Value-driven Engineering for US Global Competitiveness

A Call for a National Platform to Advance Value-driven Engineering

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Introduction

As the nation struggles to develop bipartisan solutions to the complex challenges of deficit reduction, certain truths emerge. One of these is simple: we cannot sacrifice the nation's defining leadership in biomedical innovation as we struggle collectively and decisively to right a listing economic vessel. Innovation and value rest in the competing cross-currents that define today's debate on how we will recover from an economic crisis that appears to be the challenge of our generation. On one hand, access to innovation offers tremendous potential for improved health, both human and economic. On the other, health care costs are rising at a rate that is unsustainable, requiring sharp, decisive response.[1] As Peter Orzag, former Director of the Office of Management and Budget (OMB), stated recently, while it appears that we cannot afford cost-driven technologies, neither can we afford as a society to lose the health outcomes associated with such innovation.[2]

Many worry that an immediate and tempting approach to stemming the tide of rising health care costs will be to cut off access to new technologies. A technology that delivers high value and high return on health might be viewed suspiciously as being "the newest, the fanciest, and the most expensive," and not justified in terms of value to the consumer, to the provider, to the payer. Market corrections to rein in health care costs may shift to either under or over-correct in allowing access to innovative technologies.[3]

An under-correction in affording access may take away a valuable mechanism to address health care costs, which, as we know, threaten to exceed 17.6 % of our gross domestic product, higher than any other industrialized nation.[4] An over-correction in limiting access may mean that we encourage only the incremental but not the disruptive; that our reimbursement systems fail to embrace current evidence that supports the adoption of proven new approaches; and that we introduce even greater uncertainty into the biomedical technology market, which is already threatened to a point of serious decline if not near extinction. These are very real concerns.

"The US must take creative and innovative steps to retain its lead in device development and continue to secure and create American jobs."

– Dr. Frank L. Douglas
President and CEO,
Austen BioInnovation Institute in Akron

As we work to understand how to shore up our own economic future, we must also look offshore to assess the current movement of medical technology related research and development (R&D) and clinical studies outside the United States (US). Stakeholders need to determine the extent of this movement and the core reasons for the transfer of key intellectual capital assets outside the US in order to reverse this trend. Likewise, it is critical to have structured, data-driven assessments of the robustness of the regulatory and payment systems within the US to support and advance Value-driven Engineering (VdE). Joint stakeholder studies, conducted in Safe Haven or similar environments, are going to be key.

In April 2011, the Food and Drug Administration (FDA) released its Strategic Priorities, noting:

> *"Today, the FDA is facing a critical set of public health challenges; challenges brought about by the unique demands of the 21st Century. Science and technology are changing our world in dramatic ways; we are seeing an explosion of knowledge and capabilities emerging from many domains of research and from around the globe. In addition, we are living in an increasingly globalized world … Although it will not be easy, we will address these challenges and aim to fulfill our mission by embracing innovation and actively pursuing partnerships with federal, state, and local agencies; international authorities; academia; non-government organizations; and the private sector."* [5]

We at the Austen BioInnovation Institute in Akron (ABIA) endorse this new vision for the FDA and as part of this endorsement have led the effort that has produced this White Paper. We do not believe that the challenges before the nation to preserve our lead in biomedical innovation and in driving a new "BioInnovation Economy" can be addressed by any one player in the market, public or private. We believe that only through partnerships across government, academia, industry and the nonprofit sector will we ensure that short-term measures do not become short-sighted missteps.

In March 2011, ABIA convened a Summit on Value-driven Engineering and US Global Competitiveness. The Summit was designed to consider new demonstrations of value in biomedical product engineering, to draw upon lessons we might learn from our global partners, and to help pave a path forward for the review, approval, and payment for medical technologies that are indeed "value-driven."

What is "Value-driven Engineering"?

As you will read in this White Paper, we have much to learn from innovators across the US and abroad on how to design and manufacture medical devices that respond to consumer need, reduce manufacturing complexities and ultimate cost, while not sacrificing quality. A national conversation on VdE asks how we will design, develop, approve and pay for "value" – as determined by a new value equation that takes a fresh look at the interrelated function among clinical utility, reduced complexity and cost.

At the Summit, leaders from industry, academia, and the public and private sectors gathered to explore the issue of VdE and US Global Competitiveness. This Summit was conducted in a "Safe Haven" environment where presentations on the record were followed by discussion and debate conducted in accordance with the Chatham House Rules, openly and with the assurance of non-attribution.

This White Paper presents the observations from the Summit and from the associated work of a committed, highly-regarded group of thought-leaders from academia and industry who comprise the VdE Summit Steering Committee, see below. The members of the VdE Summit Steering Committee are themselves pioneers in the field of VdE. Many have launched ground-breaking technologies that have demonstrated value and new returns on innovation to the consumer and to health care systems. Many have introduced products in global markets experiencing first-hand the effects of cultural perceptions of value and how these affect product approval and reimbursement. Many lead programs within our finest academic institutions that capture the imagination of our best and brightest young minds, creating environments that are nurturing today's and the next generation of innovators.

The input from the Summit is the central foundation for the recommendations contained in this White Paper. The Summit was launched with a keynote presentation by Aneesh Chopra, Chief Technology Officer in the White House Office of Science and Technology, examining "Value-driven Engineering and US Global Competitiveness." Stage-setting presentations followed from leaders across many sectors. Dick Gephardt, Former House Majority Leader, and Chair of the Council for American Medical Innovation, discussed the role of public-private partnerships to drive a national response to competitive challenges. Charles Vest, President of the National Academy of Engineering, offered observations stemming from the National Academy of Sciences report, "Rising Above the Gathering Storm: Category Five." Raj Jammy, Vice President, Emerging Technologies, SEMATECH, outlined the evolution of this seminal public-private enterprise. Seth Greenwald, Director, Orthopaedic Research Laboratories, examined today's challenges in bringing a medical device to market, and Mike Hess, Vice President, Innovation Excellence, MEDTRONIC, addressed the costs of designing, engineering and manufacturing medical devices. Panels explored case studies from the US and the global marketplace that demonstrated VdE product development and today's leading academic programs to train the next generation of VdE innovators. *(See Addendum A, Summit Agenda).*

Attendees broke into Workgroups to explore key components of a VdE national agenda:

- Workgroup A: Training the next generation of Value-driven Engineers
- Workgroup B: Creating a framework for identifying areas of opportunity for VdE
- Workgroup C: Developing current and new strategies for funding programs that support VdE
- Workgroup D: Creating a new public-private partnership model to advance US VdE in a global marketplace

This White Paper builds on all of these substantive contributions to the Summit along with subsequent deliberations by the Steering Committee. We bring these together in a cohesive call for a new national **Platform to advance Value-driven Engineering (PAVE)**. PAVE is an integrated, federal architecture that recognizes how the key links between VdE and our global competitiveness encourages a new national conversation on how we measure and design toward "value," and calls for each of the following:

1. Demonstrated value, employing the VdE Value Equation.
2. Patient-centricity, with community and customer engagement in product demand and design.
3. Public private engagement and investment, dependent upon innovative and budget sensitive federal funding mechanisms, cross sector human and financial capital contributions, and collaboration across disciplines, bringing engineering into a close integrated working relationship with biology, medicine, clinical application and health system performance.
4. Educational focus requiring the adoption of new academic programs that train today and tomorrow's cadre of VdE engineers.

The Steering Committee recognizes that there remain key impediments to innovation within current US regulatory structures and more must be done to advance innovation, particularly in the areas of unmet clinical need. This White Paper is presented as a significant contribution to addressing this challenge. To do this effectively, we suggest actionable policy recommendations that can be implemented outside the legislative process. These recommendations span public-private funding strategies, regulatory and reimbursement incentives, investments to attract and train VdE innovators, and suggestions to support the commercialization of US VdE products. We trust this paper will prompt a national conversation on value and VdE and result in the adoption of PAVE, one sure means of enhancing our competitive future and assuring our continued leadership in advancing innovations that improve human health.

Frank L. Douglas, MD, PhD,
President and CEO,
Austen BioInnovation Institute in Akron

Executive Summary

Introduction

US-based companies dominate the roughly $350 billion global device industry and account for approximately 40% of the world market for medical devices and instruments.[6] Thirty-two of the 46 medical technology companies with more than $1 billion in annual revenue are based in the US.

Despite this snapshot of US medical device industry, there is great concern that the US is losing its competitive edge among other countries when it comes to medical device innovation. The challenges to continued US leadership in innovating and commercializing bio-engineered technologies and devices are significant. Our global leadership is uniquely dependent on a complex ecosystem of economic, scientific, regulatory and societal drivers. It is presently under attack from rapidly developing economic competitors abroad, challenges to regulatory predictability, and dramatic changes under way in the US health care environment.

Defending US leadership of this unique industry requires a unique set of targeted policy solutions that will accelerate the evolution of the US BioInnovation Economy and its ability to meet the pressures posed by newly capable foreign competitors and a new value paradigm in the US health care system. One key component of the national strategy involves a new platform for Value-driven Engineering.

Value-driven Engineering (VdE) offers tremendous potential to serve as a tool to bring healthcare costs in line with quality outcomes thereby bolstering our global competitiveness. VdE in healthcare is an approach to developing new products that are in line with a set of core, defining **VdE principles**:

- **Quality** that is a given, assuring that performance and delivery are never sacrificed for the sake of a "cheaper" or "less costly" version of a product or process;
- **Clinical utility** that is driven by patient-centricity in demand, design, use and function;
- **Reduced complexity** in product design; and
- **Cost savings and cost efficiency** across the health system.

Components of these principles – clinical utility, reduced complexity and cost – become the variables in a new VdE "Value Equation." The function of VdE Value Equation – and the interdependency of these components – is complex and will demand elegant investigation against a vast array of empirical data. *How do these factors comprising the VdE value equation inter-relate? What is the function of each to the other? How to we accelerate efforts to test this equation against health system, product performance, and payment data to refine and apply the complex inter-related function of each component of the equation?*

Understanding and responding to these challenges will be central to advancing a new national platform for Value-driven Engineering called for in this White Paper.

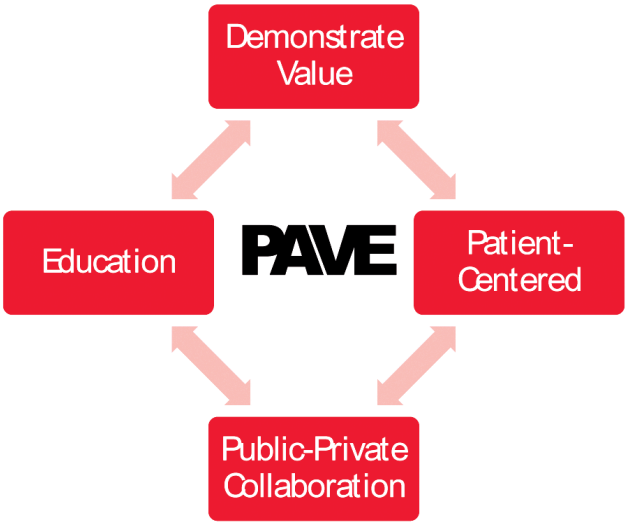
PAVE – a platform for advancing Value-driven Engineering is a new concept presented in this white paper. PAVE is a networked architecture of funding mechanisms, regulatory incentives, supports for cross sectors investments, and educational leadership that incorporate the principles of VdE and deploys the VdE Value Equation as a core driver and test for VdE device product innovation. This PAVE framework, thus, is founded on the following pillars:

1. Demonstrated value, employing the VdE Value Equation.
2. Patient-centricity, with community and customer engagement in product demand and design.
3. Public-private engagement and investment, dependent upon innovative and budget sensitive federal funding mechanisms, cross sector human and financial capital contributions, and collaboration across disciplines, bringing engineering into a close integrated

working relationship with biology, medicine, clinical application and health system performance.

