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A Policy Framed Analysis of the Valley of Death in U.S. University Technology Transfer

William Ker Ferguson
University of Southern Mississippi

The University of Southern Mississippi

A POLICY FRAMED ANALYSIS OF THE VALLEY OF DEATH IN U.S. UNIVERSITY TECHNOLOGY TRANSFER

by

William Ker Ferguson

Abstract of a Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

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ABSTRACT

A POLICY FRAMED ANALYSIS OF THE VALLEY OF DEATH IN

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At least as far back as the enactment of the Bayh-Dole Act of 1980 there has been an ongoing desire on the part of politicians, policy-makers and the public in the U.S., to obtain greater economic returns on the federal investment in publicly funded university research. Today among policy-makers there is an apparent belief that a capital shortage in the mid-stages of technological development is the rate-limiting factor, preventing the maximum flow of university inventive knowledge from entering the marketplace. The consequence is a Valley of Death demise for the vast majority of university inventions. In order to mitigate the problem, changes to federal granting policies are placing increased emphasis on funding more applied and translational research than basic fundamental science. Given the foregoing direction of policy, the study set out to confirm the current understanding of the Valley of Death on the part of policy-makers and relate this understanding to the historical evidence.

Consistent with present-day political pronouncements, the study findings verify an overwhelming belief that a shortfall of applied research funding is the root cause of the Valley of Death. Policy-makers believe this shortfall constrains the development of basic research into commercializable products. However, the study also found that this perception is inconsistent with the empirical evidence. The study reveals a gap between these sectors but the gap is independent of the stage of technological development. A

funding difference extends the entire length of the research and innovation spectrum, suggesting other factors are responsible for the adoption of university inventions, bringing into question the direction and likely efficacy of current policy initiatives.

The findings lend credence to the less cited cause of the Valley of Death, namely a Darwinian Sea of survival of the economically fittest technologies (Auerswald & Branscomb, 2003). The actual stage of development of a university invention will determine the extent of investment funding necessary for its continued development, but economic factors will determine if further investment in its development is warranted. A death does exist for many inventions, but it is the result of natural market causes and not a funding shortfall, per se.

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Approved:

Chad R. Miller
Director

Cyndi H. Gaudet

Patti P. Phillips

Dale L. Lunsford

Brian W. Richard

Maureen A. Ryan
Dean of the Graduate School

May 2014

DEDICATION

Foremost I want to dedicate this project to my wife Cindy whose patience, personal sacrifices, support, and continuous encouragement allowed me to successfully take on this challenge and enabled my progression over the course of this journey. I would also like to dedicate this work to our two daughters, Ashley and Brittany, who have and will continue to be an inspiration to me and who have taught me that life is not a dress rehearsal.

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Additionally, I would like to state that this endeavor would not have been possible without the support of Dr. Russ Lea. As one of his direct report employees at the outset of this journey, he challenged me to engage myself in further professional development and simultaneously provided the necessary latitude and support for my success. I will always remain grateful for both his challenge and support.

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LIST OF ABBREVIATIONS AND DEFINITIONS OF KEY TERMS

ACF – Advocacy Coalition Framework

AUTM – the Association of University Technology Managers

Applied Research – generally a systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met (NSF, 2011).

ATP – Advanced Technology Program under the authority of the National Institute of *Standards and Technology, abolished under the America Competes Act of 2007.*

BARDA – The Biomedical Advanced Research and Development Authority, a department within the U.S. Department of Health and Human Services.

Basic Research – generally a systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind (NSF, 2011).

Bayh-Dole – the Bayh-Dole Act of 1980. Section 6(a) of Pub. L. 96–517, Dec. 12, 1980, 94 Stat. 3018, is also popularly known as the Bayh-Dole Act and as the University and Small Business Patent Procedures Act of 1980.

CRDG – Collaborative Research and Development Grant

Developmental Research – generally a systematic applications of knowledge or understanding directed toward the production of useful materials, devices, and systems or methods, including design, development and improvement of prototypes and new processes to meet specific requirements (NSF, 2011).

GDP – gross domestic product

IP – Intellectual Property consisting of discoveries, inventions, patents, know-how, etc., emanating from research and development activities, which may or may not contain potential for commercial exploitation.

JOBS – The Jumpstart Our Business Startups Act

NIH – National Institutes of Health

NPF – Narrative Policy Framework

NSERC – Natural Sciences and Engineering Research Council of Canada

NSF – National Science Foundation

R&D – research and development

Research – a systematic study directed toward fuller scientific knowledge or understanding of the subject matter; may be sub-classified as basic, applied, or developmental according to the objectives of the study.

RFI – specific request for information as published in the Federal Register, March 2010, p.14476

S&T – science and technology

SBIR – Small Business Innovation Research

STTR – Small Business Technology Transfer

TTO – technology transfer office at a university

U.S. – United States

USPTO – the United States Patent and Trademark Office

CHAPTER I

INTRODUCTION

Increasingly, the value of academic research to society is being measured by the translation of its results into marketable products and services (Obama, 2011). Central to these translational efforts is the university technology-transfer process, which has been the subject of growing academic and public interest in the U.S. since the time of the Bayh-Dole Act of 1980 and today remains a focal point of policy attention (Graff, Heiman, & Zilberman, 2002). This interest is no better exemplified than when the White House issued a request for information (RFI) to identify ways to increase the economic impact of the federal investment in university research (RFI, 2010). The White House requested information on current best practices in the field and sought suggestions to help expedite the movement of technologies out of the laboratory and into the market. Evidence to date indicates the vast majority of university inventions fail to achieve economic success, and this phenomenon has been dubbed the Valley of Death (Auerswald & Branscomb, 2003). This metaphorical valley represents the graveyard for new technologies where they perish in an attempt to move along their development pathway from an initial idea to the end-market in the form of new products, processes, and services.

The White House RFI was an initiative to gather input on the issues of the Valley of Death and to develop a consensus strategy to mitigate its effects. It is generally accepted in the public policy literature that perceptions and coalitions of shared beliefs form the impetus of policy-making (Sabatier, 1991; Shanahan, Jones, & McBeth, 2011). As such, the RFI provided a mechanism to crystallize shared beliefs and to help form a coalition for future policy direction on the Valley of Death. Unfortunately, a review of the literature reveals little published empirical work to lend credence to any anecdotal evidence, which could be proffered from the responses to the RFI. To help support the attainment of national goals for the effective translation and market adoption of university inventions, further research is needed on the nature and cause(s) of the Valley of Death. Contribution to these aims underpinned the motivation for the study.

Background

President Obama's Administration's attention to the economic potential of academic research is most laudable. However, recognition of the importance of basic scientific research and its role as a driver of technology-based economic development in the U.S. is not new, neither is the desire for politicians and policymakers to seek ways to enhance its effectiveness (cf. Abramovitz, 1956; Arrow, 1962b; Bush, 1945). A deeper recognition of the merits of basic scientific research to society began to emerge in the United States toward the end of the Second World War. Vannevar Bush, Director of the Office of Scientific Research and Development at the time, presented a report to the President on a program for postwar scientific research (Bush, 1945). As a prefacing comment to the published report, President Roosevelt remarked "the Office of Scientific Research and Development represents a unique experiment of team-work and cooperation in coordinating scientific research and applying existing scientific knowledge to the solution of the technical problems paramount in war" (Bush, 1945, p. vii). Roosevelt further speculated that the structure employed and the lessons learned could be effectively utilized in times of peace, and toward that end, he expressed the following:

> The information, the techniques and the research experience developed by the thousands of scientists in the universities and in private industry, should be used in the days of peace ahead for the improvement of the national health, the creation

> of new enterprises bringing new jobs, and the betterment of the national standard of living. (taken from the copy of a letter from President Roosevelt, reproduced in the preface to Bush, 1945, p. vii)

The net result of Roosevelt's belief was the development of a national policy position on the utilization of scientific knowledge for the *public good*, and that principle has formed an essential component of U.S. administrative and economic policy for almost seventy years.

Concurrent with the policy position espoused by Roosevelt, the economic thought-leaders of the day were re-formulating classical and neo-classical economic theory. Innovation, over and above labor and capital, was becoming recognized as the primary impetus of economic growth (cf. Arrow, 1962b; Bush, 1945; Schumpeter, 1939; Solow, 1956). Consequently, the U.S. policymaking principles of fostering basic science as a potential driver of innovation and economic development directly paralleled emerging academic thinking. Formal federal commitment to the application of science from that time has been evidenced by such follow-on measures as the creation of the National Science Foundation in 1950, the passage of the Bayh-Dole Act in 1980, the Small Business Innovation Act 1982, the National Cooperative Research Act of 1984, the Technology Transfer Act of 1986, the Advanced Technology Program under the Omnibus Trade and Competitiveness Act of 1988, the Technology Innovation Program under the America Competes Act of 2007, and has most recently revised patent legislation under the America Invents Act of 2011.

Within the public policy realm of university technology transfer, the Bayh-Dole Act of 1980 has been touted as having a key influence on the rate of growth of technology transfer activity (Mowery, Nelson, Sampat, & Ziedonis, 2004). Similar to the motivation for the recent White House RFI, the original purpose of the Bayh-Dole Act was to address a perceived failure in the transfer of public sector research results to the private sector. Unlike today where the failure to translate research results is now believed to stem from an applied research funding shortfall, in 1980 the consensus belief for the failure was a lack of granting agency consistency with respect to ownership and transferability of intellectual property rights ("Bayh-Dole," 1980). The resulting legislation vested universities with ownership rights to inventions emanating from federal research funding, plus the ability to license those rights to industry.

By many accounts the Bayh-Dole Act has been considered a success and as stated in the Congressional Research Service's recent report to Congress, "the Bayh-Dole Act appears to have met its expressed goals of using the patent system to promote the utilization of inventions arising from federally-supported research ... and to promote collaboration between commercial concerns and nonprofit organizations, including universities" (Schacht, 2012, p. 8). In one of the earliest reviews of the legislation, the General Accounting Office found agreement among university administrators and small business representatives, stating that the Bayh-Dole Act had "a significant impact on their research and innovation efforts" (U.S. General Accounting Office, 1987, p. 3). The Association of University Technology Managers (AUTM), the professional body for universities and other research-related organizations engaged in technology transfer, also cites "one need only review the data we've gathered over the past twenty years to know that the Bayh-Dole Act is working. Innovative technologies no longer sit in university labs benefiting no one" (AUTM, 2010, p. 3). The organization boasts that, as a result of university innovations, products that benefit the public enter the market every day and new companies are formed each year, "putting Americans to work and bolstering local economies" (AUTM, 2010, p. 3). In addition, AUTM notes 38,473 active technology licenses exist between its members and industry, producing approximately $2 billion annually in licensing revenue for universities (AUTM, 2011).

What both AUTM and the noted reports to Congress fail to highlight is the approximate 300,000 invention disclosures received by TTOs since the enactment of Bayh-Dole that have failed to make it to market (AUTM, 2011). Utilizing AUTM's numbers represents a potential multiplier effect of approximately 9 times what has been commercialized to date, or an estimated $18 billion annually in additional royalty income to universities. Since universities only receive royalty licensing income as a small percentage of the final product sales by a licensee company, averaging 3% (Stevens & Phil, 2003), the potential economic opportunity cost of the failure of inventions to be commercialized translates to $600 billion annually.

The foregoing estimate of the potential economic scale of the issue not only provides a logical rationale for the level of public interest but also underscores the concern that the commercialization process should be as effective as possible. This concern is evidenced not only by the previously mentioned RFI, but also by calls from other engaged parties such as the Kauffman Foundation. They have argued "although there is general consensus … that the Act [Bayh-Dole] has accelerated the commercialization of university-developed inventions … there is reason for believing that the pace and amount of commercialization is sub-optimal" (Litan & Mitchell, 2009, p. 1). The calls for improvement immediately prompt additional questions, not the least of which is to increase the emphasis of academic R&D as a strategic vehicle for economic development rather than economic development being a by-product of university R&D, which are two radically different objectives. This re-focus represents a fundamental shift in academic purpose that many academicians question and fear (Lee, 1996).

From a political standpoint, the 2012 presidential race between Obama and Romney served to provide recent insight into current perceptions on the matter of university research commercialization. On the one hand, Obama stated he would seek to increase the federal commitment for basic research, which is consistent with his previously stated positions, including the time when he noted in a National Academy speech, “it was basic research … that would one day lead to solar panels … the CAT scan … GPS satellites” (Obama, 2009, p. 4). Contrastingly, Romney recognized the value of basic research but would have focused federal research policy on developmental programs (versus basic research) to form a platform for future private sector commercialization (Obama & Romney, 2012). Romney did not suggest how new underlying basic research would emerge as a feeder for follow-on development. In this regard, Obama’s position appears more nuanced than Romney’s does, given Obama follows accepted academic thinking and provides an acknowledgement of the understanding that basic research forms a foundation for invention, which is an input for economic innovation (Maclaurin, 1953). Despite differences in political positions, a common underlying belief was demonstrated by both politicians, namely a need to enhance the technology transfer process.

Prima facie academic evidence for the belief that the research currently taking place on U.S. university campuses may lay the foundation for future economic growth and societal well-being is further demonstrated by the peer-reviewed journal, *Economic Development Quarterly*. This journal focused its entire February 2013 edition to the matter of university technology transfer and its impact on economic development. The potential of basic university research is also captured in the following statements contained in the Federal Register, “The Federal government supports university-based research for a variety of reasons. Expanding the frontiers of human knowledge is a worthy objective in its own right. Basic research that is not motivated by any particular application can have a transformative impact” (RFI, 2010, p. 14476). However, at the opposite end of this ideological position is the reality politicians and policymakers face, namely the accountability associated with spending taxpayers’ dollars. This dilemma is evidenced by an ensuing statement contained in the same RFI cited above, “The Administration is interested in working with all stakeholders (including universities, companies, federal research labs, entrepreneurs, investors, and non-profits) to identify ways in which we can increase the economic impact of federal investment in university R&D” (RFI, 2010, p. 14476). In a similar vein, recent academic attention has focused on the efficiency and effectiveness of transferring the results of publicly funded basic research to the private sector (cf. Graff et al., 2002; Litan & Mitchell, 2009; Niosi, Treurnicht, & Samarasekera, 2008). The dichotomy between the level of federal investment in R&D activity and the perceived economic returns frames the current political and policy environment surrounding university technology transfer.

A desire exists to utilize university technology transfer as an embedded and fundamental element of an innovation-driven, national economic development strategy (Obama & Romney, 2012; RFI, 2010). The current mechanisms of university technology transfer have predominately grown from patenting and licensing activity being undertaken as a specific consequence of the Bayh-Dole Act and have become an embedded component of American university infrastructure (Graff et al., 2002; Mowery et al., 2004). Although a technology transfer process is in place to support the translation of research results, the most efficient and/or effective structure for that process remains a question (RFI, 2010). Given the indication of the extent of potential economic benefit available should more inventions be able to complete the process of commercialization (*Economic Development Quarterly*, February 2013), a full comprehension of this issue is warranted. Deeper understanding, in turn, will yield appropriate, fact-based models to lend credence to the belief systems to guide the policy process (Sabatier & Jenkins-Smith, 1993). In the pages that follow, including the conceptual and theoretical frameworks in this chapter and the literature review in Chapter II, additional perspective has been provided on university technology transfer and the Valley of Death, which are framed within the U.S. federal policy context.

Conceptual and Theoretical Underpinnings to the Study

To better understand the technology transfer environment and the positioning of university commercialization activity relative to academic research and industrial innovation, a conceptual framework outlining this interaction is provided in Figure 1. The conceptual framework locates federal R&D grant funding as input into the production of new knowledge. The subsequent dissemination and adoption of this new knowledge yields societal returns in such forms as improved education, health and welfare, etc. The theoretical basis underpinning this component of the conceptual framework is founded in human capital development theory, the essence of which is the creation, dissemination, and application of knowledge for individual, organizational, and societal benefit (cf. Becker, 1964, 2002; Kern, 2009; Leslie & Brinkman, 1988; Mincer, 1984).

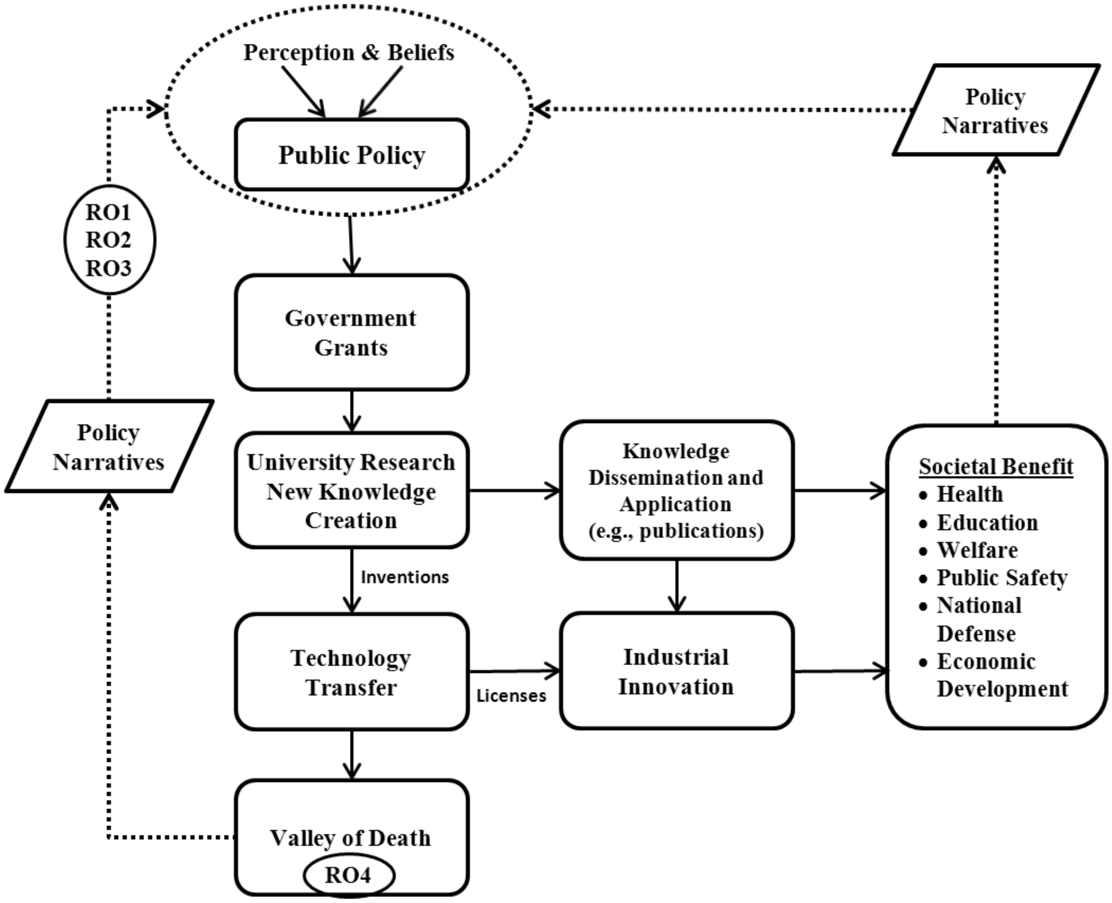

Figure 1. Conceptual framework for the generation and dissemination of academic knowledge and how policy on the granting process are shaped from perceptions and beliefs surrounding the outcomes.

From time to time, outputs of the university, knowledge production-function may take the specialized form of an invention. Knowledge in the form of inventions becomes input to the university, technology transfer process, which falls under the purview and management of university technology-transfer offices (TTOs). The flow of inventive knowledge reaches TTOs in the form of invention disclosures from the institution's researchers. Essentially, the TTOs endeavor to have inventions incorporated into the industrial innovation process through contractual arrangements with the private sector to produce mutual economic benefit (Graff et al., 2002). Transfers to the private sector have the potential for broader societal effect through their influence on innovation and technology based economic development. Current understanding of the impact of this component of the conceptual framework and the secondary knowledge flow it generates has its foundation in the precepts of endogenous economic growth and economic development theory (cf. Aghion, Howitt, & García-Peñalosa, 1998; Arrow, 1962a, 1970; Brzustowski, 2006; David, 1975; Denison, 1962; Duesenberry, 1956; Freeman, 1990; Romer, 1994; Schmookler, 1966; Schumpeter, 1939). For the reader unfamiliar with university technology transfer operating procedures, Appendix A provides a detailed description of the technology transfer process and the historical performance measures associated with TTOs.

Unfortunately, not all of the knowledge emanating from TTOs finds its way to market, and the great majority of university inventions fail to be commercialized, ending up in the Valley of Death prior to reaching industry (AUTM, 2011; Ford, Koutsky, & Spiwak, 2007). Today, the apparent consensus of thought among politicians, academics, and policy-makers is that an applied-research funding shortfall constrains basic university research from translating into further commercial development (cf. Auerswald & Branscomb, 2003; Frank et al., 1996; H.R. Rep. No. 105-B, 1998; Katehi, 2010; Markham, 2002; Moran, 2007; Murphy & Edwards, 2003, Wessner 2005; Williams, 2004; Wylie, 2011). The foundation for this prevailing belief is drawn from the notion that the focus of university research is primarily conducted at the basic end of the research spectrum, whereas industry's research focus is at the developmental end. A funding gap in the middle stage (i.e., applied research) creates a disconnection, which is manifested as the Valley of Death.

From the conceptual framework in Figure 1, both the positive outcomes (Societal Benefits) and negative outcomes (Valley of Death) that result from the academic research enterprise create perceptions and beliefs surrounding the effectiveness of the process in the minds of politicians, policy-makers and the public. Importantly, perceptions and beliefs frame the design and implementation of public policy (Sabatier, 1991; Sabatier & Jenkins-Smith, 1993; Sabatier & Weible, 2007). As a growing body of empirical literature has demonstrated (cf. Bedsworth, Lowenthal, & Kastenberg, 2004; Bridgman & Barry, 2002; McBeth, Shanahan, Hathaway, Tigert, & Sampson, 2010), policy narratives are the key mechanism for influencing the perceptions and beliefs that eventually direct policy-making. Governing policies need to be congruent with the desired outcomes in order to achieve objectives; therefore, the perceptions and beliefs surrounding the Valley of Death need to be fully informed to effectively direct policy and address the Valley's root cause.

Statement of the Problem

In an attempt to respond to calls for greater economic returns and to mitigate the Valley of Death phenomenon, politicians, policymakers, and program directors for the U.S. national research granting councils are implementing strategic changes to federal grant programming. Changes are reflected in such initiatives as *i*Edison, which was introduced to track patenting and commercialization activity associated with inventions resulting from federal research grants (NIH, 2013a). In addition, an amendment to NSF's grant terms and conditions requires universities to publicly report their transfer of technology and the commercialization of research results emanating from NSF grants (NSF, 2013c). Furthermore, both the NIH and the NSF granting councils have amended their application forms to include specific references to potential patentability and a principal investigator's history of patent citations (NSF, 2013d). From a more political standpoint Lamar Smith, Chair of the House of Representatives' Science, Space and

Technology Committee, drafted a bill that according to ScienceInsider, “in effect, would replace peer review at … NSF with a set of funding criteria chosen by Congress … it would also set in motion a process to determine whether the same criteria should be adopted by every other federal science agency” (Mervis, 2013, para. 1). The proposed congressional criteria, among other things, would require the research to advance national prosperity. The use of such criteria is an overt move to place funding priority on research that holds the potential for more economically driven outcomes over ‘*disinterested*’ fundamental scientific research. A political and philosophical change is emerging from previous policy positions, whereby it has been stated that “many government managers, especially those in the core funding agencies, are as concerned about building up scientific and technical capacity as much as producing discrete impacts from particular projects” (Bozeman, 2000, p. 649). Shifts in policy of this nature can hold broader significance in the realm of human capital development, since too great an emphasis on the applied or developmental aspect of academic research and its commercialization might actually slow down the social rate of innovation (Feller, 1990).

Notwithstanding the current moves by politicians and policymakers, studies thus far on the Valley of Death have only provided figurative representations of this phenomenon, with little empirical basis. Based on the literature review, no confirming evidence isolating the actual historical location of the Valley of Death along the R&D spectrum has been identified (i.e., the applied research phase), nor has any attempt been made to quantify the amount of the perceived funding shortfall. Since no fact-based work has been observed, it is unclear to what extent the policy changes targeting the Valley of Death are necessary, or beneficial, and if they are focused at the appropriate point in the process. Not only is there the potential misapplication of resources and efforts, but changes may also result in the unintended consequence of affecting the rate of broader human capital growth and societal innovation.

In summary, a problem exists in that the commercial application of university research is considered sub-optimal and, as a result, changes in grant funding criteria are being implemented to ameliorate the situation. However, to confound the issue, policy changes are being initiated based on limited empirical evidence. While the ultimate effect is yet unknown, the direction of this particular change has been previously hypothesized to hold broader negative societal implications (Feller, 1990). Given the potential impact of proposed policy changes, both positive and negative, an accurate assessment of the basis of the Valley of Death phenomenon needs to be ascertained.

Purpose of the Study

Knowing the current policy direction and the lack of underlying empirical foundation for any proposed changes, the purpose of the study is to develop data that would help inform policy-makers on the phenomenon of the Valley of Death. This was accomplished by first confirming the current perception and shared beliefs held among policy-makers with respect to the perceived cause of the Valley of Death. Secondly, was the development of a more accurate account of the Valley of Death based on the historical record. A comparison of the data generated provides the consistency of presently shared beliefs with historical evidence. More specifically the research objectives were structured as follows:

Research Objective 1 – determine the frequency of use of the term Valley of Death by policy-makers in the context of innovation and technology development;

Research Objective 2 – determine the frequency of use and the referenced position of the term ‘funding shortfall’ when policy-makers describe the Valley of Death in innovation and technology development;

Research Objective 3 – determine the pattern of use over time by policy-makers of the term Valley of Death in the context of innovation and technology development;

Research Objective 4 – determine the historical research spending patterns by category of research for the university and industrial sectors.

Limitations

With respect to research objectives 1, 2, and 3, Titscher, Meyer, Wodak, and Vetter (2000) suggest content analysis be used when the communicative content is of greatest importance. In performing content analysis on a text, the data must be subject to strict categorical definitions and procedures and not demonstrate any observer dependency (Krippendorff, 2012). The key limitation of this method is that it simply describes what is there, but may not reveal the underlying motives for the observed pattern, that is, the '*what*' but not the '*why*' (Titscher et al., 2000). Content analysis is also limited by the use of relevant material, which in this case will be contained to the Congressional Record. As a formal public record, the method of speech and delivery of the message by the speaker may be influenced and thereby potentially skew the content (Krippendorff, 2012).

