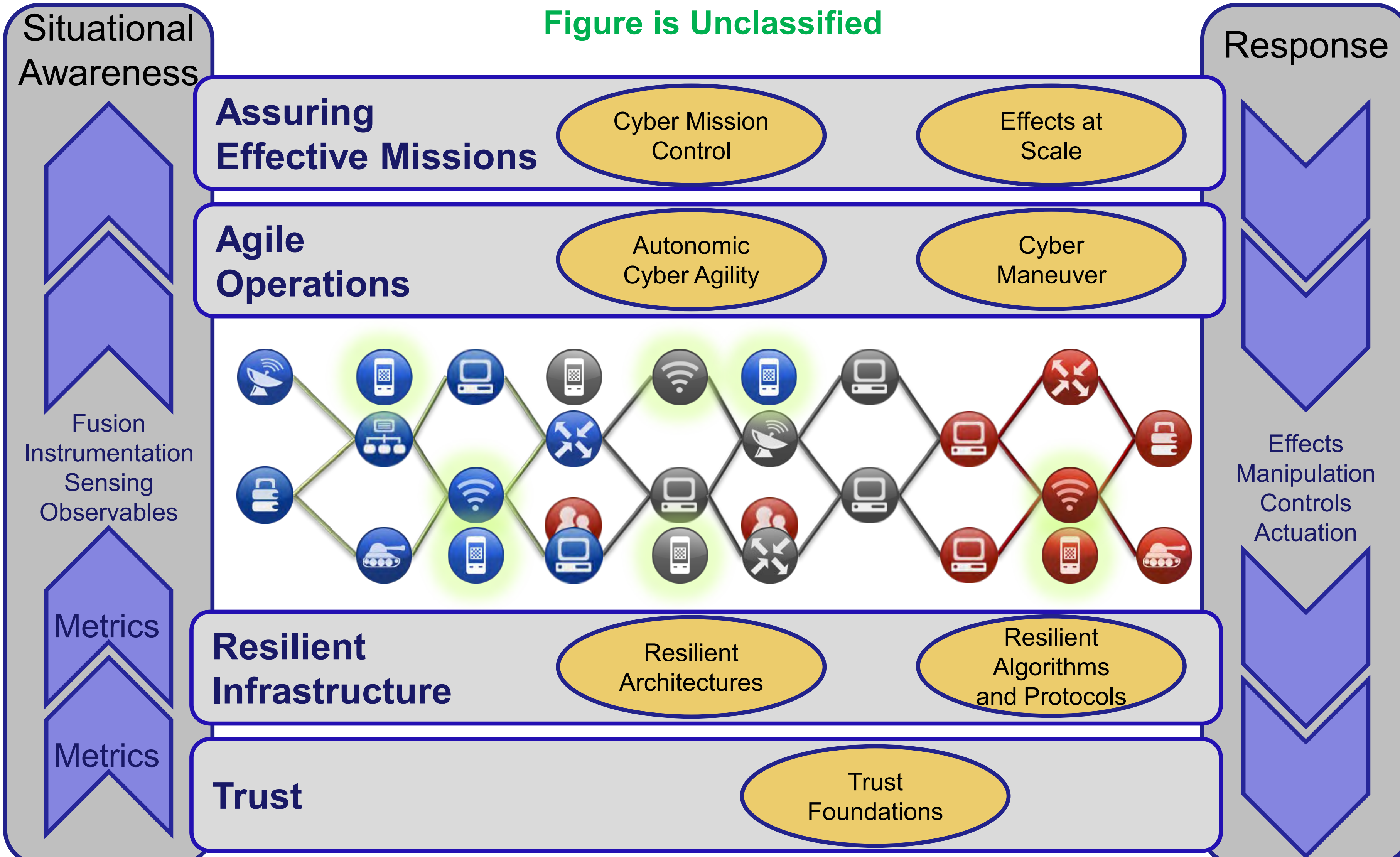
(No Open BAAs)

Acquisition Resource Center
Phone: (443)-479-9572
E-mail: nsaarc@nsaarc.net

Office of Small Business Programs
Phone: (443)-479-9572
E-mail: nsaarc@nsaarc.net

Technology Challenge Summary

POC: Dr. Steven E. King



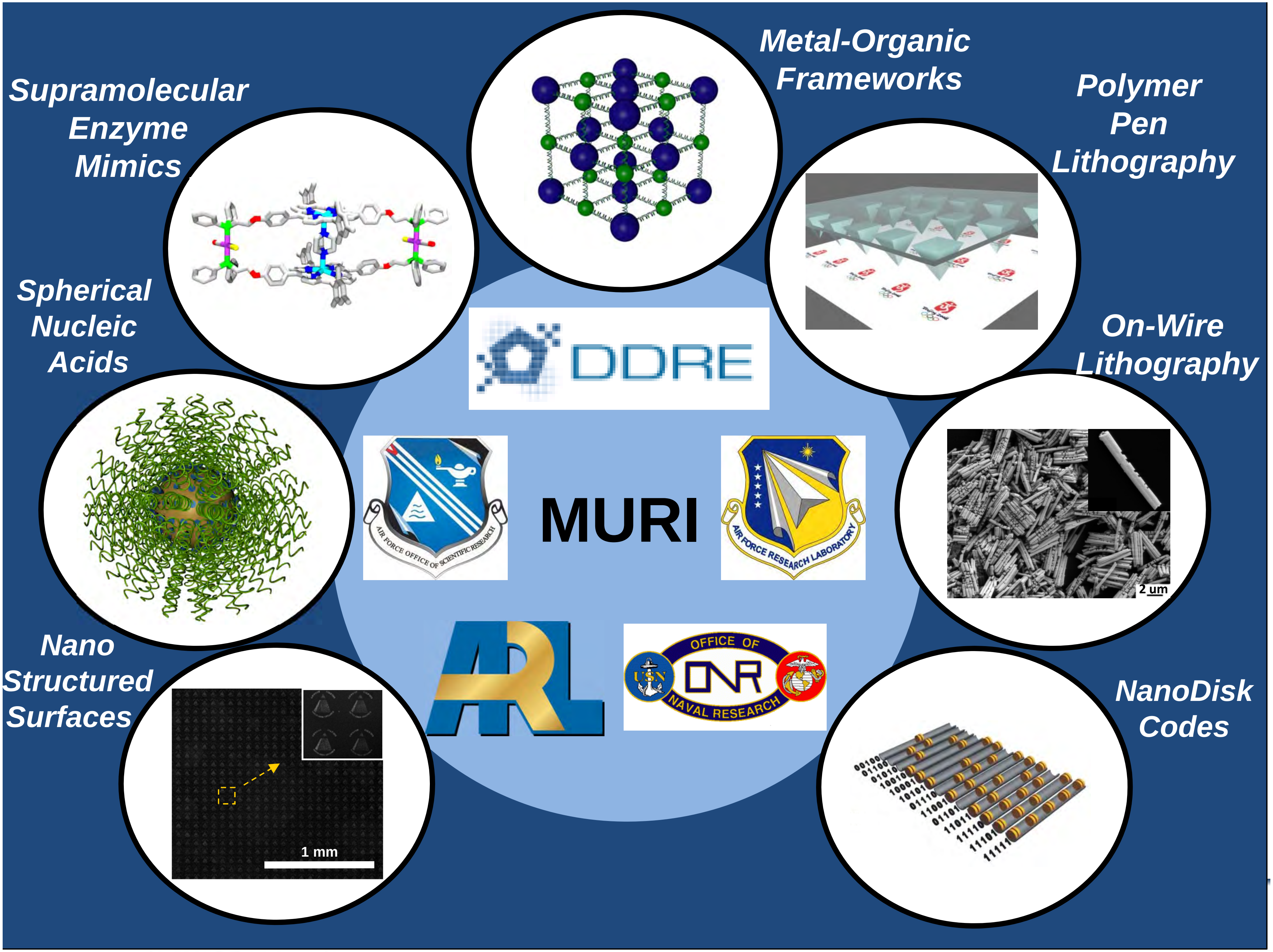
MURI-Funded Scientific and Technological Blockbusters from Northwestern University

Chad A. Mirkin

Department of Chemistry and International Institute for Nanotechnology
Northwestern University
2190 N. Campus Drive
Evanston, IL 60208-3113

MURI Support at Northwestern University

- **MURI-00**: Surface Templated Bio-Inspired Synthesis and Fabrication of Functional Materials (F49620-00-1-0283/P01, 2000-2006)
- **DURINT-01**: Ultrasensitive and Selective Chip Based Detection of DNA (F49620-01-1-0401, 2001-2007)
- **MURI-04**: Biomechanical Interfaces for Cell-based Microsystems (W911NF-04-1-0171, 2004-2009)
- **MURI-07**: Bio-inspired Supramolecular Enzymatic Systems (FA9550-07-1-0534, 2007-2012)
- **MURI-11**: Bioprogrammable One-, Two-, and Three-Dimensional Materials (FA9550-11-1-0275, 2011-2014)
- **MURI-11**: Conductive DNA Systems and Molecular Devices (N00014-11-1-0729, 2011-2014)


Supramolecular Enzyme Mimics
Metal-Organic Frameworks
Polymer Pen Lithography
Spherical Nucleic Acids
On-Wire Lithography
DDRE
MURI
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
AIR FORCE RESEARCH LABORATORY
2 um
Nano Structured Surfaces
ARL
OFFICE OF ONR NAVAL RESEARCH
USN
NanoDisk Codes
1 mm

MURI-00: Surface-Templated, Bio-Inspired Synthesis and Fabrication of Functional Materials

Team

- Program Manager: H. DeLong
- NU
  - C. Mirkin, V. Chandrasekhar, V. Dravid, R. Letsinger, G. Schatz, S. Stupp, D. Ginger
- Harold Washington
  - T. Higgins
- Tufts
  - D. Kaplan
- Scripps
  - M. Ghadiri
- Perkin Elmer Applied Biosystems
  - E. Mayrand
- Lucent Technologies
  - P. Wiltzius
- DoD Labs
  - Valdes, Stone, Naik

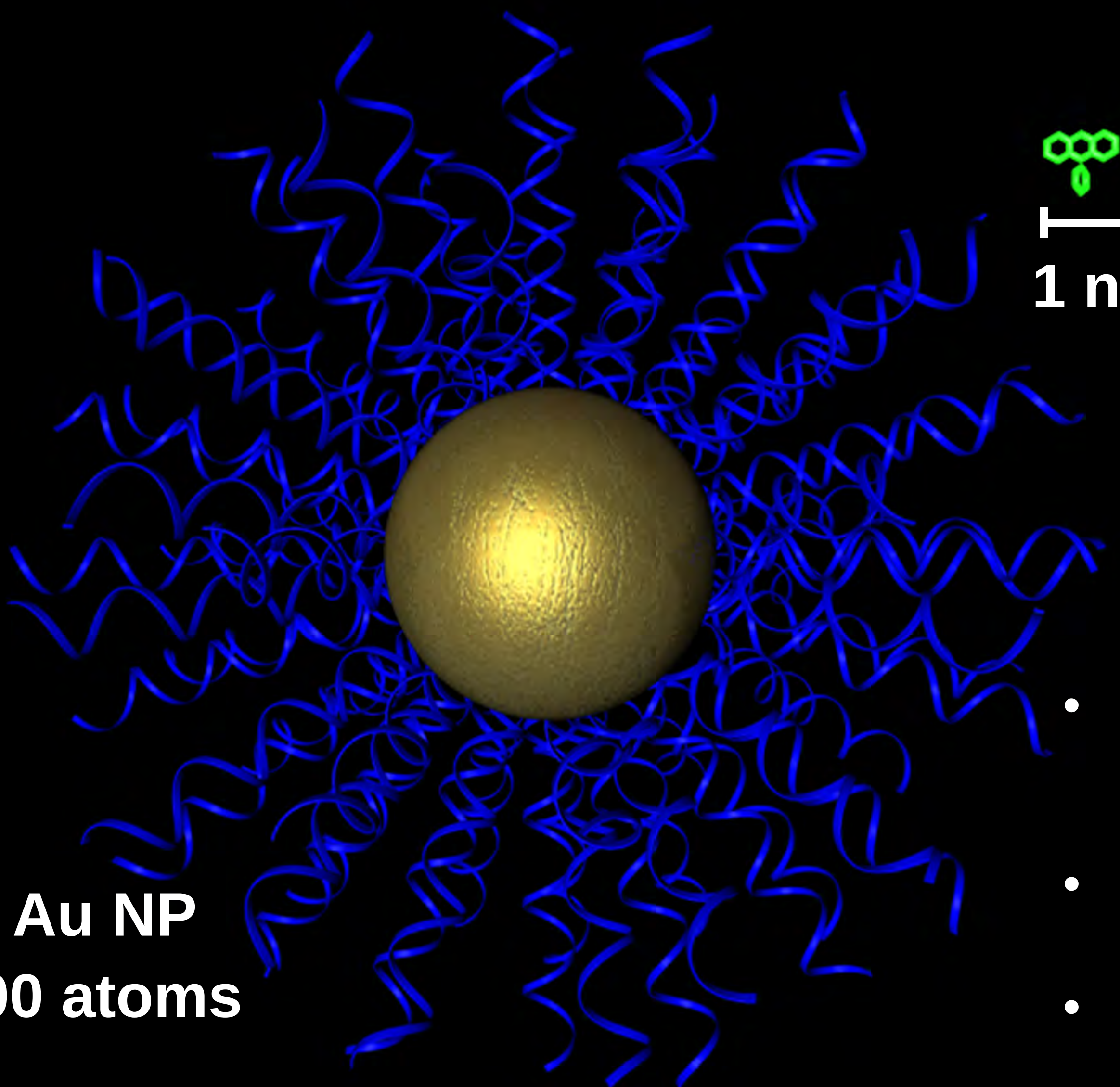
Goals

- Establish rules that can be used in 2D and 3D assembly of biomolecules
- Merge solution phase assembly with DPN
- Develop computational tools to predict the properties of assembled nanostructures

Outcome

- *Design rules for assembling particles into colloidal crystals with pre-conceived structures*
- *An understanding of the fundamental factors that control molecular transport from tip-based scanning probes*

Spherical Nucleic Acid Nanostructures



Fluorescein

37 atoms

1 nm

40-mer
Oligonucleotide
1400 atoms

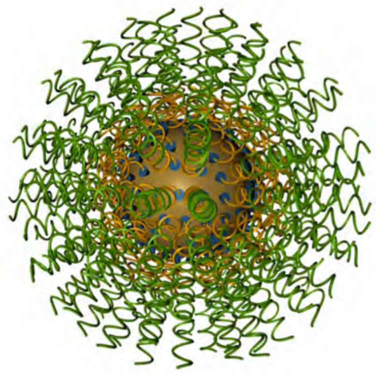
- **Synthetically Programmable Recognition**
- **Multivalency and Multi-functionality**
- **New Properties: Cooperative binding, Catalysis**

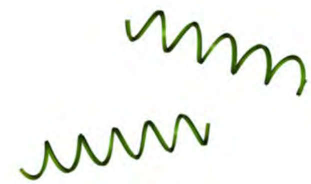
13 nm Au NP

~67,500 atoms

Mirkin *et al, Nature* 1996 (382) 607-609

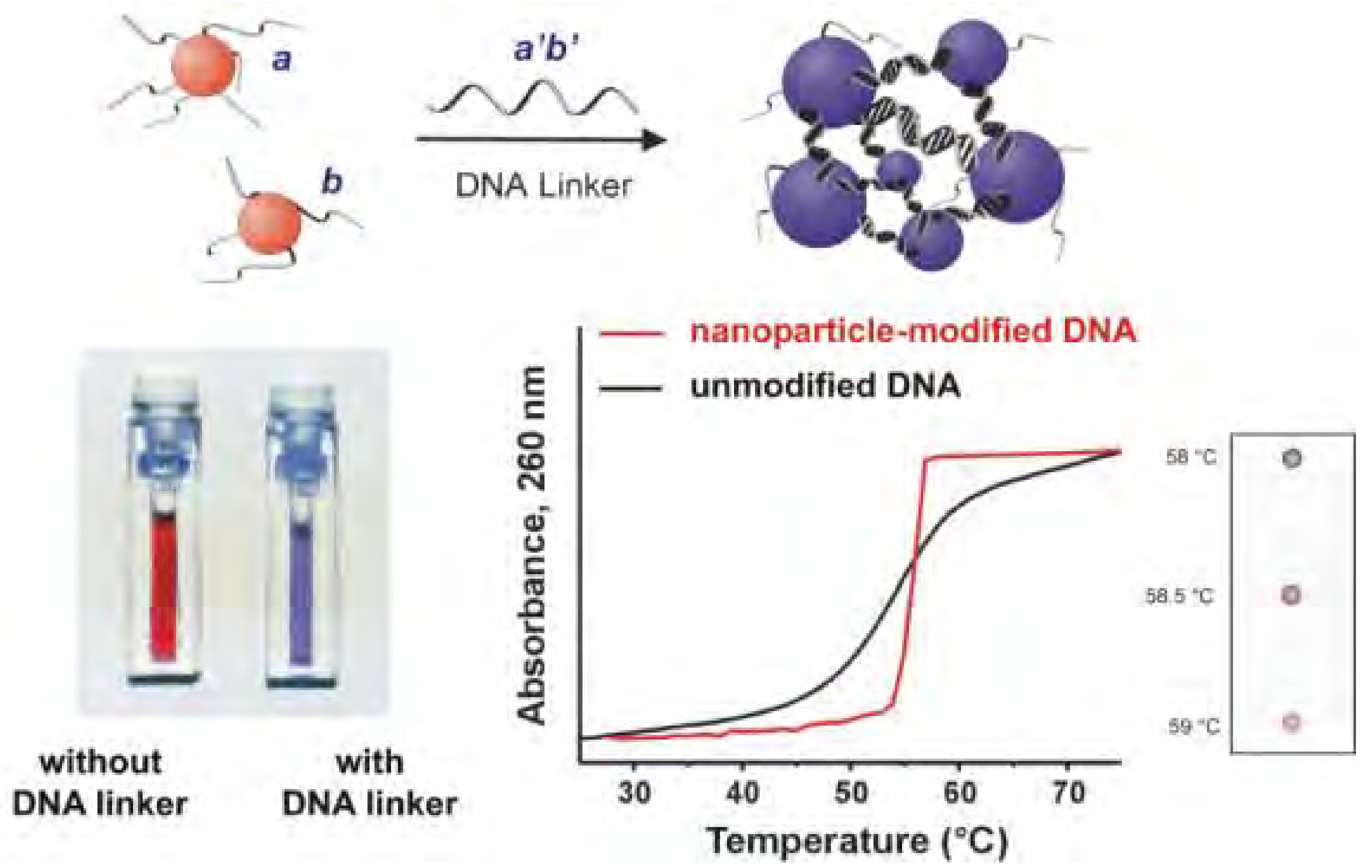
SNAs Have Unique Properties Distinct From Their Linear Counterparts





Property	Spherical Nucleic Acids	Linear Nucleic Acids
Melting Transition	Cooperative and Narrow (~2-8ºC)	Broad (~20ºC)
Cellular Uptake	Transfection agents NOT required	Lipofectamine™, Dharmafect™, etc
Immune Response	Minimal	Elevated Interferon-β
Stability	Resistance to Nucleases	Rapid Degradation
Inorganic Core's	Plasmonic, Catalytic, Magnetic, Luminescent	N/A
Binding Strength	K_{eq} = 1.8 x 10^{14}	K_{eq} = 1.8x10^{12}

Properties of Hybridized Nanoparticle Probes



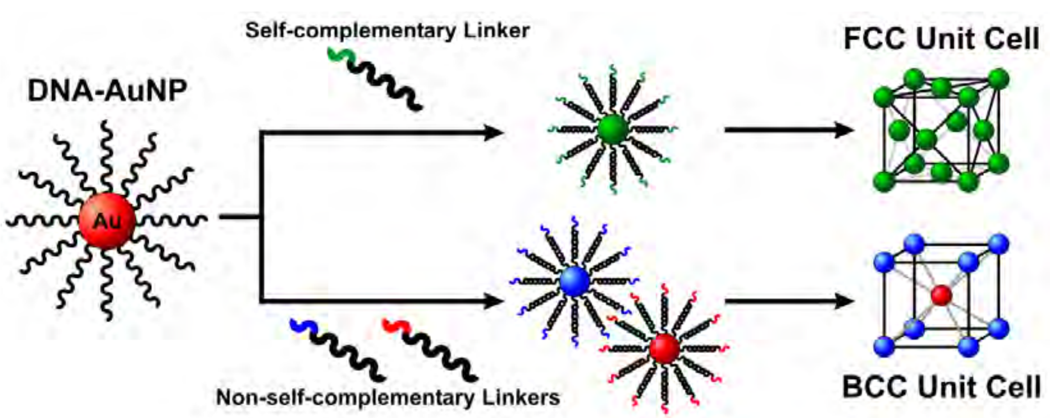
Color: Hybridized aggregates of DNA functionalized Au nanoparticles show distinct color changes in their hybridized (purple) and unhybridized (red) forms.

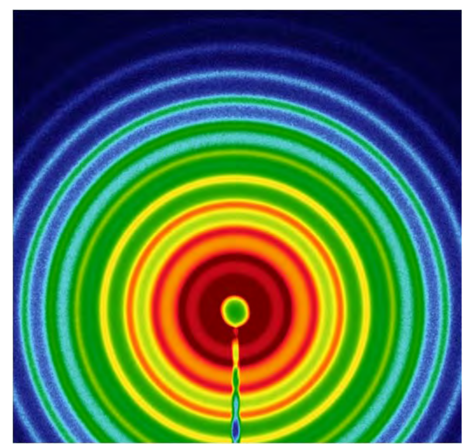
Cooperativity: Hybridized aggregates of DNA functionalized Au nanoparticles show sharper melting transitions than the same DNA duplex free in solution.

Mirkin *et al, Nature* 1996, Elghanian, R. *et al, Science,* 1997

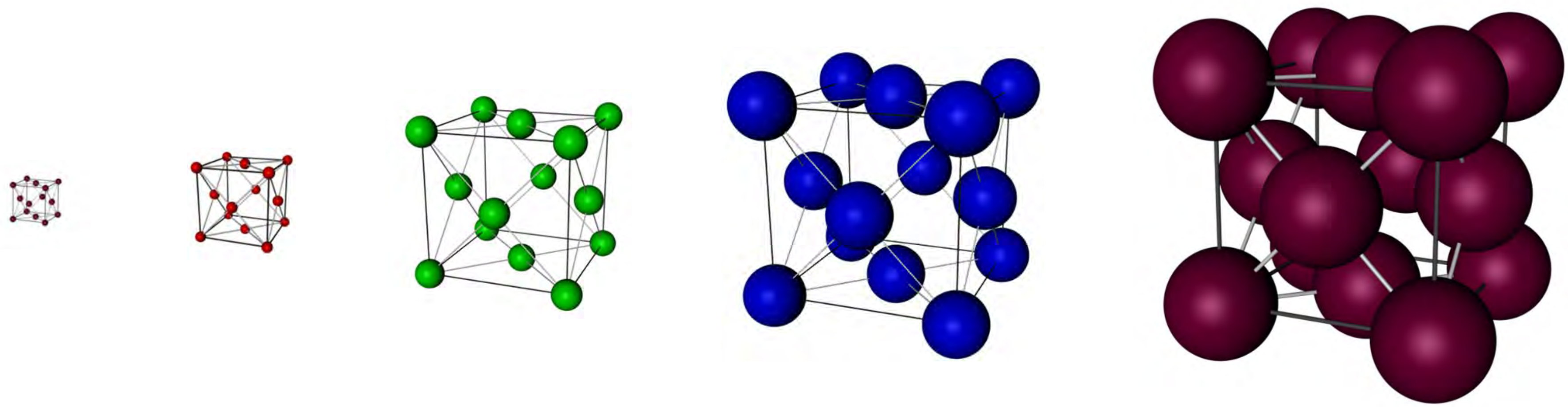
DNA-Programmable Nanoparticle Crystallization

- DNA guides the assembly of the same inorganic particle into different crystalline states
- Solution based
- Crystallization driven by maximizing hybridization interactions
- Independently tailorable design parameters (NP size, interparticle distance, crystallographic symmetry)

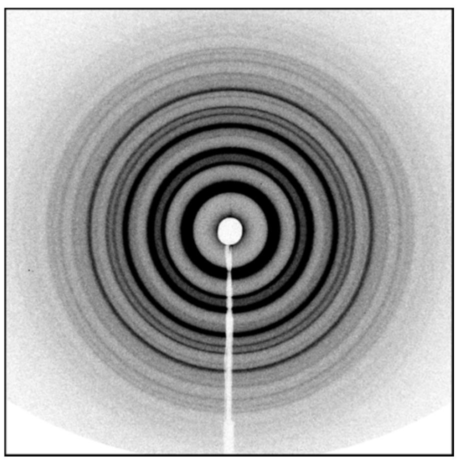




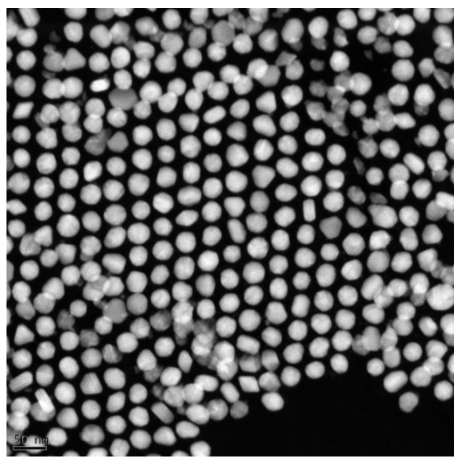
Crystallization Over an Order of Magnitude of Sizes



5 nm — Diameter of NPs Crystallized → 80 nm



5 nm AuNPs, 38 nm DNA

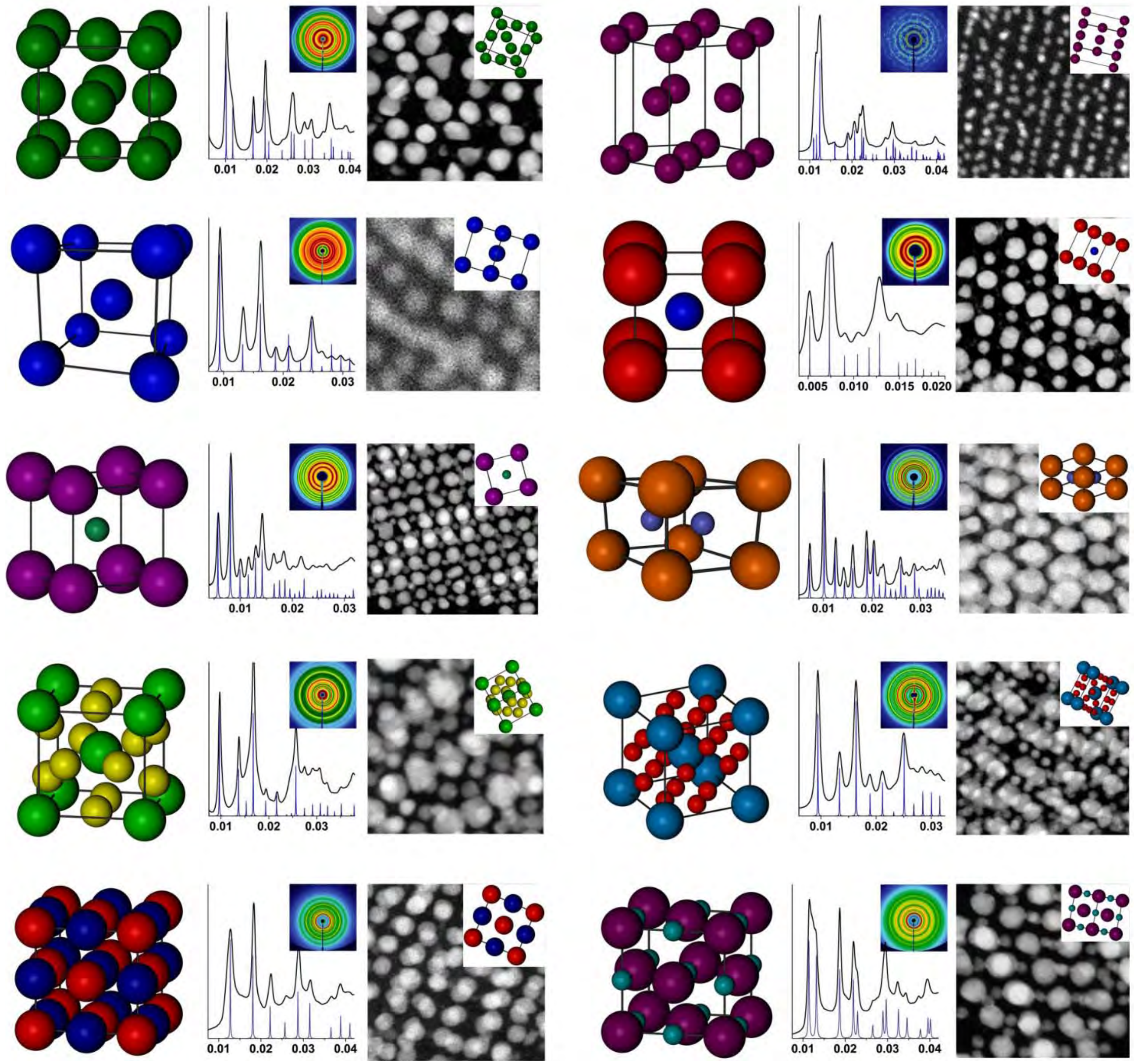


30nm NPs, [111] axis
Unit Cell Edge Length
~100 nm
(Before embedding)

Diameters of NPs:
5 nm – 80 nm
Crystal Lattice Parameters:
25 nm – 225 nm
Average Crystal Size: **1.5 μm**

Macfarlane et. al., *Ange. Chemie Int. Ed.* 2010, *49*, 4589

Different Crystallographic Symmetries



FCC

HCP

BCC

CsCl *(20-40nm)*

CsCl *(20-50nm)*

AlB_2

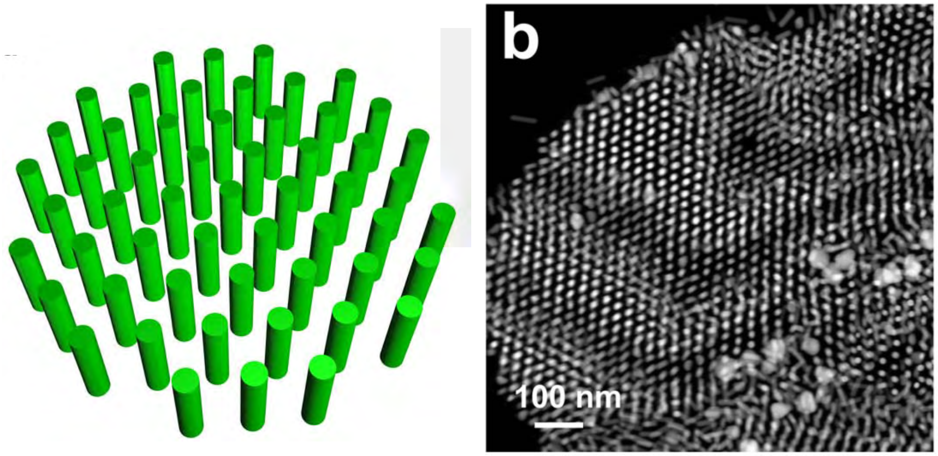
AB_3 (Cr_3Si)

AB_6 (Cs_6C_{60})

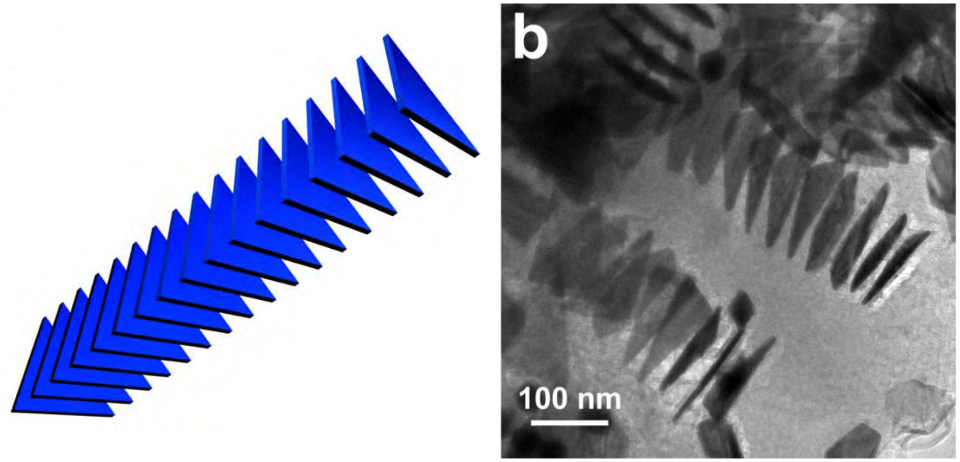
Simple Cubic

NaCl

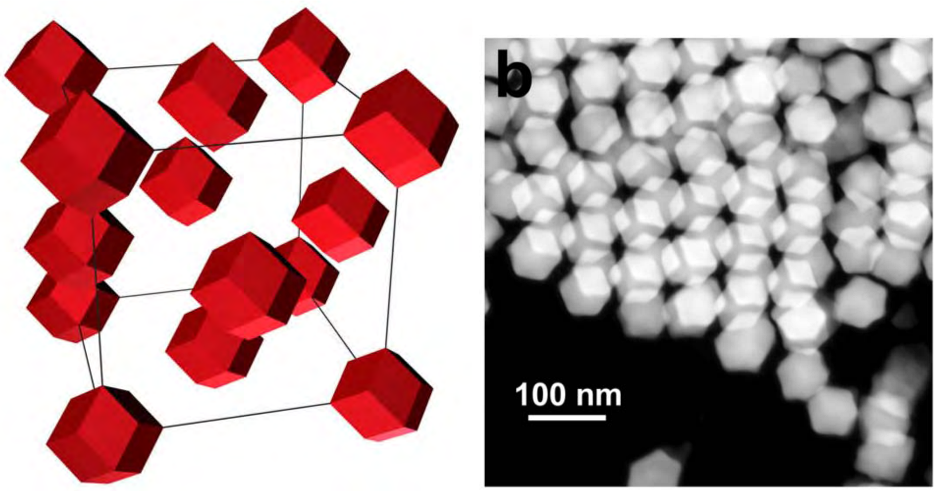
Anisotropic Particle Assembly: Introducing Valency Into the Process



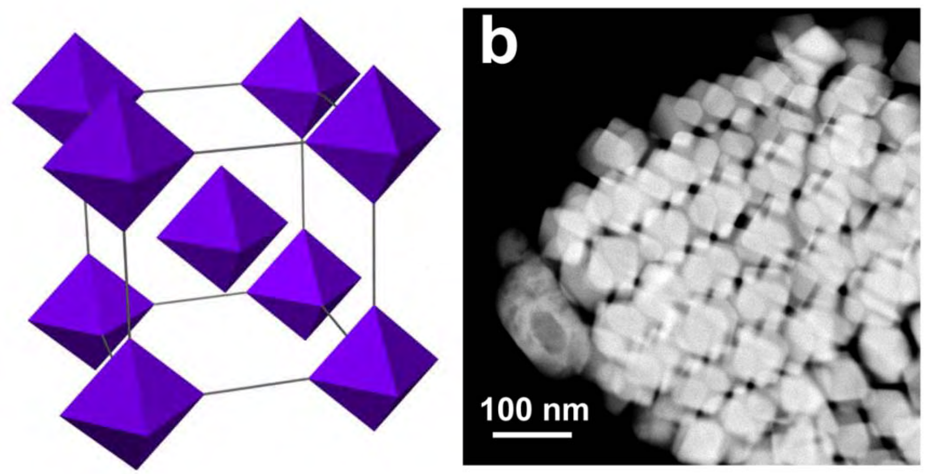
Nanorods ("1D" Structures) form 2D Hexagonal Arrays



Nanoprisms ("2D" Structures) form Linear 1D Arrays



Rhombic Dodecahedra form FCC Lattices



Octahedra can form BCC or FCC Lattices Depending on DNA Length

MURI-04: Biomechanical Interfaces for Cell-Based Microsystems

Team

- Program Manager:
  B. LaMattina (ARO)
- University of Chicago
  - M. Mrksich, A. Dinner
- NU
  - C. Mirkin
- CalTech
  - M. Roukes
- University of Pennsylvania
  - C. Chen
- UCSB
  - A. Evans, R. McMeeking

DoD Labs
L. Whitman, M. Stone

Goals

- **Develop an integrated platform for installing mechanical and chemical interfaces to cells.**
- **Employ platform in investigating chemo-mechanical signatures and actuation of cellular behavior.**
- **Prototype cell-based devices with high impact for the DoD.**

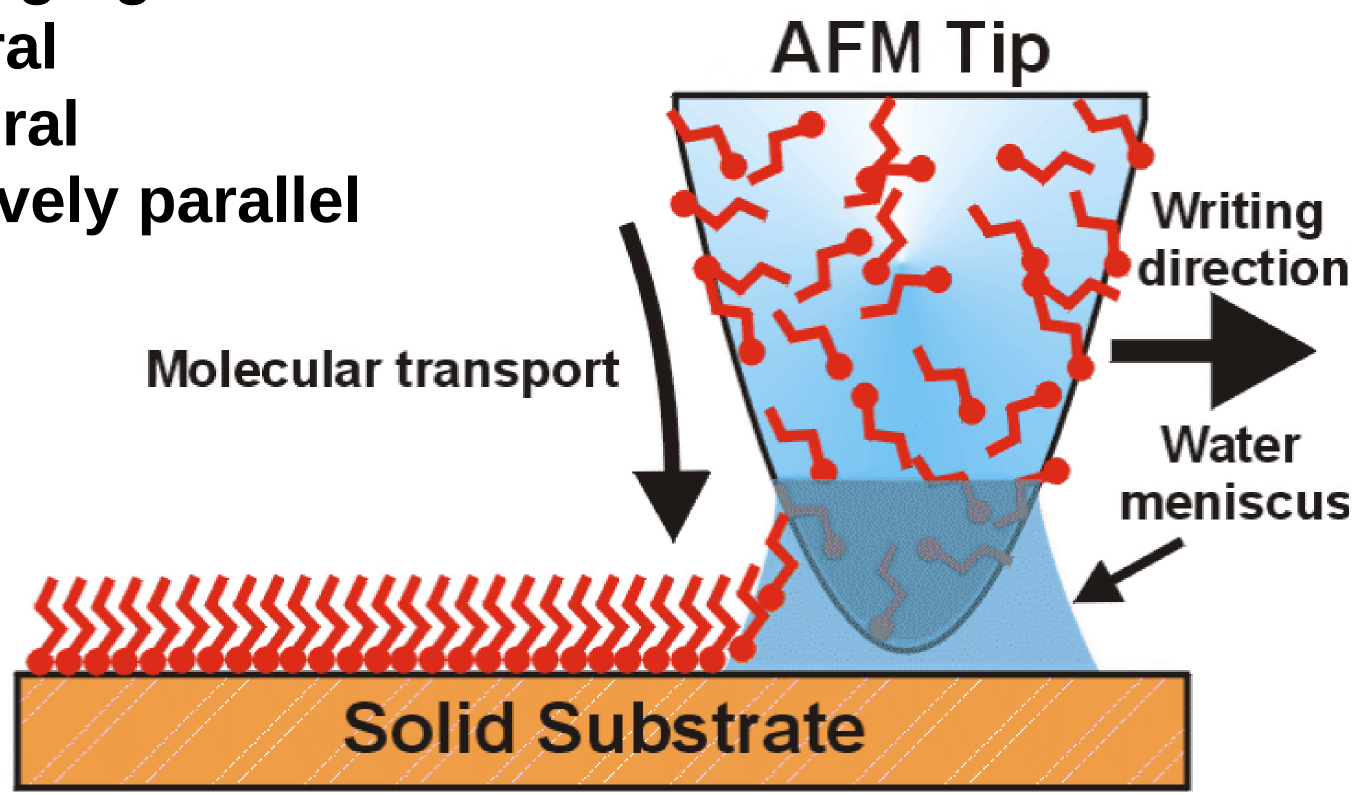
Outcome

- ***An understanding of how to use scanning probe molecular printing techniques to reconstruct models of extracellular matrices.***
- ***Unprecedented ability to manipulate individual biological entities for cell based technologies.***

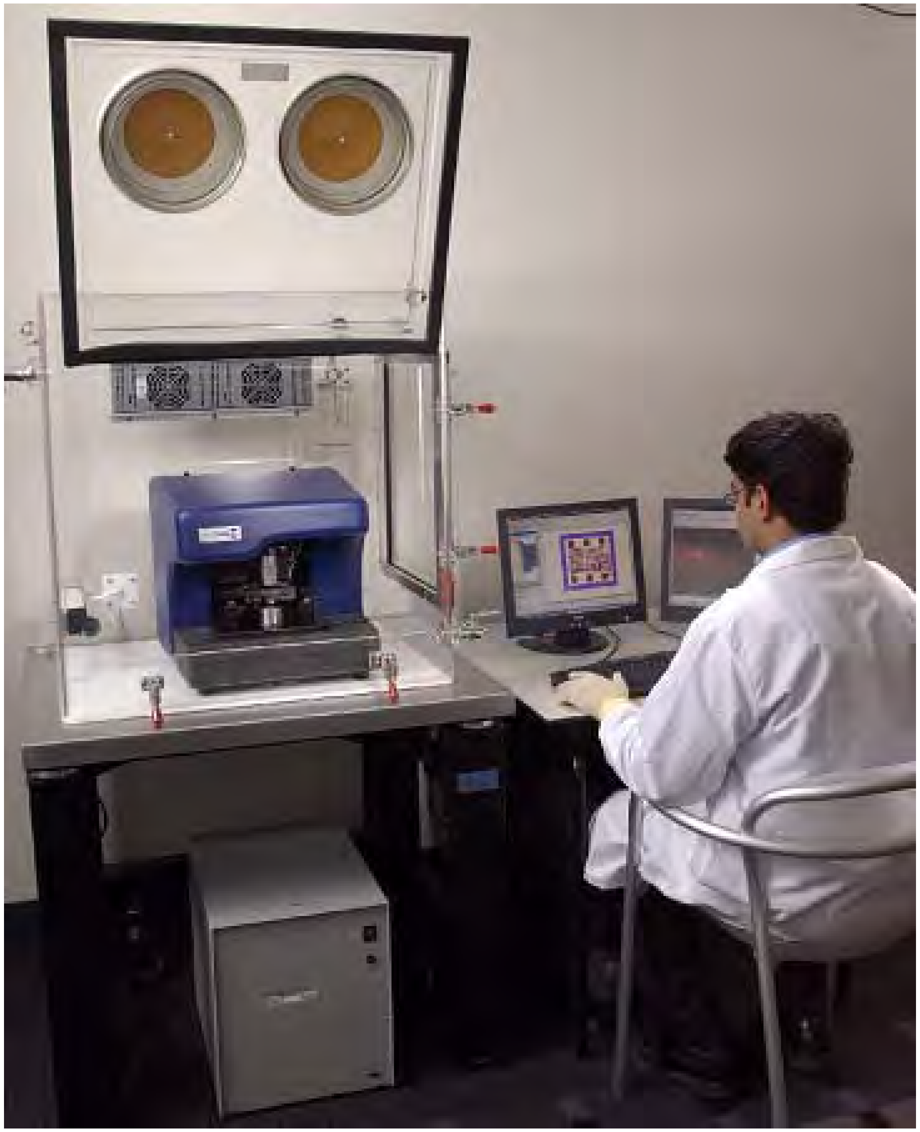
Dip Pen Nanolithography (DPN)

Attributes of DPN:

- Direct-write
- High resolution: 10 nm line width, ~5 nm spatial resolution
- Positive printing
- Writing and imaging with same tool
- Molecule general
- Substrate general
- Serial or massively parallel

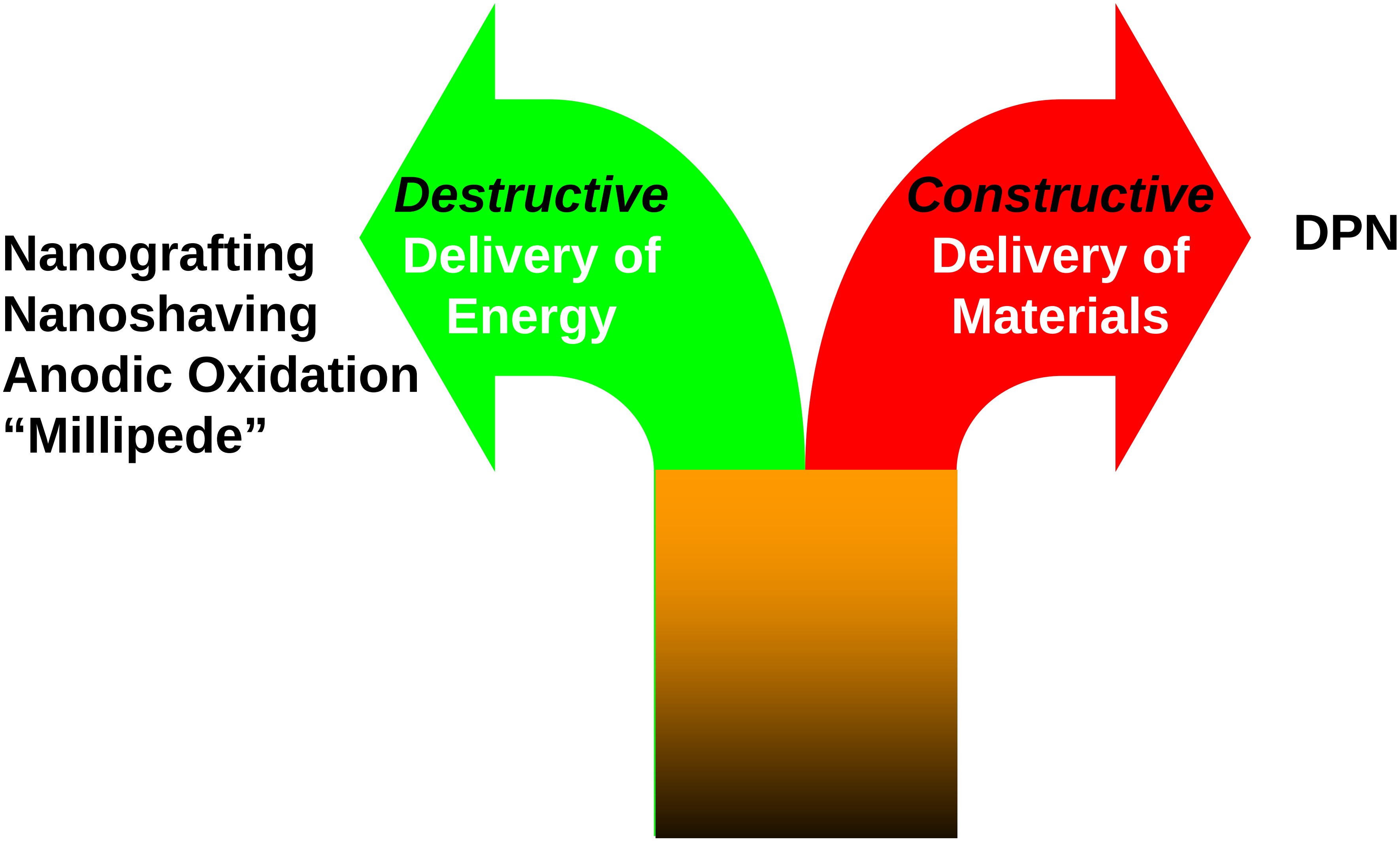


The NSCRIPTOR™
An Integrated DPN System

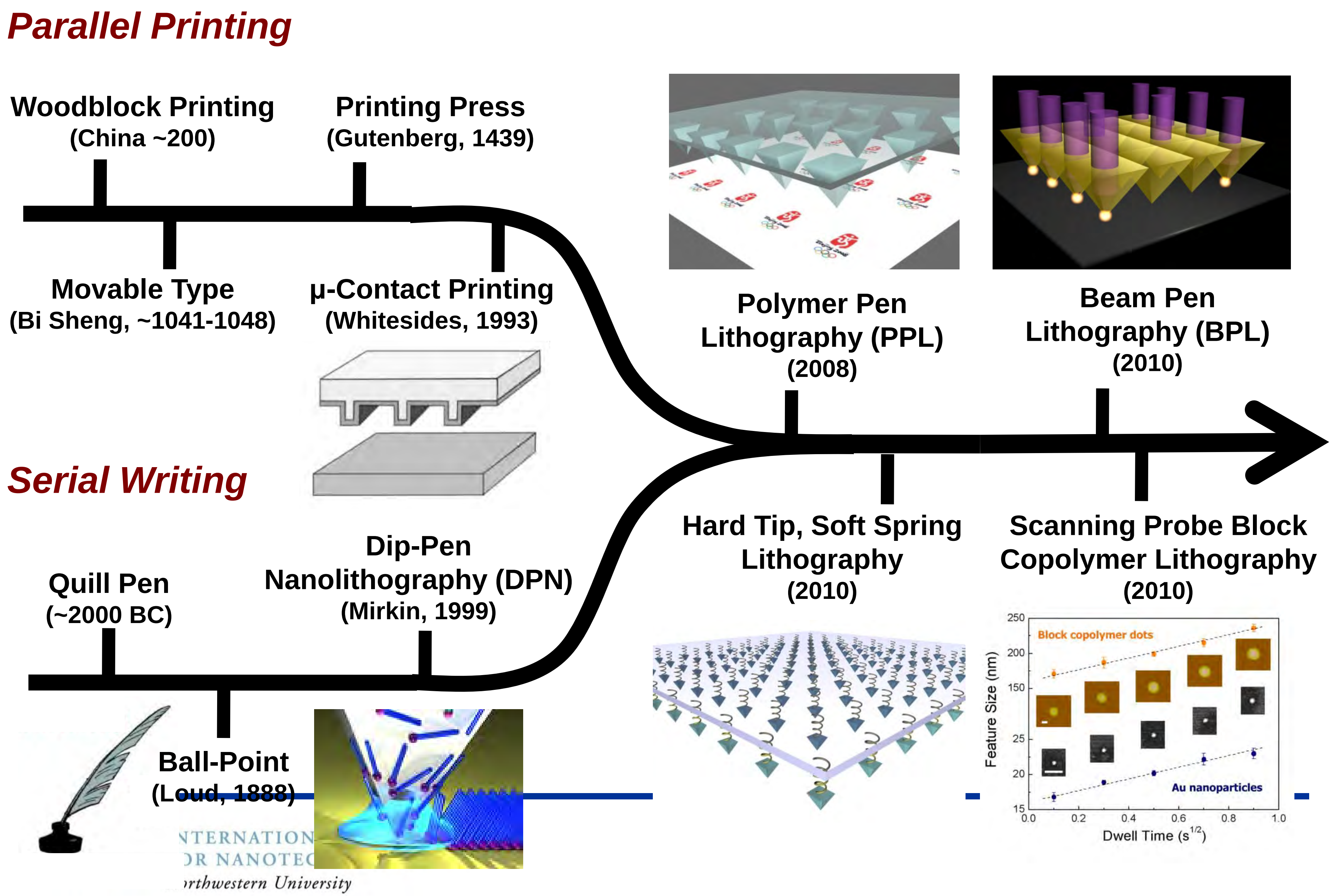


NanoINK INC.

Scanning Probe Lithography: A Dichotomy is Emerging

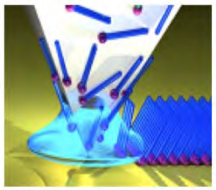


Development of Writing & Printing Tools

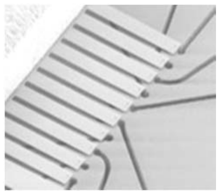


Scanning Probe Molecular Printing

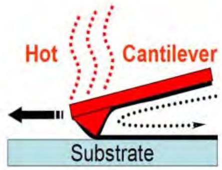
Cantilever-Based



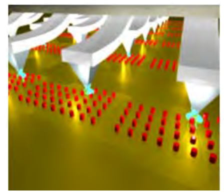
DPN
(1999)



1-D Multipen
Cantilever Array
(2000)



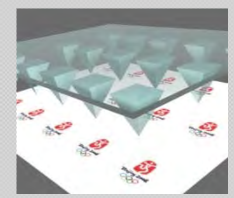
Thermal DPN
(2004)



2-D 55,000 Pen
Cantilever Array
(2006)

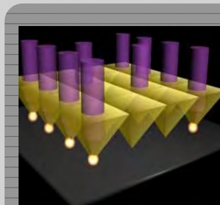
Key Advance 1:
Deposition of materials (through a meniscus) rather than energy

Cantilever-Free

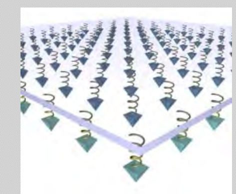


Polymer Pen
Lithography
(2008)

Key Advance 2:
Move the "spring" in a cantilever to an elastomeric pyramid on a solid backing for cantilever-free printing



Beam Pen
Lithography
(2010)

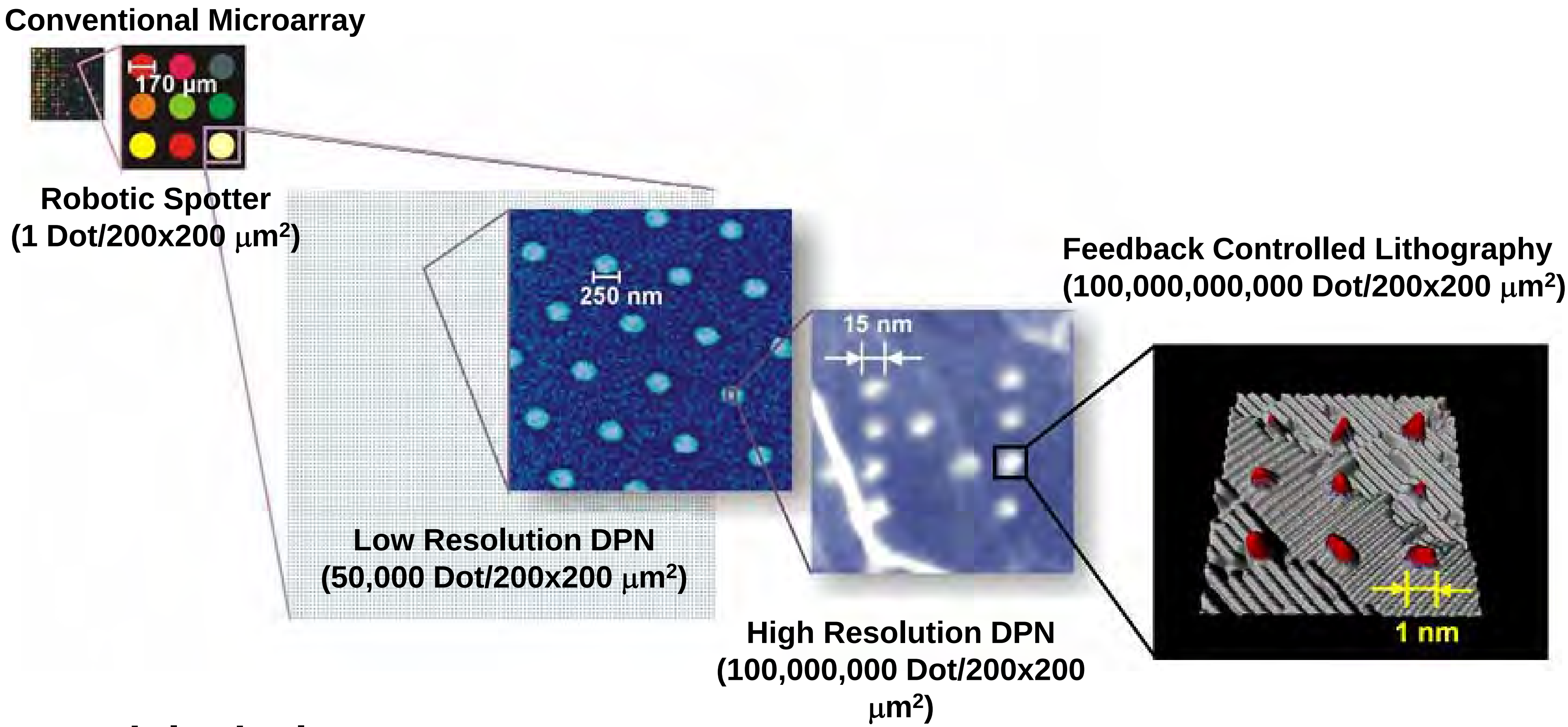


Hard Tip, Soft Spring
Lithography
(2011)

Key Advance 3:
Move the "spring" from the tip (in PPL) to a polymer backing layer

Giam, LR and Mirkin, CA. *Angew. Chem*. 2011. *50*, 7482.

The Ultimate in High Density Arrays

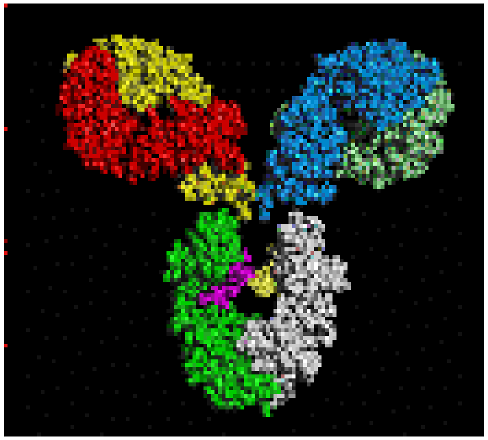


Biological Nanoarrays:

- More than just miniaturization with higher density
- New opportunities for biodetection and studying biorecognition
- Templates for guiding the assembly of larger building blocks
- Open up the opportunity to study multivalency and surface cooperativity

Can DPN be Used To Generate Multicomponent Templates that are Used to Recognize and Larger Biological structures and Organisms?

8.5 nm

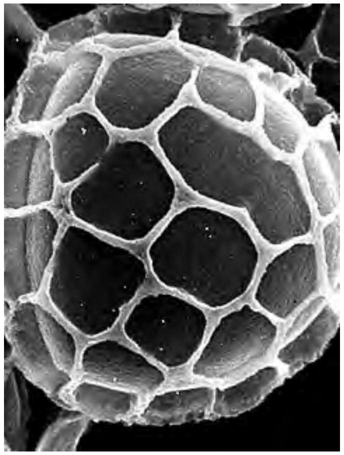


Protein
(Human IgG)

120 nm

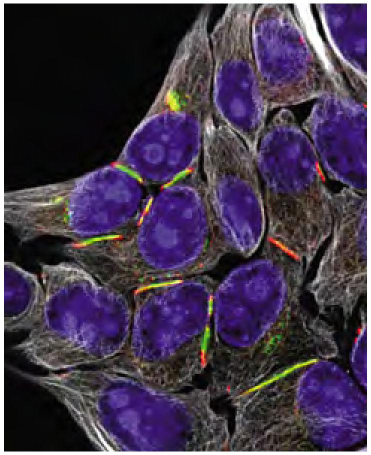
Virus
(HIV)

~20 µm



Spores
(Anthrax)

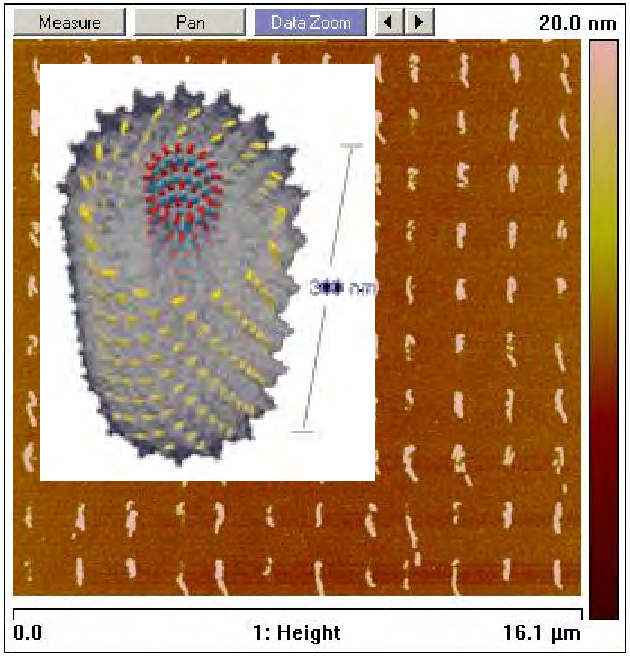
~15 µm

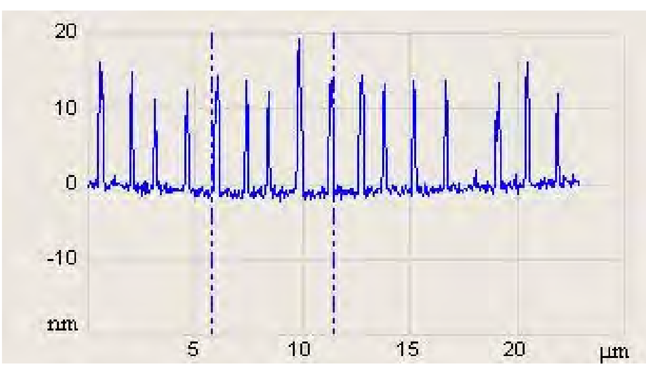


Living Cells

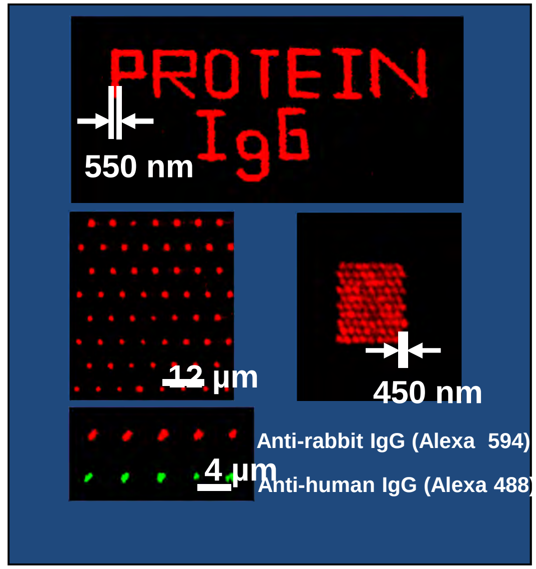
Patterning of Biological Structures

Viruses (TMV)

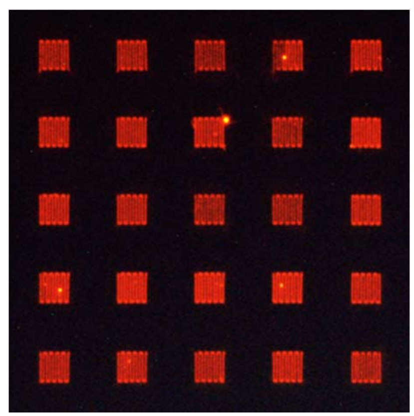


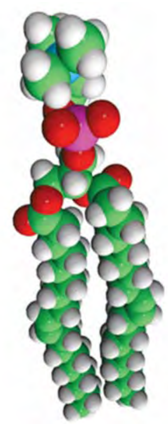


Proteins

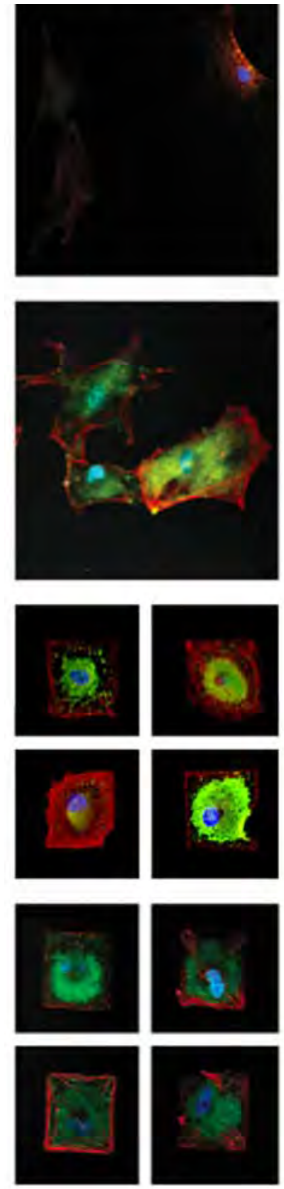


Lipids





Cells



DURINT-01: Ultrasensitive and Selective Chip Based Detection of DNA

Team

- Program Manager: H. DeLong
- NU
  - C. Mirkin, M. Ratner, A. Baron, C. Liu, G. Schatz
- DoD Labs: J. Valdes, M. Goode, M. Stone

Outcomes

- ***Design and creation of novel chip-based detection platforms for the detection of DNA, proteins and peptides that are currently being commercialized by Nanosphere, Inc. and AuraSense, LLC.***

Goals

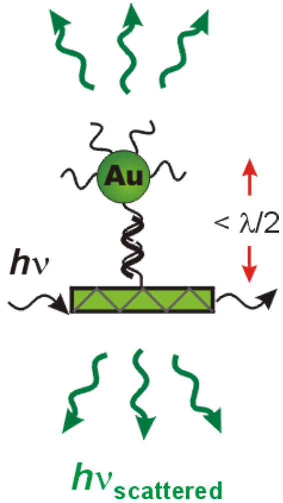
- **Develop understanding of nanoparticle-based sensors for DNA**
- **Engineer chip-based detection platforms**
- **Design and interface target isolation and purification to integrate DNA analysis systems**
- **Create chip based detection strategies for rapid identification of biological warfare agents**

The Properties of Spherical Nucleic Acid (SNA) Nanoparticle Conjugates

Optical

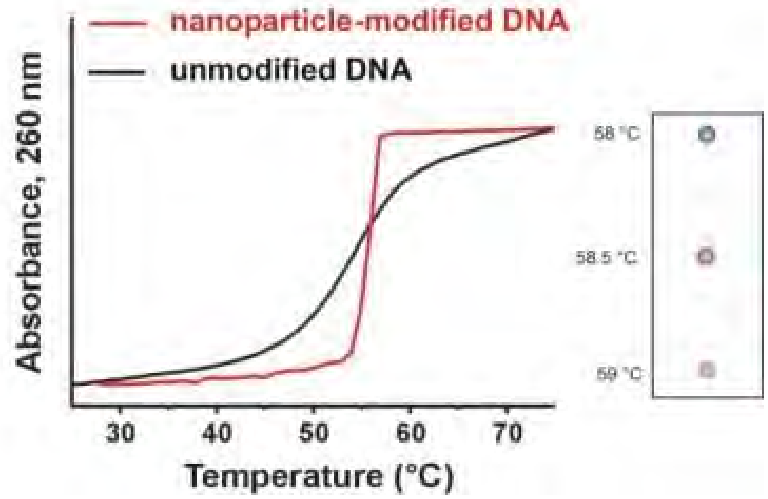
Nature, 1996, *Science*, 1997

Plasmonic



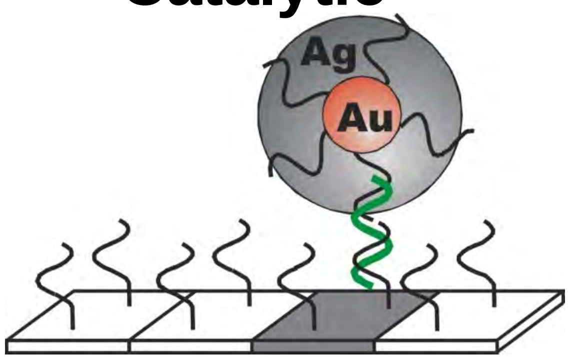
JACS, 2000

Cooperative Binding



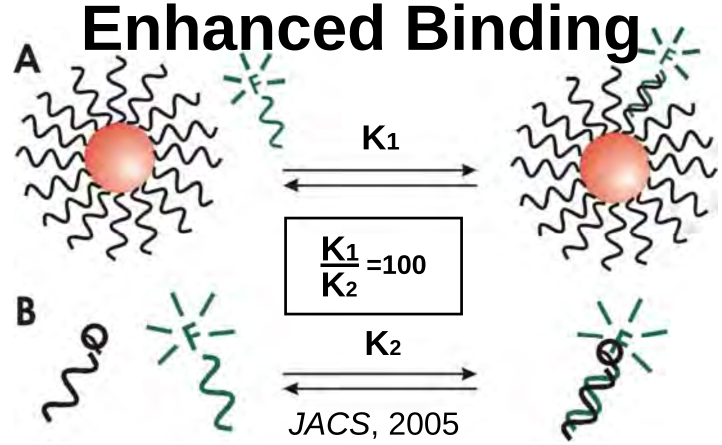
Nature, 1996, *Science*, 1997

Catalytic



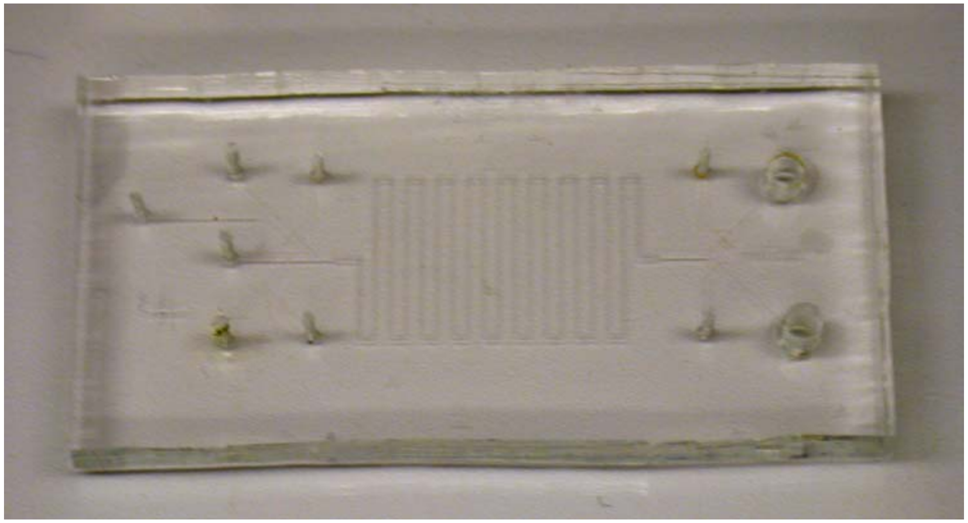
Science, 2000

Enhanced Binding



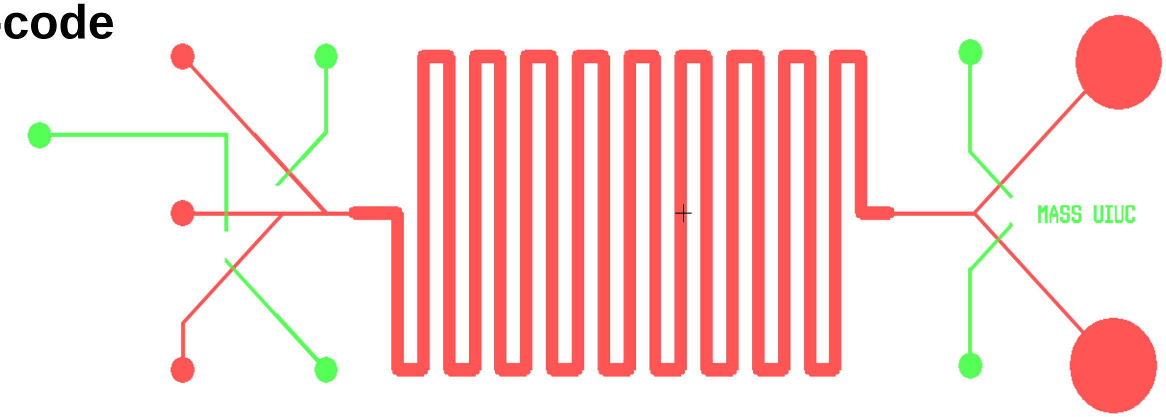
JACS, 2005

Chip-Based Bio-bar-code Assay



- PDMS microfluidic chip on a glass substrate
- A magnet is placed under the chip to immobilize magnetic micro-particles

Several iterations of protocol development were performed to adapt the standard bio-bar-code assay to micro-channels

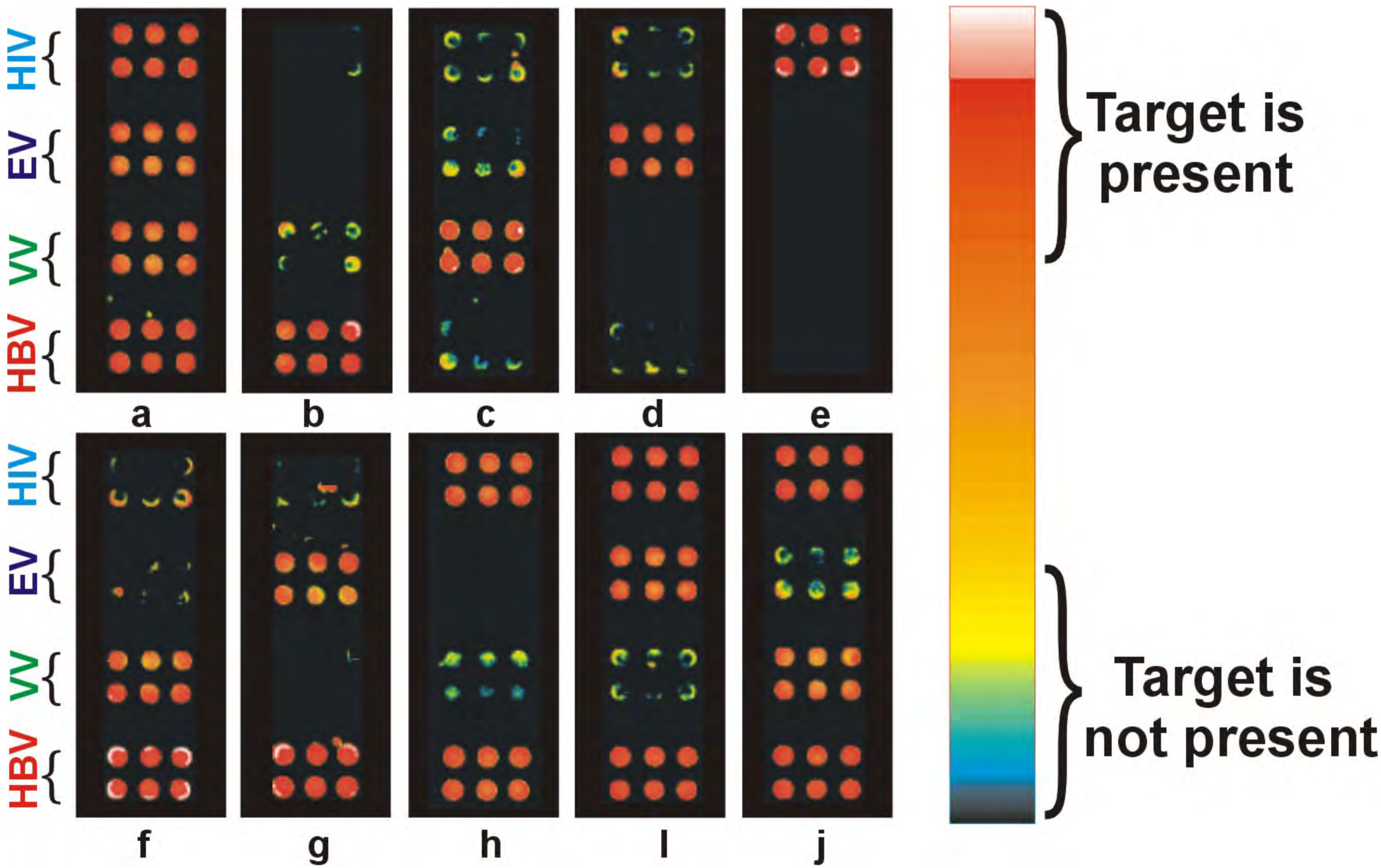


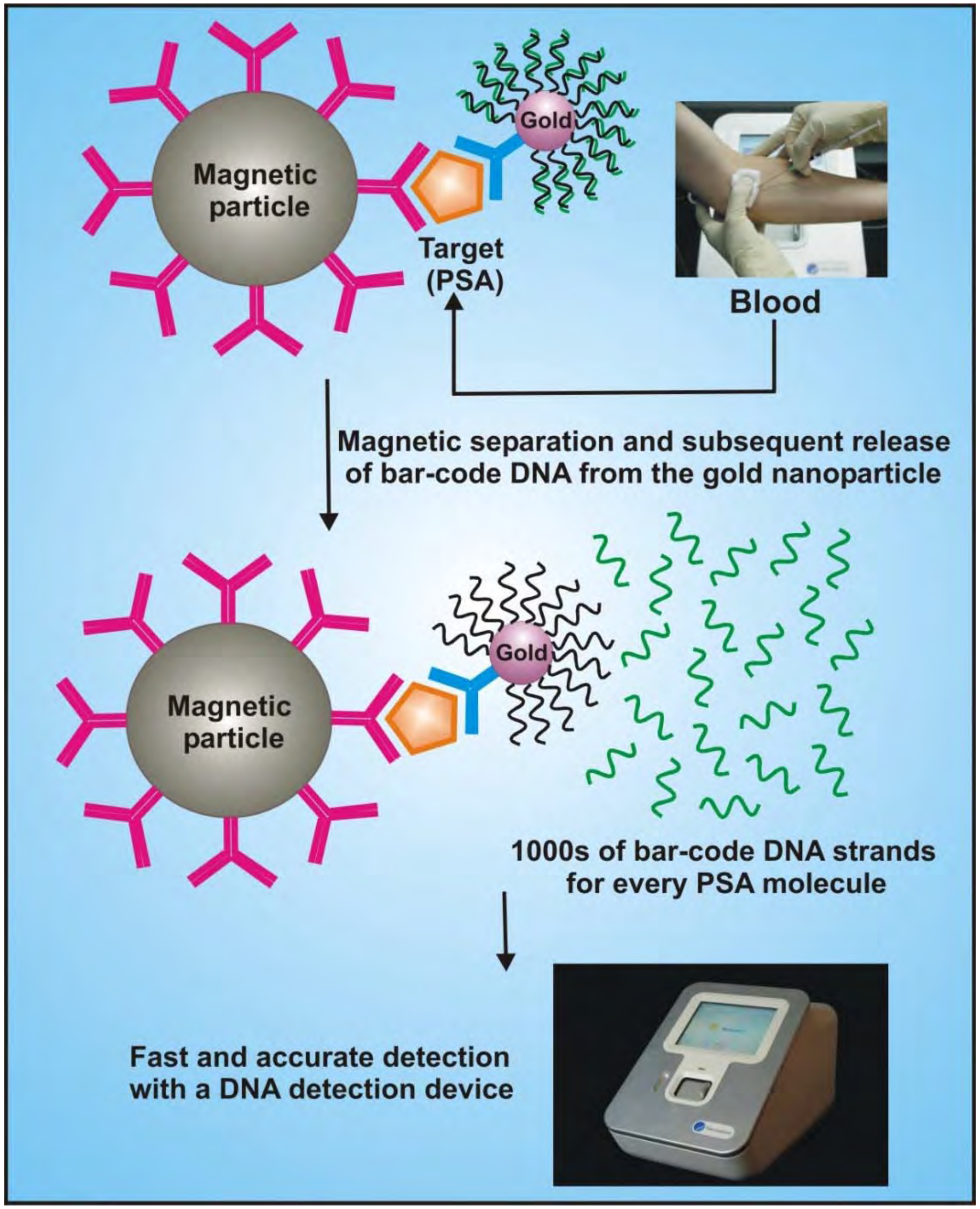
Verigene™ System

FDA-Cleared Hypercoagulation, Warfrin Metabolism, Cystic Fibrosis, and Influenza Assays

- Direct genomic detection
- ~100 aM (10^{-18}) LOD
- Multiplexed targets
- Automated assay process
- Ease of use
  - Minimal training required
  - Automated data tracking
  - No interpretation required

Multiplexed DNA Detection (HIV, Ebola Virus, Small Pox, Hepatitis B): Nucleic Acid Markers