4. Educational focus requiring the adoption of new academic programs that train today and tomorrow's cadre of VdE engineers.

PAVE will move VdE into a central role in the nation's effort to reduce the looming costs of health care, including Medicare, and should become a recognized component of our nation's effort to maintain its global economic competitiveness in the 21st Century.



Recommendations

1. The VdE Value Equation

1.1 A study should be commissioned to test, refine, model, and develop the VdE Value Equation for use in the PAVE platform.

2. PAVE: Platform to Advance VdE

2.1 Launch and manage PAVE as a program of the Administration with the authority and capacity to assure cross departmental coordination and optimization of pooled federal resources.

2.2 Adopt process mechanisms that embrace a Safe Haven environment for cross sector, shared dialogue, while ensuring that best practices for transparency and good guidance are met.

2.3 Assure input and engagement of experts, scientists, and the public, including those who may take advantage of downstream adoption and use of VdE innovation.

2.4 Encourage development of funding mechanisms, regulatory reforms and federal support systems that are concrete and executable through administrative – as opposed to legislative – action.

3. Federal Funding Architecture for VdE

3.1 Existing Model

3.1.1 Adopt high-functioning, cross-agency pooled funding mechanisms that will extract the highest value from every research dollar invested and promote the ultimate commercialization of VdE products.

3.1.2 Build on current models of cross-agency initiatives and existing federal programs to pool resources and activities that promote the advancement of innovation.

3.1.3 In the Accelerator Challenge, consider a regional cluster priority that encourages the adoption of VdE in a future iteration of the competitive award. Special consideration could be given to those applications that have adopted and are committed to incorporating PAVE concepts throughout their work.

3.1.4 The Jobs Council should include a specific focus on BioInnovation and VdE as an area for workforce development and training and a key mechanism of keeping America globally competitive. Furthermore, the Jobs Council should heavily consider the inclusion of a qualified representative of VdE to the Council.

3.1.5 While the application deadlines have expired for these funding opportunities, explore the prospect of incorporating PAVE concepts in future funding opportunities of the National Science Foundation's Accelerating Innovation Research (AIR) and Partnerships for Innovation (PFI) programs.

3.1.6 The Department of Veterans Affairs (VA) should incorporate PAVE concepts into subsequent VA Innovation Initiative (VAi2) solicitations in an effort to further the program's goals. Veterans could benefit from VdE devices that make their lives easier, ranging from next generation prosthetics to devices that support delivery of care innovations and telehealth.

3.1.7 Once created at the National Institutes of Health (NIH), the National Center for Translational Science (NCATS) should include VdE expertise in its advisory council and should call for the inclusion of VdE principles in initiatives that are included within NCATS and as a component of the Cures Acceleration Network, or CAN.

3.1.8 The Small Business Administration (SBA) should expand funds for the underserved, yet critical, Phase III (the translation phase from lab to commercialization), especially as it relates to VdE small businesses. SBA may consider a pooled funding model to fund Phase III Small Business innovation Research (SBIR) awards, as a pilot program. Criteria for the program and funding opportunity could require a matching investment by the private or nonprofit sector to ease the capital crunch that so many small businesses face.

3.2 New Paths

3.2.1 Use "Challenge-Driven Innovation" to drive VdE and the new BioInnovation Economy. Create a platform for Challenge-Driven Innovation within PAVE, deploying the Safe Haven concept that allows stakeholders to discuss regulatory or other issues in an environment that encourages consideration of disruptive, high value-added projects, protecting the "disruptors" from static thinking or entrenched interests and allowing innovative ideas to advance and succeed – or fail – on their own merits.

3.2.2 Use the power of procurement to support PAVE. Develop a focused VdE procurement program,administered by the Department of Defense (DoD), Department of Veterans Affairs (VA), and NIH – individually or, optimally, collectively. This VdE program would begin with the identification of patient areas of need or challenge that are appropriate for VdE solutions. The program would formally solicit through the procurement process proposals for targeted VdE device solutions, requiring the incorporation of PAVE core principles in all stages of product development.

3.2.3 Create a framework for public-private investment. Develop a public-private SEMATECH-type model to lead PAVE. Use a Safe Haven construct for public-private collaboration among government, nonprofit organizations, academia and industry. Draw upon lessons learned from past and current efforts, including SEMATECH, In-Q-Tel, OnPoint and other federal platforms, to understand how best to attract private capital without overly burdensome government intrusion, while protecting downstream intellectual property, ensuring transparency, and providing proven incentives for cross sector investments.

3.2.4 Develop a VdE Venture Capital Fund. Create a federally supported and publicly leveraged VdE Venture Capital Fund, built on the lessons learned, that is an integral part of the PAVE public private model.

3.2.5 Examine the creation of BioInnovation Trade Missions to support commercialization of US VdE products in the global marketplace.

4. Adopt a regulatory framework to advance VdE product development

4.1 Create VdE Scoring metrics utilizing the concepts set forth in this White Paper and subsequent VdE development. Within the Premarket Approval (PMA) system, allow products meeting VdE criteria to be given "fast track" priority status.

4.2 Special attention should be given by FDA to incentives for the application of VdE principles to the development of pediatric medical devices.

4.3 The FDA should allow the introduction and utilization of computer simulation and modeling as a component in the design and development of VdE devices.

4.4 The FDA should consider identifying specific medical device testing laboratories with expertise in both physical and computational evaluation of devices coming before the agency for 510(k), IDE, PMA, or humanitarian device approval to provide independent review and validation of a device's adherence to VdE criteria.

4.5 Continue to consider financial incentives for VdE products.

4.6 510(k) Reforms

4.6.1 FDA should explicitly support as "substantially equivalent" devices that take the therapy or diagnostic "downstream" to less specialized, lower cost health care providers and even to patients.

4.6.2 Recognize the 510(k) reform process as a key opportunity to build VdE principles into product development and testing processes.

4.7 Market incentives for VdE

4.7.1 Recognizing the distinct variation between drugs and devices, the FDA should explore market incentives appropriate to VdE products.

4.8 Enhanced support for the VdE innovator

4.8.1 Fund a regulatory science grant to examine the scientific and engineering methods of VdE product development.

4.8.2 Create regulatory science Centers of Excellence in VdE.

4.8.3 Establish a system to support VdE device innovators as they seek to move an innovative device through the intricacies of the regulatory process deployed through independent PAVE centers, approved by FDA, with demonstrated VdE expertise and a willingness to provide mentoring support for start-up VdE innovators.

4.9 Value-driven reimbursement

4.9.1 Create linked FDA/CMS pathways that innovators will use.

4.9.2 Define the respective areas of expertise between CMS and FDA.

4.9.3 Avoid duplicative or iterative data requirements.

4.9.4 Provide priority consideration for reimbursement of VdE products that utilize a parallel FDA/CMS review track.

4.9.5 Allow the introduction and utilization of computer simulation and modeling approaches to demonstrate clinical utility, reduced complexity and projected cost reduction associated with VdE products.

4.9.6 CMS should be encouraged to adopt a coverage with evidence outcome for VdE compliant products and not deny coverage given these product's satisfaction of VdE criteria and the preliminary nature of the data.

5. PAVE innovators: Training and inspiring the innovators of today and attracting the best and brightest leaders of tomorrow

5.1 Education

5.1.1 Adopt the Open Innovation and experience-based model for education.

5.1.2 Develop and distribute a guidebook of best practices for all disciplines, including academia, industry and non-academic partners who are close to the practice of Value-driven Engineering.

5.1.3 Promote Innovation Literacy: "Utility rather than Complexity."

5.1.4 Develop and distribute a program (modeled on NSF's Research Experiences for Teachers) in which K-12 teachers partner with postsecondary institutions and corporations to have innovation experiences and develop innovation literacy curricula to be used at the K-12 level.

5.1.5 Empower and motivate young people to be innovative by providing venues to further their technical abilities.

5.1.6 Create a National Innovator Corps. Provide a volunteer pathway for all ages to experience and practice Value-driven Engineering in the service of society, thereby enlarging the pool of innovators and creating a cultural celebration of innovation.

5.1.7 Sponsor national-yearly PAVE conferences and workshops on the topic of VdE, where private and public participants share and learn best practices.

5.1.8 Sponsor national PAVE competitions designed to accelerate VdE design thinking and solutions, including student competitions, early-stage companies competitions, and larger Xprize competitions.

5.2 Federal funding strategies

5.2.1 Mandate all Federal funding agencies to include in their educational grant RFA's a requirement for attention to the need for development of course content that focuses on VdE, including educational and training materials for use in training employees within organizations interested in expanding into markets requiring products based on VdE principles on two tracks: (1) development of in-depth academic programs of education and research focused on understanding and advancing the field of VdE, and (2) inclusion of VdE principles and practical training throughout the US engineering curricula, developing a paradigm for US engineers.

5.2.2 Provide funding to support the development and establishment of short-term courses (2-3 weeks) at universities on VdE engineers with America's biomedical industry.

5.2.3 Mandate all Federal funding agencies to increase funding support for programs that send US-based engineers to low-resource areas as part of programs that educate participants on ethnographic skills, and challenge them to design and deliver solutions that are viable for those markets and environments.

5.2.4 Provide tax credits for corporations to develop VdE devices as well as internship programs at international locations.

5.3 Workforce development

5.3.1 Sponsor national "PAVE Young Scholars Program (K-12)" to promote and attract projects driven by innovation and awarded with the opportunity to present at the White House Science Fair.

5.3.2 Undergraduate: Sponsor PAVE Undergraduate Fellowships tied to internships, problem driven undergraduate projects, and training in innovation awarded based on grades and submission of a strong proposal idea for innovation.

5.3.3 Graduate: Sponsor PAVE fellowships for graduate students targeting innovation, interdisciplinary research, team-based education and research, and exposure to entrepreneurship.

PAVE

A Platform to Advance Value-Driven Engineering

Paving the way forward for innovation and innovators in today's economy.

I. Value-driven Engineering (VdE) and Healthcare in the US

A. The Concept of Value-driven Engineering

VdE is similar in concept to "frugal engineering" – an innovative way of approaching product design to provide the essential functions people need at a price they can afford without compromising quality. VdE is about reducing complexities in product design, improving efficiencies in product performance, listening to the ultimate consumer, and designing high quality products that meet both lifestyle and economic needs. It is about identifying needs at the bedside before the bench, and then reverse engineering to meet these identified needs, with a constant assumption of quality, but with a very new focus on clinical utility, reduction in complexity – both in product design and use, and both as a function of cost – to the patient, the health system, society.

In VdE, quality is a given.

Quality includes the ability of the product to meet its intended and expected uses from a diagnostic or therapeutic perspective. Quality is much more than whether the product breaks. In a formal sense, quality is governed by guidelines put forth by the regulatory bodies. In the US, the FDA sets the standards and regulates products for clinical quality. The quality management systems typically required cover a host of activities from processes that are used to producing a product to the verification of steps required to ensure that the produced products are indeed good. Thus, while not sacrificing on quality is somewhat implicit in being able to achieve clinical utility, quality relates to ensuring that the clinical utility can be predictably and reliably achieved – patient after patient. Without quality, the best diagnostic or therapeutic concept may be of limited utility and patients may potentially be harmed.

B. A Focus on Value

Innovation, a concept discussed widely today across science, medicine, policy, government, and health systems, is being driven by a new, central focus on **value**. *What is the value of innovation – specifically medical innovation – to the economy and to human health*?

As implied by its name, understanding value through this new lens is at the core of any concept of VdE. In this White Paper, we will explore the metrics for the "value equation" for VdE below, recognizing that these metrics are complex, inter-dependent, and in demand of further study. How do these factors comprising the VdE value equation inter-relate? What is the function of each to the other? How do we accelerate efforts to test this equation against health system and product performance, payment data and short and longer term health outcomes to refine and apply the complex inter-related function of each component of the equation?