In order to determine the construct of the Valley of Death (Research Objective 4), data was sourced from the historical record contained in the NSF’s database of National Patterns of R&D Resources (NSF, 2011). To the extent that these records were incomplete, contained errors, or had altered their collection methodology and/or descriptions of data over time, the conclusions drawn from the analysis are limited. In addition, the NSF's classification of R&D spending data under the terms of basic, applied and developmental research formed the structure of the database and therefore limited the presentation of the Valley of Death phenomenon. The lack of more detailed data is the key point made by Godin (2006) with respect to describing the overall nature and limitations on the use of the linear model of innovation, which itself forms a key assumption of this study. The foregoing limitations lead to potential construct validity as well as potential threats to external validity. These threats are further discussed in Chapter V.

Delimitations

Delimitations are those characteristics selected by a researcher to define the boundaries of a study. One key delimiting factor of the study was the use of the Congressional Record as the source of information for policy narratives related to the meaning and perception of the Valley of Death. Use of wider textual sources could provide richer meaning to the term; however, focus on the Congressional Record ensured the sources of the information and the targeted listening audiences were direct influencers on the policy process.

A second delimiting factor was the confinement of the study to U.S. university research funded from federal sources. In its broadest sense, the Valley of Death covers the development of all research-based technologies. Given that almost 30% of the U.S. annual federal research budget goes to universities and colleges and as this sector has represented the largest single sector for federal R&D spending since 2002 (NSF, 2011), U.S. universities and colleges formed the primary and logical focus for the study on the Valley of Death consequence of technology transfer. However, as a result non-U.S. players were excluded as were other publicly funded sources of research. Examples of these other areas include State or foundation funded research, federal labs, research hospitals, government agencies, and federally funded (private sector managed) proof of concept centers. Additionally, attention was solely on university-generated inventions and not those inventions created within industry, which could also receive federal funding support (i.e., Small Business Investment Research grants) and which may too, fail to reach market. Restrictions on the interpretation of the findings caused by the delimitations of the study are more fully addressed in the discussion of the results in Chapter V.

Assumptions

There are two main assumptions associated with the research objectives of the study. First, Advocacy Coalition Framework (ACF) and Narrative Policy Framework (NPF) are considered to form the underlying structure to the general policy-making process, but the application of these frameworks to the issue of technology transfer and the commercialization of university research has not yet been examined. The process surrounding federal research grant policy was assumed to be consistent with the other federal policy-making processes, which have formed the precepts for these frameworks and hence, the applicability of these models to the study.

A second assumption underpinning the study is the use of the linear model of innovation to provide the theoretical structure that governs the relationship among basic, applied, and developmental research. This model holds that these three categories of research are sequential and together form a developmental continuum from lab to market (Godin, 2006). The linear model of innovation frames the graphical plane (i.e., the x-axis) on which the “Valley of Death” is historically depicted.

Summary

The conceptual and theoretical precepts related to university technology transfer demonstrate how innovation emerges from the inventive process and how inventions are derived from the development of new knowledge. The relationship of knowledge and invention to end-market products or services are juxtaposed at opposite ends of an innovation process spectrum (reflective of the linear model of innovation). Such juxtaposition sets up the potential for discontinuity (i.e., Valley of Death) along this innovation continuum, especially if various actors are operating at different points within this spectrum.

In an age of increasing global competition, the ability to innovate is seen as the basis for continued economic growth (Friedman, 2007; Romer, 1994). Innovative capability is the capacity to generate and apply new knowledge and is a function of the level of human capital development achieved (Mincer, 1984). In the United States, a substantial amount of federal dollars is expended on university R&D to expand the human capital base and create new knowledge (NSF, 2011), providing the potential for enhanced economic competitiveness and growth. However, much of the inventive activity emerging from university labs is lost along the development pathway to market and ends up in a proverbial Valley of Death (Ford et al., 2007). The consensus belief cited for this failure is a lack of funding in the applied research stage of development (Beard, Ford, Koutsky, & Spiwak, 2009). In response, federal policy is evolving and since policy-making is a function of shared beliefs and perceptions (Sabatier, 1991), the first objective of this study confirmed the current meaning and common use of the term Valley of Death by policy-makers and legislators. This is followed by an empirically based model of the Valley of Death, demonstrating how the current perception/belief aligns with the historical evidence.

The remaining chapters of this study include a review of the relevant literature, a detailed explanation of the research methods employed, the results, and a discussion of the findings. The study closes with recommendations for additional research, with particular emphasis on areas that may assist in informing future policy direction.

CHAPTER II

LITERATURE REVIEW

Introduction

The argument has been presented that the theoretical framework for this study can be described as an interdisciplinary examination residing at the intersection of human capital development theory and endogenous growth theory. The generation, dissemination, and application of new knowledge in the form of inventions, a human capital development matter (cf. Becker, 1964, 2002; Kern, 2009; Leslie & Brinkman, 1988; Mincer, 1984), creates a foundational input to innovation driven economic development, an endogenous growth matter (cf. Aghion et al., 1998; Arrow, 1962b, 1970; Freeman, 1990; Romer, 1994; Schmookler, 1966; Schumpeter, 1939). From this perspective, the failure to commercialize university inventions essentially reflects the direct consequence of the market not fully adopting all new knowledge emanating from TTOs. An applied research-funding shortfall is attributed as the cause of the problem, and current federal policy direction is shifting the focus of available grant funding in an attempt to address the issue (Ford et al., 2007). This literature review is structured to focus on the foregoing interrelationships and circumstances and will follow the logical flow of the conceptual framework depicted in Figure 1 herein.

The literature on the interrelationship between human capital development and endogenous economic growth leads to the industrial innovation process, which is specifically manifested in the linear model of innovation (Godin, 2006). The linear model forms the underlying pathway for the commercialization of new inventions, and an investigation of its principles reveals how inventions translate into the final products and services that eventually make their way to the marketplace. The evolving role of the university in this process is reviewed to provide perspective for the basis of the current practice of university technology transfer. The substance of this prefacing examination establishes an overall perspective for the circumstances surrounding the Valley of Death, which then forms a specific section of the literature review. The Valley of Death component addresses the extent of the current comprehension of this phenomenon, including how it has been defined as well as its currently known delimiting parameters. The recognition of the existence of the Valley of Death in relation to the accepted role of the federal government in R&D and technology transfer is explored in the final section of the literature review. This approach to the literature review provides a full and appropriate foundation for the research objectives of the study.

Human Capital, Invention, and Industrial Innovation

Most of the literature and growth in understanding the relationship of innovation to the economy originated from the founding works of the renowned economist, Schumpeter (1939). As summarized by Nelson "virtually all contemporary general accounts of the capitalist engine are based on Schumpeter" (Nelson, 1990, p. 193). One early study that led directly from Schumpeter's initial principles on innovation was conducted by the historian and economist, Maclaurin (1953). He analyzed the sequence from invention – to innovation – to economic growth. Within his work, he laid the framework that related: (1) the propensity to develop pure science; (2) the propensity to invent; (3) the propensity to innovate; (4) the propensity to finance innovation and; (5) the propensity to accept innovation (Maclaurin, 1953). Maclaurin's chain of events demonstrated an evolution in the understanding associated with the overall process of innovation and important to universities, he added the elements of pure science into the mix as a pre-curser to invention. Today, it is generally accepted that basic science provides a natural starting point for the industrial innovation process (Godin, 2006) and the industrial innovation process is commonly referenced alongside the concept of '*the linear model of innovation*'. According to Godin (2006), the linear model contends that innovation starts with basic research, moves through applied research, then development, and ends with production and diffusion in the marketplace.

The exact origin of the linear model does not appear to have ever been documented (Godin, 2006). Instead, the model appears to have been generally taken for granted, but according to many, it initiated from Bush's work, *Science: The Endless Frontier* (for examples of this attribution refer to: Freeman, 1996; Hounshell, 1996; Irvine & Martin, 1984; Mirowski & Sent, 2002; Mowery, 1997; Stokes, 1997). However, Bush like Schumpeter, only discussed linkages between science (i.e., basic research) and socioeconomic progress. They did not provide details on the mechanism whereby science translates into either social or economic benefit through some sequential linear or other linked process (Godin, 2006).

Godin traced the history of the model and concluded that it developed in various overlapping stages. He argues that the linear model of innovation was not a spontaneous invention arising from the mind of one individual, that is to say Vannevar Bush; instead, it evolved over time in three notable phases:

1. The first phase was during the period from the beginning of the twentieth century to the end of the Second World War (i.e., during the times of Bush and Schumpeter), and it was predominately concerned with the first two terms in the model namely, basic and applied research. This period was characterized by the ideals of pure science and its adoption into new technologies.

2. The second phase lasted from 1934 to 1960 and added a third term to the equation, namely development. This created the standard three-stage model of innovation: Basic research → Applied research → Developmental Research. Analytical as well as statistical gathering methodologies were cited as being responsible for driving this period of evolution of the model.

3. The third phase, starting in the 1950s extended the development end of the model to non–R&D activities of production and diffusion as is exemplified the work of Maclaurin (1953).

Godin demonstrated how the evolution of the linear model of innovation also reflected the successive entry of three separate academic disciplines into the field. First were natural scientists (academic and industrial); they espoused that basic research is the source for applied research and technology. Second were researchers from business schools; they studied the industrial management of research and the development of technology. Third were the economists; they advanced the understanding of innovation and the economy. The three groups of academicians, with their differing perspectives, were advocating on three different fronts, respectively: (a) public support for basic university research; (b) the importance of technological development to the firm and; (c) the impact of research on economic growth and societal benefit.

The linear model of innovation has survived despite criticisms of its simplicity such as “the linear model is insufficient as a descriptor of the industrial innovation process. Everyone knows that the linear model of innovation is dead ... It was a model that, however flattering it may have been to the scientist and the academic, was economically naive and simplistic in the extreme” (Rosenberg, 1994, p. 1). More than just being dead, it has been postulated by Edgerton who states, “it [the linear model of innovation] never existed” (Edgerton, 2004, p. 8).

According to Godin, the model’s longevity is fundamentally rooted in the use of available statistics. By collecting official data on research as defined by three key components (i.e., basic, applied, developmental), presenting, and discussing one after the other within a sequential framework the federal government has crystallized the model. The survival of the linear model indicates both how the use of statistics supports concepts and how their absence limits adoption of other analytical models. Godin (2006) states “rival models, because of their lack of statistical foundations, could not become substitutes easily” (p. 641). Refinements to the linear model, which may be fully justified and advocated by Rosenberg and Edgerton, will not occur until refinements to the data are obtained.

Invention, the Basis of Innovation

As noted above, the linear model of innovation initiates with new knowledge and invention (Godin, 2006; Maclaurin, 1953), but the question of how and why invention takes place remained a question. This was separately studied by Usher, whose findings led to definition of invention as the emergence of new things, which require an act of insight going beyond the normal exercise of technical or professional skill (Usher, 1954). Additional work within the field suggests that required acts of insight can be precipitated by social needs (Bijker, 1995), they respond to economic opportunities, perceived risk, and factor price changes (David, 1975; Dosi, 1998; Freeman, 1990; Rosenberg, 1982), they emerge from the accretion of both cultural and scientific knowledge (Mokyr, 2002), and they can be catalyzed by the exchange of information within networks of colleagues (Aitken, 1985; Lane & Maxfield, 1997).

What distills from the foregoing collage of scholars is the commonality that novelty and inventiveness stem from increased awareness and a growing knowledge base. The standard academic modus operandi of constantly researching to add to the body of knowledge therefore forms an ideal foundation for inventiveness. The role of U.S. universities' contribution to the process of innovation is reviewed in the following section.

U.S. Universities and Technology Transfer

The American land-grant university system emerged with distinctive structural characteristics that differentiated them from their European counterparts (Kerr, 1963). The Morrill Act of 1862 was founded on the commitment that American universities should serve their citizens (Kerr, 1963). Under the Morrill Act, the purpose of education shifted away from classical studies to more applied studies to prepare students for roles after graduation (Kerr, 1963). As a result, universities in the United States have been making positive contributions to the nation's economic and social wellbeing throughout their history (Mowery et al., 2004).

Major research universities generate a huge economic footprint (Lugar & Goldstein, 1997). In many locales, universities are the largest employer, and several have total expenditures that put them at the level of some of the largest corporations in the nation. However, as important as this economic activity may be from a regional development standpoint, it is recognized that a greater contribution stems from the university's basic mission of generating and disseminating knowledge (Leslie & Brinkman, 1988; Mansfield, 1991). As noted in Chapter I, many groups are seeking to utilize university expertise in a more expeditious fashion for greater and immediate economic effect. Their objective is being specifically pursued through the direct application and commercial exploitation of university intellectual property for economic growth through the process of technology transfer.

Although American universities have been committed to technology transfer since inception (Mowery et al., 2004), the post-war era has witnessed the occurrence of three distinct modern evolutionary phases of technology transfer (Geiger, 1992, 2004; Godin, 2006). The first phase of technology transfer evolution occurred between universities and the defense establishment. Academic scientists were financially supported to conduct research, develop and maintain expertise in key areas, and ultimately to produce solutions that were demanded by the military. These tasks were accomplished through directed processes rather than market relationships. Although close relationships sometimes developed between supporting agencies, university scientists, and the companies that manufactured the final products, markets played virtually no part in coordinating the university's role (Geiger, 1992, 2004).

The second major phase of modern university technology transfer evolution grew from advances in medical research and similar to the first phase, the federal government was also the patron, specifically the NIH (Geiger, 1992, 2004). The ultimate objective of the NIH's substantial investment in basic biomedical research was to cure disease and improve the human health condition. Prior to 1980, this activity largely involved non-market relationships among government, industry, and academe. Any interaction with universities primarily focused in clinical research, which concerned diagnosis, identification of therapeutic targets, and refinements of treatment, not the invention of products. From a market perspective, medical and pharmaceutical firms typically looked to university scientists to help perfect, not invent, their products (Geiger, 1992, 2004).

The third aspect of the modern technology transfer evolution has moved universities in a fundamental way into the marketplace and has occurred predominately since 1980 (i.e., the time of the Bayh-Dole Act). This phase has been dubbed "*civilian technology transfer*" by Geiger (1992, p. 9). Because of civilian technology transfer, both the purpose and modus operandi is now quite different. Universities actively seek to sell research services to industry, market intellectual property, and launch and nurture new companies, sometimes with their own venture capital funds (Geiger, 2004). Tassey (2001) further describes the change in the fundamental character of the products and services being developed for civilian technology transfer. He notes a movement from public to private goods over the course of a technology's development, and the end product reflects a combination of both public and private goods. Tassey observed that while "basic science is widely recognized as close to a pure public good … technology is a *mixed* good, containing both private and public elements" (Tassey, 2001, p. 37). Moreover, the public/private mix adjusts as technologies become more developed. The slow development into a viable product is a process of creating private value but they contain public resources as their foundation. The argument behind the public support of private gain from public dollars is derived from the notion that broader public benefit will eventually accrue in terms of present and future economic spin-off activity (Tassey, 2008).

Today the research and technology development enterprise has merged activities that previously occupied opposite ends of the development spectrum and involved different actors (Mowery et al., 2004). A result has been a stimulation of investment in certain areas of university basic science and engineering; however, the economic relevance of those fields has simultaneously brought a greater emphasis on commercialization of that science (Tassey, 2001). The new reality for universities is that these endeavors are no longer differentiated components at opposite ends of the spectrum, but part of a complex, unified endeavor. A philosophical dichotomy arises given the private nature of the end-products versus the public source of funding used to develop those products (Tassey, 2001, 2008). This suggests that the mission of U.S. universities to provide public service via public goods (Kerr, 1963) has morphed. In the original model, no one was precluded from using the knowledge at hand. In the current model, private property rights emerge; there is an operational focus on the generation and transfer of public goods for the benefit of private actors (Tassey, 2008). This is manifested by the emergence of university TTOs seeking and licensing patent rights, mostly on an exclusive basis (Mowery et al., 2004).

Modern Patterns of Technology Transfer

According to Abramson, Encarnacao, Reid and Schnmoch, "the principal contribution of universities to the technical needs of industry is human capital, consisting of well-educated, skilled graduates" (Abramson, Encarnacao, Reid, & Schnmoch, 1997, p. 11). This quote emerged from a bi-national panel on technology transfer systems in the United States and Germany. The bi-national panel also distinguished between direct and indirect forms of technology transfer by noting "direct technology transfer is linked to specific technologies or ideas and to more visible channels such as contract or cooperative research projects … indirect technology transfer concerns the exchange of knowledge through such channels as informal meetings, publications or workshops" (Abramson et al., 1997, p. 3).

The relative importance of the various forms of technology transfer and the dissemination of university knowledge to industry, including the direct and indirect forms mentioned above, was examined by Cohen, Nelson, and Walsh (2002). They surveyed managers of R&D units of manufacturers located in the U.S. The survey sample was randomly drawn from private labs listed in public directories and entailed a sample size of 3,240 labs. The authors received 1,478 responses, yielding a gross response rate of 46%. Among the questions posed, the authors asked industry to what extent they relied on various forms of information exchange with universities. Their results have been summarized in Table 1.

Table 1

Relative Importance of Source Mechanism of Technology Transfer to Industry

Source Mechanism	Percentage of survey respondents rating source as "moderately" or "very important"
Publications and reports	41.2
Informal interaction	35.6
Meetings and conferences	35.1
Consulting	31.8
Contract research	20.9
Recent hires	19.6
Cooperative R&D	17.9
Patents	17.5
Licenses	9.5
Personnel exchange	5.8

Source: Adapted from Cohen et al. (2002).

As revealed in Table 1, the relative positioning of patents and licensing (i.e., direct technology transfer) as industry's source of new knowledge was eighth and ninth in a list of ten. The patents and licenses categories reflect the mechanism of technology transfer employed by university TTOs and are a direct representation of '*inventions*' in the conceptual framework outlined in Chapter I.

Cohen et al.'s (2002) findings reveal a direct contradiction to the basic arguments of policy makers and other original proponents of the Bayh-Dole Act. The Bayh-Dole legislation had been advocated based on the position that technology transfer was failing due to weaknesses in intellectual property rights and in order to create more effective transfer and application of university research; specific ownership control and mechanisms for the transfer of patenting rights were required. The policy-makers position is specifically captured in the preamble to the Act: "It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development" ("Bayh-Dole," 1980, § 200). Cohen et al. (2002) have demonstrated the original argument for the Bayh-Dole Act was misaligned with the facts, which reinforces the relevance of the research objectives of this study.

The actual growth and prevalence of TTOs is relatively new (i.e., since 1980), and it appears that the Bayh-Dole Act is the precipitating event for this occurrence. In Figure 2, there is a noticeable transition point in the growth of university technology transfer as evidenced by the change in the slope of the graph in and around 1980.

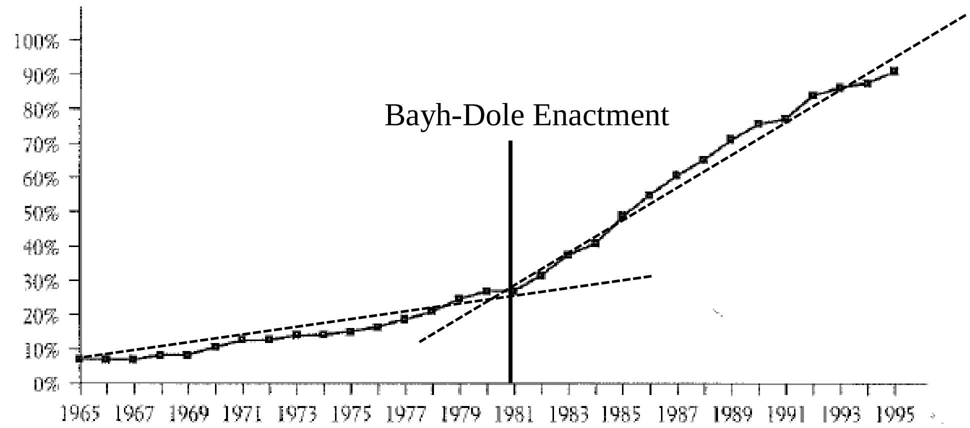

Figure 2. The proportion of Carnegie Research Universities employing greater than .5 full-time equivalent, technology-transfer personnel. Graph adapted from Mowery et al. (2004, p. 48) with permission, copyright Stanford University Press.

While TTOs emerged from the Bayh-Dole, it is unclear if Bayh-Dole has yielded the desired effect on the underlying patenting activity of universities it was designed to enhance. Evidence suggests, “That the growth in university patenting predates Bayh-Dole” (Mowery et al., 2004, p. 48). Figure 3 plots the number of university patents applications per dollar of R&D expenditure over time and a positive growing trend (dashed line) is visually apparent commencing around 1971, approximately ten years prior to the enactment of Bayh-Dole in December of 1980. This already-present growth pattern tends to negate the reported level of success otherwise credited to the Bayh-Dole legislation. According to Mowery et al., this prior trend in patent applications can be attributed to a combination of factors that includes timing of substantial advances into the biomedical sciences contemporaneously with changes in the legal treatment on life forms by the U.S. Patent Office (Mowery et al., 2004).

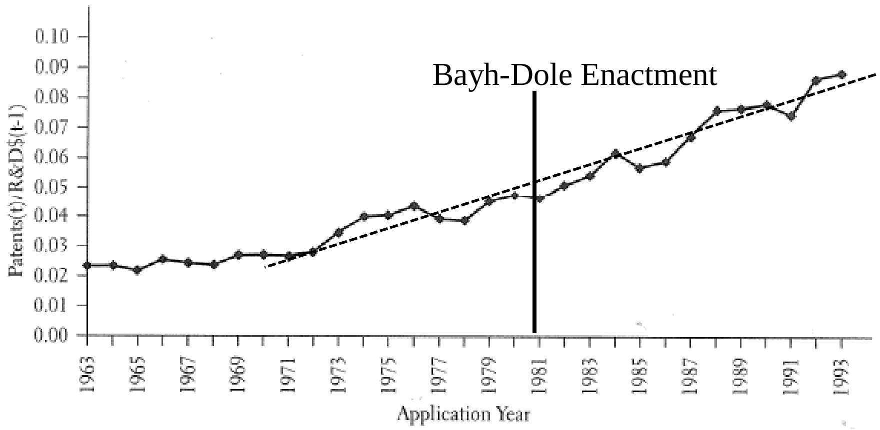

Figure 3. University Patenting Activity per R&D Dollar. Patent activity is represented by the number of non-provisional patent applications filed in a given year, whereas R&D represents research expenditures for the calendar year prior to the patent. Graph adapted from Mowery et al. (2004, p. 49) with permission, copyright Stanford University Press.

Operating Mandate and Funding of TTOs

According to Abrams, Leung, and Stevens (2009), "when university presidents speak publicly on the commercialization of technologies, they focus more on the public's right to see a return on the investment of their tax dollars in research grants via the availability of new products and services [as per the objectives of Bayh-Dole], rather than on the financial return that they might hope to see" (p. 4). For example, during an address by Dr. Coleman President of the University of Michigan at the 2005 Annual Meeting of AUTM she stated, "you heard me correctly. It is not about the money .... Revenue generation is NOT the ultimate goal. It is simply the means by which we can increase the transfer of new knowledge into the business sector" (Abrams et al., 2009, p. 4).

Abrams et al. found that the above statements by Dr. Coleman, in fact, reflected the general case. Abrams et al.'s (2009) work consisted of a survey of the directors of U.S. TTOs. They obtained 340 names of directors from AUTM and received a 48.5%

response rate to a directed survey. Of the survey responses, 112 of the respondents replied to every question. From their analysis they concluded "that although a small number of academic institutions have reaped very large rewards from their technology transfer activities … these rewards appear to be a consequence of programs driven by broader objectives" (Abrams et al., 2009, p. 2).

Synopsis of the U.S. University System of Technology Transfer

What has been gleaned from this component of the literature review is the understanding that from the beginning, U.S. universities have taken an application driven approach to their mission, and as a result, technology transfer has existed throughout their history (Mowery et al., 2004). In the past, the technology transfer process has taken many forms in order to effectively disseminate the new knowledge being generated on campus. Historically, this knowledge has been able to be exploited as a public good to create economic and societal benefit (Kerr, 1963). Today, TTOs represent a new manifestation of that dissemination process, focused specifically on the application (i.e., private licensing) of new knowledge contained in the form of inventions and patents. The difference being that this knowledge, in the form of patents, is not a public good, and it is being applied through selective licensing arrangements for commercial exploitation and private gain (Tassey, 2001). At the highest policy levels the rationale for this activity (which is also contained in the preamble to the Bayh-Dole Act), is the notion that this private process does provide benefit to society at large through the provision of goods and services that would otherwise not be readily available, most notably advances in the life sciences (AUTM, 2011; "Bayh-Dole," 1980; Schacht, 2012). The eventual public benefit from private goods argument, plus the potential economic development impact has motivated policy-makers to attempt to mitigate the Valley of Death (RFI, 2010). A review, specific to our current understanding of the Valley of Death, follows.

The Valley of Death

The objective of this component of the literature review is to detail the evolution of the Valley of Death metaphor leading to its current connotations. A valley, by definition, is a hollow or expanse of low ground, which forms a connecting point between two formations. In the context of university technology transfer, it is the apparent expanse between the academic knowledge enterprise formation on one side and the industrial innovation enterprise formation on the other side. Metaphorically, the Valley of Death reflects the final resting place for those university inventions that do not successfully crossover from academe to the market. The use of the term Valley of Death related to technology transfer is a relatively recent occurrence. By way of example, a Google Scholar search of the terms: invention, innovation, technology transfer and Valley of Death produced ten references for articles and books written prior to the year 2000. None of these ten references included the search term Valley of Death in their titles.

History of the Metaphor

Among the earliest and most cited references of the term, Valley of Death, is the report of United States House of Representatives, entitled "Unlocking Our Future: Toward a New National Science Policy" (H.R. Rep. No. 105-B, 1998). The Vice Chairman of this Committee and the individual who oversaw the content of the report, Vernon Ehlers, has been given much of the credit for the widespread adoption of this metaphor, including attribution for the conceptual depiction of the Valley of Death contained in Figure 4 (Wessner, 2005). While Figure 4 does not formally appear within the Committee report, Wessner states Ehlers used this depiction as a visual aid to explain the circumstances of the report: “Vernon Ehlers, one of the few scientists in the U.S. Congress, described the situation [Valley of Death] with the striking image shown in [Figure 4 below]” (Wessner, 2005, p. 9). Of particular note in Figure 4 is the concept of the need for capital to bridge new research ideas and product innovation.