Advantages of the Nanoparticle-based Bio-Barcode Assay

1. **Up to 10^6 times more sensitive than conventional ELISAs.**
2. **Evaluate new biomarkers for diagnosing and following human diseases (e.g. HIV, Cancer, and Alzheimer's Disease).**
3. **Single-cell protein expression experiments.**

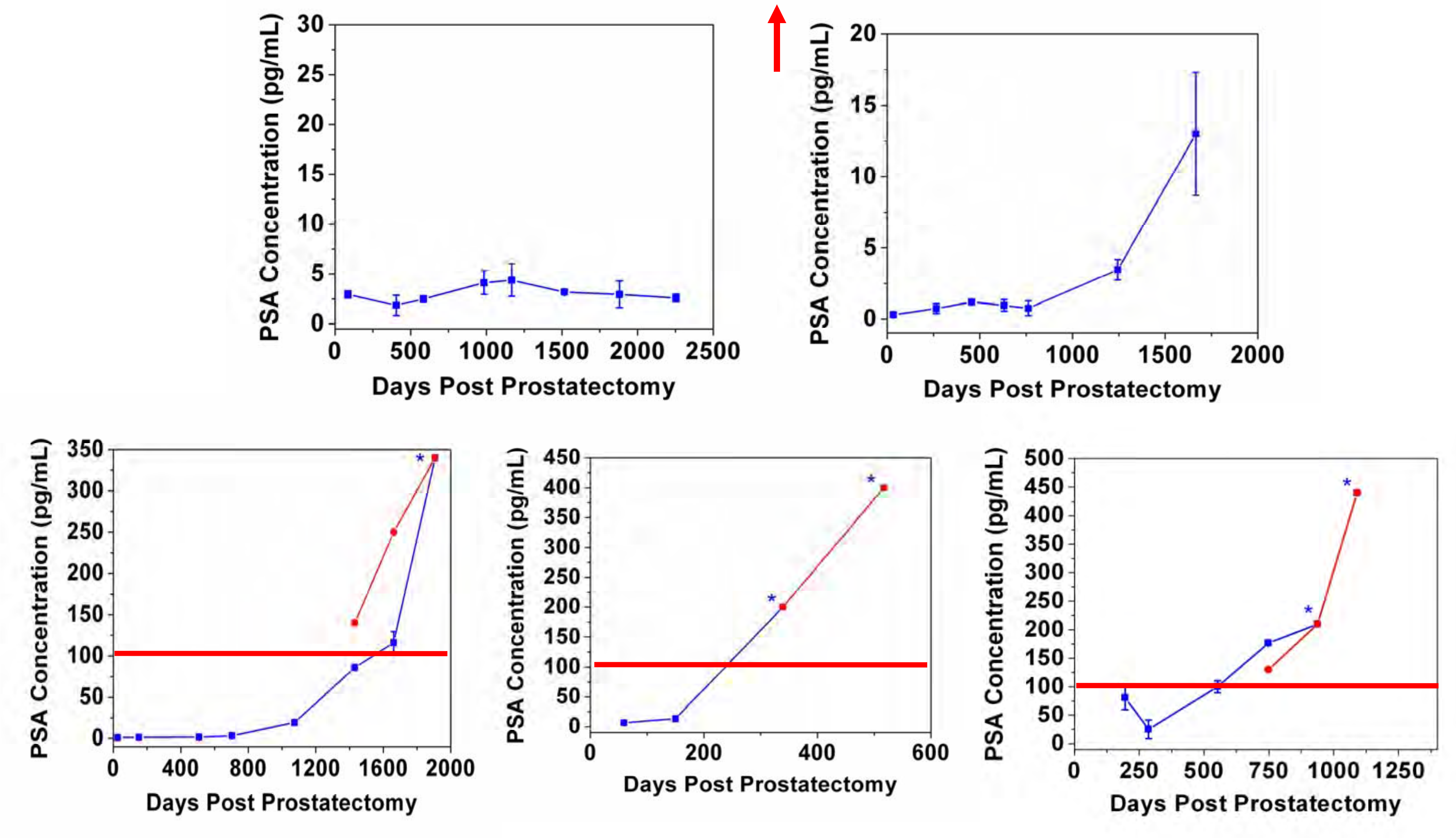
Nanosphere

Field Defining Technologies

Concentration	Molecule/Drop	Detection/ Targets/Disease
10^{-3}- Millimolar	Quadrillions	**Colorimetric/ Enzymatic Chemistry** Blood Sugar (Diabetes)
10^{-6}- Micromolar	Trillions	**ELISA & Chemiluminesence** Troponin, CK-MB, BNP, βHCG
10^{-9}- Nanomolar	Billions	
10^{-12}- Picomolar	Millions	
10^{-15}- Femtomolar	Thousands	**Bio-barcode Technology** Alzheimer's Disease, Mad Cow, Ovarian, Breast, and many other cancers, Pulmonary Disease, Cardiovascular Disease
10^{-18}- Attomolar	Tens	
10^{-21}- Zeptomolar	<1	

Bio-barcode Assay Detects PSA Levels Undetectable by ELISA (450 patient study)

ELISA LOD 100 pg/mL



Acknowledgements

ASD (RE), AFOSR, ARO
DARPA, and ONR

Engineered Resilient Systems (ERS) S&T Priority Description and Roadmap

Dr. Robert Neches

ERS PSC Lead

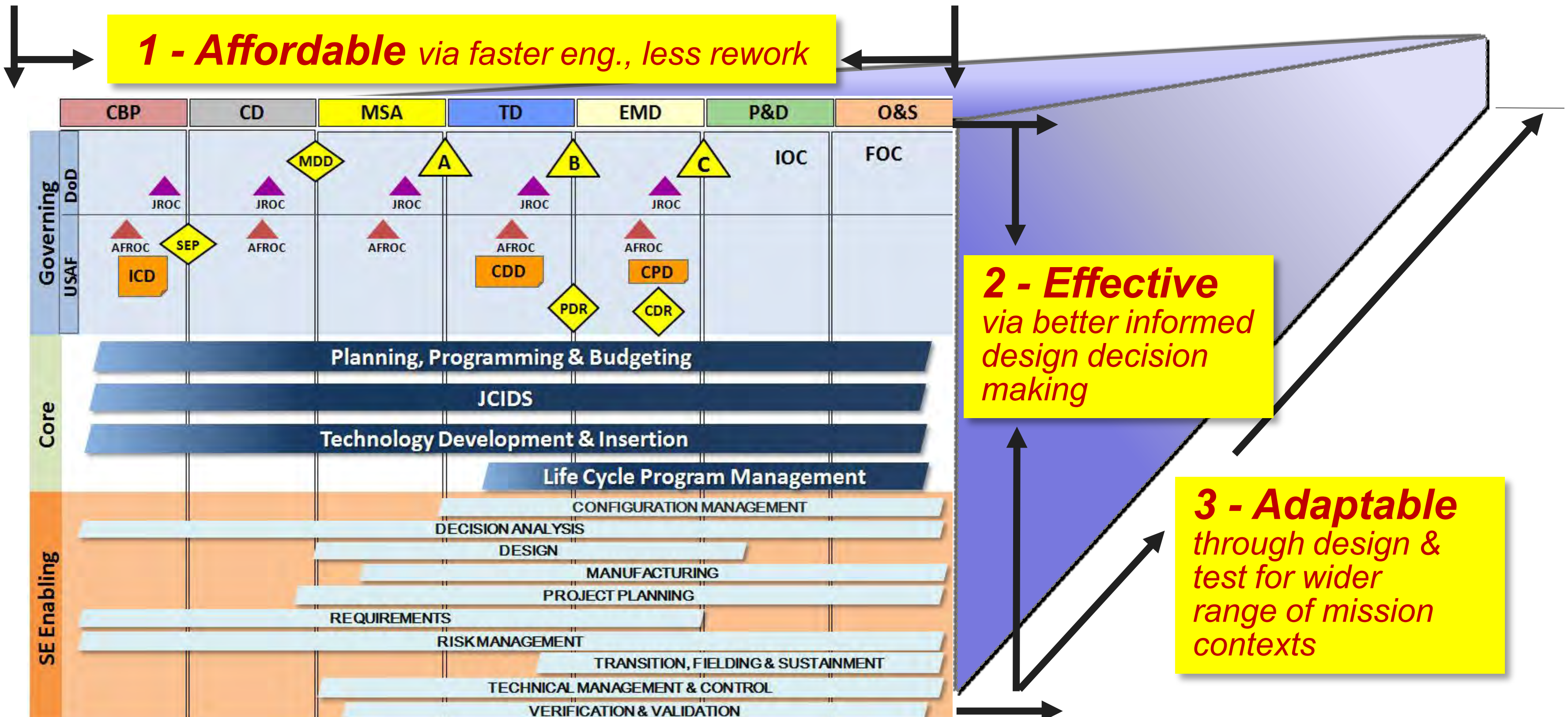
Director, Advanced Engineering Initiatives, ODASD SE

NDIA 8th Annual Disruptive Technologies Conference

8 November 2011

Engineered Resilient Systems Spans the Systems Life cycle

Resilience: Effective in a wide range of situations, readily adaptable to others through reconfiguration or replacement, with graceful and detectable degradation of function



Uncertain futures, and resultant mission volatility, require affordably adaptable and effective systems – done quickly

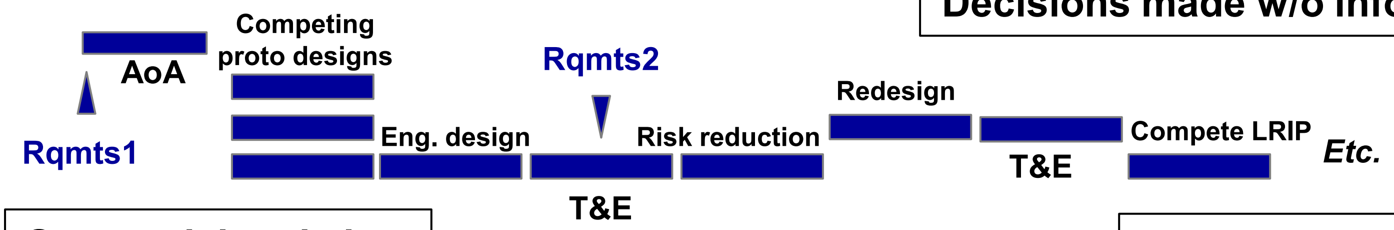
Engineered Resilient Systems

Today

50 years of process reform haven't controlled time, cost, and performance

Rapidly necks down alternatives

Decisions made w/o info



Sequential and slow

Information lost at every step

Ad hoc reqmts refinement

New tools help engineers and users understand interactions, identify implications, and decide how to manage consequences

Fast, easy, inexpensive up-front engineering:

- Automatically consider many variations
- Propagate changes, maintain constraints
- Introduce and evaluate many usage scenarios
- Analyze to compare and understand technical & operational tradeoffs
- Iteratively refine requirements in light of feasibilities and opportunities
- Learn and update

Where We Need to Go

Engineered Resilient Systems: Needs and Technology Issues

Creating & fielding affordable, effective systems entails:

- **Deep trade-off analyses across mission contexts**
  - **Adaptability, effectiveness and affordability in the trade-space**
  - **Maintained for life**
- **More informative requirements**
- **Well-founded requirements refinement**
- **More alternatives, maintained longer**

Doing so quickly and adaptably requires new technology:

- **Models with representational richness**
- **Learning about operational context**
- **Uncertainty- and Risk- based tools**

Starting point: Model- and Platform- based engineering

System Representation and Modeling: Technical Gaps and Challenges

Technology	10-Yr Goal	Gaps
Capturing • ***Physical and logical structures*** • ***Behavior*** • ***Interaction with the environment and other systems***	**Model 95% of a complex weapons system**	• Combining live and virtual worlds • Bi-directional linking of physics-based & statistical models • Key multidisciplinary, multiscale models • Automated and semi-automated acquisition techniques • Techniques for adaptable models

We need to create and manage many classes (*executable, depictional, statistical...*) and many types (*device and environmental physics, comms, sensors, effectors, software, systems ...*) of models

Characterizing Changing Operational Environments: Technical Gaps and Challenges

Technology	10-Yr Goal	Gaps
Deeper understanding of warfighter needs ***Directly gathering operational data*** ***Understanding operational impacts of alternatives***	**Military Effectiveness Breadth Assessment Capability**	• Learning from live and virtual operational systems • Synthetic environments for experimentation and learning • Creating operational context models (missions, environments, threats, tactics, and ConOps) • Generating meaningful tests and use cases from operational data • Synthesis & application of models

"Ensuring adaptability and effectiveness requires evaluating and storing results *from many, many scenarios* (including those presently considered unlikely) *for consideration earlier* in the acquisition process."

Cross-Domain Coupling: Technical Gaps and Challenges

Technology	10-Yr Goal	Gaps

Better interchange between incommensurate models
 	
Resolving temporal, multi-scale, multi-physics issues
	Weapons system modeled fully across domains	• Dynamic modeling/analysis workflow
		• Consistency across hybrid models
		• Automatically generated surrogates
		• Semantic mappings and repairs
		• Program interface extensions that:
		    • Automate parameterization and boundary conditions
		    • Coordinate cross-phenomena simulations
		    • Tie to decision support
		    • Couple to virtual worlds

Making the wide range of model classes and types work together effectively requires new computing techniques (not just standards)

Tradespace Analysis: Technical Gaps and Challenges

Technology	10-Yr Goal	Gaps
Efficiently generating and evaluating alternative designs ***Evaluating options in multi-dimensional tradespaces***	**Trade analyses over *very large* condition sets**	• Guided automated searches, selective search algorithms • Ubiquitous computing for generating/evaluating options • Identifying high-impact variables and likely interactions • New sensitivity localization algorithms • Algorithms for measuring adaptability • Risk-based cost-benefit analysis tools, presentations • Integrating reliability and cost into acquisition decisions • Cost-and time-sensitive uncertainty management via experimental design and activity planning

Exploring more options and keeping them open longer, by managing complexity and leveraging greater computational testing capabilities

Collaborative Design & Decision Support: Technical Gaps and Challenges

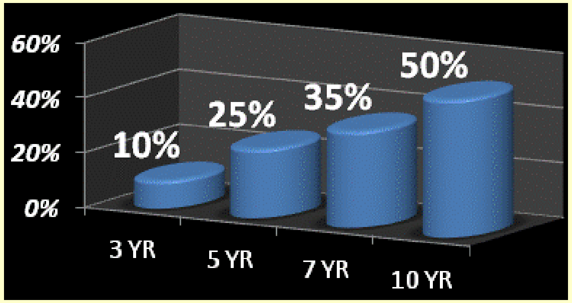
Technology	10-Yr Goal	Gaps
Well-informed, low-overhead collaborative decision making	**Computational / physical models bridged by 3D printing** ***Data-driven* trade decisions executed and recorded**	• Usable multi-dimensional tradespaces • Rationale capture • Aids for prioritizing tradeoffs, explaining decisions • Accessible systems engineering, acquisition, physics and behavioral models • Access controls • Information push-pull without flooding

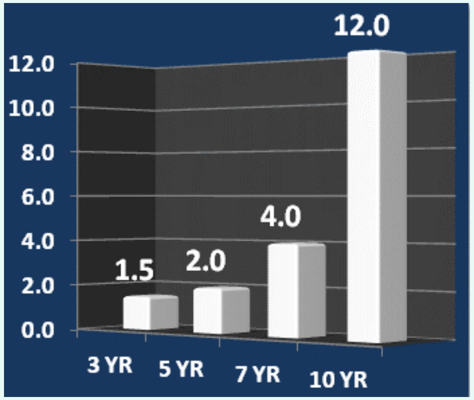
ERS requires the transparency for many stakeholders to be able to understand and contribute, with low overhead for participating

What Constitutes Success?

Adaptable (and thus robust) designs

– Diverse system models, easily accessed and modified
– Potential for modular design, re-use, replacement, interoperability
– Continuous analysis of performance, vulnerabilities, trust
– ***Target: 50% of system is modifiable to new mission***



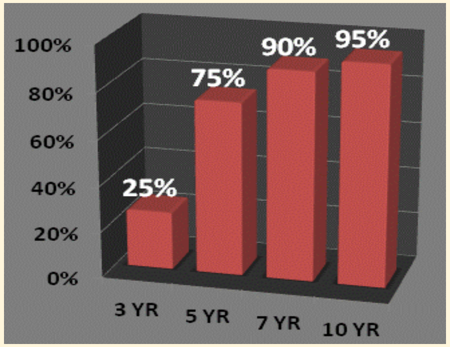


Faster, more efficient engineering iterations

– Virtual design – integrating 3D geometry, electronics, software
– Find problems early:
– Shorter risk reduction phases with prototypes
– Fewer, easier redesigns
– Accelerated design/test/build cycles
– ***Target: 12x speed-up in development time***

Decisions informed by mission needs

– More options considered deeply, broader trade space analysis
– Interaction and iterative design among collaborative groups
– Ability to simulate & experiment in synthetic operational environments
– ***Target: 95% of system informed by trades across ConOps/env.***



Opportunities to Participate

DoD Needs Innovative Tools and Algorithms from Industry and Academia

Organization	BAA Title	Closing Date	Reference #
ONR	Energetic Materials Program R&D	23-Dec-11	12-SN-0001
Dept of Army	Adaptive Vehicle Management System (AVMS) Phase II	6-Jan-12	W911W6-11-R-0013
NAWC Lakehurst	BAA Reconnaissance and Surveillance payloads, sensors, delivery systems and platforms	14-Feb-12	N68335-11-R-0018
NAVFAC	BAA Expeditionary technologies	2-Mar-12	BAA-09-03-RIKA
US Army USACE	2011 BAA	31-Mar-12	W912HZ-11-BAA-02
NRL	NRL-Wide BAA	16-Jun-12	BAA-N00173-01
US Army RDECOM-ARDEC	Technology Focused Areas of Interest BAA	15-Sep-12	W15QKN-10-R-0513
ARL	Basic and Applied Scientific Research	31-Dec-12	W911NF-07-R-0003-04 & -0001-05
Dept of Army	Army Rapid Innovation Fund BAA	29-Sep-12	W911NF11R0017
ONR	BAA, Navy and Marine Corp S&T	30-Sep-12	ONR 12-002
NASC Training Sys Div	R&D for Modeling and Simulation Coordination Office	4-Dec-12	N61339-08-R-0013
AFRL Kirtland	STRIVE BAA	Draft Posted	FA945311R0285
WHS	DoD Rapid Innovation Fund	n/a	HQ0034-RIF-11-BAA-0001
AFRL WPAFB	Reasoning, Comprehension, Perception and Anticipation in Multi-Domain Environments	n/a	BAA-10-03-RIKA
AFRL Rome	Emerging Computing Technology and Applications	n/a	BAA-09-08-RIKA
AFRL Rome	Cross Domain Innovative Technologies	n/a	BAA-10-09-RIKA
AFRL Rome	Computing Architecture Technologies BAA	n/a	BAA-09-03-RIKA
WHS	Systems 2020	n/a	Subject to Presidential Budget Approval

Envisioned End State

Improved Engineering and Design Capabilities

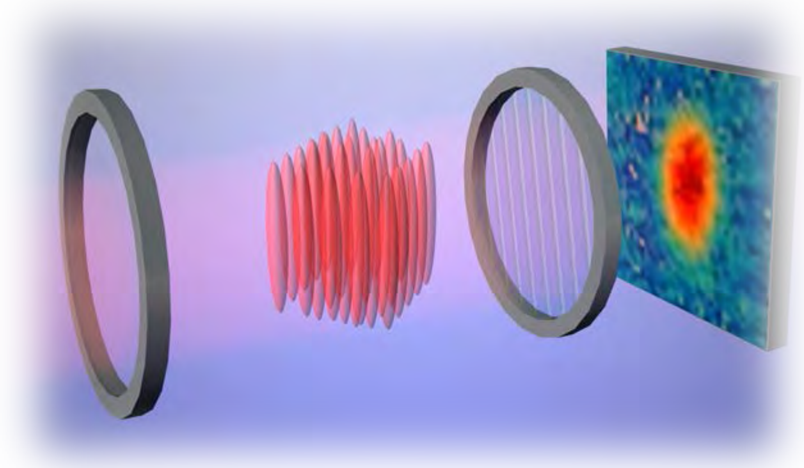
- More environmental and mission context
- More alternatives developed, evaluated and maintained
- Better trades: managing interactions, choices, consequences

Improved Systems

- Highly effective: better performance, greater mission effectiveness
- Easier to adapt, reconfigure or replace
- Confidence in graceful degradation of function

Improved Engineering Processes

- Fewer rework cycles
- Faster cycle completion
- Better managed requirements shifts



The Excitement of the MURIs

Dr. Peter Reynolds
Senior Research Scientist
Physical Sciences
Army Research Office

Some MURIs I have known

- **Atom Optics**
- *Optical Clocks/Frequency Combs*
- Laser cooling of solids (e.g., semiconductors)
- Quantum Computing/Quantum Information
  - Quantum Memories, Interfaces, Repeaters…
- Quantum Imaging
- Optical Lattices
- Atomtronics
- *Ultra-cold Molecules*

Outline

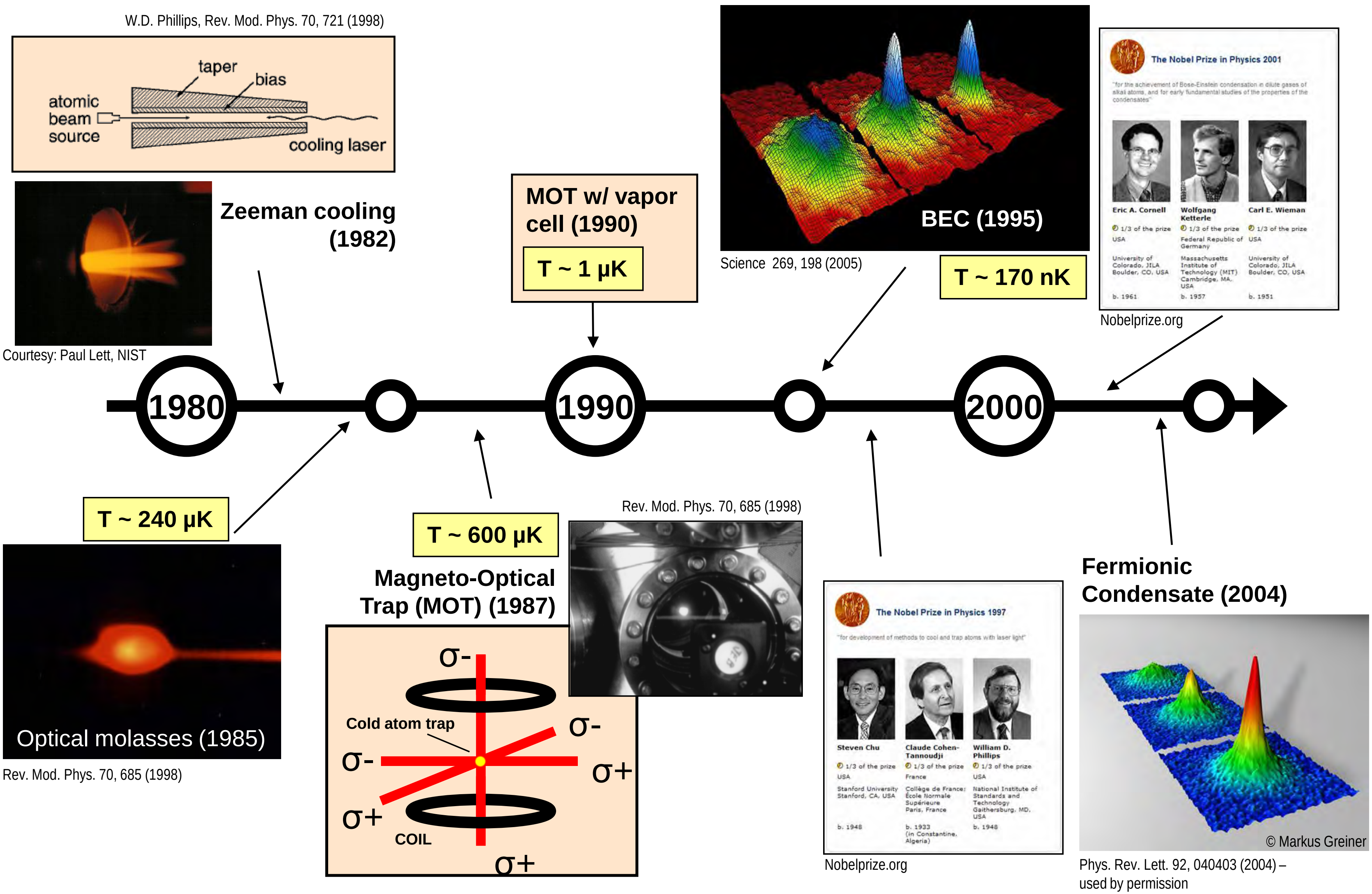
- Case study: Atom Optics MURI
  - Basic Research as Foundation to MURIs
  - MURI Research
  - Follow-on programs
  - Transition to Industry

- Some recent and current MURIs

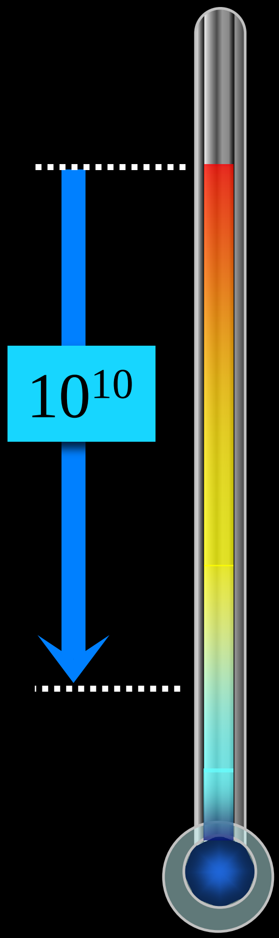
Case study: Atom Optics MURI
Basic research pre-history—Key elements

- 1980s to early 1990s: Laser cooling and trapping of atoms
  - Used largely for improving spectroscopy / fundamental measurements. (e.g., Parity Non-conservation)
  - Potential role in time and frequency recognized by ONR and NIST
- ~1990: Atom interferometry
  - Largely based on atomic beams, then later incorporated laser cooling
  - 1991: First atom interferometry using nanofabricated mechanical grating
- 1993: Atom guiding
  - JILA experiments, first with hollow optical fibers, later with magnetic guides
- 1995: First demonstration of Bose-Einstein condensation
- 1995: Atom analog of optical laser
  - BEC and more generally "ultracold" became a focal point for AMO physics
- 1997: Atom guiding and interferometry on "atom chips"
- ~2000: Fermi degeneracy and later superfluidity

A History of Basic Research in Cold Atoms

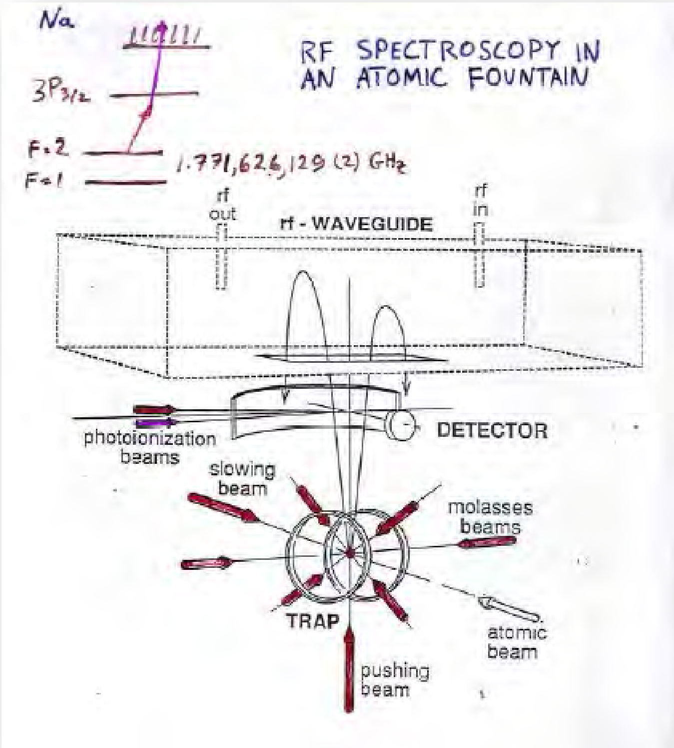


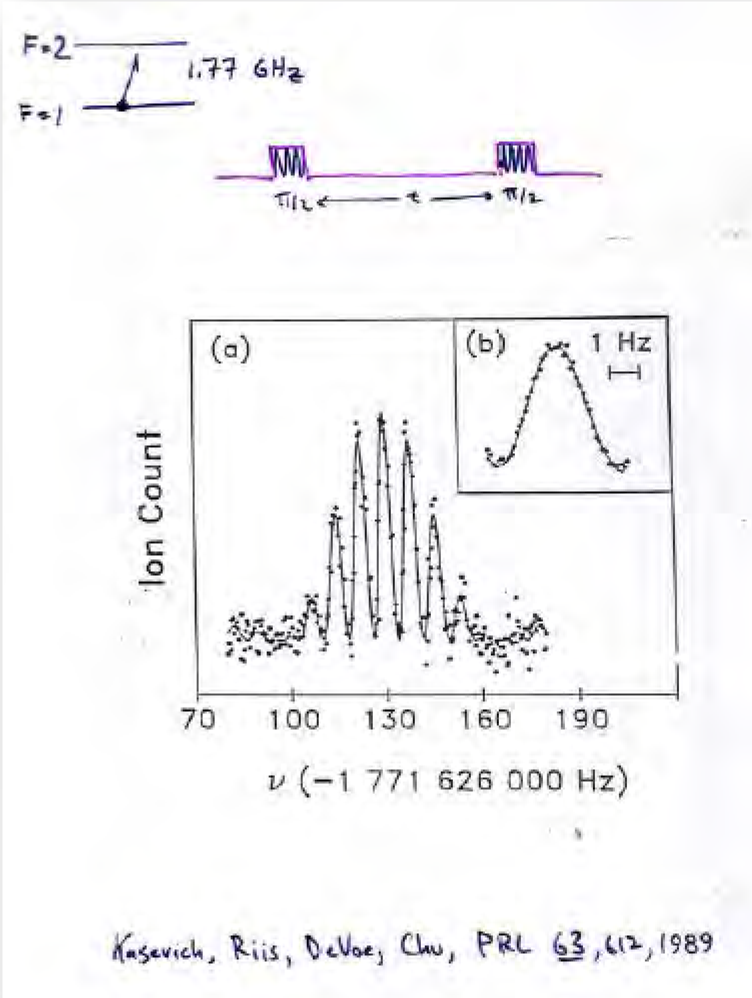
The Wavelength of an Atom (^{87}Rb)



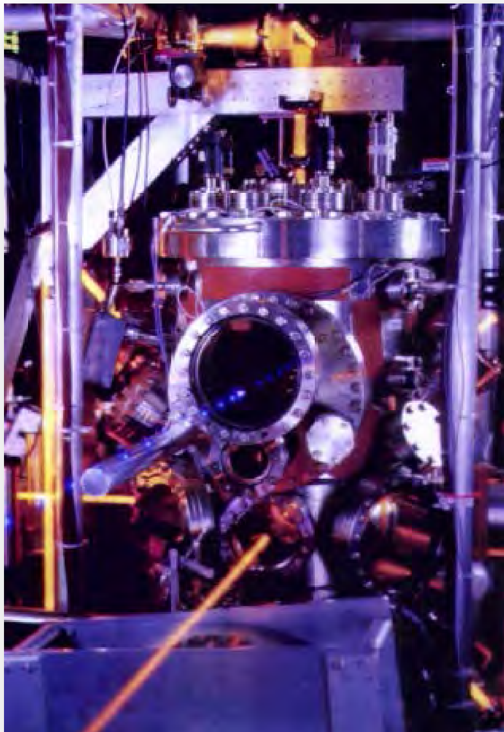
T (K)	λ (nm)	v (m/s)	t (s)
300	.02	300	.03
	(Smaller than the atom itself)		
1	0.3	20	0.2
	(The size of a small molecule)		
10^{-3}	9	0.5	6
	(The size of a medium molecule)		
10^{-6}	300	2 cm/s	2 min
	(Approaching the wavelength of light)		
10^{-9}	9000	0.5 mm/s	1.5 hr
	(MEMS size)		

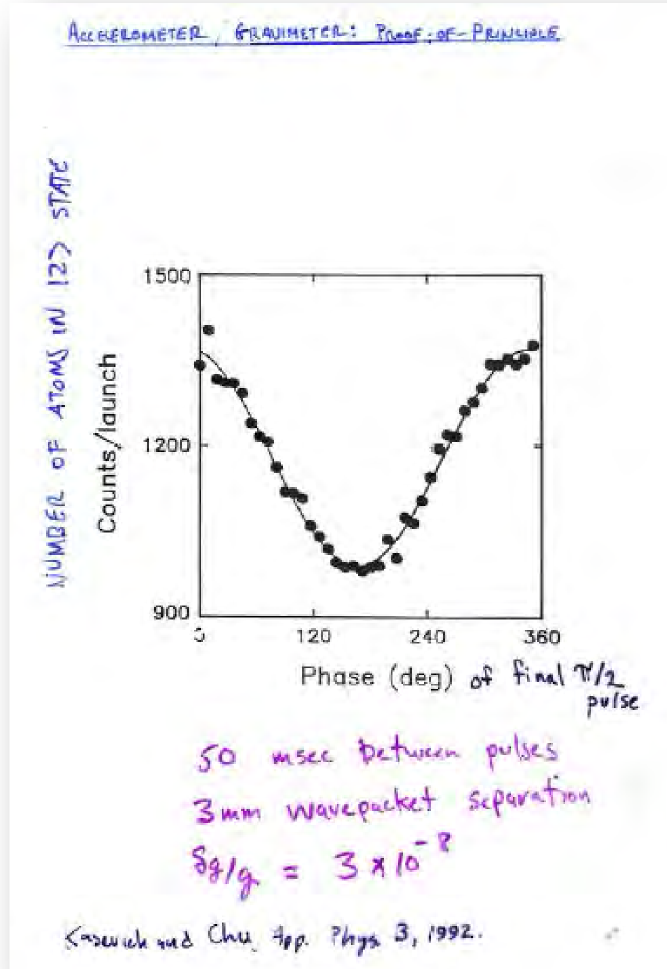
1989 Atomic Fountain RF Spectroscopy





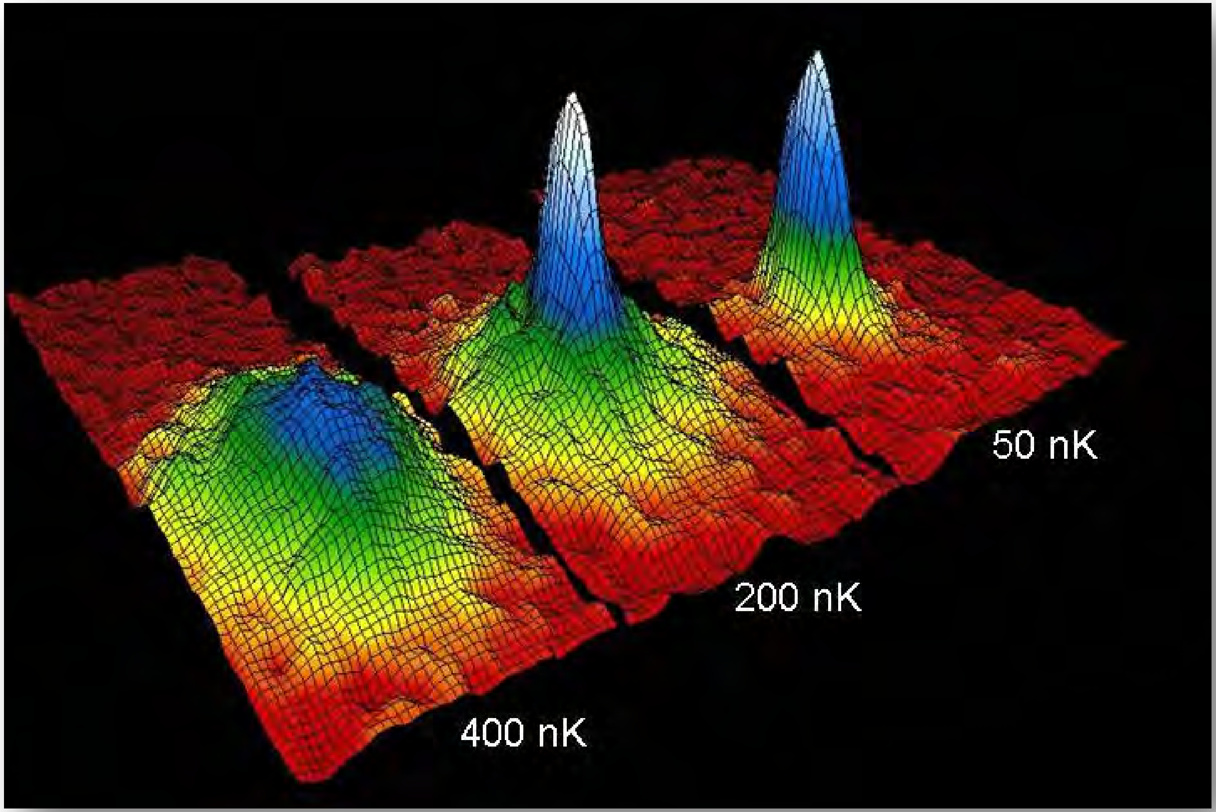
1991 Light-Pulse Atom Interferometer





1995 Bose-Einstein Condensation

- Thermal cloud
  - Maxwell-Boltzman distribution of energies



- BEC
  - All atoms share same quantum wavefunction
  - Quantum mechanical coherence

What is a BEC?

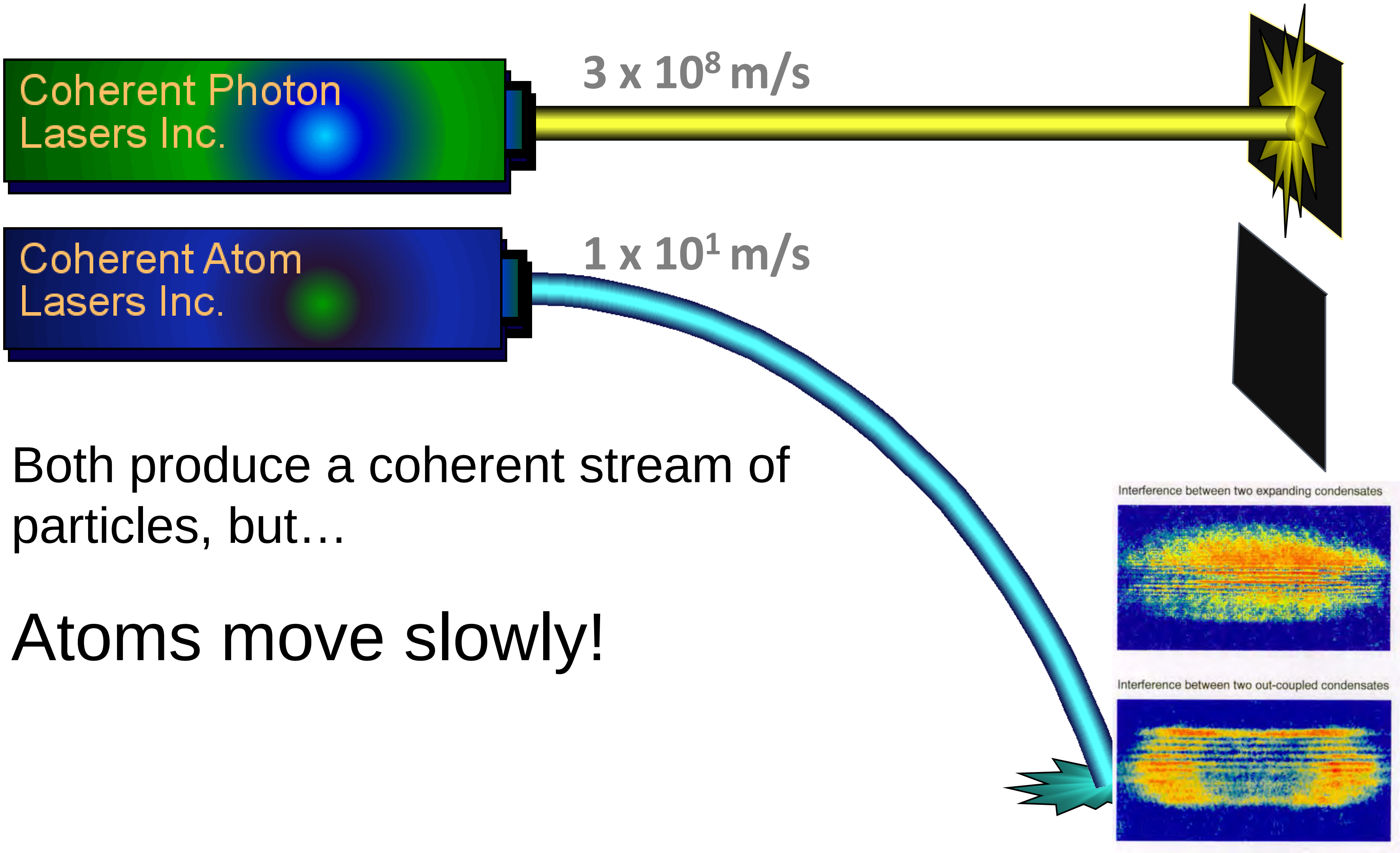
The BEC:

A source of mutually coherent *atoms*

The Laser:

A source of mutually coherent *photons*

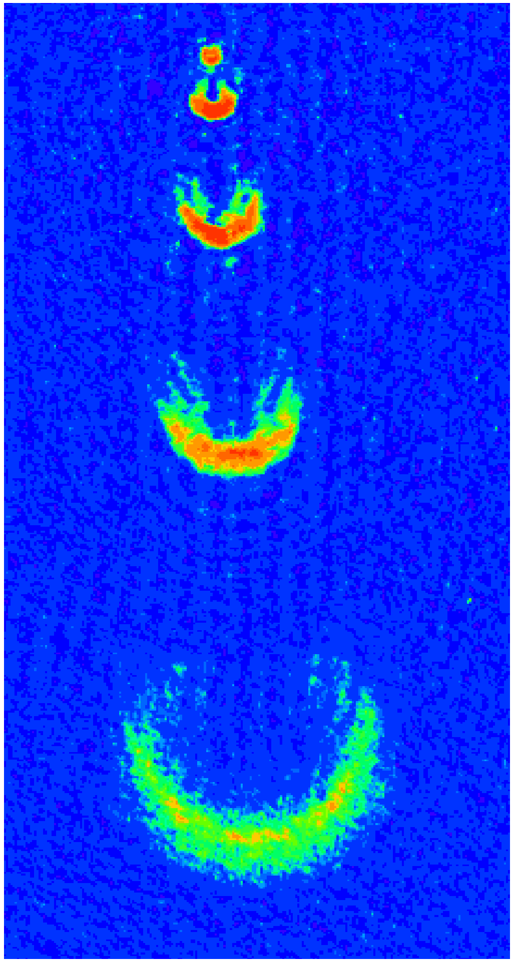
Photonic versus atomic laser



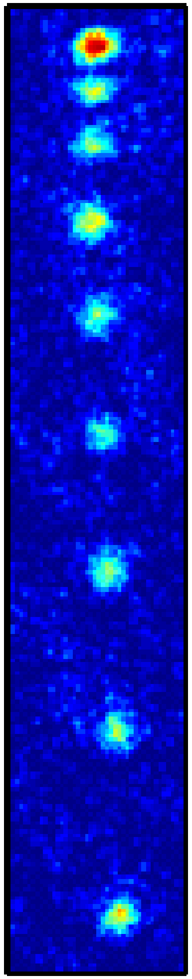
Both produce a coherent stream of particles, but…

Atoms move slowly!

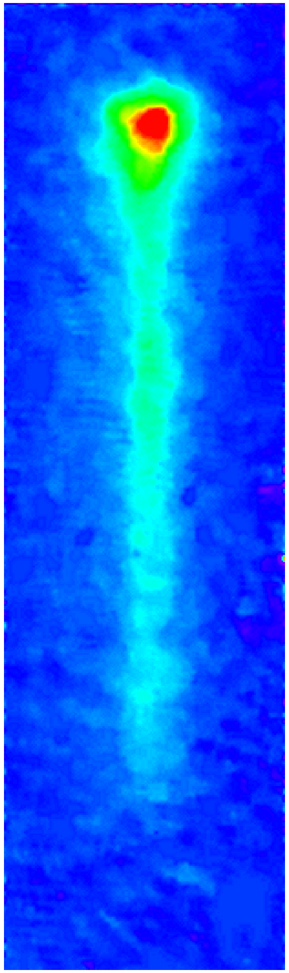
Atom Laser Gallery



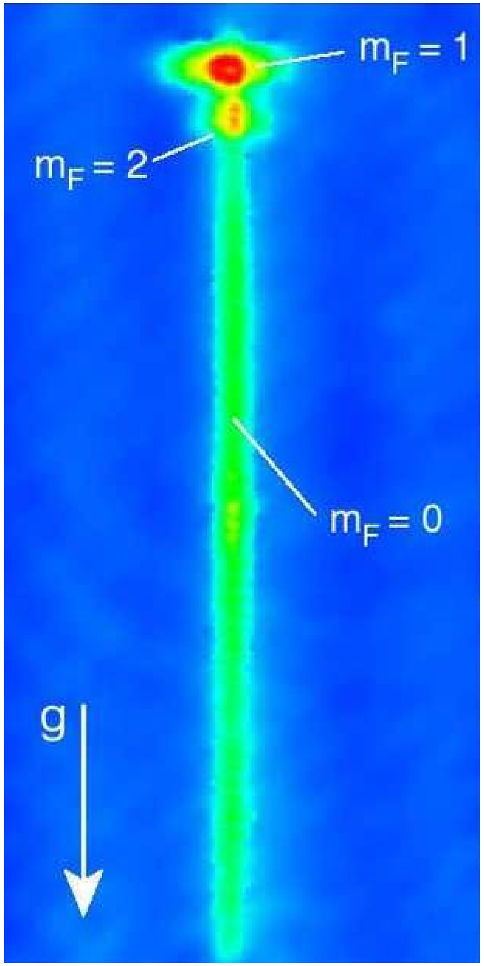
MIT



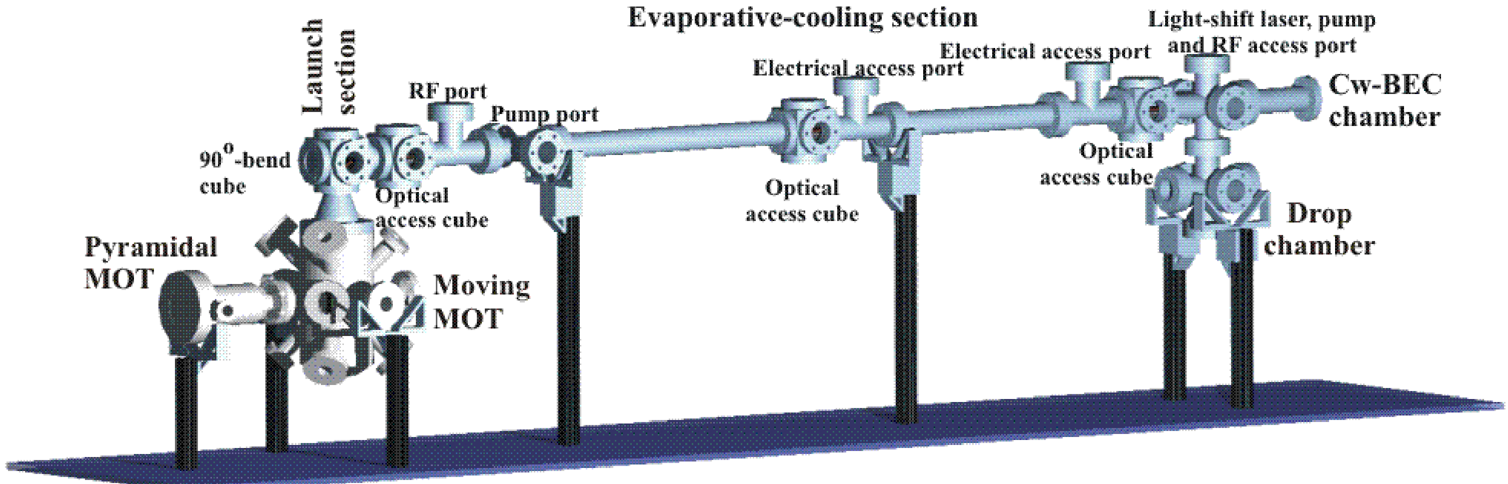
Yale



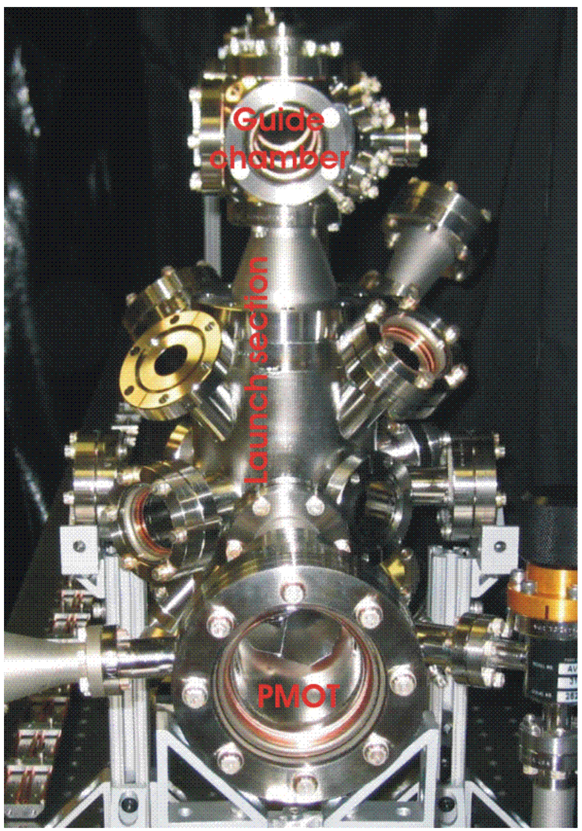
NIST

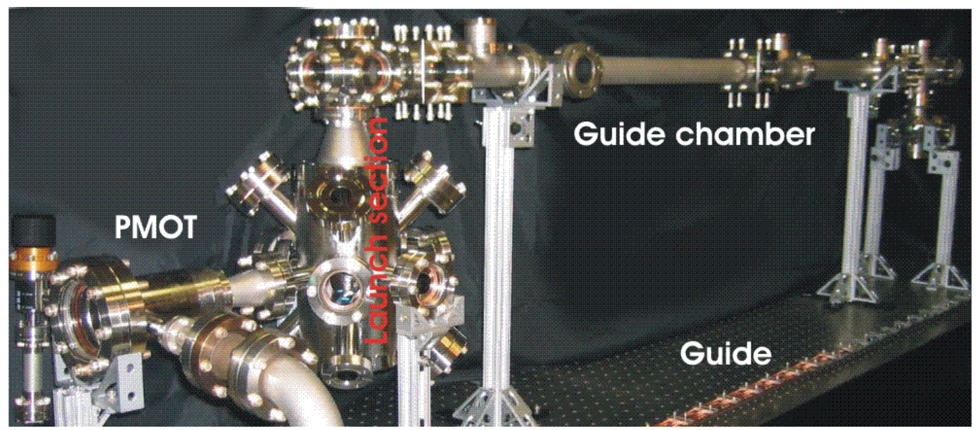


Munich



Continuous Atom Laser in a Magnetic Guide

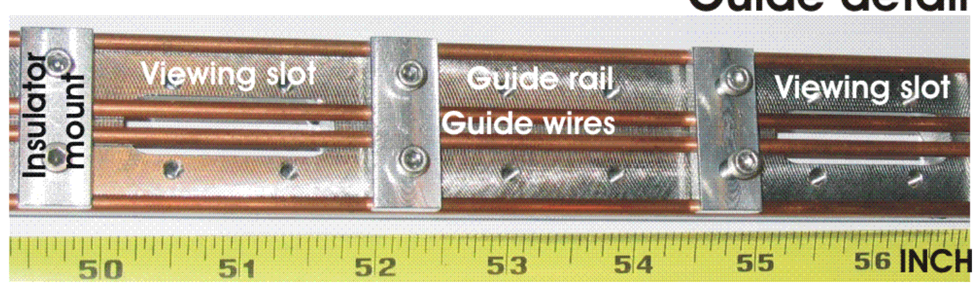




Main chamber side view

Main chamber front view

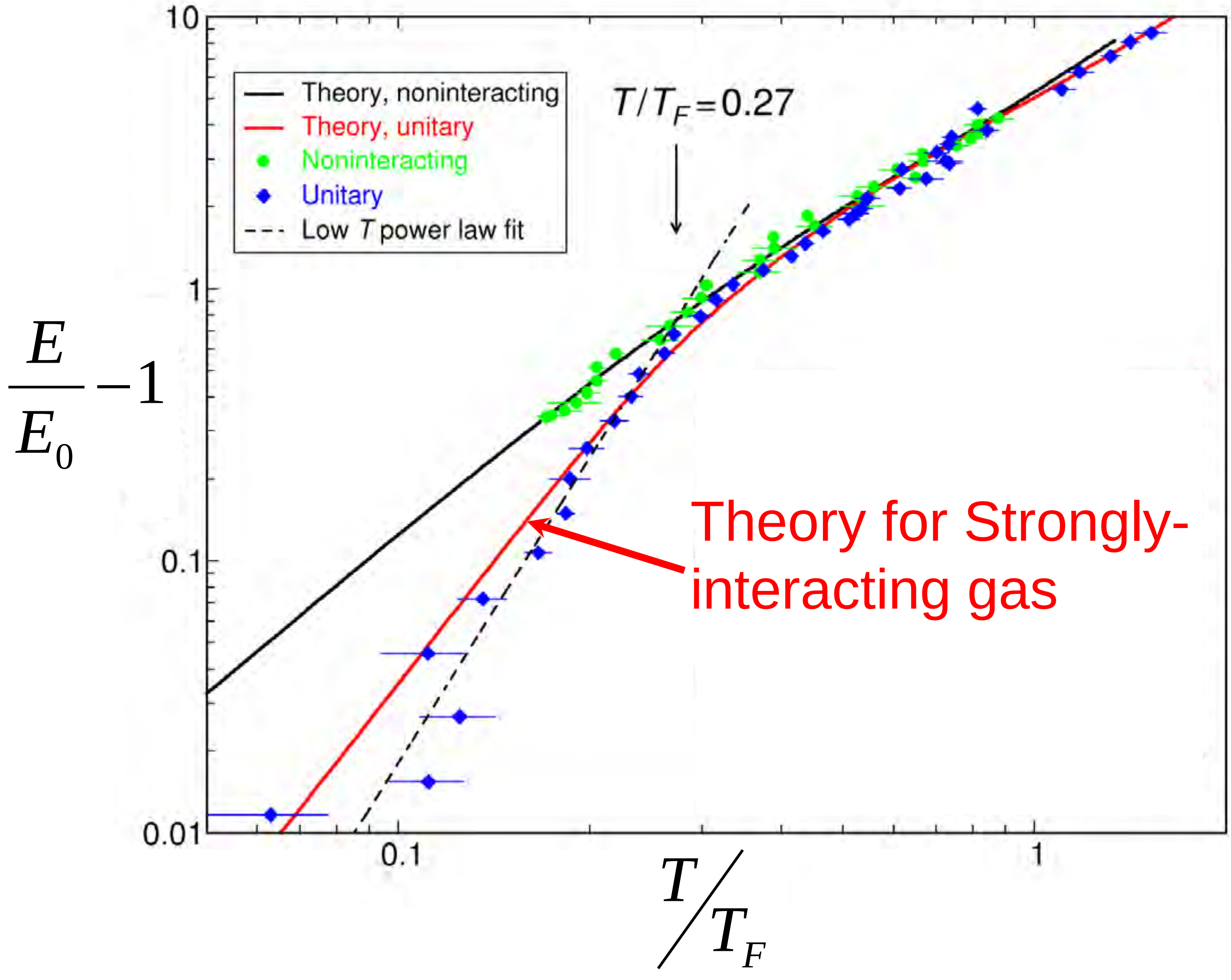
Guide detail



Cooling Fermions

- More difficult to reach degeneracy
- Final step towards BEC requires evaporative cooling
- Need interactions for constant re-equilibration
- Fermions “see” each other less as T is reduced
- Quantum degeneracy has potential for even more exotic behavior than with Bosons
- Pairing (e.g., Cooper pairs) possible
- Novel superfluids
- Insights into ordinary and high Tc superconductivity

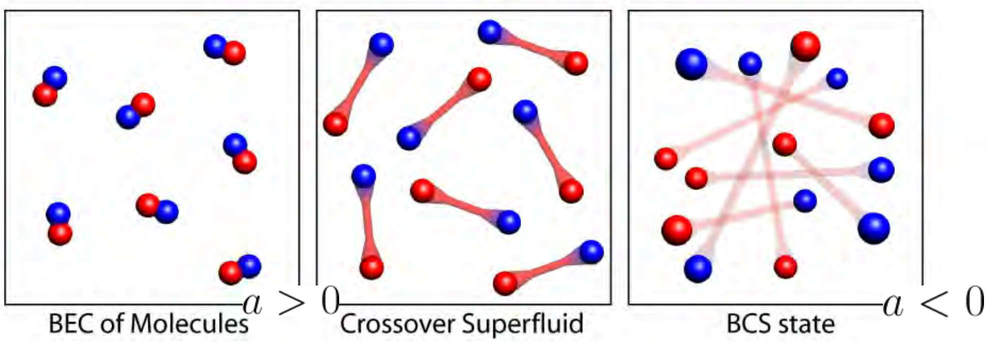
Cooling Fermions: Superfluid Transition

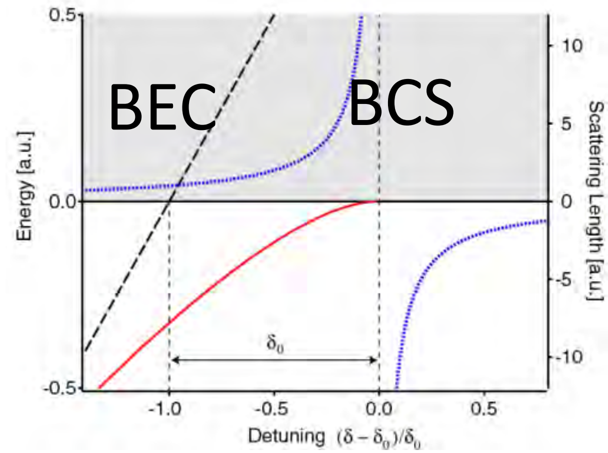


Feshbach Resonance Control of Interactions

BEC to BCS crossover

– Superfluid of Fermion pairs





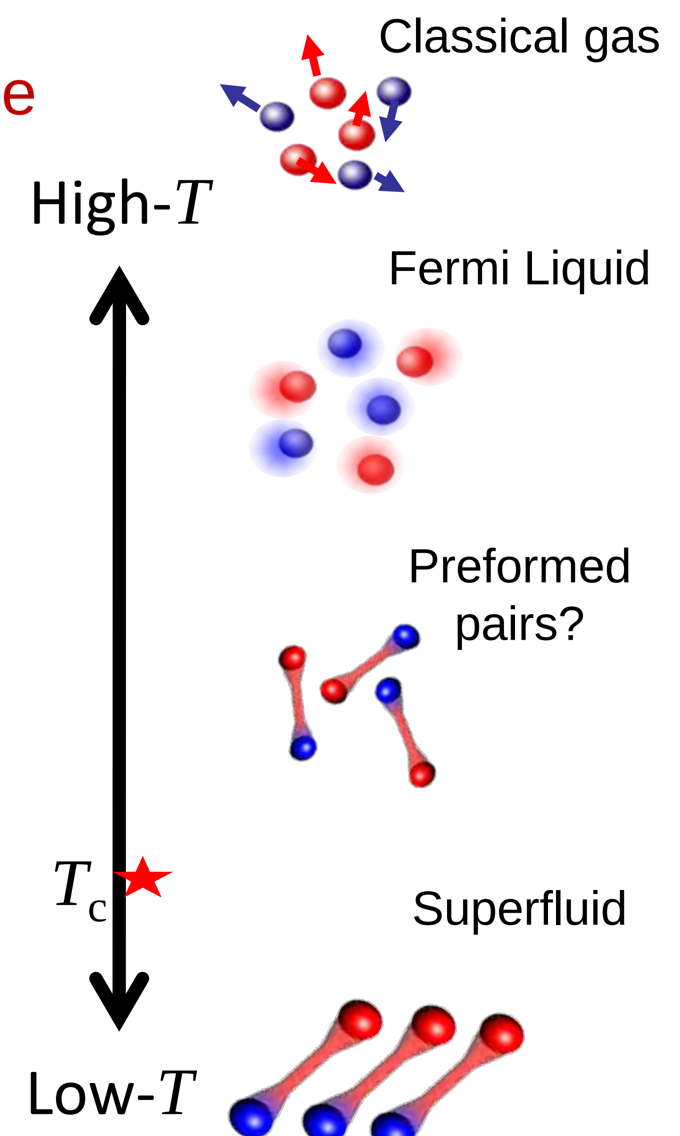
– Molecules on BEC side (2-body bound state)

– Cooper pairs on BCS side (Many-body physics)

Control of interactions
Thermodynamics of Unitary Fermi Gas

Spin ½ - Fermi gas at Feshbach resonance
(strong coupling regime)

- *Normal state:*
  - Is it a Fermi liquid?
  - Are there preformed pairs (a pseudogap regime)?
- *Superfluid properties*:
  - Transition temperature
  - Critical entropy
  - Energy of the superfluid
  - …



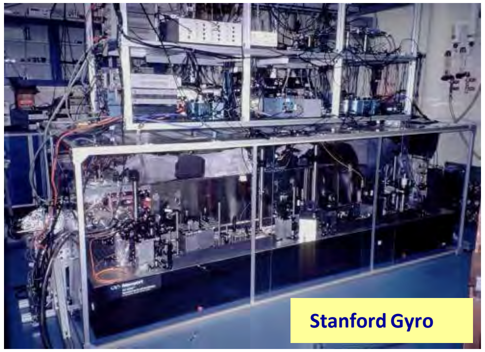
1998: Ultracold Atom Optics MURI

Do for atom optics what lasers, waveguides… did for light

- Develop general-purpose cold-atom techniques amenable to a wide variety of applications
  - Waveguides, beamsplitters, traps, taps, couplers, manipulators, detectors
  - Cold atom and BEC sources, EIT cells
- Use atom interferometry for sensing
- Bring cold atom S&T to broader research community
  - Make BEC economical and routine
  - Simplify and evolve laser cooling and trapping technology towards "standardization"

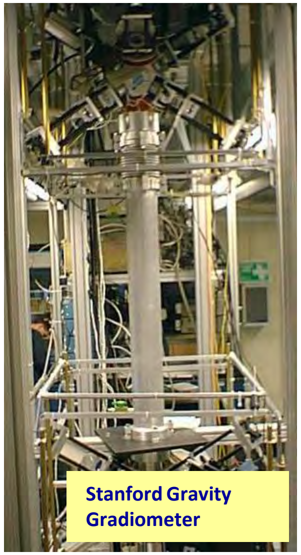
The Virtues of Cold Atoms

Translation and Rotation



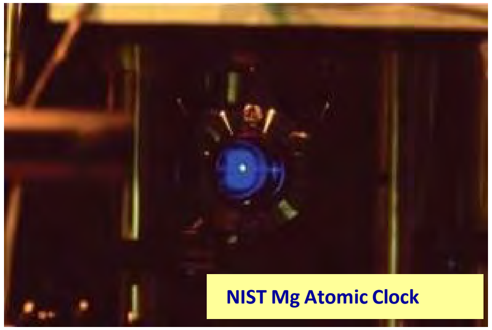
Rotational Sensitivity: 4×10^{-8} (rad/s)/$Hz^{1/2}$

Gravity Sensing



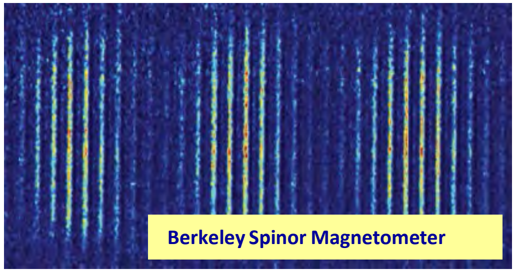
Differential Acceleration Sensitivity: 4×10^{-9} g/$Hz^{1/2}$

Time



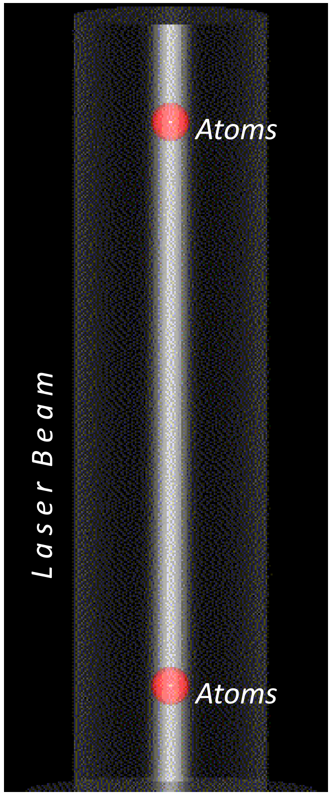
Accurate to 1 s per billion years

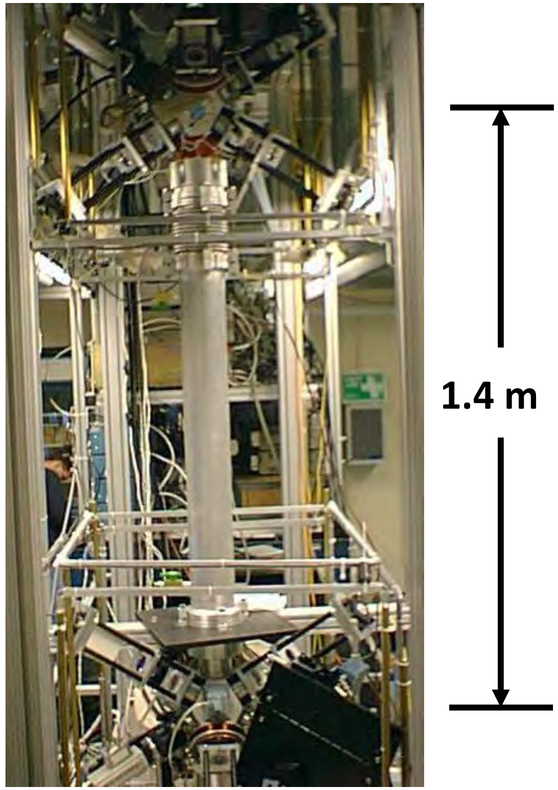
Magnetic Field Sensing

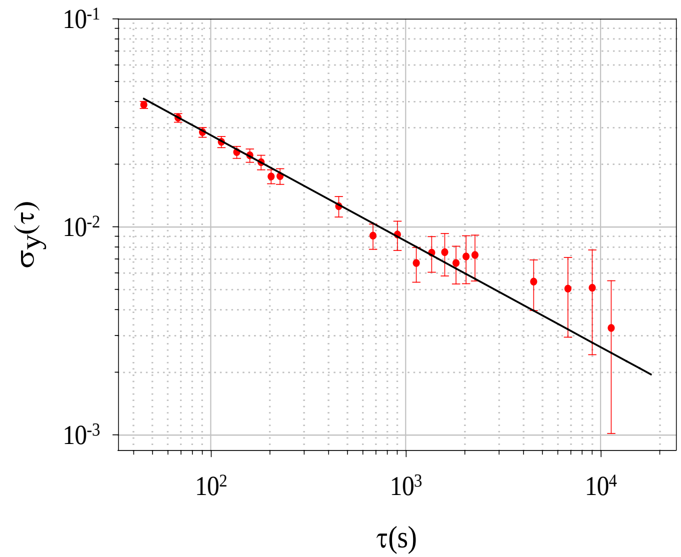


Magnetic Field Sensitivity: 8.3 pT/$Hz^{1/2}$

1998 Stanford/Yale laboratory gravity gradiometer







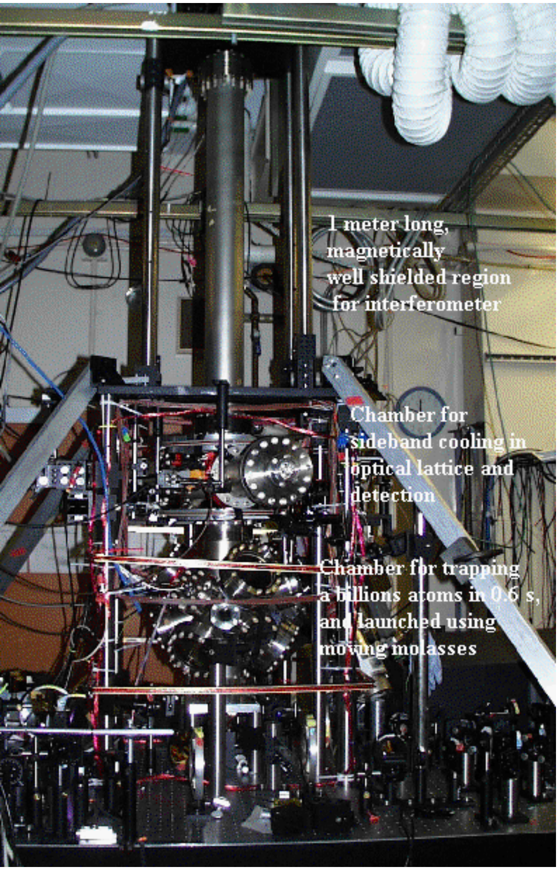
Distinguish gravity induced accelerations from those due to platform motion with differential acceleration measurements.

Demonstrated diffential acceleration sensitivity:

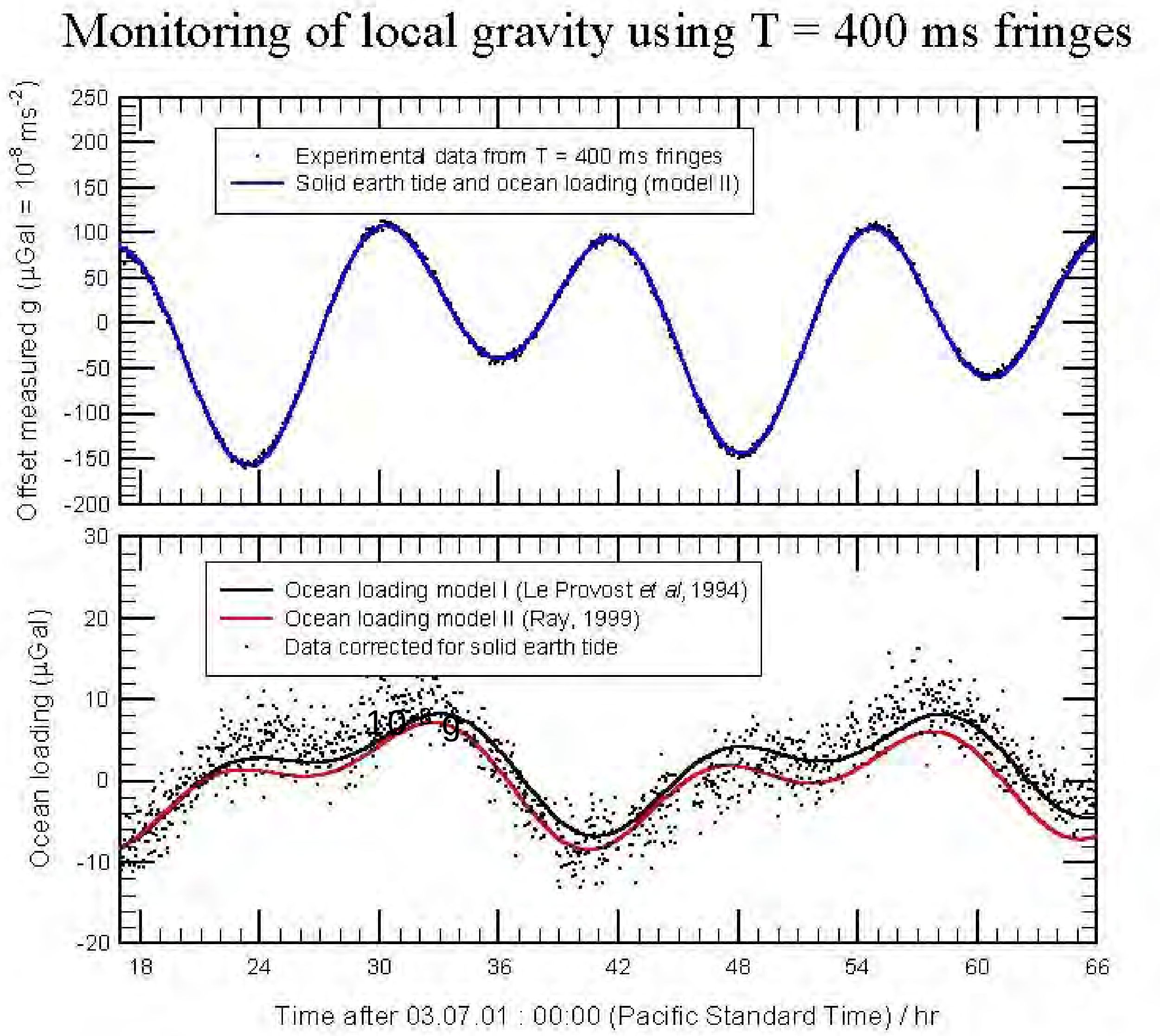
$4\mathrm{x}10^{-9}$ g/Hz$^{1/2}$

($2.8\mathrm{x}10^{-9}$ g/Hz$^{1/2}$ per accelerometer)

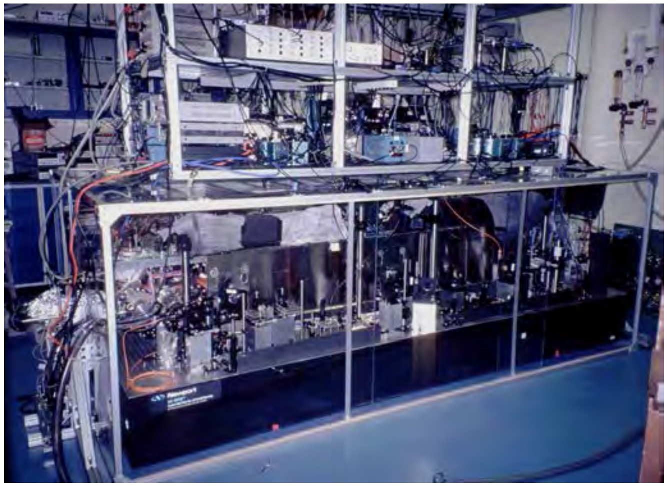
2000 Stanford laboratory gravimeter



Courtesy of S. Chu, Stanford



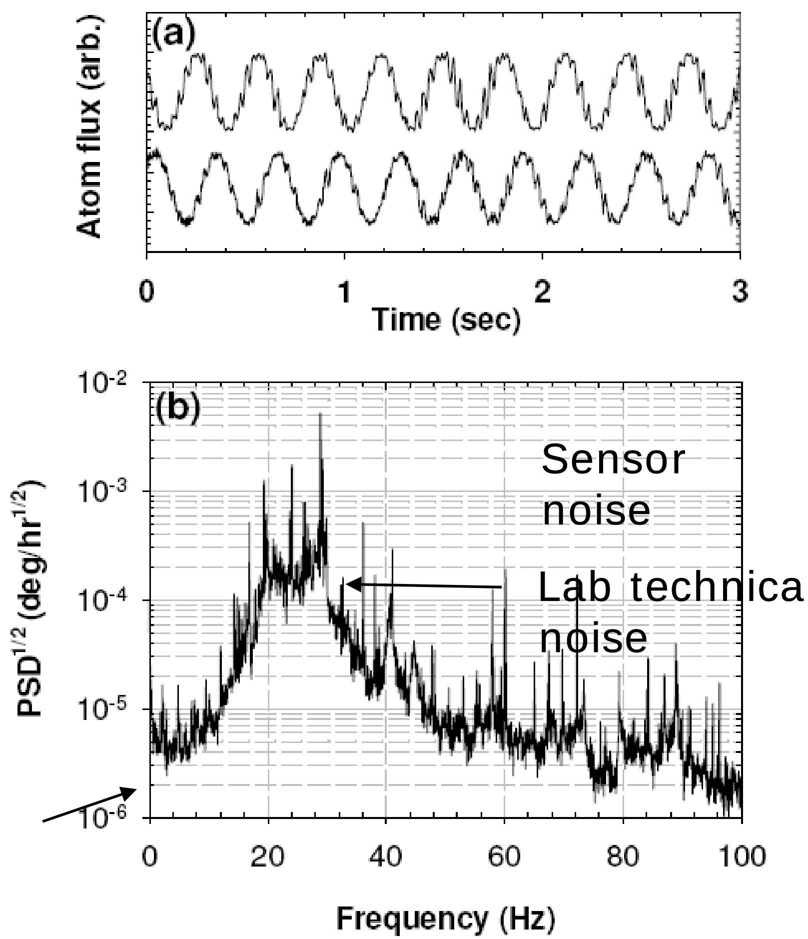
1997-2003 Gyroscope



AI gyroscope

Noise:	3 μdeg/hr$^{1/2}$
Bias stability:	< 60 μdeg/hr
Scale factor:	< 5 ppm

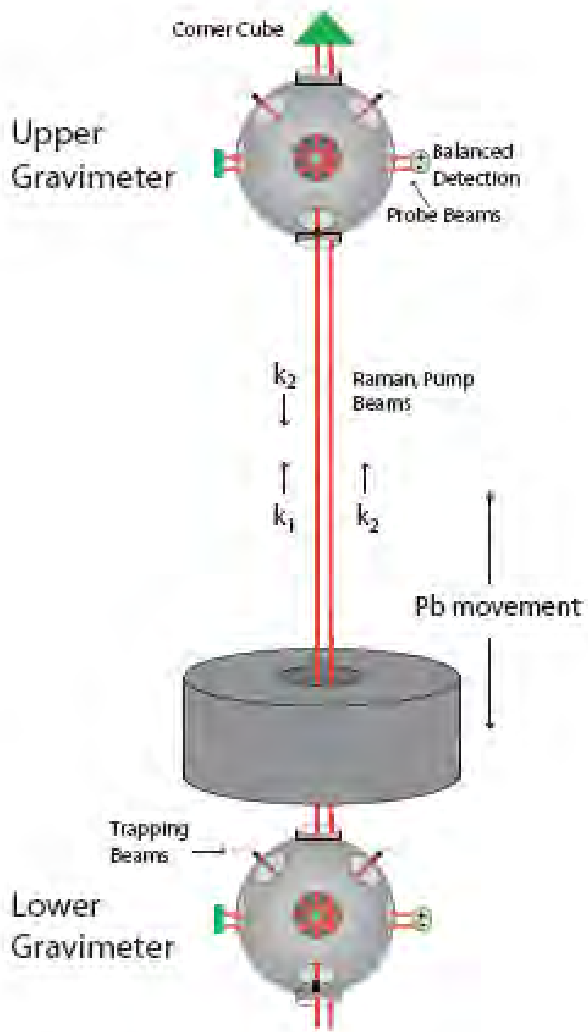
Gyroscope interference fringes:



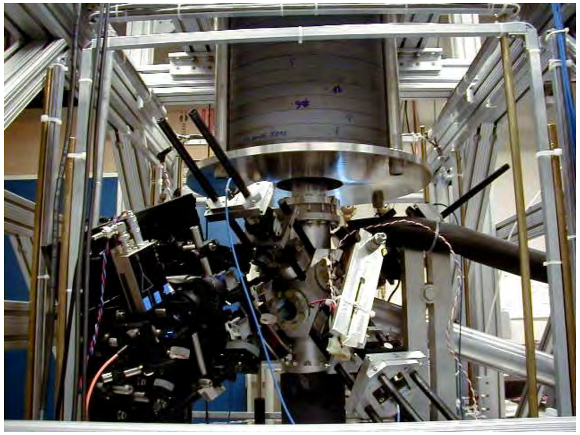
Atom shot noise

Gustavson, et al., PRL, 1997,
Durfee, et al., PRL, 2006

2003 Measurement of Newton's Constant

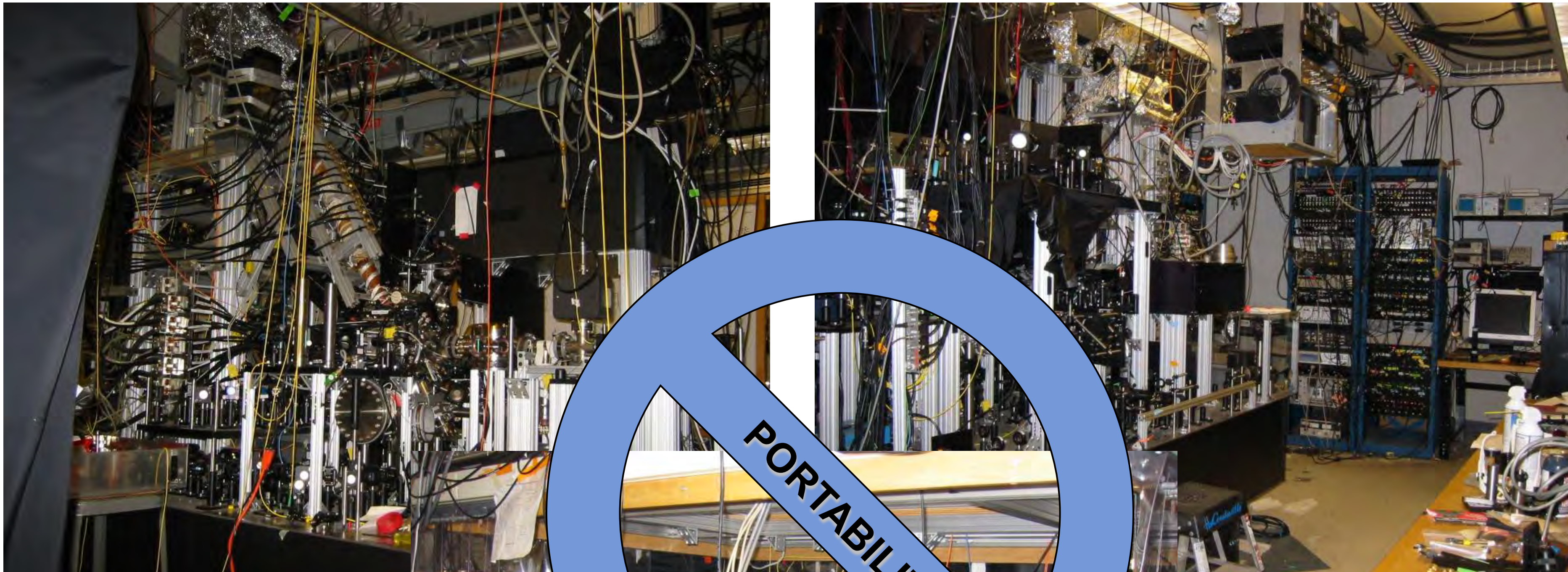


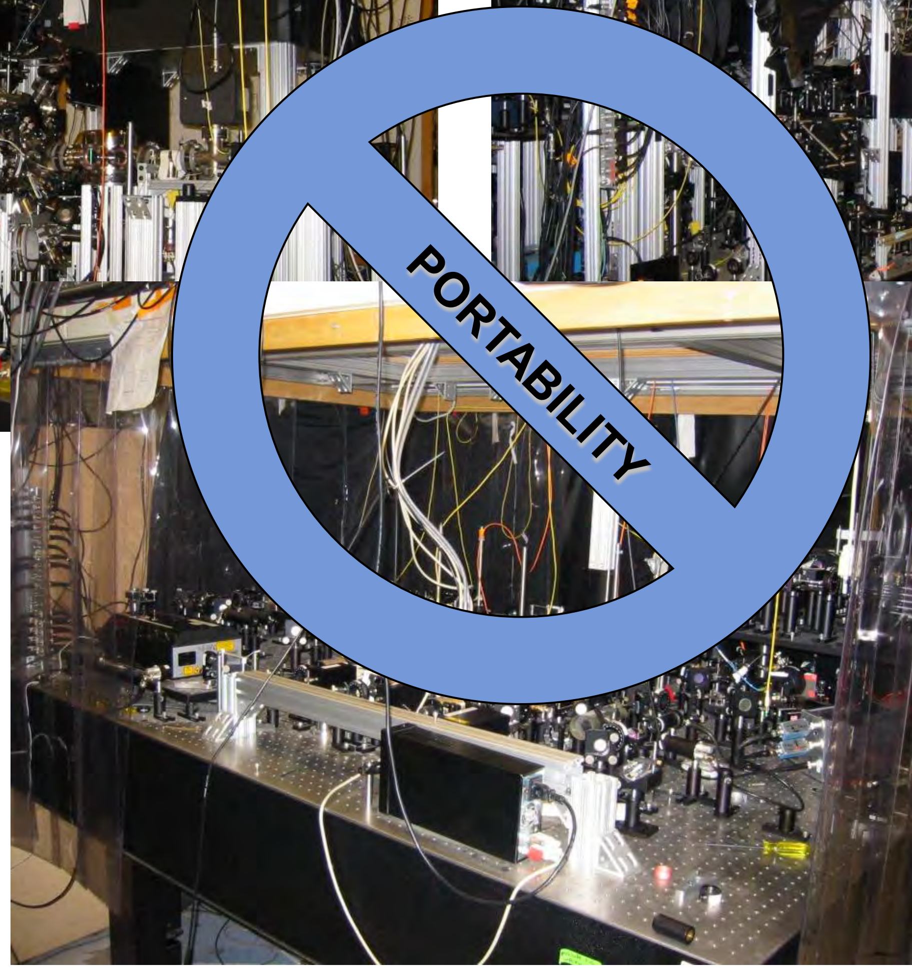
Pb mass translated vertically along gradient measurement axis.