In advancing VdE approaches to product design, engineers, users and consumers, regulators and payors, must embrace a common articulation of how a project or solution has addressed three critical areas:

"We need to out-innovate, out-educate, and out-build the rest of the world. We have to make America the best place on Earth to do business. We need to take responsibility for our deficit, and reform our government. That's how our people will prosper. That's how we'll win the future."

– President Barack Obama
State of the Union (January 2011)

- **Clinical utility** that is driven by patient-centricity in demand, design, use and function;
- **Reduced complexity** in product design; and
- **Cost savings or cost efficiency** across the health system.

These three components, each complex in its own right, are aggregated into a "value function" for VdE. Their interdependency is complex and requires modeling against real world empirical data. Testing, modeling, refining, adopting, adapting, applying, and then recalculating the function of this value equation will be at the center of the recommendations contained in this White Paper and the development of a new national platform for VdE.

The VdE value equation is consistent and reflective of the "Triple Aim" for improving the US healthcare system, advanced by Acting Centers for Medicare & Medicaid Services (CMS) Administrator, Dr. Don Berwick:

> *Improving the US health care system requires simultaneous pursuit of three aims: improving the experience of care, improving the health of populations, and reducing per capita costs of health care. Preconditions for this include the enrollment of an identified population, a commitment to universality for its members, and the existence of an organization (an "integrator") that accepts responsibility for all three aims for that population. The integrator's role includes at least five components: partnership with individuals and families, redesign of primary care, population health management, financial management, and macro system integration.*[7]

C. Understanding value as a function of clinical utility, design complexity and cost

Clinical Utility. Medical innovation has often focused on understanding clinical needs based primarily on the clinical encounter. Clinical utility has traditionally meant addressing an unmet clinical need to improve health care outcomes. These outcomes can be quite varied, but in general may include things such as a reduction in hospitalizations, a reduction in hospitalization length, a reduction in mortality or increase in life span, a reduction in procedure time, reduction in repeat procedures, visits, or tests, an improvement in quality-of-life, a reduction in complications, etc. To have "clinical utility" a VdE innovation must address and demonstrate one or more of such recognized clinical outcomes.

VdE emphasizes not only clinical outcomes but the need to understand key user requirements in framing a clinical utility. Properly framing user expectations can ensure that a solution to their need will enable them to deliver or experience the clinical utility of a new innovation. A user, of course can be a highly trained specialist, a range of healthcare providers, or a patient. Thus, a key aspect of VdE is moving medical technology "downstream" so that it is usable by lower cost elements of the health care delivery system and by patients and caregivers. VdE requires identification of the appropriate metrics to guide the identification of products and processes, to address regulatory needs and to measure success.

Many clinical benefits may take years to prove. A challenge for VdE is to ensure that innovative new costly breakthrough technologies, especially those created by high-growth entrepreneurial start-up companies that are creating many new jobs, are coupled with VdE design innovation that increases the ease of use by the patient and physician through reduction of design complexity.

Reduced Complexity. The implantable cardioverter-defibrillator (ICD) demonstrates how reduced complexity and complication risk is the breakthrough needed to expand a therapeutic benefit from a small patient subset to a much larger patient population. The breakthrough that opened the ICD to the vast majority of the current patient population was

a different innovation – namely the transvenous lead, which is entirely contained within the vasculature of a patient. Before the introduction of the transvenous lead, an ICD could be implanted only via open chest surgery during which several electrical patches were sewn onto the exterior surface of the heart. Particularly for older or sicker patients, the trauma and risk of such surgery made the ICD an impossible option. Also, fewer patients received ICDs because fewer doctors and hospitals had the facilities and skill sets to perform such complex and risky open chest procedures. The key to opening this therapy was to provide the same therapeutic outcome (namely defibrillation when experiencing usually fatal ventricular fibrillation) with a less invasive, lower risk product. The transvenous lead permitted the same therapy delivery only through a lead introduced through a small (minimally invasive) incision. Achieving the same clinical outcome is this less invasive and safer fashion also permitted more patients to benefit from the therapy and more physicians to provide it in substantially lower cost environments.

Reduced complexity is achieved not only by the major breakthrough or leap forward, such as with the transvenous lead, but also by seemingly small steps that together lead to a tipping point in clinical benefit or clinical adoption of the new therapy or technology. In the orthopedic space, the initial development of a joint replacement represented a major breakthrough. Since that major step forward, industry and physicians have identified and implemented a significant number of incremental improvements in materials, design and implantation techniques that have resulted in greater predictability in the procedure and continually improved outcomes, such as better quality of life, reduced complications and immobility, increased range of motion, and reduced pain, all at a lower risk.

Other medical technology breakthroughs have increased clinical utility by reducing complications and making therapies safer and easier. The now common tools used for minimally invasive surgeries of many types have saved millions of patients from more invasive and much less safe surgical interventions. Even apart from the cost savings, these tools have provided substantial clinical benefit through safer, less invasive clinical procedures.

Reduced complexity can also move a therapy "downstream" from the specialist to more common and accessible health care professionals or even to the patient. Delivering care at the closest point to the patient increases access and clinical outcomes in a number of ways including closer monitoring of health care status, faster access to therapy and greater patient autonomy. Moving the diagnostic testing of, for example, warfarin blood levels from the physician's office to the patient's bedside permits better blood level control, high levels of compliance, greater patient control and reduced cost. With a reported two million emergency room visits each year due to medication errors, having better in-home testing is of obvious value. Likewise, allowing a parent to test a child for strep throat before sending her to school (or going to a physician's office or urgent care center) provides broad public health benefit through reduced exposure to infectious diseases, improved individual medical care and reduced cost. Indeed, it may be that the closer medical devices move toward becoming consumer products, the more effective the return on value will be. As an example, imagine a day when Walmart might sell camera pills that individuals could swallow, and have their data transferred to a central site. Gastrointestinal cancer rates might be reduced dramatically. Thus, VdE value proposition and metrics should include the reduced complexity of moving therapeutic and diagnostic testing as close to the patient as possible.

Demonstrated cost savings to the healthcare system or society. The challenges in understanding the financial benefits of innovation are multi-factorial. First, is the challenge of capturing cost. As Dr. Berwick notes, "Measuring per capita costs is still a big challenge; it requires that we capture all relevant expenditures, index them appropriately to local market circumstances, and be able to measure actual costs in a care system whose current methods of pricing and discounting obscure them. . . . Citing one serious gap, the IOM recently concluded that measures of both cost and care across the continuum, impeded by the fragmentation of delivery itself, still need much more developmental work." [8]

Understanding that disruptive innovation can often lead to more being done for less is also recognized by Dr. Berwick in his presentation of the "Triple Aim" for improving the US healthcare system:

> ***Promising innovations.*** *Despite these obstacles, a handful of innovators are starting to challenge the US health care market. These disruptive innovations are by no means yet mainstream, but the examples align surprisingly well with the objectives of the Triple Aim. For example, innovations in primary care such as the medical home, as well as "Minute Clinics" and other retail health care providers are challenging the prevailing approach to primary care. Experiments in telecommunications are offering care that is no longer location-specific. One form of foreign competition – "medical tourism" – is beginning to catch on. Also, a few hospitals, such as Virginia Mason Medical Center, Denver Health, and ThedaCare, are learning to use systems knowledge to reduce costs and improve profit, such as by adapting "lean production" to health care.*[9]

Here, again, as a specific example of device innovation the case of ICD is instructive. While certain studies had definitely proved that prophylactic implantation of these life-saving devices in patients with a reduced heart function could be of significant benefit, only after several studies had confirmed this did insurance payers agree to pay for all of the indications initially delineated in the initial trials. It took time, it took repeated data, it took sustained investment by the innovators to turn this corner.

D. The VdE Value Equation

As cost includes the cost and time for research and development, clinical trials, regulatory approvals and clearances, and manufacturing implementation, understanding the potential financial impact of a new innovation on the healthcare system should lead to increased success for an innovator and a more cost-efficient and appropriately developed product. In fact, since payers, as representatives of the healthcare system's financial arm, may ultimately benefit the most from a new innovation developed using a VdE approach, in an optimal future state payers will be incentivized to take an earlier and more collaborative approach to new innovations because of the wide spread adoption of the VdE Value Equation.

Taken together, we suggest that the concept of "VALUE" encompassed by VdE can be captured in the following equation:

$$Value = f\left(\frac{Clinical\ Utility}{Complexity \times Cost}\right)$$

While this equation is stated simply, nothing about it is simple. The function of each of its components requires study and recalculation based upon the application and modeling from real-world empirical data, including outcomes data from claims, the clinical record, patient self report, etc. mapped to a device innovation and factoring in the cost of device development and healthcare expenditures. Specifically, we suggest viewing the factors in the equation as follows:

Clinical Utility is a measure of the benefit/risk ratio of a new product or process.

Design complexity is a measure of the "user-friendliness" of the design of the device to patients, physicians and manufacturers.

Cost represents healthcare expenditures over the course of a disease state due to implementation of a new innovation minus healthcare expenditures over the course of a disease state currently (without the new innovation).

Recommendation: *A study should be commissioned to test, refine, model, and develop the VdE Value Equation for use in the PAVE platform.*

E. VdE, Innovation, and US Global Competitiveness

i. VdE Case Studies from the US and Across the Global Market

Companies in India, China and Brazil are moving to embrace VdE as a driver for new product development. Today, VdE products are not only designed and launched with country-centric markets in mind, but rather are mounting challenges in the global marketplace against higher cost products that have traditionally met similar needs.

The most referenced example of VdE is the Nano, a mini, low-cost car. Tata Motors, an Indian automobile company, used this concept to develop a car that would allow people with lower incomes access to a reliable car. The company did not design a simpler version of a traditional, more expensive car. Instead, Tata Motors looked to three-wheeled vehicles, alternative materials and questioned the necessity of certain standard features that have become more sophisticated and often more expensive as engineering has advanced. As a result, the Nano uses a wiper system with only one blade, one side view mirror, and the seats are not adjustable. In addition, the engineers replaced the radio with storage space with the understanding that the typical Nano customer would find more value in storage than a radio.[10]

"You can't just make a cheaper ventilator, you have to make a new way of ventilating…when we think about things that are cost effective, yes, the platform we developed is cheaper, it's only got 12 parts, it's wonderfully accurate, it's as accurate as a $30,000 ventilator. Just because something is cheaper doesn't necessarily mean that it's not as good."

– Dr. Matthew Callaghan
Founder, OneBreath (March 11, 2011)

The current economic crisis and soaring health care costs in the US and globally require innovation with a greater focus on technologies and techniques that maximize value to the patient while minimizing costs. Other countries are already using the VdE approach to product design and are developing lower cost medical devices and drugs. For example, in China, Zhongzxing Medical has developed an X-ray machine that costs a fraction of a typical X-ray machine. In India, Shantha BioTech, has developed a recombinant Hepatitis B vaccine. The price in the US is $18 per dose; in India 40 cents.

Case studies from the Summit demonstrate the competitive advantages associated with VdE. Examples of US VdE innovation presented at the summit include:

iRhythm Technologies, Inc. ("iRhythm") – iRhythm, a venture and corporate backed US company whose technology is licensed from Stanford University, has developed a low-cost, easily deployable, and highly compliant single-use long-term (14 days) cardiac rhythm monitor that can be used in many clinical settings beyond that of just the cardiac specialist, including emergency departments and primary care offices. By expanding the venue for the initiation of long-term monitoring, iRhythm facilitates earlier and more effective diagnoses of patients who present with symptoms that could be due to an abnormal heart rhythm. Earlier diagnosis with one highly diagnostic test prevents the need for additional tests or physician visits and can better triage only patients with a true abnormal heart rhythm to a specialist for treatment, thereby saving costs at multiple levels. By focusing on the need for a simple long-term device without unnecessary technology to enable diagnosis of most patients and by leveraging the worldwide drop in cost for certain electronic components as well as employing new information technology modalities such as cloud computing, iRhythm has been able to also significantly streamline and further reduce the cost of long-term monitoring for the majority of ambulatory patients needing cardiac rhythm monitoring.