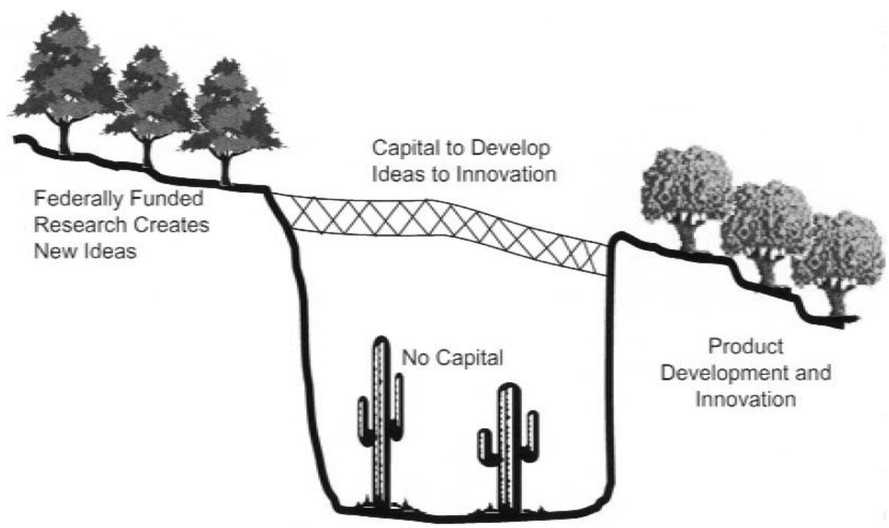

Figure 4. Image of the Valley of Death, attributed to V. Ehlers. Adapted from “Driving innovations across the valley of death” by C.W. Wessner, 2005, p. 10. Copyright 2005 by Industrial Research Institute, Inc., with permission.

Within the 1998 report’s examination of the roles for government and the private sector, a concept described as a *research gap* emerged. Specifically this concept was described as follows: “Today’s technology-driven company must bridge the research gap between basic science and product development if it wants to remain on the cutting edge of the industry” (H.R. Rep. No. 105-B, 1998, p. 39). The research gap is a mid-level or applied research gap and is typically necessary to develop basic research results into an emerging technology, leading into a marketable product (Vest, 1996). Contained in the report, and consistent with the linear model of innovation are the distinctions among basic research, applied research, and developmental research. The Committee on Science recognized the limited resources of the federal government and accordingly reaffirmed government's need to remain focused on its "irreplaceable role in funding basic research" (H.R. Rep. No. 105-B, 1998, p. 40).

In the Committee's report (H.R. Rep. No. 105-B, 1998), not only was the research gap recognized and defined, but it was also stated that it was expanding, "This gap, which has always existed but is becoming wider and deeper, has been referred to as the Valley of Death" (p. 40). The explanation given for this expansion was a function of the limited level of federal resources on the one hand, thereby containing federal R&D funding to the front end of the development spectrum and market forces driving industry toward more short term, rapid payback periods on the other hand, thereby forcing industry to focus at the opposite end of the development spectrum (H.R. Rep. No. 105-B, 1998). Within the report, the use of the term Valley of Death is attributed to others, but no other specific source reference was cited.

The actual origin of the term, Valley of Death, as applied to the innovation process appears to have initially emerged from an even earlier report prepared by Mohawk Research Corporation for the Department of Energy and Argonne National Labs (Lux & Rorke, 1991). In contrast to the purpose of the Committee on Science report (i.e., policy driven), the Mohawk report was to serve as a primer on the innovation process, and it examined considerations to be made when taking a product from the concept state to market entry. The key difference between the two reports is the Committee on Science is discussing moving basic research (i.e., research that is not considered to have any identified end use or product in mind) through applied research and then into product development, whereas Mohawk is discussing taking a product idea (i.e., something already at the forefront of the developmental stage) to final market readiness. Restated, the Committee's gap commences in the applied research stage, and Mohawk's gap commences in the developmental research stage. The Mohawk version of the Valley of Death is, by their calculation, the summation of the negative cash flow encompassing the period from the start of product development through to the point of profitability derived from market sales. The imagery used by Mohawk for their Valley of Death is depicted in Figure 5:

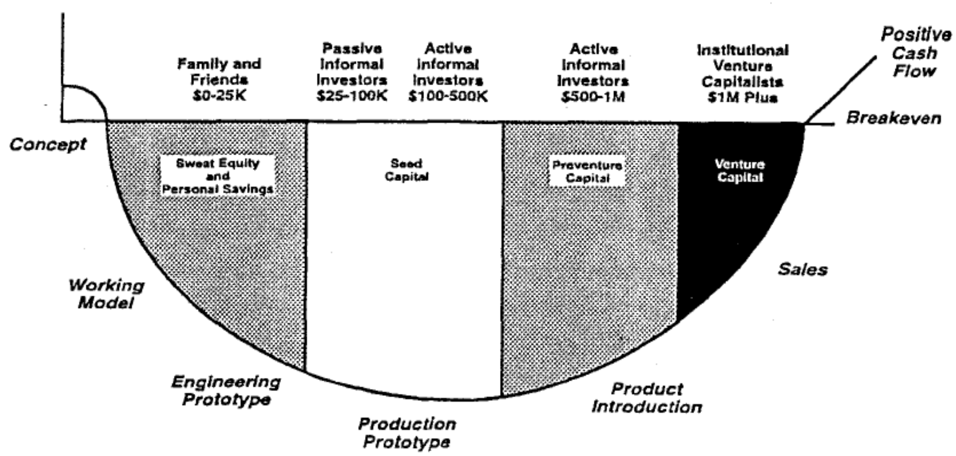

Figure 5. Mohawk Research Corporation's Image of the Valley of Death. Adapted from "From Invention to Innovation: Commercialization of New Technology by Independent and Small Business Investors," (Lux & Rorke, 1991, p. 19). Copyright 1991 by Mohawk Research Corporation, with permission.

Emerging since the time of the Mohawk and Ehlers's depictions is a further evolution of the industrial sector Valley of Death. This version was presented by Markham (2002), and it has been reproduced in Figure 6. He describes the Valley of Death as follows:

> Most companies have the resources, personnel and organizational structure for technology development. These components are present on the left side of the valley. Similarly most companies possess the resources for such commercialization activities as marketing, sales, promotion, production and

distribution, which appear on the right side of the valley. The Valley of Death between discovery and commercialization thus represents a lack of structure, resources and expertise. (Markham, 2002, p. 31)

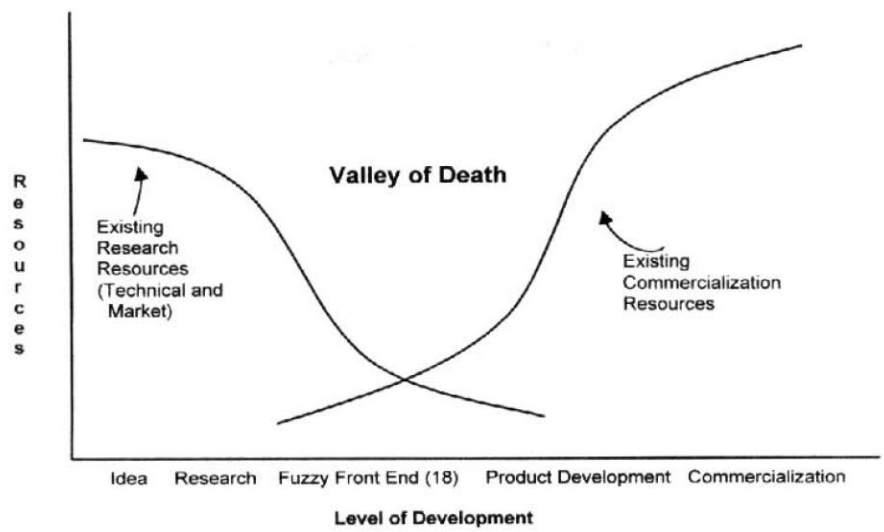

Figure 6. Markham's Image of the Valley of Death. Adapted from " Moving technologies from lab to market" (Markham, 2002, p. 32). Copyright 2002, Industrial Research Institute Inc., with permission.

Markham's (2002) image of the Valley of Death is a depiction of his interpretation of gaps in structure, resources and expertise and he defined the position of the Valley of Death as the "decision space between existing research resources and commercialization resources" (p. 32). Since Markham focused his research on industrial behavior, his depiction also reflects product development occurring solely within the private sector innovation process. Accordingly, his construct of the Valley of Death describes a shortfall of private sector resources.

A further evolution and variation of the Markham drawing has been observed, but it does not yet appear to be contained within the academic literature. It has made several appearances at various general conferences and popular addresses on the subject of innovation and technology transfer (e.g., University Economic Development Association

Annual Summit, Indianapolis, 2011; Association of University Technology Managers, Eastern Annual Meeting, Baltimore, 2011; Gulf Coast Patent Association Annual Meeting, Mobile, 2011; I-Ten Wired Annual Summit, Pensacola, 2010; BIO International Convention 2010, Chicago, IL; Gulf Coast Technology Council, Spring Meeting, Mobile, 2009, etc.). A sample of this evolved version of the Valley of Death is captured in Figure 7. This depiction was retrieved from the web site of the Chancellor of the University of California - Davis Campus, Dr. Linda Katehi. It formed part of her presentation on technology transfer at the BIO International Convention in Chicago (Katehi, 2010).

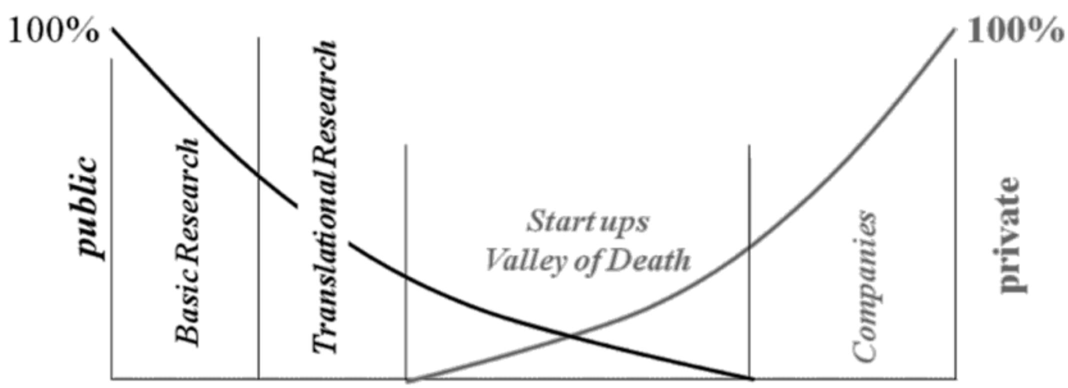

Figure 7. Katehi's Image of the Valley of Death. Adapted from "The role of universities, biotechnology companies and technology transfer in the innovation economy", (Katehi, 2010, slide 7); figure entitled "The Continuum of Innovation", used with permission.

Dr. Katehi's image maps the level of resources required for development against the level of technological development achieved. It starts with the earliest stage of development (basic research) being conducted in the public domain and the end stage of development (a commercialized product) being generated by companies in the private sector. The Valley of Death portrayed in Dr. Katehi's image is a clear illustration of the different roles and the relative differences in the focus of the resources employed by two potential complementary but separate groups in the overall innovation process. Of further note is the use of the word continuum, which Dr. Katehi used in the title of her image, suggesting she sees university basic research inexorably linked to the innovation process.

The most recent variation of the Valley of Death to emerge is an image portrayed by the NSF, refer to Figure 8 (NSF, 2013a).

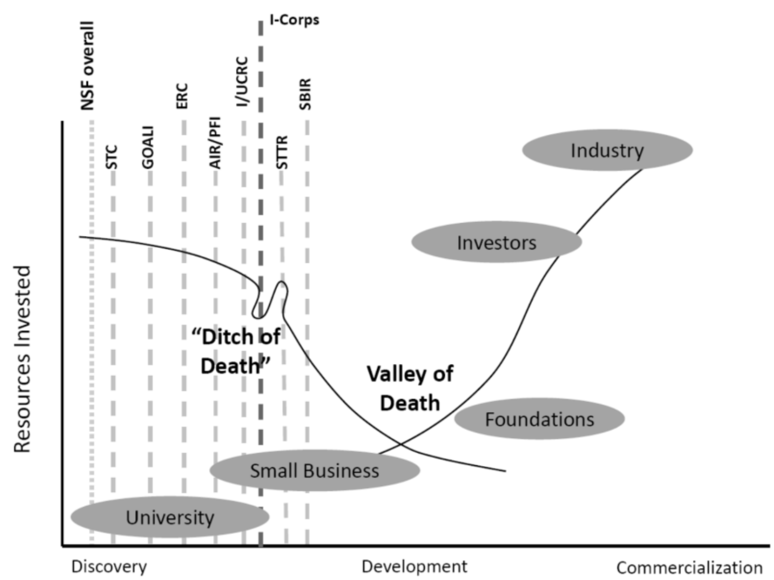

Figure 8. National Science Foundation's Ditch of Death. Depiction of the relative positioning of the Ditch of Death versus the Valley of Death (NSF, 2013a, slide 22). Public government document, no copyright.

Consistent with prior images, the level of research resources employed is mapped against the stage of development. However, it also overlays the relative positioning of different actors involved in the process and indicates where the various federal programs come into play to assist in the discovery and commercialization process. In addition to this information, the NSF also adds an irregularity to the university/federal research side of the Valley. They have formed a "*Ditch of Death*" (NSF, 2013a, slide 22) which they have identified as a further and highly specific funding shortfall in the technology development process. According to the NSF, this Ditch represents a gap in assessing the commercial feasibility of technology concepts that are in the earliest stages of development.

The Current Consensus of the Valley of Death as a Funding Shortfall

Supporting Ehlers's original notion of a lack of capital in technology development (refer Figure 4), there has been an ongoing consensus in the literature the Valley of Death is the consequence of a shortfall in the availability of capital resources in the mid-stage of product development. This consensus is captured in an early and comprehensive description of the Valley of Death by Frank et al. (1996):

> The "valley of death" is a concept used to refer to the situation in which a technology … fails to reach the market because of an inability to advance from the technology's demonstration phase through the commercialization phase. The valley of death occurs when the developer of a particular technology has successfully demonstrated the efficacy of the technology but is unable to obtain *financing* [emphasis added] for the scale-up and manufacturing process. At this point, the government considers the technology too "applied" to continue to provide funding, since the government's role is to fund more basic research, yet the private sector does not want to invest capital because the technology has not yet been implemented. (p. 61)

Similar styled definitions of the Valley of Death have been made in subsequent works as exemplified as follows:

- " A dearth of sources of funding …", (Auerswald & Branscomb, 2003, p. 232).
- "The cash flow valley of death …" (Murphy & Edwards, 2003, p. 3).

- “The ‘Valley of Death’ is the name given to the gap between the great plains of research funding and the orange groves of manufacturing ...” (Williams, 2004, p. 23).
- “The early-stage capital gap, often called the valley of death …” (Wessner, 2005, p. 9).
- “The technology transfer gap has always been with us but in drug discovery it has widened to form a valley of death …” (Moran, 2007, p. 266).
- “A ‘funding gap’ or ‘Valley of Death’ exists …” (Beard et al., 2009)
- “The ‘Valley of Death’, a term used to refer to ideas that are interesting but too early stage to attract commercial investment … ” (Wylie, 2011, p. 1169).

The consistent theme throughout the foregoing cited works is a lack of funding is a contributing, if not, the cause of the Valley of Death. This lack of funding has not been quantified by any of these authors nor have they referenced any other source that quantifies the funding shortfall. Additionally, the researchers provide only a generalized descriptive notion of where the funding shortfall occurs, somewhere between the end of solving a basic research issue and the point where industry is interested in taking on further development of the product.

Advancing the Funding Shortfall Model

The work of Auerswald and Branscomb (2003), entitled “Valleys of death and Darwinian seas: Financing the invention to innovation transition in the United States” broadened the understanding of the Valley of Death. The title still suggests funding issues as the basis of the Valley of Death, but the addition of a new metaphor provides deeper understanding:

> The imagery of the Valley of Death … suggests a barren territory when, in reality, between the stable shores of the S&T [science and technology] enterprise and the business and finance enterprise is a sea of life and death of business and technical ideas, of 'big fish' and 'little fish' contending, with survival going to the creative, the agile, the persistent. Thus, we propose an alternative image the 'Darwinian Sea.' (pp. 229-230)

The metaphor of the Darwinian Sea describes an environment where survival goes to the most economically fit technologies.

Auerswald and Branscomb (2003) state "whether or not efficient markets exist on Wall Street may be an open question. However, efficient markets do not exist for allocating risk capital to early stage technology ventures" (p. 231). This statement provides the key distinction between this and other works citing funding shortfalls as the precipitating factor of the Valley of Death. The authors further explore the funding shortfall by presenting viewpoints from either side of the Valley. On the one side, there is the perspective of the private sector (the demand side), which is distinguished from the perspective of the academic knowledge enterprise (the supply side). In the case of the supply side, the funding shortfall stems from policies focusing on funding basic research with a lack of applied research grant opportunities. On the demand side, industry seeks out capital investment through market-based mechanisms to develop early stage technologies and as a result the funding shortfall as a capital market issue. The authors suggest that too much risk/uncertainty surrounds investment in early stage technologies, which directly affects the supply and cost of capital for those technologies. To market suppliers of capital, the risk-adjusted rates of return on these early stage technologies are too low when compared to other investment opportunities (Weston & Brigham, 1975).

Building on the work of Auerswald and Branscomb (2003), Beard et al. (2009) utilized mathematical modeling to predict the occurrence of the Valley of Death. Starting from the standard premise of the Valley as a shortfall in funding in the mid-stages of development, the authors provided a mathematically derived, theoretical explanation for the shortfall. The study concluded the Valley of Death stems from an overinvestment in non-economic research at the very early stages of technology development and the Valley of Death should not be an unexpected consequence. (Beard et al., 2009). In essence, the Valley of Death remains a funding issue and to remove it one must either (1) substitute more economically driven basic research, assuming that could even be determined in advance, and/or (2) fund more intermediate research. Although these conclusions may appear self-evident, the value of this study is provided as confirmation of Auerswald and Branscomb's findings that early stage technologies are in an economic competition with other potentially economically feasible projects and that the fallout (i.e., the Valley of Death) is a result of economic forces and natural market mechanisms choosing which technologies to pursue.

Despite findings for market-based economic factors as the cause of the Valley of Death, Beard et al. recommend public policy intervention, namely increased government financial support for intermediate (applied) stage projects (Beard et al., 2009). This conclusion prefaces the need for a review of past and currently evolving federal policy aspects of the Valley of Death, which is provided in the following section.

Federal Policy Perspectives and the Valley of Death

The 1998 Committee on Science's report confirmed the position of the federal government with respect to the Valley of Death. Namely, it constitutes a gap between basic and more applied research, and beyond the realm of basic research, the federal government has little interest, aptitude or even mandate to pursue (excluding such notables as national defense and healthcare). By inference, the Valley of Death is a private sector concern. The Committee on Science (H.R. Rep. No. 105-B, 1998) specifically elaborated on this matter as follows:

> The Mid-level research has customarily been performed, and should continue to be done, in the private sector. The fruits of this research are proprietary; the company is the primary or even sole beneficiary of any new technologies. At the same time, the company must also bear the risk that the research project will not yield any profitable results. (p. 39)

The past federal policy position is consistent with the basic precepts of the U.S. market driven economy; market rewards go to those that take market risks. Therefore, any further market-oriented development of research outputs must responsibly rest within the purview of the private sector (H.R. Rep. No. 105-B, 1998).

In addition, the Committee on Science (H.R. Rep. No. 105-B, 1998) noted that the Valley of Death phenomenon was being exacerbated as a result of industry's short-term focus on profitability and its desire for a rapid return on investment. It observed, "The deployment of industry scientists on research … for which there are expected near-term payoffs suggests that these scientists will … not be encouraged to take part in longer-term, more exploratory research" (p. 39). Former Undersecretary for the Department of Commerce, Good, made similar observations when she previously testified at a federal hearing on the Department of Commerce's technology grant programs, "Now, in this environment, what we find is that the competitive pressures of the global marketplace have forced our American firms to move their R&D into shorter-term product and process improvements" (Good, 1997, p. 5). Good (1997) went on to state, "and what we are in the process of seeing is an *innovation gap* [emphasis added] and it is developing between the fundamental research that is done primarily at the university level … and the shorter-term development activities of U.S. corporations" (p. 5).

Good's comments and the Committee on Science report were issued approximately seventeen years ago, but these comments remain just as relevant today. According to the Global Competitiveness Report for 2011-2012, the global market place is considered to become only more and more competitive with innovation as the key driver of success. The United States is currently ranked 20th in the world in measures of its companies' competitiveness in international markets (World Economic Forum, 2011). This is a dropping of one ranking position from the prior report and a fall from 12th position in 2008. Despite a strategy of capturing "*closest to market*" innovations, U.S. companies are falling behind their world counterparts.

A Shifting Policy Viewpoint Regarding Government's Role

The historical policy position adopted by federal policymakers and legislators is that the research gap/innovation gap/Valley of Death is a market driven phenomenon. The gap is perceived not only to continue, but it is also estimated to widen. As a result, the White House issued the 2010 RFI, referenced earlier in this document, to identify ways in which to move technologies more effectively out of the lab and into the marketplace. Within the RFI, suggestions were specifically being sought regarding what changes in public policy and research funding should the Obama Administration consider that would promote commercialization of university research (RFI, 2010, p. 14477). The White House has taken the position that a research-funding gap exists and has acknowledged, through the RFI, financing that gap through federal programming would constitute a change in policy. In this regard, the following sub-section reviews aspects of the literature on the policy-making process to provide perspective on the actions of the current administration and to help frame the observed movement in current federal policy direction.

The Policy-Making Process

In the past, researchers have presented models consisting of various sequential and iterative stages to explain the policy-making processes. As early as 1936, Harold Lasswell articulated the concept of '*stages heuristic*' to describe the process (Lasswell, 1936). In his model, these stages included identifying policy problems, formulating policy proposals, legitimizing public policy, implementing public policy, and evaluating public policy. After the evaluation stage and assuming a change in outcomes is desired, the process repeats itself. Refinements of the staged process model have taken place since Lasswell; however to date, all staged approaches have been criticized for being insufficient and specifically do little to explain the drivers of policy change (DiNitto, 2011). Staged models are mostly regarded as simply representing a process flow, but they have been influential in conceptualizing how people look at policy in general (Nakamura, 1987).

Specific to policy change in the policy process, political scientists had perceived it as the outcome of strategic power struggles among political groups (Easton, 1965; Truman, 1951; Wilson, 1973). Political groups hold different values and interests and bring different resources to bear on existing regimes to effect change. However, in 1974 Heclo concluded that such tactics could only account for a portion of experienced changes. Heclo determined that policy change was a product of large scale social, economic, and political changes as well as the strategic interaction of people within a policy community, involving both competition for power and efforts to develop more knowledgeable means of addressing the policy problem (Heclo, 1974). It was found that government programming is primarily driven through policy analyses, which set out to ascertain causal theories regarding the problem being addressed (cf. Berman, 1978; Majone, 1980; Mazmanian & Sabatier, 1981, 1983; Wildavsky & Tenenbaum, 1981). As a result, much of policy change is currently understood to be disputes over the validity of causal theories and the appropriateness of the underlying data supporting the need for change.

Policy change theory further evolved in the late 1980s, when Sabatier argued that "policy change is best seen as fluctuations in the dominant belief system (i.e., those incorporated into public policy) within a given policy subsystem over time" (Sabatier, 1988, p. 158). This premise forms the basis of Sabatier's ACF. In the context of ever-changing information and events, ACF empirically seeks to explain the dynamic processes of policy learning and policy change through policy subsystems and the formulation/re-formulation of coalitions that occupy those subsystems based on common beliefs (Sabatier, 1988). ACF now appears to be the most dominant method of analysis of policy-making by scholars around the world (Weible, Sabatier, & McQueen, 2009).

Recent work emerging from the literature, and complementary to ACF, is a class of study known as NPF. NPF utilizes the role of narrative elements as a mechanism to explain ACF's policy subsystems, advocacy coalitions, shared beliefs, and public opinion (Shanahan, Jones, & McBeth, 2011). NPF centrally locates the role of policy narratives in ACF. As a developing framework, NPF is informed by theories from a number of disciplines and academic fields (cf. Riker, 1986; Sabatier & Jenkins-Smith, 1993; Schattschneider, 1960; Stone, 2002) and produces a model that not only accurately captures and describes policy narratives, but also helps assess the influence of policy narratives on public opinion and policy outcomes (Shanahan et al., 2011).

According to Shanahan et al. (2011), narrative elements can be classed as variables to serve as quantitative measures providing a means of assessment. Proponents of NPF contend it better illuminates facets of the policy process (McBeth, Shanahan, Arnell, & Hathaway, 2007). The basis by which stakeholders ascribe meaning to a situation can be best captured through an empirical investigation of the stories that the policy sub-systems strategically deploy and Shanahan et al. (2011) state, "stakeholders use words, images, and symbols to strategically craft policy narratives … to produce a winning coalition" (p. 536). Therefore, the inclusion of policy narratives as causal variables in the policy change process is both valid and necessary (Shanahan et al., 2011).

Summary

The literature reveals that the success rate of TTO activity is falling short of expectations, and the failure of TTOs to transfer most inventions to industry is reflected in a phenomenon characterized as the Valley of Death. The Valley of Death metaphor provides an intuitive conceptualization of university inventions falling short of the market. It can be concluded that the majority of work finds that there is a funding shortfall in the mid-stages of the development cycle, causing the premature death of many inventions. This funding gap is a product of both the current government grant structure and the operation of private sector capital markets, and if the funding gap were to be filled, then far more university inventions would find their way to market. The literature review finds the work to date falls short of any quantified assessment of the funding shortfall, or confirmation where this shortfall may be located along the innovation sequence.

Further evidence from the literature suggests that, commencing with the Bayh-Dole Act itself, past policy positions on technology transfer have been misinformed. In addition, the shared beliefs that currently exist and which are now driving policy change, appear to have limited empirical foundation and as such may hold similar, potential misconceptions of the true underlying nature of the problem. Without appropriate underpinning analysis, current policy direction may be counterproductive. Through the literature review, key gaps in the knowledge base have been identified which validate the need for the research objectives of the study.

CHAPTER III

RESEARCH DESIGN AND METHODOLOGY

Introduction

As evidenced in Chapter II, the academic consensus is that the Valley of Death is precipitated from a funding gap in the mid-stages of the R&D process (cf. Auerswald & Branscomb, 2003; Frank et al., 1996; H.R. Rep. No. 105-B, 1998; Murphy & Edwards, 2003). This funding gap is intuitively understandable since the focus of university research (i.e., approximately 80% of federally funded R&D) occurs at the basic research end of the innovation spectrum, whereas industry's focus (i.e., approximately 80% of industrial R&D spending) is at the developmental end (NSF, 2011). The comparative polarization of research activity by each sector, coupled with a relative lack of overlapping funding in the middle produces the gap known as the Valley of Death. A concern with the current state of understanding is that beyond a basic description and an easily conceptualized notion, little empirical evidence supports the accepted position of a funding shortfall interrupting the mid-stages of development and being the precipitating cause of the Valley of Death. Compounding the current situation, evolving federal policy direction on research grant funding appears to be promulgated based on this basic causal belief.