Characterization of source mass geometry and atom trajectories (with respect to source mass) allows for determination of Newton's constant G.
Use gravity gradiometer to reject spurious technical vibrations.

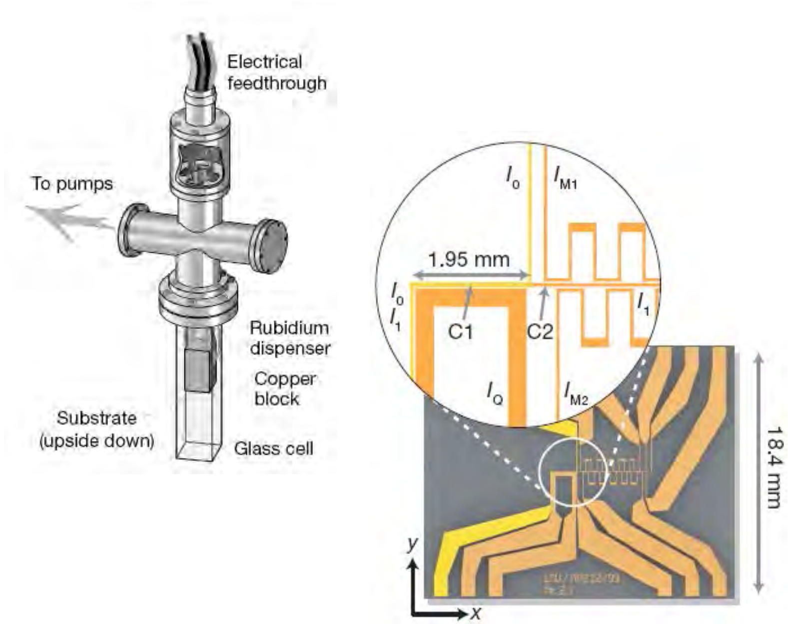
The Vices of Cold Atoms





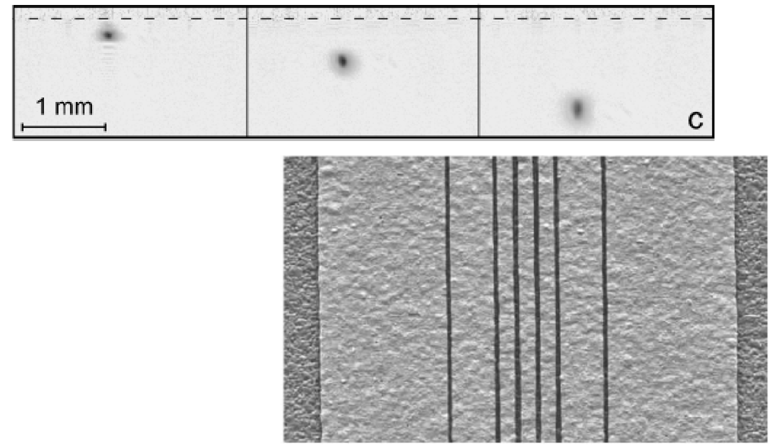
<u>Typical Lab</u>
Size: ~500 m^3
Weight: ~3000 kg
Power: ~100 kW
2 Grad Students

One Solution: Atom Chips



W. Hänsel *et al*., Nature **413**, 498 (2001)

(Hansch Group)



H. Ott *et al*., Phys. Rev. Lett. **87**, 230401 (2001)

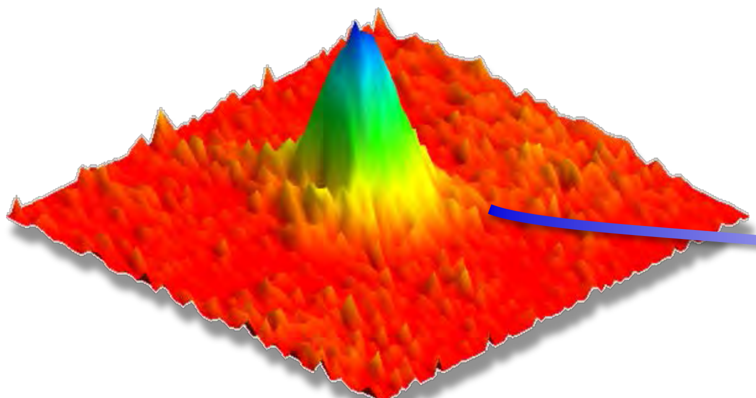
(Zimmerman Group)

A.E. Leanhardt *et al*., Phys. Rev. Lett. **89**, 040401 (2002)

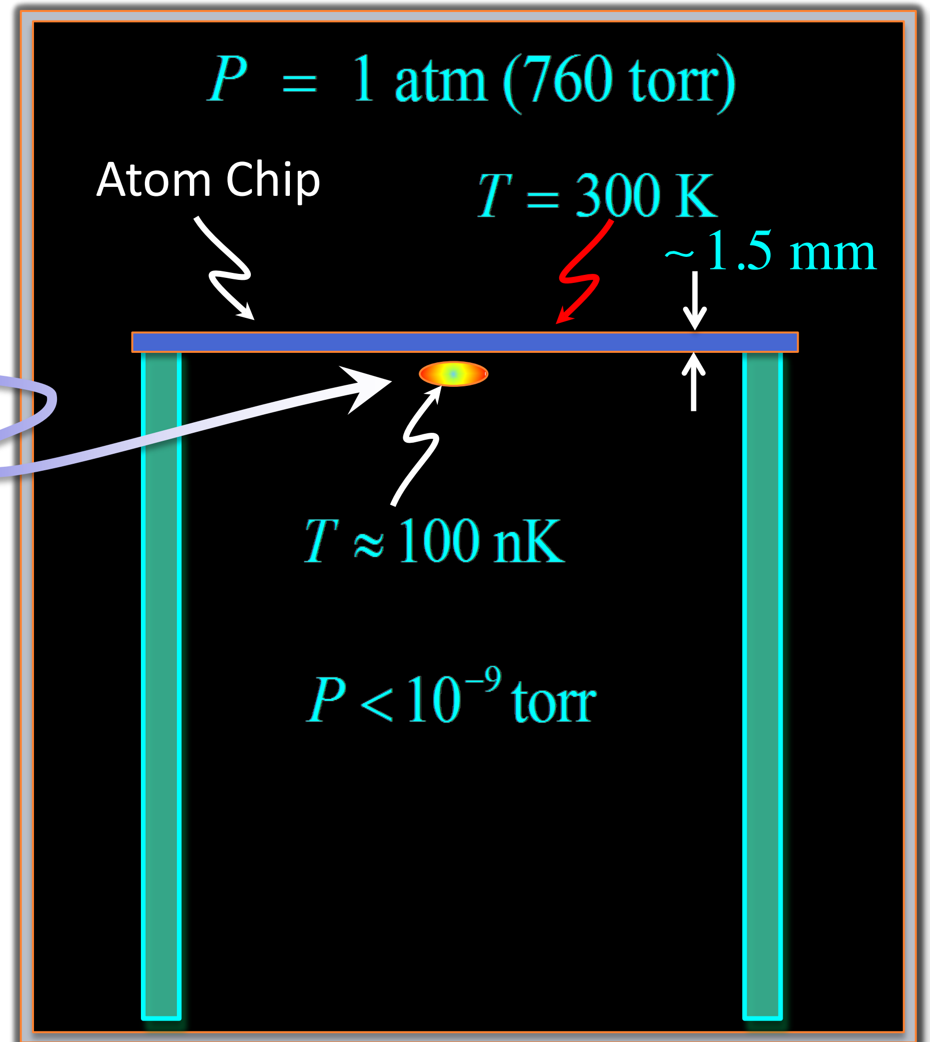
(Ketterle Group)

Atoms: Ultracold & Ultraclose

Ultracold:



A macroscopic ensemble of atoms occupying a single quantum state.



From MURI onward: 2004 -

- Success of S&T under MURI led to DARPA Precision Inertial Navigation and Sensing (PINS) program
  - emphasis on *enabling technology for inertial sensing based on ultracold atoms.*

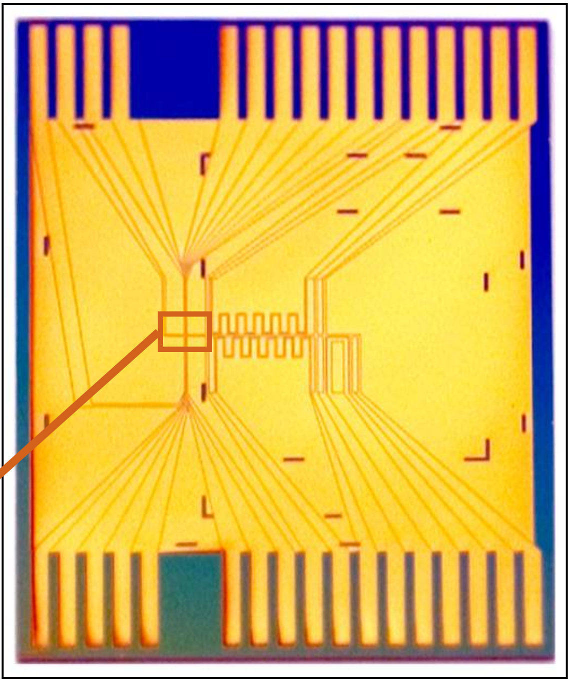
- ~2007 DARPA PINS split into:
  - PINS with more engineering focus on inertial sensing
  - gBECi (guided BEC interferometry) with a more basic focus

- Additional investments from SP-24, NGA, and others

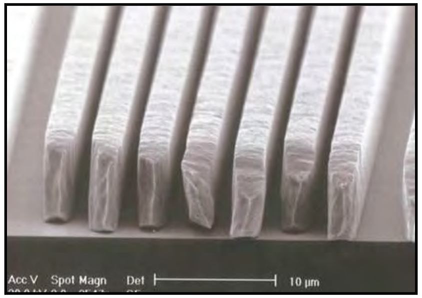
- Spin-off companies: AOSense and ColdQuanta

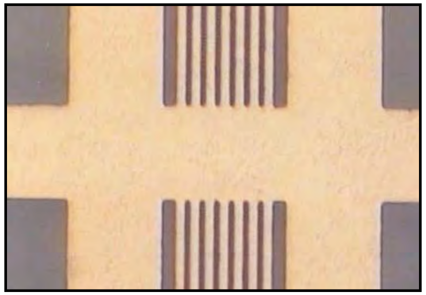
Multi-scale Atom Chips

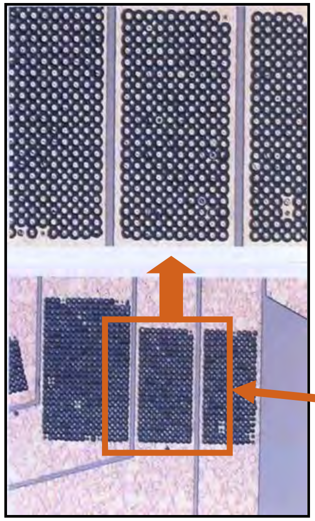
- Integrated high-current large scale features with low-current small-scale features on the same chip
- Features of metal deposition: ~ 8-10mm tall; ~ 2mm line/space
- Current chips utilize high-vacuum through-chip via arrays for electrical connections, and curved waveguides for controlled, closed loop atom motion



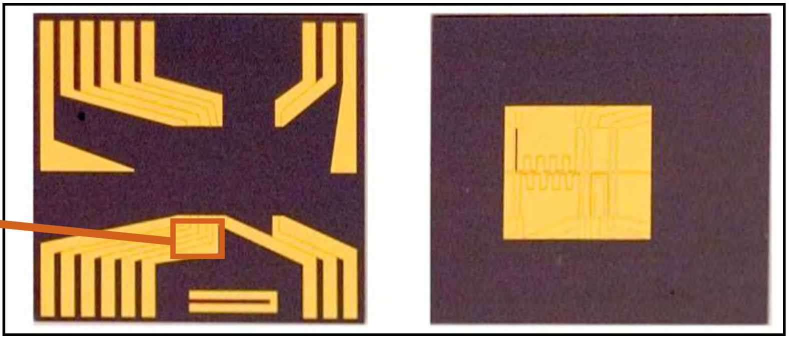
Detailed views of beamsplitter structure segment for single layer atom chip.
- (far right) Top view
- (right) SEM of side view detail



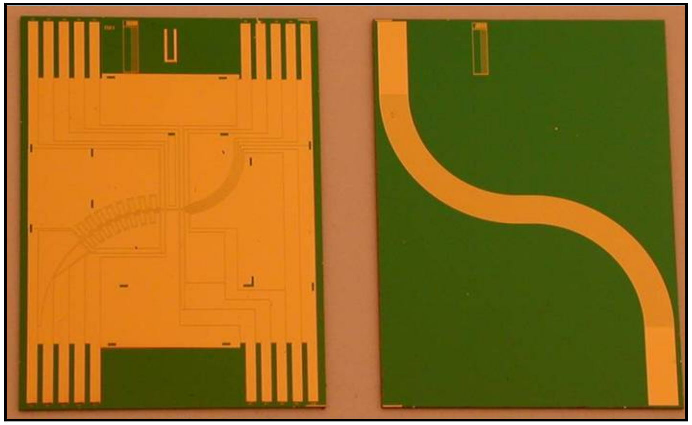




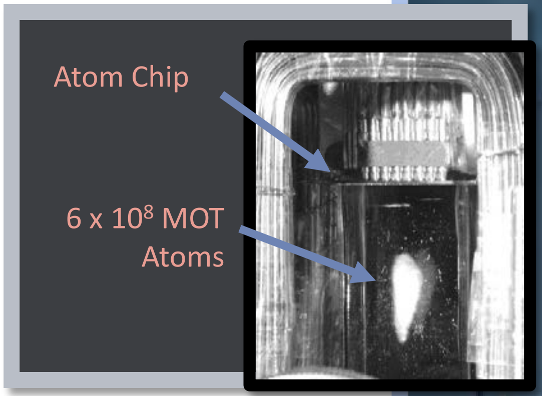
- (below) Front and back view of Via Chip
- (left) Detailed view of ultra-high vacuum-compatible via arrays used for each high current electrical feedthrough on Via Chip



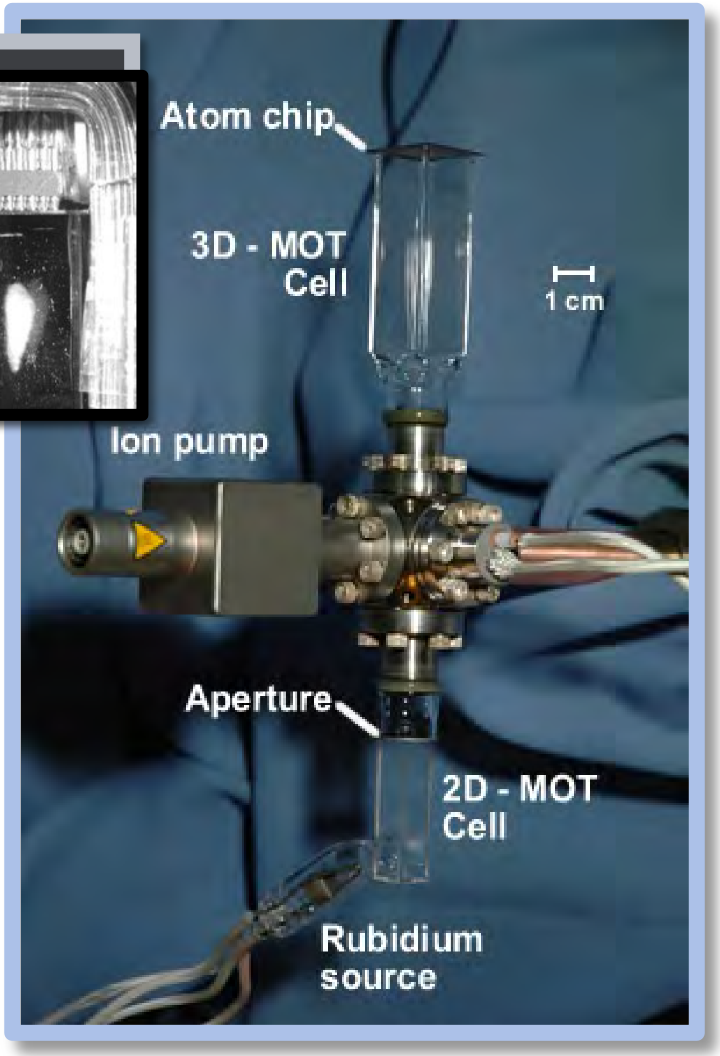
- (left) Fabricated one-layer atom chip on Si
- (right) Curved atom waveguide chip



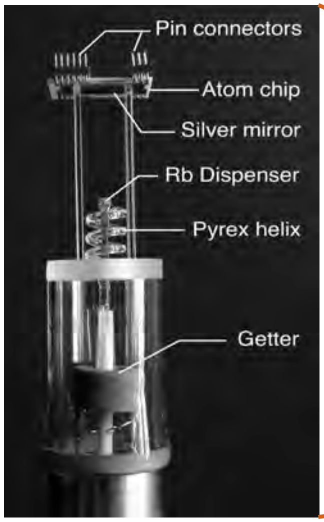
Double-MOT Atom Chip Cell

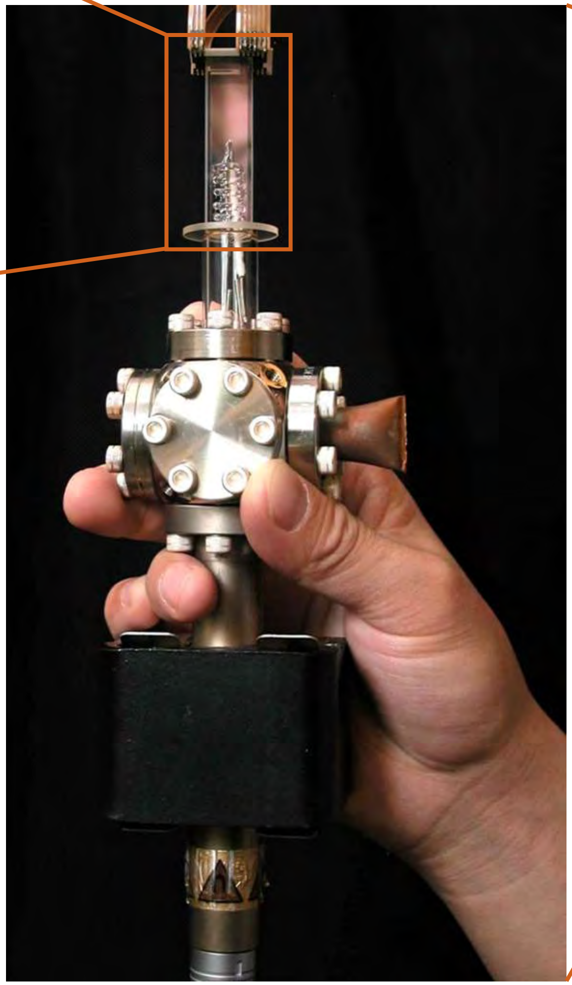


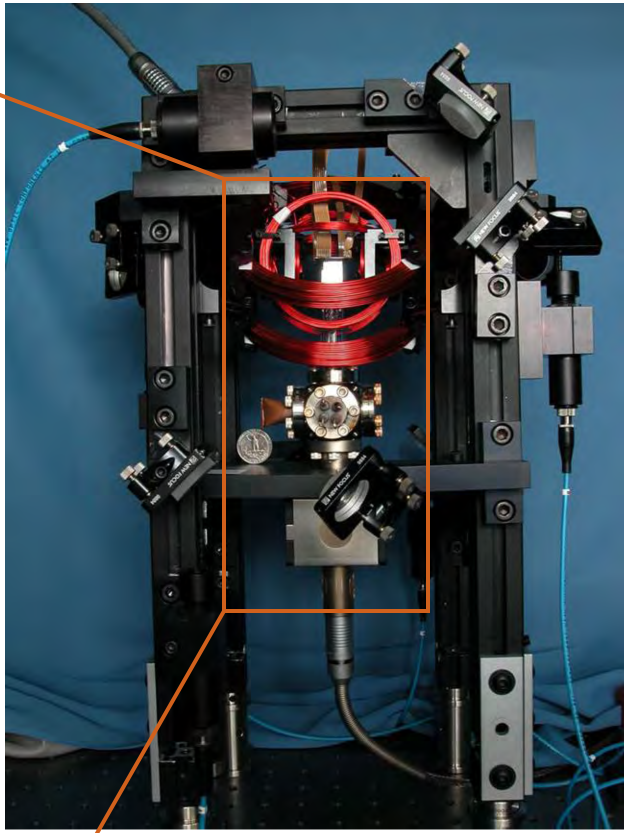
Actual Cell



Vacuum Cell Construction
Hand-held Atom Chip Cell and the "Hat"





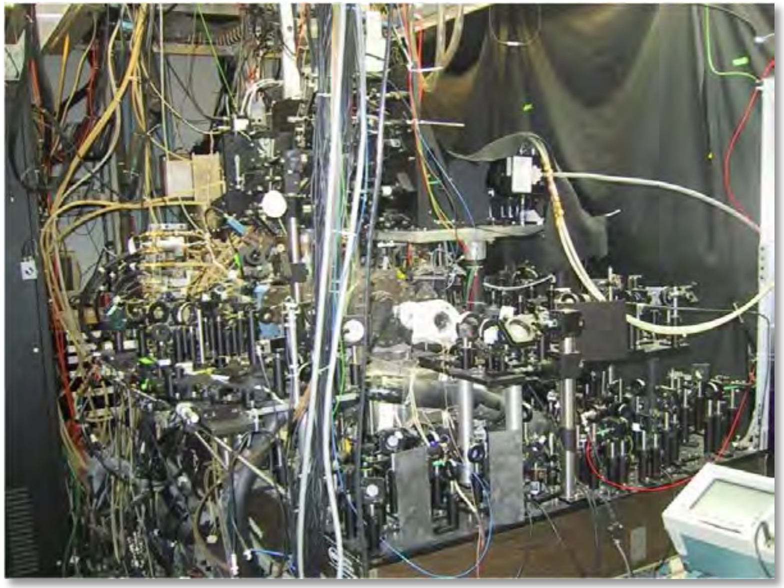


- Complete self-contained UHV atom chip vacuum cell
- Atom chip produces a Magneto-Optical Trap or a Bose-Einstein Condensate
- Inserts into "Hat" assembly
  - Carries bias & MOT magnetic field coils
  - Fiber coupled cooling & imaging beams
  - Enormously simplifies alignment
  - Typically achieve MOT in 2-3 hours after pinch-off vs days with conventional setup

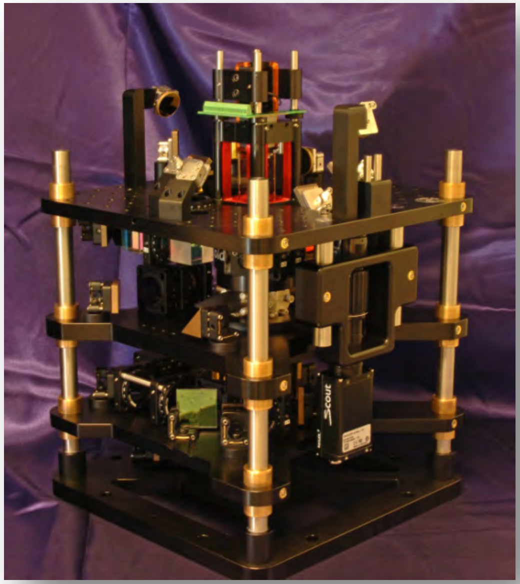
From Room Scale to Chip Scale

That was then…

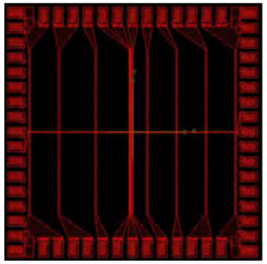
…this is now

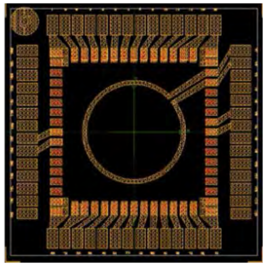


Ketterle BEC System on a 8’x4’ table



Compact Atom Chip System
about 50 x 30 x 30 cm





Atom chip technology has enabled miniaturization of ultracold atom systems from 7 ft to 12” systems

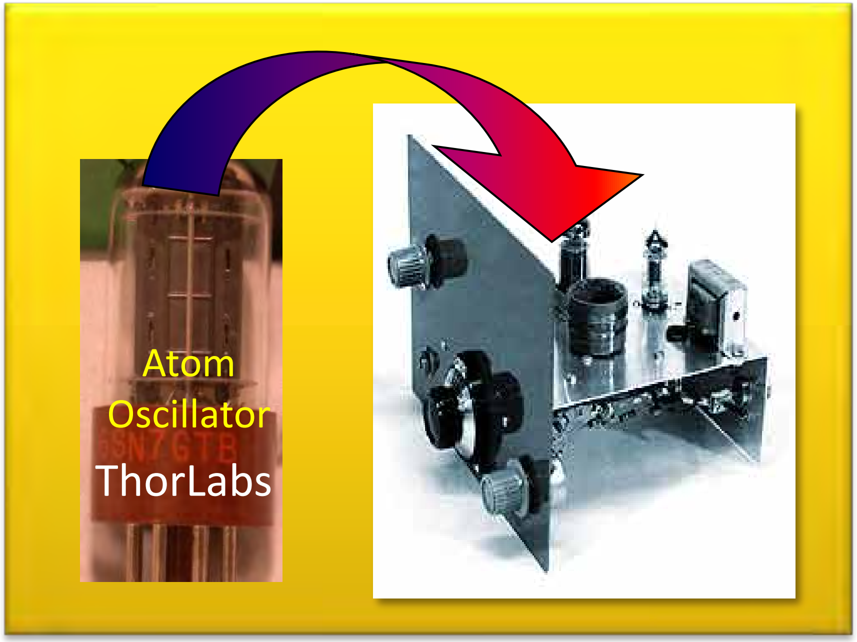
Ultracold Receiver

Atom chip cell “mass” production

Custom atom chip component

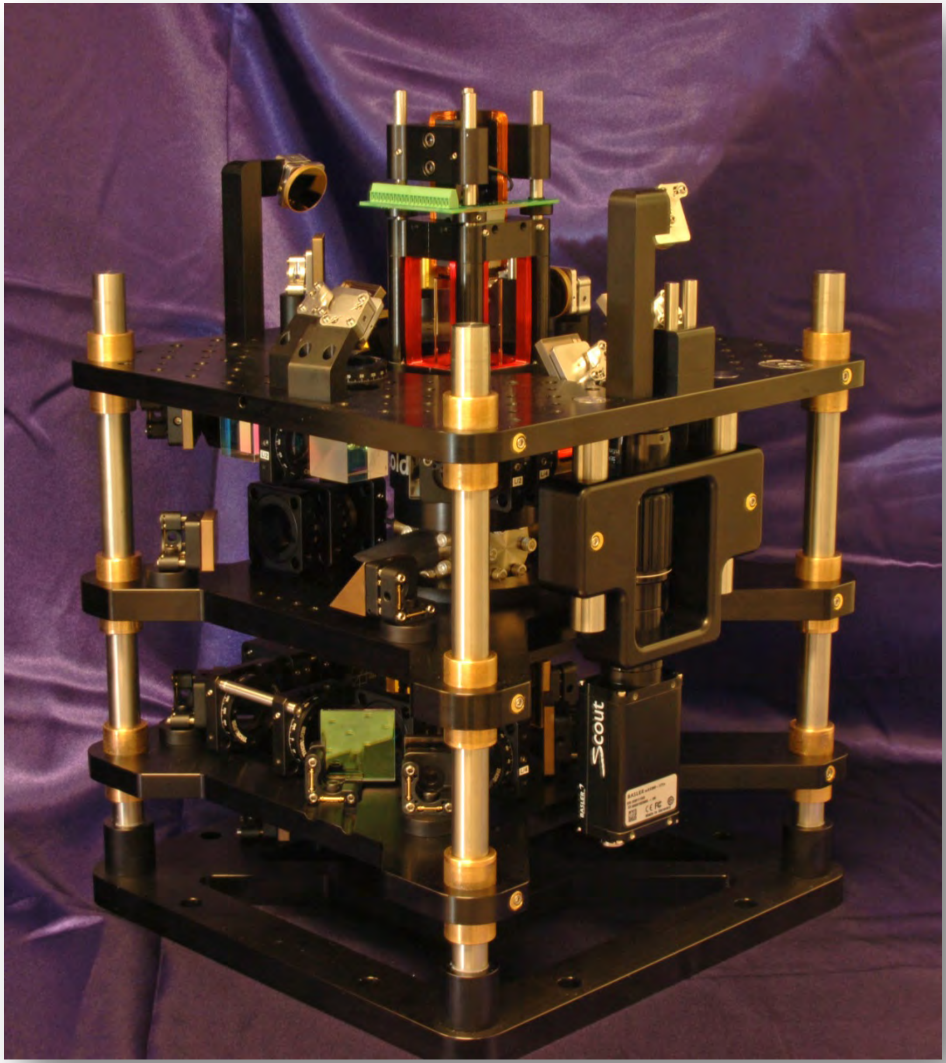
Into a

Standardized atom chip receiver



Atom Chip "Receiver"…

- Rapidly remove and replace an atom chip cell
- Still provides flexible access to the atom chip

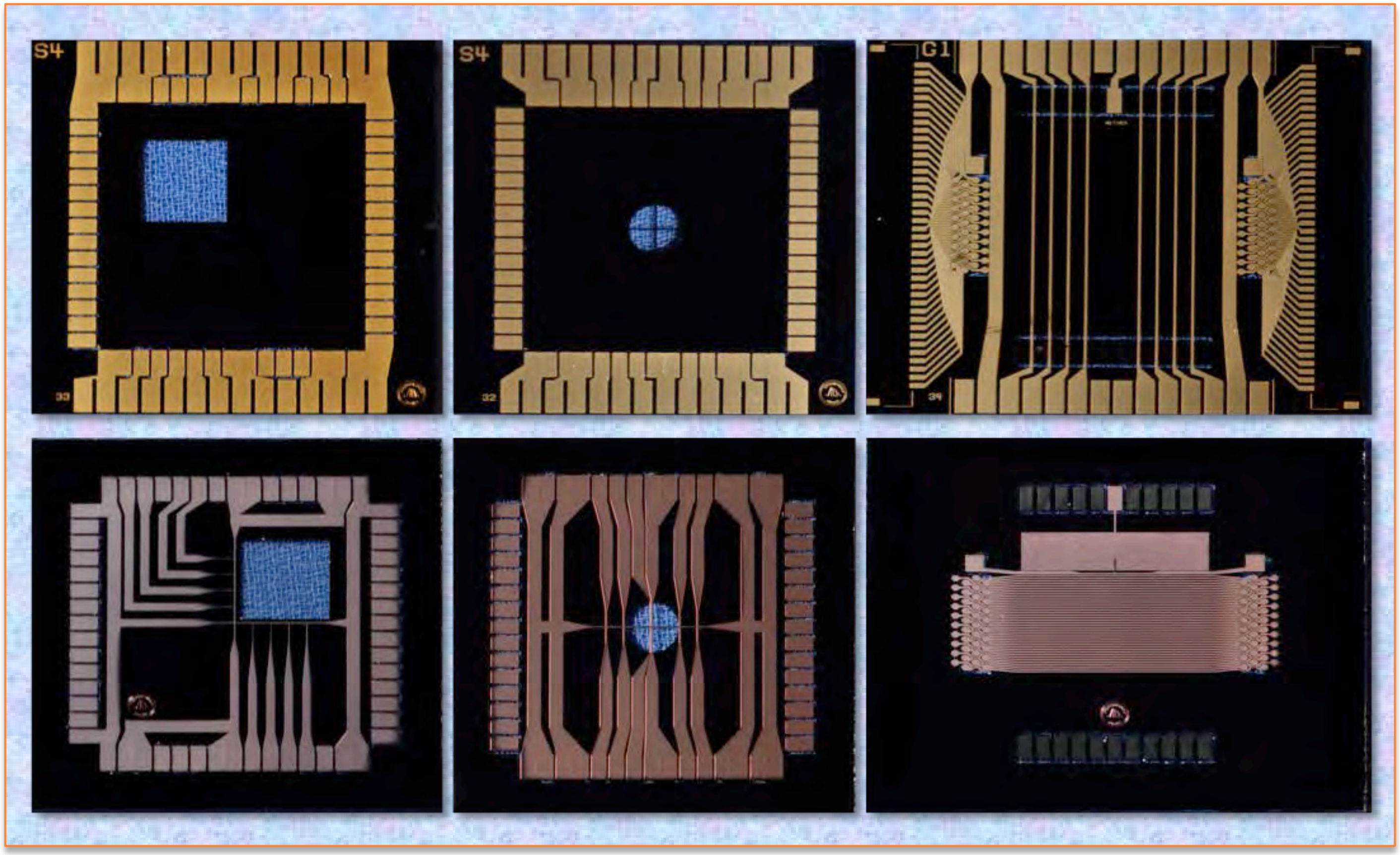


Versatility of Atom Chip Approach

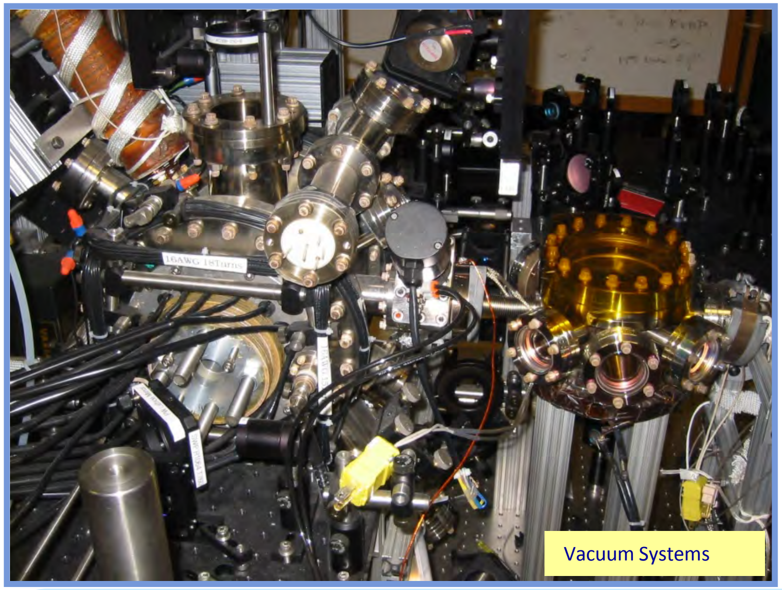
- The ultracold atom source remains constant, while *functionality is* determined by chip design.
- Below are chips for three different BEC systems (chips are ~23 mm x 23 mm).

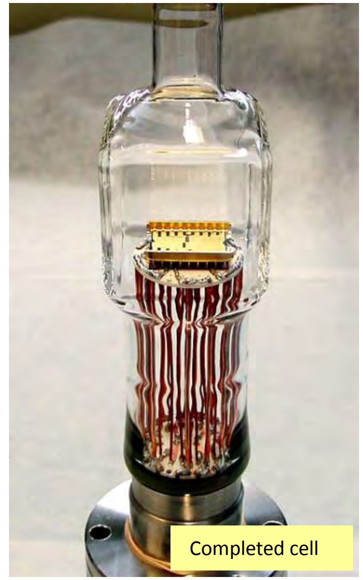
Ambient

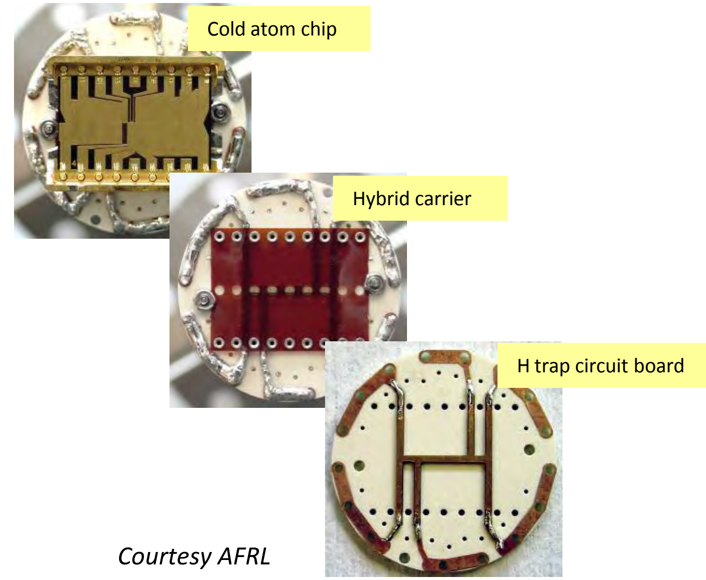
Vacuum



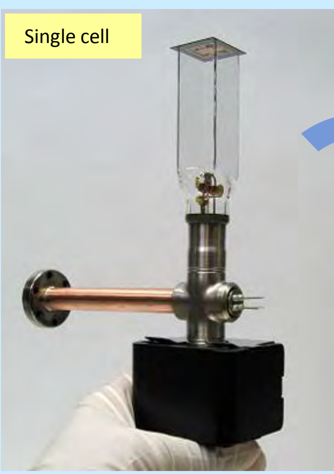
Portable Vacuum Systems



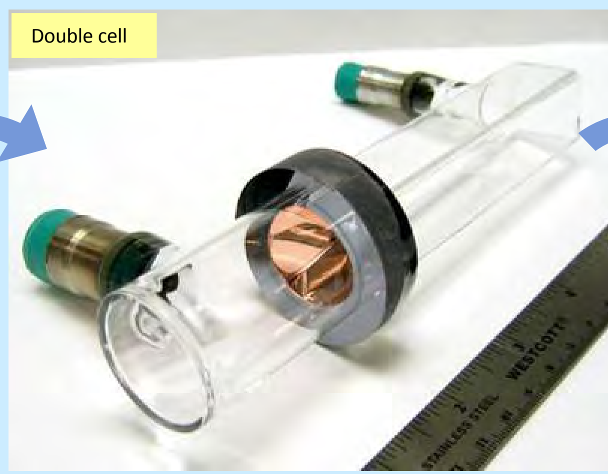




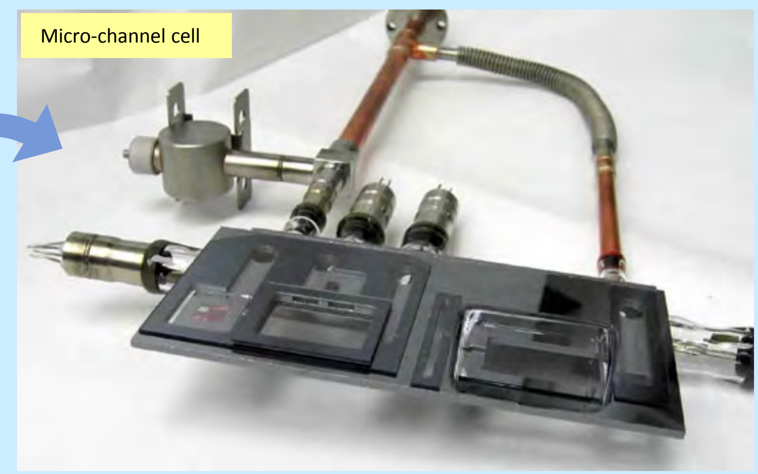
Courtesy AFRL



Single cell design: Achieved an unprecedented level of integration.



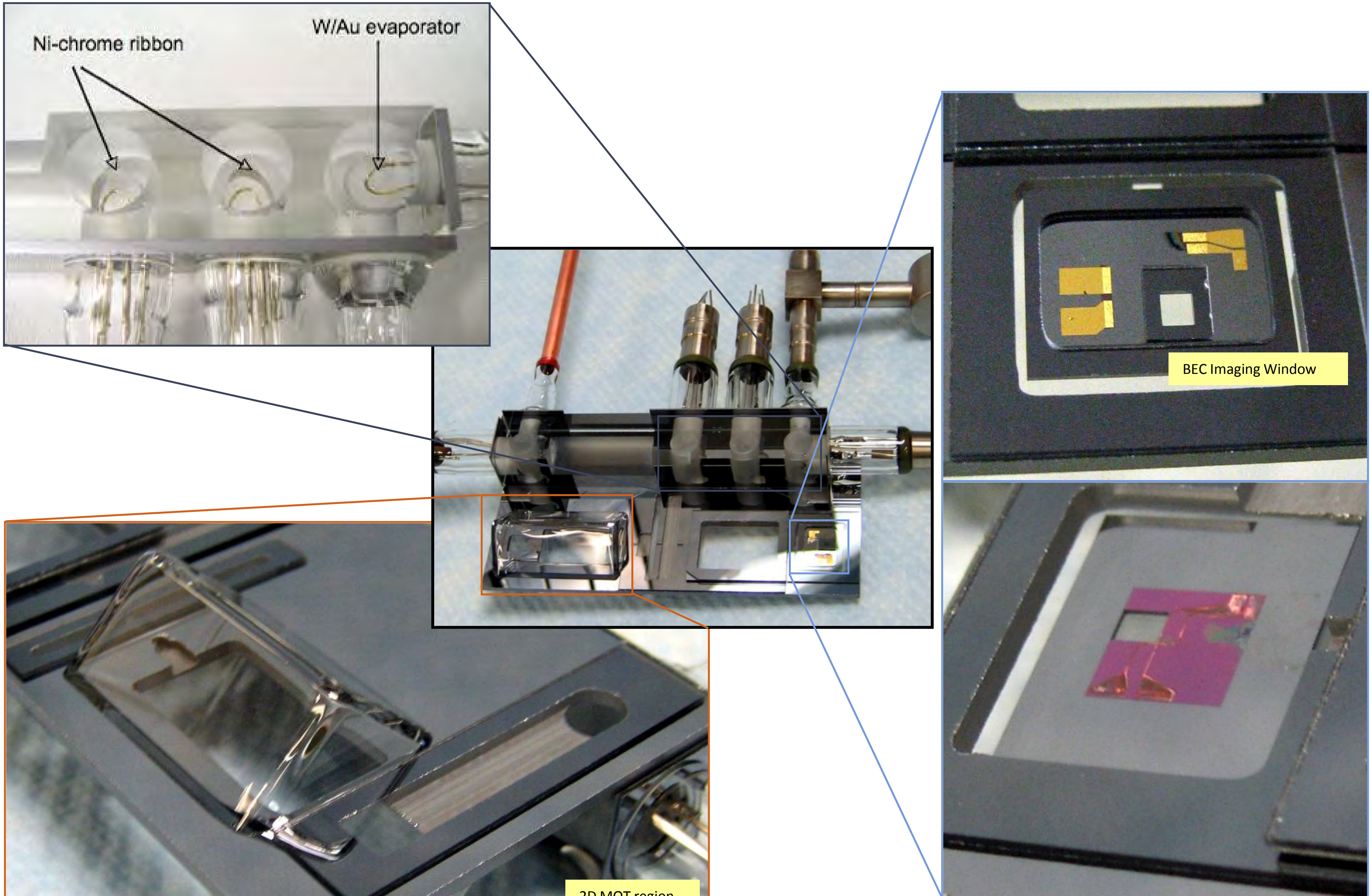
Double cell design: Additional differential pumping to reduce background pressure and increase source brightness.



Micro-channel design: Improved differential pumping and additional optical isolation to reduce light scattering and increase duty cycle.

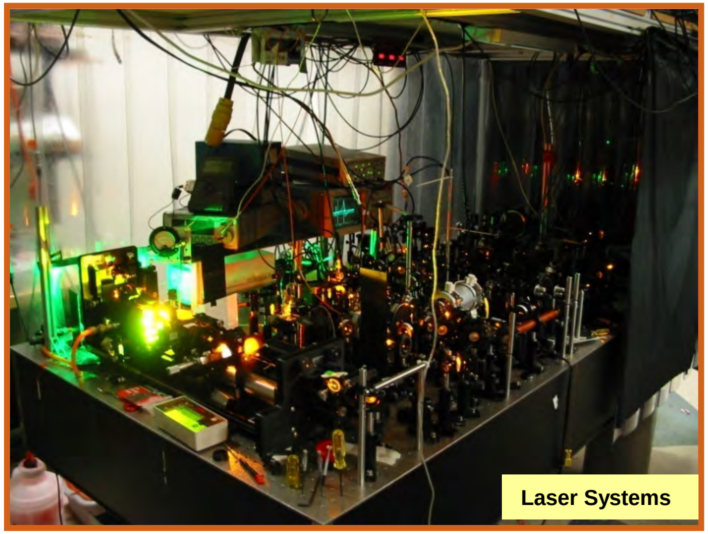
Courtesy UC Boulder/Sarnoff

Micro-Channel Cell Details



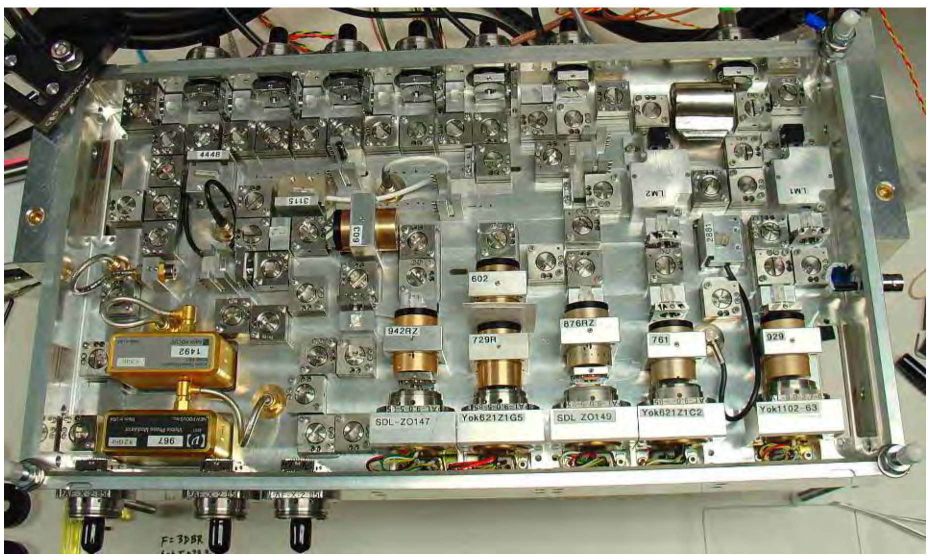
Courtesy UC Boulder/Sarnoff

Portable Laser Systems

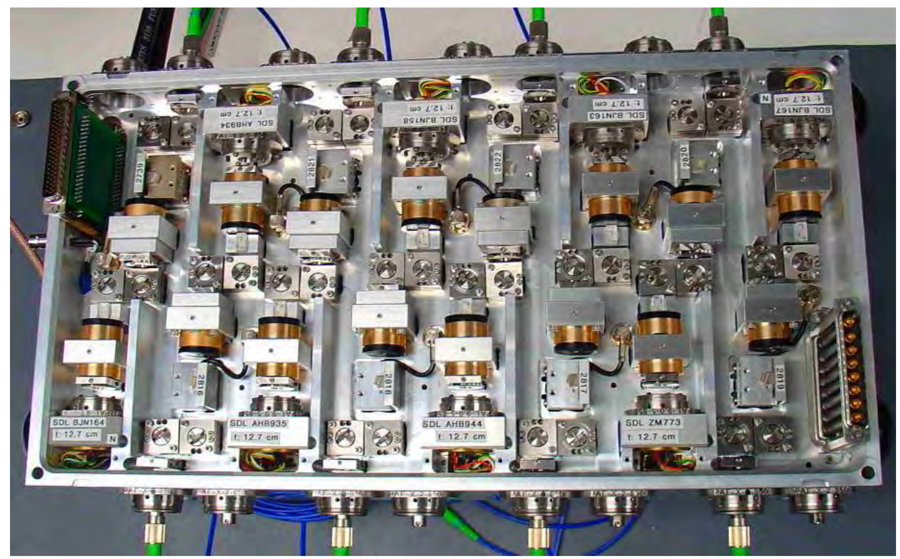


Courtesy UC Boulder/Sarnoff/Vescent

Rb MOT Laser System



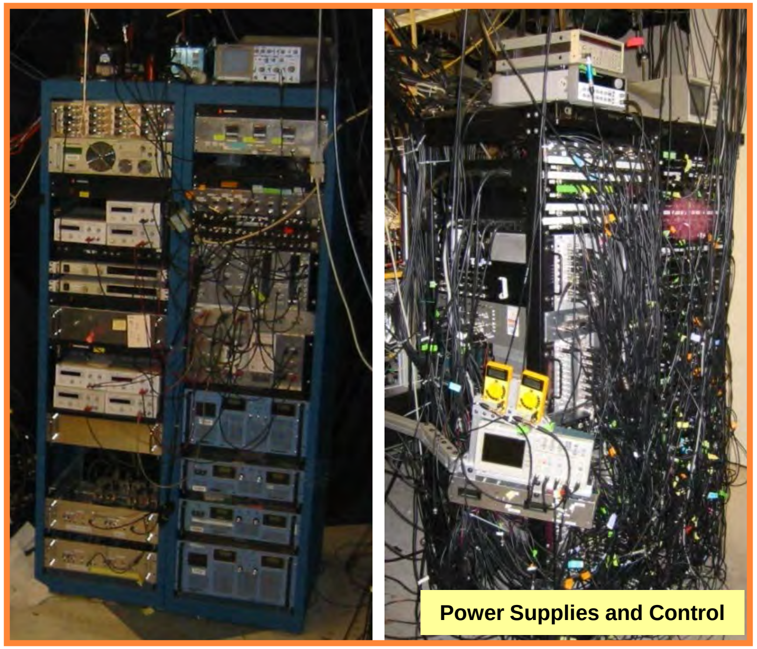
Master Laser



Laser Amplifier

Courtesy Stanford/AOSense

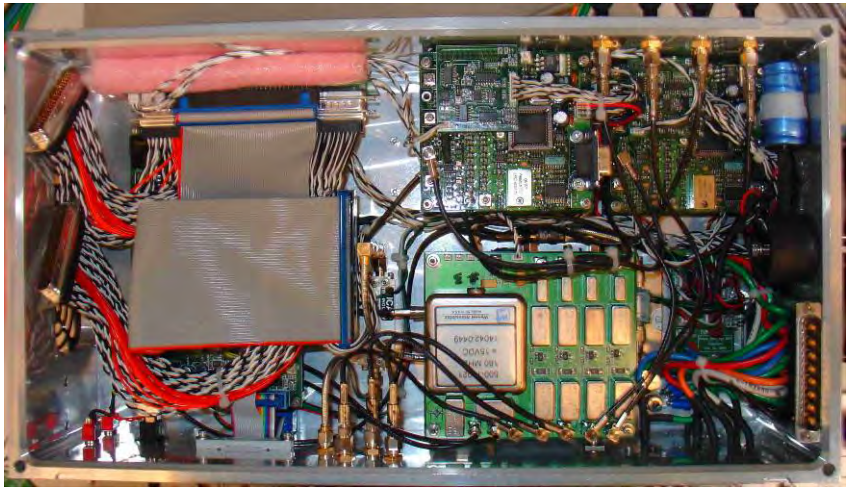
Portable Power and Control Systems



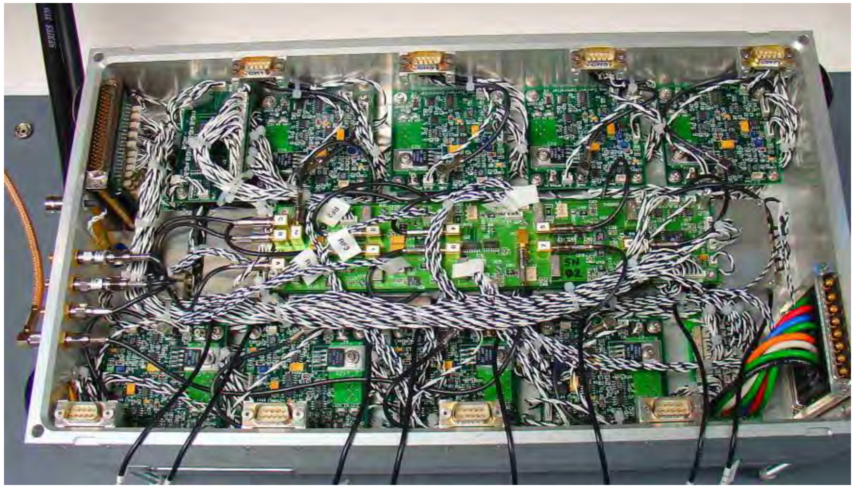
Power Supplies and Control

Laser Controller

Courtesy UC Boulder/Sarnoff/Vescent



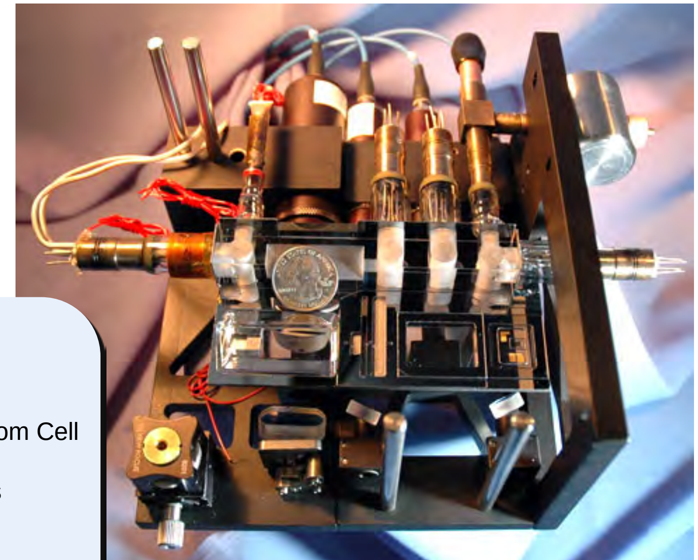
Digital Signal Processor



RF Amplifiers

Courtesy Stanford/AOSense

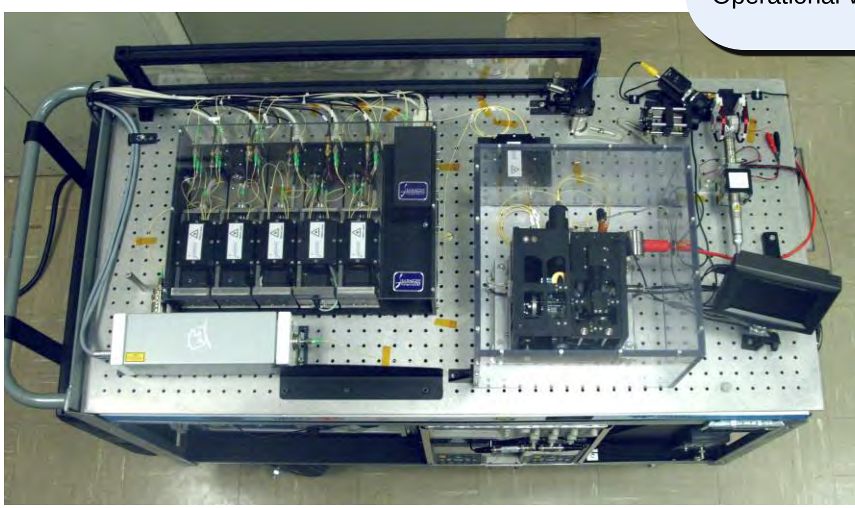
1st Generation Portable Cold Atom System



Portable MOT Demonstration

- Integrated Cold Atom Cell
- 5 Laser System
- Control Electronics
- Instrumentation
- UPS

Battery Powered
Operational while in motion



Courtesy UC Boulder/Sarnoff/Vescent

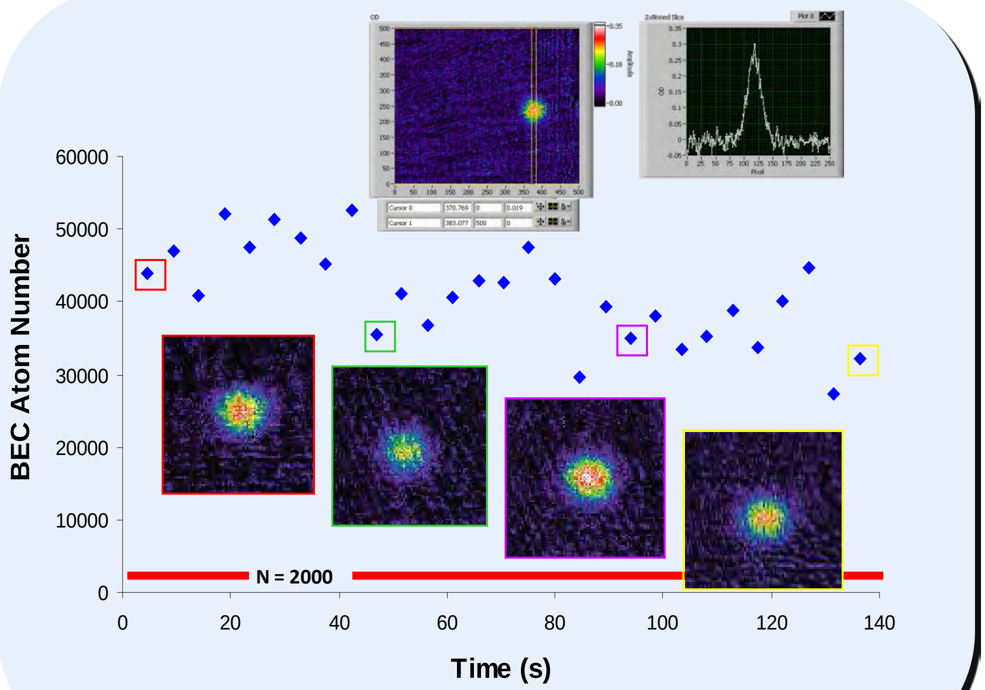
World's Smallest BEC System

FIRST BEC PUBLIC DEMO:
APS MARCH MEETING 2010

- < 0.4 m^3;
- 187 kg (400 lbs);
- 500 Watts
- BECs in less than 3 s
- First on-road BEC

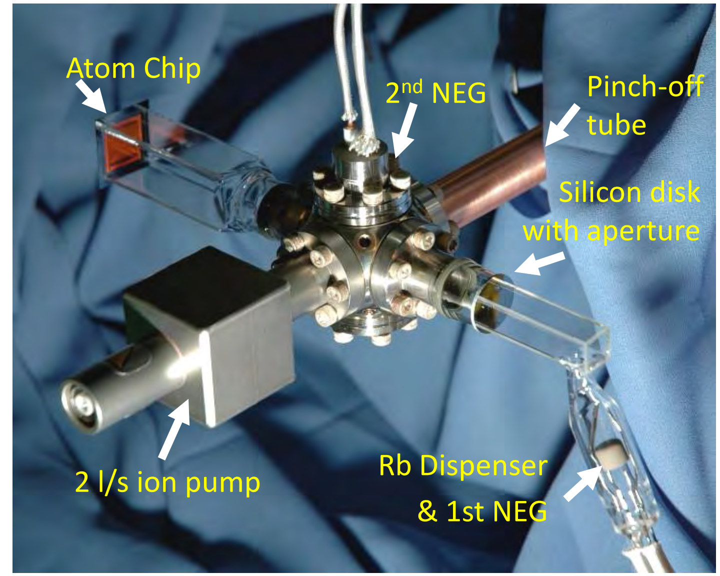
Rapid BEC Production

Quasi-Continuous BEC

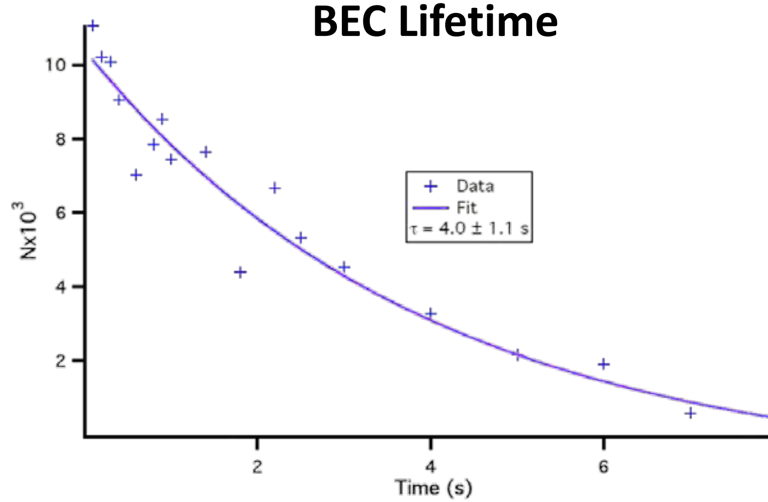


40,000 BEC atoms produced every 4.7 s

Portable Apparatus

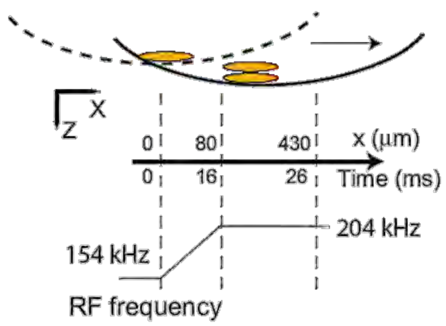


BEC Lifetime

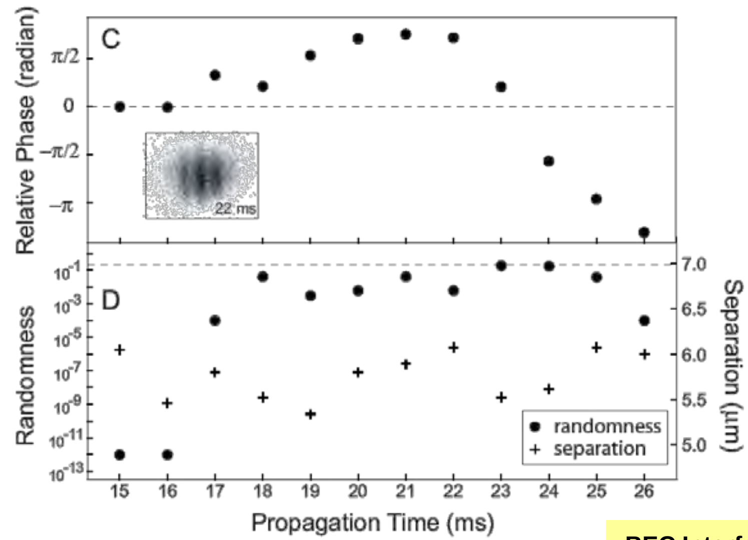


Atom-chip BEC lifetimes of 4 s

Rotationally-Sensitive Chip-Based Interferometry

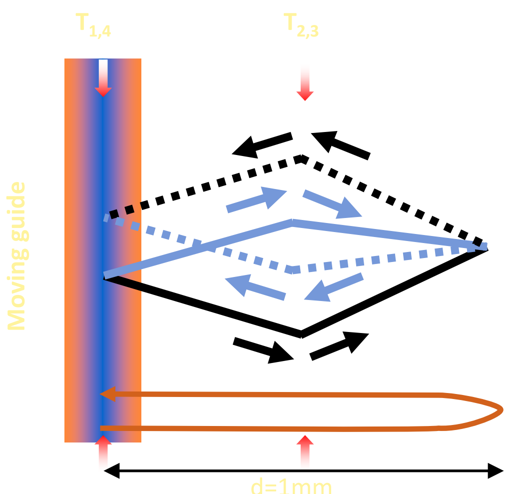


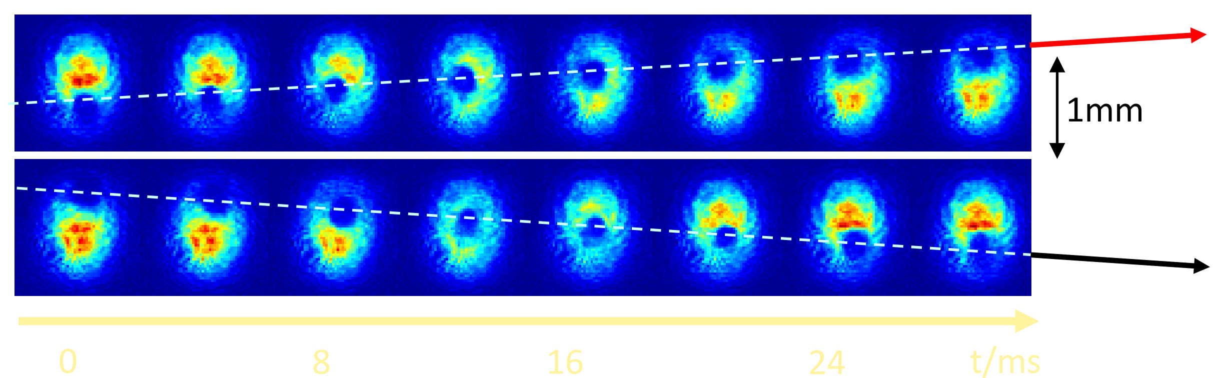
$$S_\Omega = 7.9\times10^{-5}\,\frac{rad}{\Omega_e}$$



BEC Interferometer

Courtesy of MIT



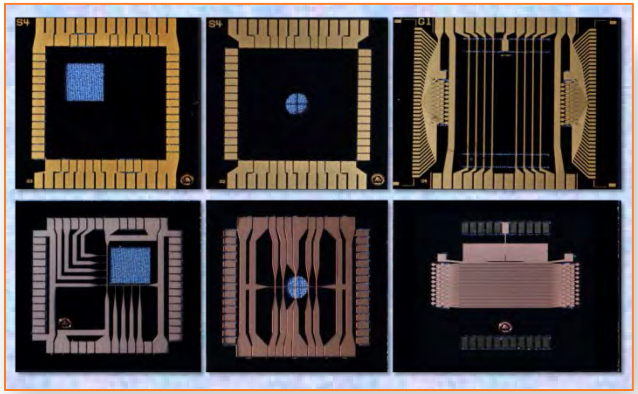


$$S_\Omega = 0.04\,\frac{rad}{\Omega_e}$$

Cold atom interferometer

Courtesy of Harvard

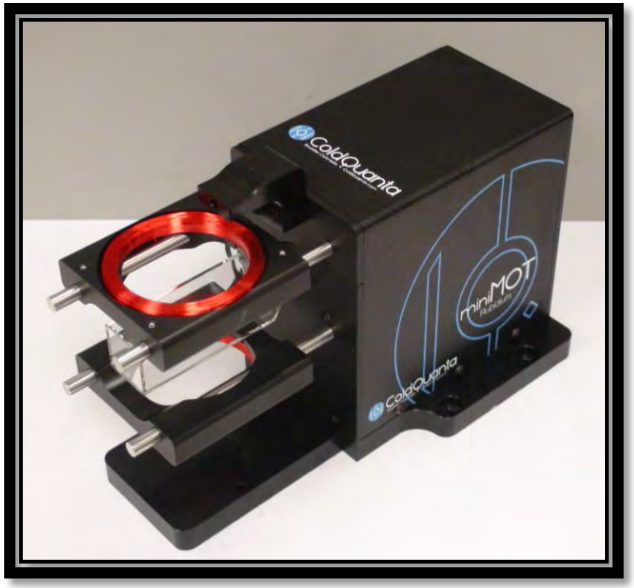
Commercialization of Cold & Ultracold Instruments



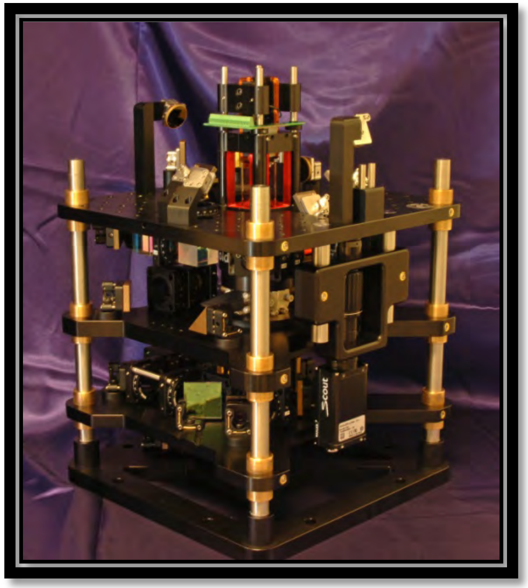
Custom atom chips

ColdQuanta, Incorporated

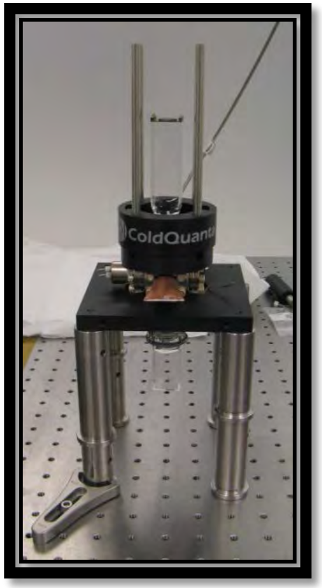
- Founded in 2007
  Rainer Kunz, Jakob Reichel,
  Ted Hänsch, & D. Z. Anderson



miniMOT™ & miniMOT kit

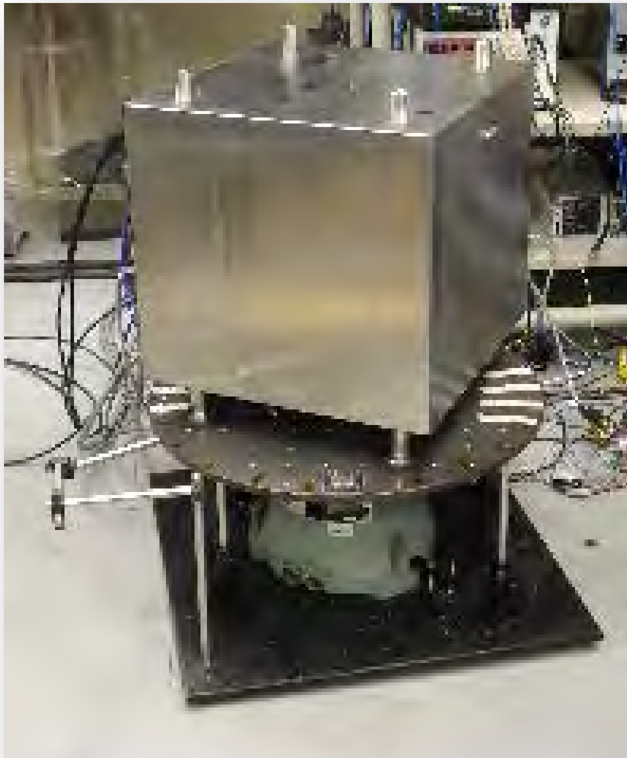


BEC Physics Station

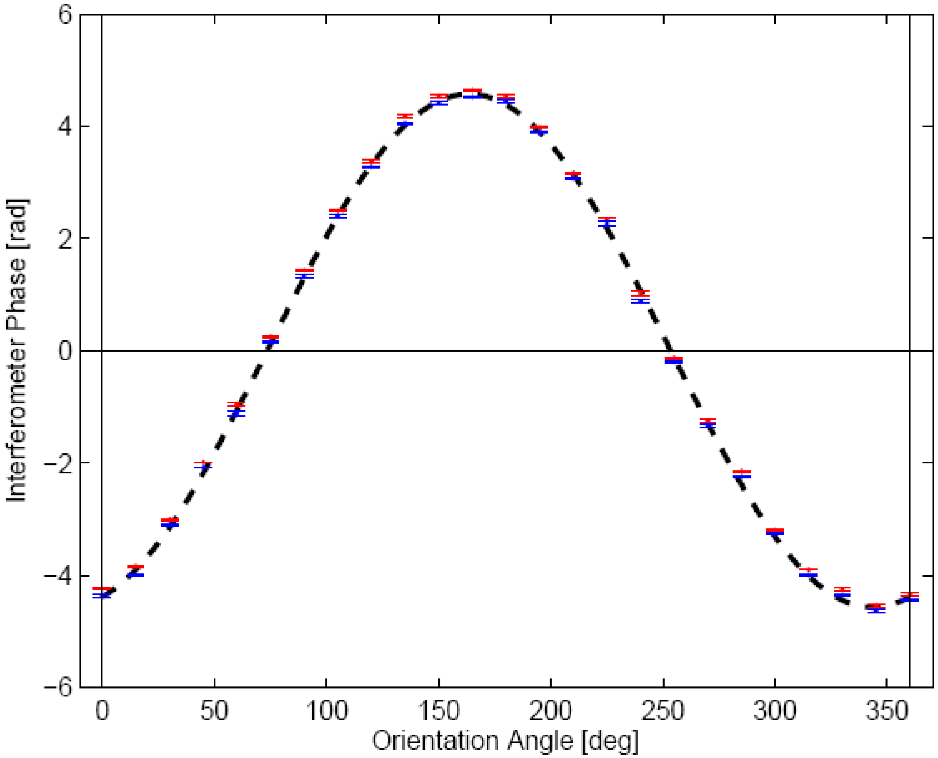


RuBECi

Another Route: *Free Space* Interferometry
2007 Hybrid Sensor/Gyroscope Mode

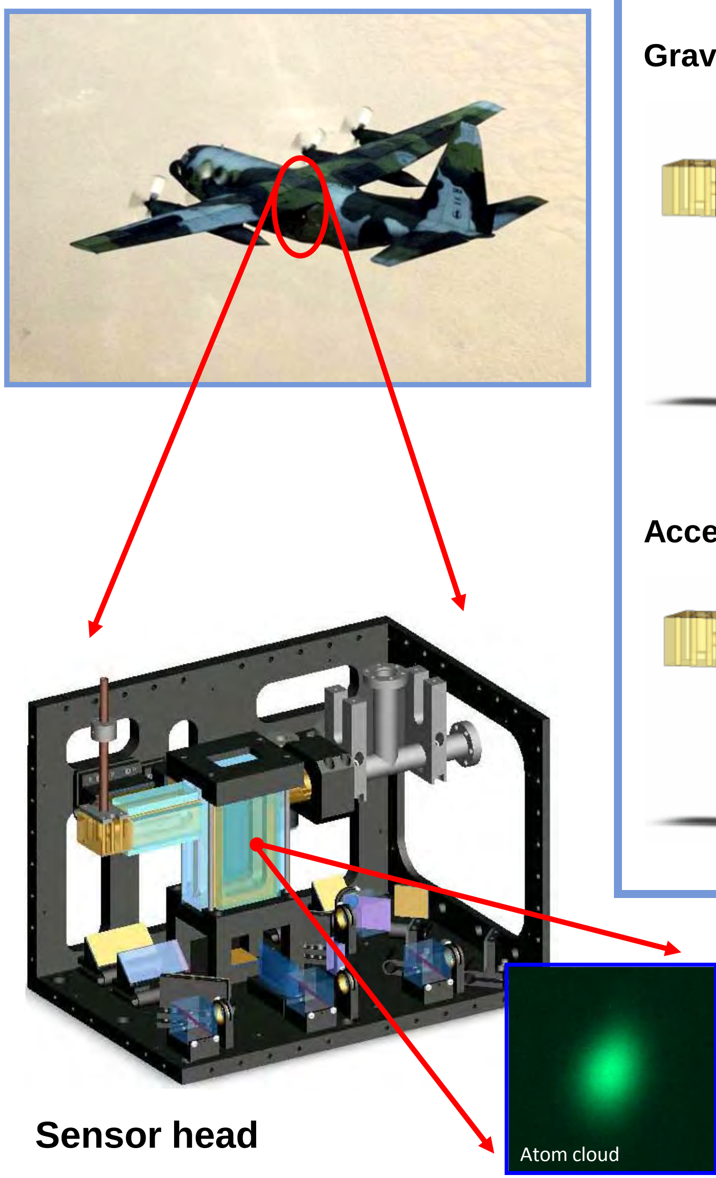


Measured gyroscope output vs.orientation:

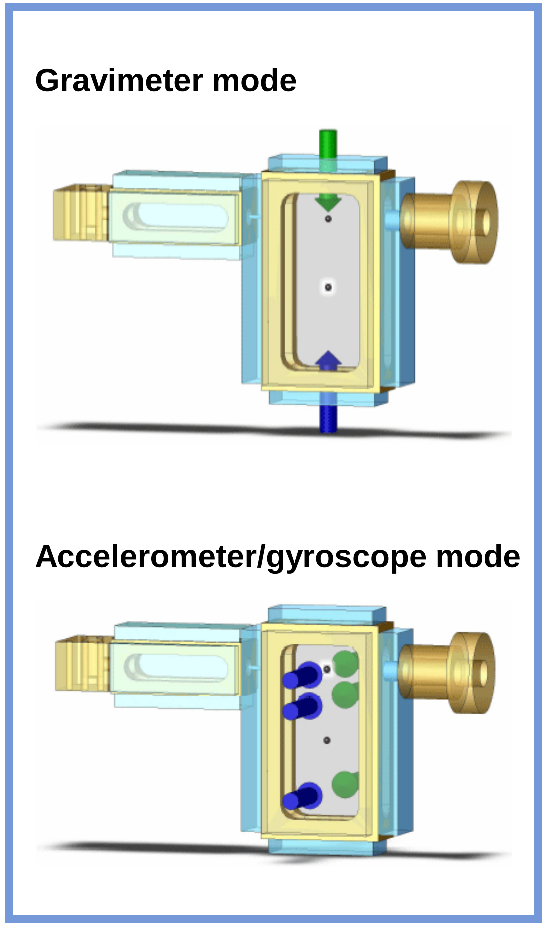


- Inferred ARW: ~ 100 μdeg/hr$^{1/2}$
- 10 deg/s max input
- <100 ppm absolute accuracy

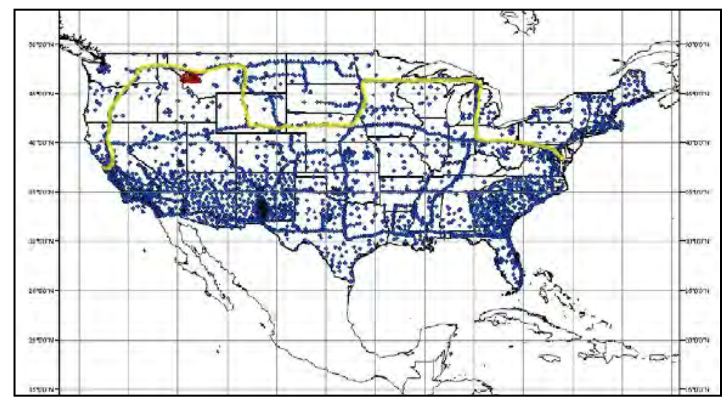
Atom Interferometer-based Inertial Navigation (DARPA)



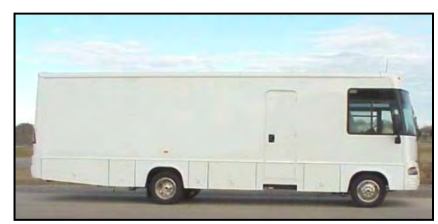
Sensor head



- Demonstrated performance of single-sensor designs
  - Accelerometer: <10ng bias
  - Gyro: <5 μdeg/hr bias
  - Gradiometer: <10 E/Hz$^{1/2}$
- Phase 3 Goal: 5 meter/hour gravity-compensated inertial navigation system demonstration

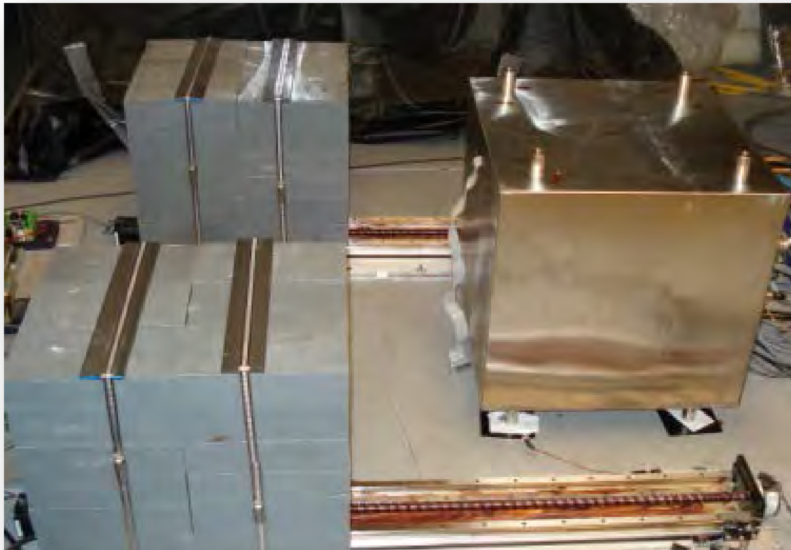


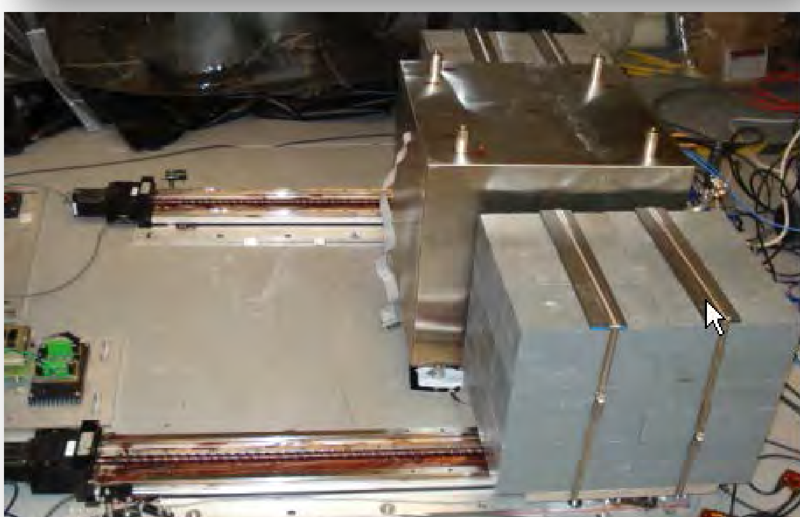
Cross-country Navigation Test Route

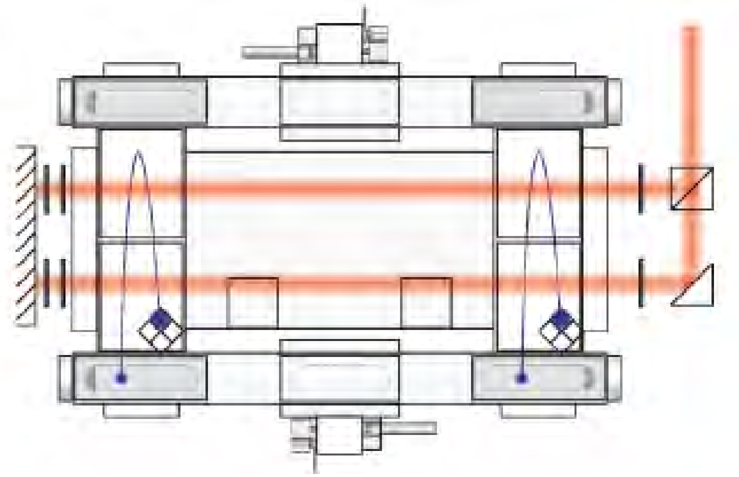


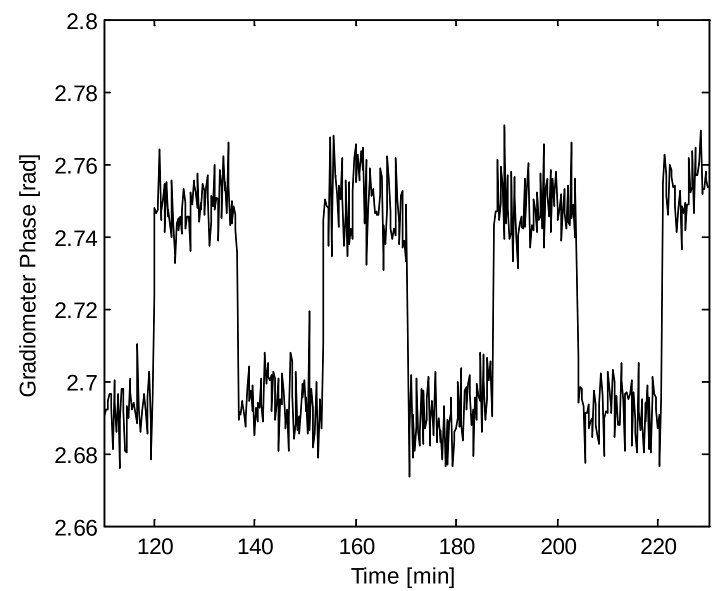
Navigation Test Vehicle

2007 Hybrid Sensor/Gravity gradient mode (SP-24)

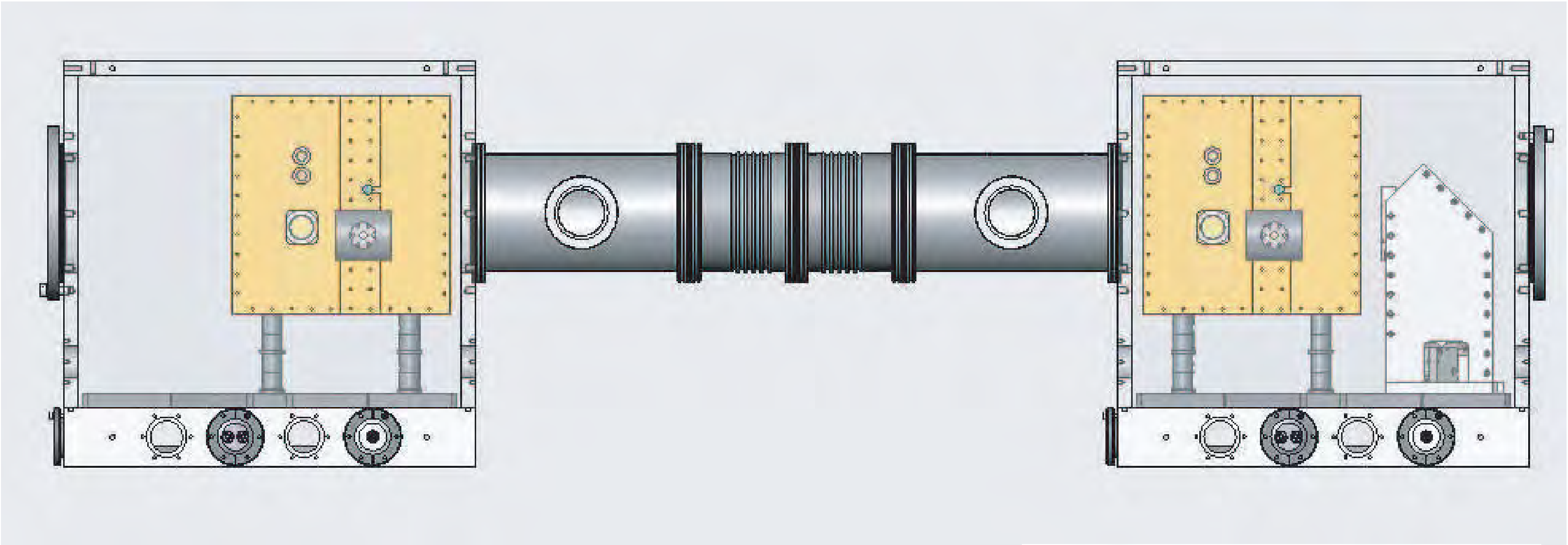


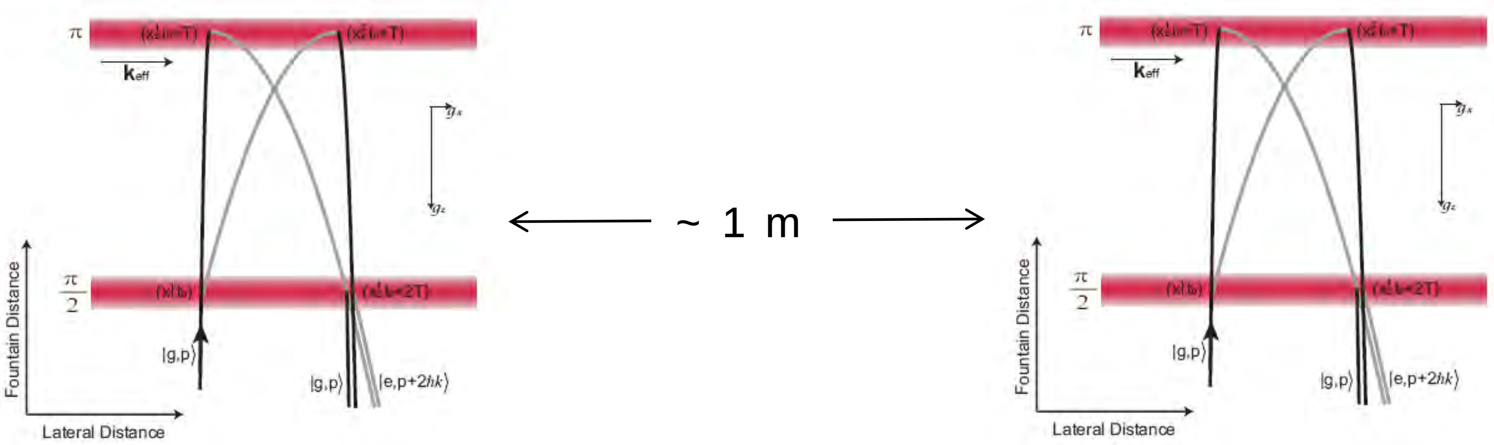






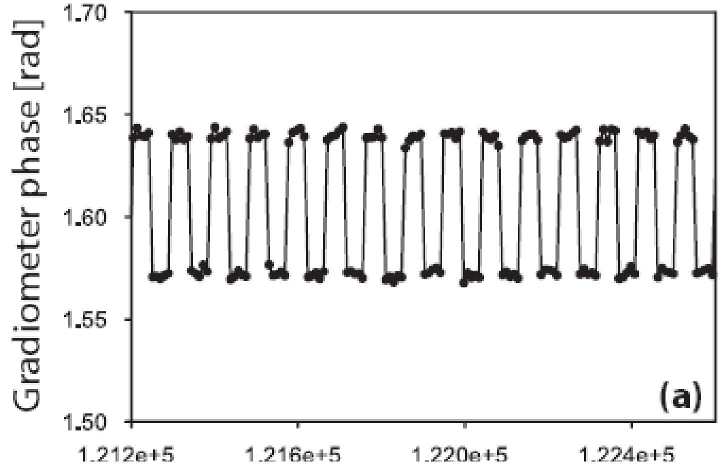
2007 Gravity Gradiometer (NGA)

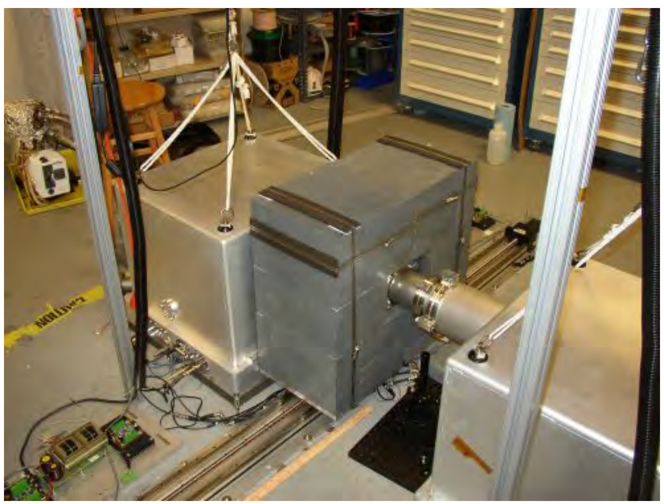


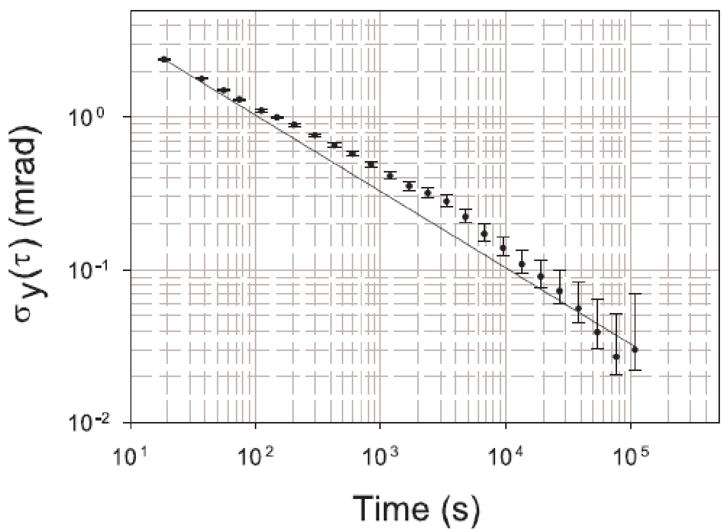


Applications in precision navigation and geodesy

2007 Gravity Gradiometer (NGA)

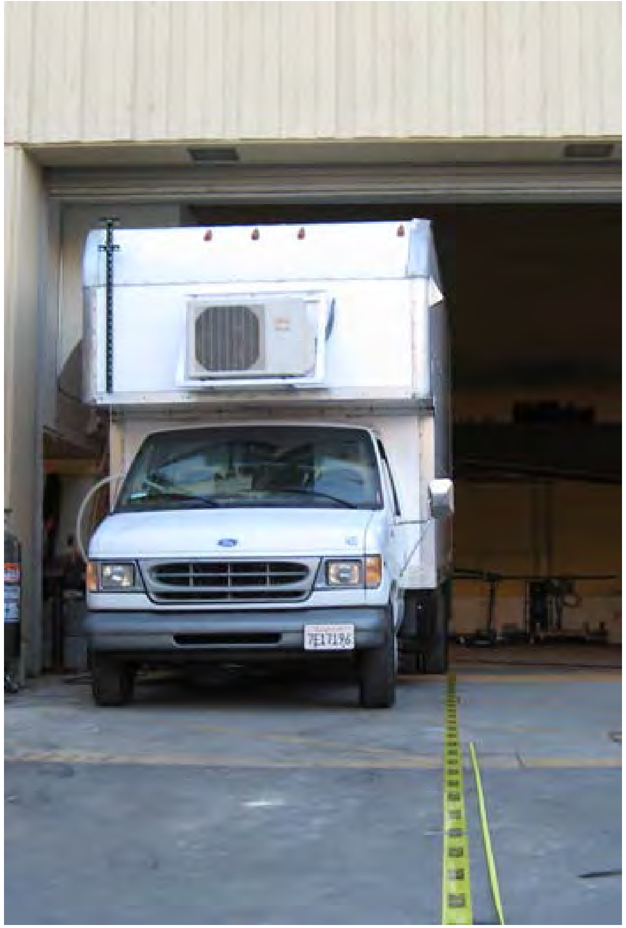






Demonstrated accelerometer resolution: ~10^{-11} g.

2007 Truck-based Gravity Gradient Survey (NGA)



ESIII loading platform survey site

AOSense, Inc.

- Formed in 2004 to develop cold-atom navigation sensors
- Core capability is design, fabrication and testing of sensors based on cold-atom technologies
- 20k sq. ft. R&D space, located in Sunnyvale, CA

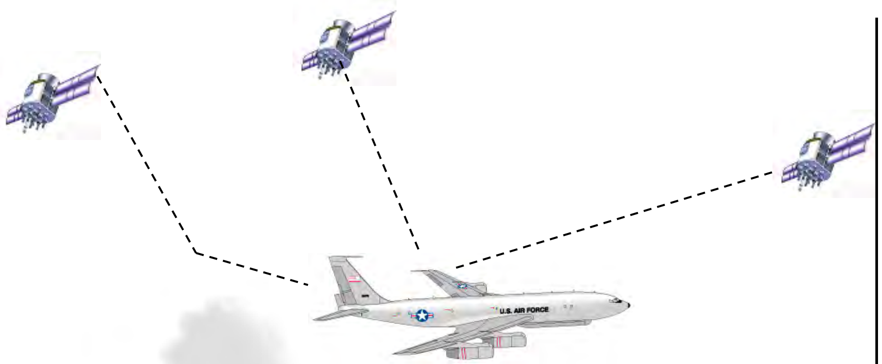
Commercial Cold Atom Gravimeter

- Noise < 1 μg/Hz$^{1/2}$
- Shipped 11/22/10
- First commercial atom optics sensor

AOSense

byoung@aosense.com

Atomic and Molecular Physics leads to DoD Application



Vision: Jam-proof, non-emanating inertial navigation with near-GPS accuracies for future military systems

Current Navigation

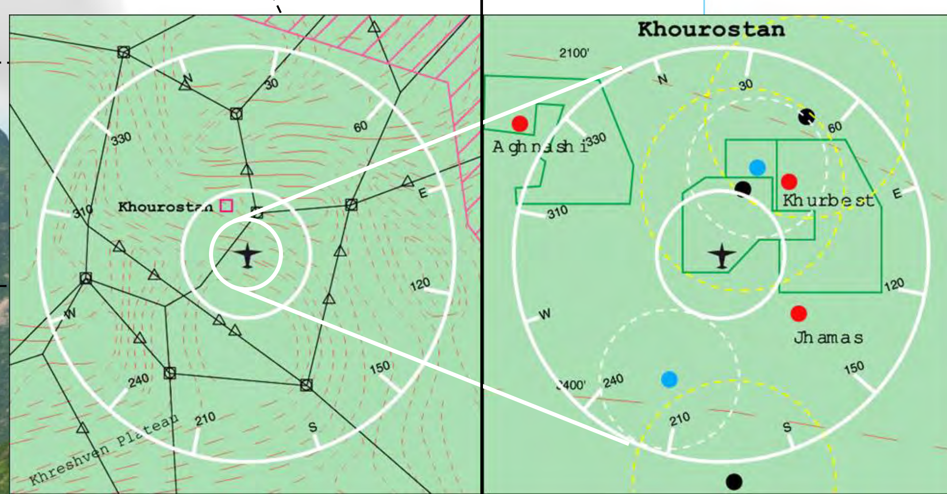
GPS + INS

- GPS transmission to platform vulnerable to jamming, geographic limitations, etc.
- Without GPS, position determined to within 1-2 miles after 1 hr

Future Navigation

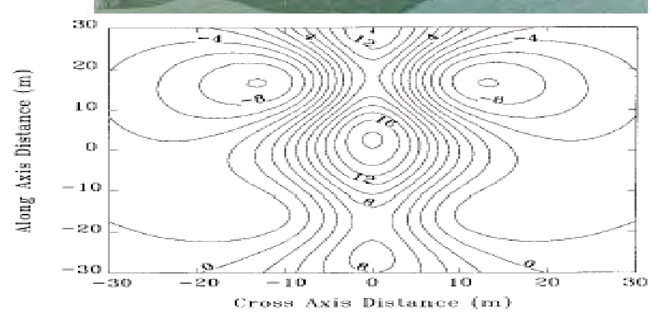
GPS + PINS

- Position determined to within 5 meters after 1 hr, regardless of geography
- Precision independent of transmissions to or by platform



Atomic and Molecular Physics leads to DoD Application

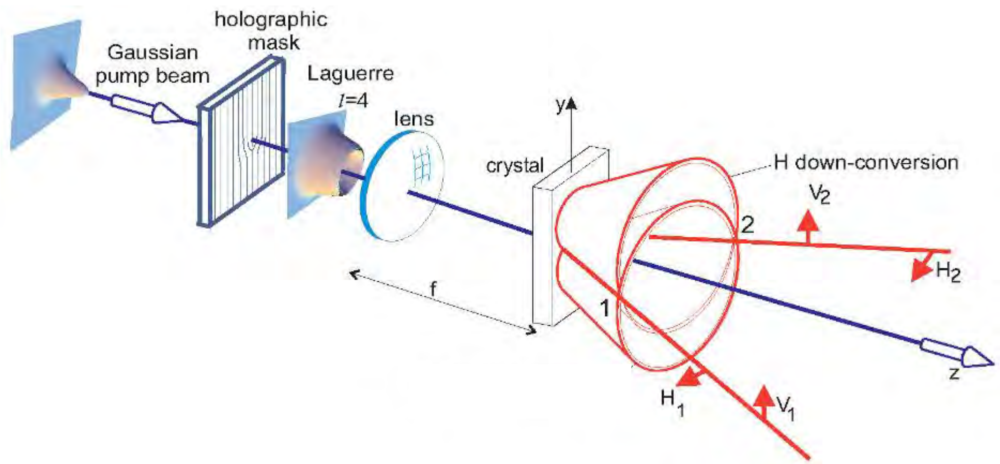
- Standoff detection of underground structures: a long-standing Army need
- Conventional gravity gradiometers can detect geological formations
- Atom Interferometery gravity gradiometer
  - x10 sensitivity improvement (0.1 E/(Hz)$^{1/2}$)
  - Excellent long-term stability
  - Intrinsic immunity to vibrations
  - Sensitivity to detect 5 meter diameter tunnels by aircraft 500 feet above ground
  - . . . or a 50 ton tank at 100 meters (5 mph)
- Possible further improvement of ~10^8



Some recent and current MURIs

- Quantum Imaging
- Optical Lattices
- Atomtronics
- Quantum Information Sciences

Quantum Imaging MURI



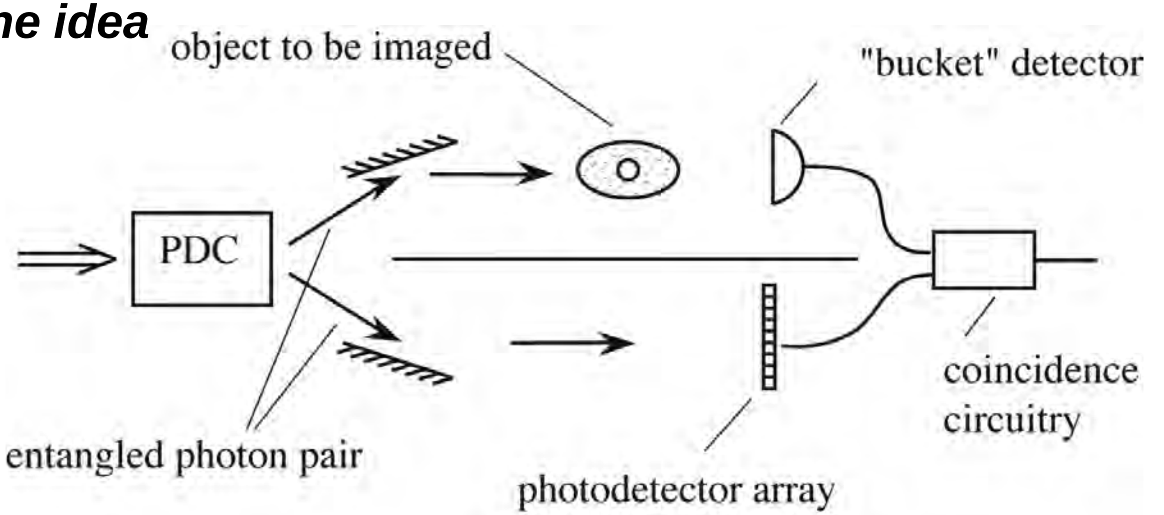
Motivations and Research Goals

- Can images be formed with higher resolution, greater sensitivity, or by interaction-free measurement through use of quantum states of light?
- For example, can one “beat” the Rayleigh limit?
- Can one use “ghost imaging” for detection and surveillance?

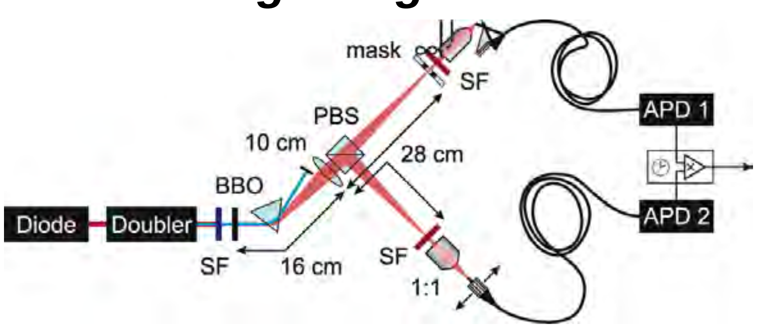
Coincidence (Ghost) Imaging

- Image is formed by photons that have never interacted with the object
- Obvious applicability to surveillance and remote sensing
- Utilizes entangled photons, correlated beams, or intensity fluctuations
- Can enable imaging through obscurants; or in different spectral bands than sensor

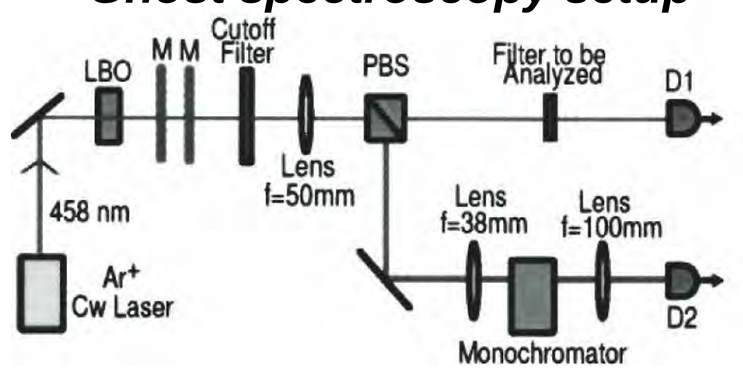
The idea



Entangled light source



Ghost spectroscopy setup

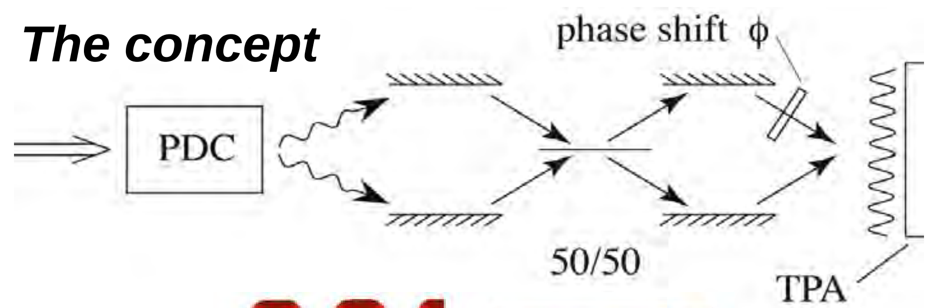


Quantum Lithography

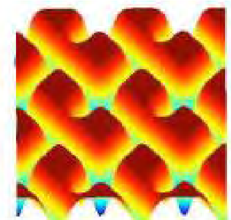
Objectives

- Perform photolithography with sub-Rayleigh resolution
- Develop related methods for obtaining sub-Rayleigh resolution in microscopy and other imaging

The concept



Simulation of arbitrary pattern



AFM of lab fringes

Approach

- Create entangled photons by down conversion; Construct OPA source
- Combine interferometrically
- Observe non-classical fringe spacing
- Develop sensitive multiphoton lithographic materials

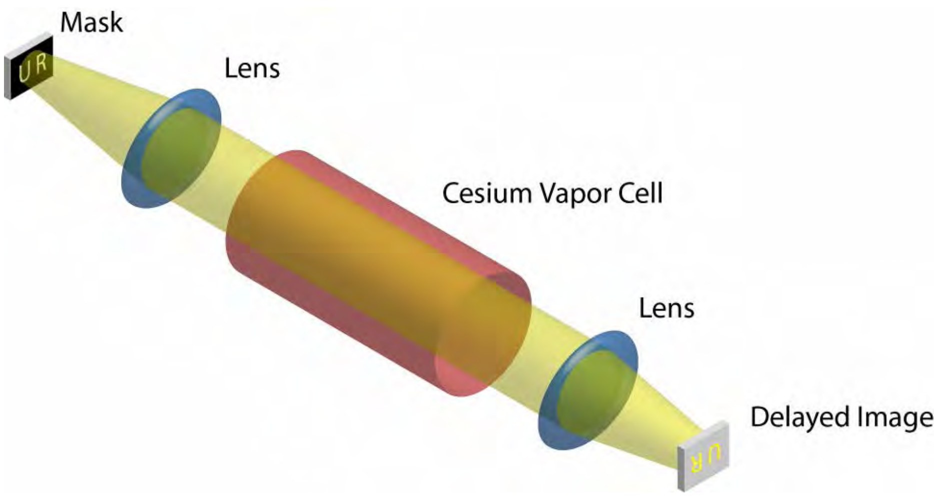
Accomplishments

- Performed study of use of OPA as an intense source of entangled photons
- Established PMMA as suitable recording material; identified more sensitive alternatives
- Demonstrated ability to write $\lambda/6$ features
- Developed protocol for writing non-sinusoidal features

High-Dimensional Entanglement and Imaging

Objectives

- Measure & characterize high-D entanglement
- Demonstrate high-D cryptosystem
- Demonstrate high-D spin violation of Bell's inequalities (e.g., spin 20 to 50)
- Single photon transverse coherence
- Low noise, coherence-preserving buffer for quantum images



Approach

- Measure & characterize time-energy and transverse entanglement
- Use Fourier transform pairs for quantum particles to generate secret key with security
- Use transverse entangled photons and analogs with spin to violate Bell inequality with continuous variables
- Use steep dispersion in double resonance system for delaying images

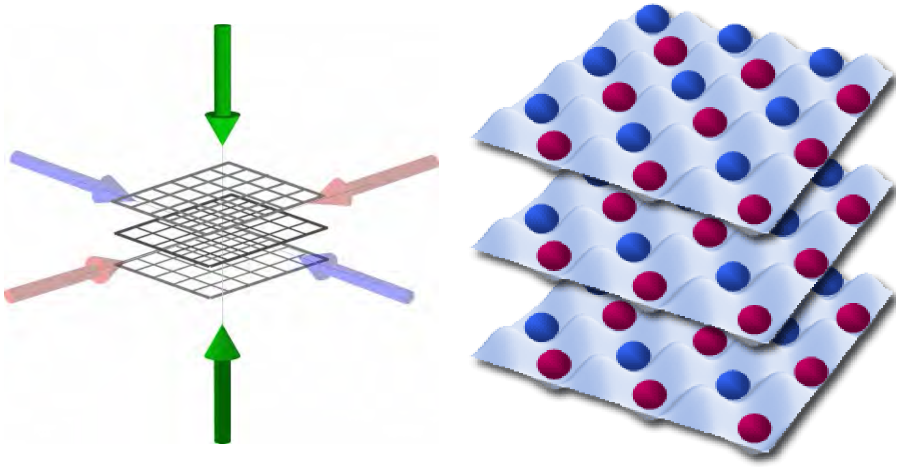
Accomplishments

- Measured over 6000 states in a single pair of entangled photons
- Demonstrated 10 bit/pair high-D cryptosystem
- Theory and simulation of transverse entanglement and spin
- Demonstrated single photon transverse coherence
- Demonstrated excellent fidelity single photon or classical image buffering in a vapor

Optical Lattices MURI

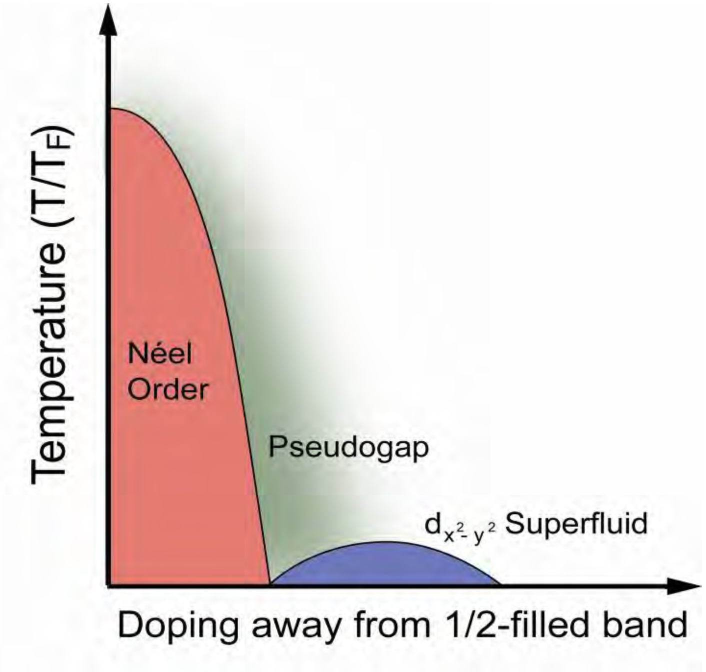
Objectives:

- Ability to design matter
- Quantum simulation of systems that can't be treated by computer
- "Parallel" sensing with squeezing



- New functional materials
- Room temperatures superconductors
- New classes of devices

Hubbard Model
Anti-ferromagnetism and superconductivity

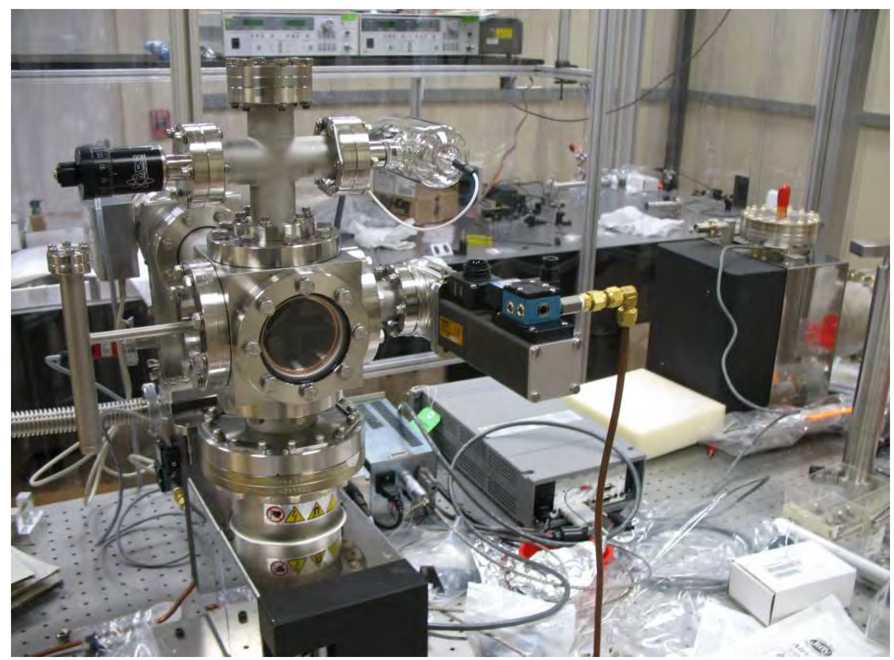


Phase diagram of the high-T_c superconducting cuprates.

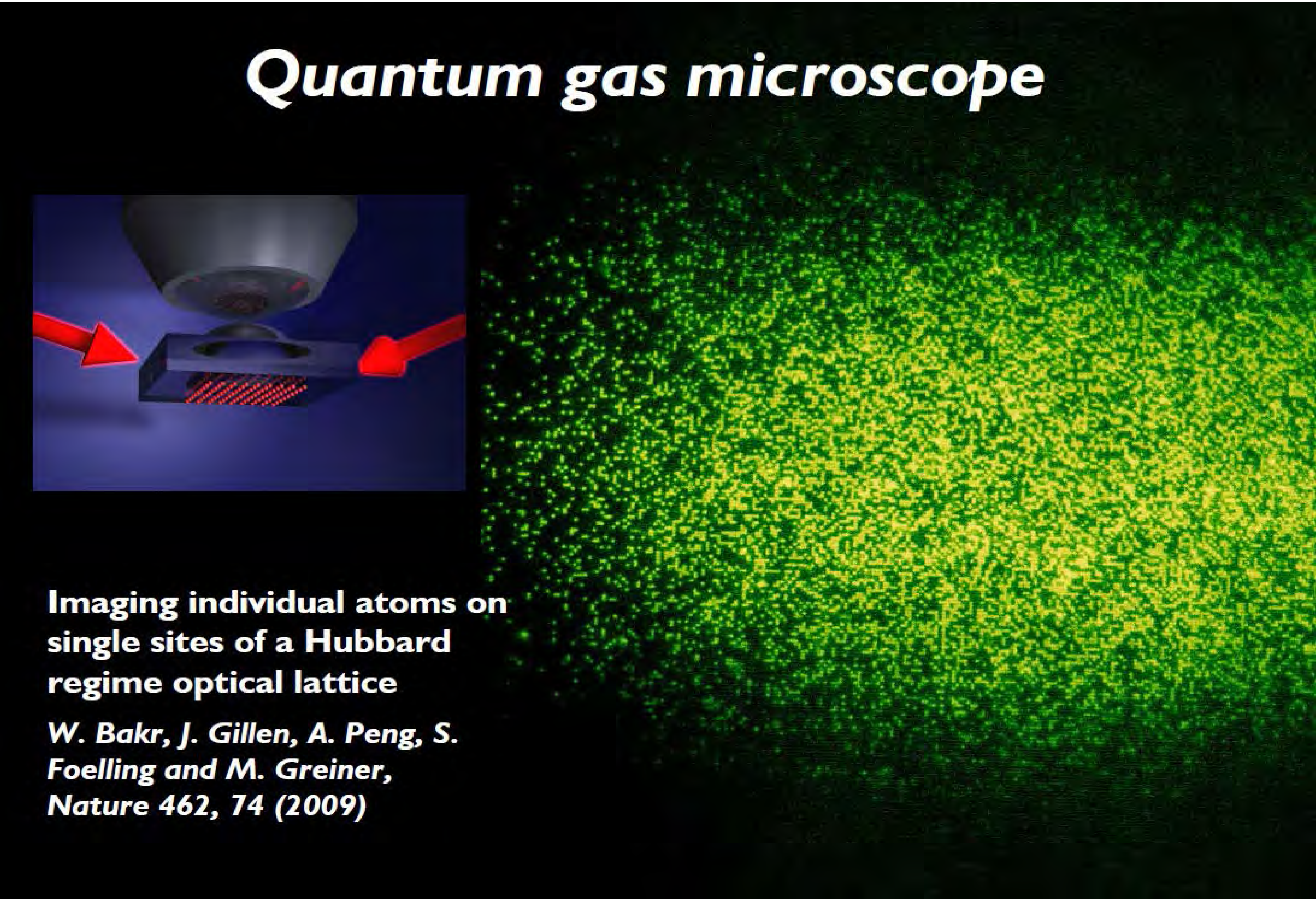
Whether or not the Hubbard model exhibits a similar phase diagram is an open question.

Accomplishments

- Bose Hubbard studied: Mott insulator transition studied and matched to theory
- 1D Fermi lattice studied / crossover to 3D
- New ways to cool/remove entropy to reach AFM state in 3*D* lattice with harmonic confinement



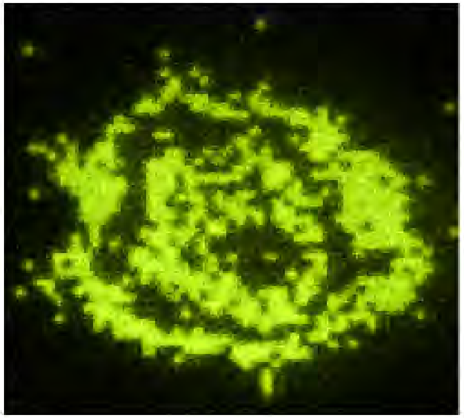
Direct Imaging



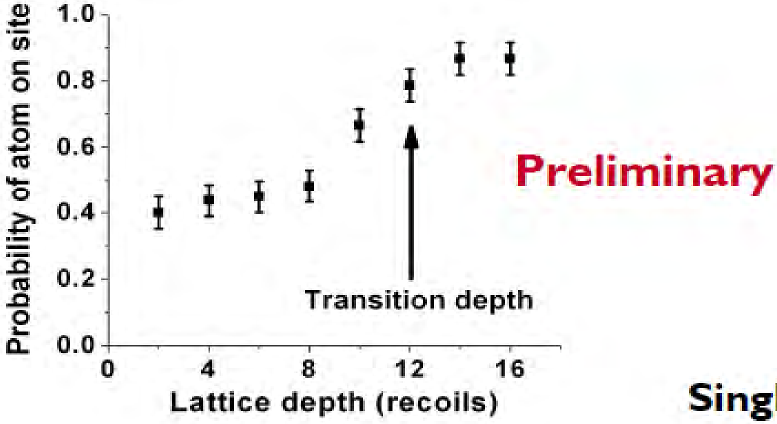
Direct Detection of Mott Insulating Phase

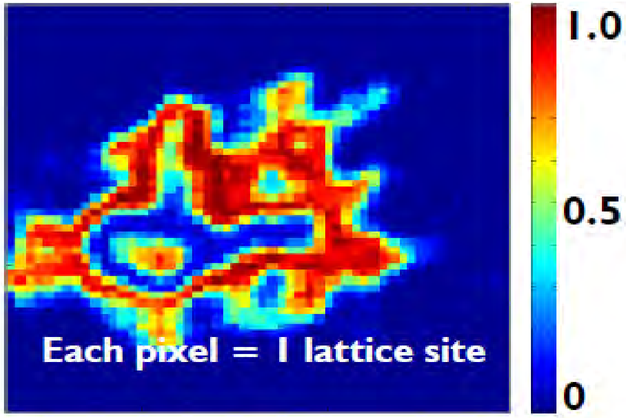
Harvard, Greiner

- Directly detect Mott insulator phases with 1, 2, 3, 4 atoms per lattice site
- High fidelity imaging with defect densities as low as 5%



4 shells: Mott insulator with 4 – 3 – 2 – 1 atoms/site

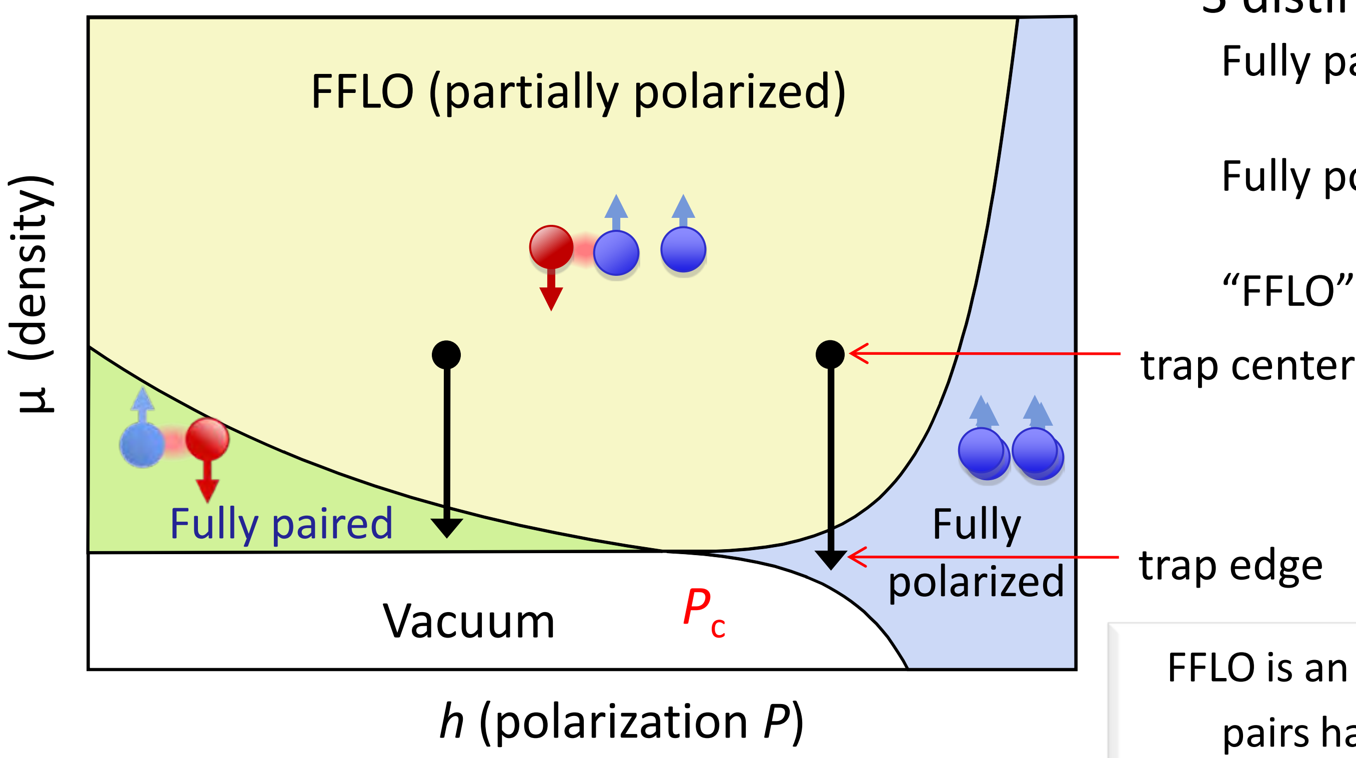




Single atoms on sites fitted, then averaged over 100 runs

Spin Imbalanced 1D Fermi Gas

Rice, Hulet

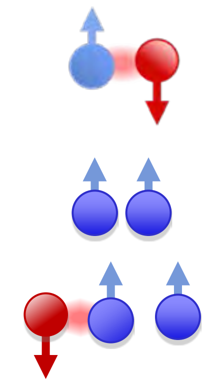


3 distinct phases:

Fully paired

Fully polarized

"FFLO"



FFLO is an exotic superfluid whose pairs have finite momentum

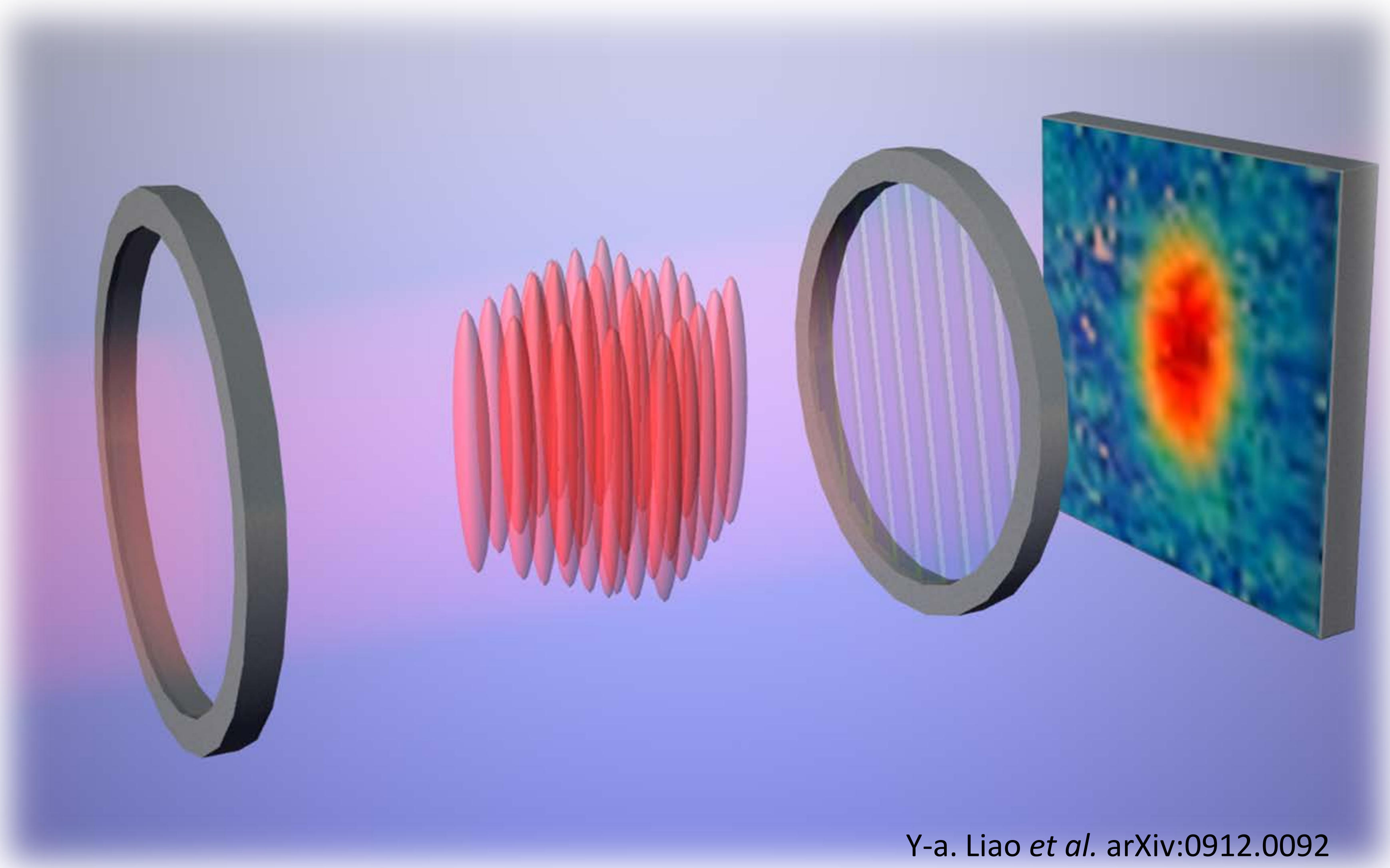
→ Breaks translational symmetry

Coexisting magnetic and superconducting order found in heavy Fermion compounds — but smoking gun for FFLO not previously observed

Orso, PRL (2007); Hu *et al.*, PRL (2007)

1D-3D crossover

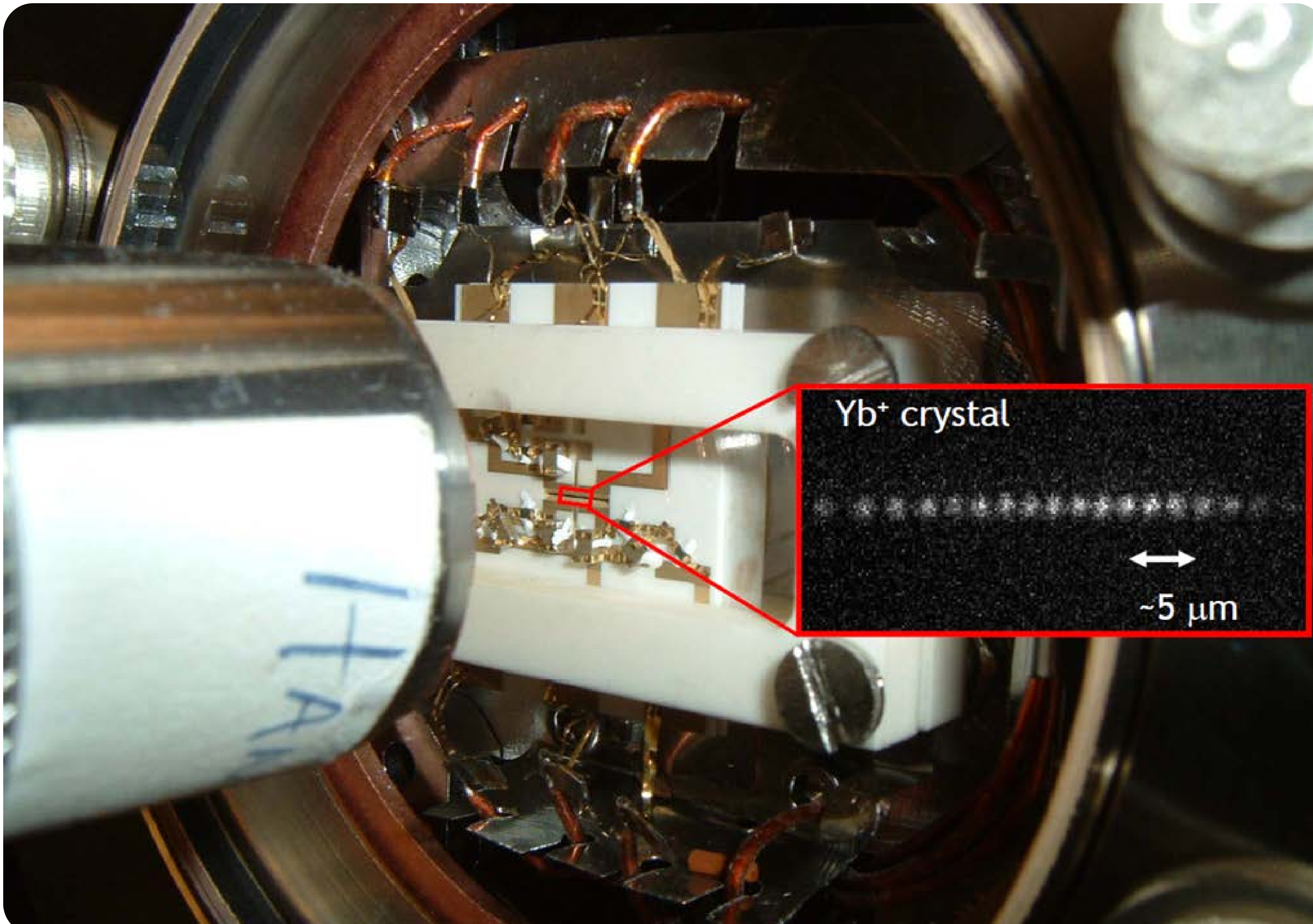
Rice, Hulet



Y-a. Liao *et al.* arXiv:0912.0092

Simulation of 1D Quantum Magnetism with Trapped Ions

Maryland, Monroe

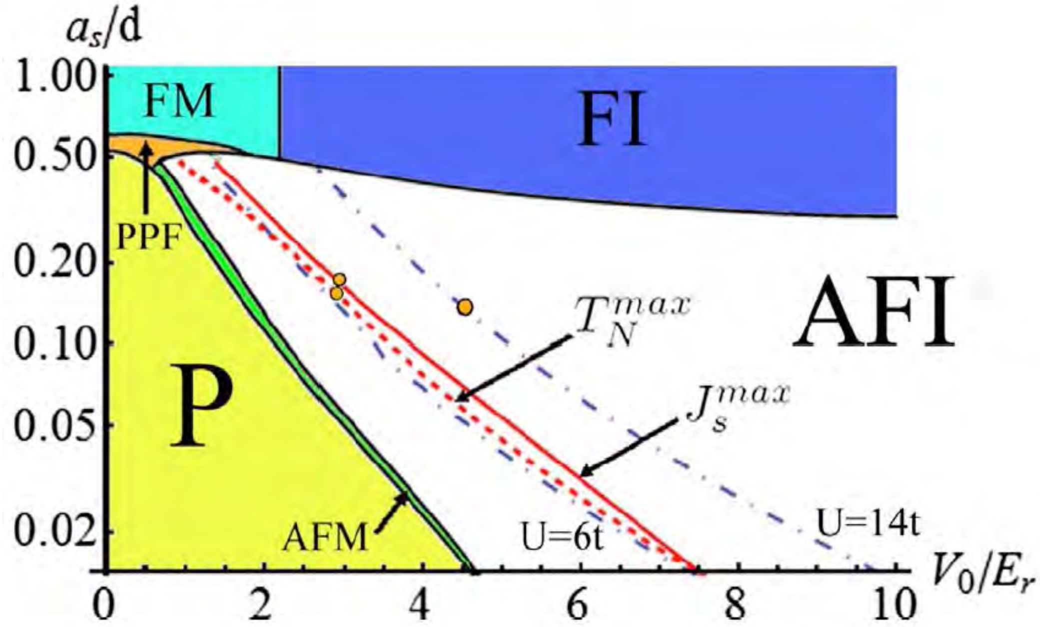


Magnetic ordering of atoms in optical lattices

Multi-species lattices lead to complex ordering/phase diagrams

Groups and platforms:

- *JQI/NIST/UMD (Porto) Yb-Rb mixture*
- *UC Berkeley (Stamper-Kurn) Li-Rb mixture*
- *Univ. of Chicago (Chin) 2-comp. Cs and 2-comp. Li*



Atomtronics MURI

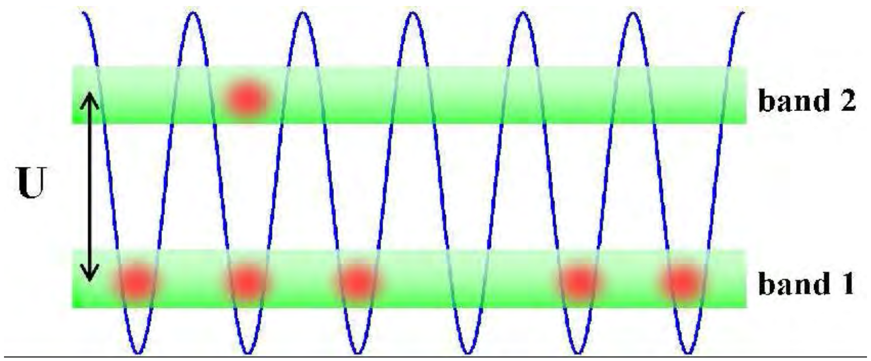
Devices & circuits *based on ultracold atoms* instead of electrons

Novelty: considerably more degrees of freedom to exploit

- What do all the additional degrees of freedom enable?
  - ❖ Internal state structure
  - ❖ Spin symmetry including mixtures
  - ❖ Variable mass, including mixtures
  - ❖ Variable charge, including mixtures
  - ❖ Spin (e.g. spintronics), including multiple spin states

- Not just analogs of electronic devices but something possibly quite new!

Band structure: conductor



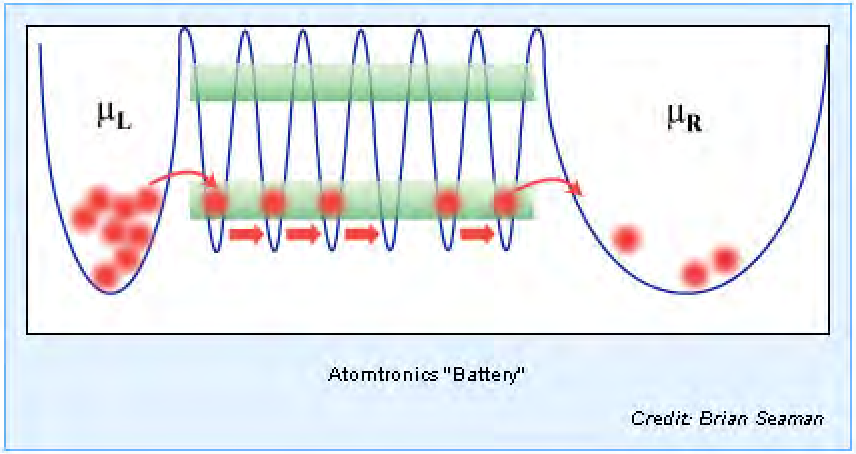
Band gap results from

- On-site interaction U (Bosons)
- Pauli principle (Fermions)

Strange new physics of wires:

1D allows controllable Fermionization of Bosons

Atomtronic battery



Reservoirs on left and right control chemical potentials

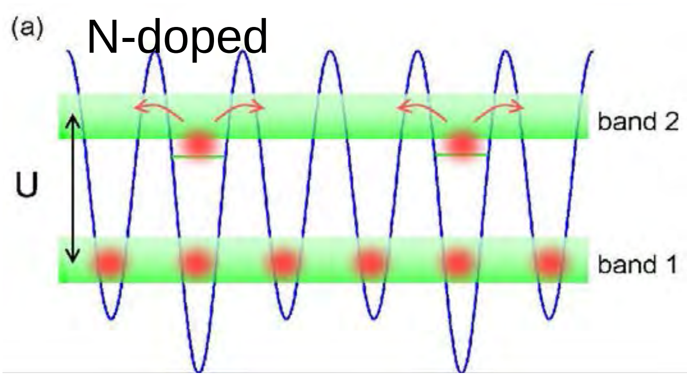
$V \equiv \mu_L - \mu_R$

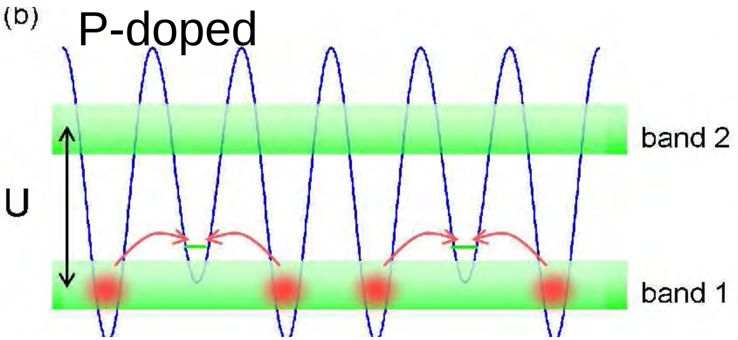
One clear impact of spin statistics:

- Supercurrents for Bosons—dissipationless “resistance” in I-V curve
- Metallic behavior for Fermions
- Further differences arise in both diodes and transistors

“Semiconductors”: doped lattices

- Replacing atoms in certain wells seems obvious… but
  - ❖ more difficult to load
  - ❖ not the true analog
- Locally modifying lattice potential is the analogy
- Defects are deeper or shallower levels; at low density act as acceptors or donors





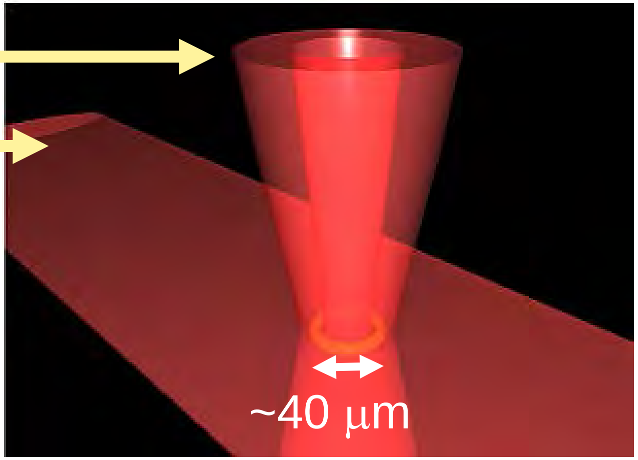
"SQUIDs": BEC in optical toroidal trap

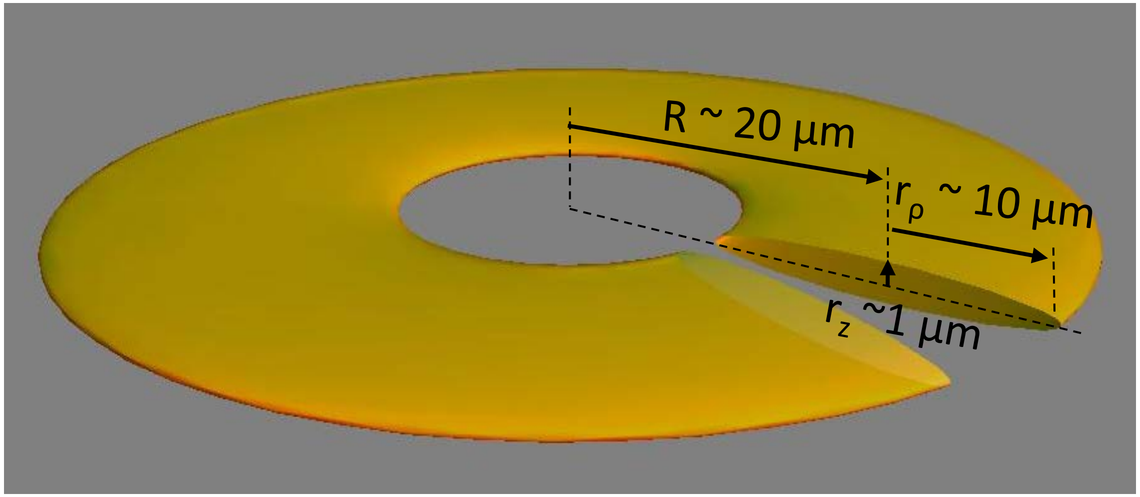
Inducing Circulation with OAM Beams

LG_{01} 'Ring' beam

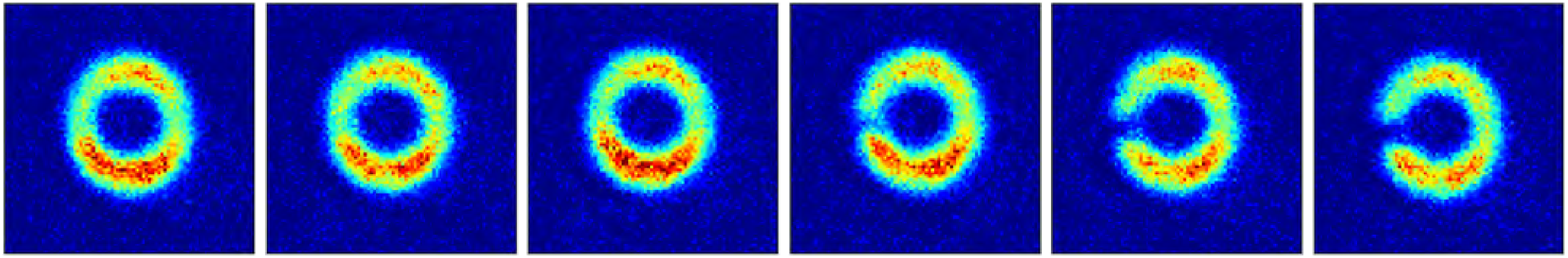
'Sheet' beam

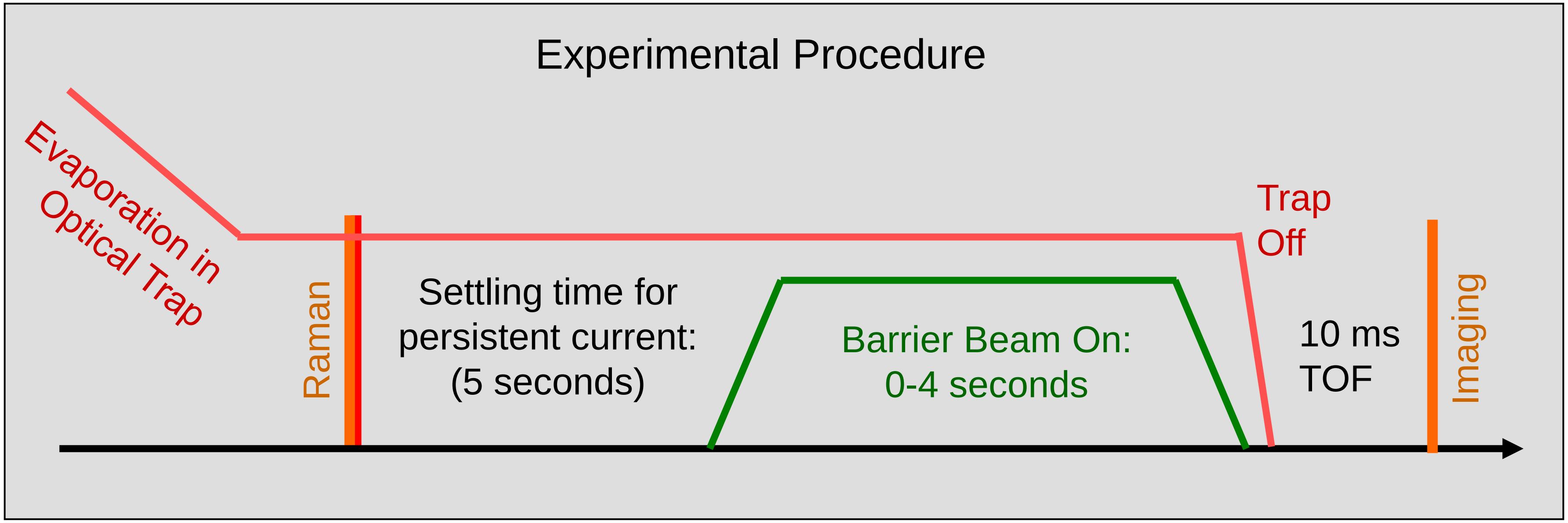
T < 40nK





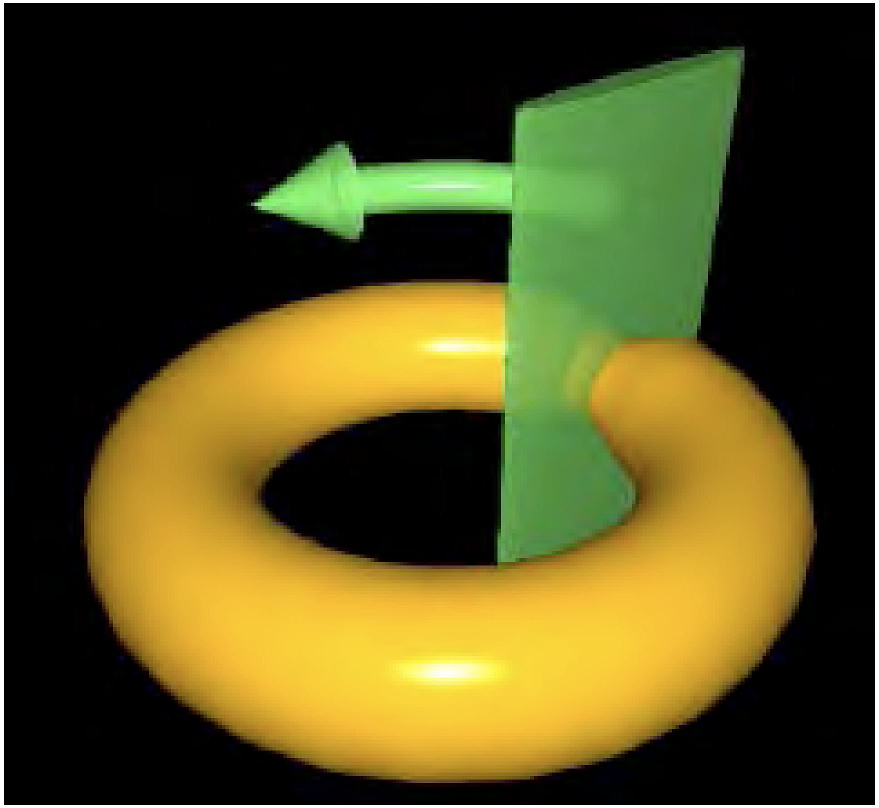
Breaking the Flow With a Barrier





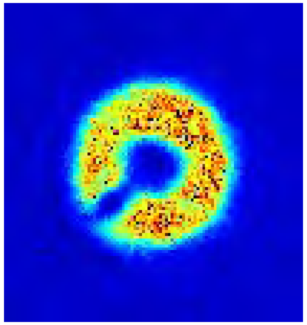
Superfluid Atom Circuits

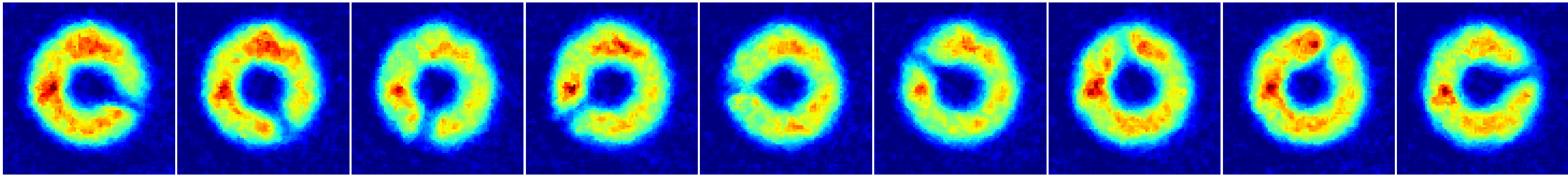
- Superconducting Josephson junction analog
- Changing the rotation velocity is like changing the applied field to a SQUID.
- What happens if you stir slower than one quantum?
- How fast can you stir?