Further, by initially understanding the needs of the healthcare system to efficiently manage costs across different physicians in diagnosing

"Our economic competitiveness was threatened by expanding debt, declining manufacturing and waning dominance in technology and innovation. Today, we face those challenges, coupled with competition from emerging powers in Asia. America's bio materials, biomedical and health care industries understand these challenges."

– Sen. Sherrod Brown (D-OH)

and treating a disease state, iRhythm has positioned itself well to meet the challenges of upcoming changes to the healthcare system. This type of paradigm – innovating by considering how to lower costs as a requirement for the US as well as more efficiently impact a disease state – has important implications as it may help US companies to more easily and readily adapt to meeting the challenges of a more cost-conscious and value-based healthcare system in the US as well as lay a solid foundation for sales in international markets, in which cost and value have always been important.

One Breath – The concept for the OneBreath low-cost ventilator initially stemmed from a US need to treat respiratory distress in thousands of people during an influenza pandemic. The founders realized that their technology could be applied to developing parts of the world, including India and Western China, where the need for low-cost ventilation is an ongoing critical need every day. OneBreath, which is in the process of obtaining FDA approval, is projected to be sold at a fraction of the cost of a traditional hospital ventilator. The company lowered manufacturing costs by reducing the number of parts and airflow is measured and controlled with propriety software rather than hardware.

ii. VdE and Innovators: Capturing a picture of today's leaders and tomorrow's generation of disruptive VdE innovators

VdE is not possible without well-trained engineers who are motivated to develop game changing innovation that enhances US competitiveness and provides high value to cost solutions for societal or health problems. Some universities around the US have begun to incorporate VdE concepts into their curriculum. Three examples presented at the Summit are highlighted below.

Stanford University Biodesign Program – The Stanford Biodesign Program teaches students and fellows a systematic approach to needs finding and the invention and implementation of new biomedical technologies. A central feature is providing a meaningful experience embedded in the "environment" in which the problem and solution reside. As a whole, since its inception 10 years ago, the program has taught many fellows and students how to solve unmet needs in cost effective, innovate ways and several start-ups have come from it such as iRhythm Technologies and OneBreath.

The Center for Bioengineering Innovation & Design at Johns Hopkins University (CBID) – CBID's twofold mission is to educate and develop the next generation of leaders in medtech innovation, and to improve human health around the world through the creation and early-stage development of health care solutions. Our design teams, composed of Johns Hopkins biomedical engineers plus Johns Hopkins clinicians, engage closely with VCs, regulatory, legal, IP, and experienced industry advisors to design, build, test, and commercialize innovations that have a high potential for significant health care impact as well as commercial success. CBID's depth of experience in medtech innovation and commercialization allow us to understand and prioritize needs and assess technology gaps based on multiple factors, including clinical value, technical feasibility, technology landscape and business model feasibility. Each year, the center fields 10-12 undergraduate Design Teams and 3-4 graduate teams, impacting about 120 students. Since its

establishment in 2008, CBID Design Teams and the program itself have won several national awards for both design and for innovative business plans. In 2010, CBID launched its Global Health Innovation program within its one year MSE degree program. While global health is one goal of this new program, we launched it in part to ensure our student engineers develop the skills, experience and mindset that will enable them to design high-quality low-cost innovations for the US and the world. CBID is rapidly building a high-value pipeline of health care innovation and talent to ensure US leadership in medtech innovation.

The Austen BioInnovation Institute in Akron (ABIA) – ABIA is a public, private, philanthropic partnership that was founded by the University of Akron, the Akron Children's Hospital, the Akron General Hospital, the Summa Health System, the Northeastern Ohio Medical University and the Knight Foundation. The major purpose of the Institute is patient centered innovation and commercialization with a focus on biomaterials, orthopedics and wound healing. Through its research platforms and BioInnnovation and Entrepreneurship courses, the institute has developed a collaborative process for sourcing, evaluating, prototyping and developing product ideas to address problems identified in the treatment and care of patients and their disorders.

One product emanating from this collaboration is "Pacer Man," a simulated mannequin to train physicians in transvenous cardiac pacing technologies.

iii. Driving VdE device innovation as a key contributor to the new BioInnovation Economy

There is great concern that the US is losing its competitive edge among other countries when it comes to innovation, particularly in its ability to compete with VdE products.

The National Academies of Science in its 2007 report "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future"[11], states:

> *"Today, Americans are feeling the gradual and subtle effects of globalization that challenge the economic and strategic leadership that the United States has enjoyed since World War II. A substantial portion of our workforce finds itself in direct competition for jobs with lower-wage workers around the globe, and leading-edge scientific and engineering work is being accomplished in many parts of the world. Thanks to globalization, driven by modern communications and other advances, workers in virtually every sector must now face competitors who live just a mouse-click away in Ireland, Finland, China, India, or dozens of other nations whose economies are growing. This has been aptly referred to as "the Death of Distance."*

Though we often refer to the US as number one, some alarming statistics offer another story. The US is ranked:

- number six in global innovation based competitiveness and number 40 in the rate of change in that metric;
- number 11 among the Organization for Economic Co-operation and Development (OECD) countries in the fraction of young adults who have graduated from high school;
- number 16 in college completion rate in the developed world;
- number 22 in broadband internet access for our citizens;
- number 24 in life expectancy at birth; and
- number 27 among developed nations in the portion of college students who receive degrees in science and engineering and according to the World Economic Forum.

Unique opportunities in the US bio-engineered device industry require a targeted response. Despite the story presented

by these statistics, the US remains a dominant global figure in device engineering. US-based companies dominate the roughly $350 billion global device industry. Thirty-two of the 46 medical technology companies with more than $1 billion in annual revenue are based in the United States. The country accounts for approximately 40% of the world market for medical devices and instruments.[12]

However, this snapshot of the US medical device industry as an economic sector in robust health obscures myriad challenges to continued US leadership in innovating and commercializing bio-engineered technologies and devices. Medical device innovation leadership is uniquely dependent on a complex ecosystem of economic, scientific, regulatory and societal drivers that are presently under threat from rapidly developing economic competitors abroad and dramatic changes under way in the US health care environment.

Defending US leadership of this unique industry requires an equally unique set of targeted policy solutions that accelerate evolution of the US BioInnovation Economy to overcome the pressures posed by newly capable foreign competitors and a new value paradigm in the US health care system.

Targeted public policy is critical. Market forces alone are insufficient to address the challenges to US leadership. The principle obstacle impeding evolution of the US medical device industry is its past success and present global dominance.

Virtually peerless reimbursement levels for medical devices and widely available coverage through private insurance and government entitlement programs have historically drawn robust investment into the US bioinnovation ecosystem including venture capital investment averaging approximately $2.5 billion annually for the past decade.[13]

US momentum in this sector has been further weighted by its position as the largest single country market for medical devices representing nearly 40% of the $350 billion global market. However, a new and more austere reality is emerging and public policy solutions are required to mitigate the instinct to defend the status quo that has been successful for decades.

While high reimbursement and market size have contributed undeniably to US bioinnovation leadership, these dynamics have also enabled a regulatory clearance pathway that globally ranks sixth (out of nine) in difficulty of approval process and seventh in length of approval time [14] leading only China and Japan.

Additionally, the nexus of a necessary political mandate to scrutinize and redefine value across the spectrum of health care and diminished US GDP growth since 2007 accompanied by durable high unemployment will almost certainly instigate downward pressure on US reimbursement levels for medical devices. The predictable outcome will be an erosion of private investment in US bioinnovation.

US medical device industry is driven by small businesses and entrepreneurs that depend on private investments. Eighty percent of medical device companies employ less than fifty people, yet these companies account for most of the innovation and product development in the medical device sector. Small device companies assume large amounts of risk in a capital-intensive environment and are extremely sensitive to unpredictable reimbursement and regulatory policies for innovative devices.

Pressure from foreign competitors is acute. The Chinese and Indian medical device markets are predicted to realize growth of approximately 15% and 23% respectively over the next five years [15] with attendant public and private investment in all elements of their bioinnovation ecosystems. It is likely that US bioinnovators will not only face competition from these emerging global players in the US, but that US innovators may be deflected from entering these markets by protectionist and other trade barriers.

These hard realities demand targeted policy initiatives that accelerate evolution of the US medical device industry and the BioInnovation Economy that supports it.

"… we [US] need every idea that we can come up with, so that's first. Second, we've always been a leader and we need to continue to be a leader."

– Dick Gephardt, President and CEO Gephardt Government Affairs; Chair, Council for American Medical Innovation (March 2011)

The good fight. In 2008, the US medical technology industry shipped approximately $140 billion worth of products and employed over 426,778 workers across 25 US states paying them $24.6 billion in compensation earnings. Likewise, this important sector defied the general economic downturn starting in 2007 to grow employment, compensation earnings and products shipped by 12.5%, 11.4% and 11.6% respectively and also supported ancillary industries and jobs ranging from manufacturers in the supply chain to contract testing and research organizations supporting innovation efforts. [16]

The technologies and treatments that derive from the bio-engineered device sector contribute to the health and wellness of the American citizenry and leadership in the sector bestows health advantages through fostering health care innovations

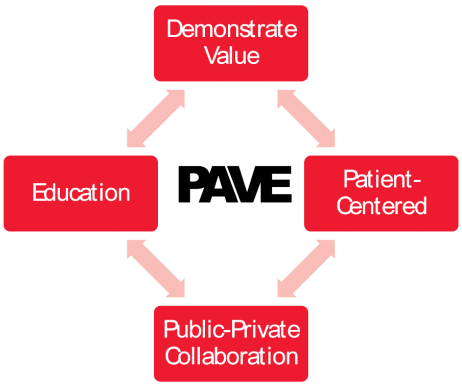
In short, the bioinnovation sector is an outsized contributor to both the health of the US economy and the health of our citizens and sustaining US bioinnovation leadership demands an approach that leverages targeted public policy in tandem with private sector efforts.

II. PAVE – A new national Platform to Advance VdE

PAVE – a platform to advance value-driven engineering is a new concept presented in this White Paper. PAVE is a networked architecture of funding mechanisms, regulatory incentives, supports for cross sectors investments, and educational leadership that incorporates the principles of VdE and deploys the VdE Value Equation as a core driver and test for VdE device product innovation. This PAVE framework, thus, is founded on the following pillars:

1. Demonstrated value, employing the VdE Value Equation.
2. Patient-centricity, with community and customer engagement in product demand and design.
3. Public-private engagement and investment, dependent upon innovative and budget sensitive federal funding mechanisms, cross sector human and financial capital contributions, and collaboration across disciplines, bringing engineering into a close integrated working relationship with biology, medicine, clinical application and health system performance.
4. Educational focus requiring the adoption of new academic programs that train today and tomorrow's cadre of VdE engineers.

PAVE will move VdE into a central role in the nation's effort to reduce the looming costs of health care, including Medicare, and should become a recognized component of our nation's effort to maintain its global economic competitiveness in the 21st Century.



A. The Four PAVE Pillars

1. Demonstrated value, employing the VdE Value Equation

Demonstration of value is based on the adoption and application of the VdE Value Equation to VdE product development. Inherent in the Value Equation are the concepts of clinical utility, reduced design complexity and cost savings and efficiencies. The application of the VdE Value Equation should guide and have a positive, incentive-driven effect on product development, product review, market incentives, and payment. As discussed in Section I above, the VdE Value Equation is presented as follows:

$$Value = f\left(\frac{Clinical\ Utility}{Complexity\ \times Cost}\right)$$

2. Patient-centricity, with community and customer engagement in product demand and design

PAVE product development path engages the community and the customer (patients, providers and payors) in the design of the VdE product. These principles of engagement draw from research on community based participatory research, including the Agency for Healthcare Research and Quality's (AHRQ) community-based participatory research (CBPR) models, and are central to the FDA's interesting total life cycle product development. [17]

3. Public-private engagement and investment, dependent upon innovative and budget sensitive federal funding mechanisms, cross sector human and financial capital contributions, and collaboration across disciplines, bringing engineering into a close integrated working relationship with biology, medicine, clinical application and health system performance

The third principle, public-private engagement and investment through a PAVE structure that is dependent on cross-sector collaboration, cements PAVE. PAVE will be founded on collaboration across multiple fronts, which will include interdisciplinary, inter-institutional, cross government, and cross sector. Developing the value proposition for VdE works only if the relevant stakeholders are engaged in the determination of the conceptual and cultural notions of what constitutes "value," in how this concept of value will be measured, and in how the outcomes of the measurements will guide adoption, payment and use.