Knowing that policy decision making is founded on the application of shared beliefs (Sabatier, 1991), driven by policy narratives (Shanahan et al., 2011), it is important to understand how these underlying aspects of the policy process may apply to current policy direction with respect to the Valley of Death. Consistent with ACF and NPF principles, the prevailing policy narrative needs to be congruent with the empirical evidence if effective policy is sought. Research, by generating new knowledge, plays a role in shaping shared beliefs and coalitions (Sabatier & Weible, 2007) and provides credibility to the policy narrative (Shanahan et al., 2011). Recognizing these relationships, the study objectives first confirm the shared beliefs currently motivating policy direction and then derive an empirical model of the Valley of Death to determine if its actual characteristics are congruent with those shared beliefs. The understanding to be gleaned from these objectives will either confirm or help re-inform U.S. federal policy on the funding and commercialization of university research.

Given the variations in research objectives, the study methodology incorporates a mixed-method approach. Research objective 1 requires a qualitative review of the content of the Congressional Record to capture the relevant data for the desired frequency analysis (quantitative) on the concept of the Valley of Death in the innovation sequence. The data retrieved is further qualitatively refined under research objective two and subjected to quantitative assessment to ascertain the meaning being attributed to the Valley of Death. Research objective 3 is accomplished strictly through quantitative analysis of the data obtained under research objective one. Research objective 4 is also examined under a strictly quantitative lens, although applied to a different data set than research objectives 1, 2, and 3. The data analysis procedures employed under each of the research objectives is explained in greater detail in the following section.

Data Analysis Procedures

Research Objectives 1, 2, and 3 – Narrative Policy Framework and the Valley of Death

The first three research objectives are investigated by analyzing data obtained through a deductive, structured content analysis. This analysis determines the contextual meanings (qualitative) and frequency of use (quantitative) of the term Valley of Death in the text-based records associated with the federal legislators and policy-makers responsible for directing policy. For this purpose, the U.S. Congressional Record from the 102nd Congress (1991) through to the current session, 113th Congress, forms the source of data for examination (Library of Congress, 1995) because this covers the period when the Valley of Death came into usage. The relevant passages in the Congressional Record are extracted as individual text units for the analysis.

It is known that a great deal of negotiation and deal-making occurs prior to Congress' full-body debates on an issue, and many argue that roll call votes (Schroedel & Jordan, 1998) or personal interviews (Dodson et al., 1995) may provide better insight into politicos' *true beliefs*. But, the best way to assess the beliefs of the state's politicians and policy-makers is through their prepared speeches (Schafer, 2000). Hancock (2004) supports this stance as she notes, "a member's remarks furnish not only his or her stance (pro or anti) on proposed legislation, but the arguments and ideological justifications for their positions. It is in these justifications that the unacknowledged social meaning of public identity lurks" (p. 89). According to Hancock, public identity is a social cognition formed from "the product of thinking about things, forming object-specific impressions and communicating about them with other people" (Hancock, 2004, p. 89). From this point of view, the Congressional Record forms a logical and legitimate source to ascertain the true beliefs surrounding the concept of the Valley of Death.

The content analysis started with partitioning the use of the term, Valley of Death, into two mutually exclusive categories (1) '*Innovation and Technology Transfer*' and (2) '*All Other Contexts*' (e.g., prayer). Once isolated in this fashion, the Innovation and Technology Transfer category is then further subdivided according to its contextual meaning, with all statements that relate to a '*funding issue*' grouped together. By determining the frequency of the use of funding issues as a sub-category and comparing to the frequency of other uses of the term, the overall prevailing shared belief of the Valley of Death is identified. Further sub-categorization to account for the location of the Valley of Death along the innovation spectrum helps to additionally frame the understanding of the term. This methodology also provides a ranked measure of all definitions of the term, relative to each other.

Use of content analysis is well founded in the literature and according to Titscher et al. (2000), content analysis is "the longest established method of text analysis among the set of empirical methods of social investigation" (p. 55). While its approach originally focused on methods that targeted clearly quantifiable aspects of text content (e.g., absolute and relative frequencies of words per text), the concept was extended to include all those procedures which operate with categories and similarly seeks to quantify those categories by means of a frequency analysis (Titscher et al., 2000). This methodology has been previously employed in studies ranging from an analysis of debate in the U.S Senate (Lehnen, 1967) to changing definitions in social issues (Cook & Skogan, 1984) to social movements (Polletta, 1998) to poverty (Hancock, 2004). While many examples of content analysis exist, each of the foregoing references was cited because their content analysis was specifically drawn from the U.S. Congressional Record as was conducted herein. In addition, Jones and McBeth (2010), specifically propose content analysis of the Congressional Record for the study of policy narratives to determine public opinion on policy matters.

Elo and Kyngas (2008) state there are two types of content analysis, inductive and deductive. Inductive content analysis is used when there is little perceived knowledge about the phenomenon under study. Deductive content analysis is used when the structure of the analysis is founded on existing knowledge and the purpose of the study is theory testing. In this case, deductive content analysis forms the methodology proposed, since the subject matter has been previously defined and knowledge already exists regarding the perceived cause of the Valley of Death. Deductive content analysis is operationalized through a coding process (Babbie, 2001) where raw data is transformed into a standardized form. This transformation consists of reducing texts into a matrix and analyzing that matrix quantitatively. The researcher produces such a matrix by applying a set of codes to a set of qualitative data (Ryan & Bernard, 2000). The object matter of content analysis can be any kind of recorded communication, namely transcripts of interviews/discourses, protocols of observation, video tapes, and written documents in general (Kohlbacher, 2005). The analysis may also take the form of either a structured or an unconstrained format. When using a structured matrix of analysis, only the aspects from the data that fit the categorization framework and dimensions are employed (Elo & Kyngas, 2008).

This study's content analysis of the Congressional Record was initiated utilizing the Library of Congress' on-line text search engine to identify individual instances of the use of the term Valley of Death. The complete content of each edition of the Congressional Record containing the term was retrieved through the web site http://beta.congress.gov. These source documents form the raw data input for analysis using the content analysis software NVivo (NVivo, 2013). Within NVivo, the captured editions were categorized based on the contextual use of the term. Instances where Valley of Death was affiliated with innovation and technological development formed a category for further analysis, while all other uses were discarded. Classification in this manner limited the analysis to the appropriate context for the study.

The mechanism used for further analysis of the relevant documents followed the methodology employed by Hancock in her study of poverty in America (Hancock, 2004). She examined the Congressional Record as source input to create what she called the *public identity* of poverty. To gather appropriate content for her analysis she established certain '*dimensions*' which are descriptors that are considered to be commonly associated with poverty. For example, her dimensions included such terms as: don't work, lazy, cross-generation dependency, single-parent family, drug users, teen mothers, etc. A search of the Congressional Record under these dimensions provided the starting content for her detailed data analysis. In parallel fashion, research objectives 1 and 2 of this study are designed to confirm the *public identity* of the term Valley of Death. To isolate the relevant content from the Congressional Record and address research objective 1, the following dimensions were established as the criteria for the Valley of Death related to innovation and technology development: research, development, R&D (in case abbreviations were used in the text), innovation and technology. The actual roots of these words were used in the search of the text to allow for variations in usage. For example, '*innovat*' was used to generate results from such words as innovate(s), innovating, innovative, innovation, etc. These dimensions were chosen from the descriptions in the literature review based on the fundamental understanding of the Valley of Death related to the linear model of innovation. All passages containing instances of the term Valley of Death associated with one or more of the dimensions noted above were identified and captured to produce the content considered appropriate not only for research objective 1, but also for further analysis under research objectives 2 and 3.

With respect to research objective 2, the instances of the selected text content were more deeply scrutinized to determine if they were statements supporting other factors used to describe the Valley of Death such as a funding issue or not and/or if a position along the innovation spectrum was mentioned for its location. The dimensions used to specify funding issues were set as a group of synonyms around availability of capital, specifically – funding, financing, money, capital, investment, loans, credit and grants. The dimensions established to examine for the location of the Valley of Death were commercialization, ideas, applied research, products, between, bridge, and market. The terms for the position dimension were drawn from a generalized statement of understanding of the literature, whereby *additional resources are required to commercialize ideas into market products and bridge the applied research gap between basic and developmental research.* As with research objective 1, the roots of the words forming the dimensions for research objective 2 were used as the search terms to isolate the relevant text. If one or more of the supporting dimensions were located within the text under examination, then that text was selected as fulfilling the criteria to describe that particular factor. The selected text units supporting a factor were then quantitatively assessed against all text units obtained under research objective 1 to determine the relative importance of that factor vis-à-vis all other discussion.

Under research objective 3, the findings for use of the term Valley of Death, in the context of innovation and technology development (i.e., the pertinent findings of research objective 1), were then aggregated by year of occurrence and relative frequency of use calculated.

Research Objective 4 - Empirical Basis of the Valley of Death

The methodology employed for this research objective utilized a post facto, non-experimental approach (Sprinthall, 2006) to determine the historical R&D spending patterns by the university and industrial sectors. This research objective primarily relied on the use of descriptive statistics of each of the categories of R&D spending over the period of 1998 through 2011 to generate the model. Referencing the various figures provided in Chapter II, the Valley of Death has been typically illustrated on a two-dimensional graphical plane such that the abscissa reflects the technological stage of development, or phase of research, while some measure of R&D resources expended is presented on the ordinate axis. On this plane, figurative renderings of the R&D spending patterns for both universities and industry have been depicted as separate s-shaped curves (mirroring the sides of hills), and the apparent horizontal gap between these curves has been dubbed the Valley of Death (Katehi, 2010; Markham, 2002; NSF, 2013a). By utilizing these standard depictions as the base model and by applying both the academic and industrial sectors' actual past R&D spending patterns, a first-hand quantification of the underlying structure of the Valley of Death phenomenon is produced. To provide the reader with clearer understanding of the standard R&D spending model and the one used in this study, a visual portrayal of its general underlying structure is illustrated in the two-dimensional graphical plane in Figure 9.

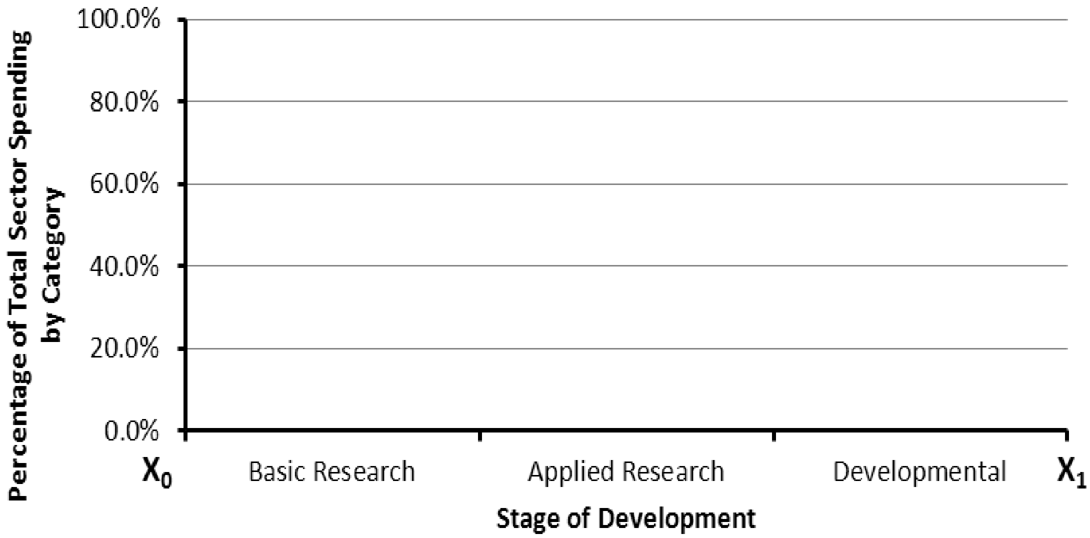

Figure 9. The standard graphical plane used to depict the Valley of Death for the comparisons of patterns of R&D spending between the university and industrial sectors.

From Figure 9, the three categories of research are seen to sequentially align and build on each other along the x-axis, reflective of the linear model of innovation. As laid out in Chapter II and according to Godin (2006), the linear model contends that innovation starts with basic research, moves through applied research and then to developmental research, ending up with production and market diffusion. Prior to any research spending the stage of development is considered as solely an idea depicted as point X_0 at the origin of the x-axis in Figure 9. After proceeding through the various R&D phases, and once all the stages of development are concluded, the technology is ready for production and market distribution depicted as point X_1 at the extreme right of the x-axis in Figure 9.

The y-axis of the graph represents the measure of R&D spending. As shown in Figure 9, it is typically the percentage amount of the total spending in each category of research by sector (Katehi, 2010; Markham, 2002; NSF, 2013a). By utilizing the historical mean amount of annual spending within each category of research and calculating its percentage relative to sector total spending, the data presents the overall historical spending pattern for both the university and industrial sectors. Each sector results were individually calculated and presented and a trend line was attached to the results. Next, the percentage results for each sector category were superimposed on each other, and when constructed in this fashion, the x-y plane and accompanying trend lines provided the necessary vehicle to depict the historical patterns of spending for both the university and industrial sectors, in a manner consistent with prior published renderings.

Advancing from the initial depiction, which provided an empirically based rendition of the currently accepted model of the Valley of Death, a second level of analysis was conducted by utilizing absolute dollar spending levels. The y-axis was amended to represent the actual dollar-spending amount by category, instead of relative percentage spending by category. In this way, all individual categories of research spending, within and across sectors, were equally scaled and directly compared to each other. Continuing from this second level of graphical analysis, the model was further adjusted to reflect the level of university R&D spending associated with the inventions that it produces. The information to conduct this further modification was obtained from estimates of the number of inventions (AUTM, 2011) and the average federal grant associated with those inventions (NIH, 2013b; NSF, 2013b). This refinement is a further logical extrapolation of the model, since only research associated university inventions is relevant to the Valley of Death. The research inventions disclosed to TTOs are what must subsequently traverse the Valley of Death to be adopted by industry. This subsequent adjustment and rendition provided a direct comparison between the university invention enterprise and the industrial innovation enterprise and hence a true final perspective of the Valley of Death.

Population and Sample

Recognizing the differing styles of analysis and sources of data for the study objectives, the discussion of the population and sample has been sub-divided. In this regard, research objectives 1, 2, and 3 have been combined and will be discussed separately from the discussion of research objective 4:

Research Objectives 1 through 3

The population for these research objectives consists of all policy narratives of federal legislators and policy-makers engaged in advocating for or against policy on the Valley of Death related to innovation and technological development. The sample used to represent narratives for this population was obtained from the Congressional Record during the period covering the 102nd Congress (1991) through the 113th Congress (2013).

Research Objective 4

Under this research objective, a comparison of R&D spending patterns between two statistically, mutually exclusive sub-populations was analyzed over the period between 1998 and 2011. The first sub-population is represented by U.S. based research universities, whereas the second sub-population consists of U.S. private sector corporations conducting R&D within the U.S. The university sub-population sample consisted of a census survey of the entire universe of U.S. research universities, performing R&D in excess of $150,000 per year (N=912). The historical data have been collected by the NSF from each accredited institution in this sub-population and are available on line at the NSF website (NSF, 2011).

With respect to the second sub-population, namely U.S. corporations conducting domestic R&D, the NSF estimates the total population count of this group to be 2,090,181 (NSF, 2011). More formally, the corporate sub-population is defined as all for-profit, nonfarm companies that are publicly or privately held, have five or more domestic employees, perform or fund R&D, or engage in innovative activities in the United States. The NSF produces a countrywide profile of R&D spending for the corporate sub-population through annual survey instruments. For example, 43,002 companies were sampled by the NSF in 2011 with 40,300 companies incorporated in the final data evaluation. Reasons for the initial elimination of certain companies from the sample reflect mergers, acquisitions, and instances where companies have gone out of business in the interim. Of the companies included in the final data evaluation, 73.1% were considered to have met the full criteria for a complete response to the 2011 survey. The final sample (n) of 29,459 fully valid responses measured against the overall population estimate represents 1.5% of the total estimated population.

Data Collection and Variables for the Study

Data Collection - Research Objectives 1 through 3

For these research objectives, data was sourced through a structured content analysis of the Congressional Record for the period covering the 102nd Congress (1991) through the 113th Congress (2013). Using this time period serves two purposes, first it covers the period from the initial use of the phrase Valley of Death in an innovation context (Lux & Rorke, 1991), and secondly, it is fully accessible and retrievable electronically through the web site portal Thomas.gov. All data are categorical.

Thomas.gov is a service of the Library of Congress that was launched in 1995 to make federal legislative information freely available to the public. Included among the data available is the Congressional Record (Library of Congress, 1995). The Congressional Record is a verbatim account of the floor proceedings of the House and Senate that contains documents collectively known as the Extensions of Remarks. The

Extensions of Remarks include additional legislative statements not actually delivered on the House floor, plus other extraneous material such as texts of speeches delivered outside Congress, letters from and tributes to constituents, and newspaper or magazine articles. Similar extraneous material from Senators is inserted in the Additional Statements section of the Senate part of the record. The Congressional Record therefore provided a highly relevant source to extract details of the discussion and narratives about the Valley of Death within the political and policy-making environment.

Data Collection - Research Objective 4

The data utilized for this component of the study consists of ordinal and interval data drawn from three independent third-party sources: the NSF, NIH and AUTM. These sources represent two federal agencies and an industrial source, respectively. The NSF data provided the initial information for the analysis used to determine the fundamental historical patterns of R&D spending for each sector (ordinal). The NIH and AUTM data enabled a refinement to the results to represent a more accurate estimate of the amount of R&D associated with university inventions related to technology transfer (interval). Details of each data source follow.

The NSF dataset. The data were derived from annual surveys conducted by the NSF, initially through its Division of Science Resources Statistics and now through its National Center for Science and Engineering Statistics. Specifically, the data were drawn from the reports contained in National Patterns of R&D Resources, detailing R&D performance and funding in the United States. The NSF's statistics on R&D expenditure levels have been recorded annually since 1953 and have been categorized by: (1) R&D performers (i.e., business sector, federal government, federally funded research and development centers, universities/colleges, and other nonprofit organizations); (2)

sources of R&D funding (i.e., business sector, federal government, nonfederal government, universities/colleges, and other nonprofit organizations); (3) the character of work performed, that being the category of research undertaken (i.e., basic, applied, and developmental research) and; (4) the monetary basis (i.e., recording of the expenditures in both current dollars and constant inflation-adjusted dollars). The raw data extracted from the NSF reports and utilized in this study have been reproduced and tabulated in Appendixes B and C herein.

Data covering the industrial sector are reported on a calendar-year basis to NSF and are used directly in the national pattern totals. The data for universities and colleges are collected on the institution's fiscal-year basis and then converted to a calendar year by NSF prior to publication. In 1998 and later years, the university R&D figures were adjusted to eliminate double counting of funds passed through from one academic institution to another. For university/college R&D, the character-of-work estimates were also revised for 1998 and later years. According to the NSF, the revised procedure along with respondent data corrections yielded an increase of approximately five percentage points in the share of academic R&D identified as basic research. Similarly, the character-of-work estimates (i.e., basic, applied, and development research) for the industrial sector were revised for 1998 and later years. These changes resulted in a net decrease in the proportion of business R&D classified as basic research. In view of the changes to survey methodology, and unless otherwise suitably adjusted, the basic research data for 1998 and later years are not explicitly comparable with data for 1997 and earlier years (NSF, 2011). Given the changes in survey methodology, research objective 4 solely utilized the data for the period 1998 through 2011 to provide the most recent structure of the Valley of Death and yield the most reliable comparison between sectors and categories.

The AUTM dataset. AUTM data were drawn from annual surveys of its members who report on the level of their respective institution's activities. The membership in the U.S. responding to the 2011 survey represented 160 research universities that conducted 95% of all federally funded research granted in that year (AUTM, 2011). From the AUTM surveys, the data on the total number of invention disclosures, in conjunction with the NIH and NSF average grant data sets (see below), formed the basis for estimating the total amount of federal R&D funding attributed to university inventions. This provided a method for defining the level of university R&D spending relevant to the commercialization process. All raw data captured from the surveys and utilized in the analysis are compiled in Appendix D.

The NIH dataset. Additional data to further refine the pattern of R&D spending for universities was drawn from the NIH Research Portfolio On-line Reporting Tools (NIH, 2013b). This public, on-line, searchable database provides information on historical grant awards by the NIH. The data obtained from this database represents the total number of NIH grants and the total dollar amount of those grants awarded to all US-based, higher education institutions over the period of 1998 through 2011, inflation adjusted to 2005 dollars. The data gleaned from the online database has also been incorporated in Appendix D.

NSF individual grant dataset. This additional data, when used in conjunction with the NIH dataset discussed above, further helped refine the pattern of R&D spending for universities. It was drawn from the NSF web-based Budget Internet Information System (NSF, 2013b). This public, on-line, searchable database provided information on historical grant awards by the NSF. The data obtained from this database represents the total number of NSF grants and the total dollar amount of those grants awarded to all US-based, higher education institutions over the period 1998 through 2011, inflation adjusted to 2005 constant dollar levels. The data gleaned from the on-line database has also incorporated in Appendix D.

Variables - Research Objectives 1 through 3

The variables under examination consisted of researcher-designed categories to accumulate counts of contextually defined terms as they were found within the official archived text of the Congressional Record. The primary division of categories was between the uses of the term Valley of Death in the context of innovation versus all other use of the term. All descriptions of the Valley of Death in the context of innovation were then divided into sub-categories. For example, a description of the Valley of Death (in the context of innovation) as a funding shortfall was placed in one sub-category, whereas the description of the Valley of Death as something other than a funding shortfall was placed in a separate category. Likewise, additional categorization related to the position of the Valley of Death along the innovation spectrum was sub-categorized whenever possible. The amount of sub-categories was originally established as open-ended to account for all potential descriptions. All variables are categorical (Sprinthall, 2006).

Variables - Research Objective 4

The variables under this research objective represent two sub-population groupings representing the university and industrial sectors. Within each sector is a sub-division of the data into the classifications of basic, applied, and developmental research. The values for basic, applied, and developmental research represent the amount of annual spending in that category for each sector, recorded in both percentage of sector total and in absolute dollar terms. In addition, a further sub-grouping within the university sector was established for R&D spending related solely to invention disclosures. This categorized structure yielded fifteen separate variables utilized in analyzing the Valley of Death. Tables 2 and 3 summarize the variables for both the industrial and university sectors, respectively.

The dollar amounts of research in the university sector reflected only the federally funded portion of research at U.S. universities. In the industrial sector, the variables represented domestic U.S. corporations conducting R&D, but the value of the R&D included only private sector sources of funding. Thus, the resulting comparison among variables was between federally funded, university knowledge generating research and purely economically motivated research. All other sources of grants to the university and industrial sectors were removed to narrowly focus the interaction of these two sectors and therefore provide the best estimator of the Valley of Death in university technology transfer.

Table 2

Schedule of Industrial Sector R&D Spending Variables1,2

Character of Spending	Definition
Basic %	The average annual percentage of total industrial research spent on basic research.
Applied %	The average annual percentage of total industrial research spent on applied research.
Developmental %	The average annual percentage of total industrial research spent on developmental research.

Table 2 (continued).

Character of Spending	Definition
Basic $	The average annual dollar amount of total industrial research spent on basic research.
Applied $	The average annual dollar amount of total industrial research spent on applied research.
Developmental $	The average annual dollar amount of total industrial research spent on developmental research.

1. Averages taken over the period 1998 through 2011

2. Dollar amounts are in inflation adjusted, constant 2005 terms

Table 3

Schedule of University Sector R&D Spending Variables[1,2]

Character of Spending	Definition
Basic %	The average annual percentage of total university research spent on basic research.
Applied %	The average annual percentage of total university research spent on applied research.
Developmental %	The average annual percentage of total university research spent on developmental research.
Basic $	The average annual dollar amount of total university research spent on basic research.
Applied $	The average annual dollar amount of total university research spent on applied research.
Developmental $	The average annual dollar amount of total university research spent on developmental research.

Table 3 (continued).

Character of Spending	Definition
Basic Invention $	The average annual dollar amount of total university research spent on basic research related to invention disclosures.
Applied Invention $	The average annual dollar amount of total university research spent on applied research related to invention disclosures.
Developmental Invention $	The average annual dollar amount of total university research spent on developmental research related to invention disclosures.

1. Averages taken over the period 1998 through 2011

2. Dollar amounts are in inflation adjusted, constant 2005 terms

While the data was originally collected annually on a current dollar value basis, it has been recorded by the NSF on both a current and constant dollar basis. The actual statistical analysis used in the study relied solely on the constant dollar values. The rationale for this approach stems from the fact that basic research is antecedent to applied research and applied research is antecedent to developmental research (Godin, 2006). The use of constant dollar terms lessened potential variability in the analysis brought on by inflation-induced effects on the spending over time, given the noted temporal sequence of the research. Constant dollars were calculated utilizing 2005 as the base year, and changes in the U.S. annual consumer price index acted as the adjustment factor (NSF, 2011).

The survey instruments utilized by the NSF to tabulate the data for each of the academic and industrial sectors contained slightly different governing definitions for the categories of basic and applied research. Differences were designed to help respondents more accurately categorize their research activity. The definitions contained in each of the survey instruments and any differences are summarized below (NSF, 2007):

Basic research. Within the federal, university, and nonprofit sectors, basic research is defined as research directed toward increases in knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific application toward processes or products in mind. For the industry sector, basic research projects are defined by original investigations for the advancement of scientific knowledge, which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company.

Applied research. Within the federal, university, and nonprofit sectors, applied research is defined as research directed toward gaining knowledge or understanding necessary for determining the means by which a recognized and specific need may be met. The applied research definition for the industry sector includes research projects which represent investigations directed to discovery of new scientific knowledge and have specific commercial objectives with respect to either products or processes.

Development Research. The survey definition of development research for both sectors is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes. It excludes quality control, routine product testing, and production. This definition is consistent throughout the various survey instruments employed.