Rotating the Barrier

Barrier can be controlled dynamically using a 2-axis AOD deflector





Rotational Quanta:

$v_0 = 0.13$ mm/s

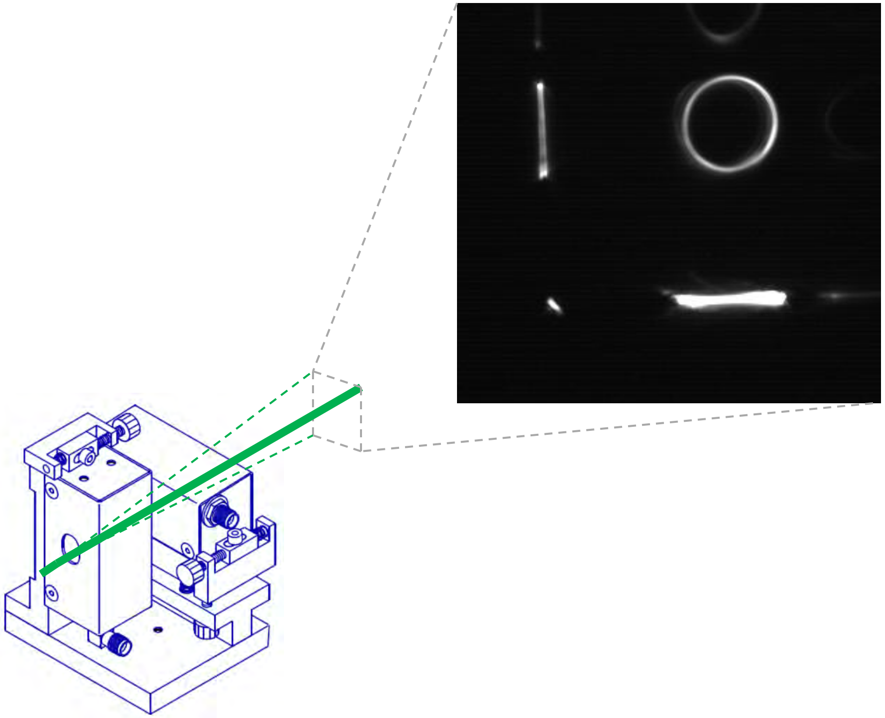
$\Omega_0 = 0.9$ Hz

Sound Speed:

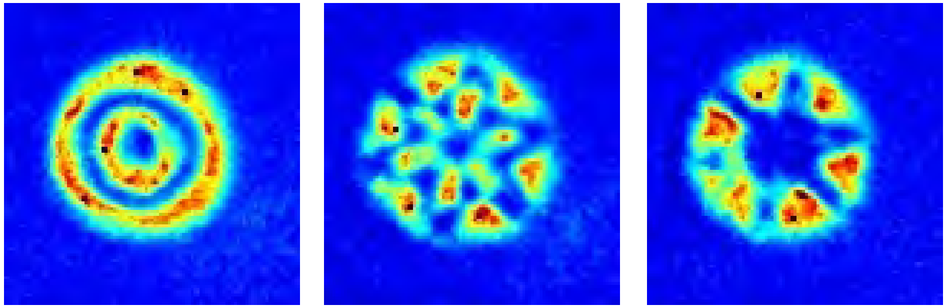
$c = 3\text{-}5$ mm/s

$\Omega_s = 20\text{-}35$ Hz

$\tau_s = 50$ ms

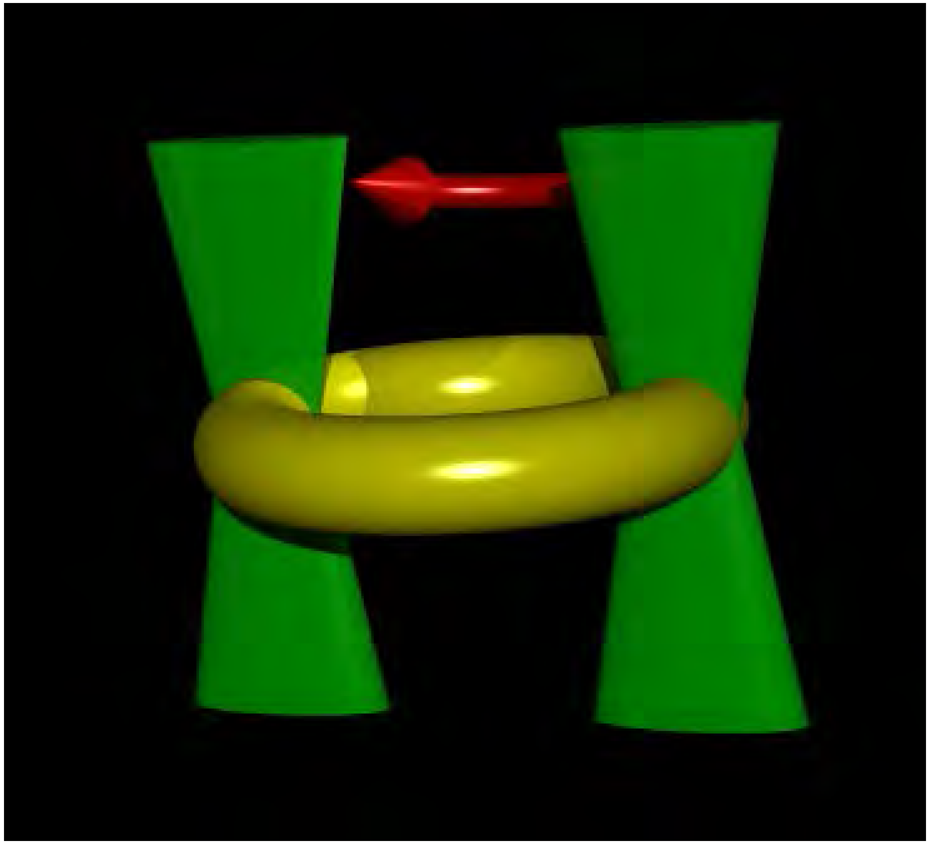


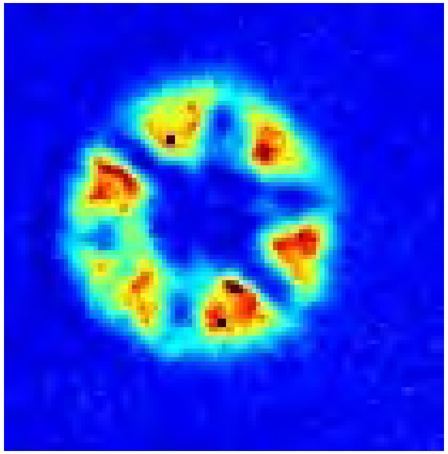
Dynamically vary trap geometry-
`Etched' potentials:



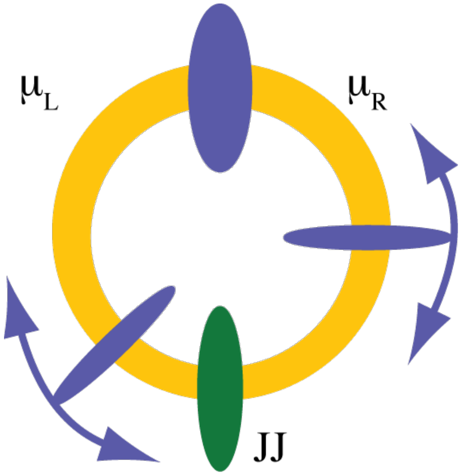
Double Barrier

- Movable double-barrier: analogous to biased DC SQUID
- Could it also be used to detect changes in acceleration across the ring, i.e as a Gradiometer
- What about a ring lattice i.e a Josephson Junction Array?

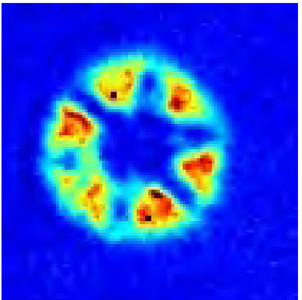


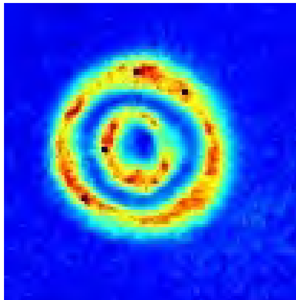


Circuit elements



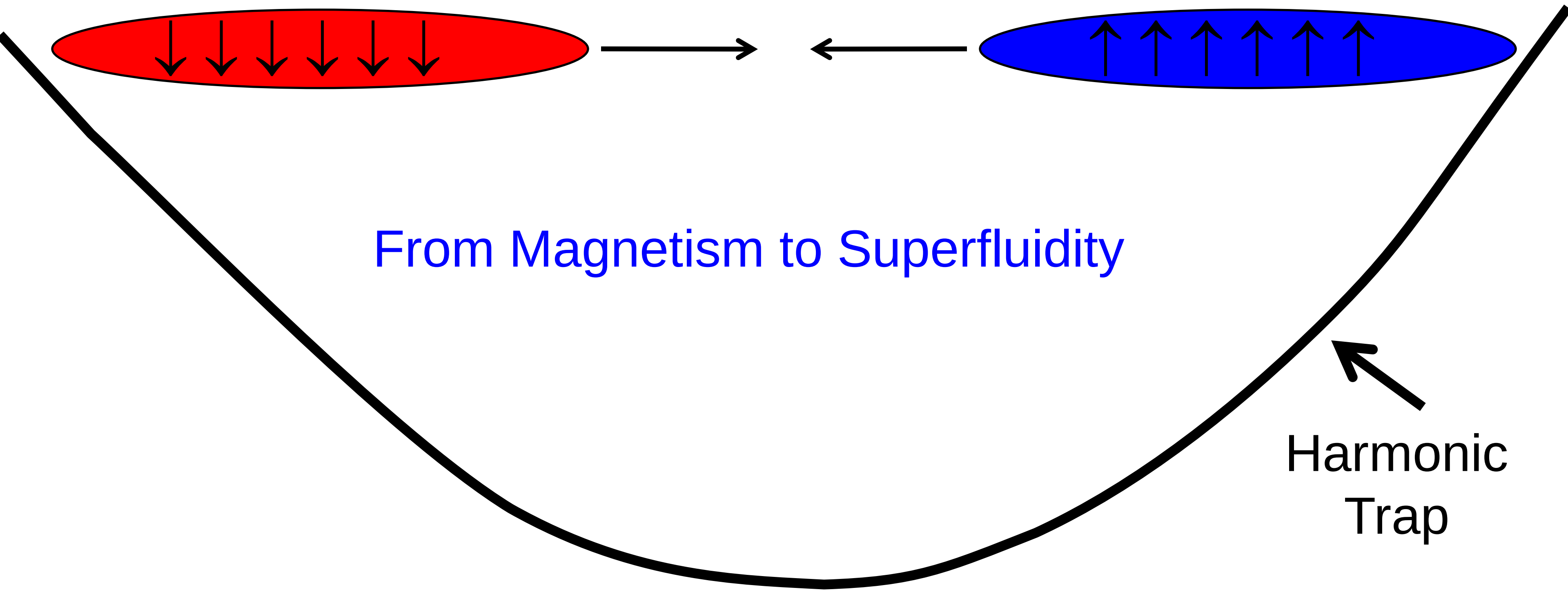
- 3-terminal functionality?
- Batteries-Ability to create "reservoir" of chemical potential
  - Study the effects of static and dynamic periodic potentials applied to the ring
- How could other elements be created: *i.e.*, capacitors, inductors, resistors
- Coupling rings together





Controlling Spin Dynamics

A $\downarrow$ Fermi gas collides with a $\uparrow$ cloud with resonant interactions

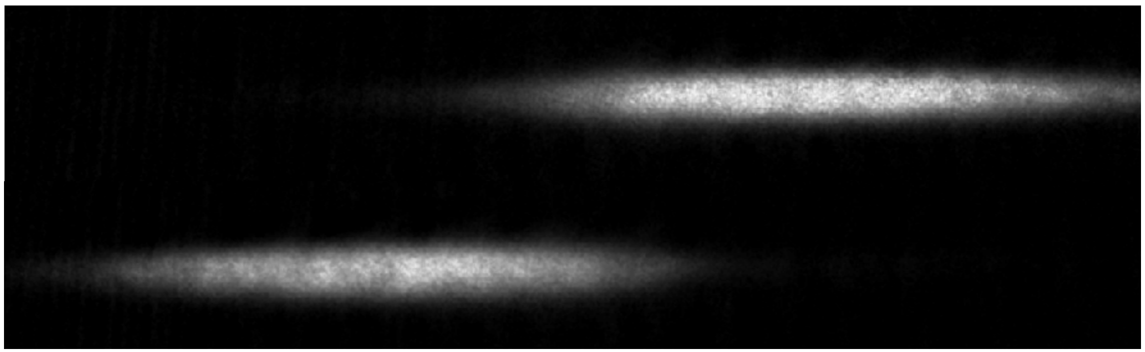


A. Sommer, M. Ku, G. Roati, MWZ, Nature **472**, 201 (2011)

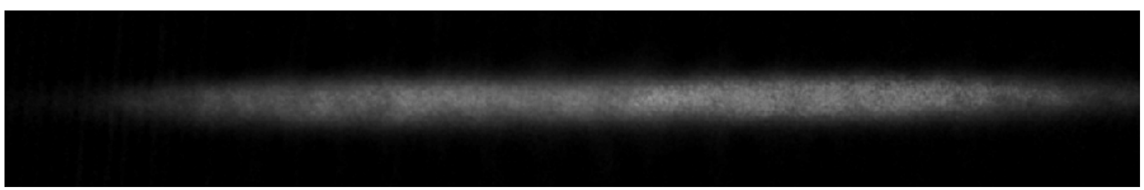
Little Fermi Collider

Preparation: Mix, cool, kick, and rush to resonance

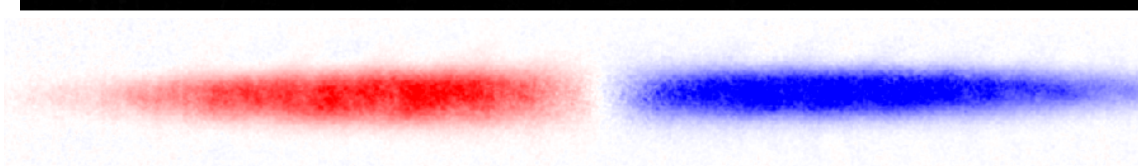
Rapid (10 μs) probing of spin up and down



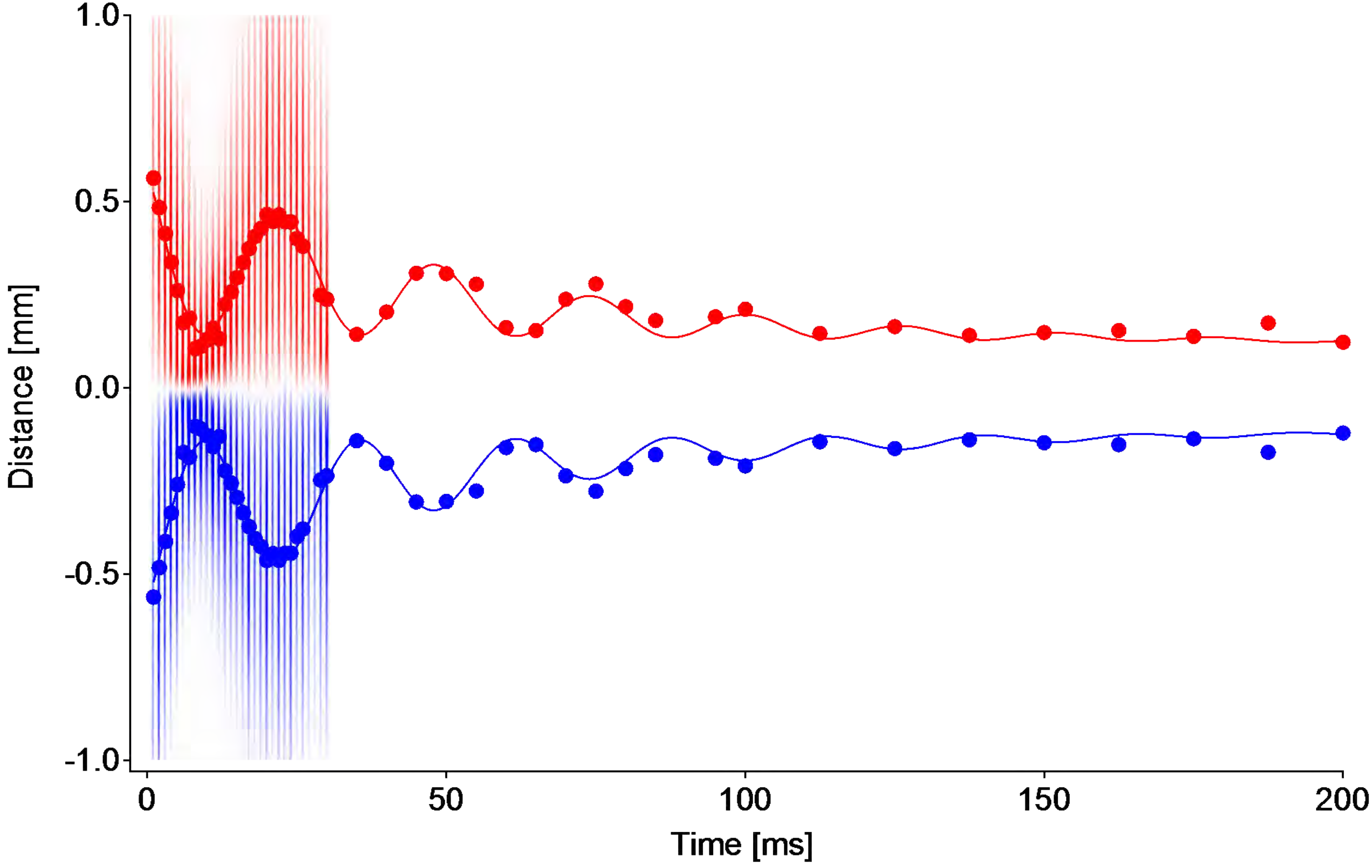
Total OD



Difference



Completely Impenetrable at Resonance

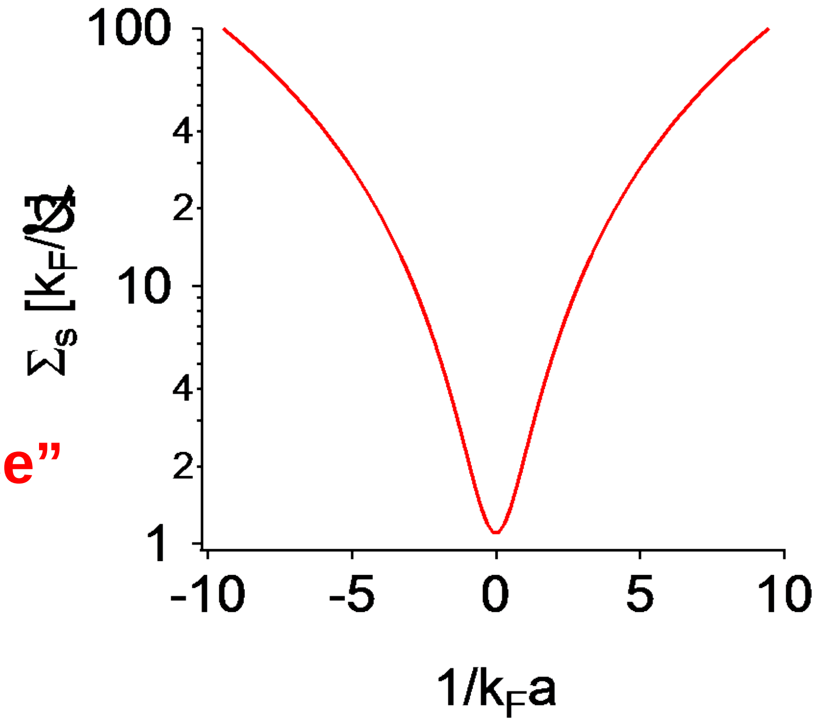


Tunable Spin Conductivity

- Spin conductivity in cold Fermi gases is tunable over a wide range

$$\Sigma_{spin} = \frac{n}{m}\frac{1}{\Gamma_{SD}} = \frac{1}{m\sigma v}$$

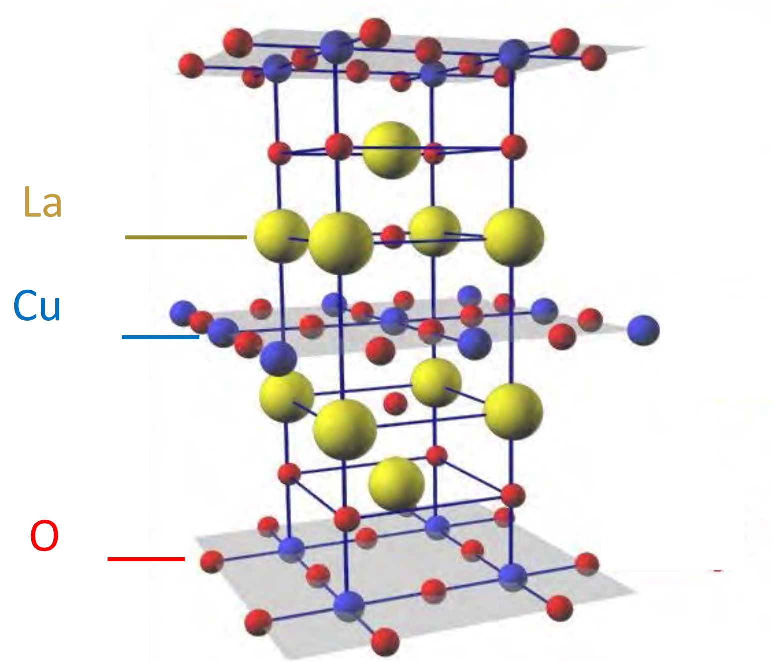
$$\Sigma_{spin} \underset{T\sim T_F}{\approx} \frac{k_F}{\hbar}\frac{1+ck_F^2a^2}{a^2}$$



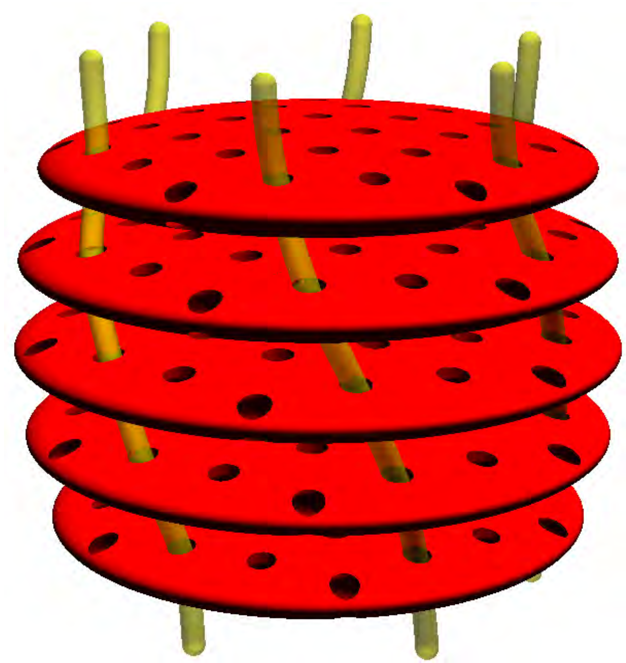
"Giant Magneto Spin Resistance"

Layered Superfluids for Atomtronic Devices

Inspiration: layered superconductors



High-T_c Superconductor with stacks of CuO planes



Stacks of 2D fermionic superfluids

Features of high T_c superconductors (e.g. cuprates, organics)

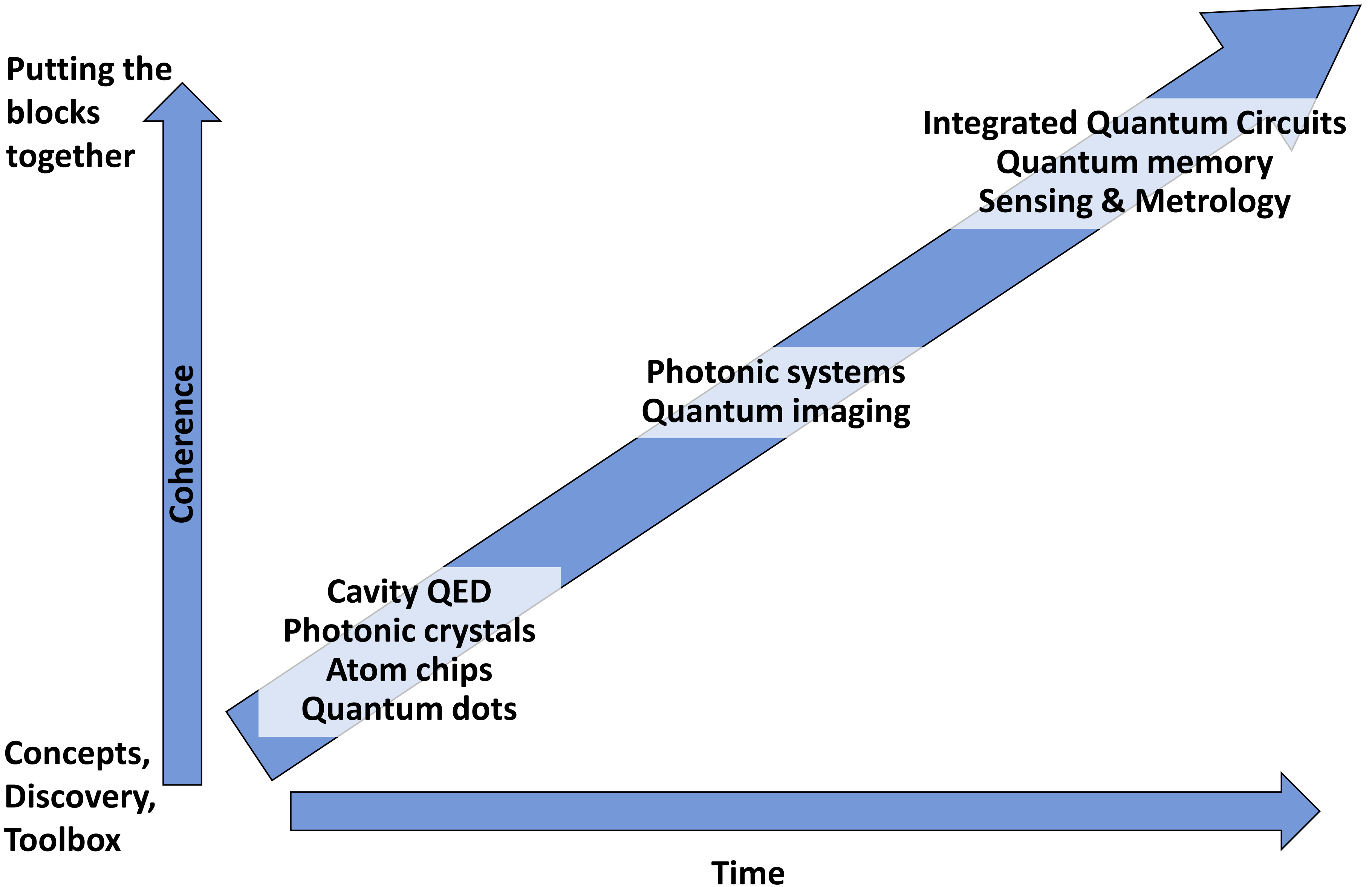
- 2D planes with strong correlations
- Interlayer coupling plays important role in enhancing T_c

Model: Anderson's interlayer pair tunneling model (1992)

Quantum Information MURIs

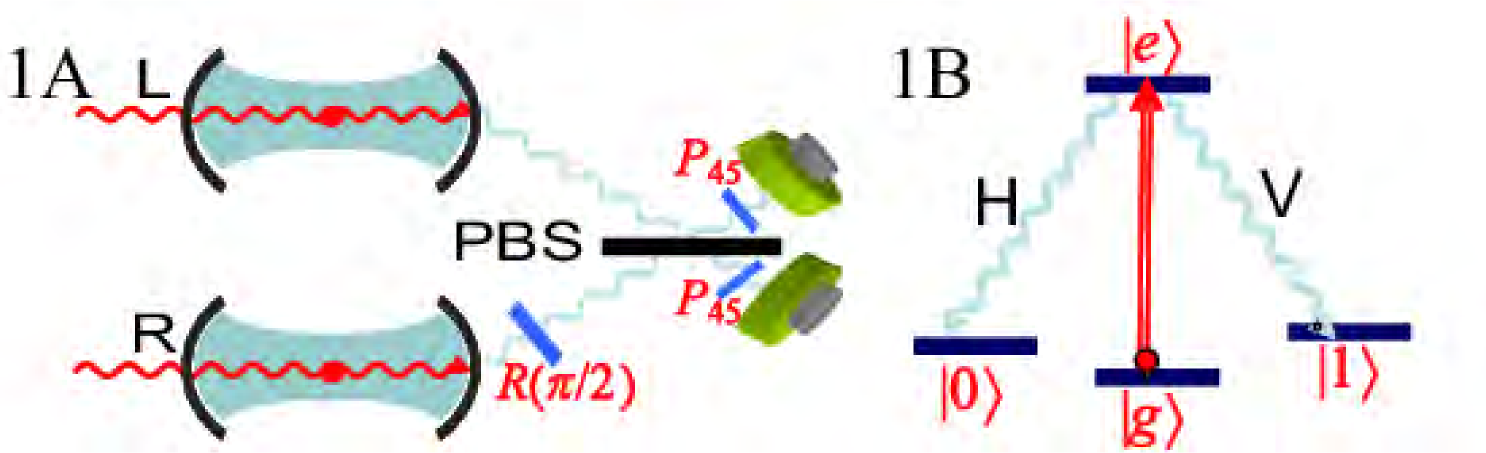
- Exploiting quantum mechanics for useful functionality
- Better than classical capabilities
  - Quantum Computing
    - Quantum systems for qubits
    - Quantum algorithms
    - Quantum memories
    - Quantum repeaters
    - Quantum teleportation
    - Interchange of quantum information
  - Quantum Metrology
  - Quantum Sensing
  - Quantum Communication/Quantum Encryption
  - Quantum Imaging

Quantum Information Science
A Decade of QIS MURIs

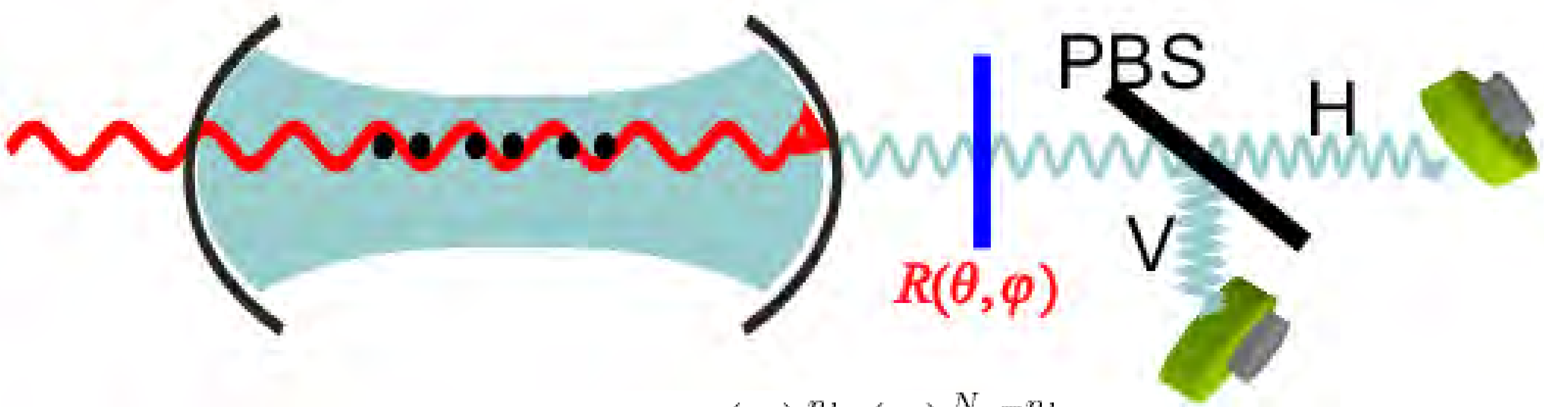


Efficient engineering of multi-atom entanglement

Entanglement generation between atoms in different cavities (L, R)

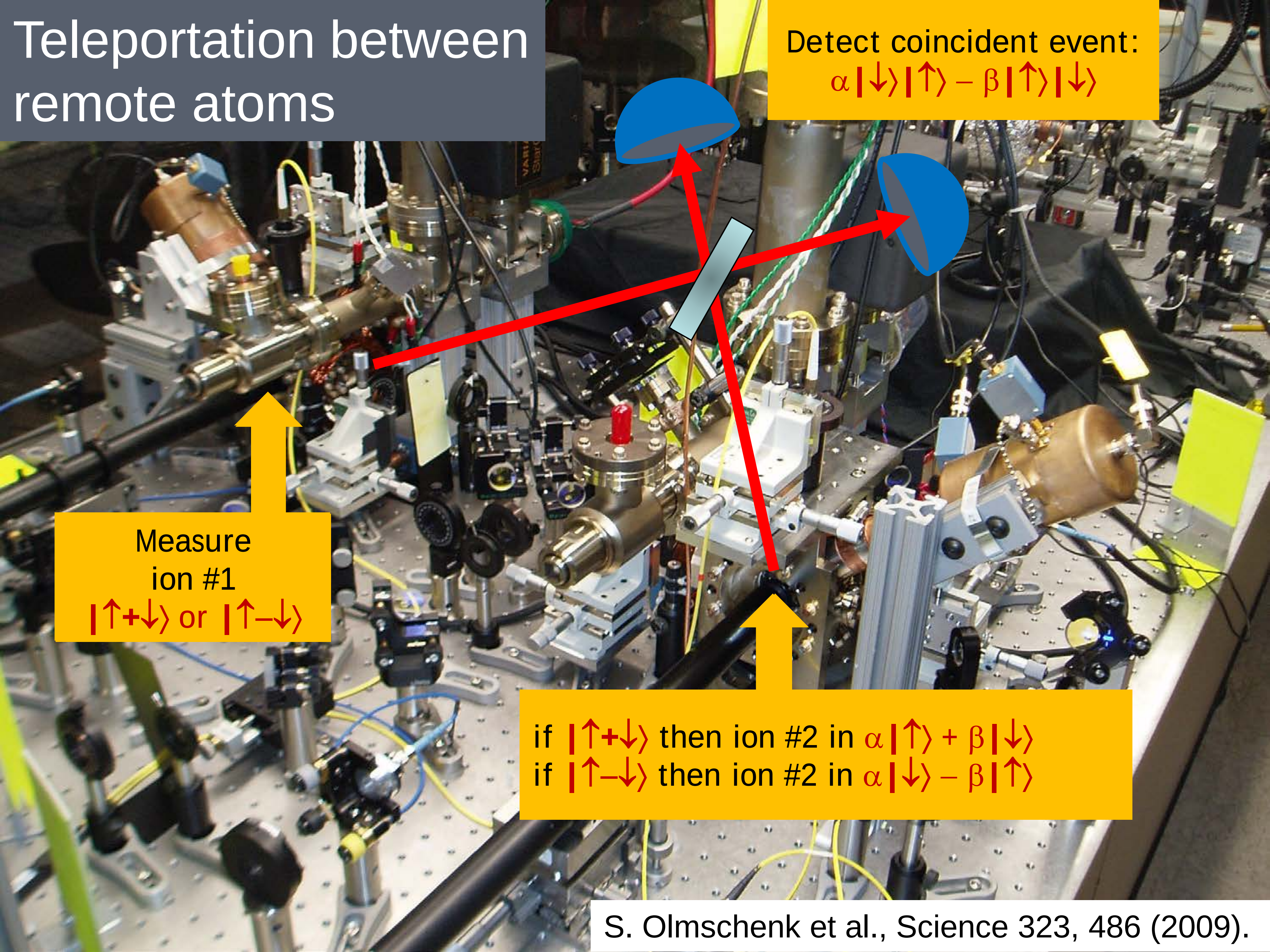


Entanglement generation between multiple atoms in the same cavity – Arbitrary superpositions of symmetric Dicke states



$$|N_a, n_h\rangle = c(n_h)\left(s_0^\dagger\right)^{n_h}\left(s_1^\dagger\right)^{N_a - n_h}|G\rangle$$

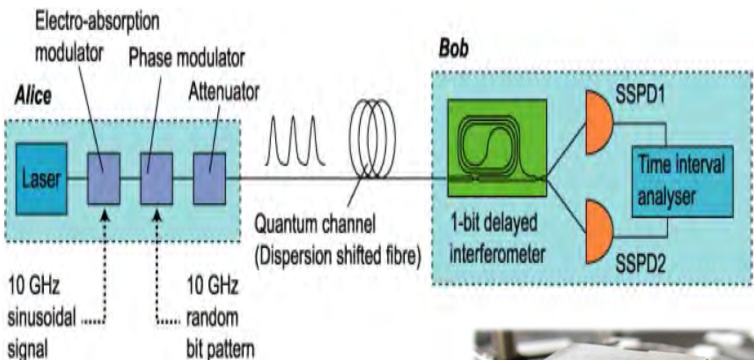
Teleportation between remote atoms

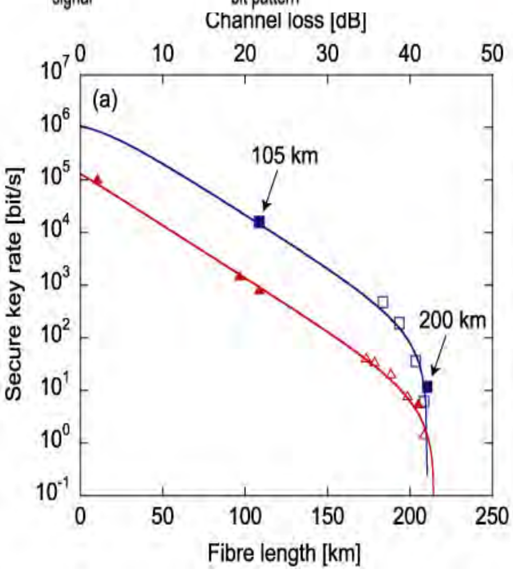


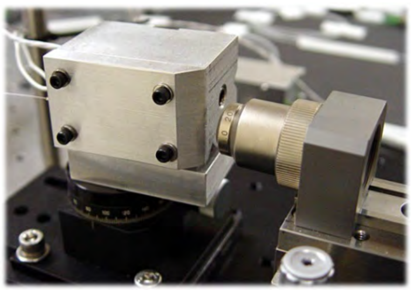
S. Olmschenk et al., Science 323, 486 (2009).

Photonic Quantum Information Processing

Yoshi Yamamoto, Marty Fejer (Stanford, Sae Woo Nam (NIST)

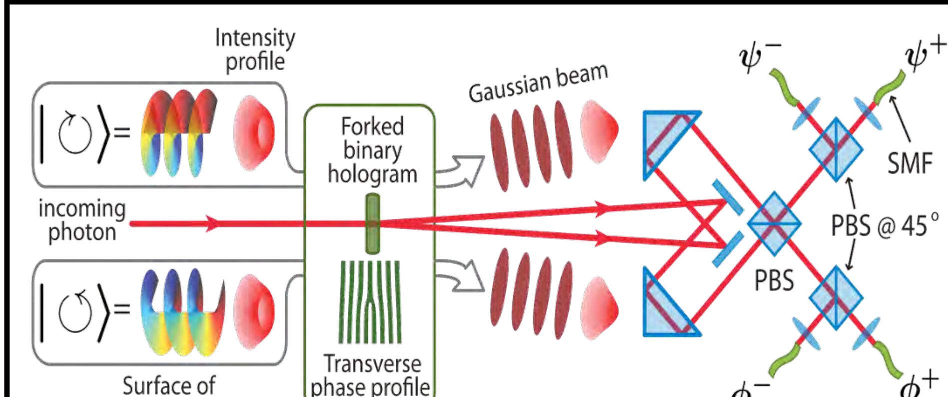


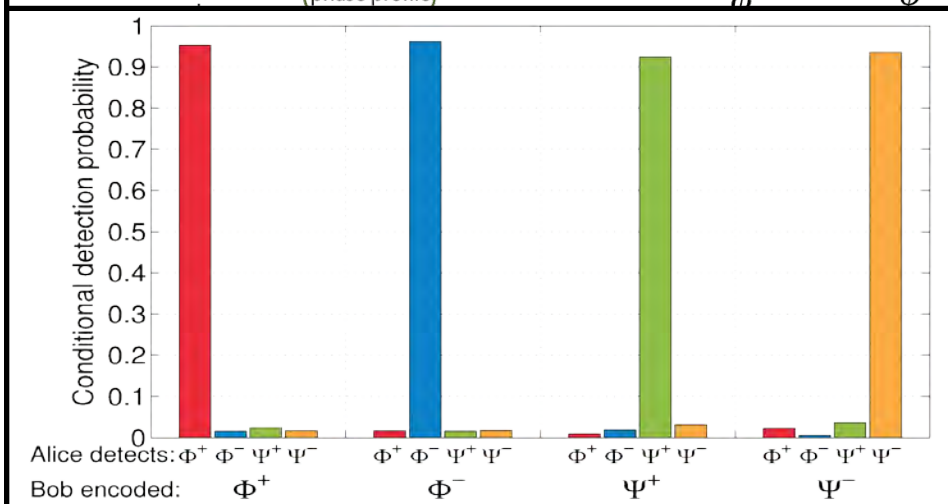




- QKD experiments in fiber
- Secure key rate ~17Kbit/s over 105Km, ~12bit/s over 200Km (error rate <4.1%)

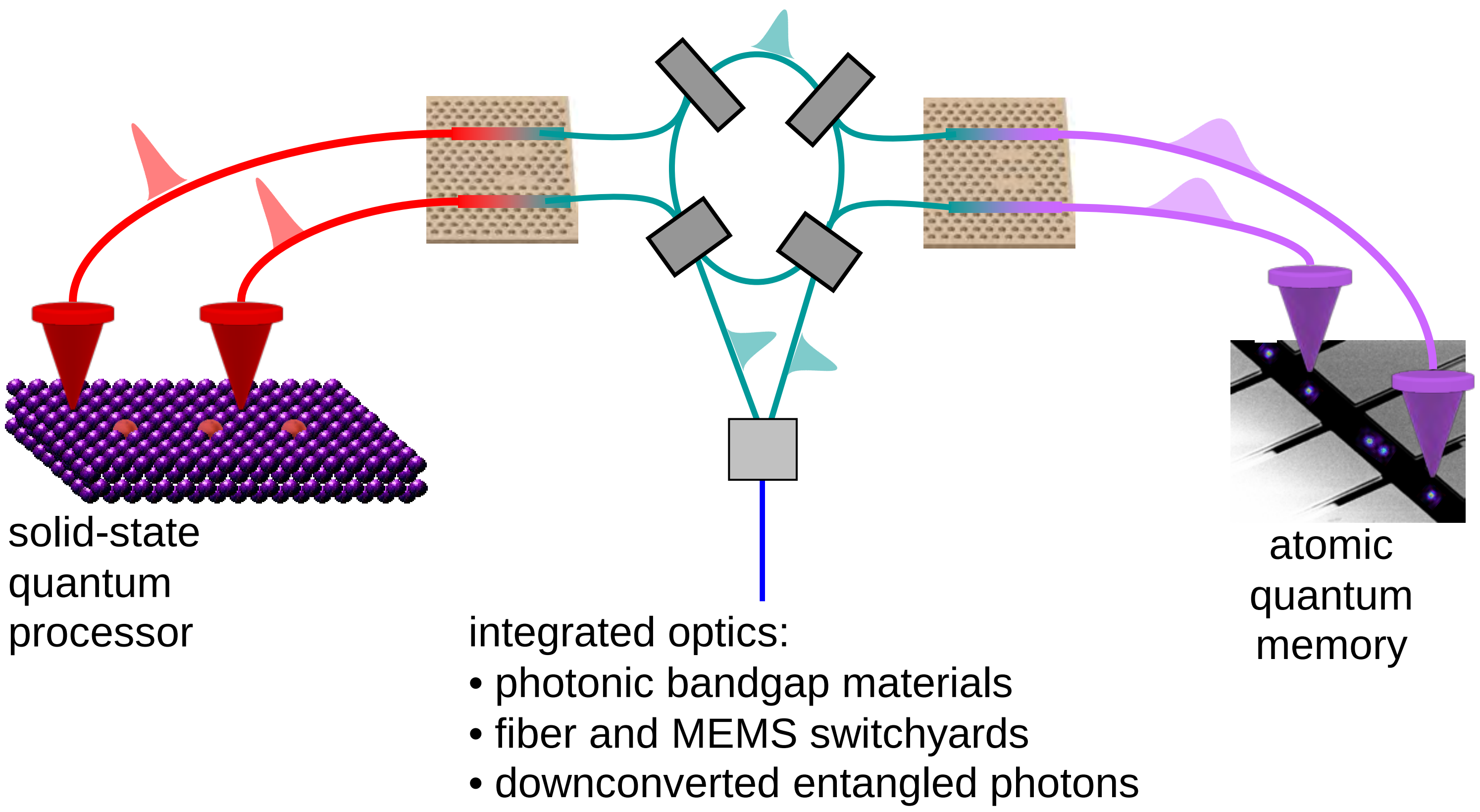
Paul Kwiat (UIUC)



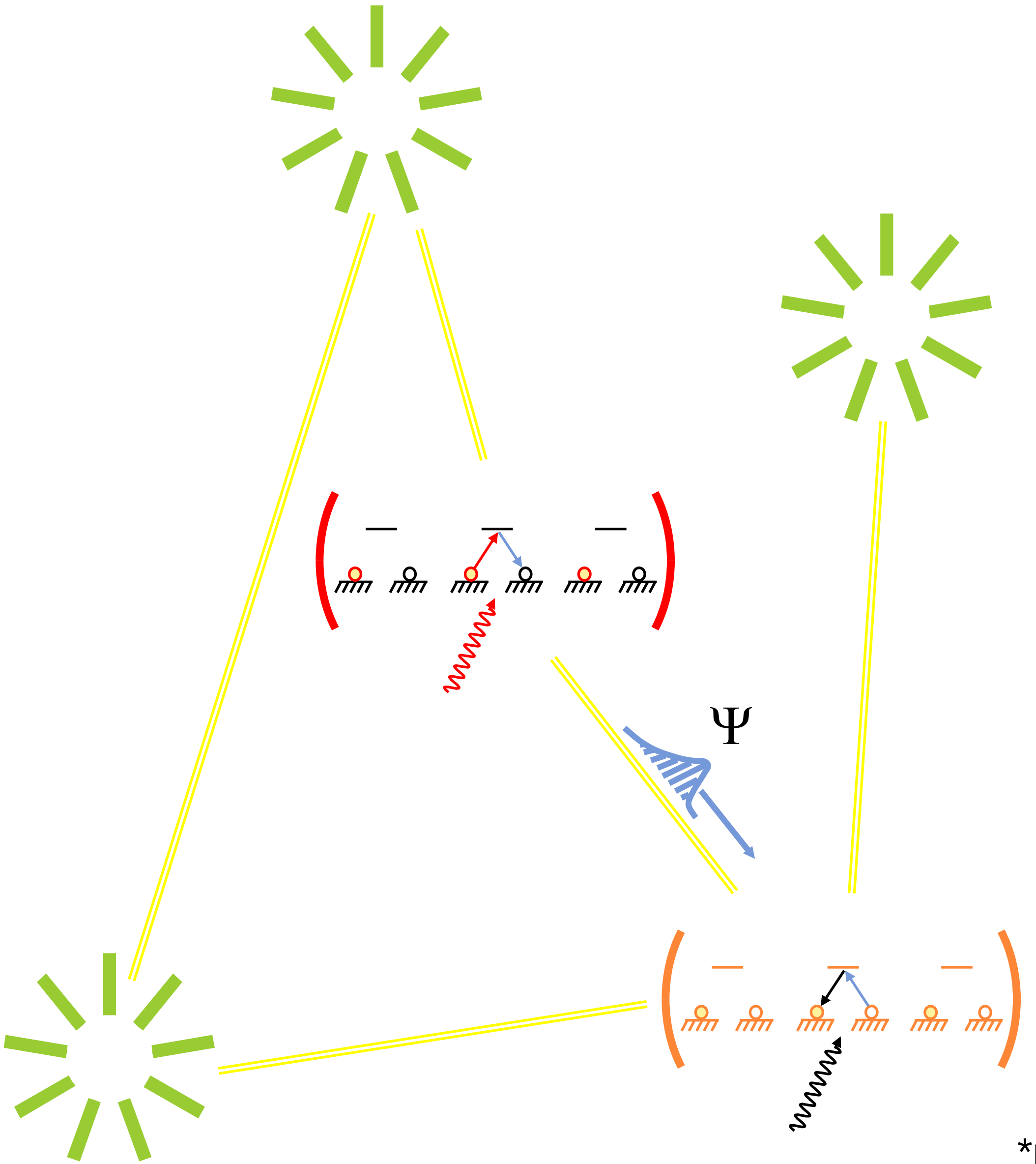


- Hyper-entanglement Enabled Full Bell-State Analysis
- Average success probability: 94%

Integrated Photonic Quantum Circuitry



Tools for Quantum Networks



simple quantum state transfer can convert local entanglement* into distributed entanglement

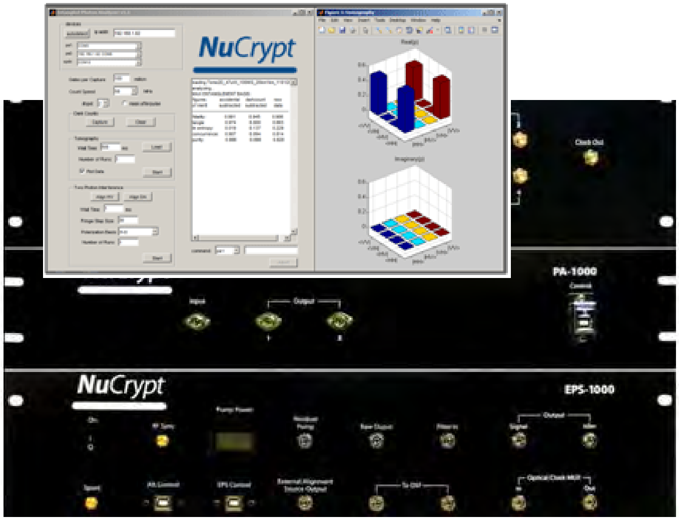
entanglement purification schemes have been invented that require limited local storage and processing

distributed entanglement* enables quantum repeater architectures based on state teleportation

quantum repeaters enable long-distance quantum networking; fault-tolerance analyses have been made

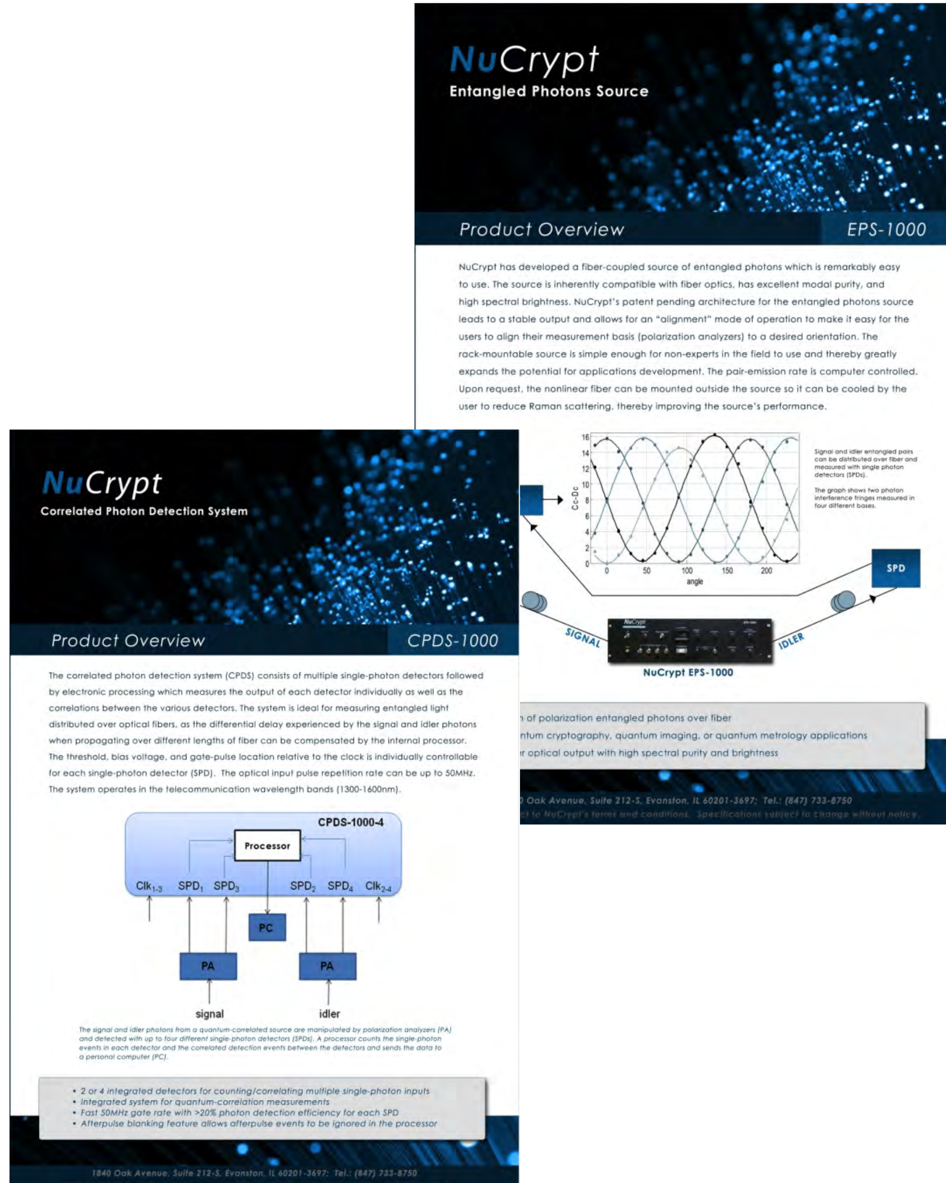
*produced by quantum logic or measurements

Commercialization



From MURIs to STTRs to commercial products for quantum communication in fiber

- Single photon sources
- Single photon detectors
- Tomography



Data-to-Decisions
S&T Priority Initiative

Dr. Carey Schwartz

PSC Lead

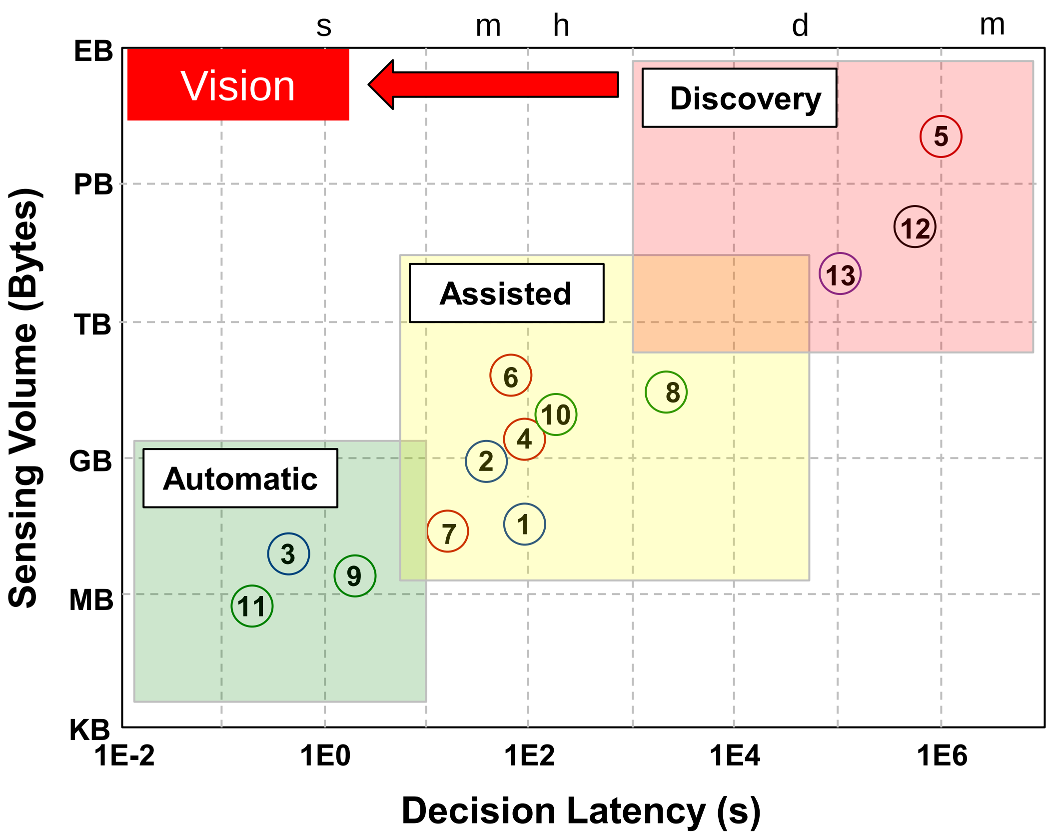
Office of Naval Research

NDIA Disruptive Technologies Conference

November 8-9, 2011

Washington, DC

Data-to-Decisions Systems Issues – Time and Volume



Defend United States
- 1. Containerized Nuclear Weapon*
- 2. Blackmail ICBM*
- 3. LACM off barge

Counterinsurgency
- 4. Unguided Battlefield Rocket
- 5. Insurgencies
- 6. IEDs
- 7. Small fast attack craft

Anti-Access Environments
- 8. Quiet submarines
- 9. MARV (Intercept)
- 10. Mobile long-range SAMs
- 11. Co-orbital ASAT

Security Capacity
- 12. Stability Operations

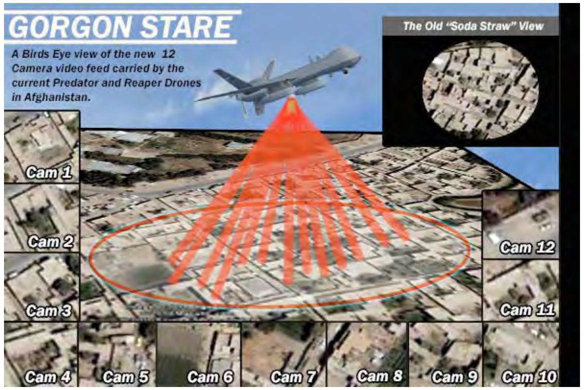
Counter WMD*
- 13. Loose Nukes

National security decision systems span all QDR missions with a focus on finding threats in a specified data volume with limited manpower within a specified time window

Data-to-Decisions Systems Issues - Personnel

Predator Sensor

Increasing Resolution and Coverage



Analysts

Number of Highly Skilled and Trained Analysts Remains Constant or Decreases

Analysts

National security decision systems span all QDR missions with a focus on finding threats in a specified data volume with limited manpower within a specified time window

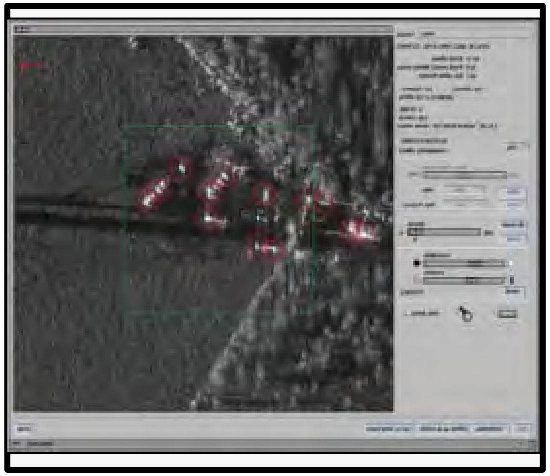
D2D Technology Assessment

- Moderately Mature
- Driven by IT Industry

Data Management Layer

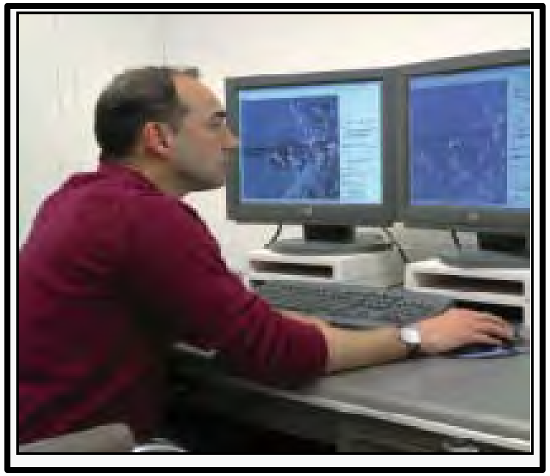
- Immature
- Driven by Defense

Analytics Layer



- Moderately Mature
- Driven by IT Industry

User Interface Layer



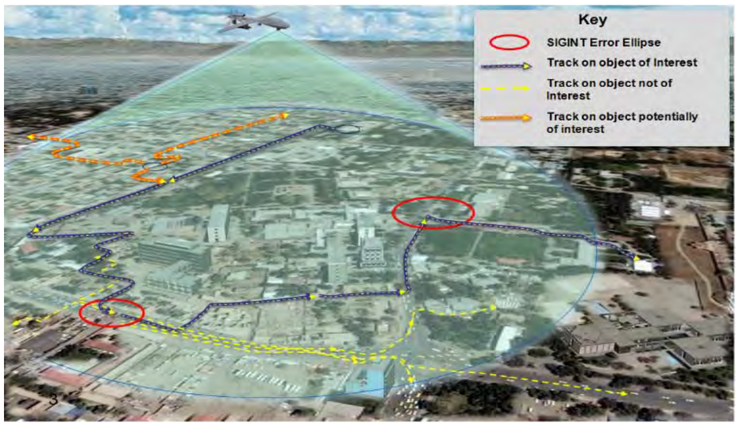
Current assessment is that unstructured data analytics is the most challenging and critical component of D2D

ASD D2D program intends to provide representative data of various types that have associated ground truth to support development and evaluation of algorithms and systems in a SOA to be made available

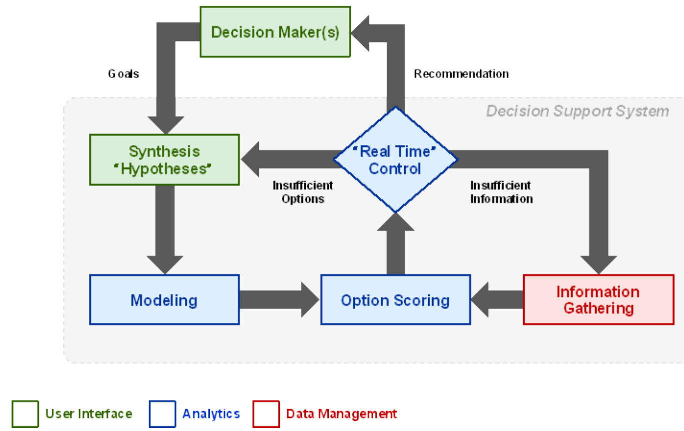
Challenge Problem and Framework for Analysis

Illustrative Challenge Problem

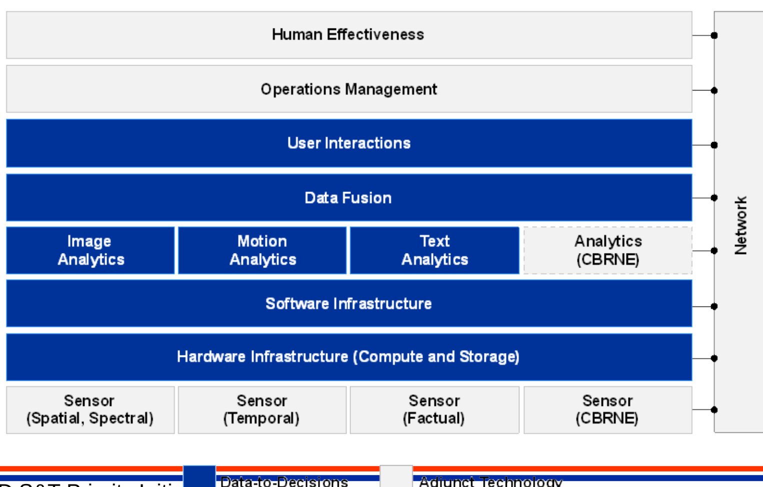
Detect, Track, and Infer Intent of Objects in an Urban Environment with All Source Data



Canonical Decision Support Architecture



Architectural Layers



Operational Issues

- Shear number of detections, tracklets, track associations overwhelm the limited number of analysts
- Integration of tracks from disparate modalities is manually intensive and time consuming
- Developing long duration tracks to support social network analysis including patterns of life
- Representation of unstructured data that is incomplete, imprecise, uncertain, and contradictory to support analysis, storage and retrieval
- Understanding the observed data in the context of multiple hypotheses that are consistent to develop indications and warnings, reduce the number of hypotheses, and to develop new hypotheses

Meeting mission timelines and operating with large sources of unstructured data requires that the analyst in the loop is more effective

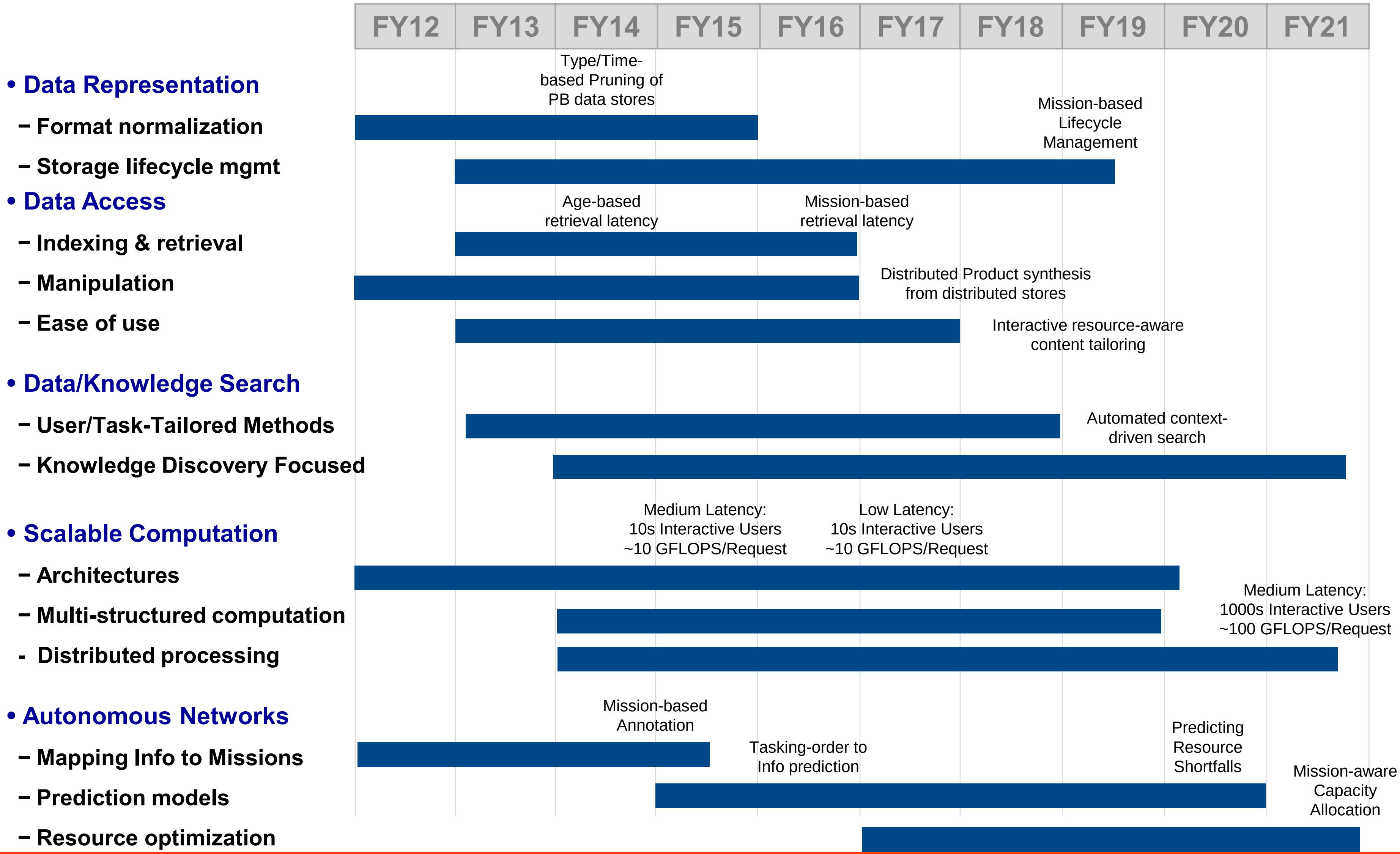
Highest Payoff Capabilities and Associated Metrics

- **Data Management**
  - **Representations: Efficient representation of structured and unstructured data supporting format normalization, mission-aware computation and 100 x compression without loss of fidelity in applications**
- **MOVINT Analysis**
  - **Automated tools that support 100x improvement in the number of tracks that an analyst manages**
    - Probability of correct association of tracklets and tracks > 0.98
    - Time to achieve track association by automation less than current SOA
- **IMINT Analysis**
  - **Automated tools that support 100x improvement in the number of objects, activities, and events that an analyst can manage**
    - Probability of correct classification of objects, activities, and events > 0.98
    - Time to develop objects, activities, and events less than current SOA
- **Text Analysis**
  - **Automated tools that improve by 100 the rate at which information is extracted from documents in any language with**
    - High Probability of correct extraction
- **User Interface**
  - **Automated tools align the information models of all participants in the distributed man machine enterprise that are 98% accurate**

Data Management Layer

- **Problem Statement: Increasing data volumes and modalities have diminished our ability to communicate, store, retrieve and process sources within mission-critical timelines**
- **3-to-5 year timeframe objective**
  - Computational infrastructure to support capturing, processing, marking, retrieval, and management of millions of information objects per second over discovery mission data requirements (PB/TB, long latency)
  - Network architecture with embedded information management on existing networks to support both real-time (MB/GB, low latency) and assisted (GB/TB, medium latency) mission data requirements
- **7-to-10 year timeframe objective**
  - Mission-aware information lifecycle management to age data from (typically) short-term concrete data storage to longer-term symbolic associative representation and retrieval based upon perceived utility and cost
  - Self-balancing merged storage and processing architecture to support analytics with minimal data movement
  - Synchronized anticipatory sensor control and compute/storage resource allocation to support rapid ingest and real-time exploitation

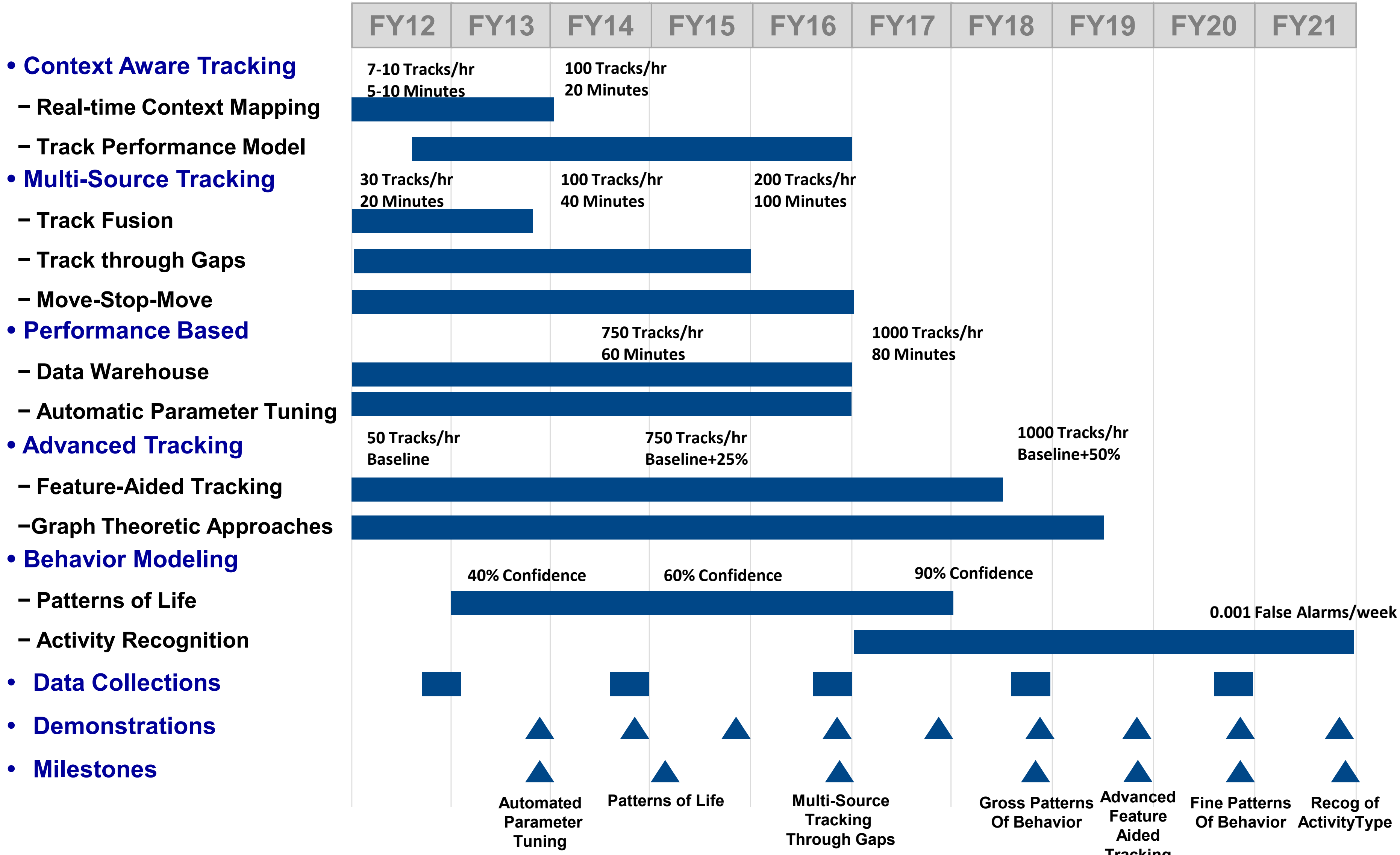
Data Management Roadmap



Analytic Layer

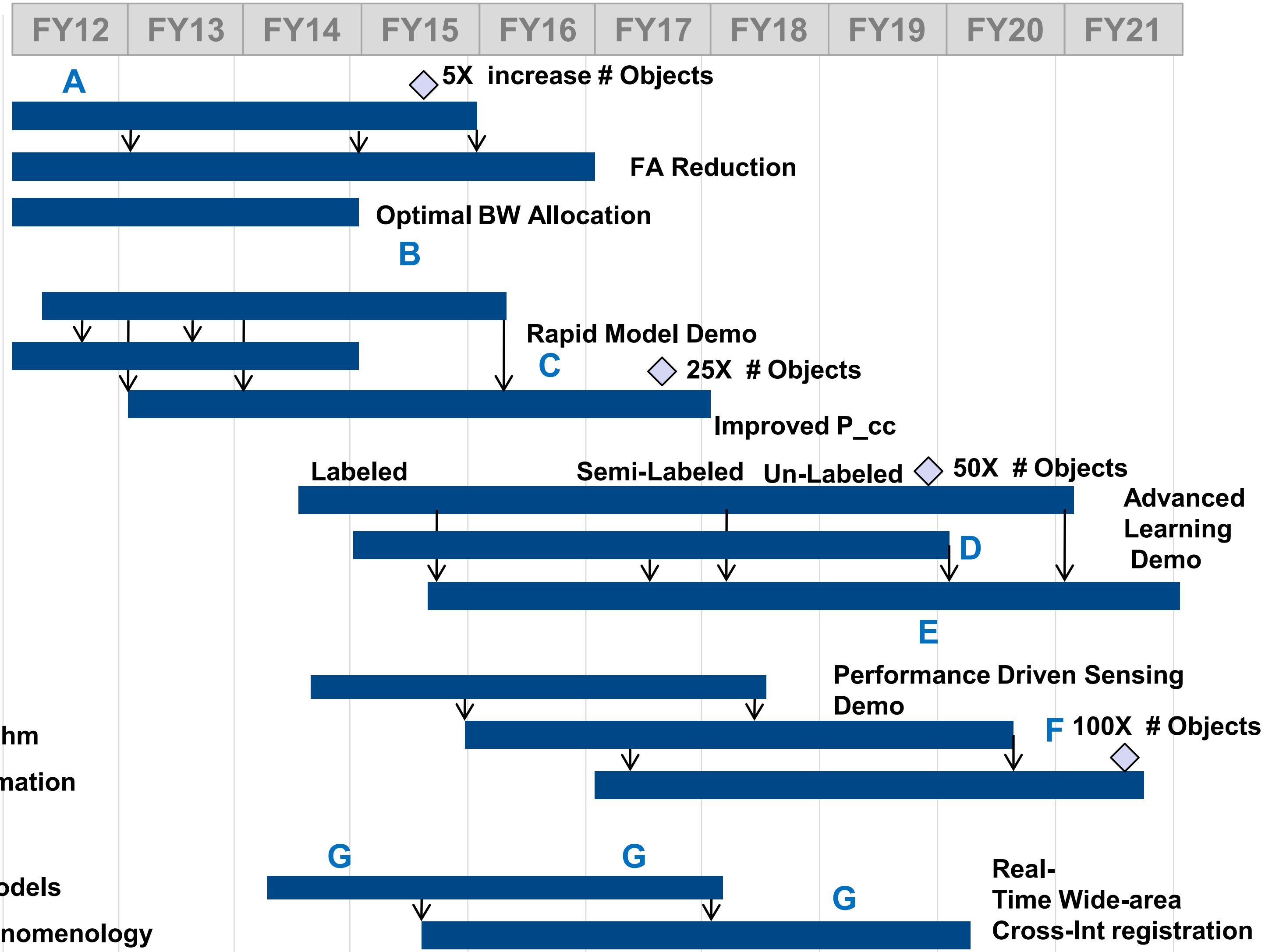
- **Problem Statement: Existing automation tools do not aid users in finding today's complex and adaptable threats within mission timelines**
- **3-to-5 year timeframe objective**
  - Robust classification to accurately detect, geo-register, classify, and identify surface objects despite difficult environments, configurations and emplacements
  - Robust automation tools to identify relationships, patterns of life and activities of objects on the ground
  - Robust tools to capture, store and retrieve HUMINT-based information to identify and leverage popular support against insurgents
  - Domain-specific tools to capture, search, mine and exploit explicit information on insurgent networks from unstructured textual data sources
- **7-to-10 year timeframe objective**
  - Robust automation tools to identify relationships, patterns of life and activities of dismounts
  - Robust tools to search, mine and exploit open-source data to identify all aspects of insurgent networks

MOVINT Roadmap



IMINT Roadmap

- **Multi-Source Detection**
  - Precision geo-registration
  - Multi-INT change detection
  - Scalable compression
- **Geometric Features**
  - 3D reconstruction
  - Rapid target insertion
  - Geometric clustering
- **Advanced Learning**
  - Large corpus training
  - Model-based learning
  - On-the-fly adaptation
- **Performance Models**
  - Sensor/Algorithm trade-off
  - Confidence reporting algorithm
  - Predictive performance estimation
- **Accurate Geo-location**
  - Dynamic adaptive sensor models
  - Disparate geometry and phenomenology



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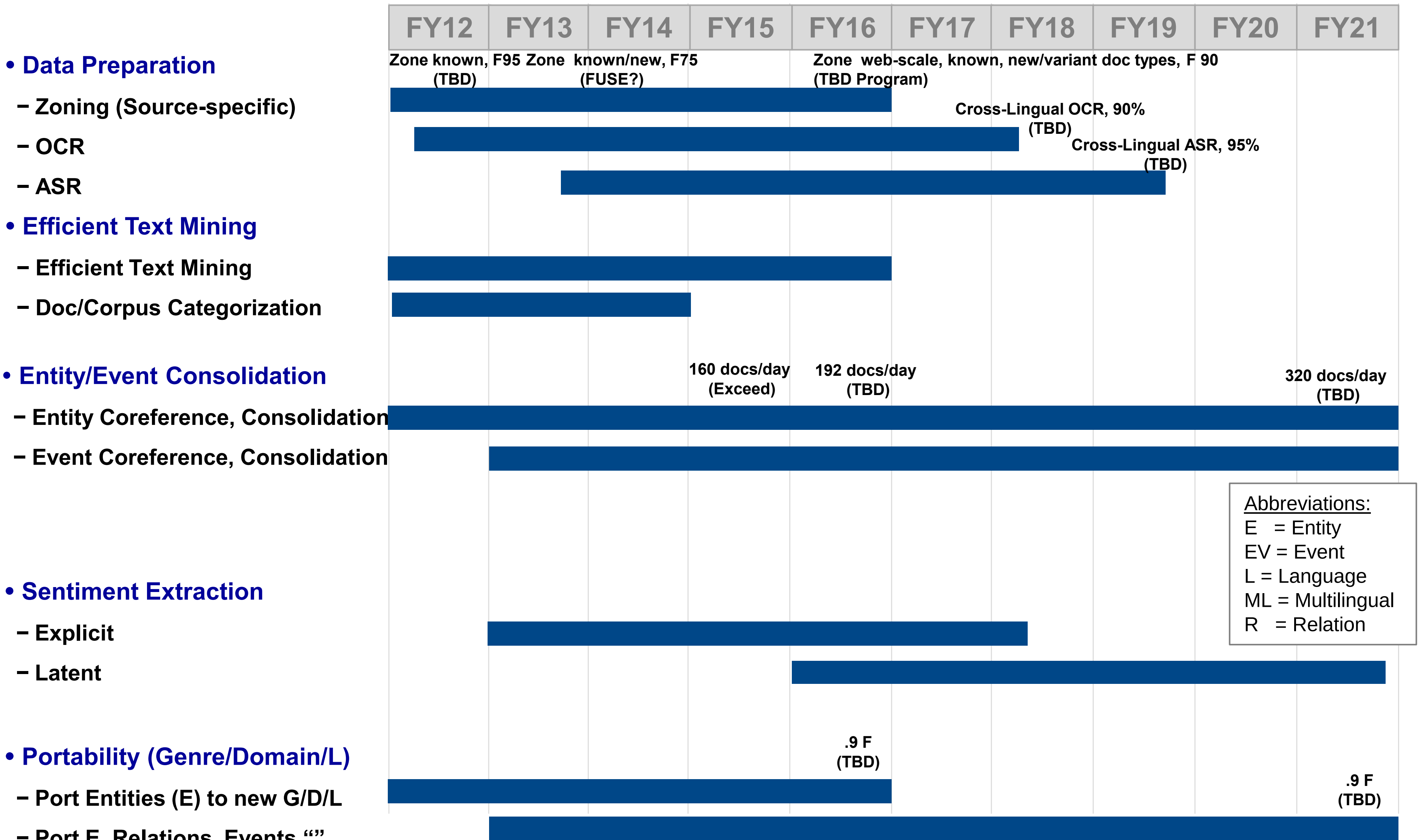
Textual Data Roadmap



User Interaction Layer

- **Problem Statement: Existing interface tools do not detect and proactively respond to the users information needs, given massive amounts of data collected from sensor and open-source assets.**
- **3-to-5 year timeframe objective**
  - Reactive intelligent interfaces
    - Acquisition of massive data, including continuous learning and inference
    - Automatic identification of potential (human) collaborators
    - User-specified interface reconfiguration
  - Adaptable displays that automatically draw human attention to problem areas
  - Workflow tools that guide analysts in complex problems
- **7-to-10 year timeframe objective**
  - Proactive intelligent interfaces and inference engines that:
    - Generate and update rich models of their users current tasks, beliefs and intentions.
    - Socially-guided machine learning to support level 2+ fusion
    - Proactively identify task-relevant data based on current estimates of users beliefs, and intentions and to offer suggestions based on these estimates.
    - Communicate with users in the most natural way possible (language, when appropriate)
  - Workflow tools that capture and teach analysts' best practices

User Interaction Roadmap

FY12 | FY13 | FY14 | FY15 | FY16 | FY17 | FY18 | FY19 | FY20 | FY21

- **Knowledge Mgmt Tools**
  - Mission Level Knowledge Tagging
  - Normalization of Ontologies

Data pedigree & history 'unpacking' >90% accuracy

- **Continuous Learning & Inf.**
  - Large Scale Cont. Learning
  - Fast Inference in Large KB's

Manual correlations >90% relevance — automated correlations from LSA >70% relevance — automated correlations from LSA >90% relevance

- **Collaboration Tools**
  - Topic/Interest Models
  - Collaboration Recommendation

Manually monitored & correlated >90% — Automated push-pull of shared searches > 80% relevance — Automated P/P > 95% relevance

- **User-Specified Interfaces**
  - User Supervision of ML Stub
  - Learning Human Operator

Automation in display >90% relevance, ML Collaboration mechanisms >90% relevanc

- **Socially Guided ML**
  - Active Transfer Learning
  - Interactive ML

Manual correlations >90% relevance — automated correlations from LSA >70% relevance — automated correlations from LSA >90% relevance

- **Rich User Models**
  - Socio-Cognitive Architectures
  - Natural Language Dialogue

Visual representation of people & tasks > 70% accuracy — > 90% accuracy

- **Best-Of-Breed Strategy Learning**
  - Crowdsourcing BoB Strategies
  - Inference over rich user models

Machine advisors > 90% accuracy — Machine advisors > 98% accuracy

FY12 Planned BAA's

- **Data to Decision Special Notice, Spring 2012**
  - POC: Dr. Carey Schwartz
- **ONR Long Range BAA BAA 12-01**
  - POC: Dr. Wen Masters
- **Research Interests of AFOSR BAA 2010-1**
  - POC: Dr. Hugh De Long
- **ARO Core BAA, W911NF-07-R-003-04**
  - POC: Dr. John Lavery
- **DARPA I2O Office Wide BAA, 11-34**
  - POC: Mr. Daniel Kaufman
- **ONR Computational Intelligence for Rapid Accurate Decision Making Special Notice, Spring 2012**
  - POC: Dr. Carey Schwartz

Summary

- **Data representative of the problem domain with ground truth to be made available for development and testing of algorithms**
- **Specifications of a Service Oriented Architecture will be made available to abet government testing and evaluation**
- **Understand the relationship between the "picture" and decisions based upon the picture**
  - Bottoms Up to identify performance controlling functions/modules
  - Top Down to manage quality of picture and manage resources
- **Symbiotic Relationship between automation and humans**
  - Human is cognitive within the architecture and not a servant to the architecture
  - Human mentors the architecture to improve performance
- **Reduce timelines between receipt of data, what does it mean, and what should be done across decision support systems**

Countering Weapons of Mass Destruction

S&T and Architecture for "Loose Nukes"

Dr. Gregory F. Simonson
OASD(NCB/NM)
(703) 693-4291

NDIA Disruptive Technologies Conference

November 8-9, 2011

Washington, DC

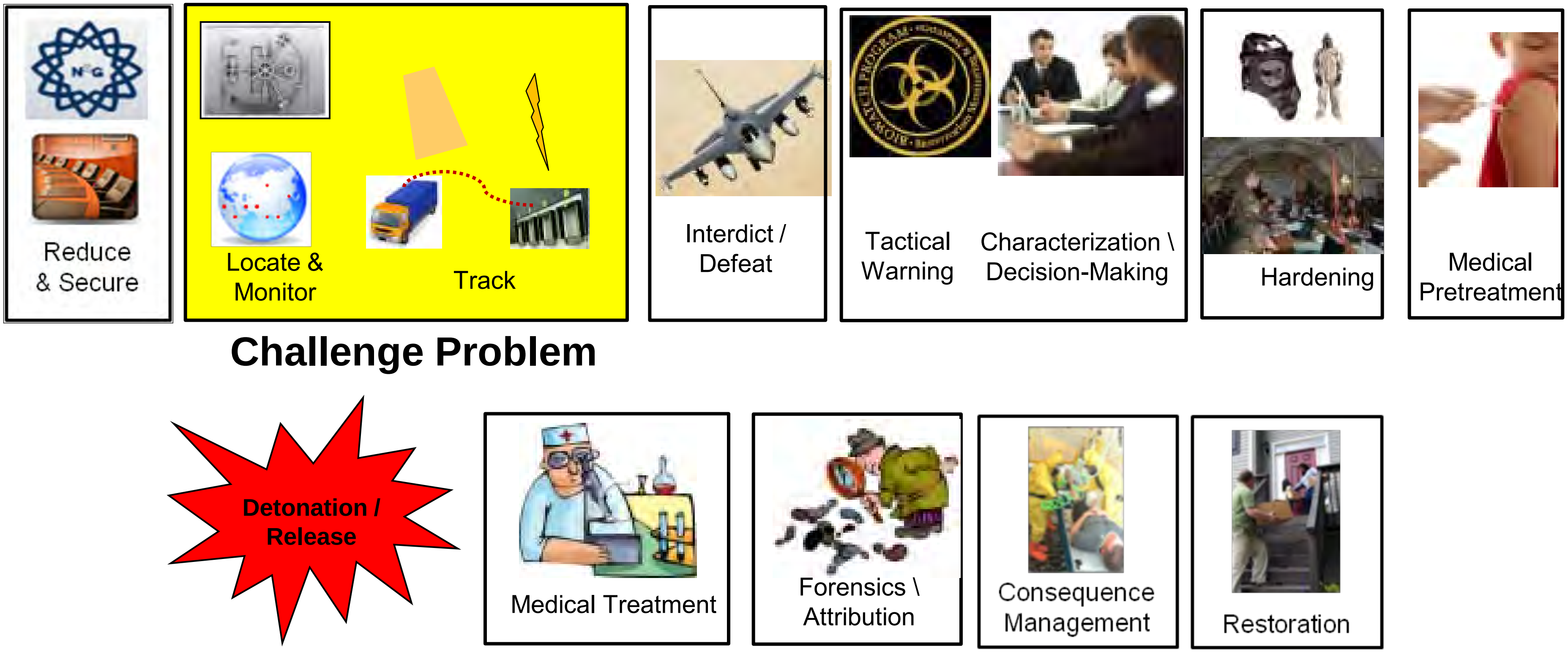
CWMD PSC Membership

NCB/NM	Greg Simonson (Chair)
NCB/NM	Michaela Eddy
Joint Staff	Leonard Izzo
Army	Eric Zimmerman
Navy	William Thompson
Air Force	Mark Fagan
OUSD(P)	Jessica Cox
OUSD(I)	Michael Spence
DTRA	Tony Pang
DTRA	Stephanie Vaughn
JASONs	

"We must ensure that terrorists never acquire a nuclear weapon. This is the most immediate and extreme threat to global security."