This pillar should examine the integration within PAVE of a major public private partnership enterprise devoted to VdE that mirrors the intent, focus, vision, incentives and ultimate productivity in the national interests of SEMATECH. For further discussion on SEMATECH and other relevant models, see Section III (B) (iii).

In developing the PAVE public-private partnership, processes that are inclusive, open, safe and innovative should be deployed. The Safe Haven model used in the initial VdE summit provides a successful, real world example of such a process. Eventually, certain aspects of the VdE approach will require regulatory changes and improvements. Safe Haven meetings provide high value, critical opportunities for stakeholders and the federal agencies to interact in a positive, constructive manner to examine such regulatory options. Changes, derived from the Safe Haven process, can then be vetted through the traditional (and required) notice and comment rulemaking or other appropriate good guidance processes. Some might challenge Safe Haven procedures on open meeting rules, conflict issues, etc.

4. Educational focus requiring the adoption of new academic programs that train today and tomorrow's cadre of VdE engineers

Whether the PAVE platform will be sustained and will grow to become a fundamental component of the US's BioInnovation economy is wholly dependent upon training and rewarding the best and brightest to today's and tomorrow's engineers for their application of and enthusiasm for VdE. How we will do this is discussed at length below in the final Section V of this White Paper.

Recommendations:

- *Launch and manage PAVE as a program of the Administration with the authority and capacity to assure cross-departmental coordination and optimization of pooled federal resources.*
- *Adopt process mechanisms that embrace a Safe Haven environment for cross sector, shared dialogue, while ensuring that best practices for agency transparency and good guidances are met.*
- *Assure input and engagement of experts, scientists, and the public, including those who may take advantage of downstream adoption and use of VdE innovation.*
- *Encourage development of funding mechanisms, regulatory reforms and federal support systems that are concrete and executable through administrative – as opposed to legislative – action.*

B. Building the PAVE Framework

Building the PAVE architecture will require an integrated network of investments and support across the public and private sectors, including:

- Federal Funding
- Regulatory and Reimbursement Response
- Public Private Investment
- Education and Workforce and Development: Training and inspiring current leaders and the next generation of Disruptive Innovators

Each of these is discussed in Section III through IV below.

III. PAVE – Federal Funding Architecture for Value-driven Engineering – Leveraging Existing Models and Developing New Paths

The vision of a globally competitive BioInnovation Economy relies heavily on capital investments. A core element of investments in biomedical innovation stems from the current federal R&D infrastructure. VdE will thrive in a model that leverages cutting-edge funding opportunities, supported by the necessary incentives to develop and commercialize new products. The BioInnovation Economy will further be spurred by the creation of new funding models founded on best practices that are realistic and attractive in the current economic climate.

The Summit produced a series of recommendations for federal funding support that center on two core principles: (i) build upon efforts of the current Administration to pool precious existing resources to drive medical innovation; and (ii) develop new paths for public-private investment in VdE. While the nation struggles to address a looming deficit and continuing economic instability, the investments outlined below are the kind of stimuli that will allow the best of the best of American ingenuity to thrive and pull the nation's economic engine.

A. Learn and deploy existing models developed by the Administration that pool resources across departments and agencies to stimulate economic growth and competitiveness

While the traditional silos of research funding across the federal enterprise have led to important discoveries in basic research, these silos continue to produce barriers to cross-agency collaboration that will promote and enhance US innovation. Stakeholders, including Congress, the Administration, and the public, are focused on assuring that heavy, early investments in R&D make it to a patient's bedside. Many suggest that the current system encourages duplicative research across agencies and institutions, with a lack of coordination and integration that today's technology is ready to serve.

"The i6 Challenge will help new biomedical technologies succeed and foster their entry into the marketplace. We welcome the opportunity to increase and accelerate technology commercialization across the United States through this partnership with the Department of Commerce."

– Dr. Francis S. Collins, Director, NIH (May 2010)

Recommendations:

- *Adopt high-functioning, cross-agency pooled funding mechanisms that will extract the highest value from every research dollar invested and promote ultimate commercialization of VdE products.*
- *Build on current models of cross-agency initiatives and existing federal programs to pool resources and activities that promote the advancement of innovation.*

Several exemplary models are highlighted below.

i6 Challenge. In recent years, federal department and agency leaders have undertaken efforts to break down traditional silos and develop funding opportunities that promote inter-agency grant opportunities. The Department of Commerce's (DoC) Economic Development Administration (EDA), in collaboration with the National Institutes of Health (NIH), the National Science Foundation (NSF), and the US Patent and Trademark Office (USPTO), launched such an effort in 2010. The i6 Challenge aims to leverage federal resources in an effort to accelerate innovation and spur regional economies across the US. key health care leaders view collaborations like the i6 Challenge as an opportunity to advance biomedical innovations. [18]

Regulatory Science. FDA and NIH Joint Leadership Council on Regulatory Science also holds promise as a model inter-agency collaboration. The Council is devoted to promoting the application of regulatory science throughout both agencies and to the review processes for which next generation technologies are assessed by the agencies. A core goal of the Council is the optimization and maximization of data from clinical trials, an area of value for the PAVE platform.

Jobs and Innovation Accelerator Challenge. Most recently, the Obama Administration announced the launch of the Jobs and Innovation Accelerator Challenge ("Accelerator Challenge") in April 2011. The Accelerator Challenge pools resources from 16 federal agencies and bureaus to promote public-private partnerships around job creation and economic growth. Organized through the DoC's EDA, a competitive solicitation was released in May 2011 that seeks to fund 20 industry clusters (across all sectors of the US economy) in urban and rural areas. The Administration sees the pooling of and competitive distribution of funds for public-private partnerships, as demonstrated in the Accelerator Challenge, as a "smarter use of existing federal resources."[19] It is intended that the competitive funding coming to these industry clusters will leverage new private capital investment to further advance regional job creation and next generation innovations.

Recommendation: *In the Accelerator Challenge, consider a regional cluster priority that encourages the acceleration of VdE in a future iteration of the competitive award. Special consideration could be given to those applications that have adopted and are committed to incorporating PAVE concepts throughout their work.*

Council on Jobs and Competitiveness. Another recent example of collaboration is the Council on Jobs and Competitiveness ("Jobs Council"). Launched in January 2011, the Jobs Council, formed by President Obama, is an effort to promote economic development through educating and training the country's workforce to compete in the global economy and job creation.

"As we enter a new phase in our recovery, I have asked the new Council to focus its work on finding new ways to encourage the private sector to hire and invest in American competitiveness."

– President Obama on the launch of the Council on Jobs and Competitiveness (January 2011)

Recommendation: *The Jobs Council should include a specific focus on BioInnovation and VdE as an area for workforce development and training and a key mechanism of keeping America globally competitive. Furthermore, the Jobs Council should heavily consider the inclusion of a qualified representative of VdE to the Council.*

PAVE concepts should be introduced into a number of cross-agency and existing agency programs to promote and advance VdE. These programs are designed to stimulate translation of basic R&D into commercialized, market-ready technologies across multiple sectors. Examples of this leadership by the Administration are explored below.

1. The National Science Foundation (NSF) launched two solicitations in Fall 2010 as an effort to "strengthen the US innovation economy", these include:

    - The Accelerating Innovation Research (AIR) program was designed to translate knowledge from R&D projects into novel new products. The NSF was specifically looking for projects that demonstrated collaborative efforts to overcome traditional barriers in the innovation pathway.
    - The Partnerships for Innovation (PFI) program focused on "knowledge-enhancing" collaborations between academic institutions and small businesses focused on the exploration, re-definition, and creation of translational research platforms.

    Recommendation: *While the application deadlines have expired for these funding opportunities, explore the incorporation of PAVE concepts in future funding opportunities of the AIR and PFI programs.*

2. The Department of Veterans Affairs (VA) launched the VA Innovation Initiative (VAi2) in June 2010 in an effort to identify, prioritize, fund, test and deploy innovative solutions that will assist the VA to meet the challenges of the 21st century. Innovative ideas will be collected from inside the federal government and by external experts. The VA is currently working on the second year of competitive funding solicitations for this program.

    Recommendation: *The VA should incorporate PAVE concepts into subsequent VAi2 solicitations in an effort to further the program's goals. Veterans could benefit from VdE devices that make their lives easier, ranging from next generation prosthetics to devices that support delivery of care innovations and telehealth.*

3. National Institutes of Health (NIH) will launch the National Center for Accelerating Translational Sciences (NCATS) in October of 2011. A cornerstone program of NCATS is the Cures Acceleration Network (CAN). CAN is aimed at bridging the Valley of Death, or the Valley of Opportunity, in biomedical research and translation. CAN, which was enacted by the Patient Protection and Affordable Care Act of 2010, will fund competitive translational partnership activities, which in some cases require matching private sector funding.

"By targeting innovations that are nearing commercialization, the Industry Innovation Competition provides a bridge between creative ideas in the private sector and real-world deployments that improve the services we deliver."

– Dr. Peter Levin
VA Chief Technology Officer
and Senior Advisor to the Secretary of the VA

Recommendation: *Once created at the National Institutes of Health, the National Center for Translational Sciences should include VdE expertise in its advisory council and should call for the inclusion of VdE principles in initiatives that are included within NCATS and as a component of the Cures Acceleration Network, or CAN.*

4. During the last year, the National Institute of Biomedical Imaging and Bioengineering (NIBIB) has been encouraging the development of low-cost medical devices through collaborations with India. In September 2010, NIBIB started providing Administrative Supplements for Research on Collaborative Projects with Indian Investigators on Low-Cost Medical Devices for awards already issued by the agency to US-based investigators. These funds support the development of diagnostic and therapeutic medical technologies for low-resource settings. Although these funds are limited (providing the lesser of either 25% of the direct cost of the parent grant or $75,000 direct costs per year), NIBIB is a federal trendsetter investing in the promotion and promise of VdE.

A final consideration comes in the form of leveraging Small Business Innovation Research (SBIR) funds across the federal landscape. The SBIR competitive awards program is used by 11 federal agencies to fund the development and production of scientific innovations for small business concerns across two phases:

- Phase I: exploratory startup research; and
- Phase II: expansion on research and development.

Currently, SBIR does not provide funding for Phase III (the translation phase from lab to commercialization), as the Small Business Administration (SBA) views the private sector as the appropriate funder in this space. Small businesses in the area of VdE experience disproportionately fewer opportunities to secure funding to move innovations from concept to market.

Recommendation: *SBA should explore an expansion of funds for the underserved, yet critical, Phase III, especially as it relates to VdE small businesses. This expansion of funds, as limited as they may be, will help VdE products cross the Valley of Opportunity. SBA may consider a pooled funding model to fund Phase III SBIR awards, as a pilot program. Criteria for the program and funding opportunity could require a matching investment by the private or nonprofit sector to ease the capital crunch that so many small businesses face.*

The PAVE platform calls upon the Administration to create more opportunities that pool existing federal resources for competitive translational VdE projects, spurring innovation and meeting the demands of the current global economy. This new model of cross-agency collaboration or expansion of existing programs makes economic and political sense in this age of austerity.

Pooling resources to stimulate innovation must become a central tool of the administration to spur job creation, and boost the US' competitive advantage, while producing life changing technologies that improve the health of US citizens.