Summary

The failure of most university inventions to achieve commercial success is captured by the metaphor Valley of Death, which holds certain connotations and beliefs in the mind’s eye of policy-makers. Policy-making is directed by a coalition of shared beliefs (Sabatier, 1988), and given the changing direction of federal policy with respect to university research grants, the study objectives were designed to firstly confirm policy-makers' current shared beliefs concerning the Valley of Death. Secondly, an empirical assessment of the Valley of Death was compared to the prevailing shared belief to determine if there was any disconnection between historical evidence defining the Valley of Death and the perception of policy-makers. The population under investigation consisted of federal policy-makers (research objectives 1, 2, and 3) and universities and industries that had engaged in R&D activity (research objective 4). All data used in the study was obtained from third party archival records and was employed in a mixed-method basis of analysis. The results of the analysis are presented in the following chapter.

CHAPTER IV

RESULTS

Introduction

This chapter presents the results of this study. The research objectives were designed to determine if the accepted beliefs held by policy-makers surrounding the cause of the Valley of Death differ from the historical evidence. The research focused on the Congressional Record as the source of data to ascertain the prevailing perceptions of policy-makers with respect to the nature and cause of the Valley of Death. To authenticate these perceptions, past R&D spending patterns of university and industry were examined to provide an empirically based model of the Valley of Death, which has otherwise not yet been portrayed in the literature. Together these research objectives demonstrate the congruence of federal policy beliefs and the proposed methods of addressing the Valley of Death with the historical evidence on the matter.

Findings

Research Objective 1

Research objective 1 was established to determine the frequency of use of the term Valley of Death by policy-makers in the context of innovation and technology development. The search engine provided by Thomas.gov was used to identify each issue of the Congressional Record that contained the phrase. The results revealed 118 instances of the term being used over the period January 1, 1991 through November 30, 2013. The term appeared in 73 individual issues of the Congressional Record, uttered by 92 different speakers. Distillation of these results to obtain the use of the phrase in the context of innovation and technology development was achieved by filtering all records by the dimensions established for this contextual use of the term, namely research, development, R&D, innovation and technology. Specific to this context, it was revealed that 58 speakers utilized the phrase 79 times in 41 editions of the Congressional Record. The coding results for each dimension, cross-referenced to each text unit, are provided in Appendix E, along with the observed number of appearances in each passage for each dimension. A summary schedule of the number of occurrences of each dimension and its relative percentage are presented in Table 4. Note that the total number occurrences of the selected dimensions (235) exceeds the number of text units examined (118), indicating an average of 2.0 dimensions per text unit.

Table 4

Summary of Occurrences of the Dimensions Established to Capture Innovation in Relation to the Valley of Death in the Congressional Record[1]

Dimension	Number of Occurrences	% Frequency of Occurrence
Research	78	33.2%
Development	48	20.4%
R&D	9	3.8%
Innovation	26	11.1%
Technology	74	31.5%
Total	235	100.0%

1. Period covering January 1991 through November 2013

A manual check of the results was undertaken by reviewing all selected occurrences of the phrase to confirm that the content did relate to the Valley of Death in innovation. The manual check confirmed that no inappropriate selections had been included with the results. In a similar fashion, all unselected occurrences were individually reviewed for correctness. In this regard, it was determined that five uses of the phrase had been inappropriately excluded from the sample. The five instances were found in the Congressional Records for May 6, 2009 (one instance), May 12, 2010 (one instance) and February 2, 2011 (three instances), and they were manually added to the sample for further consideration and analysis, increasing the overall total of valid instances to 84 (refer to Table 5). The examination of these additional records revealed that they each referred to funding the innovation Valley of Death without having incorporated any of the dimension terms included in the narrative. It was also noted that no new single term could have been added to the list of dimensions to capture these text units on the first pass. The full chronological list of all instances of the term emerging from the Congressional Record is provided in Appendix F. The list also identifies each use of the term in the context of innovation and technology development as well as the other contexts related to the use of the Valley of Death. The details of the findings contained in Appendix F are summarized in Table 5 below:

Table 5

Summary of Occurrences of the Term Valley of Death in the Congressional Record[1]

Contextual Category	Number of Occurrences	% Frequency of Occurrence
Innovation/Technology	84	71.2%
Military Tribute	16	13.5%
Military Action	12	10.2%
Congressional Procedures	2	1.7%
Other	4	3.4%
Total	118	100.0%

1. Period covering January 1991 through November 2013

From Table 5, out of all instances of the observed use of the term Valley of Death, the connection to innovation and technology development occurs 71.2% of the time (i.e., 84 out of 118 times). Other uses of the phrase were mostly in reference to descriptions of military events, prayer, and self-deprecating characterizations of Congress. All of the relevant references to the Valley of Death (i.e., in an innovative context), along with the surrounding narratives gleaned from the Congressional Record, were captured and formed the sample text units for further review and analysis under research objectives 2 and 3. All captured text units have been reproduced in Appendix G,

Research Objective 2

Research objective 2 was established to ascertain the frequency of use of a funding shortfall in the middle stages of development when policy-makers describe the Valley of Death in technology development. By determining the frequency of the association of a funding shortfall with the term Valley of Death, and its associated location, this research objective provides a basis for explaining the prevailing belief on the part of policy-makers. The relative frequency of use of a funding shortfall against other descriptors provides a weighting of this belief against other potential causes. For the analysis, each of the 84 instances of the use of the term Valley of Death identified in research objective 1 (refer to Appendix G) was examined and the surrounding content analyzed, first with respect to the dimensions established for funding (i.e., funding, financing, money, capital, investment, loans, credit, and grants) and second, the dimensions for location (i.e., commercialization, ideas, applied research, products, between, bridge, and market). The coding results of each funding dimension are provided in Appendix H, whereas the coding results for each location dimension are provided in Appendix I. The observed number of appearances of each dimension in each text unit and the corresponding count of Valley of Death occurrences are also contained in Appendices H and I.

Table 6 summarizes the number of occurrences and frequency of appearance related to each funding dimension within the 84 text units selected. Note that the total number of occurrences of the funding dimensions (102) exceeds the number of text units (84), indicating an average of 1.2 dimensions per text unit.

Table 6

Summary of Occurrences of the Dimensions Established to Identify a Funding Shortfall Associated with the Valley of Death

Dimension	Number of Occurrences	% Frequency of Occurrence
Funding	31	30.4%
Financing	6	5.9%
Capital	34	33.3%
Money	8	7.8%
Investment	15	14.7%
Loans/Credit/Grants	8	7.8%
Total	102	100.0%

Next, the 84 text units from the Congressional Record were reviewed against the dimensions related to the location of the Valley of Death. Table 7 summarizes the number of occurrences and frequency of appearance of each dimension. In this case, there was an average of 1.7 dimensions incorporated within each text unit.

Table 7

Summary of Occurrences of the Dimensions Established to Locate the Position of the Valley of Death [1]

Dimension	Number of Occurrences	% Frequency of Occurrence
Commercialization	34	23.3%
Ideas	3	2.0%
Applied Research	30	20.5%
Products	23	15.8%
Between/Bridge	35	24.0%
Market	21	14.4%
Total	146	100.0%

1. From the Congressional Record, period covering January 1991 through November 2013

The dimensions associating the Valley of Death and funding yielded a total of 61 out of 84 text units where instances of the two were linked in open discussion (refer to Table 8, lines one and two). In essence, financial parameters were tied to the concept of the Valley of Death 72.6% of the time. An example of the use of the term Valley of Death by politicians within the Congressional Record, which reflects these financial parameters was provided by Representative WU: “One of the biggest stumbling blocks to innovation is the technology so called Valley of Death the gap between angel funding and measurable venture capital, the lack of adequate private venture capital for early stage, high-risk, high-reward technology development” (Wu, 2007, p. H4453).

The dimensions associating the Valley of Death and a location yielded 64 out of 84 text units where instances of the two were linked in open discussion (refer to Table 8, lines one and three). The concept of the Valley of Death in the innovation process was associated with the middle stages of development 76.1% of the time. A sample of a text unit that contains the use of the Valley of Death in the location context is provided by Senator Smith (2005): “However, many times innovative research becomes victim of the Valley of Death by failing to advance from the research labs to application in commercial products and services” (p. S11745).

Cross-tabulating the results for both the funding and location factors, it was revealed that in 48 (line one of Table 8) of the 61 funding instances (lines one and two of Table 8), the funding shortfall was specifically identified as being in the mid-stages of the development cycle, between the outputs of basic research and final commercialization. An example of this use of the term was provided by Senator Morella (2001) when she stated, “the program seeks to provide a critical bridge for the funding gap from innovation to the marketplace of pre-competitive, emerging technologies. ATP

[Advanced Technology Program] seeks to smooth the transition from invention to commercialization, the so-called valley of death" (p. E1378).

Beyond a funding shortfall, 23.8% of the time (refer to Table 8, lines three and four) the Valley of Death was associated with market factors as its influencing cause (e.g., risk, market readiness, limited demand, etc.). These market development effects are exemplified in comments by Senator Lieberman (2008):

> Lastly, the Accelerating Cures Act of 2008 uniquely adds resources to guide researchers through the Valley of Death, a stage in biomedical development between research and commercialization where the success of an initiative is dependent on feasibility and profitability that can only be established by a market that, by definition, has not yet developed. (p. S3894)

In 75.0% of these cases, the Valley of Death was still identified as being a break in the development cycle of new technologies, situated between basic research and market commercialization.

Among all characterizations of the Valley of Death, it can be stated that a break in the development cycle between basic research and commercialization identified the location of the Valley of Death 76.1% of the time (refer to Table 8, lines one and three). A further example in the Congressional Record that demonstrates this belief was provided when Senator Bingamam (2008) stated, "this is the part of the development cycle of a new technology when the technology has been demonstrated at a lab or pilot scale and is ready to be demonstrated at a commercial scale" (p. S6444).

No other locations to identify the position of the Valley of Death were mentioned in the text units (i.e., basic research). Finally, 3.6% of the time the Valley of Death was mentioned without reference to either its cause or location in the development cycle. A summary of occurrences for all of the various characterizations of the Valley of Death in an innovation and technological development context are provided in Table 8.

Table 8

Summary of the Characterizations of the Term Valley of Death in the Congressional Record[1]

Contextual Characterization	Number of Occurrences	% Frequency of Occurrence
(1) Funding shortfall, mid-stages of development	48	57.1%
(2) Funding shortfall, unspecified location	13	15.5%
(3) Market factors, mid-stages of development	16	19.0%
(4) Market factors, unspecified location	4	4.8%
(5) Unspecific factors	3	3.6%
Total	84	100.0%

1. Period covering January 1991 through November 2013

Research Objective 3

Research Objective 3 was established to determine the pattern of use over time by policy-makers of the term Valley of Death in the context of innovation and technology development. Based on analysis of the text units extracted from the Congressional Record directly related to innovation, the pattern of use of this phrase has been seen to cycle over time. Typically the use of the phrase has shown greater frequency in years where certain legislation is up for reauthorization (e.g., Advanced Technology Program 2005, SBIR-STTR 2009 and 2011, Cures Acceleration Network Act 2009, IRS Tax Credits 2011, Department of Defense Authorization Act 2011, etc.). In the case of the Small Business Innovation Research and Small Business Technology Transfer programs' (SBIR-STTR) re-authorization legislation, the discussion centered on the need for this programming to help mitigate the Valley of Death and advance the use of new technology. Interestingly, the most recent policy narratives supporting this program were in contrast to the original stated purpose of the legislation, which was to engage small business in creating innovative solutions to technological issues faced by government agencies ("Small Business Innovation Development Act," 1982). Although slightly outside the scope of this study, this change in policy narrative is a prime demonstration of the precepts of NPF and ACF. The policy narratives are now focusing on the SBIR program as an economic development tool, which is framing a new perception and belief for the need for the program. Evidently, sufficient coalition took place around this new belief that the legislation was reauthorized.

Table 9 provides details of the annual occurrence and relative frequency of use of the term over the study period.

Table 9

Pattern of use of the Term Valley of Death in the Congressional Record over Time[1]

Year	Number of Occurrences	% Frequency of Occurrence	Key Legislative Considerations
1991-2000	0	0.0%	
2001	5	6.0%	Advanced Technology Prog.
2002	0	0.0%	
2003	0	0.0%	
2004	4	4.8%	Advanced Technology Prog.
2005	13	15.5%	Advanced Technology Prog.
2006	7	8.3%	BARDA
2007	8	9.5%	TIP
2008	5	6.0%	Accelerating Cures Act
2009	16	19.0%	SBIR reauthorization
2010	7	8.3%	America Competes reauth.
2011	14	16.7%	SBIR, DoD reauth.
2012	2	2.4%	USDA biomass R&D
2013	3	3.6%	JOBS Act
Total	84	100.0%	

1. Period covering January 1991 through November 2013

Research Objective 4

Research objective 4 was established to determine the historical research spending patterns, by category of research, for the university and industrial sectors. Table 10 provides the detail of the descriptive statistics that were calculated from the NSF survey data contained in Appendixes B and C. The table starts with the university sector and indicates the mean amount of annual research spending for each research category. Included in the table is the range of spending over the 14-year period being investigated and the standard deviation for each category. The final column in the table indicates the percentage breakdown of research spending among the categories of research for that sector. For example, 75.8% of the university sector's total, mean annual spending over the period took place in the basic research category. The percentage spending itemized within each sector will add to 100%. Similar statistics are provided for the industrial sector, as well as the statistics for the two sectors' combined spending. As expected, the results revealed that the percentage spending in the university sector approximated the mirror image of the percentage spending in industrial sector.

Table 10

Descriptive statistics for annual R&D spending, by sector and research category, over the period 1998-2011, constant 2005 dollars (millions)

Sector/Category of Research	Mean	Minimum	Maximum	Standard Deviation	% of Sector Total
University					
Basic Research	20,107	13,964	22,788	3,246	75.8
Applied Research	5,234	2,642	9,048	1,866	19.7
Developmental Research	1,180	637	2,463	575	4.5

Table 10 (continued).

Sector/Category of Research	Mean	Minimum	Maximum	Standard Deviation	% of Sector Total
Industry					
Basic Research	8,558	5,673	13,483	2,601	4.1
Applied Research	38,141	28,289	45,775	5,188	18.5
Developmental Research	159,577	129,328	185,998	15,510	77.4
Combined					
Basic Research	28,665	19,637	35,824	5,101	12.3
Applied Research	43,375	32,688	50,998	5,094	18.6
Developmental Research	160,757	130,467	186,813	15,650	69.1

A graph of the percentage results by research category from Table 10 for both the university and industrial sectors, including the trend line linking the research categories within each sector are produced in Figures 10 and 11. By then superimposing these plots on top of each other (constructed on the same scale) an empirically derived rendition of the standard image of the Valley of Death is produced (refer to Figure 12).

In the combined graph (Figure 12), the dotted-line columns depict the spending for the university sector, and the solid-line columns represent the industrial sector. The dashed trend lines for each sector provide the outline to the shape of the Valley of Death, which is presented as the horizontal gap between the trend lines within the applied research category. This result provides direct confirmation of the generalized depictions of the Valley of Death contained in the literature (refer to Chapter II). The shape and symmetry of the graph are exactly as anticipated.

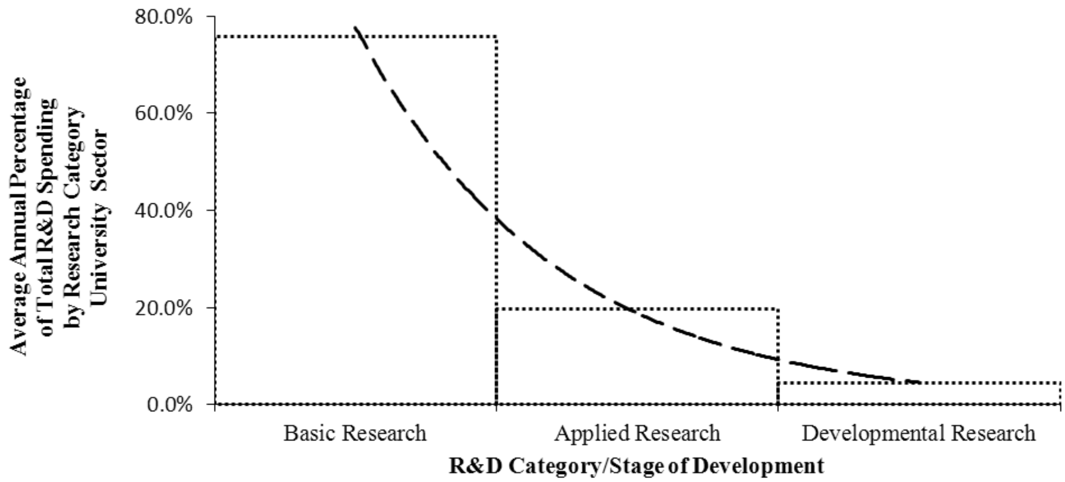

Figure 10. Historical university sector R&D relative percentage spending patterns, by category of research.

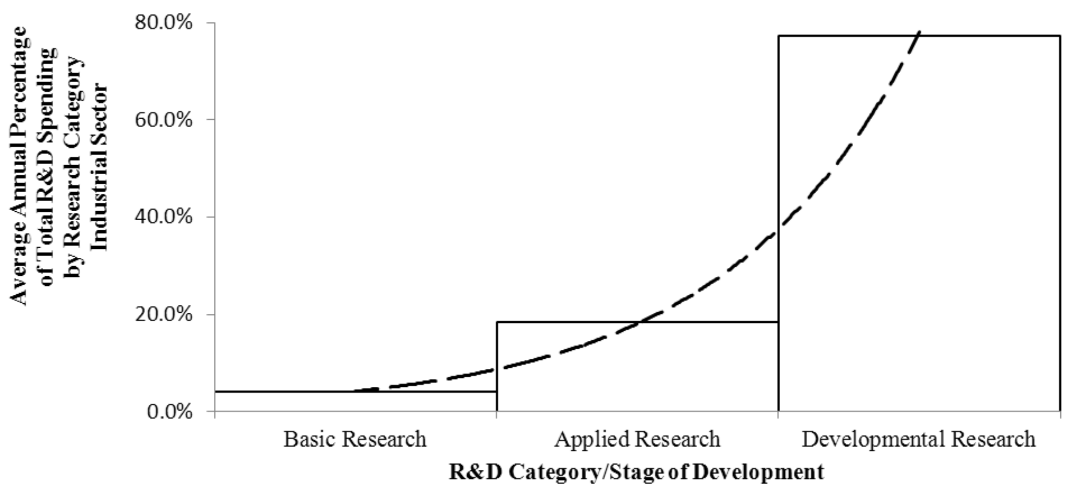

Figure 11. Historical industrial sector R&D relative percentage spending patterns, by category of research.

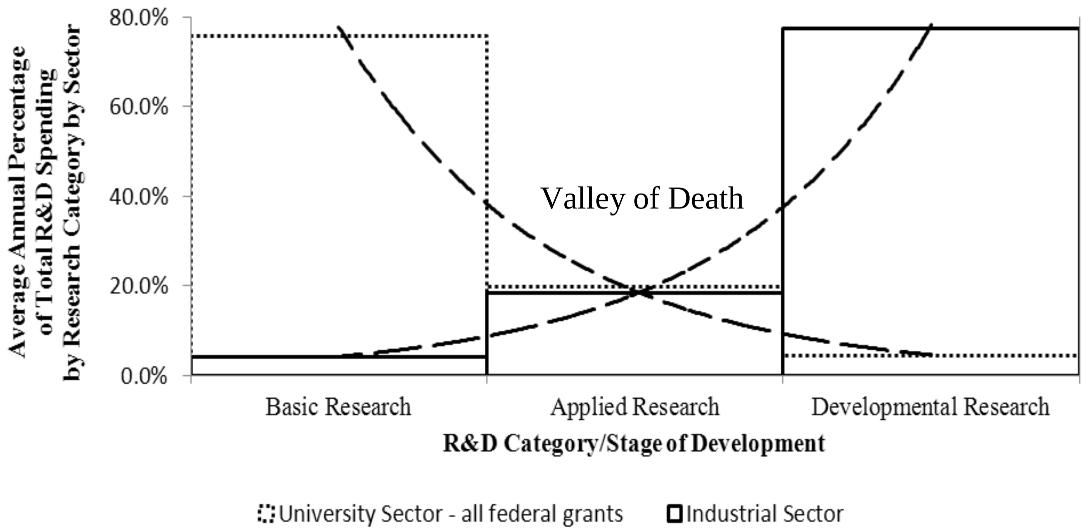

Figure 12. The empirically derived shape of the standard depiction of the Valley of Death, based upon sector historical percentage R&D spending patterns.

As can be gleaned from Table 10, the total average annual spending by universities has been only a fraction of the total average annual spending by industry over the period, namely 12.9% ($26.5B versus $206.3B). To incorporate the difference between the two sectors and appropriately depict this contrast, an adjustment to the structure of the graph to reflect the level of absolute spending by each sector is necessary. Drawing from the rendition in Figure 12, Figure 13 provides an amended depiction of the Valley of Death where the mean annual dollar spending is used for the y-axis, instead of relative percentage spending used in Figure 12. From the revised depiction, what becomes immediately apparent is how the industrial sector overwhelms the university sector because of the difference in absolute spending. The other interesting element to note is the shift in the point of intersection of the trend lines. The new depiction indicates the Valley of Death is now much flatter and lower than first envisioned. It has also shifted toward the origin, which suggests the Valley of Death originates much earlier in the innovation process than the currently perceived mid-stages of development.

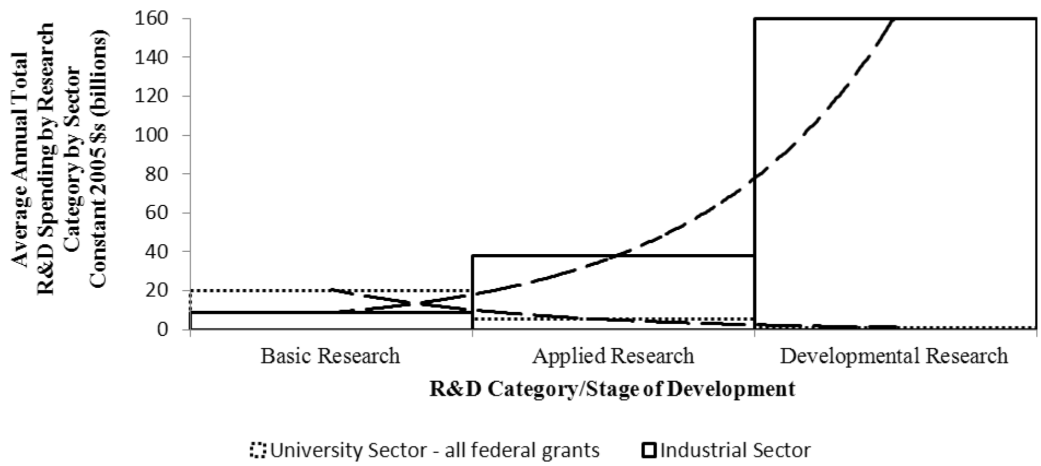

Figure 13. The empirically derived shape of the Valley of Death based upon historical actual average annual R&D dollar spending patterns.

In addition to the adjustment for the absolute level of dollar spending between sectors, it is further noted that the university spending total represents the average annual spending from all federal grants received. Many grants, particularly those in the social sciences or arts, are likely to yield little commercially viable or patentable knowledge and as such, should be excluded from any calculation related to the Valley of Death. In this regard, there has been an average of 14,798 invention disclosures per year throughout the period of 1998-2011 (AUTM, 2011), and at an average grant of $397,102, (based on the grant award amounts of the National Institutes of Health and the NSF, in constant 2005 dollars, during the same period), the total amount of federal grants generating university invention disclosures was estimated at $5.96 billion annually, representing 22.9% of all federal university research grants. Accordingly, the university sector-spending pattern was further adjusted downward to reflect only the R&D spending concerned with invention disclosures. The method of adjustment assumed the same percentage split of spending across the categories of research as indicated in the historical pattern of spending revealed in Table 10. The resulting adjusted descriptive statistics for estimates of university invention related research spending are presented in Table 11.

Table 11

Descriptive statistics for annual estimated R&D dollar spending attributed to university invention disclosures, by research category, over the period 1998-2011, constant 2005 dollars (millions)

Category of Research	Mean	Minimum	Maximum	Standard Deviation	% of Total
Basic Research	4,519	2,500	6,246	1,270	75.8
Applied Research	1,176	651	1,626	331	19.7
Developmental Research	265	147	367	75	4.5

The statistics in Table 11 provide the basis for the final rendition of the Valley of Death, which solely depicts university invention generating research against industrial R&D expenditures. Figure 14 reflects these results:

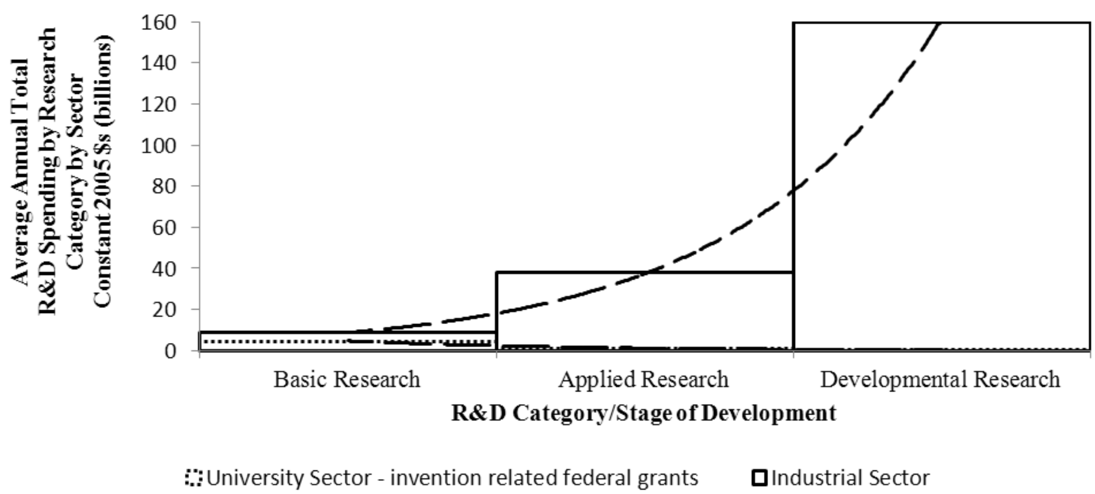

Figure 14. The empirically derived shape of the Valley of Death based upon historical actual annual R&D dollar spending patterns and limited to university invention generating R&D.

The use of the calculations in Table 11 provides the most accurate rendition of the Valley of Death, since only university inventions are considered by industry for commercialization. Figure 14 was scaled to observe the entire spending patterns of both sectors, and it reveals a separation between the two trend lines, commencing in the basic research phase of development and continuing throughout the entire development spectrum. For greater clarity on this separation, the y-axis scale was further adjusted and Figure 15 provides an expanded view indicating the clear separation in spending from the initial position of the trend lines.