President Obama, Prague, Czech Republic, April 5, 2009

Scope of CWMD Challenge Problem



Systems Performance Goals

- Broad Area Search
- Persistent Monitoring
- Tagging and Tracking

Technical Challenges

- Systems Integration
- Activity Recognition
- Advanced Signature Detection & Tracking
- Advanced Radiation Detection

CWMD Problem Statement

Scenario: Imminent theft of nuclear weapon from a foreign storage facility by terrorist cell with insider assistance

- **The U.S. needs improved capability to deal with a potential future "loose nuke" emergency involving a foreign nuclear weapon or significant amount of special nuclear material (SNM)**
  - **Earlier cue that a plot is afoot or a theft has occurred**
  - **Faster access to the area**
  - **Improved monitoring ability and TTL**
  - **Higher confidence in containment and search**
- **Radiation detectors alone will not solve the problem**
- **ISR technologies, lower latency, networks of networks, and social media may be part of the solution**

What S&T investments are central to loose nuke problem and in what architecture would new technologies be deployed?

Loose Nukes Parameter Space

	Technical Challenge	Objectives	Technical Approach
3-5 years	Existing data fusion	CWMD community in complete concert	Global CWMD Analysis System; sensor fusion
5-7 years	Alternate signature exploitation	Locate, monitor and track WMD at strategic distances	HSI, IR, FTIR, GPS, radar, lidar, RFID, nanoparticles, etc.
7-10+ years	All-source Information Integration	Pre-event cues, real-time activity detection	Net-networks; beyond physics sensing

Parameter Space: Signatures

Target Class: Vehicle

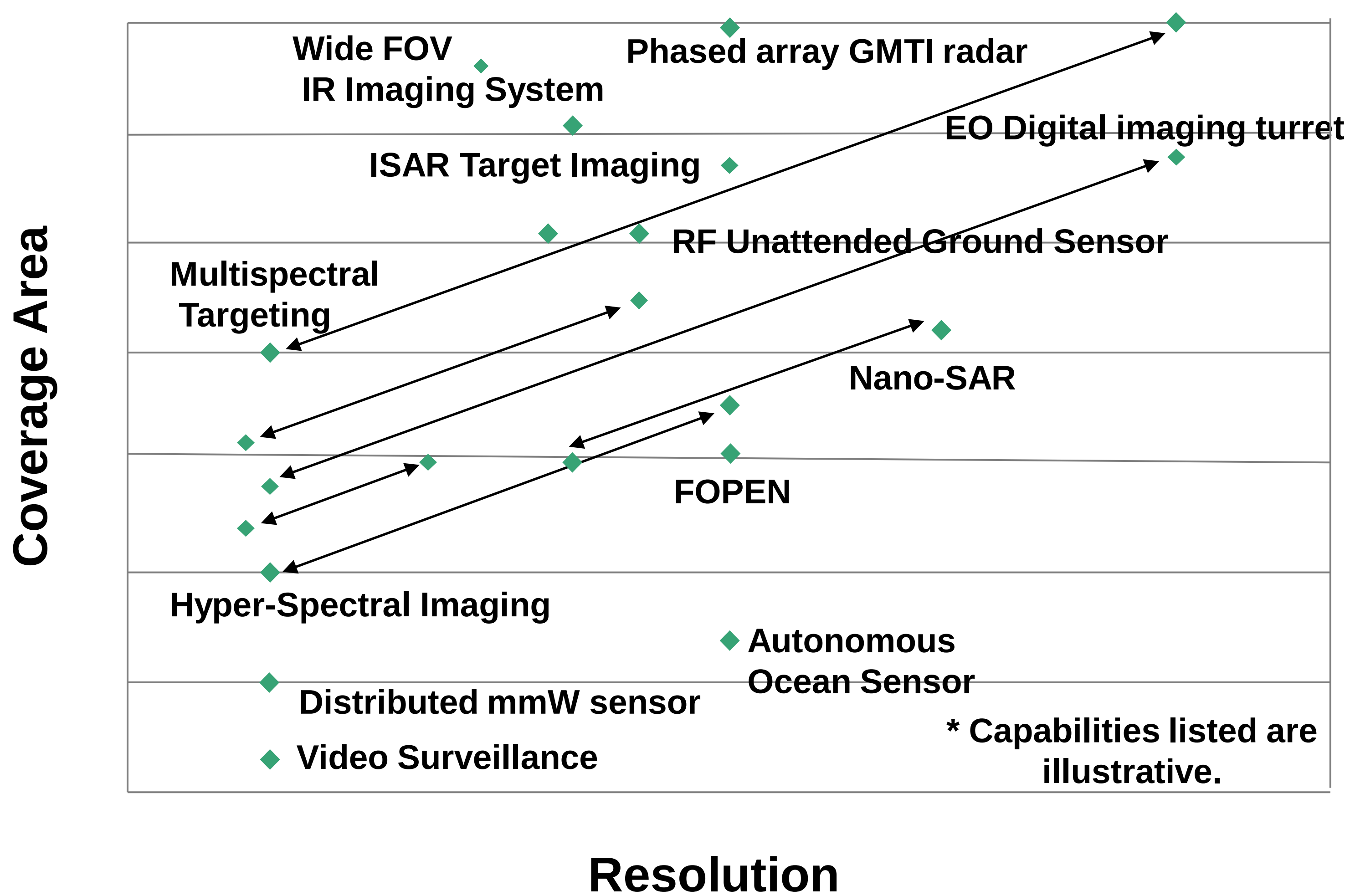
Sub-Class: Passenger Car, Light Truck, Heavy Truck, APC, Tank

Source: DTRA

Observable	Signature	Sensor
color	absorbance	HSI
material	reflectance	HSI
heat	thermal gradient	IR
chem emission	hydrocarbons	FTIR/chem
size	pixels/return/reference scale	EO/radar
motion	doppler/angular change/GMTI/GPS*	Radar/lidar/FMV
weight	seismic/magnetic	geophone/accelerometer/magnetometer
sound	acoustic/seismic	microphone/accelerometer
Location	Georeference/GPS	EO/SIGINT
EM	EM	EM (inductive/capacitive)
RF	RF	RFI/DF

And similar sets for payloads, people, facilities, sites…

Parameter Space: Sensors



Source: The Technical Cooperation Program

Parameter Space: Architecture

(#) *Increasing Level of Difficulty*

Notification of "Theft"

Access to Region	Immediate	Delayed
Immediate	(1) • Search begins immediately • Search region small Theft Notification Response	(2) • Search delayed by notification • Search region large Theft Notification Response
Delayed	(3) • Search delayed by access • Search region large Theft Notification Response	(4) • Search delayed by notification & access • Search region large Theft Notification Response

- Delays in response to theft (caused by late notification or access) increase the "level of difficulty" in recovering SNM

Technical Challenges & Metrics

- **Confidence in getting a cue**
- Sense change in SNM/NW state
- SNM rad detection
- Alt signature readiness
- **Sensor deployment latency**
- Sensor handoff
- **Data/network fusion**
- Persistent surveillance
- Tracking confidence
- Broad area search (km^2/hr)
- Behavior/intent detection
- **Social network exploitation**
- **Architecture maturity**

CWMD "Loose Nukes" Roadmap

Needed Operational Capabilities

Pre-Positioned Assets, Intel Fusion, Cue, Containment, Locate, Recover

Technology Development Areas

Rad Detection   Persistent Monitoring/ISR   TTL BAS   Intent/Behavior   Architecture

Science and Technology Development

FY 15-17	FY 17-19	FY 19-22+
Systems Integration **Activity Recognition**	**Advanced Signature Detection** **Advanced Tracking**	**All-Source Information Integration** **Advanced Signature Detection and Tracking**
Integration of all-source intel and human reasoning, multi-sensor **data fusion**, pathway analysis, automated behavioral analysis	HSI, IR, FTIR, radar, lidar, RF, FMV, GPS, accelerometers, RFID, reduced data latency, **network fusion**	Integration algorithms, matrixed detectors, networks of networks, beyond physics: social network analysis, **automated all-source information fusion**

Revolving integration, demonstration and transition to meet operational needs

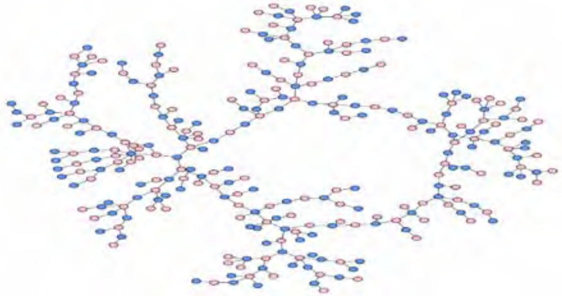
Note: These are not currently funded initiatives

Distribution Statement A: Approved for public release; distribution is unlimited.

Big Gaps: Opportunities for NDIA

- Next gen rad detection, e.g. nanomaterials; ionized air; HSI
- Alternate signatures related to weapon activity
  - People, programs, communications, facilities, behaviors…
- Persistent intelligence, surveillance and reconnaissance
  - Sensor development and platform integration
  - Technical, intelligence and social data fusion

- Data-to-Decision Tools
  - Next-generation reachback and information sciences capabilities
  - High performance computing
- Architectures for prompt access and low latency
- Beyond physics
  - Human behavior and intent detection
  - Social network analysis



BAAs and SBIRs

BAAs:

ARL Postdoc Fellowship Program	W911NF-11-R-0010
RDECOM-STTC	W91CRB-08-R-0073
ARO	W911NF-07-R-0003-04
ARL/ARO	W911NF-07-R-0001-05
DARPA	DARPA-11-34: I2O Office-Wide BAA
AFOSR	AFOSR-BAA-2009-1
AFOSR	AFOSR-BAA-2011-01
DHS	DHSS-TLRBAA11-03
DTRA	HDTRA1-11-16-RDIS-BAA
DTRA	HDTRA1-11-16-BRCWMD-BAA
ONR	BAA 12-001

also Special Notice 11-SN-0004 under this BAA, titled “Data to Decision”

SBIRs:

Army: https://www.armysbir.army.mil/default.aspx

DoD: http://dodsbir.net/solicitation/default.htm

CWMD Summary

- **Capability against loose nukes needs improvement**
  - **There is no silver bullet**
  - **Heavy reliance on early cue**
- **Radiation detection alone is not enough**
- **Many other signatures/sensors can be brought to bear**
  - **Substantial capability already exists**
  - **But data needs to be integrated**
- **Sensor handoff/sensor fusion/network fusion essential**
- **Opportunities in ISR for persistent surveillance, tracking, and broad area search in scenario-specific architectures**
- **Greatest gains may be in automating synthesis of sensor data, intel analysis, all networks including social networks, and non-physics based detection of behavior and intent**

POC: Dr. Gregory Simonson, OSD(NCB/NM), gregory.simonson@osd.mil
Pentagon 3B884, (703) 693-4291

Backup slides

Technical Challenges: Human Identification and Tracking

Target Class: Human

Sub-Class: Men, Women, Military, Civilian

Source: DTRA

Observable	Signature	Sensor
size	pixels/return/reference scale	EO/radar
motion	doppler/angular change/GMTI/GPS*	Radar/lidar/FMV
weight	seismic	geophone/accelerometer
Heat	Thermal gradient	IR
Location	Georeference/GPS	EO/SIGINT
Clothing	Absorbance/reflectance	HIS
ID	Facial/gait	EO
RF	RF	RFI/DF

Technical Challenges: Building Identification

Target Class: Building

Sub-Class: mess hall, barracks, motor pool, administrative, PX, weapon storage, unknown

Source: DTRA

Observable	Signature	Sensor
size	pixels/return/reference scale	EO/radar
motion	doppler/angular change/GMTI/GPS*	Radar/lidar/FMV
weight	seismic	geophone/accelerometer
Heat	Thermal gradient	IR
Location	Georeference/GPS	EO/SIGINT
Clothing	Absorbance/reflectance	HIS
ID	Facial/gait	EO
RF	RF	RFI/DF

Technical Challenges: Payload Identification and Tracking

Target Class: Payload

<u>Sub-Class:</u> crate, weapon

Source: DTRA

Observable	Signature	Sensor
size	pixels/return/reference scale	Radar/lidar/FMV
motion	doppler/angular change/GMTI/GPS*	Radar/lidar/FMV
weight	seismic	geophone/accelerometer
Heat	Thermal gradient	IR
Location	Georeference/GPS	EO/SIGINT
Chem emission	Foams/adhesives/HE	FTIR/chem
EM	EM	EM (inductive/capacitive)
RF	RF	RFI/DF

Technical Challenges: Site Identification

Target Class: Site

Sub-Class: low security, high security

Source: DTRA

Gestalt	Macro-observables	Fusion Elements
Security	Personnel, armament, dogs, fences, lighting, cameras	Sensors + activity
Function	Association, movement patterns, emissions	Sensors + activity + reason
Status	Gates/doors open, lights on	Sensors + activity
Pace of operations	Movement patterns	Sensors + activity + reason
Location	Georeference/GPS	EO/SIGINT

The First MURIs: 1986

NEWS RELEASE

OFFICE OF ASSISTANT SECRETARY OF DEFENSE
(PUBLIC AFFAIRS)
WASHINGTON, D.C. - 20301
PLEASE NOTE DATE

No. 315-86
(202) 695-0192 (Info.)
(202) 697-3189 (Copies)
(202) 697-5737 (Public/Industry)

FOR RELEASE AT
4:00 p.m. EDT

June 26, 1986

DOD SELECTS ACADEMIC INSTITUTIONS FOR UNIVERSITY RESEARCH INITIATIVE

Secretary of Defense Caspar W. Weinberger announced today the 70 academic institutions selected in the Department of Defense's (DoD) technical competition for the new University Research Initiative (URI). Subject to the successful completion of negotiations between DoD and these institutions and subject to the availability of FY87 funds for URI, approximately $110 million in FY86/87 funds are expected to be awarded to the 70 institutions for 86 research programs. Programs are expected to range between $170,000 and $3 million.

In announcing the selectees, Mr. Weinberger noted, "DoD received almost 1,000 URI proposals from 175 universities. These proposals requested nearly $6 billion in research funding over the three-to-five-year duration of the proposed efforts. The URI selection process was highly competitive and I wish that we were able to fund more of the many outstanding proposals that we received."

This is the first year of the University Research Initiative. URI is designed to strengthen the ability of universities to conduct research and educate scientists and engineers in ten technologies important to national defense.

The proposals selected today were principally for interdisciplinary research programs. Interdisciplinary research is an innovative approach to university-based research. An interdisciplinary URI program focuses on a single technological area of interest to DoD but brings together scientists and engineers from relevant disciplines to work on the research.

This team approach to research with cross-fertilization among disciplines will stimulate the growth of newly emerging technologies which are based on more than one of the traditional academic disciplines. By including both scientific and engineering disciplines, interdisciplinary URI programs should also smooth the transition of scientific research discoveries to their practical application in defense systems or commercial spinoffs.

(more)

Basic Science Office and MURIs

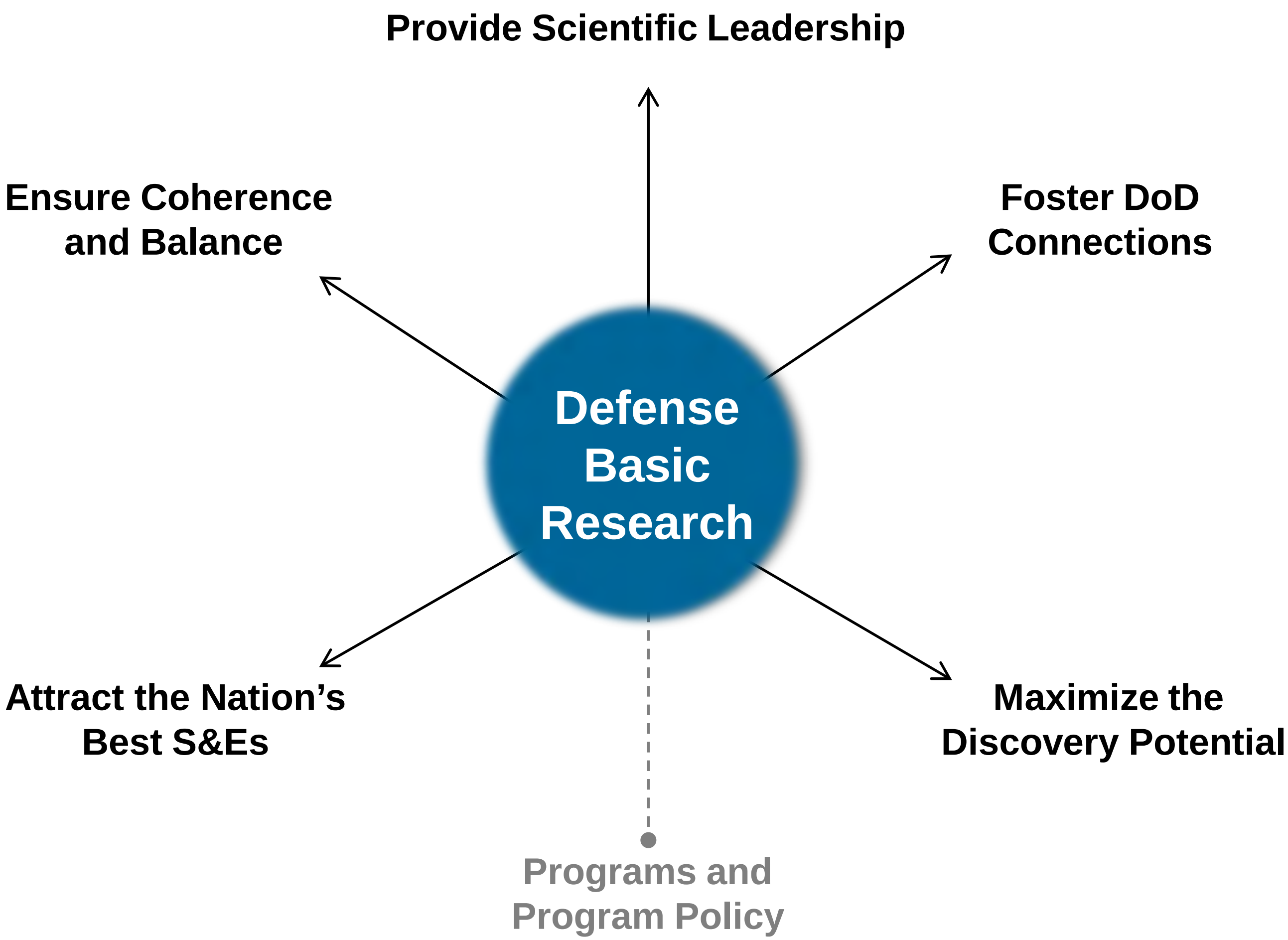
Dr. Robin Staffin
Director for Basic Science
Office of the Assistant Secretary of Defense for Research & Engineering
Department of Defense

Perspective on Basic Science and DoD

- **Future operations capabilities depend on the basic research achievements of today**
- **Five goals for DDR&E to strengthen the defense basic research program:**
  - **Provide scientific leadership** for the DoD basic research enterprise
  - **Attract the Nation's best S&Es** to contribute to and lead DoD research
  - **Ensure the coherence and balance** of the DoD basic research portfolio
  - **Foster connections** between DoD performers and the DoD community
  - **Maximize the discovery potential** of the defense research business environment
- **Achieving these goals results in a coherent, forward-thinking basic research program supported by the Nation's top researchers and paving the way for tomorrow's revolutionary breakthroughs**

Five Eigenvectors for Defense BR

<u>Goal:</u> Create conditions for basic research investments capable of creating high-payoff, transformative scientific breakthroughs for DoD



DoD Priorities for Autonomy Research and Development

MORLEY O. STONE, ST, PhD

Autonomy PSC Lead

21 October 2011

NDIA Disruptive Technologies Conference

November 8-9, 2011

Washington, DC

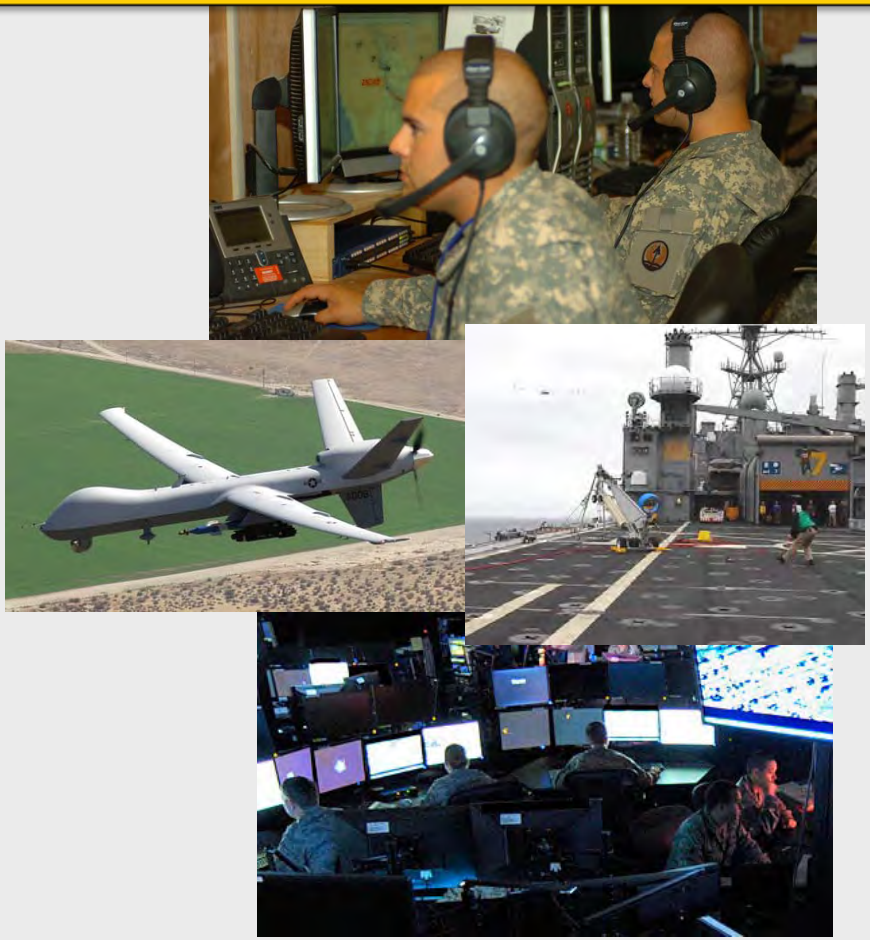
DOD Challenges Addressed by Autonomy

Decentralization, Uncertainly, Complexity…Military Power* in the 21st Century will be defined by our ability to *adapt – this is THE hallmark of autonomy

<u>Manpower efficiencies</u>: Insufficient manpower to support complex missions such as command and control and surveillance across relevant battlespace

<u>Harsh environments</u>: Operational environments that do not reasonably permit humans to enter and sustain activity

<u>New mission requirements</u>: Need adaptive autonomous control of vehicle systems in face of unpredictable environments and challenging missions



Distribution Statement A: Approved for public release; distribution is unlimited.

Autonomy—Technical Challenges

Working definition of "Autonomy" from recent DOD workshops: Having the capability and freedom to self-direct. An autonomous system makes choices and has the human's proxy for those decisions. This does not mean the autonomous system is making decisions in isolation from humans, just that the system makes the choices. The balance between human and system decision making is defined by policy and operational requirements.

1. Machine Reasoning and Intelligence
2. Human/Autonomous System Interaction and Collaboration
3. Scalable Teaming of Autonomous Systems
4. Testing and Evaluation (T&E) and Verification and Validation (V&V)

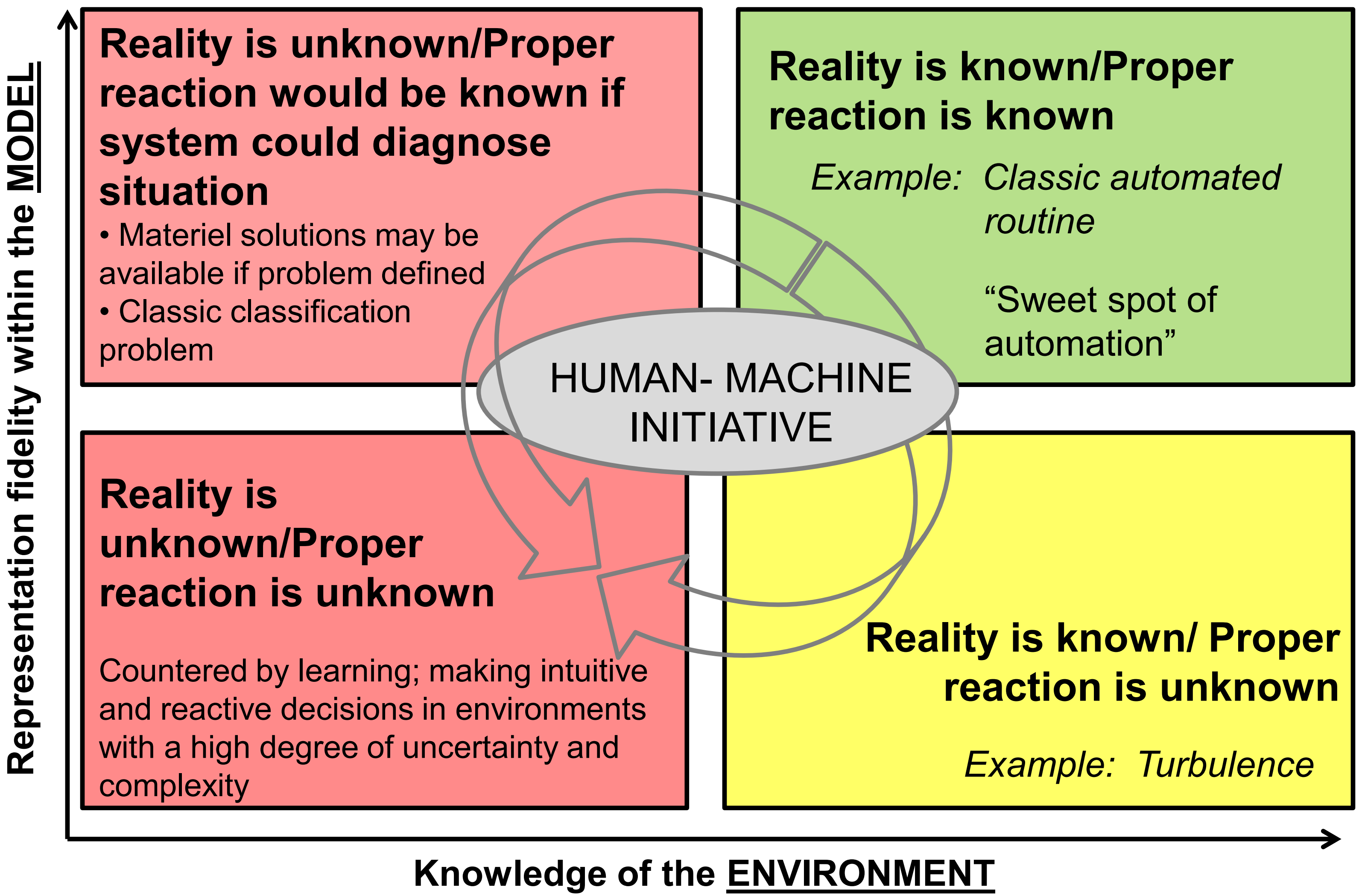
All address Two Sources of Uncertainty/Brittleness:

1. Dynamic and Complex Mission Requirements
2. Dynamic and Complex Operational Environments

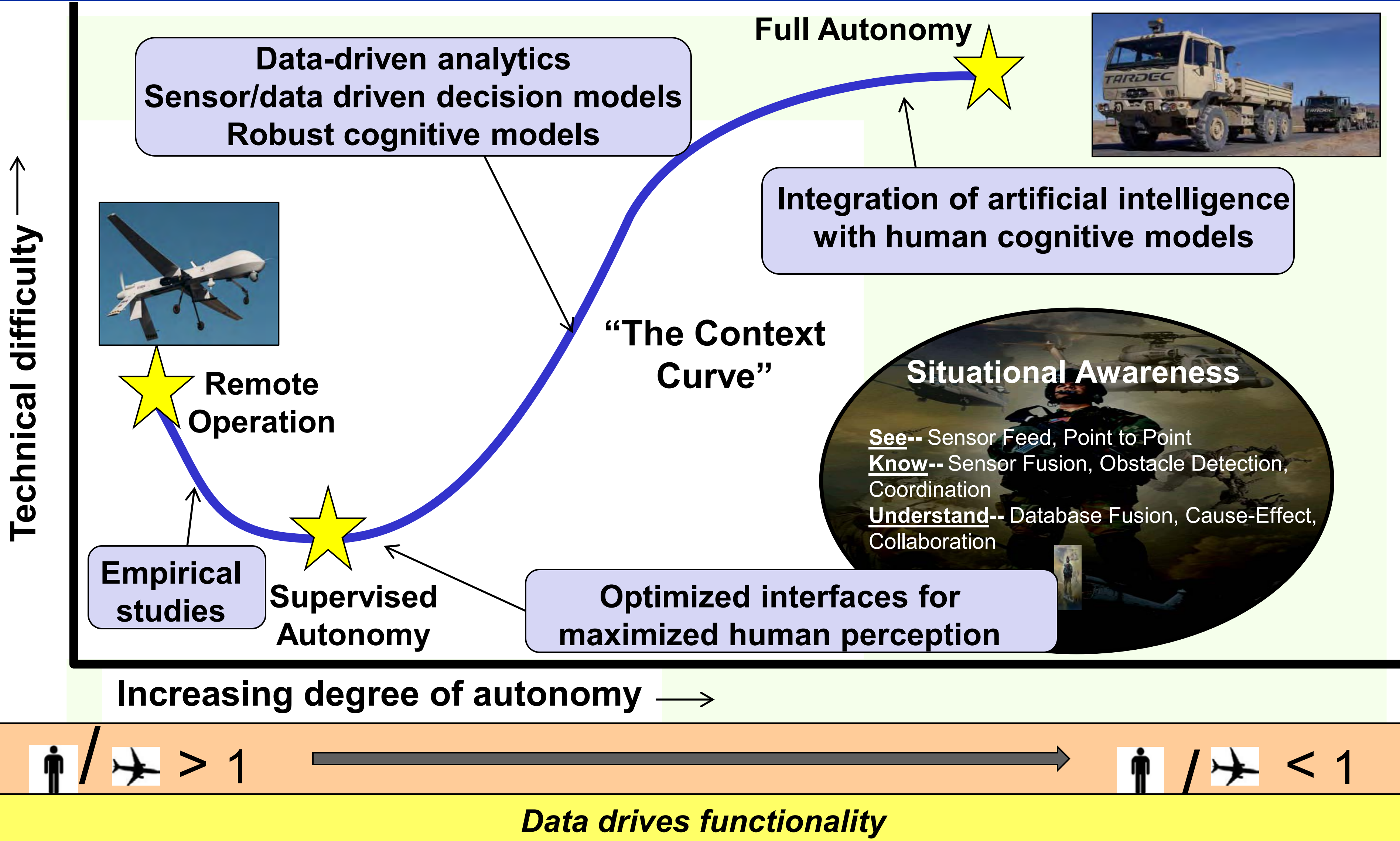
Overarching Problem Statement:

In a static environment, with a static mission, automation and autonomy converge. However, in reality, where dynamic environments collide with dynamic missions, automation can only support a small fraction of autonomy requirements.

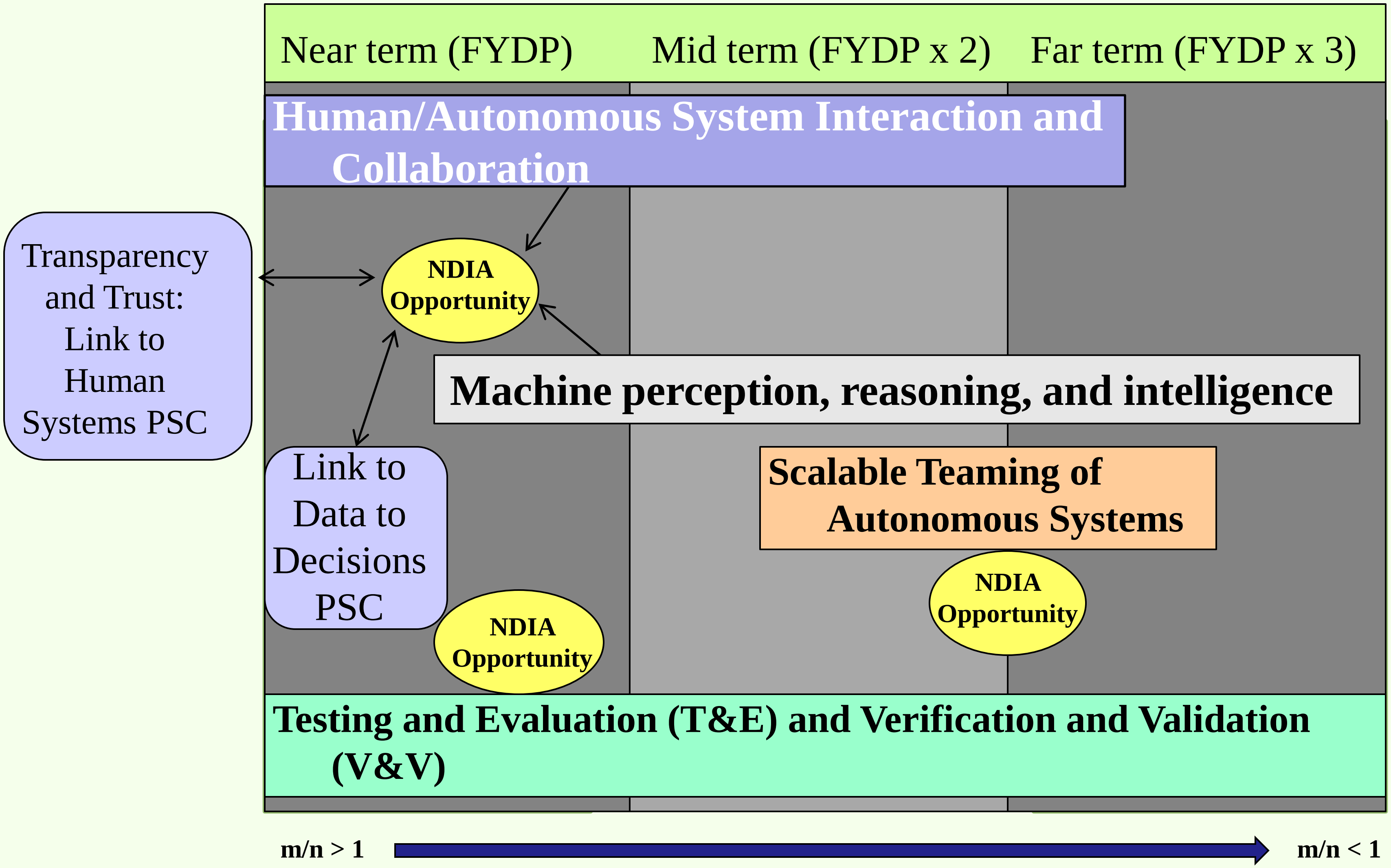
Autonomy Parameter Space



Technology-Driven Capabilities



Notional Depiction of Technology Stage-Gating



Opportunities for NDIA: Coordinated Platform Reasoning

Human/Autonomous System Interaction and Collaboration	Machine perception, reasoning and Intelligence
• Collaborative approaches to enable humans to flexibly shape and redirect the plans, behaviors, capabilities of highly complex distributed autonomous systems in real time to meet the ever changing requirements of warfighters operating in a dynamic battlespace • More natural, cognitively compatible, and effective multi-modal interactions between humans and autonomous systems for rapid coordination and collaboration • Intent-understanding relative to team members, adversaries and bystanders • Adaptable levels of autonomy • Transparency (link to Human Systems initiatives)	• Perception and comprehension (includes ATR as relevant to autonomy) • Onboard processing to reduce bandwidth requirements • Assessment/Planning in uncertain and unstructured environments (e.g. common sense reasoning, abductive reasoning, planning with partial goals, etc) • Learning, experience, adaptation: includes the ability to enhance the networks capability to rapidly achieve perception and assessment • Implementation: includes issues of computational platforms, computational and reasoning architectures, etc. • Distributed decision making coordination to mission completion

Notional examples: Multi-vehicle coordinated object discrimination and distributed decision making

Opportunities for NDIA: TEVV of Autonomous Systems

Scalable Teaming of Autonomous Systems	Testing and Evaluation, Verification and Validation
• Robust self-organization, adaptation, and collaboration among highly heterogeneous platforms and sensors in a dynamic battlespace • Decentralized mission-level task allocation/assignment, planning, coordination and control of heterogeneous systems for safe navigation, sensing, and mission accomplishment • Space (air, land, water) management operations in proximity to manned systems and units • Sensing/synthetic perception across large numbers of distributed entities	• Test and evaluation and Verification and validation approaches that support exponential growth projected in software lines of code as well as new algorithms types (e.g. non-deterministic) • Analysis tools that work with realistic assumptions including supporting timely and efficient certification (and recertification) of intelligent and autonomous control systems • Common architecture
Future solicitations to be determined	**Test Methodology—** Assess machine reasoning in dynamic environments (Phase 1) and under dynamic mission requirements (Phase 2). Largely service-specific.

Examples of BAA's, MURI's, and SBIR's that Support DOD Requirements for Autonomy-related R&D

Organization	Opportunity	Contact
AFOSR (Reliance Optimization for Autonomous Sys)	BAA-AFOSR-2012-02	Joseph Lyons
AFRL/RW (Armament Technology)	BAA RWK-10-0001	Judie Jacobson
AFRL/711 HPW (Warfighter Interface Tech Adv R&D)	BAA 09-04-RH	Ronald Yates
ONR (Behavior of Complex …Autonomous Systems)	BAA/MURI 11-026	Marc Steinberg
ONR (Long Range BAA for Navy and Marine Corps S&T)	ONRBAA12-001	Cheryl Nagowski
DTRA (Scalable Teaming of Autonomous Systems)	BRBAA08-Per5-C-008	Robert Kehlet
DTRA (TEV&V)	BRBAA08-Per5-c-0020	Robert Kehlet
DTRA (TEV&V)	BRBAA08-Per5-c-0027	Michael Robinson
ARL /ARO (Basic Scientific Research)	W911NF-07-R-0001-05	Varies by topic

Summary

- **DoD will be investing in and advancing the state-of-the-art in autonomy research**
- **DoD will be one of many players in this rapidly expanding area**
- **Investment represents significant opportunity for broad range of industrial partners, such as:**
    - **Transport**
    - **E-commerce**
    - **Healthcare**
    - **Public Safety**
    - **Non-traditional Defense Industries**
- **Autonomous technology will fill a major role in future DoD operations**

Autonomy Priority Steering Council Membership

- **USAF/AFRL – Morley Stone (Lead)**
- **US Army/TARDEC - James Overholt**
- **US Army/ARL- Jonathan Bornstein**
- **US Navy/ONR – Marc Steinberg**
- **DTRA – Stephen Dowling**

Human Systems
Priority Steering Council

Dr. John Tangney

Lead, PSC/HS

Office of Naval Research

NDIA 8th Annual Disruptive Technologies Conference

8 November 2011

New NDIA Division
HUMAN SYSTEMS

Mission

To **promote the exchange of technical information and discussions between government, industry, and academia**, and the expansion of research and development in areas **related to the human as a system** whose performance must be integrated into any system of systems

Objectives

- **Advocate human-centered research** and the integration of cognitive and biological technologies
- Promote discussions to **make the "human factor" a top priority** in Research, Development, Test and Evaluation (RDT&E)
- Conduct studies and prepare reports in response to requests from **the DoD HS Community of Interest (CoI)**
- Advocate, lead, and influence increased discussion and research on the **elements of human-system integration (HSI) domains**

Chair: Dr. Greg Zacharias, Charles River Assoc

Human Systems Overall Scope

System Interfaces

Strategic Decisionmaking

Tactical Decision Support

Autonomous vehicle control

Cyber Operations & Trust

Adaptive Planning

Personnel & Training

Adaptive, tailored instruction

Live, Virtual, Constructive simulation

Realistic immersive training

Train Partner State Forces

Social & Cultural Understanding

Information sharing w/ partners

Cultural situation awareness

Cultural & language expertise

Social Network Analysis

Cultural impact of actions

Protection & Sustainment

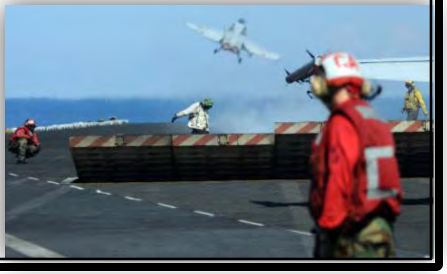
Extreme environment protection

Physical Performance Enhancement

Autonomous augmentation

Physical Aiding

Extended Combat Rations



Human Systems Priority Steering Council
FY13-17 Priority S&T

System Interfaces

Strategic Decisionmaking

Tactical Decision Support

Autonomous vehicle control

Cyber Operations & Trust

Adaptive Planning

Personnel & Training

Adaptive, tailored instruction

Live, Virtual, Constructive simulation

Realistic immersive training

Train Partner State Forces

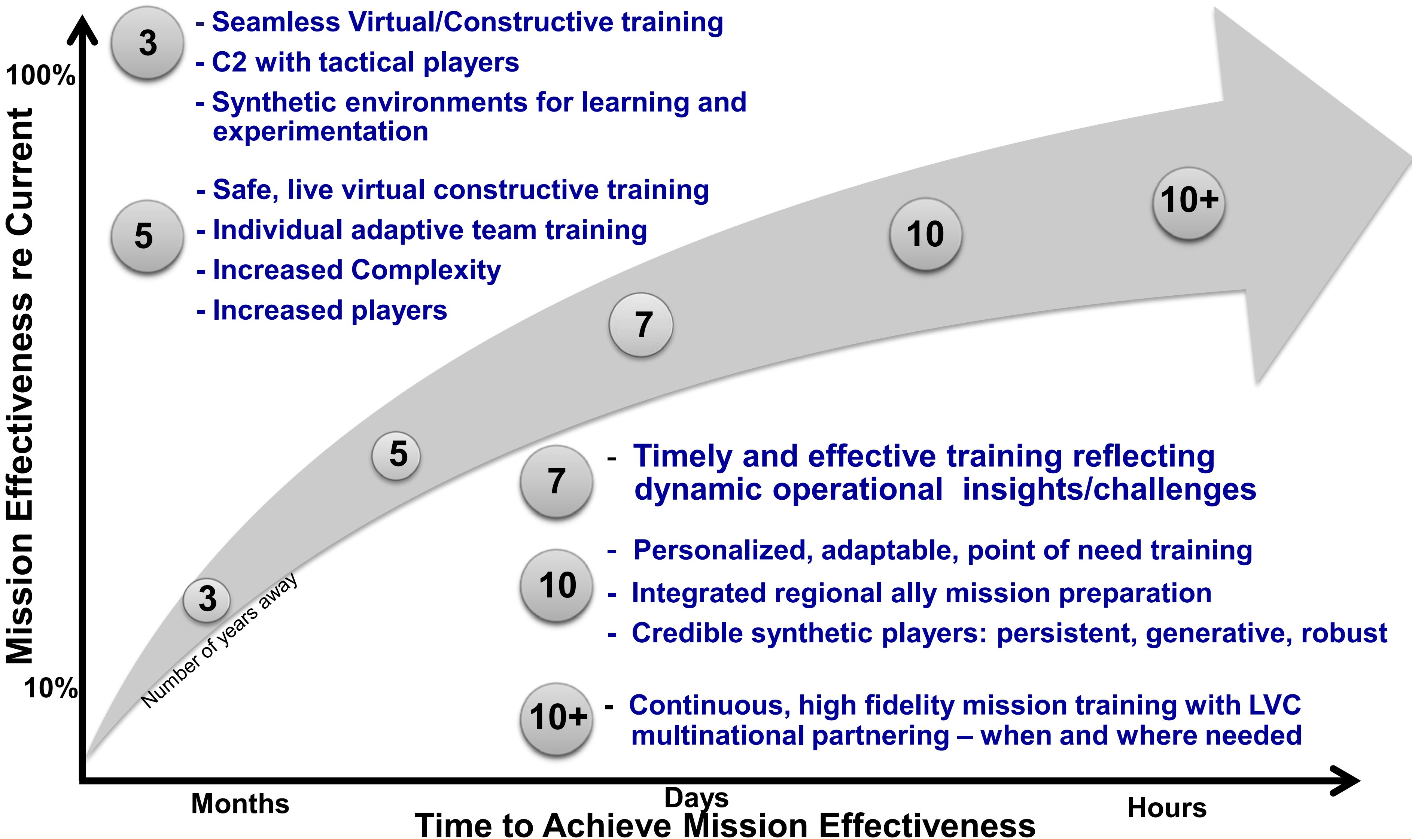
Major Focus of PSC

Human Systems Training for Readiness

Problem: Complex Evolving Threats Outpace Readiness Training

- Warriors train for tomorrow's fight using yesterday's technology, methods, and strategies
- Current training scenarios not matched to evolving mission complexity and dynamics
- Warfighters are trained to doctrine -- fight strategically and dynamically to meet new threats
- Training is costly
  - Live systems deplete inventory, consume fuel, require maintenance & wear out
  - Ranges & role players are expensive – lack responsiveness to changing scenarios
  - Training ranges not designed for flexible training and throughput is inadequate

Training
Technology End States



Human Systems Training Technical Challenges

Challenge 1: First Principles for Training Design

- Synthetic environments for experimentation and learning
- Techniques to automatically capture operationally relevant measures of performance
- <u>Validated tools to optimize</u> training outcomes across individuals and teams

Challenge 2: Realistic, Adaptive and Interactive Scenario Based Training

- <u>Persistent integration of real world events and content into scenarios and syllabi</u>
- Demonstrated and validated for the full range of warfighter capabilities reflecting recent lessons learned
- Training that adapts to individual needs of warfighters in near real-time
- Trading realism for flexibility

Challenge 3: Persistent, Affordable, Integrated Training

- <u>Mission-focused training simulations</u> that support individual and collective training
- <u>Seamless, secure</u> integration of training systems across services and coalition partners

Human Systems
Training - Measures of Success

Challenge 1: First Principles for Training Design

- Calibrating training to mission effectiveness
- Automated feedback for unit performance mission training scenarios

Challenge 2: Realistic, Adaptive and Interactive Scenario Based Training

- Automatic players in training scenarios indistinguishable from live players (‘Turing Test’)
- Improved performance resulting from training that automatically adapts in near real time
- 25% reduction in time and cost to develop training scenarios

Challenge 3: Persistent, Affordable, Integrated Training

- Capability to author once and deliver training to any internet-capable device
- Affordable, turnkey capability to link simulations across services for joint training exercises.

Human Systems Interface for Effectiveness

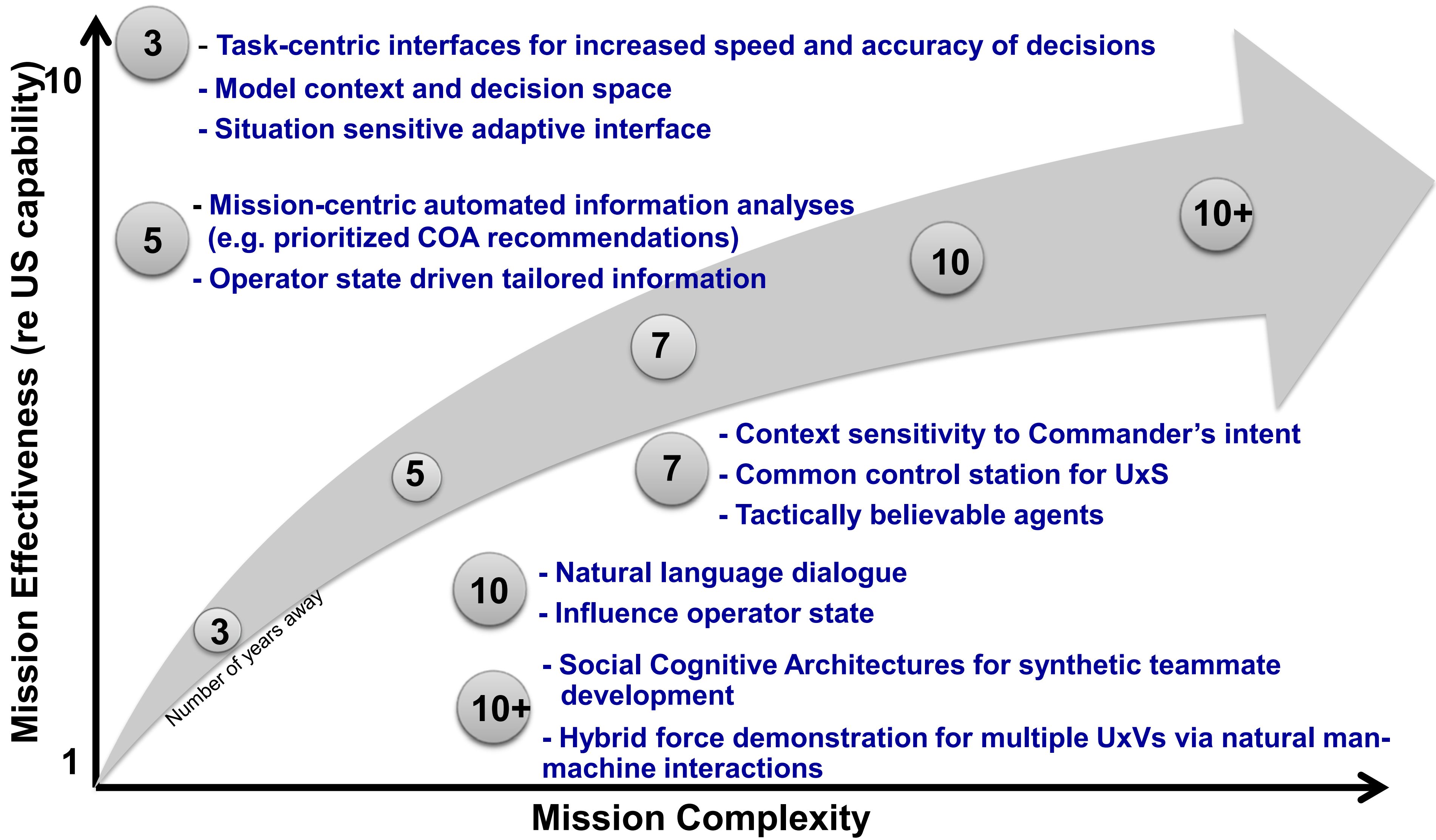
Problem: Current system operation is rigidly data-centric vice flexibly information-centric

- Modern technologies exacerbate critical manning and talent pool deficiencies by ignoring role of Mission, Task & Context – Moving & presenting data vice information
- Current adaptive planning tools do not allow rapid “course of action” analysis and generation
- Information displays typically non-interactive, adapting little to changing needs
- Data quantity will continue to increase nonlinearly

Virtual lab

Actual lab

Interfaces
Technology End States



Human Systems Interface Challenges

Challenge 1: Human-Machine Teaming

- Robots that can participate in realistic dialogue with the operator
- Domain-agnostic performance metrics for human-machine interactions

Challenge 2: Intelligent, Adaptive Aiding

- Adaptive determination of relevant data for human-machine interaction
- Platform-independent frameworks to capture cognitive concepts of rich user models: beliefs, desires, intentions, obligations, and goals

Challenge 3: Intuitive Interaction

- High fidelity operator state modeling with information from rich user models
- Coordinated command and control of hybrid forces

Human Systems Interface - Measures of Success

Challenge 1: Human-Machine Teaming

- Number of agents controlled by single operator (x → 10x)
- Percent of warfighters serviced
- Percent of operator requests anticipated to criterion (0% → 90%)
- Latency for machine-generated alternative courses of action (2*T* → ½*T*)

Challenge 2: Intelligent, Adaptive Aiding

- Speed and accuracy of decisions x scope (search time = 0)
- Transaction efficiency = ratio of relevant/irrelevant data
- Increased situation salience

Challenge 3: Intuitive Interaction

- Accuracy of operator state assessment for information optimization
- Effectiveness of natural dialogue (transaction efficiency)
- Ease of interaction, time to achieve full competency

Human Systems
Broad Agency Announcements

USAF

- BAA 09-05-RH - Science and Technology For Warfighter Training and Aiding
  - POC: Dr. Winston Bennett
- BAA 09-04-RH - Warfighter Interface Technologies Advanced Research Programs (WITARP)
  - POC: Mr. Randy Yates
- BAA 09-02-RH - Advances in Bioscience for Airmen Performance
  - POC: Mr. Mark Fagan
- BAA 09-03-RH - Research & Analytical Support for the 711th HPW Human Effectiveness Directorate
  - POC: Ms. Linda Lange
- BAA-AFOSR-2011-01 Research Interests of the Air Force Office of Scientific Research
  - POC: Dr. Hugh DeLong

Navy

- ONR BAA 11-031 - Office of Naval Research (ONR)
  - POC: Dr. William Krebs
- ONR BAA 12-001 - Office of Naval Research (ONR) Long Range BAA
  - POC: Dr. William Krebs

Human Systems Broad Agency Announcements

Army

- 11 - 13 Natick BAA Broad Agency Announcement (BAA) For Basic and Applied Research
  - POC: Multiple
- W5J9CQ-11-R-0017 U.S. Army Research Institute (ARI) for the Behavioral and Social Sciences
  - POC: Jim Belanich
- W5J9CQ-12-R-0002 - United States Army Research Institute for the Behavioral & Social Sciences
  - POC: Dr. Jay Goodwin
- W911NF-07-R-0003-04 - Army Research Office – Broad Agency Announcement for Basic and Applied Scientific Research
  - POC: Dr. Robert Ulman
- W91CRB-08-R-0073 - Research, Development and Engineering Command – Simulation and Training Technology Center
  - POC: Dr. Frank Tucker
- W911NF-07-R-0001-05 – Army Research Laboratory and the Army Research Office Broad Agency Announcement for Basic and Applied Research
  - POC: Dr. Tomasz Letowski

Summary

- **Evolving threats outpace contemporary readiness training**
- **Interfaces are not operator/information-centric**
- **Training Goals**
  - Synthetic environments for mission training
  - Continuous, real-time training with LVC multinational partnering
  - Seamless, secure integration of training systems across services
- **Interface Goals**
  - Frameworks that capture the intentions & obligations of the operator
  - Integrated data based on operators' modeling of natural language & gestures
  - Human-machine teaming based on immediate feedback and accurate predictions of operators' mental states via interactions

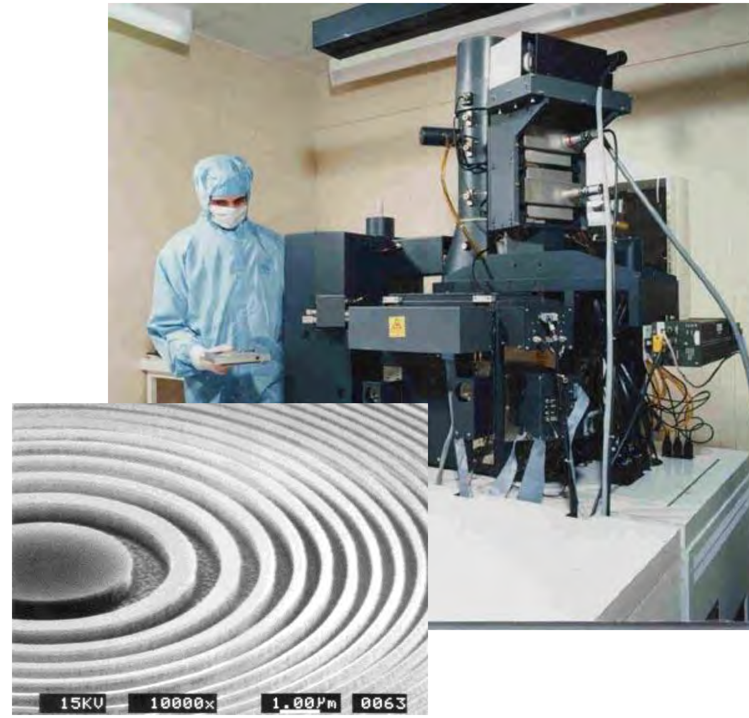
MURIs and What They Lead To

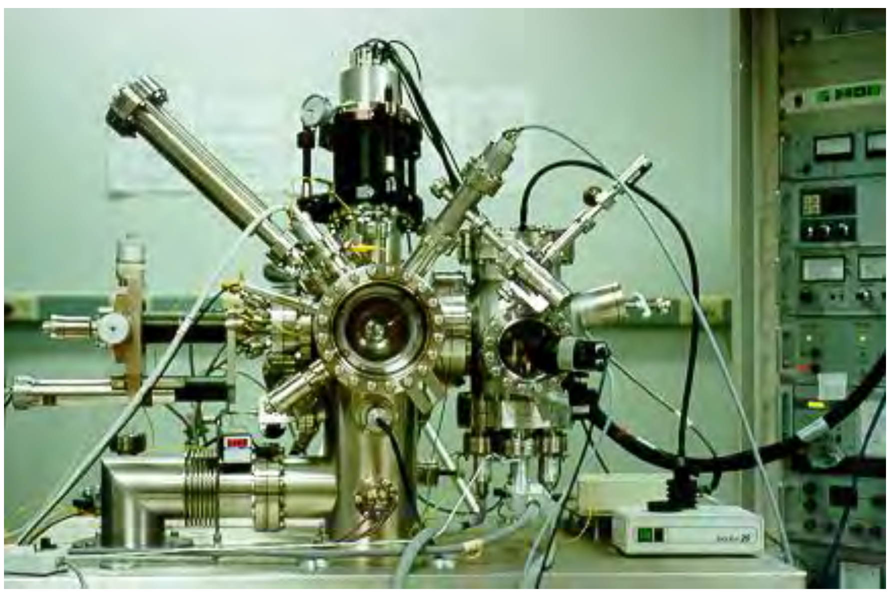
George M. Whitesides
Harvard University

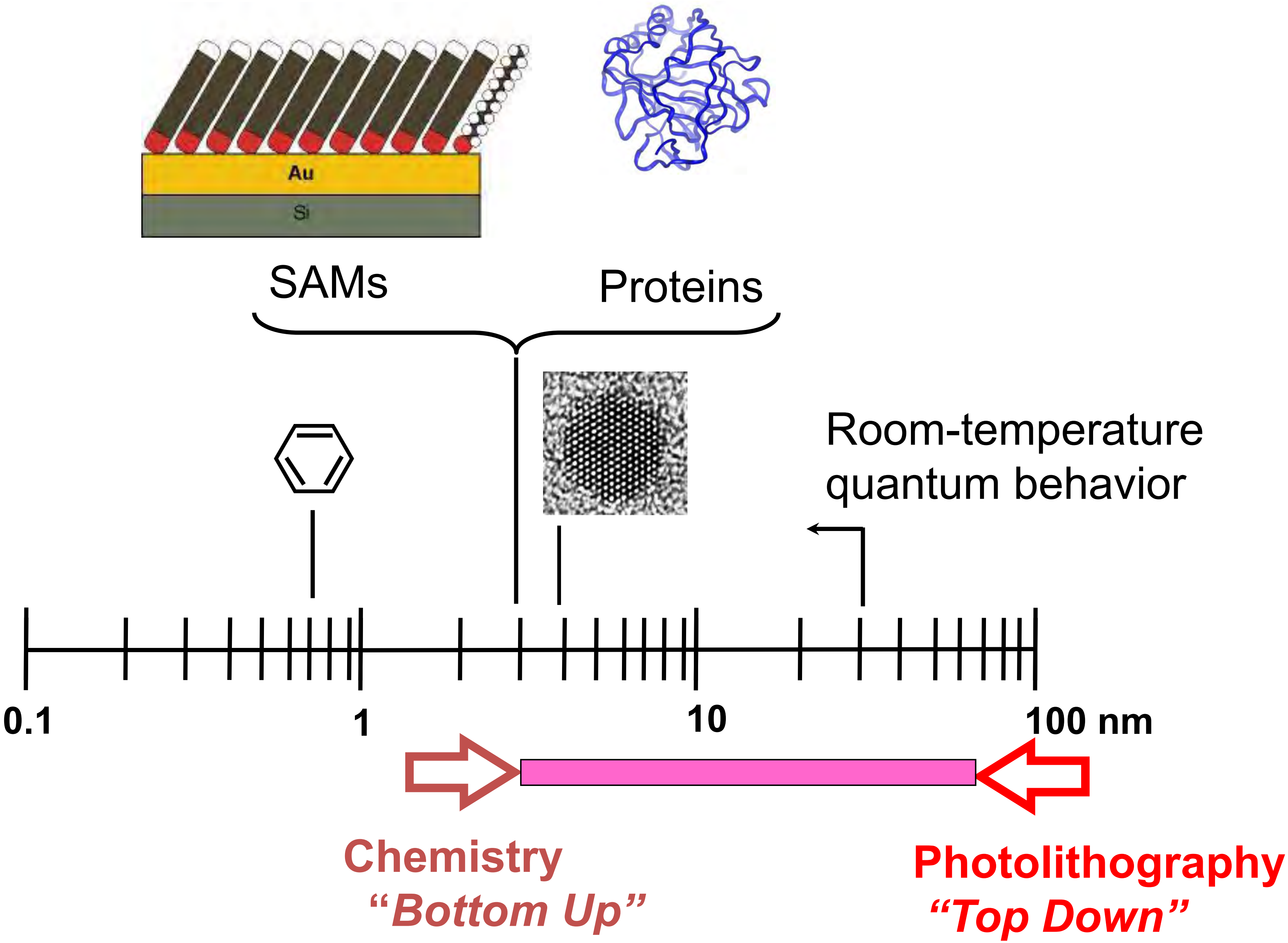
Impact? Curiosity? (Hits on Google, MM)

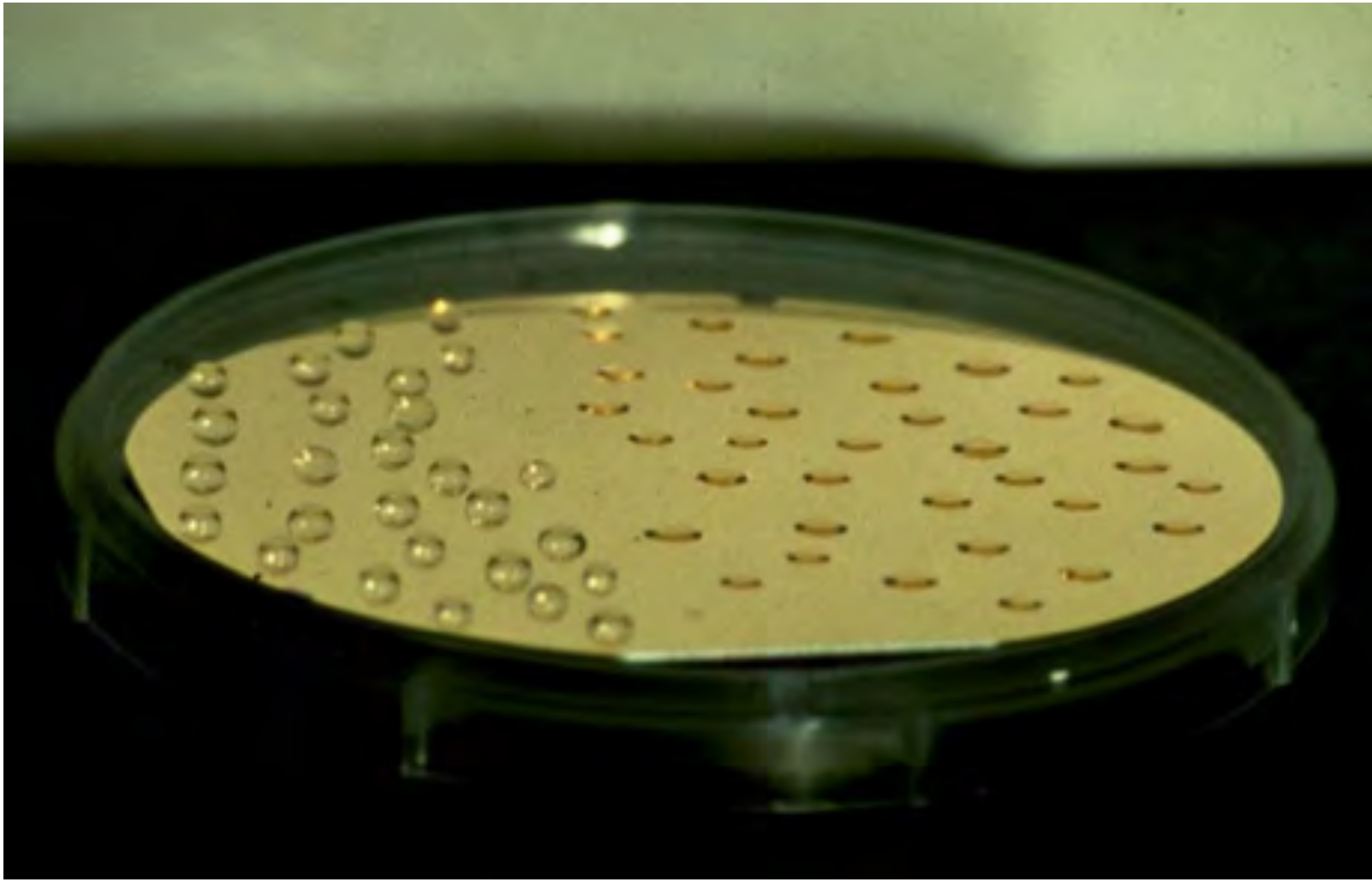
• Self-assembled monolayers	1.6
• Microcontact printing	0.24
• Soft lithography	0.22
– Dip Pen Nanolithography	0.54
– Imprint Nanolithography	0.44
• Microfluidics	1.45
• Optofluidics	0.55
• Paper Diagnostics	22.
– Diagnostics for All	77.
• Soft Robotics	(9.8)

Self-Assembled Monolayers
SAMs

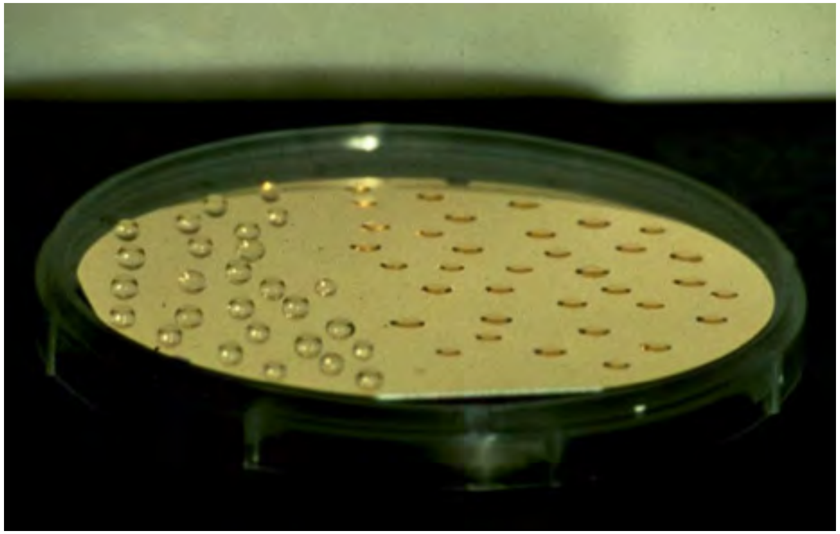

15KV
10000x
1.00µm
0063

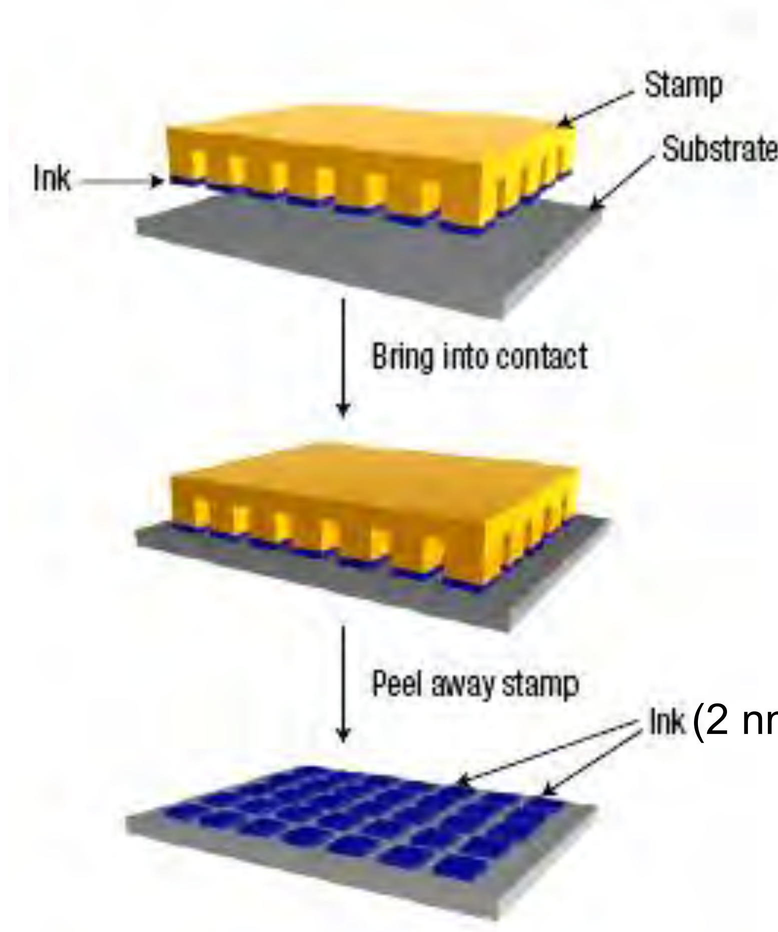



Au
Si
SAMs
Proteins
Room-temperature
quantum behavior
0.1
1
10
100 nm
Chemistry
"Bottom Up"
Photolithography
"Top Down"