B. Develop new paths for federal investment in VdE that are responsive to the current budget realities while targeted to drive growth of the BioInnovation Economy

i. Use "Challenge-Driven Innovation" to drive VdE and the new BioInnovation Economy

The role of challenge-driven innovation is well established in government and commercial organizations to spur new solution identification to established problems. Known typically as "Grand Challenges" or "Open Innovation Challenges," the initial premise requires the delineation of a difficult problem where the traditional solutions have not succeeded. Well known embodiments of this approach include the XPrize, the Grand Challenges of the NSF, Defense Advanced Research Projects Agency (DARPA), the InnoCentive Open Innovation marketplace, and numerous smaller scale academic and commercial contests. Prize amounts range from several thousand dollars for local challenges to the ten million dollar XPrize.

These challenges typically award a winner in one of two ways – either the best idea is rewarded with funding and can then be executed, or an individual or team must bring their idea to a working solution which can then be demonstrated and receive the prize purse.

In the medical technology field, the investment to create a new product is substantial. Even a simple product may require multiple millions of dollars of research and development costs to reach clinical readiness. After this point there can again be several million dollars of up front clinical costs to prove safety, efficacy, and economic and clinical outcomes. The amount of risk around new technology adoption and regulatory approval makes raising capital for new technology ventures difficult. It can be additionally difficult to investigate and evaluate technologies that are intended to replace existing standard of care treatments when established clinical and commercial parties have less incentive to fund the research.

"There are a lot of small companies, and these small companies are betting the house on this process and innovation."

– Ashesh Shah
CEO and co-founder, Maxx Medical (March 2011)

A novel approach to encouraging the development of VdE solutions would be to establish clinical and economic requirements for a therapy, where the clinical evaluation of the technology is the prize. This could be administered through the NIH. For example, the following challenges may be the problem statements that originate the technology work:

- A home based device or service that costs less than $10 per day to use which (i) reduces the 45 day readmission rate of cardiac patients by 80% or (ii) monitors pre-symptomatic cardiac patients and allows for pre-emptive intervention.
- New uses of cell phone camera technology to remotely diagnose battlefield injuries.
- Develop a drug or device that eliminates hospital acquired sepsis.

Following these criteria a more detailed specification of the desired use cases and performance characteristics would be established. Teams or individuals would then initiate their own work and when a viable prototype exists, approach the challenge owner (e.g. NIH), who after some due diligence would initiate a clinical trial to prove clinical and economic outcomes. The owner could alternatively establish a deadline by which the prototypes must be submitted and from those ideas pick the most promising approach for clinical study. In addition, the submitted proposal must adhere to the PAVE engineering principles and have a demonstrable benefit on healthcare costs.

Recommendation: *Create a platform for Challenge-Driven Innovation within PAVE, deploying the Safe Haven concept that allows stakeholders to discuss regulatory or other issues in an environment that encourages consideration of disruptive, high value-added projects, protecting the "disruptors" from static thinking or entrenched interests and allowing innovative ideas to advance and succeed – or fail – on their own merits.*

ii. Use the Power of Procurement to Support PAVE

Jack Lew, Director of OMB, has spoken publically in recent months about the changing landscape of federal procurement policy resulting from recent fiscal constraints. Federal procurement budgets tend to rise with each consecutive fiscal year (FY) – jumping from $200 billion in 2000 to $500 billion in 2008.[20] However, this trend is changing in light of the current US economy. In FY 2010, federal agencies spent nearly $80 billion less than the projected rate of growth for federal procurement goods and services. Although spending patterns for federal procurement have changed over recent years, it still remains true that procurement, especially in the US, drives product and service innovation. Establishing federal procurement opportunities for VdE will yield a significant return in product innovations in medical areas of need.

Applying resources to the purchase of needed medical products is one way to fund the development of VdE technologies in the US. The benefits of VdE can be harnessed to meet the existing and future needs of the federal government through the procurement process. Implementing a procurement driven funding model, through existing federal channels, will create an incentive structure to develop and create new VdE products, as well as enhance existing VdE products, that the federal government can fund and purchase for a much lower cost.

Remaining faithful to the principles of PAVE, the federal government should call for solicitations, focused on evidenced-based clinical needs. There are

"Advances in bioengineering, coupled with the aforementioned needs suggest a ripe opportunity for the design and development of home or mobile technologies that could enable functional independence and improved quality of life for people with disabilities, chronic conditions or mild impairments associated with aging."

– Dr. William J. Heetderks
Director, Extramural Science Program, National Institute of Biomedical Imaging and Bioengineering

numerous opportunities for innovative solutions that can address pressing public health and health care system needs. A VdE procurement process thus could be melded with the presentation of grand challenges calling for VdE solutions to stimulate innovation in areas such as:

- **Workforce** – There is a growing need for VdE devices and products that could help to ease the current and projected health care workforce shortage. Potential examples include devices that need fewer fulltime medical attendants and technologies that adopt telehealth components.

- **Chronic conditions** – More than 133 million Americans – roughly 45% of the US population – have one or more chronic diseases.[21] VdE presents an opportunity to deliver needed solutions for this costly public health concern. Product ideas include disease management tools and preventive therapies and devices that are created through VdE.

- **Combat** – With more American service men and women returning from battle with pressing medical needs, next generation VdE devices and technologies are needed now more than ever. Urgent areas of

need include prosthetics, audio/visual adaptive technologies and therapies to address mental health concerns.

Recommendation: *Develop a focused VdE procurement program, administered by the Department of Defense (DoD), Department of Veterans Affairs (VA), and NIH – individually or, optimally, collectively. This VdE program would begin with the identification of patient areas of need or challenge that are appropriate for VdE solutions. The program would formally solicit through the procurement process proposals for targeted VdE device solutions, requiring the incorporation of PAVE core principles in all stages of product development.*

iii. Create a Framework for PAVE Public-Private Investment

It will take a deep commitment from all stakeholders to drive PAVE and jumpstart VdE in the US. These stakeholders represent both public and private interests. Those serious about promoting PAVE can draw from current and past models of public-private collaborations and investments to extract best practices that respond to modern technological advances. These models, which span various sectors of the US economy, offer insights into how to best leverage opportunities to expand on the federal infrastructure, build public-private partnerships, and meet global challenges.

Efforts around a public-private investment structure would be remiss if it failed to look back and understand the underpinnings of one of the nation's most important public-private collaboratives: SEMATECH. This consortium was developed to meet the needs of the semiconductor industry in the US which had fallen behind innovators in Japan and across Asia. Initially funded through Congress in the late 1980s, SEMATECH harnessed the power of the public-private partnership to open doors to innovation and enhanced competitiveness at a time when the US faced a rising global challenge in the manufacturing of semi-conductors. SEMATECH formed a pre-competitive space for stakeholders to work together toward the common goal of moving technologies forward to further advancements in the semiconductor field and for the good of the nation. SEMATECH evolved naturally overtime as it reacted to market demands. This was seen as it moved from a public-private collaboration to private entity. Another key evolution was SEMATECH's move into international markets. This is a unique model that provides an example of ways to function in a pre-competitive platform, while naturally reacting to a changing global marketplace.

One core function that defined the early SEMATECH model was the pre-competitive data sharing platform that turned once siloed intelligence into a "pro-competitive" repository of knowledge. A public-private partnership promoting VdE would likewise build intelligence through pre-competitive sharing of data ranging from preclinical to first in human trials. Drawing upon the models of SEMATECH and other public-private partnerships that have followed, concerns about IP, technology transfer, conflicts interest, transparency and other legal considerations would be properly addressed during the creation of a VdE public-private partnership. Ultimately, the partnership could serve as a Safe Haven for interested parties to move the promise of VdE from the lab to marketplace while spurring the US BioInnovation Economy.

"When I look at the field of medical innovation, I realize, and maybe I'm looking at it as half empty, not half full, but I realize we haven't scratched the surface of what we can know and need to know about dealing with problems. We are still in the Dark Ages. So to me, this is an area that begs for, yes, more money, but more collaboration, more cooperation, more hard thinking by everybody involved."

– Dick Gephardt, President and CEO Gephardt Government Affairs; Chair, Council for American Medical Innovation (March 2011)

A public-private funding pathway should be established for PAVE that can leverage venture capital funding. The largest and most successful of the government venture capital (GVC) initiatives are the Central Intelligence Agency's (CIA) In-Q-Tel and the Department of the Army's (DoA) OnPoint Technologies. Established in 1999, In-Q-Tel's mission is to engage with entrepreneurs, growth companies, researchers, and venture capitalists to bridge the gap between the needs of the intelligence community and new advances in commercial technology. At least $1.4 billion in private venture capital has been co-invested in this initiative. Since 2002, OnPoint Technologies has been addressing the power and energy needs of the US Army through the development of better collaborative ties with young, small, growth-oriented (i.e., early stage technology) companies that take risks and push innovation. An estimated $1 billion in private venture capital was co-invested in this initiative.

Recommendation: *Develop a public-private SEMATECH-type model to lead PAVE. Use a Safe Haven construct for public-private collaboration among government, nonprofit organizations, academia and industry. Draw upon lessons learned from past and current efforts, including SEMATECH, In-Q-Tel, OnPoint and other federal platforms, to understand how best to attract private capital without overly burdensome government intrusion, while protecting downstream intellectual property, ensuring transparency, and providing proven incentives for cross sector investments.*

iv. Create a Federally Supported and Publicly Leveraged VdE Venture Capital Fund

To meet the challenges of the 21st century and remain competitive in the growing global biomedical marketplace, the US should consider creating a PAVE venture fund. Capitalizing on lessons learned from In-Q-Tel and OnPoint, policy makers and other stakeholders would create this venture capital fund to support PAVE innovations across the public, private and partner platforms. The infrastructure of the fund could take form within an existing GVC, such as In-Q-Tel, or through other independent

"It's about a new construct of public private partnerships, where if you've got limited resources, … bring the right stakeholders around the country together, as we would under normal, natural circumstances… to deliver greater response and success in the rates of entrepreneurship."

– Aneesh Chopra
US Chief Technology Officer and Associate Director of Technology, White House Office of Science and Technology Policy (March 2011)

channels. It may make sense to house the venture capital fund within whichever entity has the primary responsibility for overseeing PAVE. The organization of the funding structure would also be an element for consideration. Israel for example, at one time used an 80/20 venture capital to private equity split. [22] The division has now leveled out to about equal investments from both venture capital and private equity firms.

Recommendation: *Create a federally supported and publicly leveraged VdE Venture Capital Fund, built on lessons learned, that is an integrated part of the PAVE public private model.*

v. Consider BioInnovation Trade Mission to Support Commercialization of US VdE Products in the Global Marketplace

The administration should examine the prospect of creating BioInnovation Trade Missions (BTMs) to assist US medical device innovators in their efforts to commercialize medical technologies in global markets. BTMs could be located, for example, in Singapore, to serve China; India and Southeastern Asia; Rio de Janeiro, Brazil, to serve

South America; the European Union and Dubai, to serve the Middle East and Africa. The aim of the BTM would be to accelerate time to revenue for US BioInnovatons. The BTM would provide the requisite, market-sensitive tools and knowledge needed in increasingly attractive global markets.

Recommendation: *Examine the creation of BioInnovation Trade Missions to support commercialization of US VdE products in the global marketplace.*

IV. PAVE: A Regulatory Framework to Advance VdE Product Development

The current regulatory system is viewed by many as cumbersome, time and resource intensive and unpredictable. In order for VdE to meet its promise, improved regulatory systems or approaches are needed. All of this takes place in a context within which FDA – and specifically the Center for Devices and Radiological Health (CDRH) – might be forced by the current budget crisis to cancel its recently announced innovation initiative.