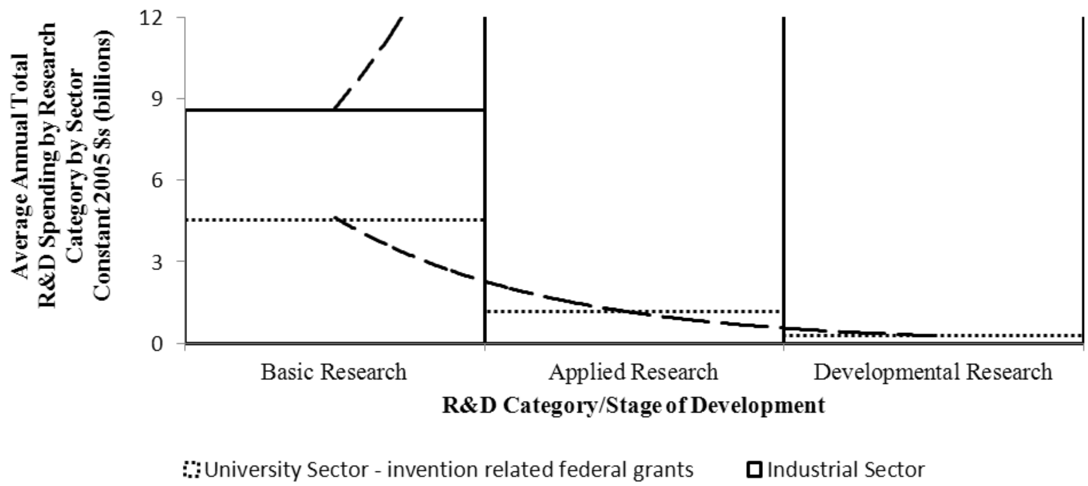

Figure 15. Exploded view of the shape of the Valley of Death in its early stages based upon historical actual annual R&D dollar spending patterns and limited to university invention generating R&D.

From Figures 14 and 15, it is clear that the level of university research spending related to inventions is a small fraction of the R&D activity of industry. The comparison of the trend lines that have been used to historically frame the Valley of Death never intersect. Over the period investigated, they have been independent of each other along the spectrum of development, and the currently conceptualized horizontal gap in the applied stage of development is not evident. Instead, a vertical gap between the two sectors is now manifest and extends across all research categories.

Summary

This chapter presented the results for the research objectives established for this study. Broadly, the purpose of the study was to provide empirical evidence to help inform federal policy-making, which is currently focused at mitigating the effects of the Valley of Death in university technology transfer. This purpose was addressed by first determining the shared belief held by policy-makers with respect to the cause of the Valley of Death. The results indicated an overwhelming majority of policy-makers believed that the Valley of Death was a funding issue associated in the middle stages of product development – falling between the results of basic research and final market readiness. Secondly, the historical patterns of R&D spending in the university and industrial sectors were derived to provide an empirically based depiction of the Valley of Death. These results showed that when one considers the absolute dollar levels of R&D grant funding associated with the development of university inventions then the historical model becomes inadequate to describe the Valley of Death phenomenon. The separation between industry and academe is not a function of the stage of development as believed. By providing data on current shared beliefs, juxtaposed against the actual historical account of the Valley of Death, the appropriateness of federal policy direction can be gauged. The results indicate a disconnection between current causal beliefs and the historical evidence. These findings are more fully discussed in the following chapter.

CHAPTER V

SUMMARY DISCUSSION AND RECOMMENDATIONS

Summary

Restatement of Purpose

The purpose of this study was to expand the current body of knowledge related to the Valley of Death in university technology transfer. The prevailing belief surrounding the cause of the Valley of Death is initiating changes to the system of federal research grants to universities; however, to date there has been limited empirical work to support the causal perceptions related to this phenomenon. By investigating the beliefs held by policy-makers on the Valley of Death and by comparing those beliefs to the historical record, appropriate perspective is provided on the direction of current policy-making.

The Basis for this Investigation, Revisited

In a globalized knowledge economy, countries today are more compelled than ever to have their domestic industries be at the forefront of innovation and technological development to drive growth and sustain economic competitiveness (Florida, 2004; Porter, 1990). Consequently, finding ways to effectively increase the rate of development of new technologies will enhance national wellbeing (Obama, 2011). The U.S. federal government invests heavily in university research, and capitalizing on that research for both societal and economic benefit is a mandate of that funding (National Research Council, 2007). Today, much of the direct economic benefit from university research is considered unrealized due to its failure to be fully exploited, with greater than 90% of all university inventions failing to be adopted by industry (AUTM, 2011). The prevailing understanding is the Valley of Death is an impediment to progress and therefore, mitigation of its effects is important to national economic objectives (RFI, 2010). In order to help contribute to the national policymaking debate on the Valley of Death, this study has advanced the body of knowledge and our understanding of the field.

Results of the Study

What the study revealed is that 72.6% of the time when the term Valley of Death is expressed by politicians and policy-makers, in the context of innovation and technology development, it is associated with a funding gap. In 78.7% of such descriptions, the funding needs are specified as being a necessary to support additional development work for new technologies as they move from discovery to commercialization. Not surprisingly, the use of the term is more frequent during periods of debate on reauthorization of certain federal programming related to technological development, for example the SBIR program.

Other than a capital shortage, additional references to the innovative Valley of Death cite general market factors 23.8% of the time to describe the difficulty in transitioning technologies from the lab to the market. Again, in 75% of such descriptions the market limiting factors are described as disrupting the process of development at the mid-stages of development. In 3.6% of all references, the Valley of Death is cited without specification as to its cause or location. None of these unspecified references has been made since December 2006, which indicates policy-makers may be more informed and/or more deliberate in their attempts to contextually frame their point of view on the issue.

In contrast to the beliefs noted above and based on the actual levels of R&D spending associated with university inventions, the study has shown the Valley of Death is *not* confined to a funding gap within a defined scope of development activity. The historical patterns of R&D spending, and hence the technology development curves for university and industry, have been independent of each other along the entire length of the innovation spectrum. Because the difference in funding between the two sectors extends across all stages of development, factors other than stage of development must have driven university inventions across the Valley of Death. This result actually supports the prior findings of Auerswald and Branscomb (2003), that the Valley of Death is more of a Darwinian Sea of economic survival than a Death Valley drought of funding. Under the Auerswald and Branscomb model, the Valley of Death is actually a manifestation of the level of market demand by industry for the inventions. The market demand is driven by the availability of information about the invention (Auerswald & Branscomb, 2003), and hence, the perceived economic return that an investment in the technology would yield to investors (Weston & Brigham, 1975). More formally, the level of market demand is a function of "*asymmetries of information*" (Auerswald & Branscomb, 2003, p. 227) and the risk-adjusted, "*expected rate of return*" (Weston & Brigham, 1975, p. 324) that is then associated with the potential investment. The remainder of this chapter discusses the findings, the limitations of the study, recommendations for policy or practice, and suggestions for future research in the field.

Discussion of Findings

The key finding of the study is the incongruence between the prevailing belief for the cause of the Valley of Death and the historical evidence that indicates the Valley of Death goes beyond a simple funding shortfall. Current beliefs are rooted in the notion of a funding gap, located in the middle stages of product development, as having limited further development of new technologies. The idea of an applied research funding shortfall originated in the minds of policy-makers in the mid-nineteen nineties through the work of the Committee of Science (H.R. Rep. No. 105-B, 1998) and has prevailed ever since (please refer to Figure 1, Chapter II, herein). The research spending shortfall is attributed to the fact the percentage ratio of R&D spending (rounded) among the three phases of research in the university sector is 76 (basic) to 20 (applied) to 4 (developmental), and the same percentage ratio of spending in the industrial sector is 4:19:77 (refer to final column of Table 10, Chapter IV). The unbalanced weighting of percentage effort at either end of the research spectrum by both sectors relative to the middle phase, established the case for an applied research-funding shortfall.

The study has shown that the ratio of historical spending patterns among the phases of research for the combined R&D effort of the university and industrial sectors is 12:19:69, and of that, the university sector represents only 11.4% of this total (refer to Table 10, Chapter IV). On a combined basis, the evidence indicates there is no unbalance in the middle phase of research, only growth from one phase to the next. This growth pattern is to be expected given the foundation of the linear model of innovation, which provides the understanding that basic research may lead to many technologies and which in turn, may spawn the development of a variety of products, each requiring substantial development prior to adoption in the market (Godin, 2006). Furthermore, when one accounts for federal funding solely attributed to invention disclosures at universities, the amount of this research relative to combined university and industry R&D spending is reduced to only 2.8%, and the overall ratio of spending among the phases of R&D becomes 6:19:75. Again, there is no unbalance in the middle stage of research, only growth in spending from one phase to the next. Since the allocation of funds by industry to each phase of research is an economically driven business decision based on potential future returns, it is concluded that the choice of a capital investment in university inventions by industry is grounded in an economic evaluation against other available investment options, as per the prior findings of Auerswald and Branscomb (2003). The Valley of Death is therefore more accurately characterized as the result of an allocation of investment funding, not a shortage of development funding. The Valley of Death as it is conceived by policy-makers is incorrect. A Valley of Death exists for university inventions, but it is simply the final resting place for inventions that fail to satisfy the economic criteria of industry. It is not something to be bridged with additional developmental resources. The lack of development funding for early stage technologies is an indicator of their perceived economic viability and not the fundamental cause of an interruption in their technological development.

The appropriately scaled graphical representations of historical spending on university inventions and industry innovation reveal the true gap in the patterns of R&D spending between the two sectors (refer to Figures 14 and 15, Chapter IV). In contrast to current beliefs and previous depictions, there has been a vertical gap in the level of R&D resources employed, not a horizontal gap in the level of development. This vertical gap is present throughout each phase of research and is precipitated by an economic allocation of resources. Therefore, in order to develop a truer representation of the Valley of Death, one that is in keeping with the findings of the study, an amendment to the parameters of the existing graphical plane is required. Instead of R&D resources plotted against stage of development, the y-axis becomes the market demand for university inventions as measured by the expected risk-adjusted rate of return on the invention. The x-axis becomes the universe of all available university inventions, and the cumulative distribution function of those expected returns for all those inventions becomes the plotted figure. Along the y-axis, there is a threshold level for the expected rate of return that an invention must be attained in order for the invention to be acceptable to industry. Achievement of this threshold enables the invention to rise out of the Valley of Death. When plotted, the area bounded by the cumulative distribution function at and above the threshold level of return represents the proportion of those university inventions that satisfy the economic criteria for adoption by industry. Figure 16 provides a generalized depiction of this interpretation of the Valley of Death. The economically feasible range of inventions is depicted by the shaded region. The Valley of Death is the area below the threshold rate of return.

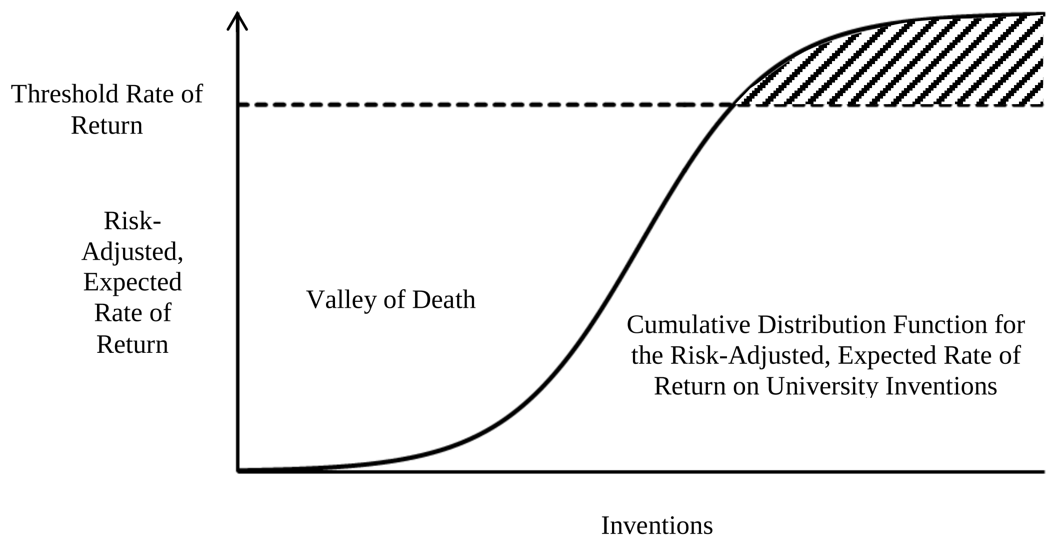

Figure 16. Revised view of the shape of the Valley of Death based upon expected market returns from investments in university inventions.

Note that this revised model also provides a method to conceptually capture the work of Auerswald and Branscomb (2003). Their premise for the level of market efficiency associated with university inventions can be theoretically measured under this model by directly comparing the number of feasible inventions adopted by industry (i.e., the number of university inventions actually licensed to industry) to the total number of economically feasible inventions (i.e., the shaded area under the curve in Figure 16). This ratio provides a percentage measure of the market efficiency.

Under the proffered interpretation of the Valley of Death, in order to have more inventions adopted by industry two options are available for future policy consideration, (1) the shape of the cumulative distribution curve will have to be altered and/or (2) the threshold rate of return will need to be reduced. This first option is the target of current policy. Essentially, by amending the nature of the style of university research to more application driven R&D, federal policy-makers are estimating that the curve's shape will be altered and a greater proportion of the distribution function will lie above the threshold rate. With respect to the second option, since the threshold rate represents the risk-adjusted expected rate of return in the marketplace, the threshold level itself cannot be directly influenced, but in the case of individual inventions, the threshold rate can be directly affected by either increasing the rate of return and/or reducing the risk. The return component is a function of a firm's potential profitability against the level of investment necessary in the invention. The risk component is a function of the variability surrounding the expected returns. By positively influencing any of the factors driving these risk/return elements, the number of inventions that fall above or below the threshold rate can be adjusted.

It is clear that under this model, policy directed at either amending the wholesale shape of the distribution function by altering the character of the research (i.e., the direction of current policy) or positively influencing the expected rate of return on individual inventions, should be able to generate the desired result of enabling more university inventions to transfer to industry. This assumes continuity in the underlying distribution, however, any discontinuity in the distribution function would not necessarily preclude policies targeted at either approach from working. A deeper understanding of the true shape of the curve would be required to determine the most effective policy design in those circumstances. It is this researcher's opinion that policy directly targeted at influencing the level of the expected rates of return on individual inventions, vis-à-vis changing the character of university research, would be more effective. The primary rationale behind this position is that this policy approach simply and directly targets the parameters governing industry decision-making; it does not substitute different research outcomes as the product available to industry. Secondly, there is no basis to assume that any change in the profile of university research outcomes would yield more economically feasible inventions, since the choice of the research subject matter is driven by academic interests and not market opportunities. In fact, if changes to the profile of university research were to produce more economically feasible outcomes, then university research would logically be becoming a substitute for private sector R&D. Studies to date indicate a complementary balance between university and private sector R&D (Diamond, 1998). If more substitutive behavior were to occur, then this shift would not only affect the academic enterprise (Lee, 1996) but, it may also affect the overall rate of societal growth (Feller, 1990).

One of the assumptions of the study was the applicability of ACF and NPF as effective mechanisms for policy change with respect to the issue of technology transfer and the commercialization of university research. Fundamental to the ACF process is its contention that policy change is not simply the result of competition among various interested parties in which financial resources and institutional control rules the day, but where '*policy-oriented learning*' within and between coalitions is an important aspect of policy change. Policy-oriented learning is a change in thought or intentions resulting from experience and/or new information, which is then employed to achieve one's policy objectives. Alongside policy-oriented learning is the notion of different structural levels for personal beliefs. First, are *deep core beliefs*, which are a person's ontological principles and which are highly resistant to change. Next, are *policy core beliefs*, which are basic normative, '*party-line*' commitments. Then, follow an individual's *causal perceptions* with respect to a particular policy issue. At any particular time, a coalition adopts one or more strategies to prompt policy-oriented learning in an effort to influence *causal perceptions* to change oppositional beliefs and realize its own policy objectives.

The strategies for policy-oriented learning are usually targeted at lower level belief aspects such as causal perceptions, which can be influenced by exogenous circumstances (e.g., changes in rules, budgets, personnel, information, etc.). In the circumstances of the Valley of Death, the current change in policy direction is neither a *deep core* nor a *policy core* change, but the result of a lower level influence – its *causal perception*. This is evidenced by the unchanging, bi-partisan policy core belief from the time of the Bayh-Dole Act of 1980 to today, namely the need for greater translation of university research. Today the difference is the change in the *causal perception* between then (i.e., confounding intellectual property rights) and now (i.e., an applied research funding gap). What is flawed within this ongoing process is the lack of a comprehensive understanding of cause and the resulting effect of the proposed change. The findings of the study suggest that new policy-oriented learning will need to take place on two levels. On one level, present causal perceptions are currently incorrect; however, amending these perceptions will not be as difficult as the additional, potentially needed higher-level learning with respect to policy core beliefs that define the purpose of university research. Problems for which accepted quantitative data and theory exist are more conducive to policy-oriented learning across belief systems (e.g., causal perceptions on the Valley of Death) than those in which data and theory are generally qualitative (e.g., the purpose of university research). Assuming stakeholders comprehend impacts of the suggested revisions to university research, coalitions will need to be formed based on supporting knowledge and strategies developed to debate and expose the social externality issues surrounding the proposed policy.

Threats to Validity and Limitations of the Study

The study objectives can be divided into two categories, assessment of current beliefs and empirical spending evidence. The approach to each of these categories entailed the use of third party data, which brings with it certain cautions due to construct and external threats. With respect to the objectives related to assessment of current beliefs, the evidence was drawn from the Congressional Record. While this source provides a verbatim account of Congressional statements as a public record, it may influence the statements being made, which is a threat to external validity due to interaction of the causal relationship with the setting (Shadish, Cook, & Campbell, 2002). In addition, the Congressional Record represents only one source for the data needed to generate inferences, which is a threat to construct validity from mono-operation bias (Shadish et al., 2002). Although these threats cannot be overlooked, the overwhelming consistency of the use of the term Valley of Death by policy-makers and its uniformity with use in the academic literature suggest the findings on the current belief system is accurate and pervasive.

With respect to the objectives related to the historical patterns of R&D spending, the main limitation of the study reflects the availability of appropriate data to directly relate the level of research spending to the stage of product development achieved. This limitation necessitated the application of the data in each phase of research as discrete ordinal categories building on each other, rather than as a single continuum as proposed under the linear model of innovation. Hence, the trend lines that were derived to describe the structure of the R&D patterns of spending and therefore the Valley of Death are not the true technology development functions of either industry or academe, but a generalized interpretation of their appearance. More refined data within and across the phases of R&D would enable the actual research spending and technology development functions to be ascertained, and the true shape of the Valley of Death established. Notwithstanding the data limitation, the absolute dollar spending patterns of the two sectors provide sufficient evidence that these sectors have not intersected with each other in any phase of development over the study period. Any new information related to the amount/pattern of basic university research that produces inventions would have to be double the historical experience in order to affect the findings and suggest independence has not existed between the sector spending patterns. The minimal extent of the limitations on the findings does not impinge on the conclusion that the existing explanation for the Valley of Death is an inappropriate description for this phenomenon.

Recommendations for Policy and Practice

In considering recommendations for future federal policy, it is assumed that politicians, policy-makers, and the public will continue to seek to mitigate the economic consequences of the Valley of Death but do not want to do so at the expense of societal growth and overall human capital development. Under this assumption, it is recommended that instead of amending the entire federal university granting system from its originally intended purpose, proposed policy should be more targeted. The granting system designed for knowledge creation and disinterested scientific research should remain intact, with the requests for funding and the outputs of research being evaluated on academic merit. Thus, the rate of overall human capital development will not be adversely affected. New knowledge emanating from the research being undertaken that appears commercially translational and shows economic promise should be the subject of separate grant programs and different evaluation criteria. Policies that push early stage university research further along its development pathway, without considering industrial acceptability of the technology, are ignoring market factors. If basic research is the forte of universities and satisfying market demand is the forte of industry then policies focused at the intersection of these two would be most appropriate – not a wholesale amendment to one end of the process (i.e., the university granting system). The design of policies affecting an entire process that could otherwise be better targeted to a limited subset of activity within the process, and without regard to other potential consequences, can be likened to using a sledgehammer on a tack.

Evidence has shown that the U.S. federal government has historically taken the position that applied and developmental research should be under the purview of the private sectors, with federal focus strictly on basic research, except in certain cases of national defense and healthcare (Bush, 1945; H.R. Rep. No. 105-B, 1998). In the U.S., government support for private sector R&D efforts meets with political difficulty, having been characterized as corporate welfare (Bozeman, Crow, & Tucker, 1999). Given the political history and the prevailing belief of the cause of the Valley of Death, policy-makers would appear to have had little alternative up to this point, other than addressing the Valley of Death via the university granting process. However, since it is not universities that have their hand on the pulse of the market, any future programming will require direct engagement with industry to be most effective. Precedents do exist for U.S. government intervention where markets are not efficient, usually where provision of services are uneconomic (e.g., rural utilities) or where excess profits can accrue (e.g., monopolies). In the case of the Valley of Death, the argument exists for market inefficiency that requires federal intervention to capture lost economic opportunity from publicly funded research. The policy narratives should be designed so as not to characterize policy as a subsidy to industry but as a mechanism to ensure the maximum amount of return is obtained from past and on-going federal investment in university R&D. The understanding of market threshold rates of return provides the basis for appropriate policy-oriented learning on the matter.

As a suggested approach, future policy should directly address market demand factors for university technologies. By implementing a program that can simultaneously influence both sides of the Valley of Death, the relevant stakeholders can be drawn together. Essentially, policy should be fashioned to help facilitate universities in the dissemination of their research findings without loss of intellectual property rights and help support industry through risk mitigating programs, enabling greater adoption of early stage technologies. This policy approach may well require additional investment in applied development, but this would not be development for development's sake. It is funding, which will lower ultimate development costs, that will yield additional evidence of profitability and firm-up market competitiveness of the invention. The new information generated will determine the extent of commercial feasibility and hence potential economic return to industry. The effect is to de-risk the invention in the eyes of industry. This effectively causes upward movement on the expected rate of return above the threshold level and hence increased attractiveness to industry.

Illustrations of where such joint policies exist may be found in other jurisdictions. For example, the Canadian national scientific granting council, the Natural Sciences and Engineering Research Council (NSERC), has among its programming a Collaborative

Research and Development Grant (CRDG). CRDGs support well-defined projects undertaken by university researchers in conjunction with private-sector partners. The industrial partner and the federal agency share direct project costs. Projects can be at any point in the R&D spectrum, and the industrial partner must contribute to the direct project costs in an amount equal to or greater than the amount requested from NSERC. The industrial partner's cash contribution must be at least half of the NSERC request, while the balance can be provided as in-kind contributions. The key difference between this program and any in the U.S. is the projects are initiated by industry and hence already have a market driven focus. By targeting such a program to involve U.S. university inventions, industry has the potential to cut development costs in half, thereby enhancing economic feasibility. Adoption of university expertise, strategic alignment of inventors with commercial partners, additional capital resources, and a clearly identified path to market for university inventions would be the result.

A further example of government – industry collaboration in applied technology development recently emerged when the European Commission announced in July 2013 that the European Union (EU) and European industry would jointly invest more than €22 billion over the next seven years in innovation. The program entails an €8 billion investment from the Commission's existing innovation program, Horizon 2020, €10 billion from industry and a further €4 billion from EU Member States. Funds are to be invested in five areas of Public-Private Partnerships, called Joint Technology Initiatives in the fields of innovative medicines, clean energy, clean air transport, bio-based industries, and electronics. In support of the program the President of the European Commission stated, "the EU must remain a leader in strategic global technology sectors that provide high quality jobs. This innovation investment package combines public and private funding to do just that " (Barroso, 2013, para. 2).

In similar fashion to the Canadian and European situations, the proposed policy recommendations would leverage the resources and capabilities of the public, academic, and private sectors for national benefit and growth.

Recommendations for Future Research

Given the revised understanding of the Valley of Death as indicated by the findings, this study suggests additional research takes place on three fronts: (1) seeks to determine the distribution of spending within the stages of development for both the academic and industrial sectors; (2) investigate the impact of a movement in the focus of university grants to more applied areas of research and; (3) analyses the risk/return factors associated with the threshold rate of return underpinning the market demand for university inventions. Additional research recommendation (1) will enable the derivation of a continuous production function for the linear model of innovation and thereby further refine the findings of the study. Additional research recommendation (2) will act as a predictor of any change in the demand for university inventions by industry and will enable a more accurate depiction of the generalized cumulative distribution curve of expected rates of return on university inventions. As well, this additional research will provide a confirmation of R&D spending behavior by industry, that is, whether or not more applied university research will act as a complement or a substitute for industrial R&D and thereby identify potential economic consequences of universities taking on more applied research. This will serve to provide additional quantitative data to support policy-oriented learning regarding the purpose and effectiveness of university research. Additional research recommendation (3) will provide a deeper understanding of the underlying parameters surrounding market acceptance of university inventions and will help provide a framework for market based policy strategies to positively influence the adoption of university inventions.

Conclusion

The study has altered the perception Valley of Death in the mind's eye of this researcher and has provided evidence about how its basis differs from the way it is perceived by policy-makers. A Valley of Death exists for university inventions, but it is the final resting place for inventions that fail to satisfy the economic criteria of industry. It is not something to be simply bridged with additional development resources. The lack of development funding for early stage technologies is an indicator of their estimated economic potential and not the fundamental cause of an interruption in their technological development. The failure of the transfer of university inventions to the industrial sector is therefore more accurately characterized as the product of an economic allocation of private sector investment funding, not a gap in available research funding.

Because the study found that the causal perception of the Valley of Death is not consistent with the historical evidence, the foundation of current policy direction is brought into question. Today the consensus policy strategy is to shift the emphasis from basic research to more applied programming in the hopes of making more university research economically attractive. The problem with this approach is that it fails to consider any other ramifications associated with the policy change. Referring back to the conceptual framework in Chapter I (Figure 1) and the discussion of the theoretical precepts underpinning its structure, it was observed that the dissemination of new university knowledge has both economic development as well as human capital development implications. To increase the emphasis of academic R&D outputs as a strategic vehicle for economic development over its historical and primary human capital development mission is a fundamental change in governing philosophy. This policy direction places the production of commercializable knowledge, solely with economic benefit, ahead of the generation of disinterested scientific knowledge that potentially contains greater and broader societal benefit. Not only does this focus have ramifications on the mission and internal operation of universities, but without a holistic appreciation of the situation, such a narrowly constructed policy direction can create negative externalities that could go well beyond any stand-alone, desired economic benefits. The fear expressed by many academicians in the 1990s (Lee, 1996) about this academic evolution should now be a center point of discussion, but it is not even being mentioned let alone debated in the current policy narratives surrounding the advocacy for change.