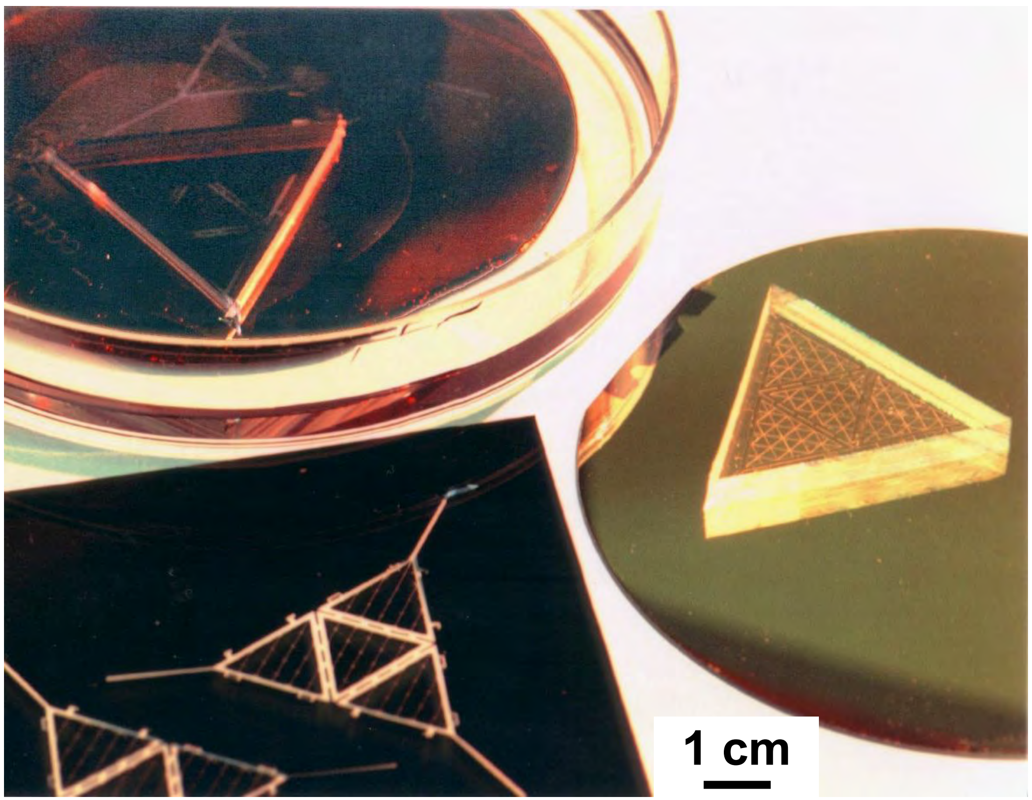
Microcontact Printing

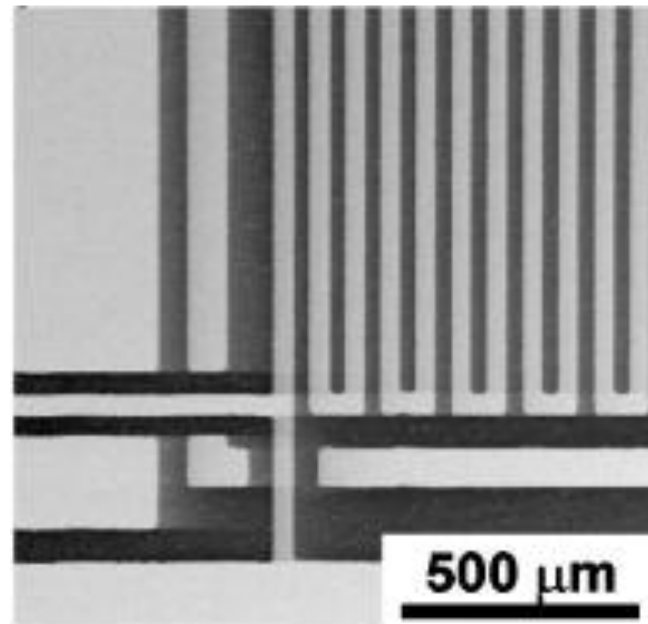


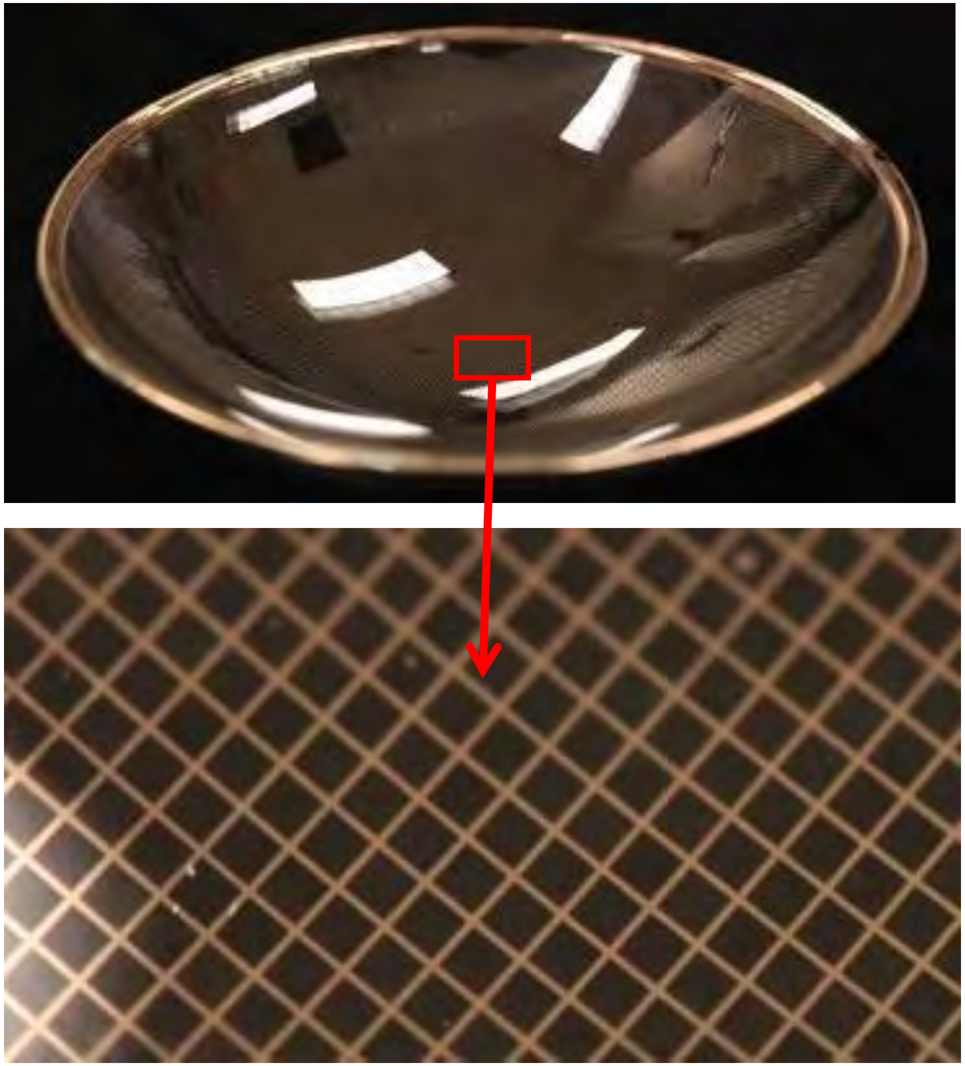


Abbott, Xia, Rogers, Aizenberg

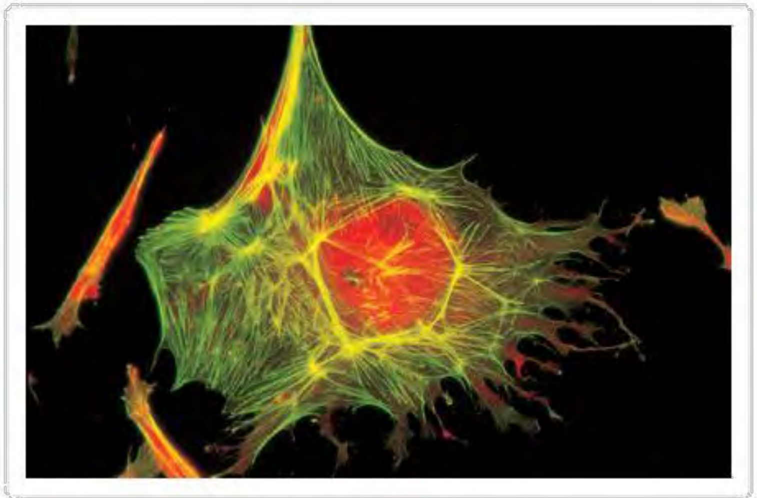

FRONT

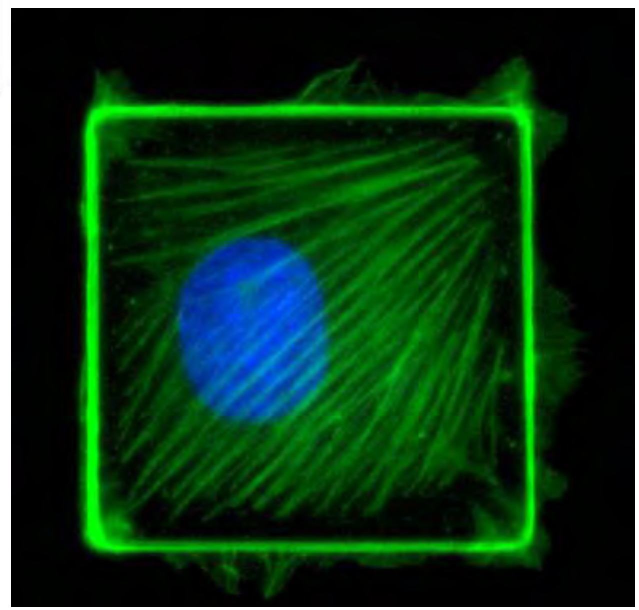

1 cm


500 μm



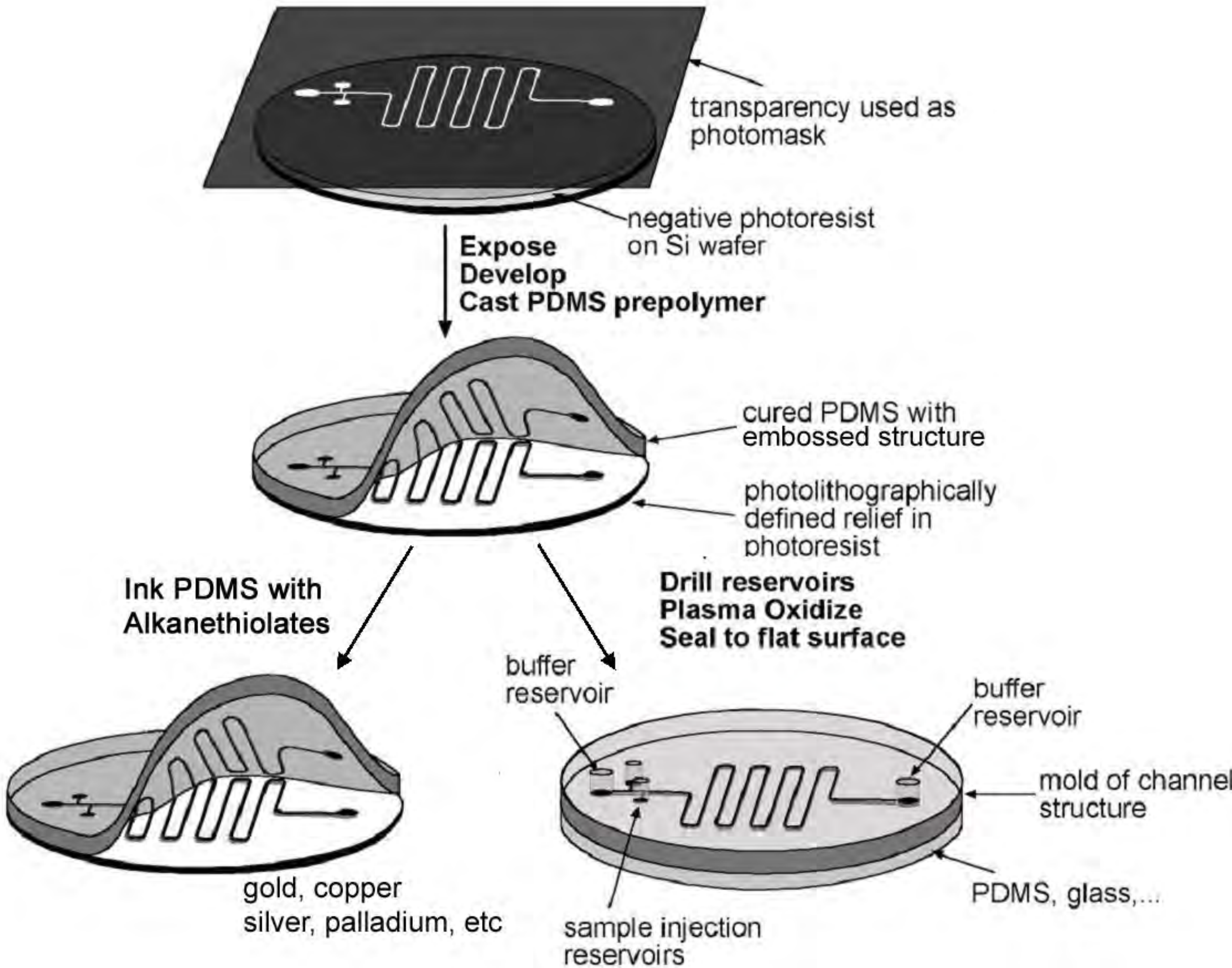
20-µm Au lines
EM shielding
X100? Cost reduction



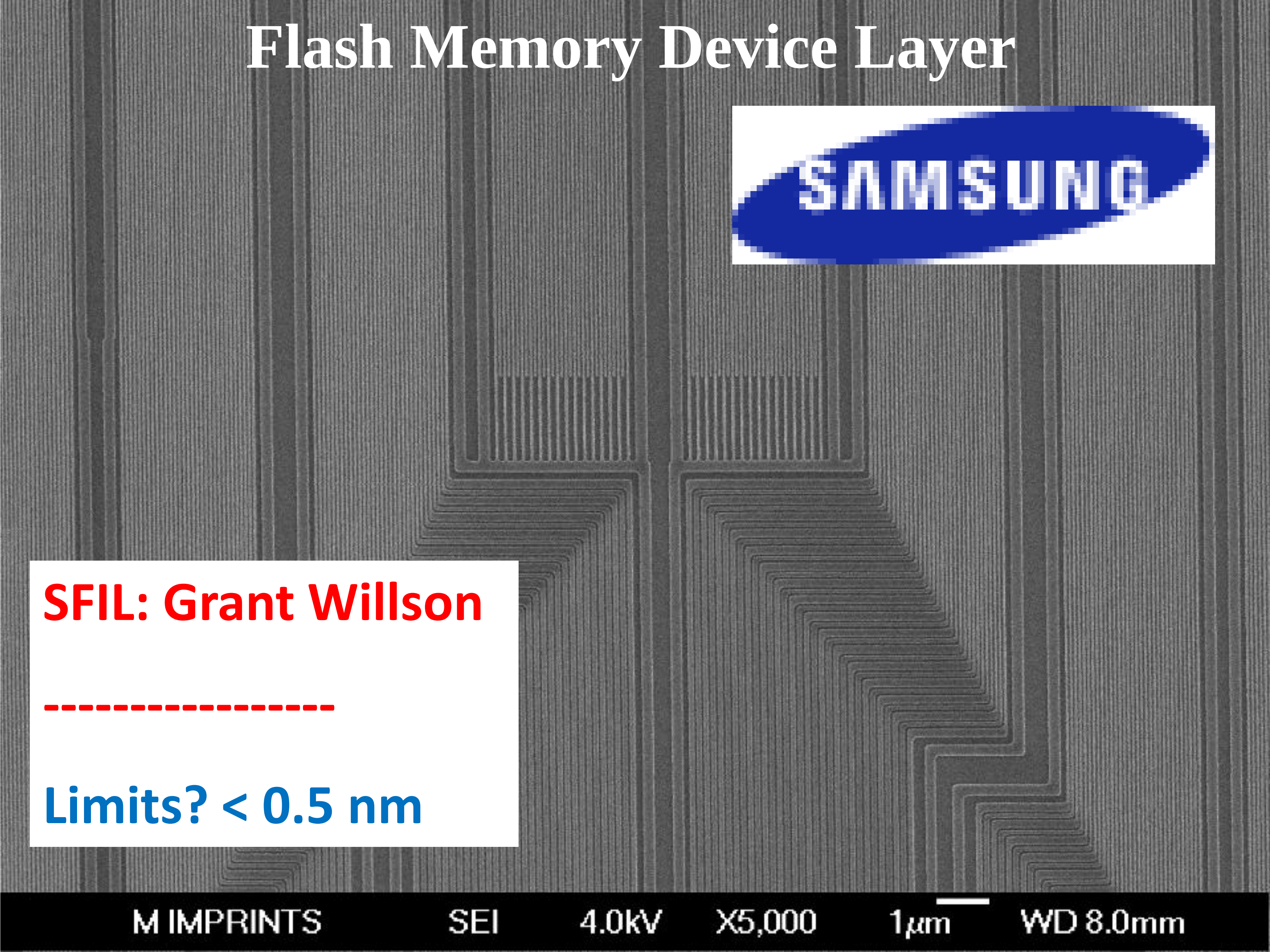


Mrksich, Ingber

Soft Lithography


transparency used as
photomask
negative photoresist
on Si wafer
Expose
Develop
Cast PDMS prepolymer
cured PDMS with
embossed structure
photolithographically
defined relief in
photoresist
Ink PDMS with
Alkanethiolates
Drill reservoirs
Plasma Oxidize
Seal to flat surface
buffer
reservoir
buffer
reservoir
mold of channel
structure
PDMS, glass,...
gold, copper
silver, palladium, etc
sample injection
reservoirs

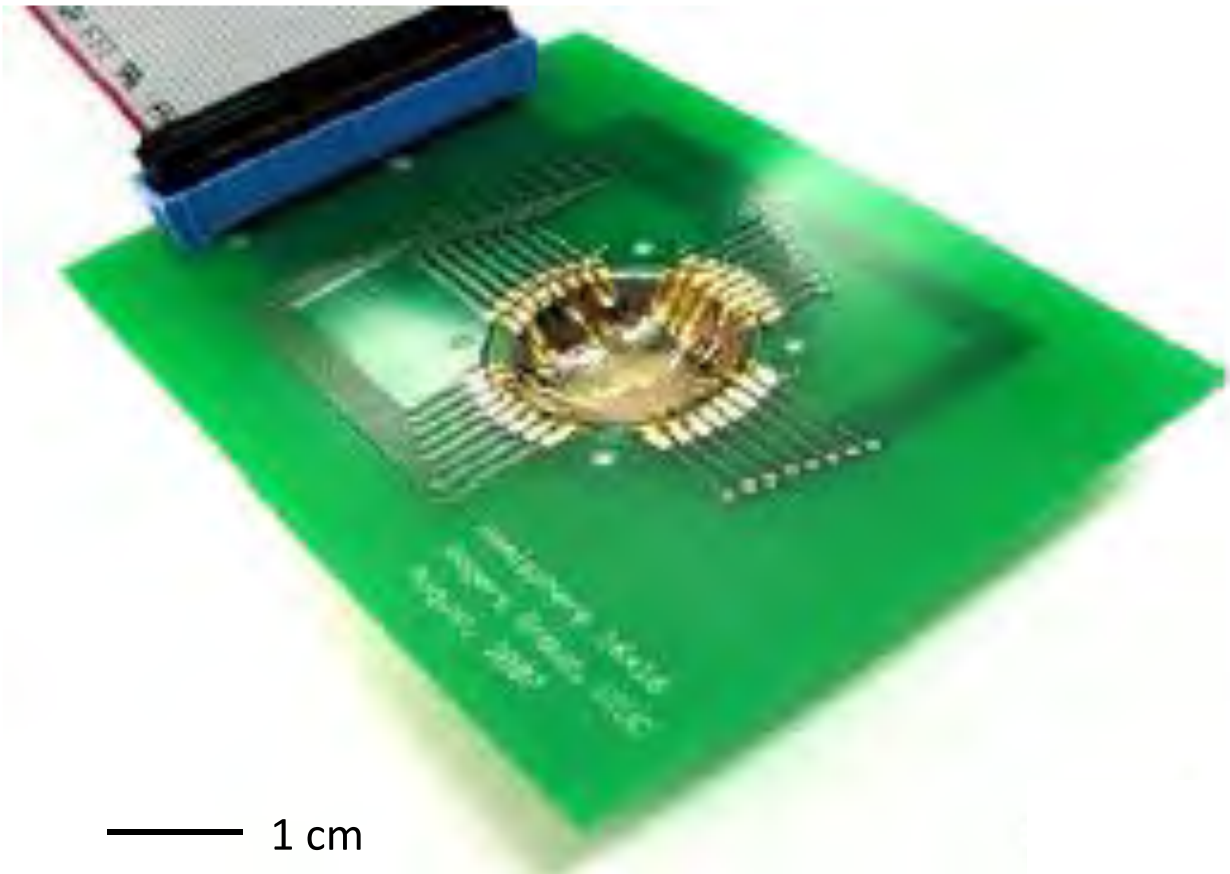
Flash Memory Device Layer

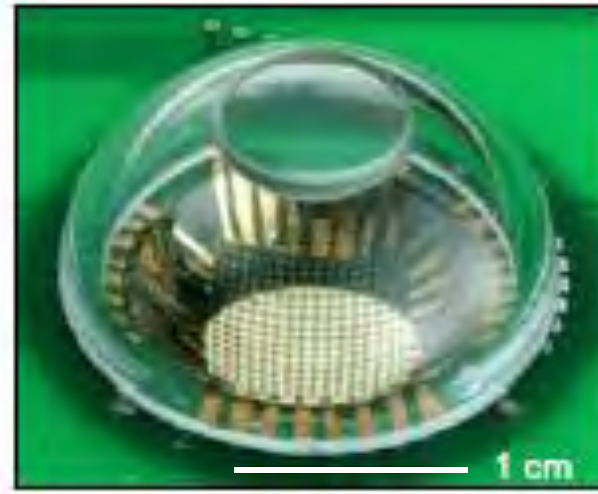


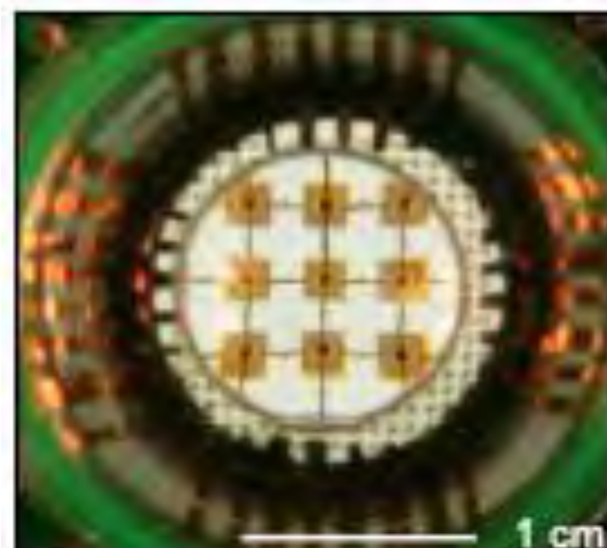
SFIL: Grant Willson

Limits? < 0.5 nm

Electronic Eyeball Camera via Stretchable Electronics



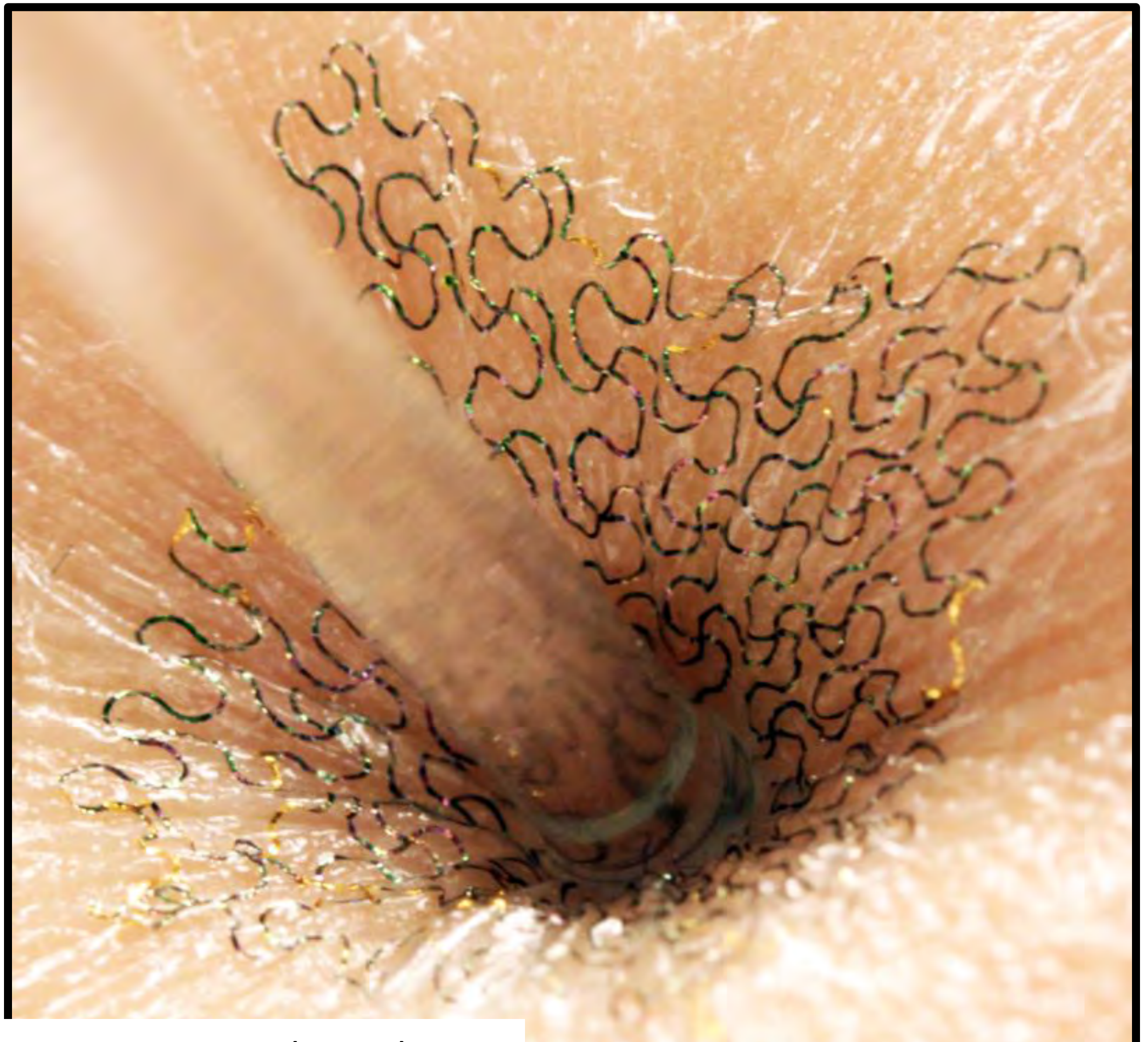




Nature **454**, 748 (2008).

Epidermal Electronics

Skin Mounted, Deformed

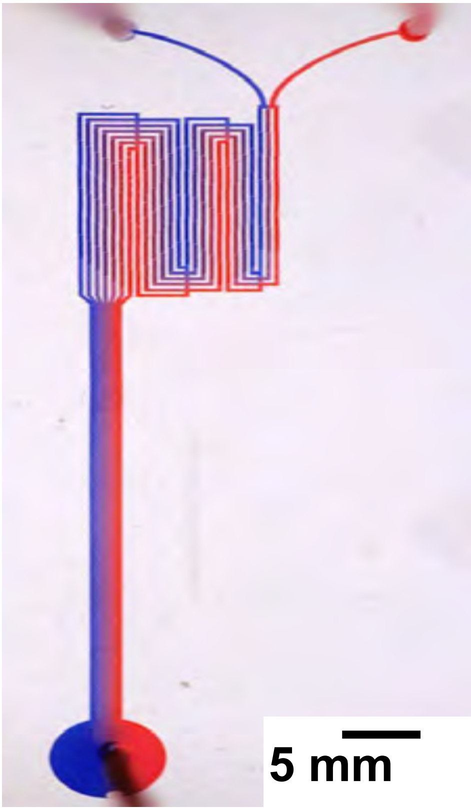


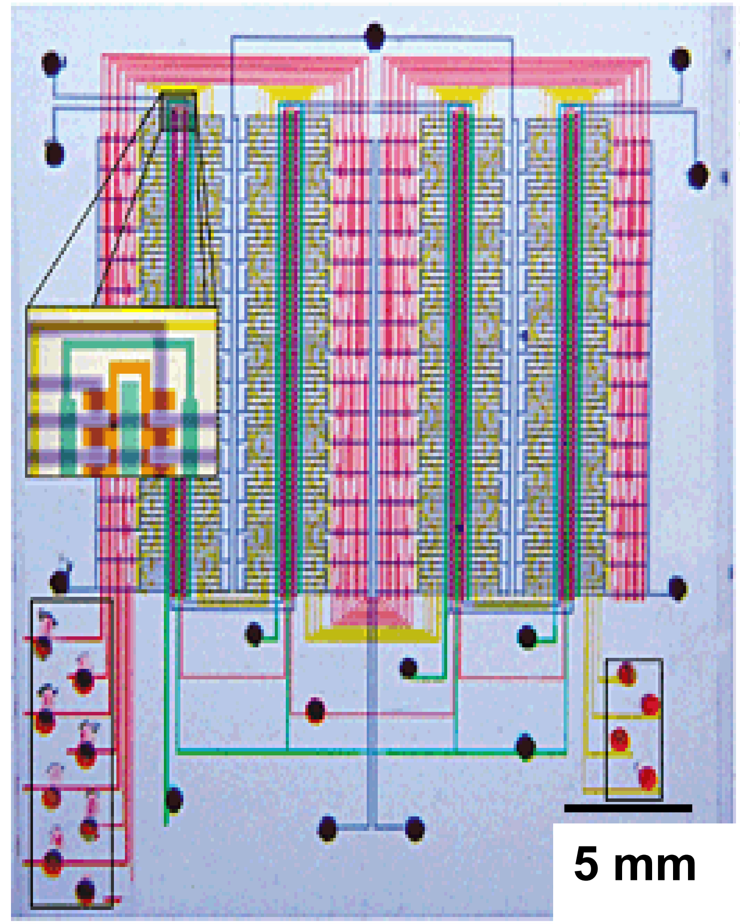
Free Standing

Science **333**, 838 (2011).

John Rogers

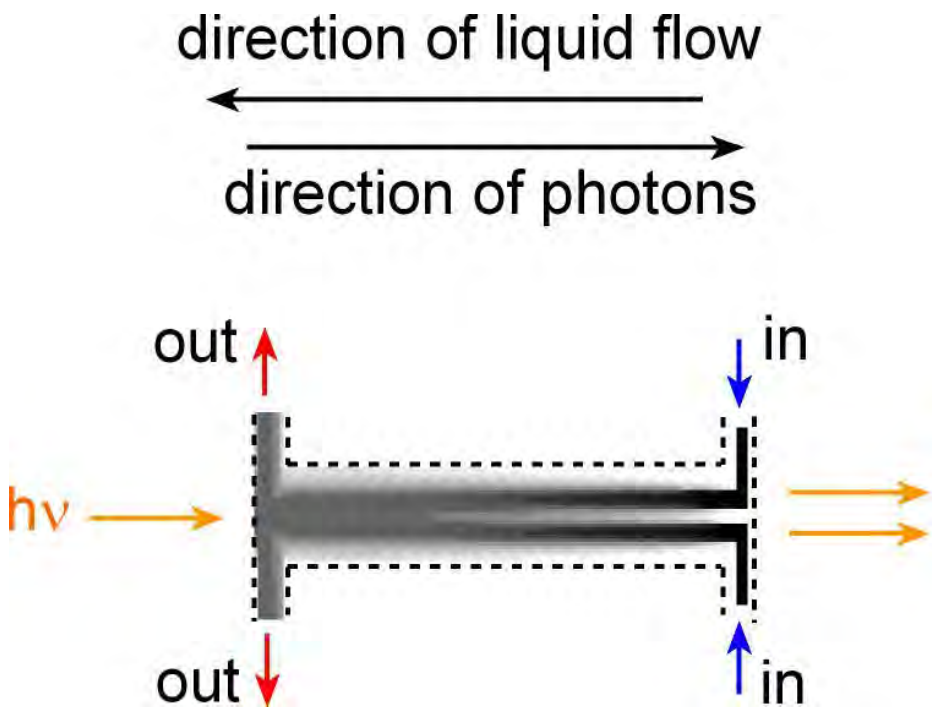
Microfluidics



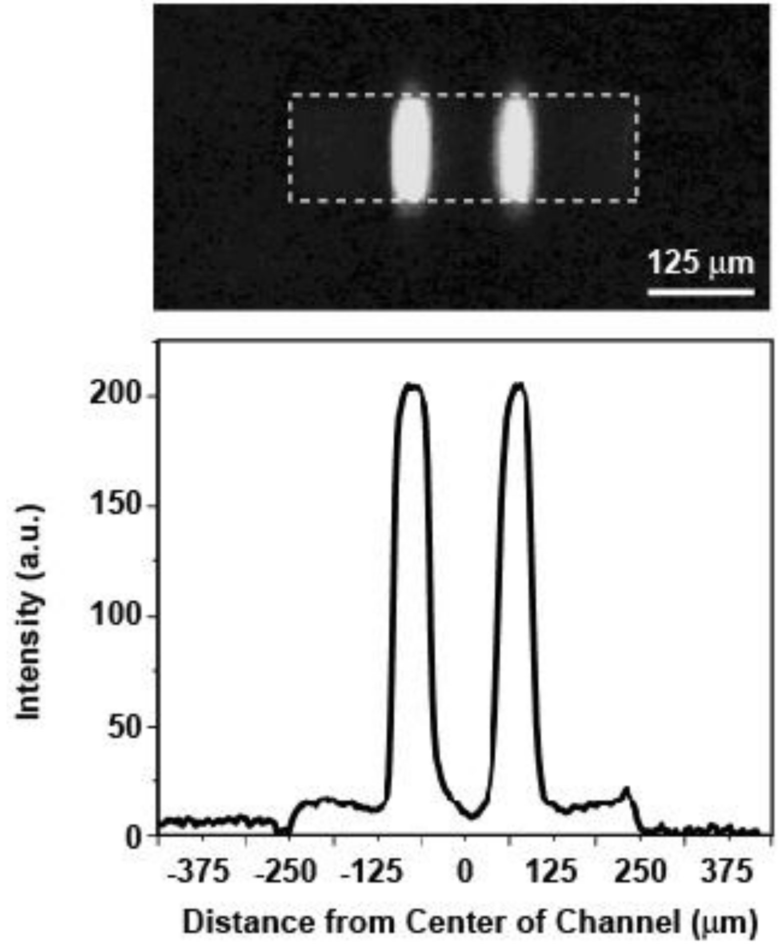


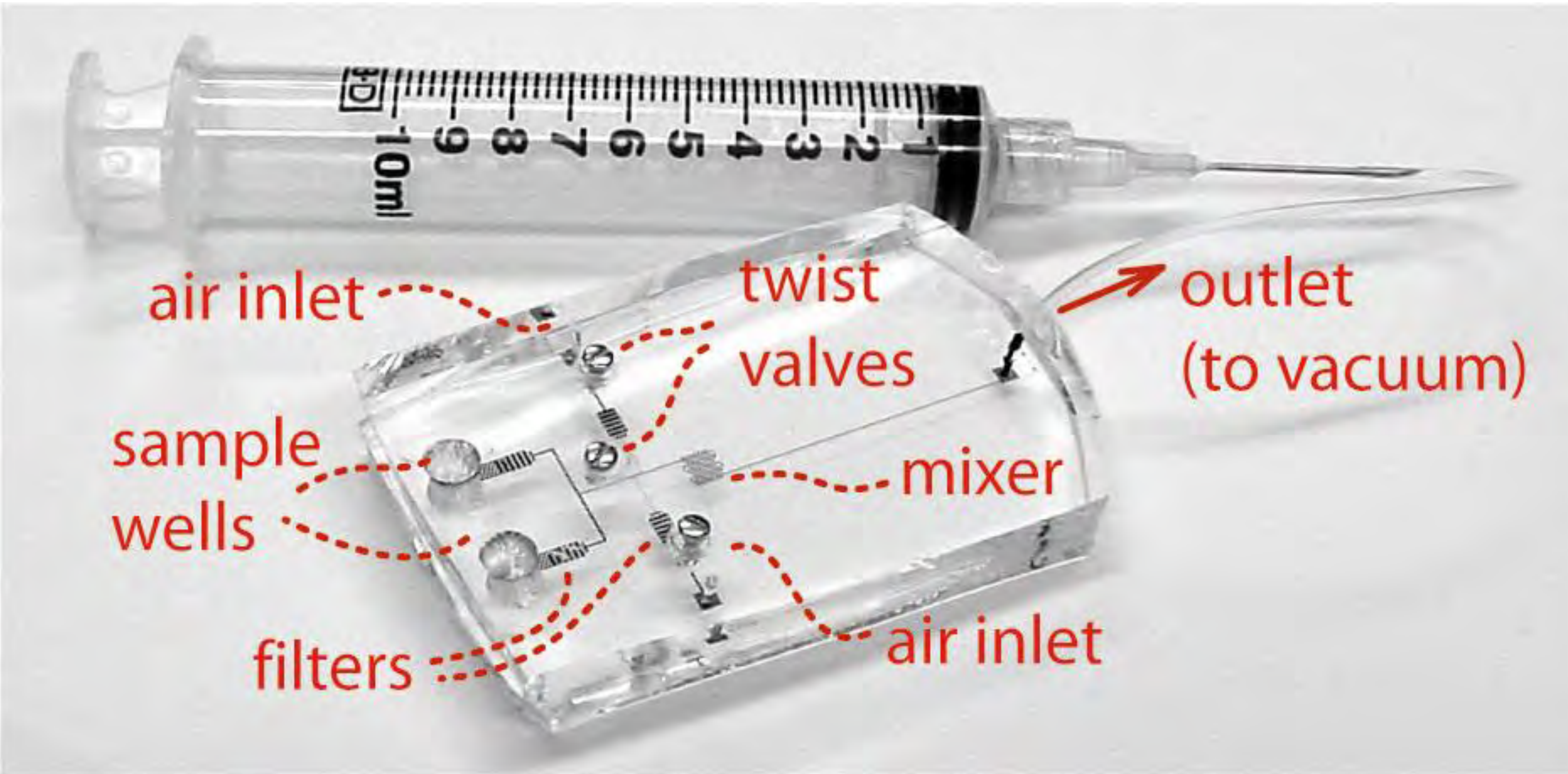
Quake/Fluidigm Inc

A diffusive splitter



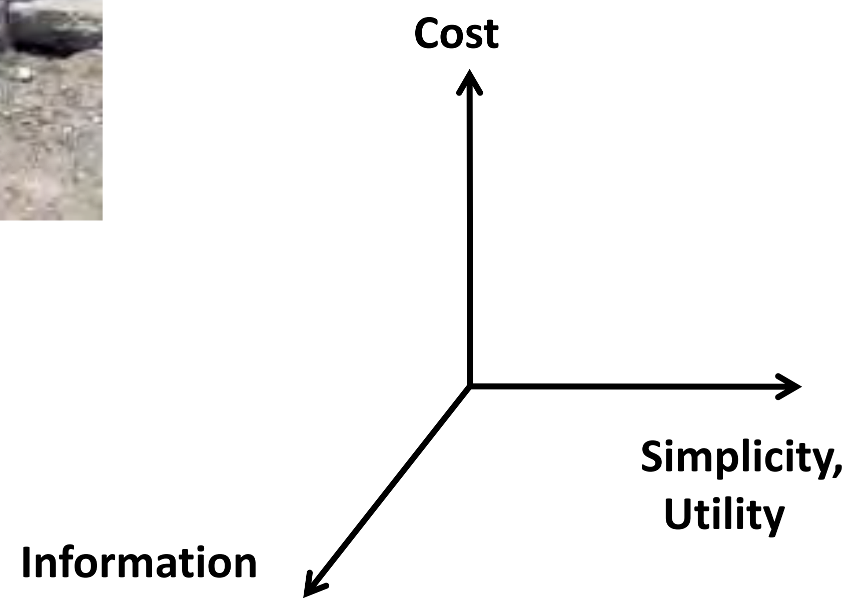
Output

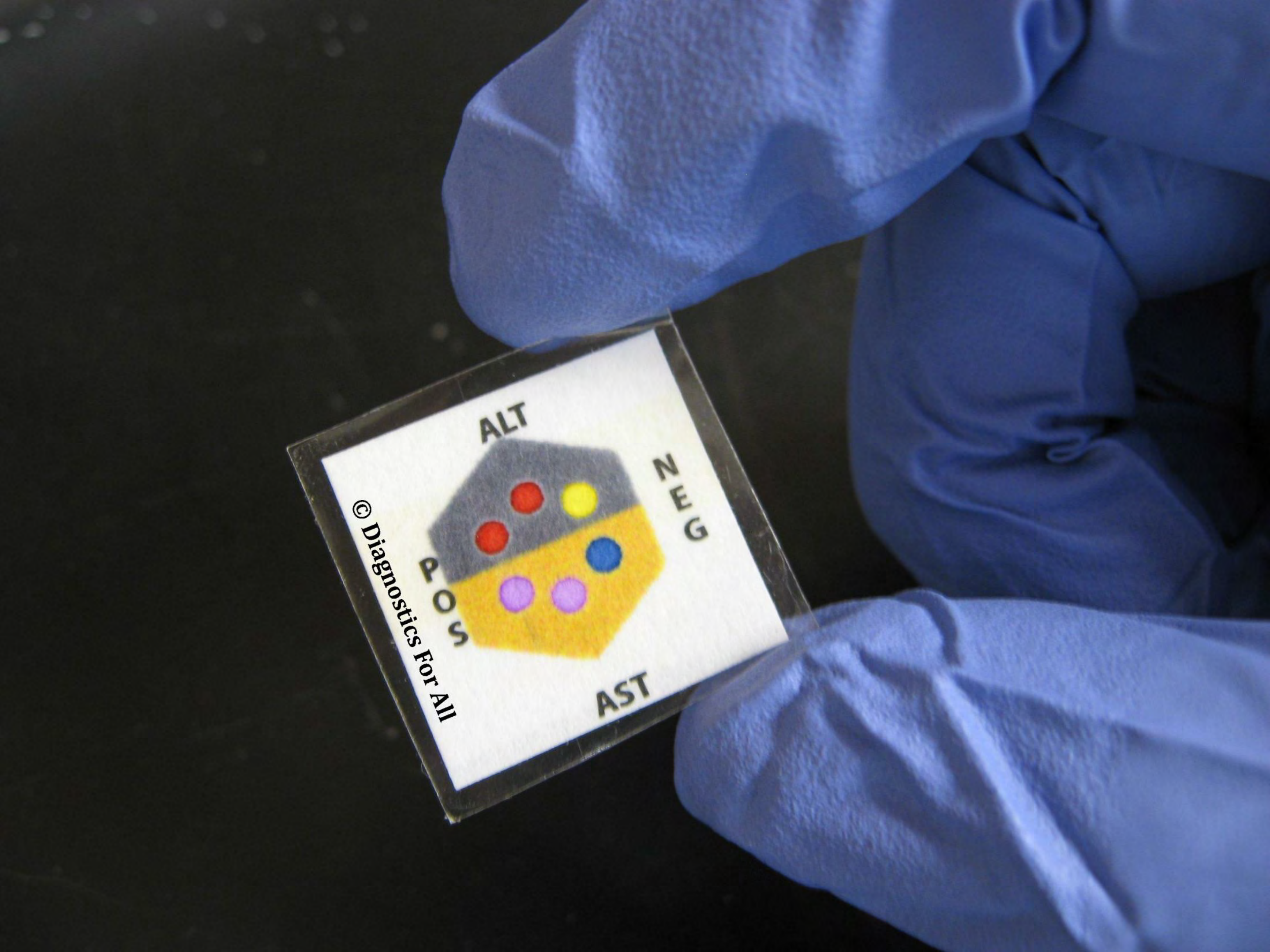



air inlet
twist
valves
outlet
(to vacuum)
sample
wells
mixer
filters
air inlet

Paper Diagnostics

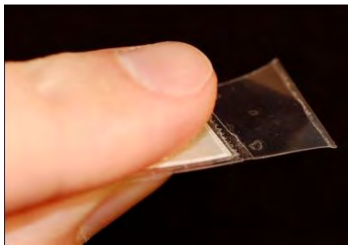

Dr.Gabhrani's
SPECIALITY CLINIC
FOR
SEX·SKIN
VD· & HIV



Cost
Simplicity,
Utility
Information

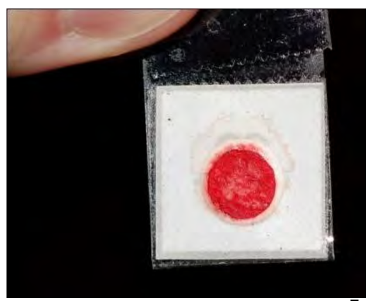

ALT
NEG
POS
AST
© Diagnostics For All

Liver Function Tests

prick
finger



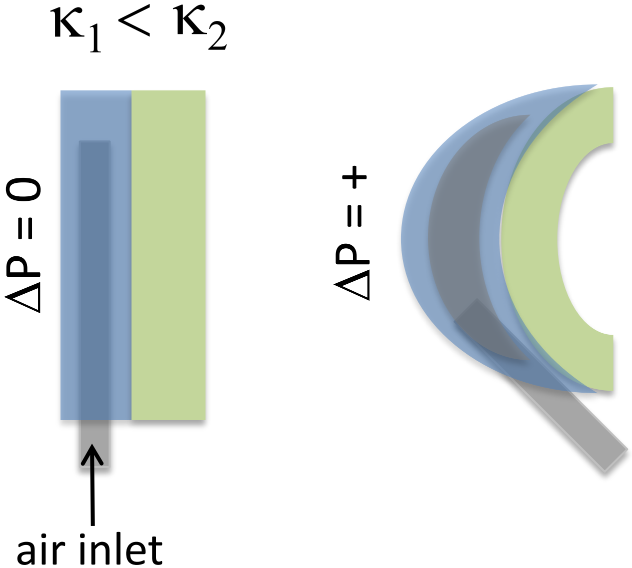
gently
squeeze
device



blood on
filter

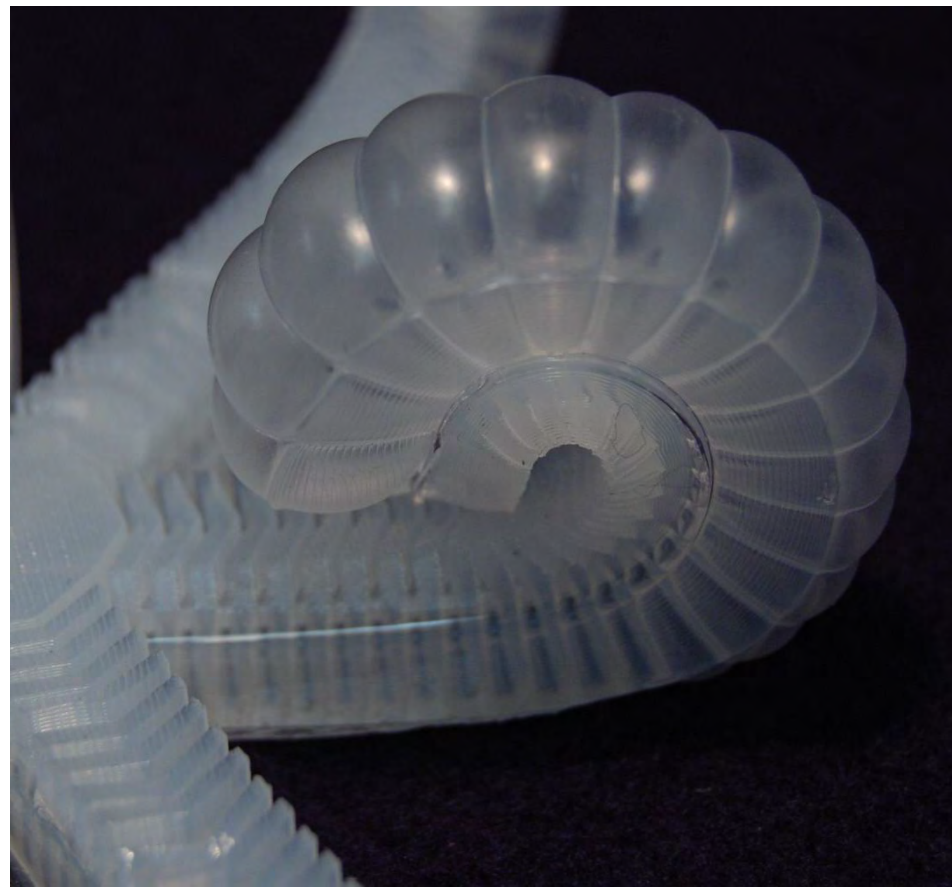
plasma
(with liver
function tests)

Soft Robotics



•**Compressed air inflates pneumatic network, inducing strain**

•**Differential strain induces curvature**



Paper/Elastomer Actuator

Harvard University. Whitesides Group.

Paper/Elastomer Actuator

Harvard University. Whitesides Group.

Technology = Companies

- Diagnostics for All
- Nano Terra
- MC 10
- Semprius
- Cool Edge
- Liquidia
- NanoInk
- Surface Logix
- Claros
- Cellectricon
- Fluidigm
- Raindance
- Biacore (chips)
- Molecular Imprints
- Minerva
- GeneOhm

As we are doing it, it is taking 10-20 years to go from “idea” to “manufactured product”.

Curiosity, or Problem

Science

“Amorphous Technology”

Product Prototype

Manufacturing Prototype

Manufactured Product

Essential

MURI
DURIP
DARPA
Gates Foundation

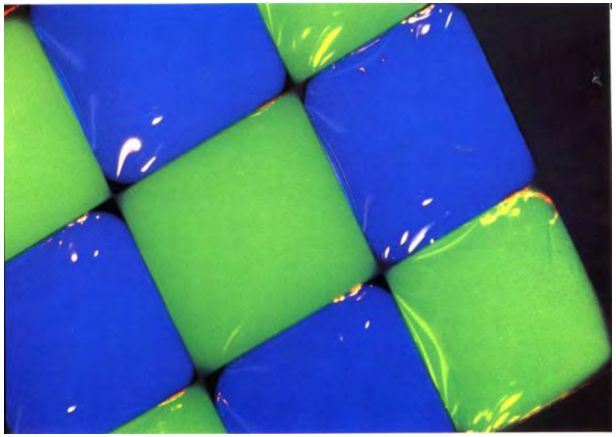
Absent

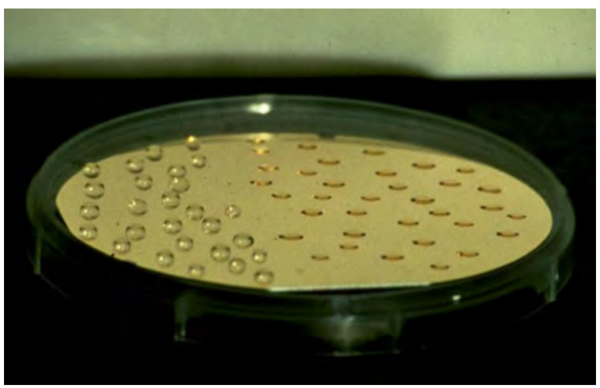
NSF
NIH
DoE

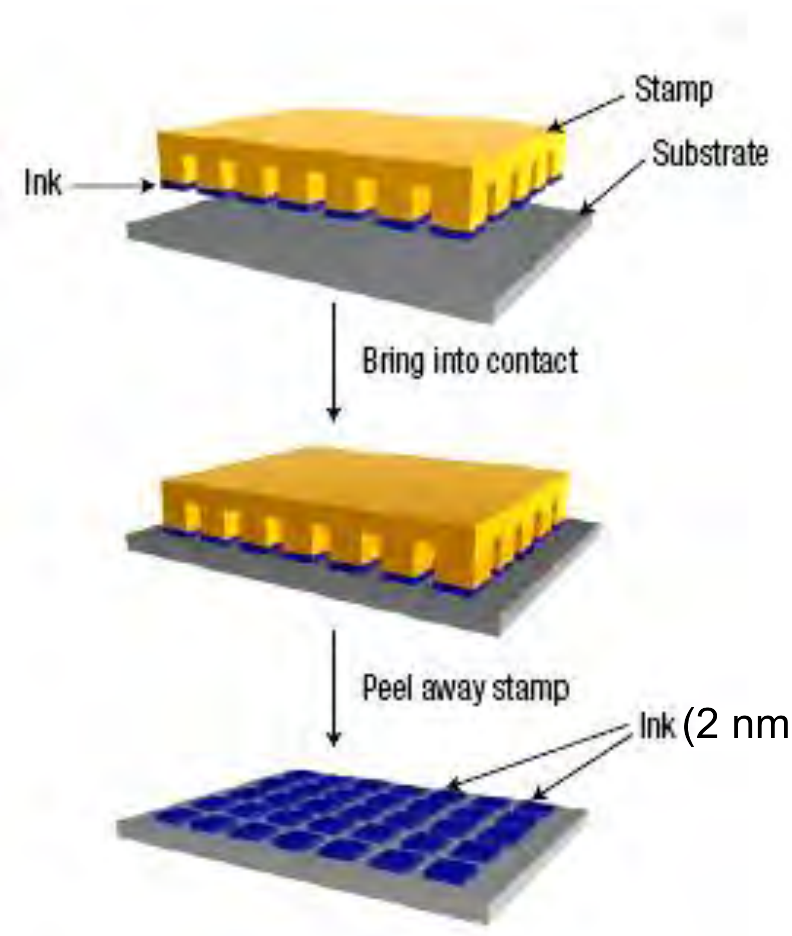
New Participants

BASF
Reliance
Wyss
CSIR (India)

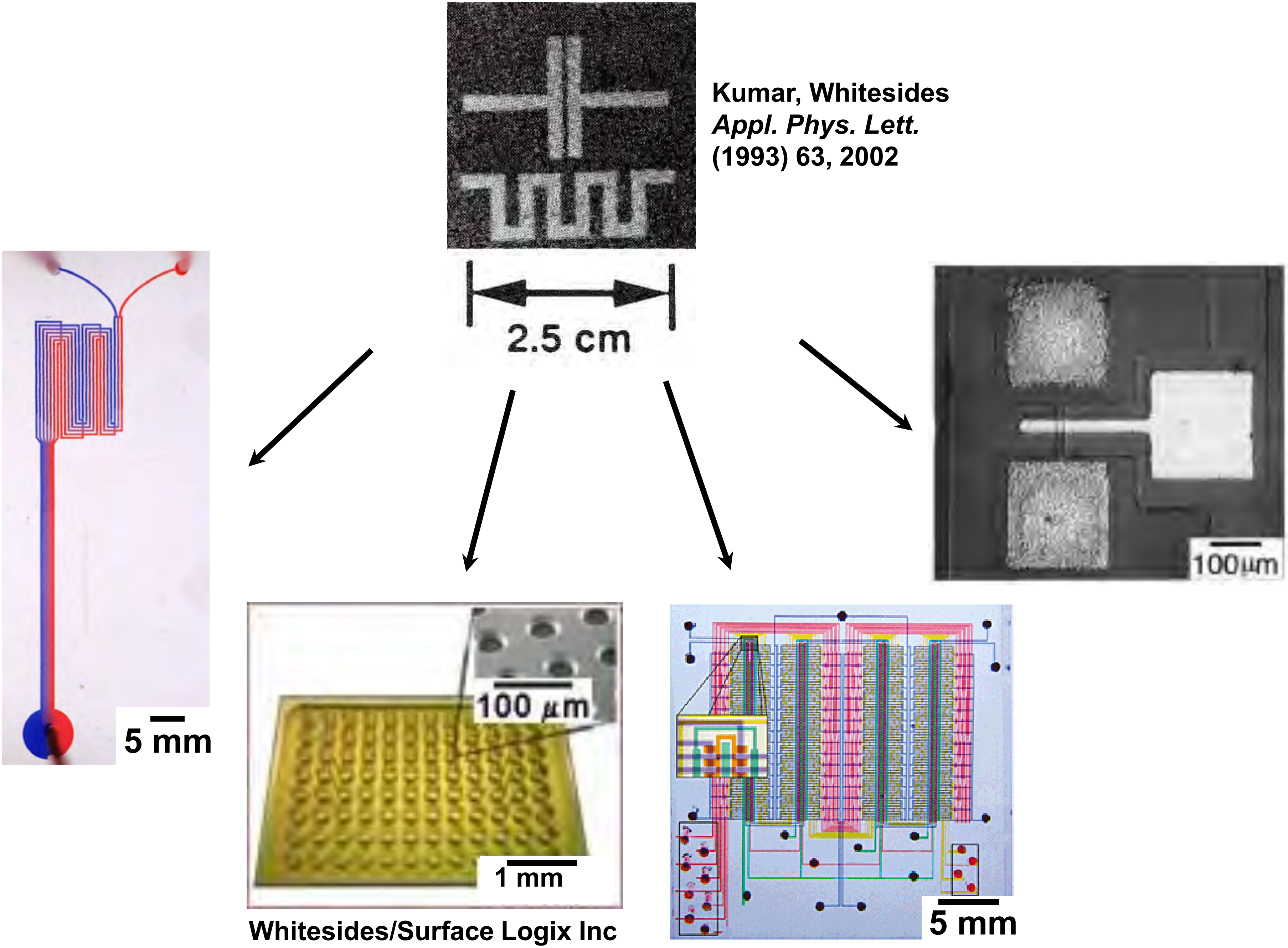
SAM → Micro contact printing

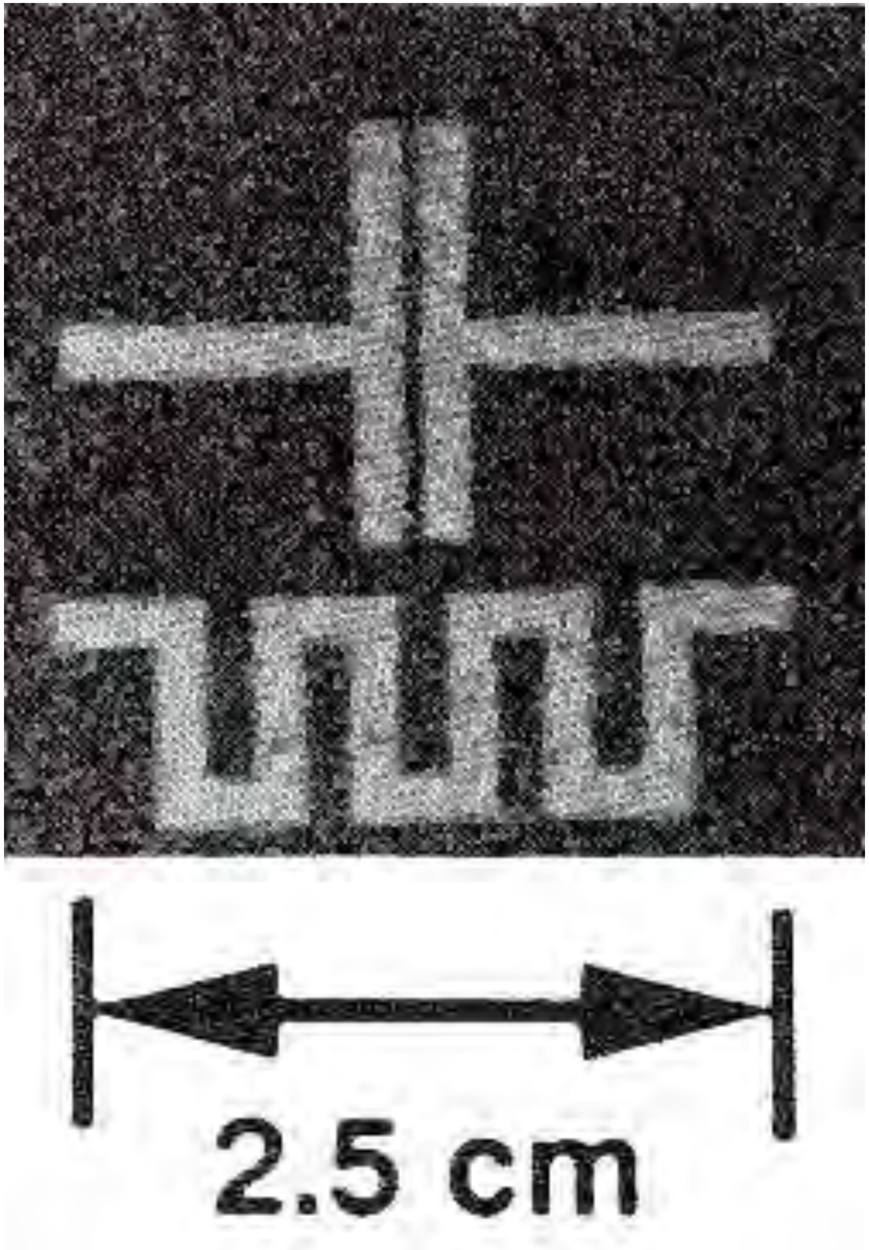






Abbott, Xia, Rogers, Aizenberg


Kumar, Whitesides
Appl. Phys. Lett.
(1993) 63, 2002
2.5 cm
5 mm
100 µm
1 mm
Whitesides/Surface Logix Inc
5 mm
Quake/Fluidigm Inc
100µm


2.5 cm

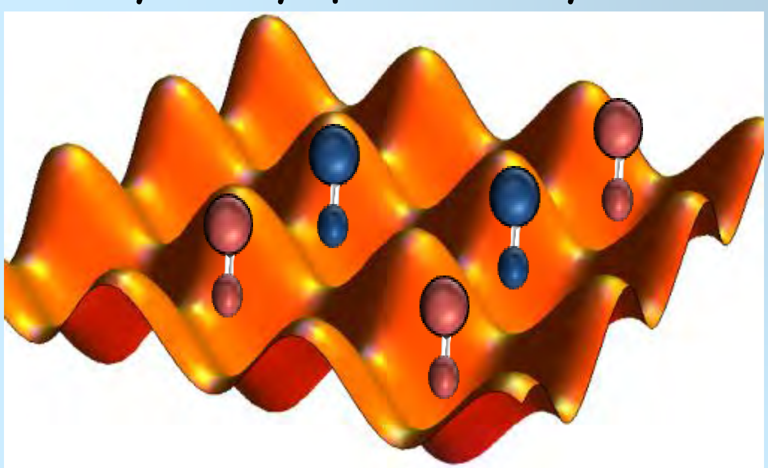
Optical Atomic Clock & Absolute-Zero Chemistry – Probing Quantum Matter with Precision Light

Jun Ye

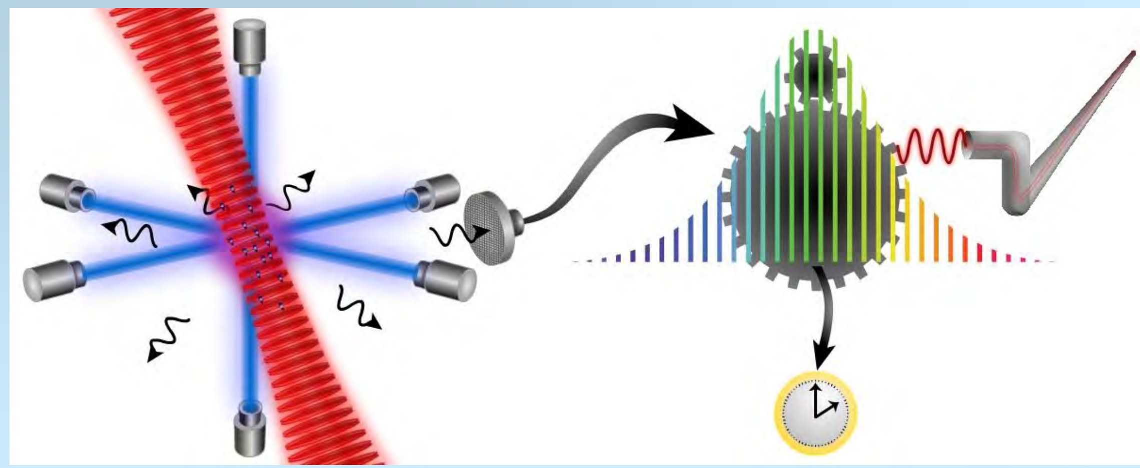
JILA, NIST & University of Colorado

MURI 25th Birthday, Washington DC, Nov. 9, 2011

Many-body quantum systems



Optical atomic clocks



Optical Clocks: *Fundamental aspects, practical issues and enabling technology*

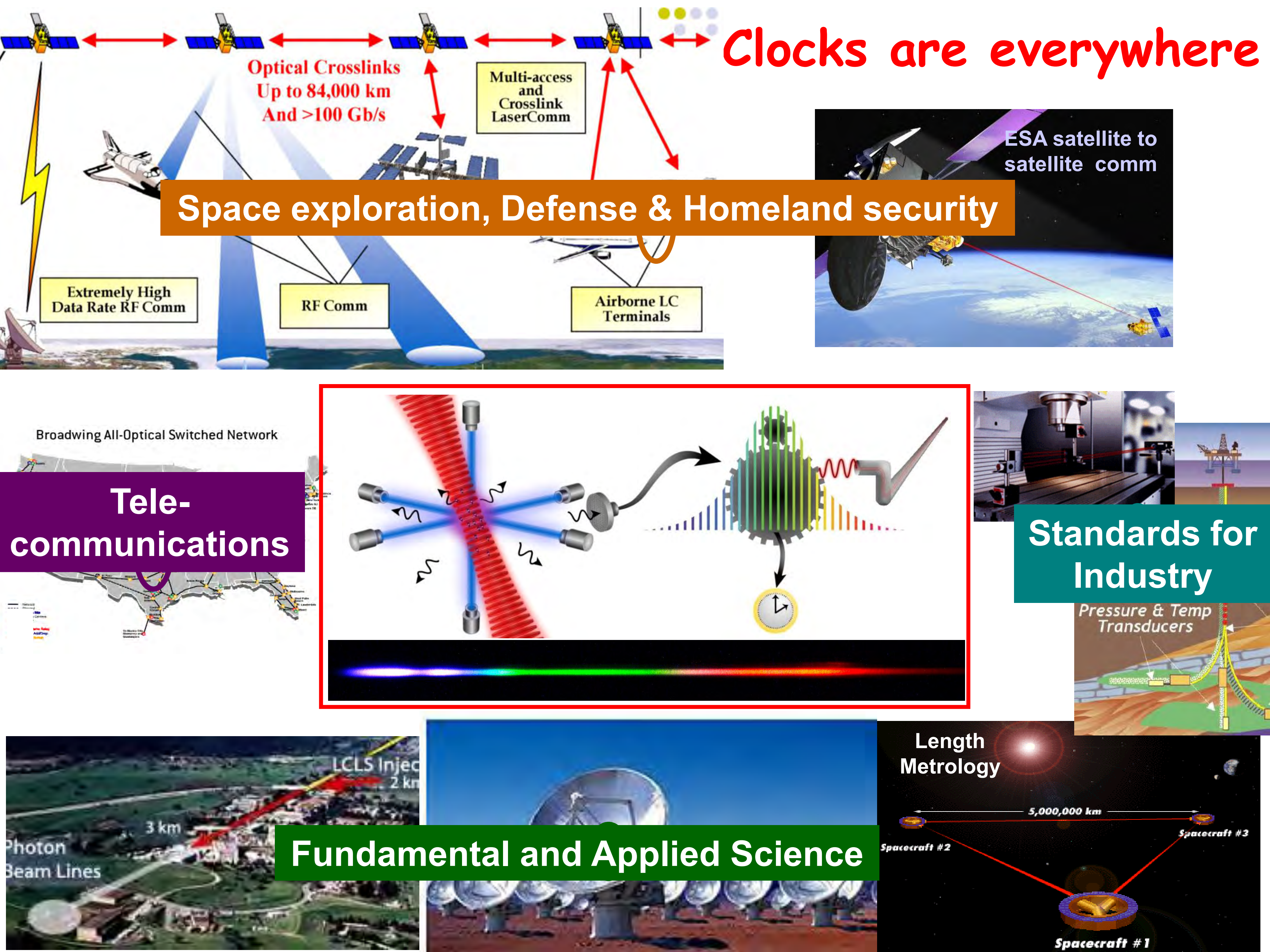
Bergquist, Cundiff, Delfyett, Diels, Gibble, Hall, Hollberg, Jones, Kapteyn, Kimble, Ye (PI)

JILA/Colorado, Caltech, Central Florida, New Mexico, NIST, Penn State

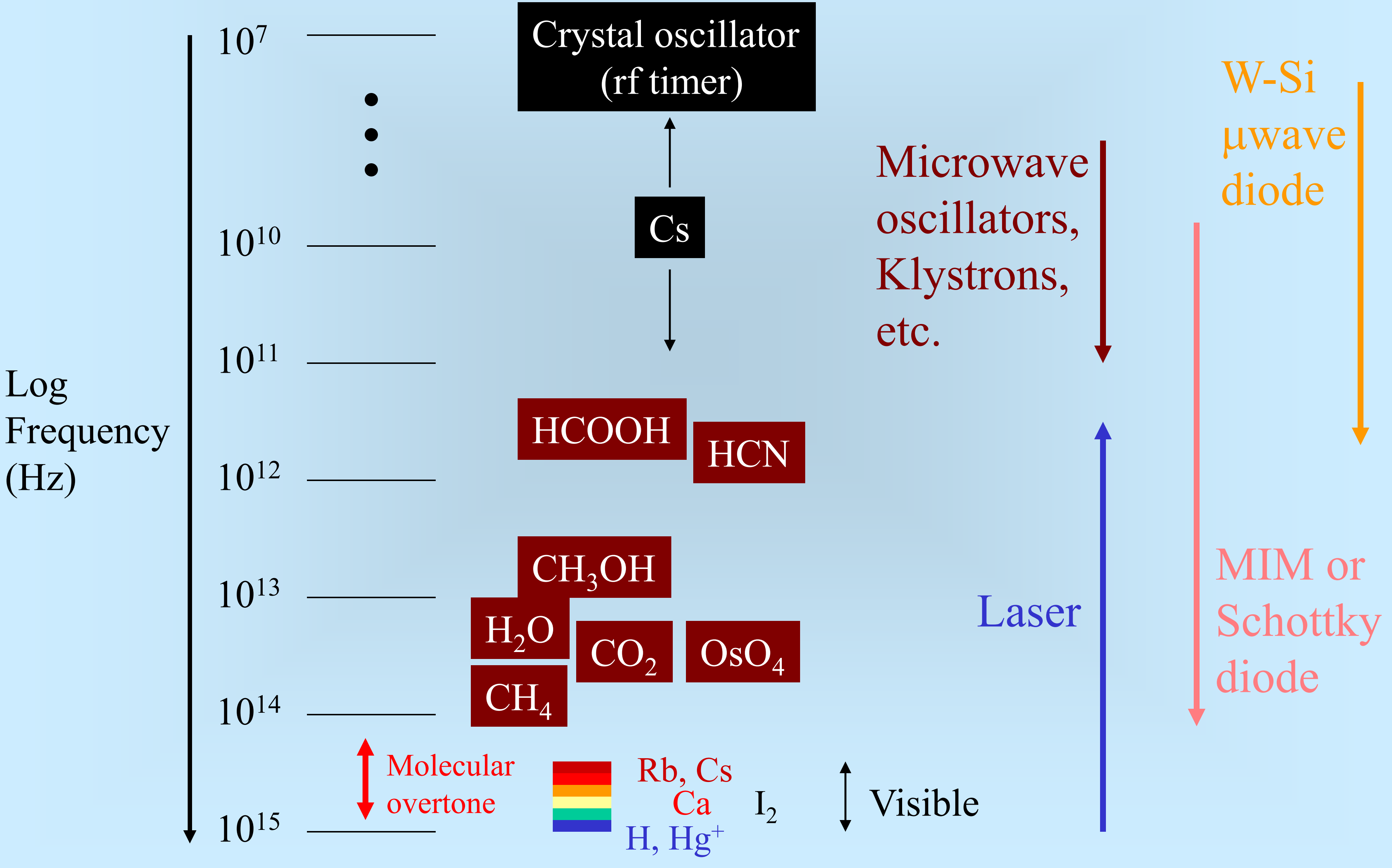
(Peter Reynolds) ONR/MURI, 2001

Outside Collaborations

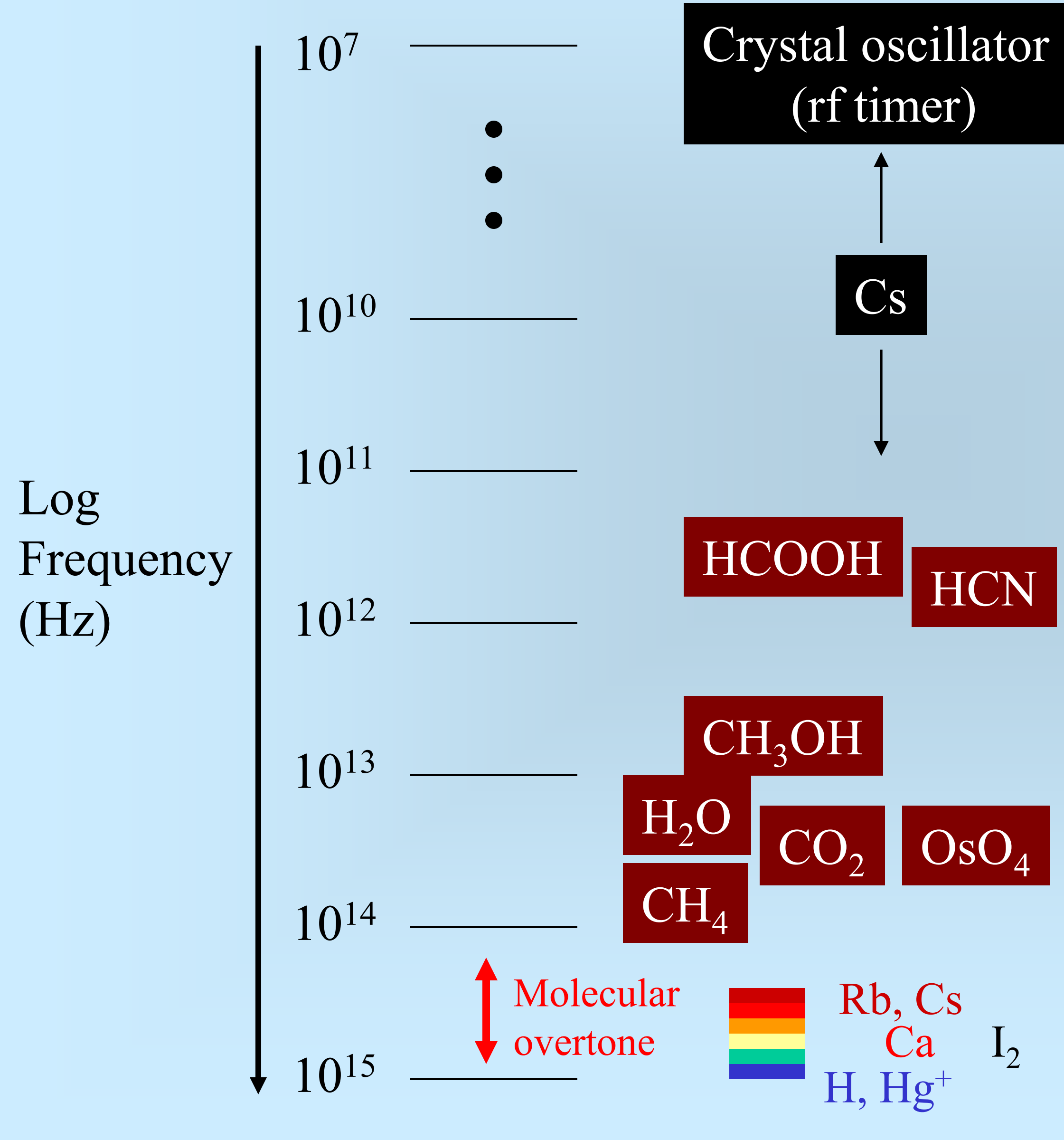
MIT (the other MURI team)

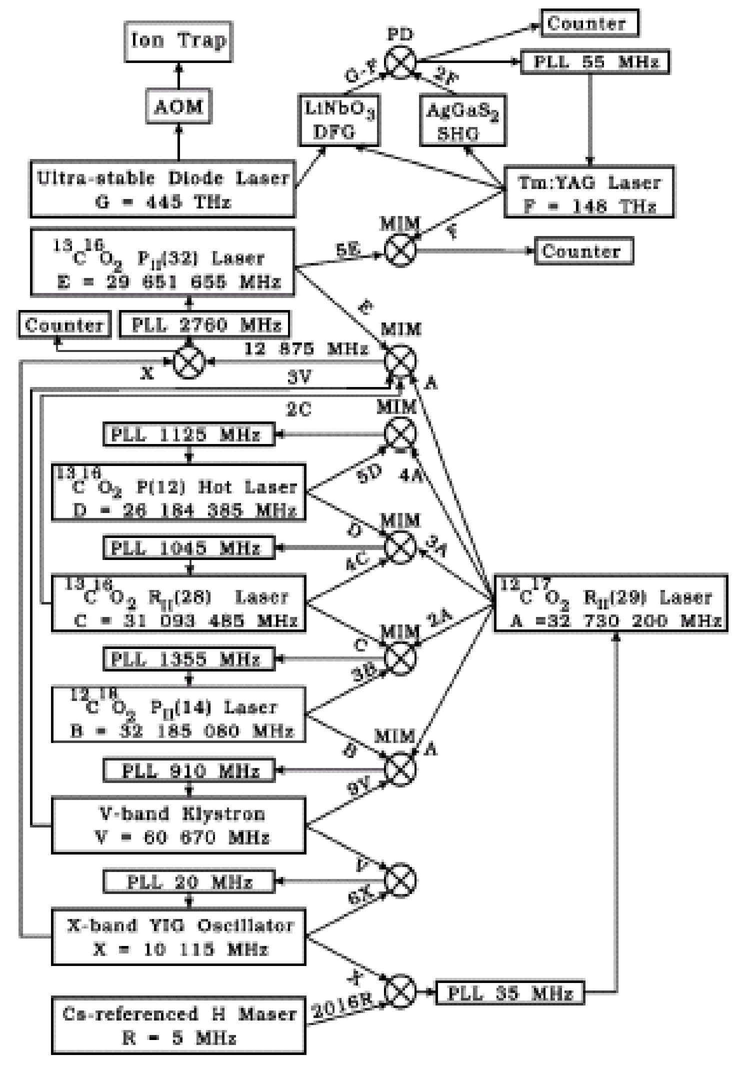

Clocks are everywhere
Optical Crosslinks
Up to 84,000 km
And >100 Gb/s
Multi-access and Crosslink LaserComm
ESA satellite to satellite comm
Space exploration, Defense & Homeland security
Extremely High Data Rate RF Comm
RF Comm
Airborne LC Terminals
Broadwing All-Optical Switched Network
Tele-communications
Standards for Industry
Pressure & Temp Transducers
3 km
Fundamental and Applied Science
Length Metrology
5,000,000 km
Spacecraft #2
Spacecraft #3
Spacecraft #1

Spectrum in optical frequency synthesis



Spectrum in optical frequency synthesis

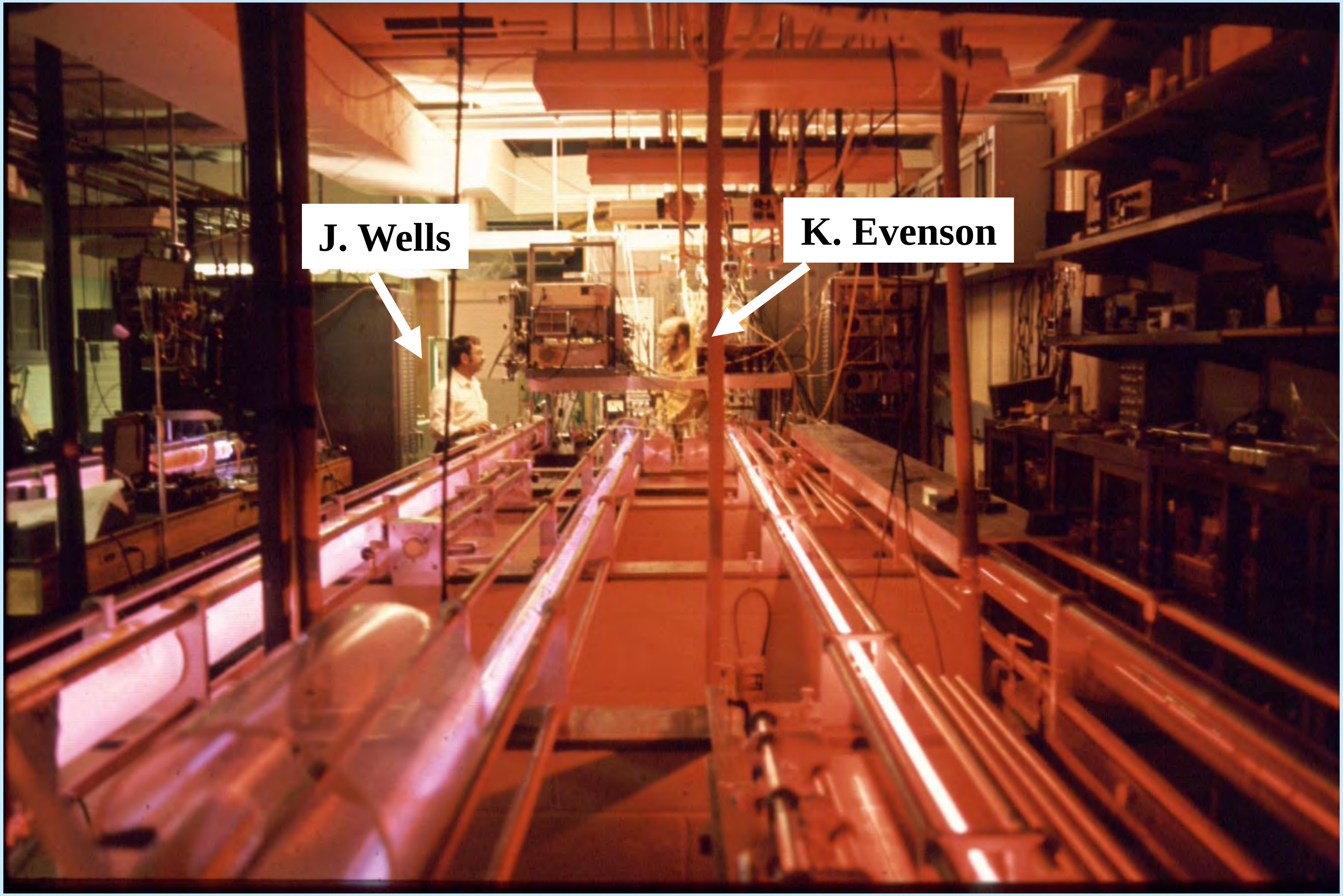




Harmonic frequency chains – NRC; PTB; …

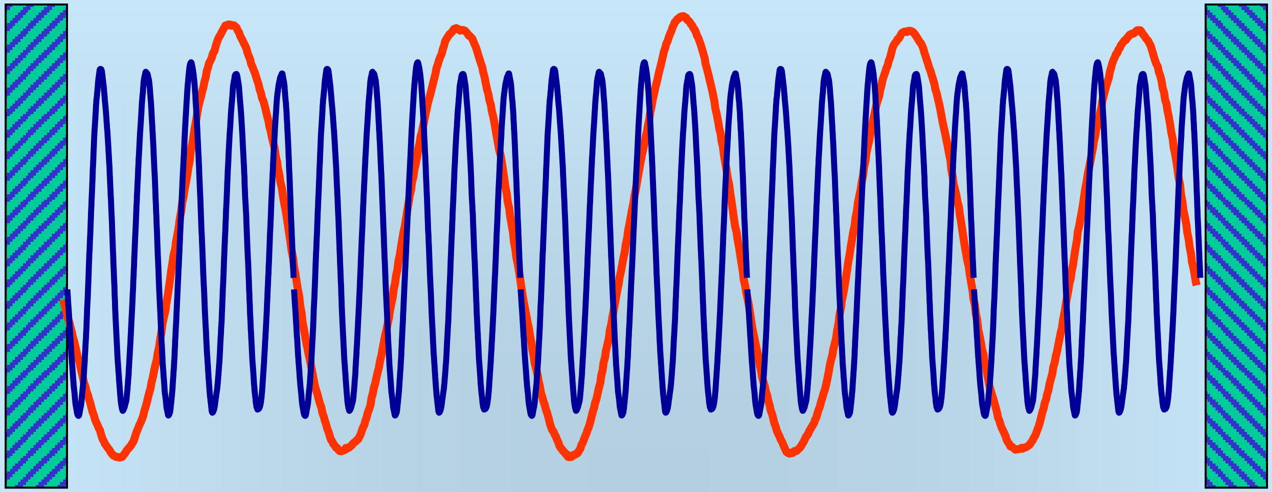
An Optical Frequency Chain

NBS (NIST): measurement of speed of light, 1972



Hall & Ye, "NIST 100th birthday", Optics & Photonics News <u>12</u>, 44 (2001).