Having a value-driven process that spans design, development, review, and reimbursement has never been more urgent. VdE offers substantial benefit in the development of new innovation processes and individual products. The value, cost and process advantages of VdE are many. However, the ability of VdE to have a positive impact on making better, lower cost medical devices available to customers (both patients and physicians) depends upon the ability of a VdE developed product to successfully complete the FDA regulatory system.

A number of regulatory initiatives should be considered in order to ensure that the regulatory system does not hinder or stymie VdE and, instead, actually supports and advances VdE. It is critical to recognize the importance of the regulatory schema in making VdE a success. It is FDA that decides what must be done to develop and test a medical device. It is FDA that controls the commencement, protocols and data needs of clinical trials. It is FDA that makes the final decision whether a product will – or will not – be made available to physicians and patients.

"In our health care system, we have lived in a world of pay for volume, and all of the work that had to be done, you built a great medical device, you have to beg to the gods of CMS to cover the device for reimbursement, you have to go work with all the payers and you've got to work with all the process because that's the world we lived in."

– Aneesh Chopra
US Chief Technology Officer and Associate Director of Technology, White House Office of Science and Technology Policy (March 2011)

This section presents a comprehensive view of many steps the FDA and the Administration should consider reshaping and reforming today's regulatory schema to be responsive to today's call for VdE product development.

A. FDA Review

VdE Priority Review. As a first step, FDA can go a long way towards advancing VdE by giving priority review to new products that score high on the VdE value metric. FDA can create a VdE "scoring" metric utilizing the concepts set forth in this White Paper and subsequent VdE development. To start, products scoring high on the VdE scale should receive priority review of Investigational Device Exemption (IDE) submissions. This will permit faster clinical trial commencement and earlier clinical and design feedback to the innovator and product development team. As part of the IDE system, FDA can and should adopt its iterative IDE process which, when fully implemented, will permit innovators utilizing VdE principles and processes to start IDE trials early and implement design and protocol iterations based on early clinical results without stopping the initial IDE and restarting.

Within the Premarket Approval (PMA) system, products meeting VdE criteria can be given "fast track" status. Fast track status can be achieved using internal FDA processes and does not require (but could be implemented via) legislative action. This status will reward innovators for adapting VdE criteria and processes. Shaving even a few months off the review process is a substantial benefit for using VdE processes. In addition, FDA can create internal and external support systems to assist VdE based products in navigating the regulatory system. Some of these ideas can be incorporated into the recently announced CDRH innovation initiative. CDRH can train and deploy process experts or managers who can be assigned to specific VdE applications. These process experts or managers will guide the innovator and the submission through the process; ensure prompt attention to the submission; organize meetings with regulators and the sponsor and generally take accountability and responsibility for prompt review of a VdE based submission.

Recommendation: *Create VdE scoring metrics utilizing the concepts set forth in this White Paper and subsequent VdE development. Within the Premarket Approval (PMA) system, allow products meeting VdE criteria to be given "fast track" priority status.*

Recommendation: *Special attention should be given by FDA to incentives for the application of VdE principles to the development of pediatric medical devices.*

Recommendation: *The FDA should allow the introduction and utilization of computer simulation and modeling as a component in the design and development of VdE devices.*

Recommendation: *The FDA should consider identifying specific medical device testing laboratories with expertise in both physical and computational evaluation of devices coming before the agency for 510(k), IDE, PMA, or humanitarian device approval to provide independent review and validation of a device's adherence to VdE criteria.*

The Administration could create financial incentives for VdE based products by reducing user fees for such products. No matter the specific structure, the user fee or tax reduction serves a dual function of encouraging and rewarding VdE adoption and recognizing the overall higher value proposition of VdE products to the general health care system.

Recommendation: *Continue to consider financial incentives for VdE products.*

VdE and 510(k). Historically, when reviewing a 510(k) submission, FDA has been most comfortable with products that add or combine features. These products are generally viewed as "innovative" and usually present no new issues of safety or effectiveness. Conversely, FDA has been seen by some stakeholders as being overly concerned with simplifying or moving the technology into less expert hands. This has been criticized by some as allowing industry and products to "regress". For example, during the Institute of Medicine (IOM) considerations of the 510(k) system, some argued that "substantial equivalence" can mean a product that is only 95% as "good" as the predicate. After a number of product generations or iterations, these stakeholders contend that the new product is a mere shadow of the old and that the system thus allows industry to downgrade the performance and safety of its products. Many therapies and diagnostic products can be moved "downstream" to lower cost users in a safe and effective manner even if the products have fewer of the 'bells and whistles" that might be of interest to high cost specialists.

One aspect of VdE is to improve existing products or technologies in order to significantly increase the value proposition of such products. In these cases, the therapeutic objectives, goals and risks are well characterized. The VdE innovator is increasing the value proposition by reducing cost, moving the technology "downstream" to lower cost delivery points or to the patient, etc. In these cases, all stakeholders are familiar with the scientific and clinical endpoints. The Product Development Protocol (PDP) under 21 USC. § 360c was designed to permit the efficient review of products with known endpoints. Under the PDP process, the company and the agency pre-agree on clinical trials and endpoints. If the clinical trial

"… one of the big ironies is that in the US health care system, particularly CMS, a company will have to underwrite the development of a project, underwrite the regulatory process, underwrite any trials, and then to get reimbursed go show that it's actually useful."

– Dr. Uday N. Kumar
Founder and Chief Medical Officer, iRhythm Technologies Inc. (March 11, 2011)

satisfies the pre-determined endpoints, the submission gets approved. The PDP process is essentially never used. Yet the potential value of this type of process is obvious. Having pre-determined endpoints provides for agency/innovator cooperation and early interactions and certainty. Assuming that the clinical endpoints are met, the PDP type process provides a fast, efficient and value added approval process. Stakeholders should work with CDRH to revitalize the PDP process to make it applicable to VdE based products.

CDRH is currently involved in rethinking the 510(k) system overall. For example, CDRH is in the midst of a pilot project using an assurance case model for product development and testing. CDRH should not adopt requirements or guidance documents that may risk inadvertently limiting, restricting or imposing any burdens on VdE based products.

Iterative products utilizing VdE processes can also be considered as "substantially equivalent" under the 510(k) program with less data submission requirements. This process would be similar to the current processes for certifying compliance with established standards as the basis for the clearance decision. Likewise, VdE processes should explicitly be considered to be design standards that satisfy quality system regulation (QSR) requirements including 21 CFR 820 and ISO 13485. Under this construct, VdE standards can satisfy design criteria for approval purposes.

Recommendations

- *FDA should explicitly support as "substantially equivalent" devices that take the therapy or diagnostic "downstream" to less specialized, lower cost health care providers and even to patients.*
- *Recognize the 510(k) reform process as a key opportunity to build VdE principles into product development and testing processes.*

Market incentives for VdE. There are also direct economic incentives that can be provided for products satisfying VdE criteria. A classic example of such incentives is extended market exclusivity. Market exclusivity can be provided through mechanisms similar to Hatch Waxman and the biosimilars legislation.

Recommendation: *Recognizing the distinct variation between drugs and devices, the FDA should explore market incentives appropriate to VdE products.*

Enhanced support for the VdE Innovator

As the VdE innovator approaches the challenges of testing and validating a disruptive VdE technology, a special focus should be given to i) scientific and engineering methods supporting the VdE product innovation, and ii) special systems in support of the VdE innovator.

Recommendations

- *Fund a regulatory science grant to examine the scientific and engineering methods of VdE product development..*
- *Create regulatory science Centers of Excellence in VdE.*
- *Establish a system to support VdE device innovators as they seek to*

move an innovative device through the intricacies of the regulatory process deployed through independent PAVE centers, approved by FDA, with demonstrated VdE expertise and a willingness to provide mentoring support for start-up VdE innovators.

B. Value-Driven Reimbursement

Historically, FDA review and approval proceeded on one track with coverage and payment decisions proceeding independently. Two regulatory decisions are necessary for market success. First, FDA must approve the product for market. Second, CMS must make coverage and payment determinations. Without both, one does not have a realistic market success.

These regulatory challenges are particularly difficult for small medical device manufacturers, yet much innovation begins with such enterprise. The regulatory costs of conducting a medical device clinical trial and device user fees require considerable capitalization, often beyond the reach of small companies. And even if the product clears the FDA, the company then faces the challenges of how to get reimbursed.

Usually, but not always, FDA approval or clearance preceded CMS reimbursement and often utilize very different criteria and evidence. A number of commentators have suggested either operating these two processes in parallel or, less commonly, having a decision by one body serve as the decision in the other. In fact, CDRH and CMS recently announced a pilot program for parallel, integrated review by CDRH and CMS. Conceptually, such parallel and coordinated review should result in faster, more efficient and more predictable decisions necessary for total market viability. However, this pilot program has not been successful primarily because sponsors see too much risk in this parallel process. The benefit of simultaneous regulatory decisions is not obvious to all comers.

The challenge is to devise a system that actually works. Here, the VdE concepts provide the bridging opportunity. Products that satisfy VdE criteria could get special priority consideration on the reimbursement side. In addition, the risk of early CMS national coverage decisions must be addressed. Sponsors fear a negative national coverage decision based on preliminary information. It is important to remember that products satisfying VdE criteria have already been through a value assessment including cost. As such, these products have already been assessed for health care value.

Recommendations

- *Create linked FDA/CMS pathways that innovators will actually use.*
- *Define the respective areas of expertise between CMS and FDA.*
- *Avoid duplicative or iterative data requirements.*
- *Provide priority consideration for reimbursement of VdE products that utilize a parallel FDA/CMS review track.*
- *Allow the introduction and utilization of computer simulation and modeling approaches to demonstrate clinical utility, reduced complexity and projected cost reduction associated with VdE products.*
- *CMS should be encouraged to adopt a coverage with evidence outcome for VdE compliant products and not deny coverage given these product's satisfaction of VdE criteria and the preliminary nature of the data.*

V. PAVE INNOVATORS – Training and Inspiring the Innovators of Today and Attracting the Best and Brightest Leaders of Tomorrow in the BioInnovation Economy

"Remember that our collective goal is not just producing more scientists and engineers. This is a means to an end. Our real goal is to use our minds and our resources to create opportunity and employment across the whole spectrum of our society."

– Dr. Charles M. Vest
President, National Academy of Engineering
(March 2011)

Value-driven engineers need technical expertise to find feasible solutions to critical problems. Yet technical expertise is not enough: value-driven engineers need to understand human and societal needs – what is desirable – and pragmatic aspects of manufacture, context, maintenance, and sustainability to produce solutions that are viable in their intended market or application. Innovation is rarely about – or driven by – technology in isolation. Educating the next generation of value-driven engineers requires broadening the questions our students are taught to ask. This is not a new call: from *Rising Above the Gathering Storm* to *Engineering the Future*, from *Wired to Care* to *Change by Design*, the need for empathetic and entrepreneurial engineers has been widely discussed. The world needs more T-shaped people – with breadth and depth – rather than solely deep – I-shaped – engineers. The challenge is how to educate them.

We learn what we practice. To produce value-driven engineers, we must create educational environments in which our students practice Value-driven Engineering. They must learn to ask their own questions, to set their own problems, to create responsive designs, obtain feedback, build, fail, try again, persevere. Interdisciplinarity and creativity are key. If we want graduates who engineer value, we must provide our students with opportunities to practice Value-driven Engineering. They must communicate, work in teams, get their hands dirty, self-evaluate, plan, reassess. Only by being apprentice value-driven engineers will they obtain the requisite skills to become masters at this craft.

Fortunately, there are numerous successful examples of educational environments providing exactly this kind of experience. Among those the group was able to identify: the Austen BioInnovation Institute at Akron; the Center for Bioengineering Innovation and Design program at Johns Hopkins University; the University of Kansas Institute for Advancing Medical Innovation; Stanford Biodesign Program; the Health Sciences and Technology Program at MIT and Harvard and MIT's Deshpande Center; Olin College; the NAE Grand Challenge Scholars Programs on many campuses. Identifying other successes and growing them – using them as models to share with others – is a first step in an agenda to educate the next generation of value-driven engineers.