Although the study set out to advance our understanding of the Valley of Death, it has added specific focus to the literature by offering empirical support to the prior work of Auerswald and Branscomb (2003) and their concept of survival of the fittest technologies in a Darwinian Sea of economic competition. In addition and perhaps most importantly, it has created a case for university technology transfer to be studied more deeply as an interdisciplinary issue. In this regard, there needs to be particular emphasis on the human capital development implications of proposed policy change. Rather than policy being driven by narrow objectives based on an outdated understanding, the study has revealed that the technology transfer process should receive the full benefit of a comprehensive interdisciplinary examination if we are to gain a true cognitive appreciation of its political, societal and economic influences. Just as the '*butterfly effect*' describes a potential ripple effect and interplay of events, to consider technology transfer policies within the specific framework of only one discipline (i.e., economic development) sets the stage for unintended consequences.

APPENDIX A

DESCRIPTION AND BACKGROUND ANALYSIS OF UNIVERSITY TECHNOLOGY TRANSFER

This appendix seeks to provide additional background and detail on the technology transfer process depicted in the conceptual framework of Chapter I (refer to Figure 1). It also includes an analysis of the key operating parameters across and within TTOs.

The meaning of technology-transfer utilized in this study is narrower than standard definitions of technology transfer, in that only one mechanism of technology transfer is considered (i.e., inventions). At the same time the examination is further restricted to the university situation. By comparison, the on-line dictionary, Dictionary.com, defines technology transfer as “the movement of new technology from its creator or researcher to a user, esp. as products or publications; also, the movement of new technology from developed areas to less-developed areas” (Dictionary.com, 2012). From a more academically inclined viewpoint, Abramson et al. defines technology transfer as “the movement of technological and technology-related organizational know-how among partners (individuals, institutions, and enterprises) in order to enhance at least one partner’s knowledge and expertise and strengthen each partner’s competitive position” (Abramson et al., 1997, p. 2). In contrast, the definition adopted here is the dissemination of new knowledge captured in the form of inventions, which have been discovered by university researchers.

The typical operating process for university TTOs, starts when an invention disclosure is received from a faculty researcher (Siegel, Waldman, & Link, 2003). The staff within the technology transfer office then initiates an analysis of the invention from a technical, patentable and commercializable standpoint. After this initial review, and if the invention is deemed to have merit, TTO staffers will then seek to commercialize it in some fashion, usually by licensing the rights for the technology to the private sector (Graff et al., 2002). In the process, TTOs will seek to protect the intellectual property, usually by filing a patent application. If fortunate, the patent office will issue a patent providing a series of claims that will be of interest and value to industry. In parallel manner to the industrial linear model of innovation, the technology transfer process can be depicted as a sequential series of steps. An example of a successful technology transfer process can be illustrated as follows:

Invention Disclosure → TTO Assessment → Patent Application → Patent Issues →

License Agreement with Industry → Income Stream to University

Similar to the criticism of the industrial linear model of innovation, as noted in Chapter I, the linear process indicated above might not necessarily follow this sequential pattern in all cases. For example, certain technologies may not be suitable for patenting, or may never issue as a patent and they may be licensed as a trade secret. Additionally, given the cost and timing associated with the commercialization/patenting process, TTOs are typically attempting to license technologies to industry at any opportune point and in many cases ahead of the actual issuance of a patent. Generally, TTOs would also seek to include reimbursement of patent costs within the license agreement (Ferguson, 2011). Since 1991, the historical operating data from each of the various steps within the technology transfer process outlined above have been collected in annual surveys of its members by AUTM. This is the largest single source of information on the subject matter. These surveys have grown in both scope and depth over the period. Today over 200 respondents complete the survey annually, including foreign members. From this data, various operating results for TTOs have emerged to be suitable performance measures for growth and comparison purposes, most notably: numbers of invention disclosures, patent applications, patents issued, licenses executed and license income. Other data collected includes such items as R&D funding, staffing levels, budgets, age of office, etc. (AUTM, 2011).

The AUTM data offers the means for an industry wide analysis across all TTOs, as well as the opportunity to conduct comparative analysis among separate TTOs. In this Appendix, both these approaches have been undertaken to provide additional perspective on the operations and effectiveness of TTOs.

Industry Wide TTO Performance Metrics

Data drawn from the most recent five years of AUTM surveys has been accumulated in Table A. This data reveals that the ratio of initial invention disclosures to patent applications to approved patents to industry licensing contracts is: 6.2 : 3.0 : 1.2 : 1 (AUTM, 2011). That is to say, for every 6.2 invention disclosures, 3.0 patent applications are filed, which results in 1.2 patents being granted and one licensing contract being executed. It should be noted that this is aggregate data and no allowance has been built into the analysis to provide for lead/lag effects. In this regard, the receipt of an invention disclosure initiates a review process, which may lead to a patent application (which may also be preceded by a provisional patent filing which potentially allows a further 12 months prior to the patent filing). Once a patent application is filed, the average time to issue is currently running 3 years (USPTO). In addition, a license agreement may be executed at any time after the invention has been disclosed. No timing adjustments were made in this instance, as the purpose is not to match one sequential event with another, but to provide an appreciation of the overall relative scale of the process. The reader is referred to Mowery et al. (2004)for a full discussion and historical account of technology transfer and its performance metrics.

Table A

Five Year Combined Operating Performance of U.S. University TTOs for the five year Period 2007 through 2011

	Federal R&D Grants Received ($ millions)	Invention Disclosures	U.S. Patent Application s	Patents Issued	Licenses Executed
Aggregate Data	$ 161,326	91,901	43,832	17,626	14,761
Conversion Rate	$1.8 per invention disclosure	100.0	47.7	19.2	16.1
Success Rate				40.2%	83.7%
Ratio to Licenses Executed		6.2	3.0	1.2	1.0

Given the data in Table A, on the surface it would appear that the least effective stage in the university commercialization process lays in the difference between the number of patents filed and the number of patents issued. This is represented by a success rate of 40.2% (ratio of 1.2 patent approvals for every 3.0 patent applications). This apparent low success ratio has created a perception that the university technology-transfer process is inefficient when cited against a forty-year average historical success rate of 65% at the US Patent and Trademark Office (Landes & Posner, 2003). When being compared to industry's success rate, it should also be noted that universities, when moving from an invention disclosure to deciding on a patent application, typically have less than a month to determine if they wish to protect the intellectual property being disclosed. For example, there were 19,732 invention disclosures in 2011 that were reviewed by 902 licensing professionals in 156 TTOs, an average of 1 invention disclosure per licensing officer every 9.4 working days. The decision process to determine whether to commercialize/patent or not entails a technical and scientific assessment, reviewed against the existing literature and patent landscape; a potential market analysis; and then development of a commercialization strategy which emerges from the market analysis. Industry has the capability to more fully develop their technologies before considering final commercial feasibility and if a need for patent protection exists. On average it takes 7 years within industry between the research finding and the first introduction of a commercial product (Mansfield, 1991, 1998). What the foregoing information reveals is an affirmation of the characteristic trait and need for universities to file patent protection at the very earliest stages of the innovation process and usually on short notice. One of the primary reasons for proceeding to patent at such an early stage reflects the need for the university researcher to publish his/her results. Publication of research results is a bar to future patent protection under current patent laws (12-month grace period in the U.S. only; complete bar under the international Patent Convention Treaty) and accordingly patenting decisions must be made in an expeditious fashion vis-à-vis a publication deadlines. In addition, the governing act for technology transfer of federally funded R&D (Bayh-Dole) requires that if any future commercialization is sought, the technology needs to be protected via patent. It is also highly likely that additional external resources will be required to develop the technology further. In this regard, the intellectual property needs to be protected before disclosing to potential strategic partners/financiers. Considering the regulatory directives on patenting, the early-stage nature of the technologies, the timing pressures on TTOs, the need for external resources for additional development, the potential opportunity cost of lost income and the risk of liability on the part of the institution from failing to file (potentially responsible for lost income to the inventor), one would expect to see a higher level of patenting activity by universities than industry.

In analyzing the performance of TTOs, it should be noted that the license income they receive represents only a small fraction of the commercial worth of the technology. University license agreements are usually structured such that payments to the university are in a form of a royalty on gross sales of the technology by the licensee. In 2011, U.S. universities produced $2 billion dollars in license revenue and taking an average 3% royalty-rate on net sales (Stevens & Phil, 2003), the total direct sales of products and services derived from university technologies would approximate $70 billion. In the same year, the federal government spent $30 billion on university R&D, thereby yielding an annual rate of return of 233% on their investment. This industry-wide analysis of TTOs serves to demonstrate that universities appear fully capable of technology transfer however; the prevailing structure for the protection of intellectual property would not appear to be congruent with the nature of their business or the stage of development of their technologies.

Complementing the foregoing industry-wide analysis, the following analysis focuses on aspects of potential differential performance among TTOs to ascertain if there are potential individual TTO 'best practices' that could be more widely adopted to enhance overall technology transfer performance.

TTO Comparative Analysis - Commercialization Best Practices

While the previous section revealed positive performance statistics for university commercialization activity as a whole, only a few select universities appear to be able to create an economic success out of their technology transfer activity. In fact, only 16% of all TTOs are self-sustaining (Abrams et al., 2009). The question arises as to whether or not the Valley of Death could be mitigated or even removed if the remainder of the TTOs adopted the best practices of the top few. Underlying this question is the basic assumption that the top performing universities possess greater capability in some aspect(s) of the technology-transfer process over and above their counterparts. Accordingly, these top performers should produce performance metrics around certain operating parameters that differentiates them from their peers. This assumption was actually analyzed statistically in the literature by Ferguson (2011). Within this work he tested the hypothesis that the top-ten license income producing TTOs are better operating performers than their colleagues as indicated by differences in the key TTO standard operating metrics: (1) number of invention disclosures received, (2) number of patent applications filed, (3) number of patents granted and (4) number of active licenses with industry.

In testing this hypothesis, Ferguson conducted independent *t*-tests between two defined groups of TTOs to determine if there is a difference in their modus operandi. The analysis consisted of two subdivisions of non-equivalent groups: the first group being the top-ten license income producing U.S. university TTOs (taken from a direct ranking of total gross licensing income for all TTOs in the AUTM database over the period 1996 through 2008) and the second group consisting of all other AUTM survey responding U.S. universities over the same period. The dependent variables consisted of the four key operating parameters of TTOs, namely: number of invention disclosures received, number of patent applications filed, number of patents issued and number of active licenses with industry. This hypothesis was tested twice. The first time as noted above and then a second series of *t*-tests were conducted after each of the four dependent variables had been factored to reflect the level of federally funded R&D taking place at the university.

The results of the first tests revealed that across all tested TTO operating parameters, the top-ten licensing universities in the country performed significantly better than their colleagues did. However, when one controls these operating parameters based on the dollar level of federal R&D received by the institution (e.g., number of invention disclosures per dollar of research funding received), it turns out that there are no statistical differences among any of the operating metrics of the top-ten universities vis-a-vis their peers. In fact, they underperform against their colleagues on all of these same operating measures with the performance metrics falling below the mean in each case. The consequence of these findings being, that whatever technology transfer practices are being employed, they appear to be systematically employed by all TTOs. There are no distinguishing "best practices" displayed within the operating metrics of the top-ten universities, which can be leveraged to enhance performance and economic impact (Ferguson, 2011).

From the same study by Ferguson it was observed that a positive correlation existing between the level of annual federal R&D spending and the amount of license income generated, with a Pearson *r* correlation calculated at .30 ($p < .001$) (Ferguson, 2011). While statistically significant, the low power of these findings suggests other variables are at play. Combining this fact with the understanding that there is no significant difference in the operating parameters between highly successful revenue generating TTOs and less successful TTOs, then the conclusion was reached that unidentified systemic factors must be influencing the lack of commercial licensing of university inventions and contributing to the Valley of Death.

APPENDIX B

FEDERALLY FUNDED R&D AT U.S. UNIVERSITIES BY CLASSIFICATION OF RESEARCH FOR THE PERIOD 1953 THROUGH 2011

(INFLATION ADJUSTED 2005 CONSTANT DOLLARS)

Year	Basic	Applied	Development	Total
1998	13,964	2,642	1,139	17,745
1999	14,858	3,067	819	18,744
2000	15,741	3,603	637	19,981
2001	17,143	3,921	742	21,806
2002	19,224	4,349	718	24,291
2003	20,883	4,837	975	26,695
2004	21,853	4,940	1,278	28,071
2005	22,186	4,900	1,168	28,254
2006	21,979	5,014	915	27,908
2007	21,692	5,079	860	27,631
2008	21,643	5,507	793	27,943
2009	22,093	5,994	689	28,776
2010	22,073	8,504	2,364	32,941
2011	22,637	9,048	2,463	34,148

Source: National Science Foundation, National Center for Science and Engineering Statistics (NSF/NCSES), National Patterns of R&D Resources (annual series).

APPENDIX C

U.S. INDUSTRIAL R&D EXPENDITURES BY CLASSIFICATION OF RESEARCH

FOR THE PERIOD 1953 THROUGH 2011

(INFLATION ADJUSTED 2005 CONSTANT DOLLARS)

Year	Basic	Applied	Development	Total
1998	5,673	34,587	129,328	169,588
1999	6,381	38,978	140,876	186,235
2000	6,892	41,133	158,060	206,085
2001	8,045	44,539	151,454	204,038
2002	7,223	28,289	156,977	192,489
2003	7,377	34,908	152,038	194,323
2004	6,988	42,007	145,284	194,279
2005	7,559	39,995	156,696	204,250
2006	6,723	43,623	166,028	216,374
2007	7,990	45,775	174,692	228,457
2008	10,032	38,189	185,998	234,219
2009	12,252	30,309	178,729	221,290
2010	13,483	36,220	170,835	220,538
2011	13,187	35,424	167,082	215,693

Source: National Science Foundation, National Center for Science and Engineering Statistics (NSF/NCSES), National Patterns of R&D Resources (annual series).

APPENDIX D

CALCULATION OF FEDERAL GRANTS ATTIBUTED TO INVENTION DISCLOSURES RECEIVED BY TECHNOLOGY TRANSFER OFFICES

Year	Number of Grant Awards	Dollar Value of Grants (000,000s)	Constant Dollar Value of Grants (000,000s)	Average Grant Value (Constant $s)	Number of Invention Disclosures	R&D Related to Invention Disclosures (000,000s)
1998	27,058	7,985	9,337	345,077	9,555	3,297
1999	28,928	8,640	9,958	344,248	10,052	3,460
2000	31,266	9,996	11,266	360,336	10,701	3,856
2001	33,173	11,199	12,344	372,107	11,259	4,190
2002	35,865	12,679	13,752	383,434	12,638	4,846
2003	37,875	14,416	15,314	404,334	13,718	5,547
2004	37,069	15,322	15,831	427,072	15,002	6,407
2005	36,998	15,818	15,818	427,526	15,371	6,571
2006	36,890	15,660	15,169	411,208	16,855	6,931
2007	37,091	16,068	15,126	407,815	17,677	7,209
2008	36,422	16,079	14,808	406,571	17,694	7,194
2009	35,664	16,579	15,110	423,664	18,163	7,695
2010	35,546	16,954	15,275	429,732	18,635	8,008
2011	35,250	16,685	14,719	417,562	19,732	8,239
Mean	34,650	13,863	13,845	397,102	14,789	5,961
Standard Deviation	2,606	2,772	1,853	27,699	3,257	1,625

Sources: AUTM(2011), NIH(2013b), NSF(2013b)

APPENDIX E

CODING RESULTS FOR THE DIMENSIONS OF THE VALLEY OF DEATH RELATED TO INNOVATION AND TECHNOLOGY DEVELOPMENT

Date of Congressional Record Examined	Dimensions for Innovation					Identified Innovation Content	Number of Valley of Death References
	Research	Development	R&D	Innovation	Technology		
3/21/1991							
4/30/1991							
6/25/1992							
8/10/1992							
11/20/1993							
5/26/1994							
4/18/1996							
9/29/1997							
3/7/2001	1				1	✓	1
7/20/2001	3	1		2	3	✓	1
9/10/2001	1				2	✓	1
9/24/2001	6	3			4	✓	2
2/25/2004	5	4			9	✓	4
4/7/2004							
5/19/2005							
6/9/2005	3				3	✓	1
7/29/2005	2	1			1	✓	2
9/14/2005 (1)	2	1				✓	1
9/14/2005 (2)	1			2	1	✓	1
10/21/2005	3			1	1	✓	2
11/18/2005							
12/14/2005 (1)	1	4	3	1		✓	1
12/14/2005 (2)	1	1		1		✓	1
12/14/2005 (3)	2	3		1		✓	2
12/14/2005 (4)	5	1		1		✓	1
2/15/2006				1		✓	1
5/4/2006				1	3	✓	2

Date of Congressional Record Examined	Dimensions for Innovation					Identified Innovation Content	Number of Valley of Death References
	Research	Development	R&D	Innovation	Technology		
9/26/2006 (1)		3				✓	1
9/26/2006 (2)	2	2				✓	2
12/5/2006							
12/27/2006	2	2				✓	1
1/4/2007				1	2	✓	2
1/17/2007		1				✓	1
5/3/2007		1		3	7	✓	2
8/2/2007 (1)		1				✓	1
8/2/2007 (2)	4					✓	1
9/27/2007				1		✓	1
12/11/2007							
12/19/2007							
4/30/2008					2	✓	1
5/7/2008 (1)	3	4		1	1	✓	1
5/7/2008 (2)	7	2		1	1	✓	2
7/8/2008				1	4	✓	1
8/1/2008							
11/20/2008							
4/27/2009							
4/28/2009	2					✓	1
5/6/2009						✓(a)	1
7/8/2009 (1)	1	1			3	✓	1
7/8/2009 (2)	3					✓	1
7/8/2009 (3)	2					✓	1
7/13/2009					3	✓	1
9/16/2009	1	1			2	✓	1
10/20/2009 (1)	2			1		✓	1
10/20/2009 (2)	2				5	✓	4
10/20/2009 (3)					1	✓	3
10/30/2009				1	1	✓	1
11/18/2009			1			✓	1

(a) Manually inserted passage

Date of Congressional Record Examined	Dimensions for Innovation					Identified Innovation Content	Number of Valley of Death References
	Research	Development	R&D	Innovation	Technology		
12/15/2009			2			✓	1
3/19/2010		1				✓	2
5/12/2010 (1)		1			1	✓	1
5/12/2010 (2)	1	2	1		1	✓	1
5/12/2010 (3)						✓(a)	1
9/29/2010							
12/8/2010							
12/9/2010							
12/21/2010	4				1	✓	2
1/7/2011							
2/2/2011						✓(a)	3
3/15/2011 (1)				1	1	✓	2
3/15/2011 (2)				1		✓	1
3/15/2011 (3)					2	✓	1
5/27/2011		1			1	✓	1
7/14/2011	3	3	1		3	✓	4
8/1/2011							
11/2/2011							
11/4/2011							
11/10/2011							
12/6/2011	1	1				✓	1
3/12/2012							
6/14/2012	1	2	1		1	✓	2
6/21/2012							
1/23/2013							
3/6/2013							
5/15/2013				1		✓	1
8/2/2013							
10/31/2013	1			1		✓	1
11/13/2013				1	1	✓	1
Count	78	48	9	26	74	58	84

(a) Manually inserted passage

APPENDIX F

CHRONOLOGICAL LISTING OF CONGRESSION RECORDS CONTAINING THE TERM VALLEY OF DEATH

Congressional Session	Date	Number of Occurrences	Context
102	3/21/1991	1	Other
102	4/30/1991	1	Other
102	6/25/1992	1	Other
102	8/10/1992	1	Other
103	11/20/1993	1	Other
103	5/26/1994	1	Other
104	4/18/1996	1	Other
106	9/29/1997	1	Other
107	3/7/2001	1	Innovation
107	7/20/2001	1	Innovation
107	9/10/2001	1	Innovation
107	9/24/2001	2	Innovation
109	2/25/2004	4	Innovation
109	4/7/2004	1	Other
109	5/19/2005	1	Other
109	6/9/2005	1	Innovation
109	7/29/2005	2	Innovation
109	9/14/2005	2	Innovation
109	10/21/2005	2	Innovation
109	11/18/2005	2	Other
109	12/14/2005	6	Innovation
109	2/15/2006	1	Innovation
109	5/4/2006	2	Innovation
109	9/26/2006	3	Innovation
109	12/5/2006	1	Other
109	12/27/2006	1	Innovation
110	1/4/2007	2	Innovation
110	1/17/2007	1	Innovation
110	5/3/2007	2	Innovation
110	8/2/2007	2	Innovation
110	9/27/2007	1	Innovation
110	12/11/2007	1	Other
110	12/19/2007	1	Other
110	4/30/2008	1	Innovation
110	5/7/2008	3	Innovation
110	7/8/2008	1	Innovation
110	8/1/2008	1	Other
110	11/20/2008	1	Other

CHRONOLOGICAL LISTING OF CONGRESSION RECORDS CONTAINING THE

TERM VALLEY OF DEATH

Congressional Session	Date	Number of Occurrences	Context
111	4/27/2009	1	Other
111	4/28/2009	1	Innovation
111	5/6/2009	1	Innovation
111	7/8/2009	3	Innovation
111	7/13/2009	1	Innovation
111	9/16/2009	1	Innovation
111	10/20/2009	6	Innovation
111	10/30/2009	1	Innovation
111	11/18/2009	1	Innovation
111	12/15/2009	1	Innovation
111	3/19/2010	2	Innovation
111	5/12/2010	3	Innovation
111	9/29/2010	2	Other
111	12/8/2010	1	Other
111	12/9/2010	1	Other
111	12/21/2010	2	Innovation
112	1/7/2011	1	Other
112	2/2/2011	3	Innovation
112	3/15/2011	4	Innovation
112	5/27/2011	2	Innovation
112	7/14/2011	4	Innovation
112	8/1/2011	1	Other
112	11/2/2011	1	Other
112	11/4/2011	1	Other
112	11/10/2011	1	Other
112	12/6/2011	1	Innovation
112	3/12/2012	2	Other
112	6/14/2012	2	Innovation
112	6/21/2012	1	Other
113	1/23/2013	1	Other
113	3/6/2013	1	Other
113	5/15/2013	1	Innovation
113	8/2/2013	1	Other
113	10/31/2013	1	Innovation
113	11/13/2013	1	Innovation

APPENDIX G

CITINGS AND CODING OF CONGRESSION RECORDS CONTAINING THE TERM 'VALLEY OF DEATH' RELATED TO INNOVATION

CONGRESSIONAL RECORD—Extensions of Remarks March 7, 2001; p. E294

> And that problem-solving ethos has been maintained to this very day—whether NIST is probing abstruse questions about the molecular structure of ceramics, or helping to ensure the security of our computers, or providing guidance to a small manufacturer on how to update his operations through the Manufacturing Extension Program. And we also still draw on NIST's expertise to solve problems that are endemic to the economy as a whole—with the Advanced Technology Program, for example, which has helped a wide variety of companies pass through the so-called ''valley of death'' that can prevent good research ideas from becoming good processes or products.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Unspecified cause, Location Described

CONGRESSIONAL RECORD—Extensions of Remarks July 20, 2001

> The Advanced Technology Program is not public financing of established technologies. It should not be seen as speculative investment nor should its success be measured in the same economic terms as private investment. Framing the debate in these terms is fundamentally wrong and misses the point of the program. The ATP is a research and development program, not an exercise in government venture capital. The program seeks to provide a critical bridge for the funding gap from innovation to the marketplace of pre-competitive, emerging technologies. ATP seeks to smooth the transition from invention to commercialization, the so-called valley of death or Darwinian Sea. The United States has the greatest research effort in the world. Our universities and industries develop more ideas and discover more innovations than everywhere else combined. We also understand capital markets and have used our knowledge to produce the world's most vibrant and robust economy. Yet we are still not very good at turning raw ideas into commercial products. While it is tempting to believe that this process is straightforward and should be understandable from basic social and economic principles, it is not and cannot. The relationship between the private sector and this intermediate stage between research and venture capital investment is poorly understood and the subject of intense scrutiny. It would be wrong to treat it as a mature, fully-formed, capital arena.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE September 10, 2001

> Is ATP a success? The answer clearly is yes. The Advanced Technology Program has been extensively reviewed. Since its inception, there have been 52 studies on the efficacy and merits of the program. These assessments reveal that the ATP does not fund projects that otherwise would have been financed in the private sector. Rather, the ATP facilitates so-called Valley of Death projects that private capital markets are unable to fund. In June 2001, the National Academy of Sciences' National Research Council completed its comprehensive review of the ATP. It found that the ATP is an effective Federal partnership that is funding new technologies that can contribute to important societal goals. They also found that the ATP could use more funding effectively and efficiently.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Unspecified location

CONGRESSIONAL RECORD—HOUSE September 24, 2001

> Approximately 5 years ago, I was chartered by then-Speaker Gingrich and the gentleman from Wisconsin (Mr. SENSENBRENNER), the chairman of the Committee on Science and Technology, to prepare a report on updating the science policy of our Nation and outline where we should be heading. That report came out of the Committee on Science and Technology, was approved by the House of Representatives, and became popular enough that it is now in paperback. In that report, we made a major statement on several issues; one of which was to bridge the so-called valley of death between basic research and applied research so that we could have more ideas flowing out of basic research into applied research and eventually into product development. The program we are talking about here today is a program which can help bridge that valley. We are recommending, based on the success of this program, that it be reauthorized and, in fact, improved. Investment in technology, research, and development and this scientific enterprise is a key component of sustaining the economic growth of the past decade, much of which is based on developments in science and technology. As growth slows, Congress must seek ways to bolster its investment and renew strong economic performance. I am pleased to rise in support of this legislation because it will bring research out of the labs and into the marketplace to help our economic engine roar back to life.