The age of atomic clocks - Chasing the SPEED!



Faster oscillations → More cycles → Smaller errors

Light ripples: 10^{15} cycles per second, & we count every one

Precision: 1 000 000 000 000 000 $\pm$ 1

Earth

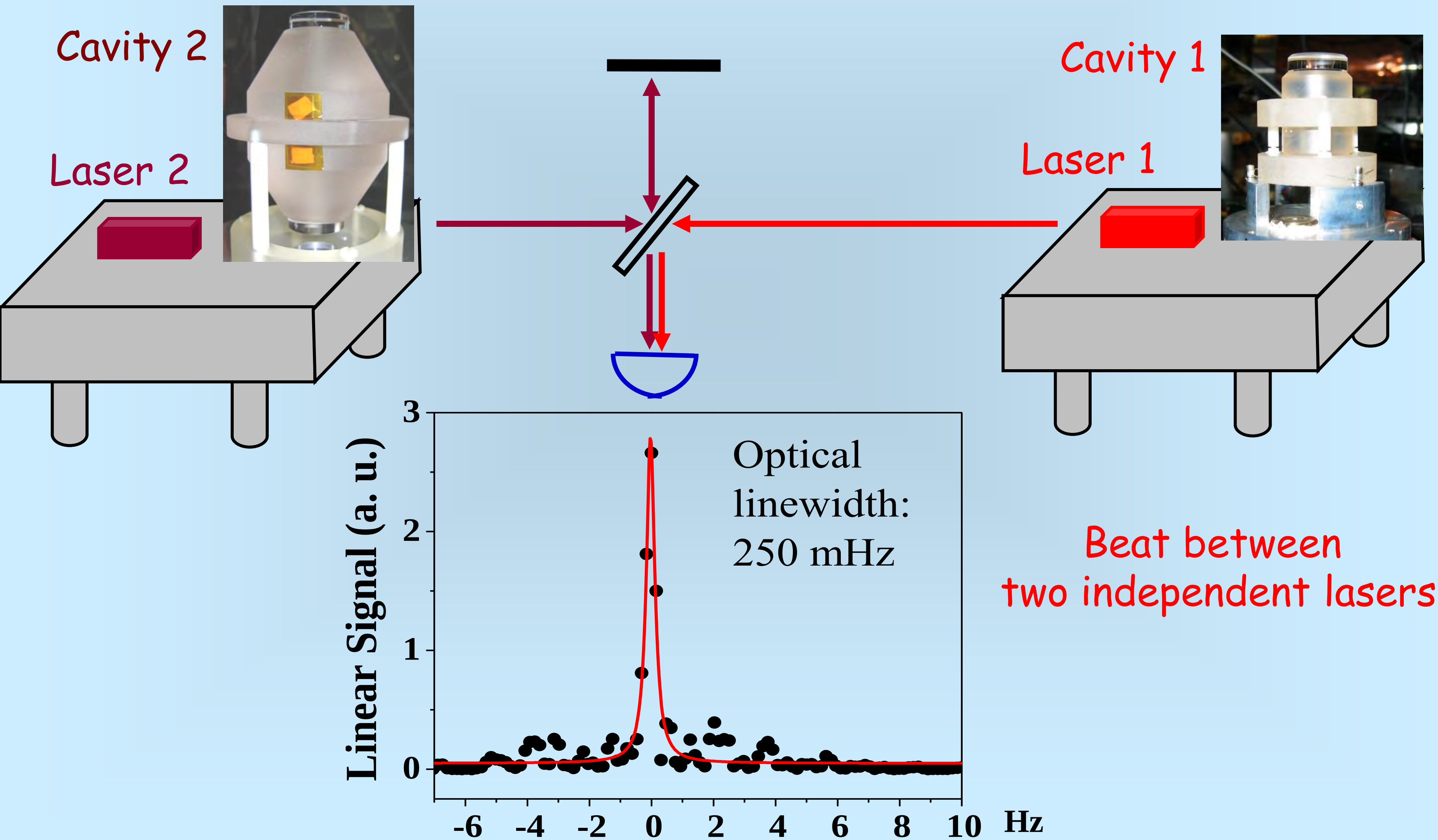
bacteria

Sun

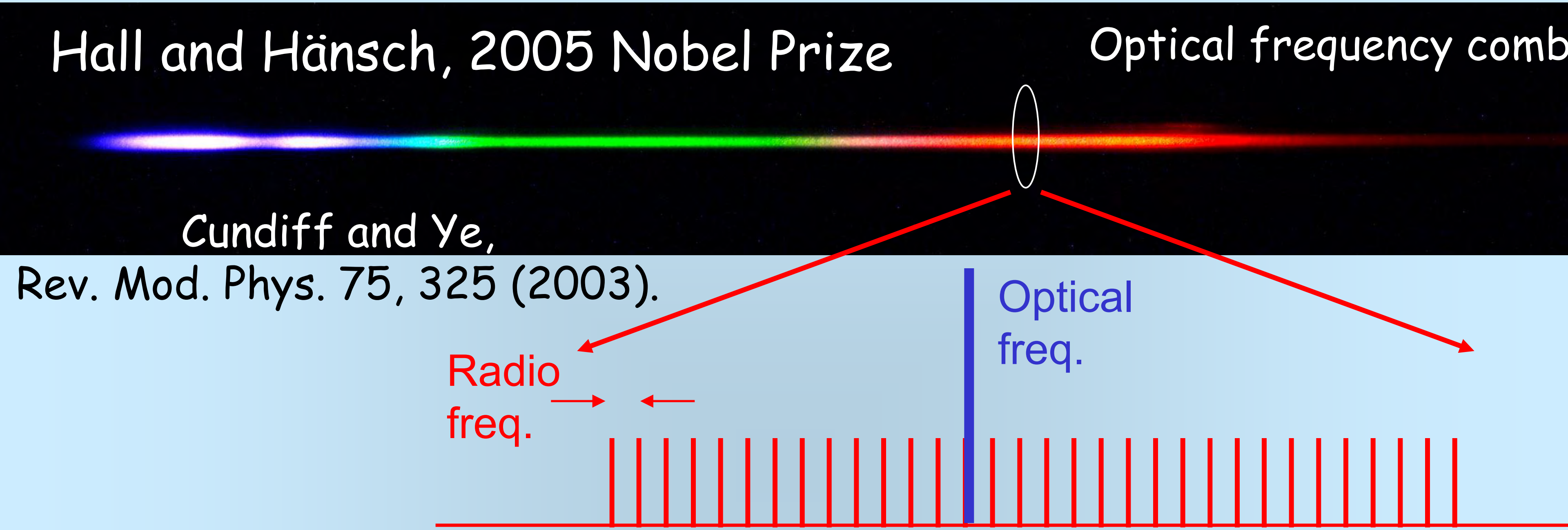
Long-term optical coherence (~~1 s~~)

10 s

Ludlow *et al.*, Opt. Lett. 32, 641 (2007).

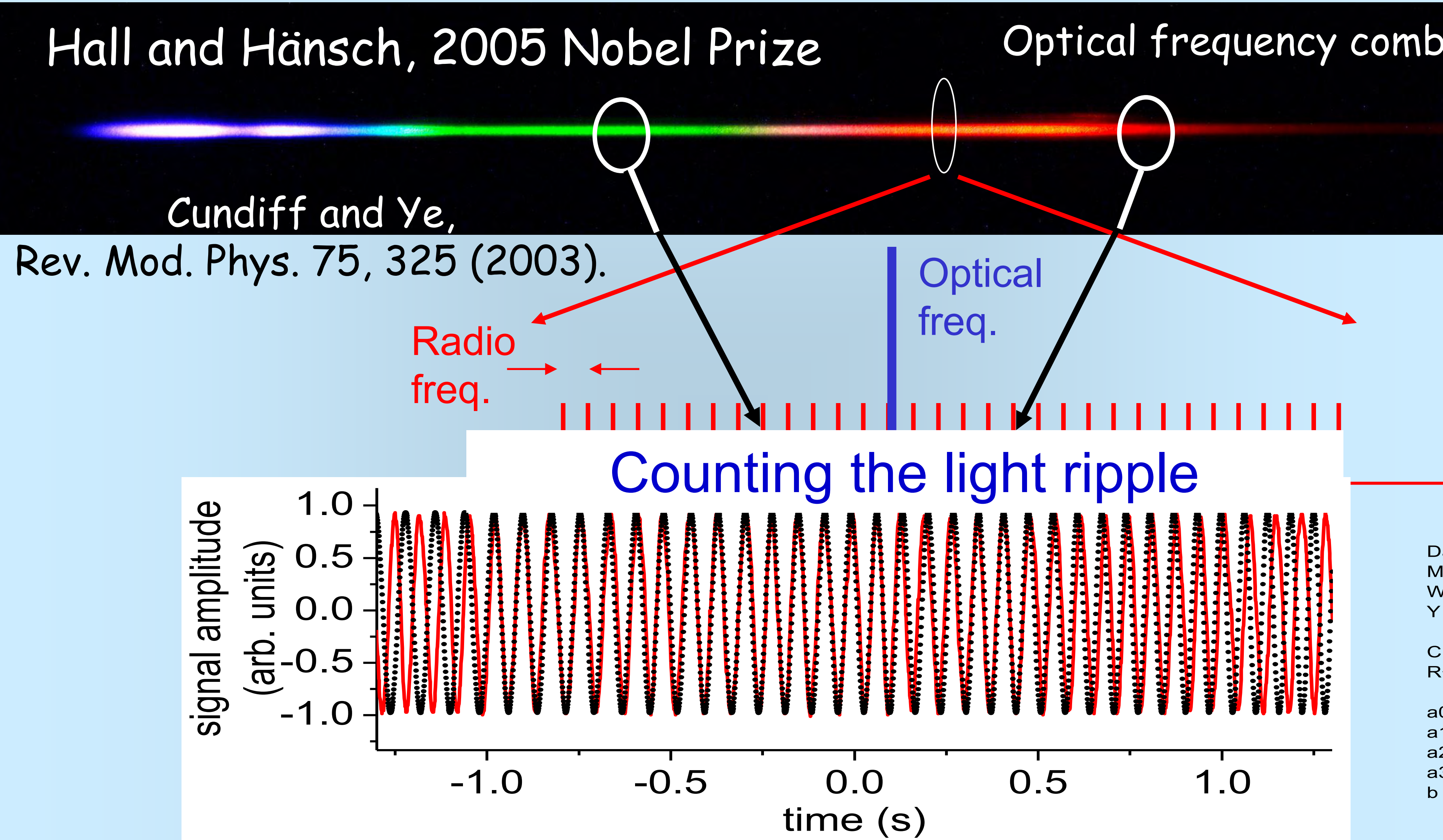


A rainbow spectrum with 10^{-19} precision



Optical coherence time > 1 s ($<10^{-15}$), anywhere in the visible
Schibli et al., Nature Photonics 2, 355 (2008).

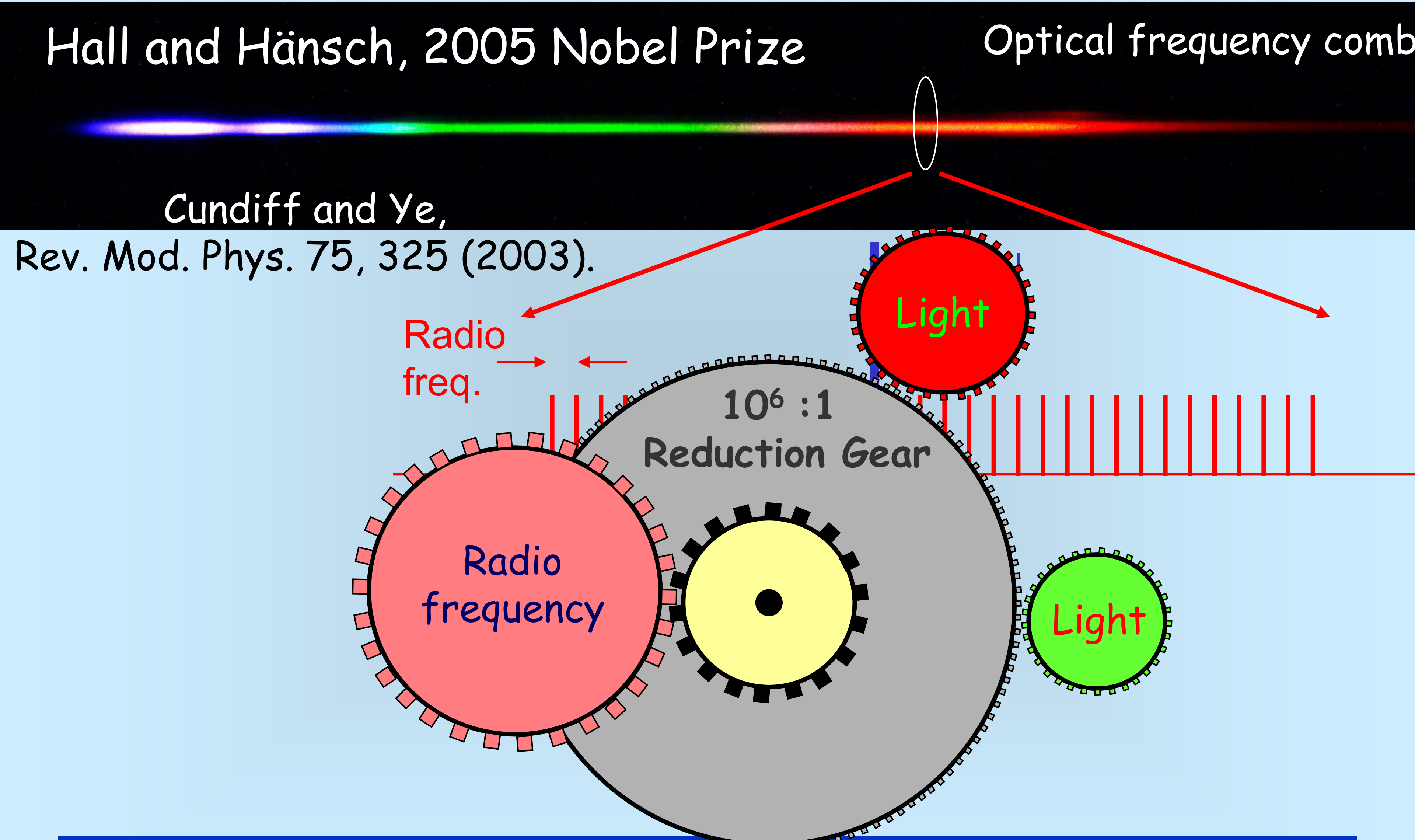
A rainbow spectrum with 10^{-19} precision



Optical coherence time > 1 s (<10^{-15}), anywhere in the visible

Schibli et al., Nature Photonics 2, 355 (2008).

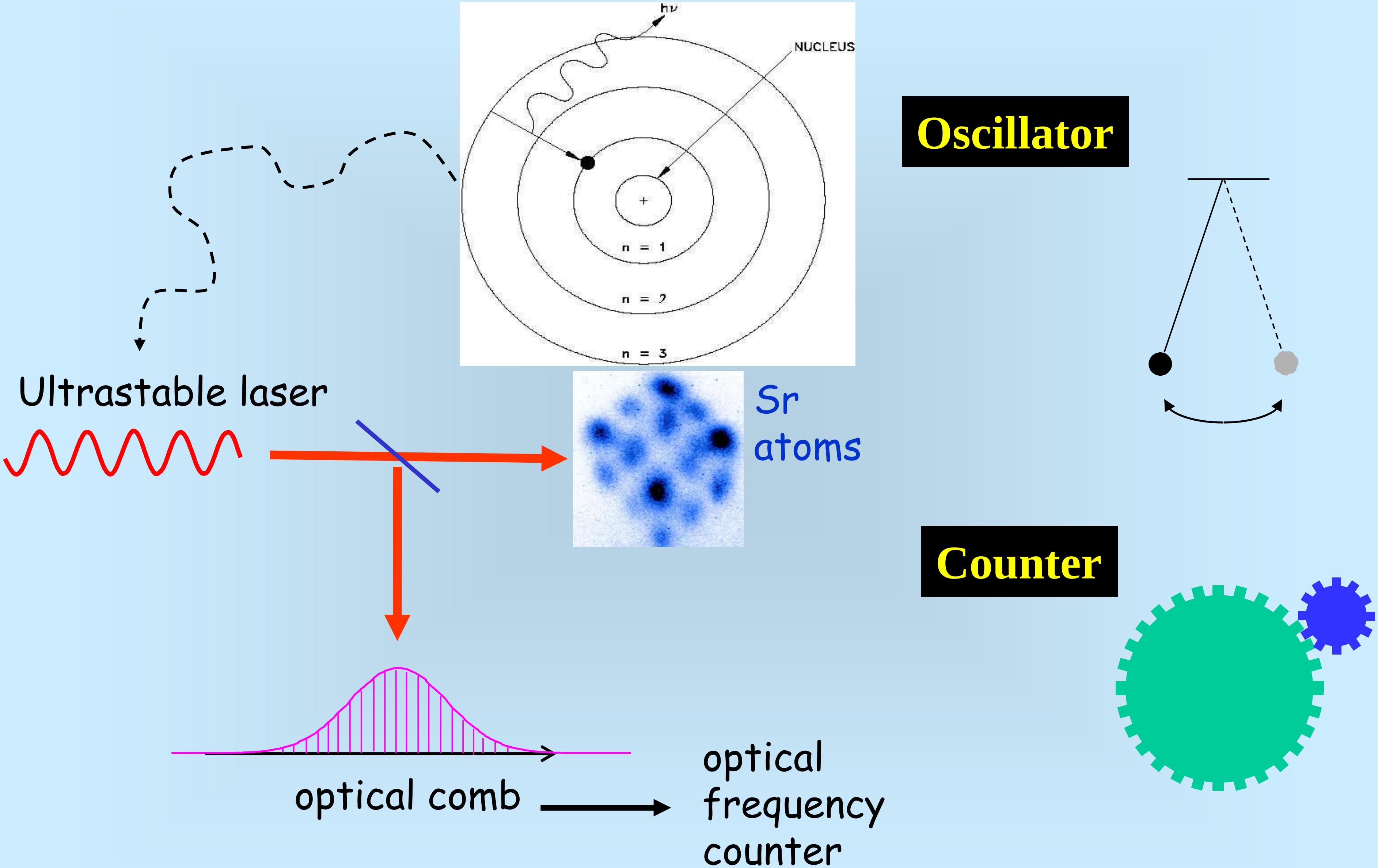
A rainbow spectrum with 10^{-19} precision



Optical coherence time > 1 s (<10^{-15}), anywhere in the visible

Schibli et al., Nature Photonics 2, 355 (2008).

Optical atomic clocks

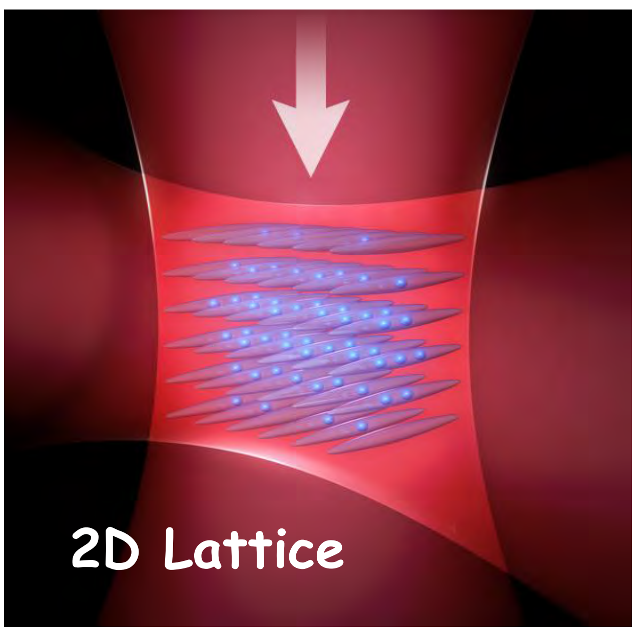


Optical lattice – a many-body quantum system

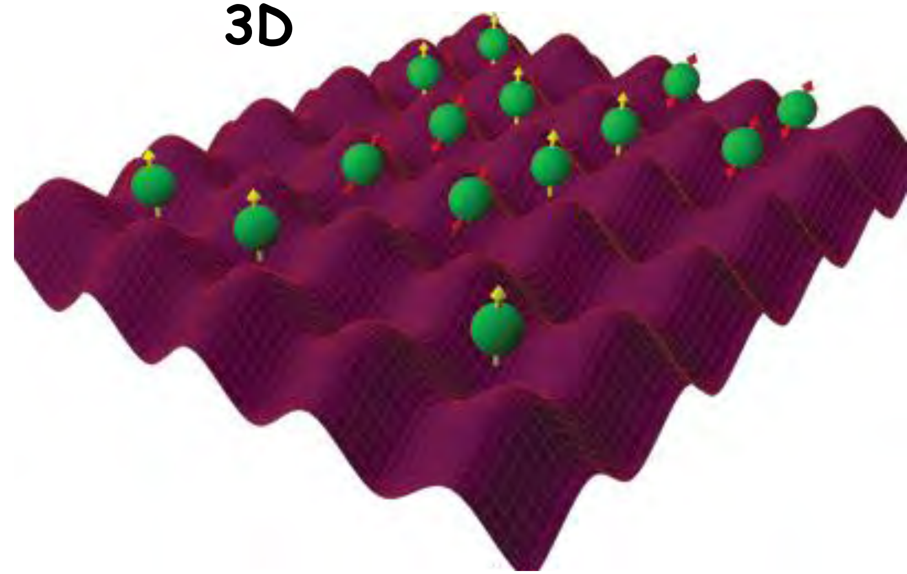
Science **331**, 1043 (2011)

- ✓ Engineered quantum states → eliminating motional effects
- ✓ Separation of internal and external degrees of freedom
- ✓ Isolation from environment
- ✓ Long coherence times
- ✓ Large atom numbers to increase signal **and accuracy**

1D Lattice



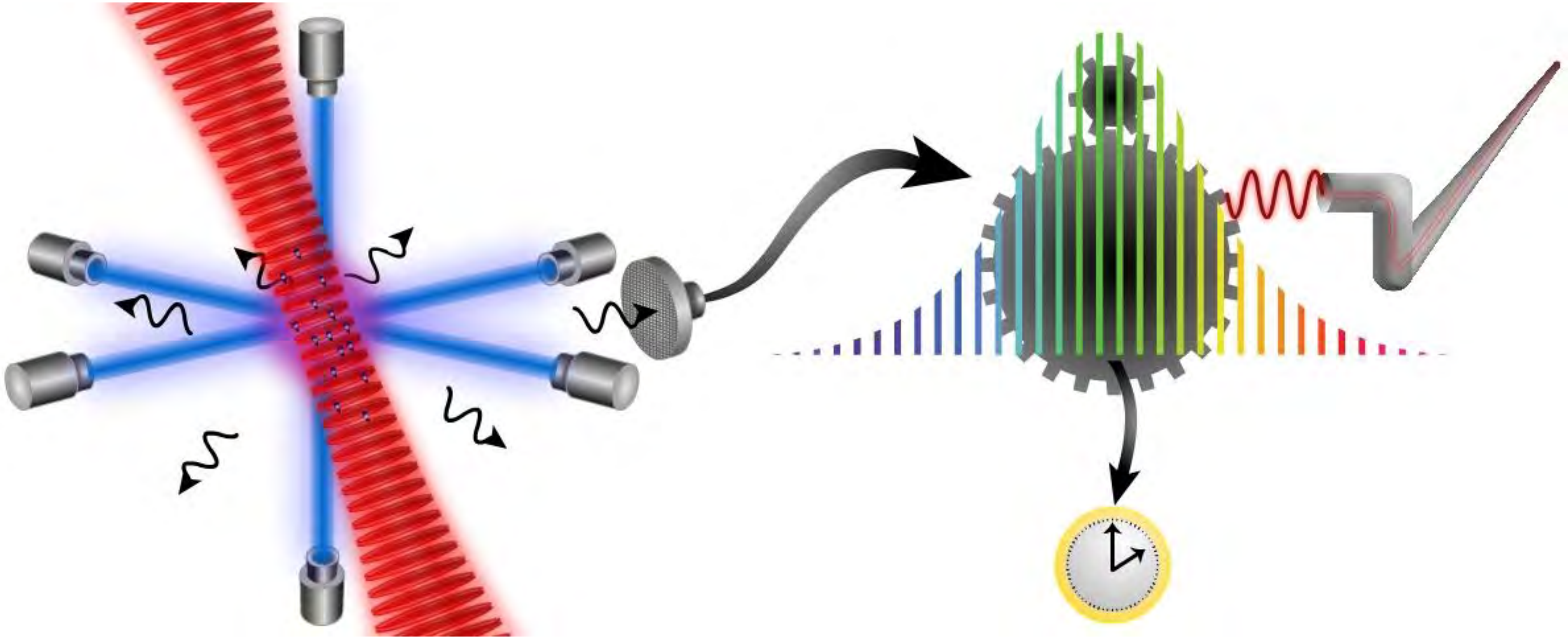
3D

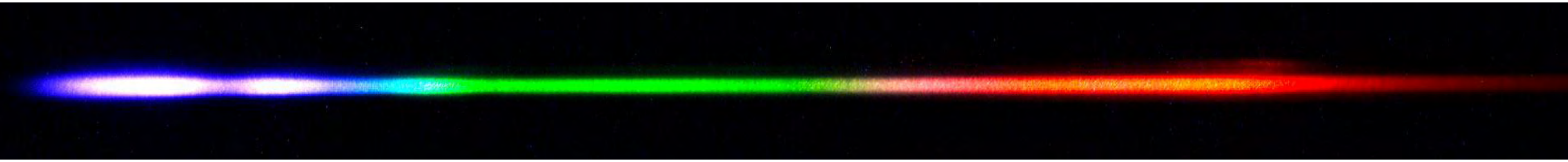


JILA Sr atomic clock

Science **314**, 1430 (2006); Science **319**, 1805 (2008); Science **320**, 1734 (2008); Science **324**, 360 (2009); Science **331**, 1043 (2011).

10, 000, 000, 000, 000, 000 ± 1 (10^{-16})

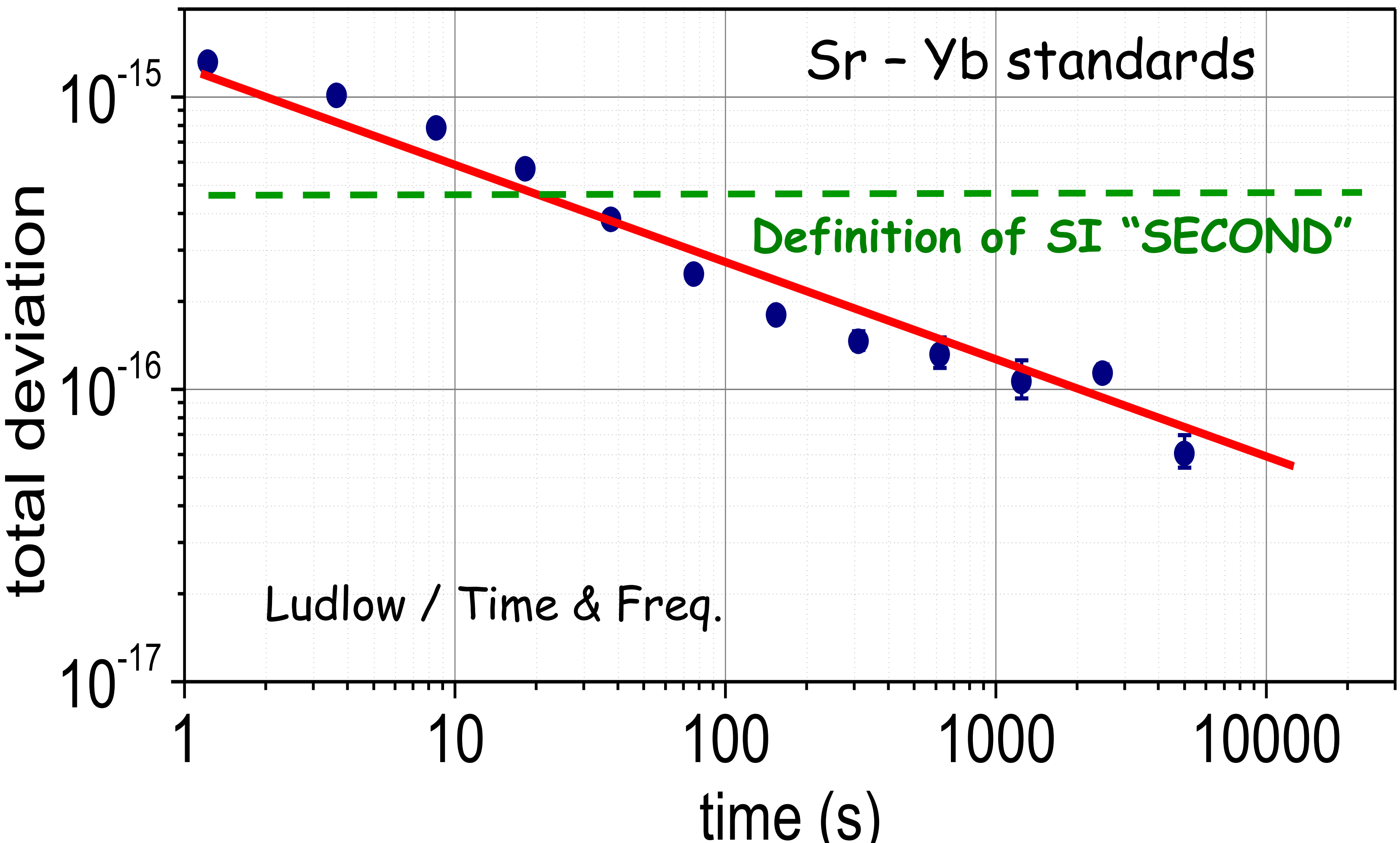




JILA Sr atomic clock

Science **314**, 1430 (2006); Science **319**, 1805 (2008); Science **320**, 1734 (2008); Science **324**, 360 (2009); Science **331**, 1043 (2011).

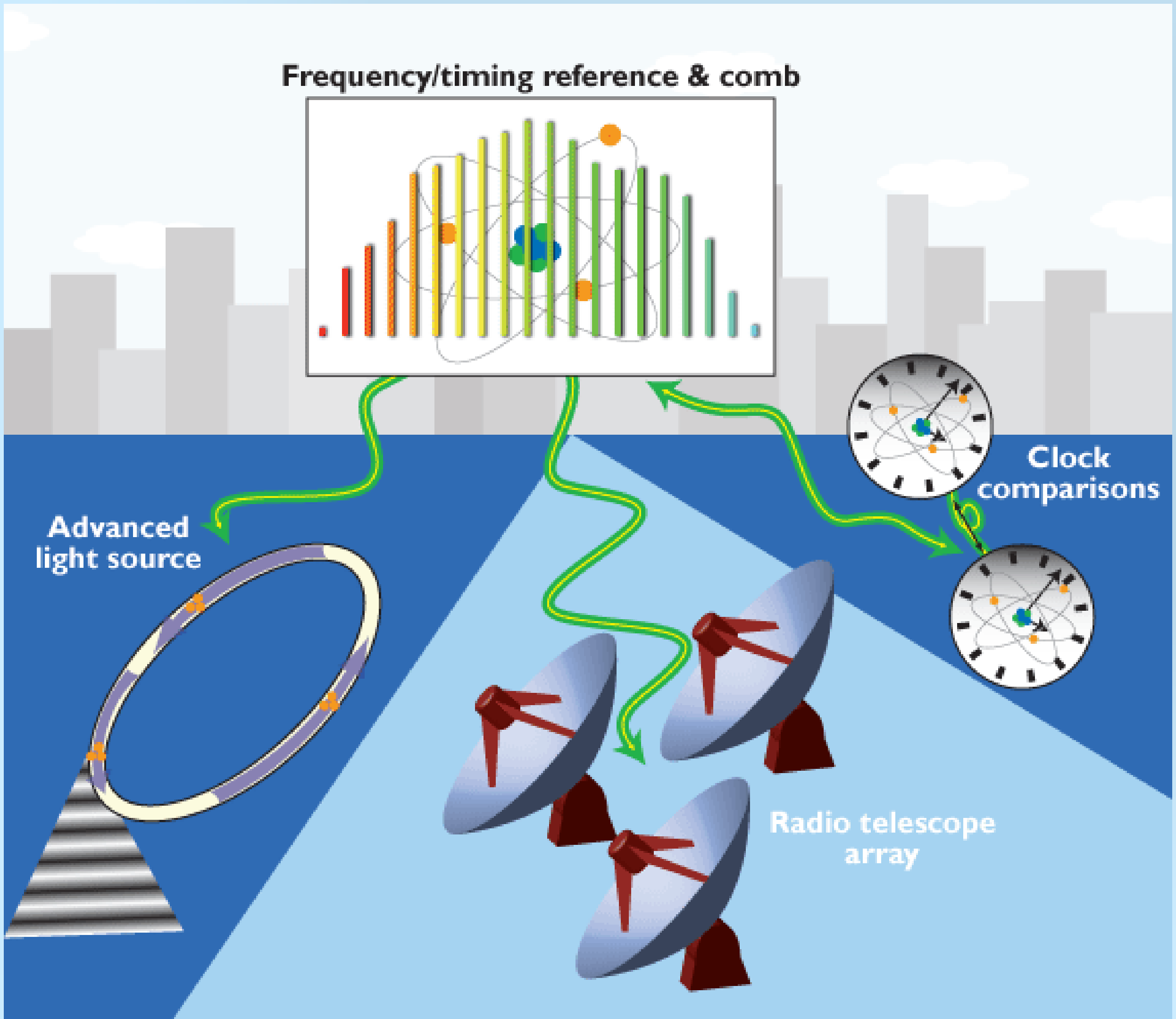
10, 000, 000, 000, 000, 000 ± 1 (10^{-16})



Precise distribution of ultra-stable signals

Foreman, Holman, Hudson, Jones, and Ye,
Cover Review, Rev. Sci. Instrum. 78, 021101 (2007).

SYRTE, NIST, …



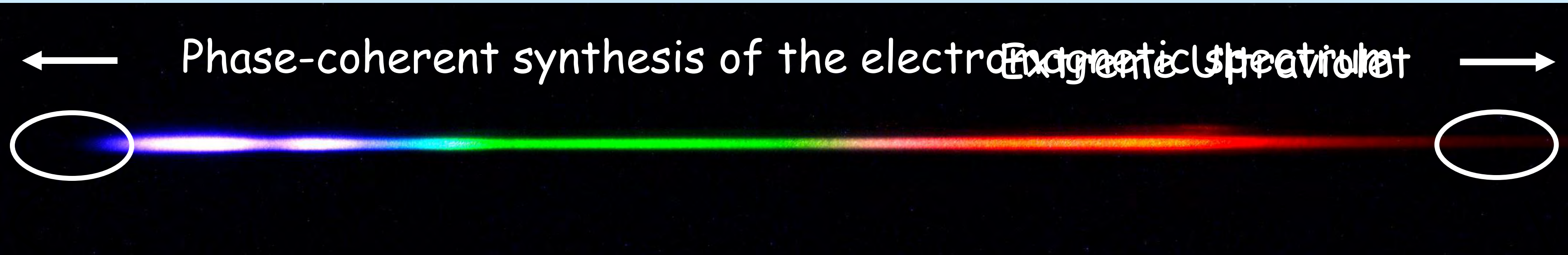
100 km fiber:

1×10^{-17} @ 1 s;

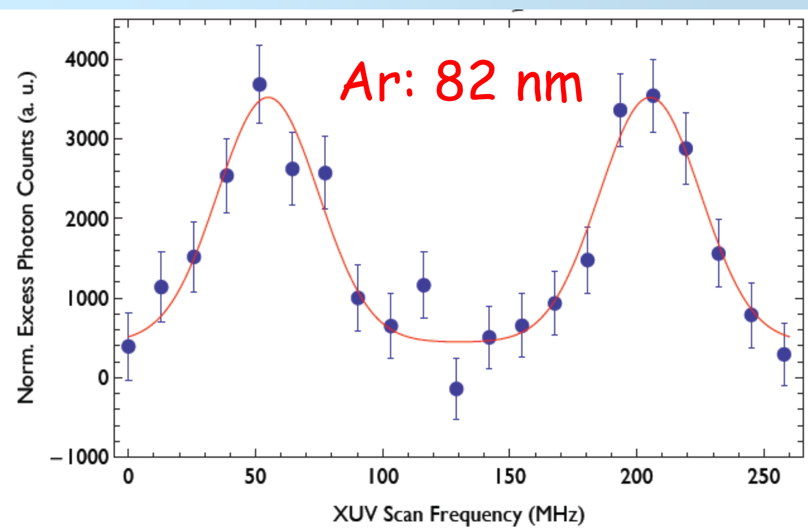
1 Hz optical linewidth;

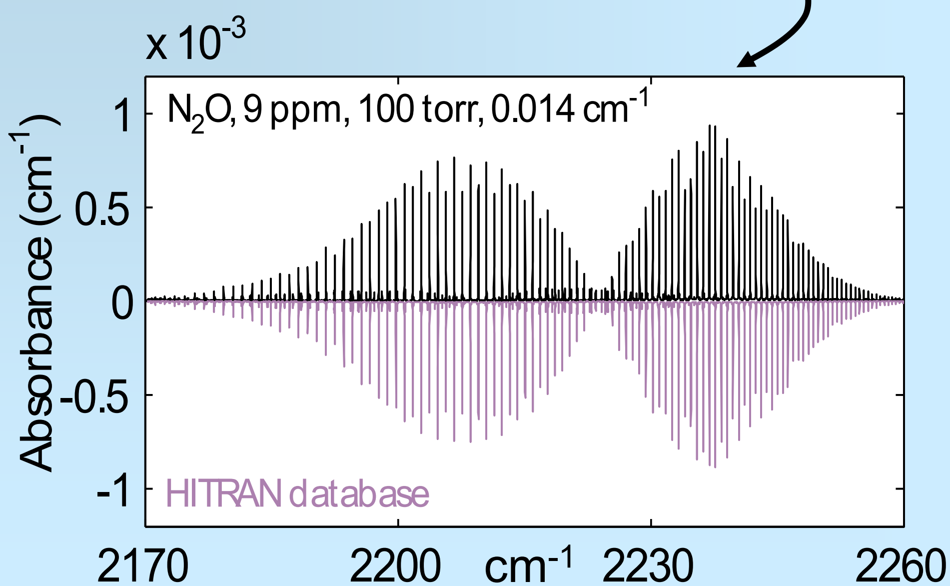
0.1 fs jitter (20 MHz BW)

Phase-coherent radiations - IR to XUV - Spectroscopy & Quantum Control

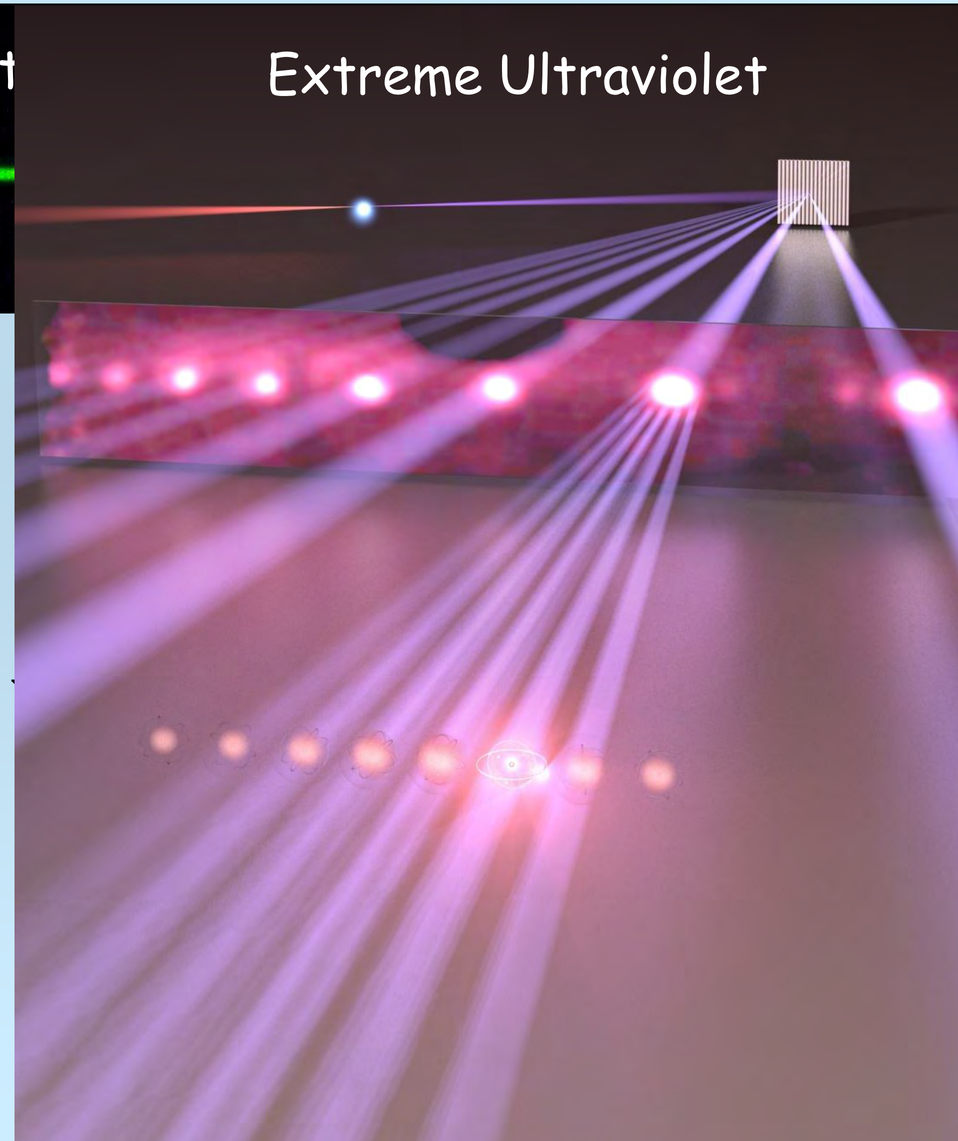


Nature, in press (2011).

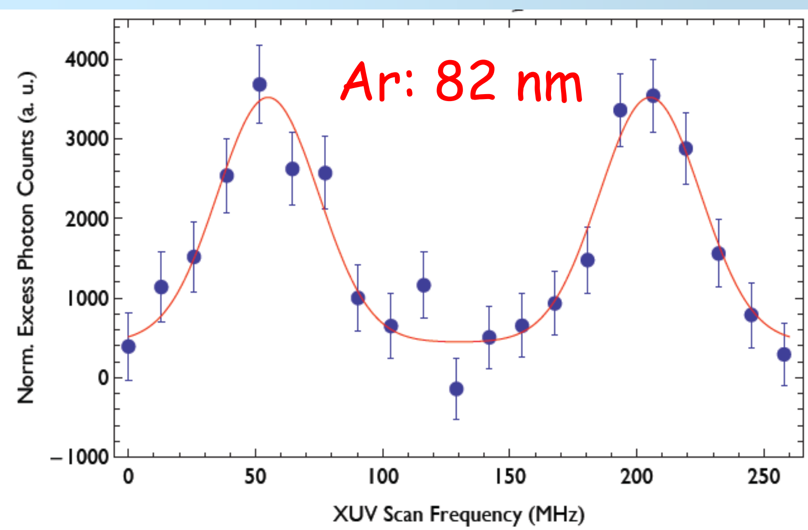




Phase-coherent radiations - IR to XUV
- Spectroscopy & Quantum Control

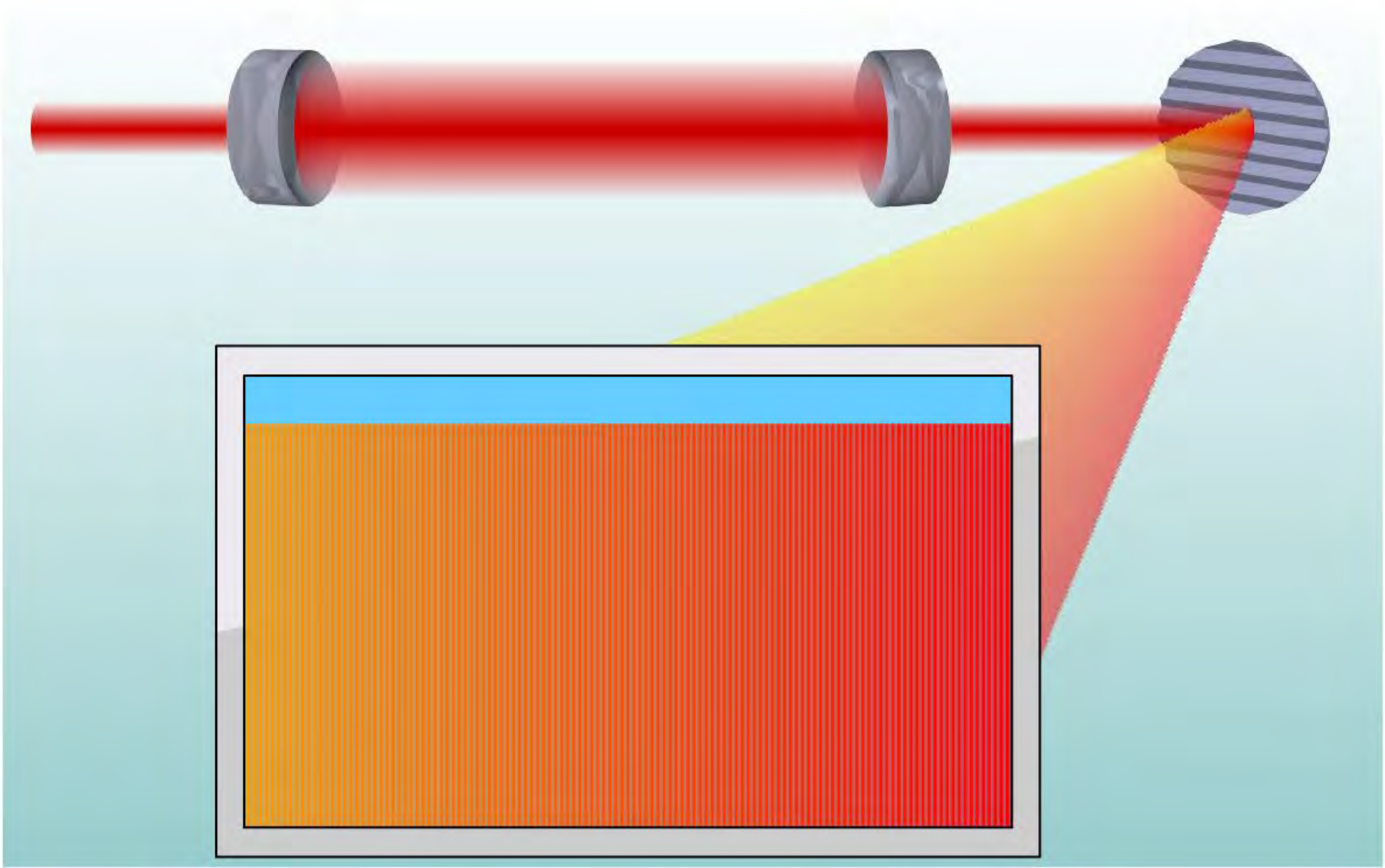


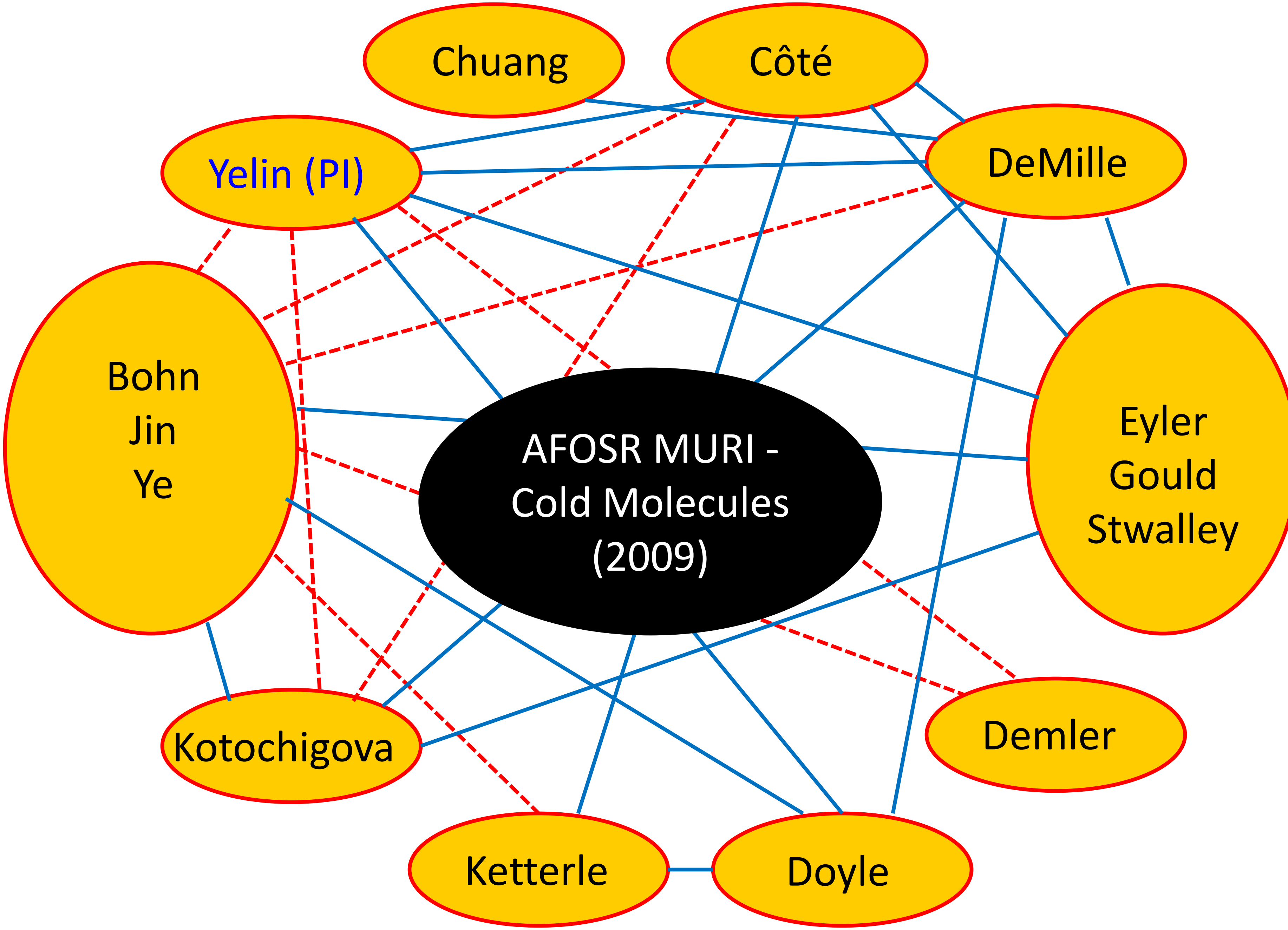
Nature, in press (2011).



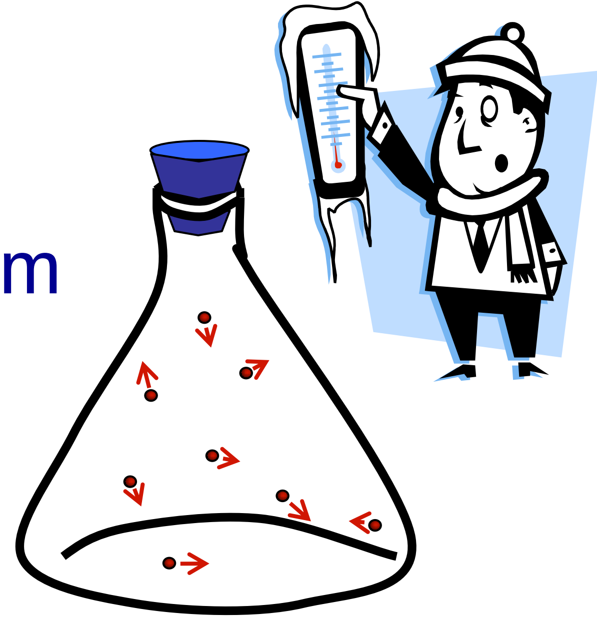
Direct Frequency Comb Spectroscopy

Thorpe et al., Science 311, 1595 (2006). Chem. Rev. 2010; Phys. Rev. Lett. 2011.




Chuang
Côté
Yelin (PI)
DeMille
Bohn
Jin
Ye
AFOSR MURI -
Cold Molecules
(2009)
Eyler
Gould
Stwalley
Kotochigova
Demler
Ketterle
Doyle

Ultracold gases



Precise control of a quantum system

applications:

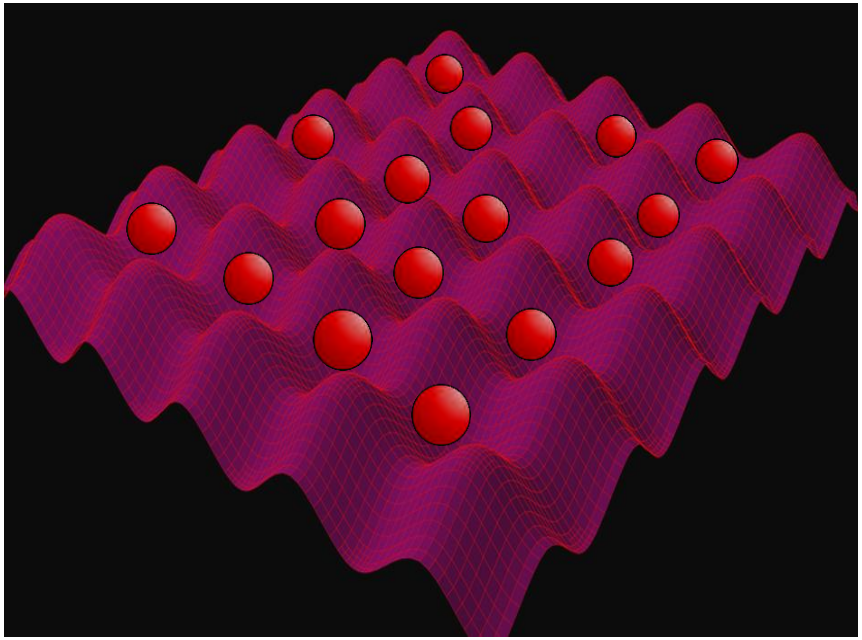
quantum computing
atomic clocks
precision measurements
cold-atom-based sensors

Control: A tool for understanding complexity.

Build up strongly correlated many-body quantum systems

- Fermi superfluidity

- fermions or bosons in an optical lattice



Why <u>polar</u> molecules?

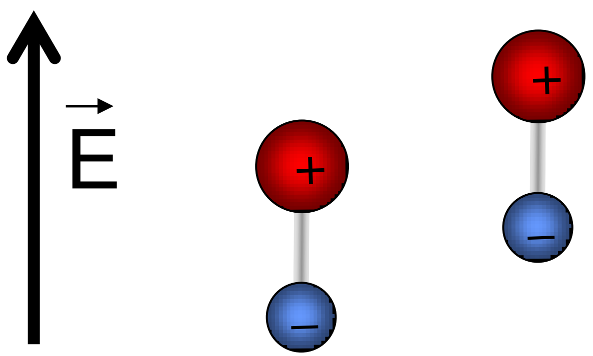
Extend our capability to control quantum systems

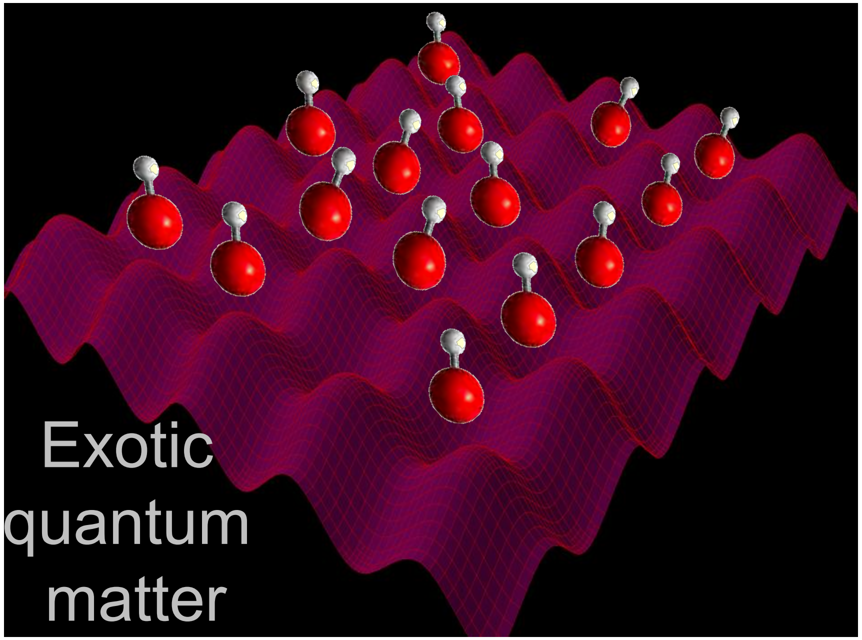
What's new (compared to ultracold atoms)?

- New internal degrees of freedom

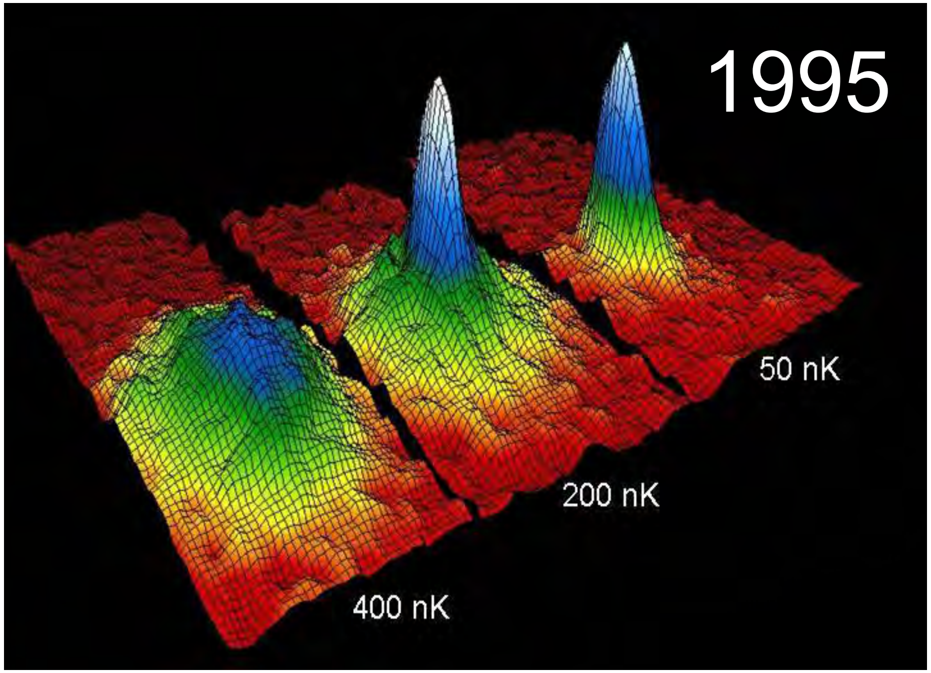
  vibration, rotation

- Chemistry
- <u>Long-range interactions</u>





Atom vs. molecule



Bose-Einstein Condensation

T = 100 nK

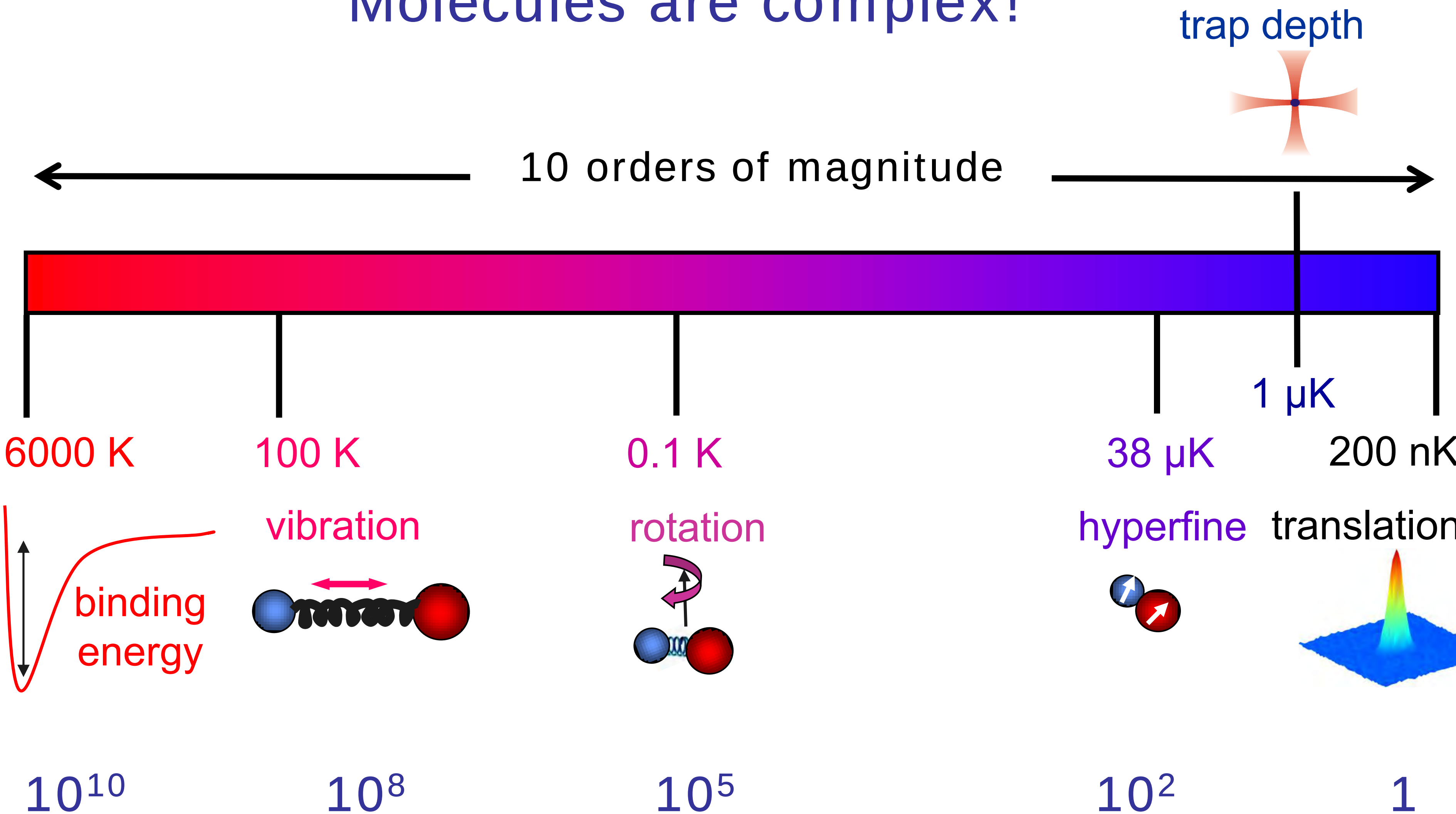
N = 10^6 atoms

n = 10^{13} cm^{-3}

Molecules:
T = 100 mK, n = 10^6 cm^{-3}

Ultracold molecules: The challenge

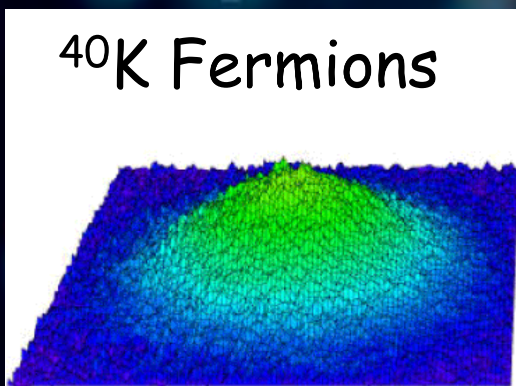
Molecules are complex!

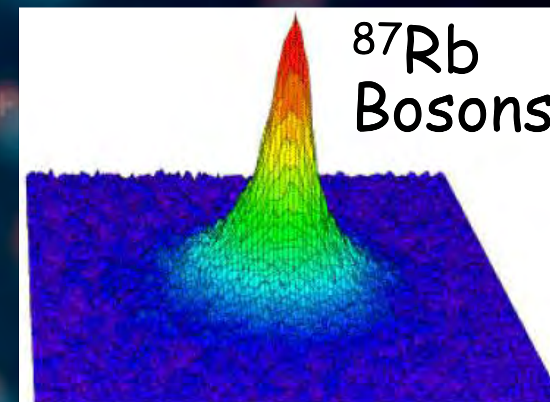


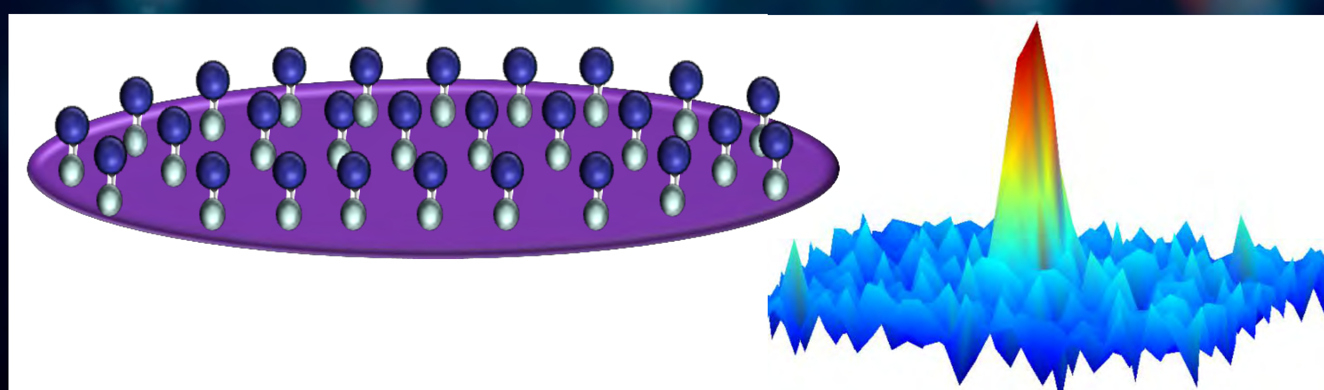
Quantum gas of polar molecules

Debbie Jin
J. Ye

Science 322, 231 (2008)
Science 327, 853 (2010)
Nature 464, 1324 (2010)

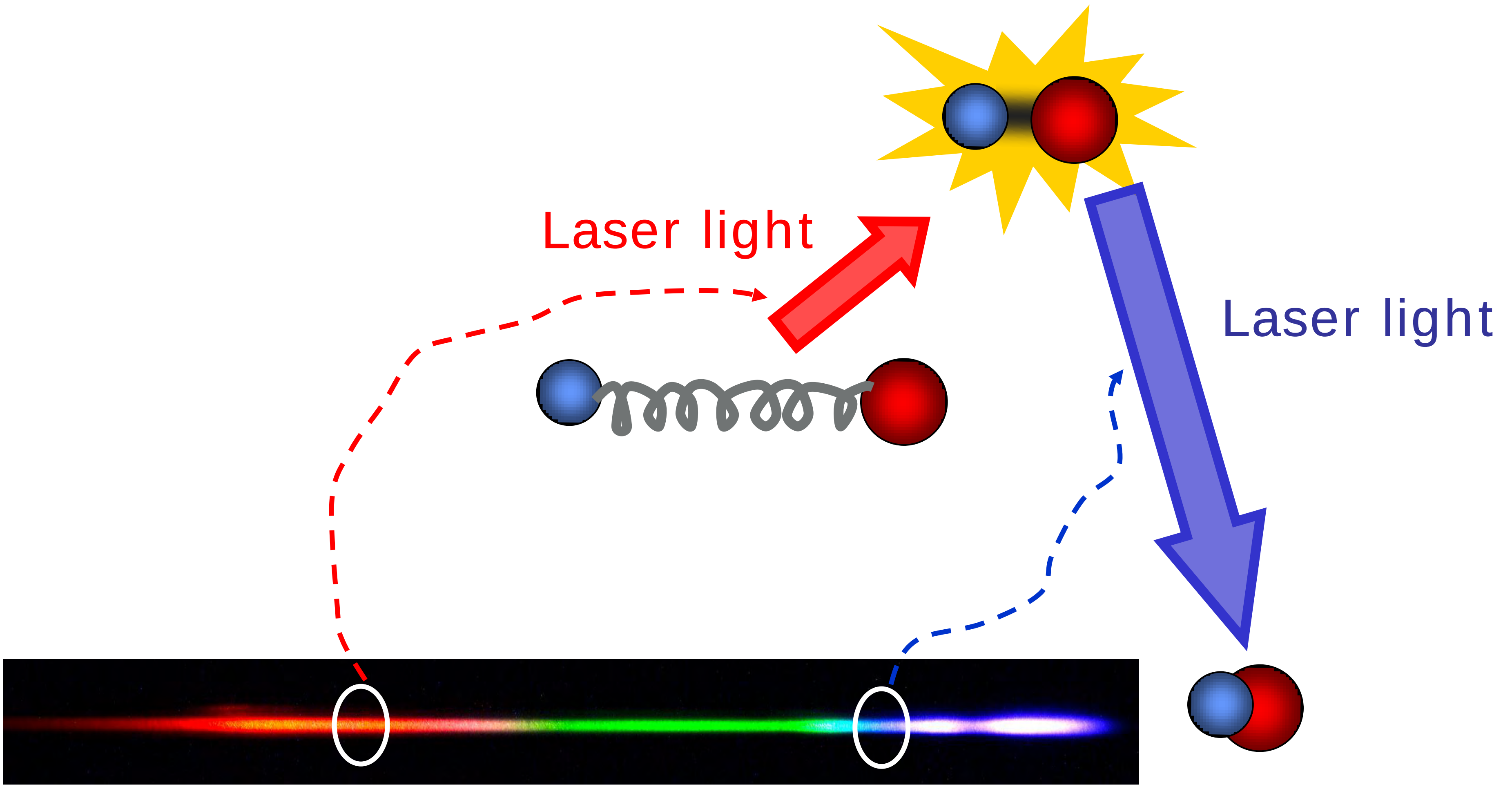






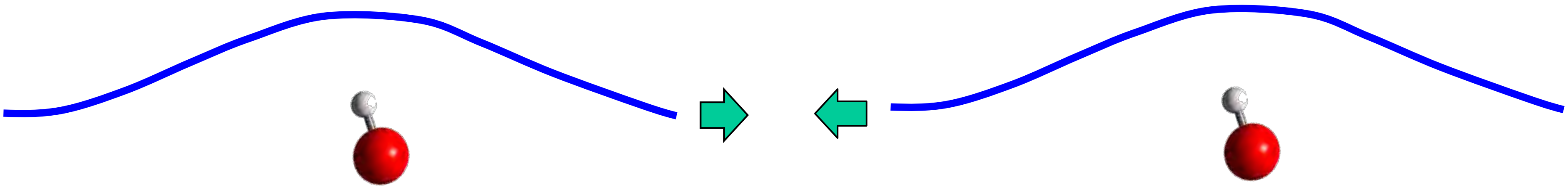
Light provides the answer

Photons carry away the energy!

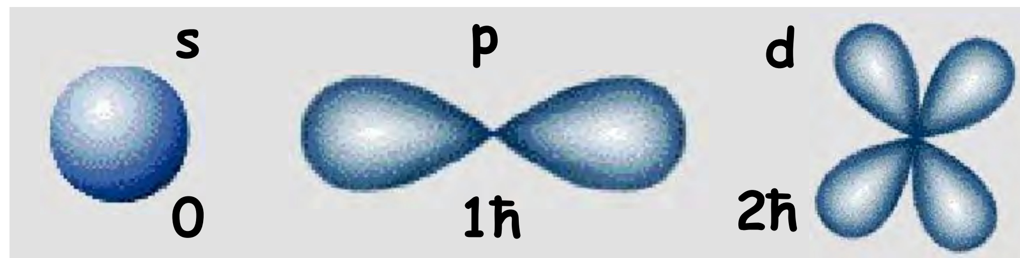


Chemistry near absolute zero

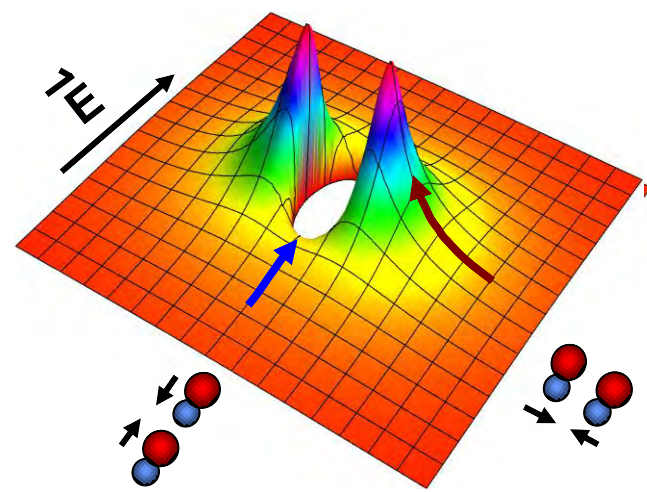
(1) Molecules behave like waves



(2) Angular momentum is quantized

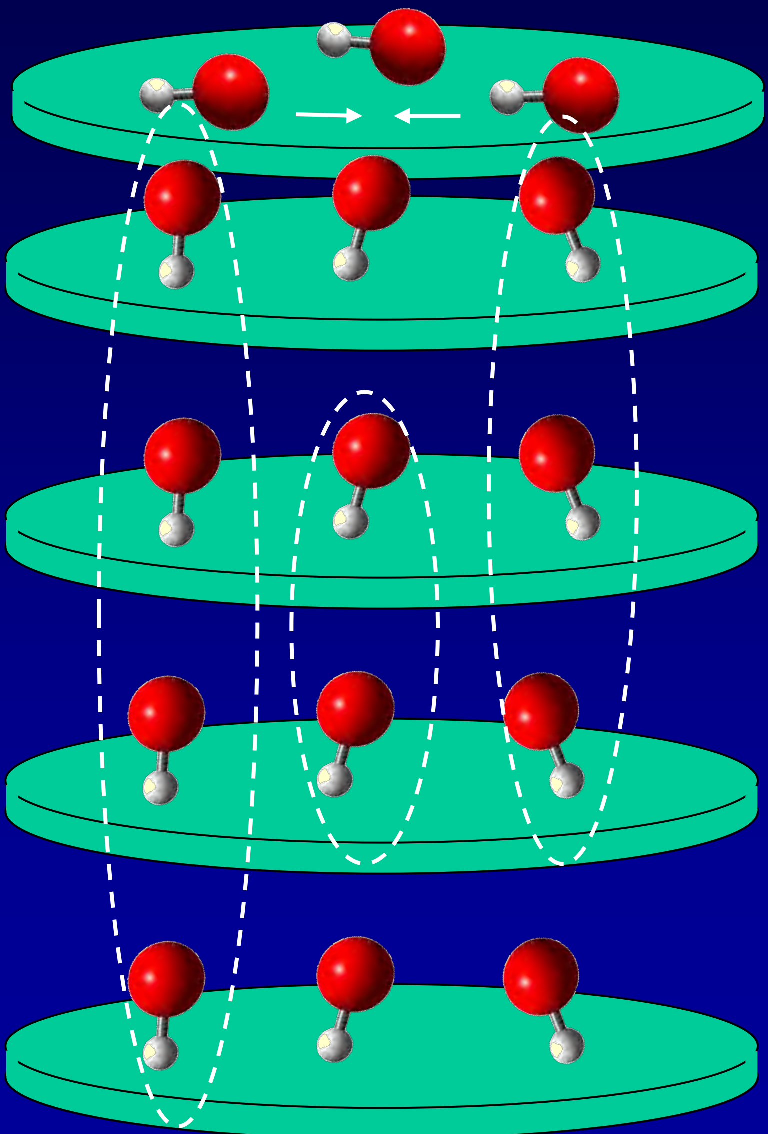


(3) Quantum statistics matter



Fermions ⇨
L = 1, *p*-wave collisions

New quantum phases and dynamics



~~Revolution~~ Ongoing !

E

- Correlated Fermi pairs
- Bi-layer Bose condensation?
- Super solids?
- … …

Zoller, Demler, Santos, … …

Over the years …

http://JILA.Colorado.edu/YeLabs

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