It is not, however, sufficient to identify successful models and expect other institutions to emulate them. A long history of failure to widely transplant educational innovation – e.g., the Engineering Coalitions project – serves to underscore the context-sensitivity of education. Ultimately, successful educational innovation is owned by its practitioners – those who instruct and implement the curriculum – and is fitted to the institutional needs and culture in which it thrives. Educational innovation is rarely straightforwardly "exportable" or "disseminable"; instead, it must be co-designed and co-created for its intended context. Thus, our recommendations substantially concern the building of communities (at the post-secondary level, at the K-12 level, and outside of academic institutions). These communities, seeded with inspiration and leadership, can create organic and authentic value-driven engineering educational environments.

Recommendations

- *Adopt the Open Innovation model for education.*
- *Develop and distribute a guidebook of best practices for all disciplines, including academia, industry and non-academic partners who are close to the practice of Value-driven Engineering.*
- *Promote Innovation Literacy: "Utility rather than Complexity."*

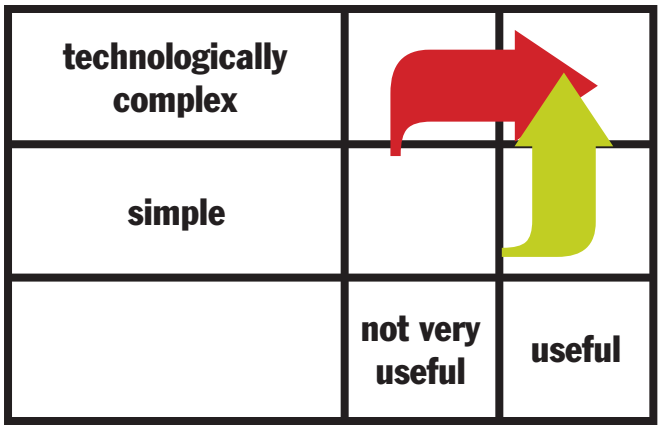
- *Develop a program (modeled on NSF's Research Experiences for Teachers) in which K-12 teachers partner with postsecondary institutions and corporations to have innovation experiences and to develop innovation literacy curricula to be used at the K-12 level.*

- *Empower and motivate young people to be innovative by providing venues to further their technical abilities.*

- *Create an Innovator Corps. Provide a volunteer pathway for all ages to experience and practice Value-driven Engineering in the service of society, thereby enlarging the pool of innovators and creating a cultural celebration of innovation.*

- *Sponsor national-yearly PAVE conferences and workshops on the topic of VdE, where private and public participants share and learn best practices.*

- *Sponsor national PAVE competitions designed to accelerate VdE design thinking and solutions, including student competitions, early-stage company competitions, and larger x-prize competitions.*



A. Critical Partners

It is absolutely essential that all sectors be involved in the process of inspiring, training, and developing the present and future innovators. These sectors include academia (i.e., universities and medical centers), government (i.e., FDA), private sector (industry), and the non-profit sector (i.e., health delivery organizations, foundations).

In general, organizations are not optimally designed for working together across multiple sectors (institutions, professions, disciplines). PAVE mechanisms will need to include considerations (incentives, processes, etc.) that help alleviate these intrinsic challenges.

B. Federal Funding Strategies

A portfolio of recommendations will be required to begin to change the culture and expectations such that VdE becomes mainstream.

There is a lack of course content, including case studies and design labs, on VdE in the standard undergrad, graduate, and professional engineering curricula in the US.

Recommendation

- *Mandate all federal funding agencies to include in their educational grant RFA's a requirement for attention to the need for development of course content that focuses on VdE, including educational and training materials suitable for use in the training of employees within organizations interested in expanding into markets requiring products based on VdE principles on two tracks: (1) development of in-depth academic programs of education and research focused on understanding and advancing the field of VdE, and (2) inclusion of VdE principles and practical training throughout US engineering curricula, developing a paradigm for US engineers.*

US-raised engineers often lack the mindset to excel in VdE due to lack of exposure to resource-constrained work environments. In addition, most companies struggle with creating profitable business models around VdE products, meaning products that serve the needs of low-resource customers in a manner that provides real value to customers and commercial sustainability to the venture.

Recommendations

- *Mandate all federal funding agencies to increase funding support for programs that send US-based engineers to low-resource areas as part of programs that educate participants on ethnographic skills, needs identification, and market constraints, and challenge them to design and deliver solutions that are viable for those markets and environments.*

- *Provide tax credits for corporations to develop VdE devices as well as internship programs at international locations.*

In addition to the need for content creation and case dissemination, there is a need for formal training programs for both students and working engineers to ensure VdE skills are deployed.

Recommendation

- *Provide funding to support the development and establishment of short-term courses (2-3 weeks) at universities on VdE engineers with America's biomedical industry.*

C. Work Force Development

The development of the culture of innovation is important at all levels of our education. This requires partnership from government, industry, and academia to work together to help in creating awareness and training of innovation from K-12 to higher education. The following outline develops some critical good practices that could be incorporated in attracting the best and brightest leaders of tomorrow.

K-12 Education: Currently across the country, there are well established programs on Science Day in K-12 education. The competition at school, district, state, and international level continues to be very effective in promoting and exposing the students to principles of scientific methods. Some examples include:

- a program of Young Inventors Hall of Fame that promotes and honors young inventors (http://nmoe.org/gallery/index.htm); and

- the Rubber Band competition at the University of Akron promotes young kids to come up with some clever ways to use rubber bands and this has resulted in some very clever invention and drive for innovation in the mind of these young kids (http://rubberbandcontest.org/).

Best Medicine Engineering Fair started at ABIA promotes interaction of students with physicians and biomedical engineers to promote innovation in the area of medical sciences (http://www.abiakron.org/bestmedicine). There is a strong need to coordinate these activities at the state and federal level. The establishment of PAVE Junior Scholars and PAVE prizes for best innovation projects at Science Day will promote the culture of innovation. The recognition, promotion, and publicity of junior PAVE scholars at a national level could go a long way in promoting and cultivating innovation.

Recommendation

- *Sponsor national "PAVE Young Scholars Program (K-12)" to promote and attract projects driven by innovation and awarded with the opportunity to present at the White House Science Fair.*

Undergraduate Education: Currently, our education is based on traditional disciplines and department. There is a strong need to develop and introduce the training of innovation in the scientific curriculum. There are some good examples of project-based approach used at Franklin W. Olin College of Engineering in promoting entrepreneurship and innovation in education. There is a strong need to incorporate the successes of these ideas in the training program in undergraduate education. Project-based design classes, reverse engineering, and VdE curriculum can be promoted. Many institutions have used student internship in industry to promote the concept of real-world training in their education. There is a value in promoting this activity at a National level.

Recommendation

- *Sponsor PAVE Undergraduate Fellowships tied to internships, problem driven undergraduate projects, and training in innovation awarded based on grades and submission of a strong proposal idea for innovation.*

The partnership of foundations like Kauffman, industry, government, and academia will be extremely useful in promoting this training. Programs such as NSF, NIH, and DOE could develop programs to fund undergraduate projects primarily driven by students rather than professors. Develop partnership between government and industry to enhance the experience of undergraduate internship through PAVE scholarships.

Graduate Education: There are several successful models in funding graduate students and research in academia using fellowship and research grants by federal agencies. Our current education is very disciplinary and has a strong need for training future scientists to innovate.

Recommendation

- *Sponsor PAVE fellowships for graduate students targeting innovation, interdisciplinary research, team-based education and research, and exposure to entrepreneurship.*

The Biodesign Class initiated at Stanford has resulted in many successes of research translating to industry (http://innovation.stanford.edu/bdn/index.jsp). The partnerships of the Stanford Biodesign team with India and Singapore brings together a valuable component of innovation in global economy. The Biodesign model has also been adopted at MIT, John Hopkins, OLIN, and University of Akron.

The PAVE graduate fellowships could specifically target toward proposals that incorporate and targets innovation. Small business grants could be developed for promoting entrepreneurship, value driven engineering, and innovation. The coupling of business, science, and medical students into research teams could be an excellent model to drive technology to market. SBIR grants from NSF, NIH, and DOE could be integrated to fund projects specifically driven by graduate students. The current funding model for research has been excellent in promoting fundamental research. The PAVE fellowships and programs targeting toward funding innovation will target the translation of these ideas to industry. The translation of these new ideas to start-ups and small companies are important to job growth and growth of our economy.

Conclusion

The Austen Bioinnovation Institute in Akron as the convener of the Summit on Value-driven Engineering and US Global Competitiveness, together with the Summit Steering Committee, appreciate this opportunity to present a call for a new Platform to Advance Value-driven Engineering – PAVE. This integrated, federal architecture will recognize the key links between Value-driven Engineering and our global competitiveness, encourage a new national conversation on how we measure and design toward "value," and offer a core component of our national response to the challenge of looming costs of healthcare. We look forward to active engagement on this national priority.

ADDENDUM A: Summit Agenda

"Value-driven Engineering and US Global Competitiveness"
March 10 & 11, 2011
Washington, D.C.

Thursday, March 10, 2011 – Evening Reception and Dinner

Keynote Address: "Value-driven Engineering and US Global Competitiveness Call to Action"

- Aneesh Chopra, US Chief Technology Officer, Assistant to the President and Associate Director for Technology, White House Office of Science and Technology Policy

Friday, March 11, 2011 – Safe Haven Summit

Opening Comments

- Frank L. Douglas, PhD, MD, President and CEO, Austen BioInnovation Institute in Akron

The Challenge

- Richard Gephardt, President and CEO, Gephardt Group Government Affairs
- Charles M. Vest, PhD, President, National Academy of Engineering
- Raj Jammy, PhD, Vice President, Emerging Technologies, SEMATECH
- A. Seth Greenwald, DPhil (Oxon), Director, Orthopaedic Research Laboratories
- Mike Hess, Vice President, Innovation Excellence, Medtronic

Video Remarks

- Sen. Sherrod Brown (D-OH)

Panel 1: Value-driven Engineering: Case Studies from the US and the Globe

- Moderator: Trevor Jones, Chairman and CEO, Electrosonics Medical Inc.
- Ashesh Shah, President and CEO, Maxx Orthopaedics
- Uday N. Kumar, MD, Founder and Chief Medical Officer, iRhythm Technologies Inc.
- Matthew Callaghan, MD, Founder, One Breath
- Charles J. Bruce, MD, Director of Interventional Imaging, Mayo Clinic
- John Sullivan, Director, Systems Integration, LifeScan Inc.
- Al Hammond, PhD, Senior Entrepreneur, Ashoka

Panel 2: Value-driven Engineering: Training the Next Generation to Change the Paradigm

- Moderator: Martha Gray, PhD, J.W. Kieckhfer Professor of Medical and Electrical Engineering, Harvard-Massachusetts Institute of Technology Division of Health Sciences and Technology (HST)
- Lesa Mitchell, Vice President of Advancing Innovation, Ewing Marion Kauffman Foundation
- Joseph Smith, MD, PhD, FACC, Chief Medical and Science Officer, West Wireless Health Institute
- William J. Heetderks, PhD, MD, Director, Extramural Science Program, National Institute of Biomedical Imaging and Bioengineering
- A. Jay Khanna, MD, MBA, Associate Professor of Orthopaedic Surgery and Biomedical Engineering, Johns Hopkins University

Working Group Sessions

- Workgroup A: Training the next generation of Value-driven Engineers
- Workgroup B: Creating a framework for identifying areas of opportunity for VdE
- Workgroup C: Developing current and new strategies for funding programs that support VdE
- Workgroup D: Creating a new public-private partnership model to advance US VdE in a global marketplace

Working Group Reports

- Representatives from each Working Group

Wrap Up and Next Steps

- Frank L. Douglas, PhD, MD, President and CEO, Austen BioInnovation Institute in Akron

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