Occurrences of 'Valley of Death': 2, (1 repetition)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE February 25, 2004

> In discussing the need for a Government role, a basic principle with which nearly everyone would agree is that a Government role makes sense when there is a market failure of some sort. When it comes to advanced technology, there is ample empirical evidence of a critical gap between the point at which Federal support for

> basic research ends and the point at which private capital market support of product development begins. Now, let me try to illustrate that by referencing this chart. This chart is called the ‘‘Valley of Death’’ just to try to wake up my colleagues to the fact that this is an important issue. Here, looking at this vertical axis, we are showing the invested money. Along the horizontal axis, we are showing the various stages of developing a technology- based product for use. The Government does invest a fair amount of money in basic research. That is shown over here at the left, in the beginning stages of developing a product or developing a technology. Here we show labs and universities … Industry invests most of its research and development dollars at the other end of this development continuum and invests those funds on commercializing short-term, low-risk, reliably profitable products, and then making incremental improvements on those products which they are fairly confident they can make a return on in the market. In between these two stages of the research and development process, we have what many in the industry call the Valley of Death. That is the gap where our private capital markets fail to invest applied research dollars to create pre-product, so-called platform technologies. This market failure occurs because such generic technologies are too expensive or they are too risky for industry to develop on its own … But for technologies with predominantly civilian applications, the Federal Government does not have the strong customer stake in developing specific technologies. So filling in this funding gap in the Valley of Death is precisely the role that the Advanced Technology Program plays for civilian technology … Let me give a few examples of actual ways in which the Advanced Technology Program has succeeded in bridging the ‘‘Valley of Death’’ for U.S. industries with a resulting positive impact on our economy and our global competitiveness. In 1991, the Council on Competitiveness characterized the U.S. printed wiring board industry as losing badly or lost. That was their description. By this they meant the U.S. was not likely to have a presence in that industry within 5 years. It attracted little private venture funding.

Occurrences of ‘Valley of Death’: 4 (3 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE June 9, 2005

> These parks are the result of a number of carefully crafted government policies and incentives dealing with taxes, real estate, and fundamental research. In the area of technology transfer, the Taiwan government helped set up the world famous Industrial Technology Research Institute (ITRI) which has over 5,000 scientists working to spin out laboratory ideas across the valley of death into new industries. Remarkably, the two chip foundry companies which now control 70 percent of the world’s foundry market were launched from ITRI. As a result of this rapid economic growth, Taiwan’s technical universities are now world class with their own excellent graduate programs. The reason they are side-by-side with these large science parks is to supply a steady stream of talented researchers.

Occurrences of ‘Valley of Death’: 1 (0 repetitions)

Coding: Unspecified cause, Location Described

CONGRESSIONAL RECORD—SENATE July 29, 2005

> This science park, like the others I visited in Asia, teams up with the local universities on collaborative research efforts. It has an incubation center with 83 start-up companies, and provides them low cost space, business planning, marketing, and employee training, as well as research and development grants from the Hong Kong Government to overcome the valley of death challenges so many new technology companies frequently face ... Additionally, the legislation proposes a Science Park Venture Capital Fund similar to SBIC's, that would guarantee debentures issued by the Fund to raise capital for start-up companies trying to bridge that valley of death, where ideas must move from the laboratory to working prototype.

Occurrences of 'Valley of Death': 2 (1 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE September 14, 2005

> How does this agency work? ATP funds development in technology that is too new or too risky for private sector investment in the so-called valley of death between research and commercialization. There is lots of money around for research and there is money around for commercialization but not for that bridge between those. ATP fills this gap. It does not displace private capital because these projects cannot get private capital.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

> The Advanced Technology Program fills a unique role in U.S. innovation policy. ATP bridges the gap, the so-called valley of death between innovative ideas arising from basic research in the laboratory, and the access to market capital to commercialize them.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE October 21, 2005

> However, many times innovative research becomes victim of the Valley of Death by failing to advance from the research labs to application in commercial products and services … My bill is aimed at narrowing this so called Valley of Death, by focusing on bringing research to commercialization. To reach this objective, my bill contains provisions requiring these institutes to partner with private sector

> entities with experience in micro- and nanotechnology and for each institute to develop and maintain business plans.

Occurrences of 'Valley of Death': 2 (1 repetitions)
Coding: Development gap, Location Described

CONGRESSIONAL RECORD—SENATE December 14, 2005

> Cures promotes the innovative efforts of small to medium sized biotechnology and bioengineering firms who require additional support in key traditionally under-funded stages of product development—the so called R&D Valley of Death. It expands the NIH's current small business support and rapid access to interventional development programs to move basic science through the product development pipeline faster.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

> Promote the innovative efforts of small to medium sized biotechnology and bioengineering firms. The ACC will support firms requiring assistance in key traditionally underfunded stages of research and development, the R&D Valley of Death. Funding will be available to assist companies with promising and novel therapeutics and diagnostics in both preclinical and clinical stages.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Unspecified Location

> Small businesses are major drivers of innovation. Facile, motivated, numerous, and creative, these small businesses can extend the limits of R&D in a way large companies with secure product lines are unable to do. However, small businesses often encounter difficulty securing capital in the so called, Valley of Death the period between a research idea with possible application to the time the safety and efficacy of a product is demonstrated in human clinical trials … Common end-pathways within the Valley of Death include development of pharmacological assays, scale-up of production from lab-scale to clinical-trials scale, development of suitable formulations, evaluation of chemical stability, evaluation of materials testing for durability or reactivity, undertaking initial toxicology studies, and planning and implementation of clinical trials.

Occurrences of 'Valley of Death': 2 (1 repetition)
Coding: Funding gap, Location Described

> Key components of the translational research process include research prioritization, an expert workforce, multidisciplinary collaborative work, facilitated information exchange, strategic risk taking, support of small innovative businesses caught along common pathways in the research and development Valley of Death, simplification and promotion of the clinical research endeavor, and involvement of

> private entities early on in the translational research endeavor that are skilled in the manufacturing and marketing process.

Occurrences of ‘Valley of Death’: 1 (0 repetitions)
Coding: Development gap, Unspecified Location

CONGRESSIONAL RECORD—SENATE February 15, 2006

> I want to point out a few things that we have proposed to make sure that small businesses are successful in innovating, and one is we have a constellation of proposals that will help small businesses across what is called the valley of death which is where they cannot get financing when they have a good idea but cannot quite get to commercialization.

Occurrences of ‘Valley of Death’: 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE May 4, 2006

> The fourth major area that my bill addresses is innovation at the small business level. Recently, representatives of a number of small nanotechnology companies came to visit me. They told me that their greatest problem was surviving what they called the ‘‘valley of death.’’ That’s what they called the first few years of business, when an entrepreneur has a promising technology but little money to test or develop it. Many businesses simply do not survive the ‘‘valley of death.’’ I believe that Congress should find a way to assist these businesses with promising technology.

Occurrences of ‘Valley of Death’: 2 (1 repetitions)
Coding: Funding gap, Unspecified Location

CONGRESSIONAL RECORD—HOUSE September 26, 2006

> While the law set aside $5.6 billion over 10 years to obtain drugs for the Strategic National Stockpile, companies receive very little compensation until they can deliver a minimum number of doses. As a result, many of these potential drugs languish in the laboratory in what is known as the ‘‘Valley of Death.’’ As with any drug, the development of biodefense drugs require efficacy trials, toxicity testing, production design and a range of other activities that are expensive but necessary to determine whether a drug will work, whether it is safe and how it will be manufactured. The centerpiece of this legislation that we are on the floor on behalf of this evening develops a new, or places a new office within HHS, the Biomedical Advanced Research and Development Authority, BARDA, which would be a single point of Federal authority for the development of medical countermeasures. This bill will empower BARDA to make milestone payments to drug developers at key

> stages of their work, helping to reduce financial risks of taking on this great challenge. In other words, we are going to get the job done.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

> So we came up with the single point of authority to make quick decisions; and the Valley of Death takes a long time, 8 to 12 years, to develop these vaccines, very labor intensive, a lot of intellectual power applied to coming up with the right vaccine to be the right prophylactic for what we know is a bioterrorism or natural-occurring event. That Valley of Death, because we are the single source of those contracts, was very real and stalling what we know is great research to happen for the cure and the development of these vaccines. Also, we found that it did not motivate academic researchers, drug and vaccine manufacturers and other possible partners to commit substantial resources.

Occurrences of 'Valley of Death': 2 (1 repetitions)
Coding: Development gap, Unspecified location

CONGRESSIONAL RECORD—Extensions of Remarks December 27, 2006

> This legislation will enable the government to better develop, procure, and make available countermeasures to chemical, biological, radiological and nuclear agents for use in a public health emergency. Bioterror countermeasures for agents of terrorism have no market other than the government. This legislation will provide assurance to companies that the government is fully engaged and a willing and able business partner. This legislation will speed up the development and procurement process by reorganizing and enhancing these responsibilities into the Biomedical Advanced Research and Development Agency, BARDA. 1. BARDA would create a single point of authority within government. 2. BARDA would streamline the approval and acquisition process to help bridge the ''valley of death'' for bio-pharmaceutical research.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Unspecified cause, Unspecified location

CONGRESSIONAL RECORD—SENATE January 4, 2007

> The fourth major area that my bill addresses is innovation at the small business level. Last year, representatives of a number of small nanotechnology companies came to visit me. They told me that their greatest problem was surviving what they called the valley of death. That's what they called the first few years of business, when an entrepreneur has a promising technology but little money to test or develop it. Many businesses simply do not survive the valley of death.

Occurrences of 'Valley of Death': 2 (1 repetitions)
Coding: Funding gap, Unspecified location

CONGRESSIONAL RECORD—SENATE January 17, 2007

> What we are talking about here is start-up capital for many of these businesses. We are not talking necessarily the United States taxpayer funding these things indefinitely ...That is a good investment for the country, if we choose wisely. But these companies will tell you they have to cross the valley of death, to get from development, where they have their prototype, until they can really commercialize it. And that is where Uncle Sam can happen. And we will get a lot more bang for our buck helping a battery company that will help us drive plug-in hybrids a few years from now than we will just giving it to a company that made $22 billion last year in the oil and gas markets

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—HOUSE May 3, 2007

> One of the biggest stumbling blocks to innovation is the technology so called Valley of Death the gap between angel funding and measurable venture capital, the lack of adequate private venture capital for early stage, high-risk, high-reward technology development … Today, the Valley of Death remains, but the global innovative environment has changed. H.R. 1868 responds to this by replacing ATP with the Technology Innovation Program, or TIP, which would provide limited, cost-shared grants to small and medium size firms and joint venture to pursue high risk, high-reward technologies, with potential for broad public benefit.

Occurrences of 'Valley of Death': 2 (1 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—HOUSE August 2, 2007

> TIP will help small, high-tech firms with big ideas cross the technologic valley of death by providing them with limited cost-shared funding to develop technologies that address critical national needs either alone or in joint ventures.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Unspecified location

CONGRESSIONAL RECORD—Extensions of Remarks August 2, 2007

> Incubational research refers to early, cutting-edge research that often occurs shortly after university laboratory research and prior to large-scale clinical trials. This stage of research is often termed the Valley of Death because the dearth of investment

> results in promising investigational therapies and products withering on the vine for lack of adequate capital.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—HOUSE September 27, 2007

> Venture capital not only serves as the raw material for economic growth and job creation, but also acts as fuel for the pursuit of new ideas and innovation. Without it, businesses cannot expand, and even the best ideas wither and die in what has come to be known as the Valley of Death between setup and commercialization.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE April 30, 2008

> From Ralph Dahl's farm in northwest Montgomery County and the technology he has employed, to high-tech companies in Cleveland looking for financing but fearing the so-called valley of death, to eager entrepreneurs in Athens who are installing solar panels and wind turbines all over their part of the State, to the work of Stark State on fuel cells.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Unspecified location

CONGRESSIONAL RECORD—SENATE May 7, 2008

> Lastly, the Accelerating Cures Act of 2008 uniquely adds resources to guide researchers through the Valley of Death, a stage in biomedical development between research and commercialization where the success of an initiative is dependent on feasibility and profitability that can only be established by a market that, by definition, has not yet developed. With the bill's strengthening and broadening of the Small Business Innovation Research and Small Business Technology Transfer programs and making available resources such as the Rapid Access to Intervention Development and Translational Development programs, investigators, institutions, small businesses, and other entities, will be better suited to navigate the regulatory and commercialization processes.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Development gap, Location Described

> Key components of the translational research process include research prioritization, a strengthening and maintenance of an expert workforce,

> multidisciplinary collaborative work, strategic risk taking, support of small innovative businesses caught along common pathways in the research and development Valley of Death, simplification and promotion of the clinical research endeavor, and early involvement of private entities that are skilled in the manufacturing and marketing process in the translational research endeavor … The Valley of Death is a stage in biomedical development between research and commercialization where the success of a product is dependent on its profitability. (b) PURPOSE.—The purpose of this Act is to create a new pathway to curing disease by enhancing public and private research to translate new discoveries from bench to bedside.

Occurrences of 'Valley of Death': 2 (1 repetitions)
Coding: Development gap, Location Described

CONGRESSIONAL RECORD—SENATE July 8, 2008

> The missing ingredient that this bill seeks to supply concerns traversing the so-called valley of death. This is the part of the development cycle of a new technology when the technology has been demonstrated at a lab or pilot scale and is ready to be demonstrated at a commercial scale. It is here, we are told, where new technologies, and particularly capital-intensive energy technologies, often languish for want of funding.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE April 28, 2009

> While the NIH funds much of the basic biomedical research at universities across the country, the CAN would take those findings found through basic research and provide funding to fill the gap between laboratory discoveries and life-saving medical therapies. This funding gap—often referred to as the valley of death arises after Federal basic science support ends and before investors are willing to commit to a promising discovery.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—HOUSE May 6, 2009

> I hope, and it's not a done deal yet, but I hope we will be creating a thing called a green bank, where Uncle Sam will provide a revolving fund that will provide lending for some of these businesses at what is called the valley of death. A lot of these businesses, you get the people in a garage, they come up with a brilliant idea. They get some venture capital, create a prototype of their device. It works. They

> scale it up, but when it comes time to put it in the factory, to the build the first factory, they can't get a loan because banks just won't loan on sort of the first commercial-sized projects.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—HOUSE July 8, 2009

> Mrs. BIGGERT. Mr. Chair, I rise today in strong support of H.R. 2965, a bill to reauthorize the Small Business Innovation Research (SBIR) and Small Business Technology Transfer Programs (STTR). Too often, I hear from small businesses in my district about what I call the valley of death that period when a firm has developed a new technology but faces difficulties commercializing it and moving it to the market. In an economy where credit is scarce, the timing to provide stable resources for small tech companies is now. There are hundreds of healthcare and energy solutions past discovery and development. They only need that one final push to advance to the marketplace.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

> The second item which I urge for inclusion in comprehensive health reform legislation is specified in S. 914, the Cures Acceleration Network Act which I introduced on April 28, 2009. That bill would help our nation's medical research community bridge what practitioners call the ''valley of death'' between discoveries in basic science and new effective treatments and cures for the diseases. This translational medical research will accelerate medical progress at the patient's bedside and maximize the return on the substantial investments being made on bio-medical research.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Development gap, Location Described

> There has been identified a so-called ''valley of death'' between the bench and clinical research and the bedside and application of the research. The pharmaceutical companies do not take up this issue because of the cost. This is something which ought to be taken up by the Federal Government as the dominant funder for the National Institutes of Health. So should the comprehensive health care include this issue to address, in a meaningful way, the very high costs of medical care? Certainly, if the tests make a determination that the less-expensive items are the ones which ought to be followed, that could meet the Federal standard and that could prevail.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE July 13, 2009

> … strengthens the Office of Technology at the SBA so that it has the authority and resources to carry out its duty to oversee the SBIR and STTR programs across the government; streamlines and improves data collection and reporting requirements for the SBIR and STTR programs, including developing metrics for annual evaluations by each participating agency, as reflected in the amendment by Dr. COBURN; helps SBIR and STTR companies move their technologies across the ‘‘valley of death’’ between the lab and the marketplace and into products and technologies for the agencies; and addresses ‘‘jumbo’’ awards, those awards that have greatly exceeded the $100,000 and $750,000 guidelines for Phase I and Phase II and cut out other businesses.

Occurrences of ‘Valley of Death’: 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—HOUSE September 16, 2009

> As we face new technologies, be they hybrid, be they new fuel sources like second-generation ethanol or hydrogen, those technologies as they mature across a pilot production line will ultimately produce a vehicle that will be offered to the American people. The business model of going from the laboratory to the actual showroom floor is as complex as the research and development. This amendment seeks to recognize that and lower those barriers. Visualize, if I might offer this: as the vehicle rolls out of the laboratory, and we have all raised children, I have a teenager. I know how to get that teenager through college. And by golly, that is what this concept does. It helps that vehicle stand on its own so it can be proudly purchased by Americans. Mrs. BIGGERT. Reclaiming my time, I know you are talking about the commercialization, which is what we sometimes call the ‘‘valley of death’’ for companies to get out beyond the demonstration to the marketplace which is probably the hardest for so many companies. And you think that this will help a lot of different companies be able to do that?

Occurrences of ‘Valley of Death’: 1 (0 repetitions)
Coding: Development gap, Location Described

CONGRESSIONAL RECORD—HOUSE October 20, 2009

> We need to go from research that is done at our universities and the private sector and further deploy into the commercialization zone, into the manufacturing efforts, those ideas. We have failed after that research investment. We need to have that valley of death as it is termed, where we don’t get the seed money that is necessary for a lot of this innovative spark to take its presence in our American economy.

Occurrences of ‘Valley of Death’: 1 (0 repetitions)
Coding: Funding gap, Location Described

> And only one phenomenon stands in the way of our accomplishing our national goals through the automobile industry, the phenomenon known as, and may I quote the automobile industry, ‘‘the valley of death.’’ … The valley of death is an automotive industry reference to the treacherous territory between proven feasibility in the research laboratory and the commercially successful products in the marketplace. Every single new technology that we have come to enjoy in automobiles, from power brakes and power steering to factory air, has languished in the valley of death until it became a commercially available product in the mass market …The least difficult of these technologies is the refinements to existing conventional engine technology, already discussed, and the most difficult are the advanced technologies that are brand new to the marketplace. Automakers everywhere recognize that the technologies at the difficult are the ones that cannot cross this automotive valley of death alone. Successful movement from research and development successes to market successes require the cooperation and support of national governments.

Occurrences of ‘Valley of Death’: 4 (3 repetitions)
Coding: Development gap, Location Described

> As it appeared in Fortune magazine, I quote, ‘‘The valley of death is auto industry speak. It is a metaphorical desert where emerging technologies reside while car executives figure out which of the experiments ought to make their way into actual cars. Every automotive leap forward has done time in the valley, turbo chargers, fuel injections, even gasoline electric hybrids like Toyota’s Prius. Hydrogen fuel cell vehicles, the alternative energy flavor of the month back in 2003, are the ones languishing today, along with hovercraft and other assorted concept cars, but perhaps not for much longer. A number of automakers are now renewing their push for hydrogen, and now it is looking as though hydrogen cars will make its way out of this conceptual vehicular valley of death.

Occurrences of ‘Valley of Death’: 3 (2 repetitions)
Coding: Development gap, Location Described

CONGRESSIONAL RECORD—SENATE October 30, 2009

> We have set up an innovative new financing mechanism, the Sustainable Energy Utility, that will help get clean technologies through the so-called valley of death

Occurrences of ‘Valley of Death’: 1 (0 repetitions)
Coding: Funding gap, Unspecified location

CONGRESSIONAL RECORD—HOUSE November 18, 2009

> This is all about growing jobs. We hear it all across America. People are looking for jobs. This is a good way to develop those jobs—R&D jobs, manufacturing jobs. Once you invest in that so-called valley of death where there isn’t that network of

> Federal resources to be matched with the angel network and the venture capitalists that take the idea from the lab, from the investment, from both the private sector, academia, or maybe even government, taking that and transitioning it over into the commercial sector, into the manufacturing sector—that is the resource we need.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—HOUSE December 15, 2009

> We have not provided for that funding mechanism to take the whiz-kid ideas in the lab and in the R&D centers— both public and private and at academia. We have not provided the funding to deploy those into manufacturing or into retail use so that we can get the return on investment that was made. The Angel Network, the venture capitalists—that ''valley of death'' as it is labeled—needs to be addressed. If we do that, we are providing more jobs, not just in R&D, but by inducing wiser manufacturing operations.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE March 19, 2010

> We have people coming in all the time wanting to get through what is called the valley of death, if they have a new idea. A new idea needs to get sustained funding and support in order to demonstrate at scale. Often it is hard to get the money. That is part of the problem in terms of the valley of death that they have to go through. Some of them never make it through. There is a person who is developing synthetic microbes that can be used to consume, or in layman's terms, eat the coal and leave methane in its wake. Wouldn't that be interesting: synthetic microbes that would turn a coal seam into methane.

Occurrences of 'Valley of Death': 2 (1 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—HOUSE May 12, 2010

> Too often, I hear from small businesses in my district about what I call the valley of death that period when a firm has developed a new technology but faces difficulty commercializing it and moving it into the market. By facilitating commercialization and opening access to advanced Federal facilities, this bill removes those hurdles.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Development gap, Location Described

> Unlike research in biotech and defense, technology developed through energy R&D must break into a deeply entrenched market at a competitive cost in order to be successful. We need policies that can help overcome the valley of death where great ideas frequently stall before they have reached the critical proof-of-concept stage. That's what we do in this amendment. We have worked with business, universities, and venture capital groups in developing this legislation.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

> The IPO market is where small and medium-size businesses go to get the capital they need to grow, to pass through the valley of death, to get on with what they have to do.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Unspecified location

CONGRESSIONAL RECORD—HOUSE December 21, 2010

> Secondly, with regard to the research, it is fundamental. I come from California, the great Silicon Valley and all of those new technologies come from the research at the universities in the surrounding area. This legislation promotes that research agenda across the Nation, not just in California, but at every other research institution throughout the United States. And finally, there is a major piece of this legislation that talks about making it in America. If we are going to have a strong middle class, a strong economy, we must once again make it in America. This legislation provides some fundamental elements necessary for us to do that. For example, the loan guarantee that was degraded just a few moments ago is exceedingly important because that's the valley of death. How does an entrepreneur, how does a new business get through the valley of death?

Occurrences of 'Valley of Death': 2 (1 repetitions)
Coding: Funding gap, Unspecified location

CONGRESSIONAL RECORD—SENATE February 2, 2011

> All of these companies started with angel investment to get them through what they call the valley of death. The valley of death is usually that period where something has gone from the idea stage to the marketplace. They usually need somewhere between $1 million and $4 million to get their ideas to market. Our bill is designed to bridge that gap and cross that valley of death so we can see a lot of startup companies come into the marketplace.

Occurrences of 'Valley of Death': 3 (2 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—HOUSE March 15, 2011

> Now, not every company will turn into Qualcomm. But without programs like this, there is what they call a valley of death. There are ideas that are created out of the minds and hearts of Americans who have been well educated, raised to believe that dreams come true, and are encouraged to risk. We are natural risk takers. We have these ideas and these innovations. But what happens is, if there is not that important, early funding to develop that kind of science and technology, in large measure some of these ideas just fall into the valley of death.

Occurrences of 'Valley of Death': 2 (1 repetitions)
Coding: Funding gap, Location Described

> Then we can continue to be the leaders in cutting- edge innovation, and the Federal Government can do its part—an important part—that venture capitalists can't do, big banks don't want to do, investment bankers aren't made to do, and small community banks don't do in this kind of lending. Only patient, directed capital can give that boost over the valley of death and create that bridge so small businesses and our scientists and engineers can walk over it safely.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Unspecified location

> That is what this program does— incentivizes or gives grants or contracts to emerging technologies well before a bank would take a look, well before a venture capital fund would even look in their direction. You have to develop the technology to a point and then have it launched. This is where there is what he described as the valley of death—great ideas, but there is just not a lot of venture capital out there and particularly in this recessionary period. So he says we helped, that without this program, it would have been very difficult to grow their company.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—Extensions of Remarks May 27, 2011

> These improvements to national security parallel new economic opportunities for the biofuel industry. According to the Biotechnology Industry Association, ''Section 526 is helping low carbon fuels bridge the 'valley of death' between development and commercialization,'' and is ''already helping the Air Force and Navy meet its alternative fuel goals.'' The domestic biofuels industry contributes 400,000 jobs and $53 billion to the American economy while supporting deployment of domestically-produced biofuels for our Armed Forces.

Occurrences of 'Valley of Death': 1 (0 repetitions)

Coding: Development gap, Location Described

CONGRESSIONAL RECORD—HOUSE July 14, 2011

> The Department of Energy spends millions of dollars each year on research and development for new technologies. However, that R&D often reaches a point known as the Valley of Death. The Valley of Death is where promising new technologies fade into obscurity because they can't attract the capital investments to move from concept to commercialization. In essence, on one side of the Valley of Death is research and development; good ideas. On the other side is the actual deployment and commercialization. A demonstration project takes the research and development just a little bit further and bridges this divide so that private entities will be interested in deployment, private entities will be interested in commercialization. This good use of federally funded demonstration projects is critical to reducing the risk to private sector investors and allows technologies to cross the Valley of Death and establish commercial viability for investors and, indeed, attract their interest.

Occurrences of 'Valley of Death': 4 (3 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—HOUSE December 6, 2011

> BARDA, which helped bridge what many termed the valley of death that had prevented many countermeasure developers from being successful. BARDA was created because we recognize that most of the CBRN countermeasures do not yet exist and medical development countermeasure is a risky, expensive and lengthy process. BARDA bridges the funding gap between early-stage research and the ultimate procurement of products from the SRF fund from the national stockpile.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE June 14, 2012

> There is so much. I could spend a long time going through all of the exciting efforts going on, literally from the east coast to the west coast, North and South, where creative entrepreneurs are coming forward, with support from the USDA to be able to get them through what is often called the valley of death, as they have a great idea but are trying to get it to commercialization, and efforts that are leveraging private dollars and public dollars to be able to have these companies move forward into full commercialization. Then they can create jobs, create renewable energy, get us off of foreign oil or create other kinds of products—all kinds of opportunities for us around products. That leads me to another important piece, which is R&D, which is always a very important part of what needs to be done as we are looking at these new ideas. Entrepreneurs, companies large and small, many small businesses—in

> fact, most of them start as small businesses with a great idea, and they are looking for how to turn that into a great business, and hiring people, and so on. The Biomass Research and Development Initiative is an integral component to bridging the gap between technology development and commercialization. As I said, this is often called the valley of death. If you are somebody out there who is an entrepreneur with a great idea, how do you actually convince somebody to invest in it so you can move forward?

Occurrences of 'Valley of Death': 2 (1 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—HOUSE May 15, 2013

> As you are well aware, one of the barriers to start-up company growth is access to capital. Although the Reg A offerings are supposed to help emerging companies get access capital, the cost of compliance with regulatory burdens made the $5 million cap unworkable. Congress was absolutely right to pass the JOBS Act requiring the SEC to promulgate rules to raise the cap to $50 million. Doing so will open new pathways by which startups and emerging companies, including those stuck in the proverbial ''valley of death,'' can access capital, allowing them to grow and create new jobs. But more than a year after this bipartisan triumph for innovators, the SEC hasn't even published Reg A rules. H.R. 701 will fix this and is urgently needed. There is much talk in Washington about helping start-ups, but your bill takes tangible action toward achieving that goal and ensuring the promise of the JOBS Act is realized. We commend you for finding a bi-partisan solution that will have real-world benefits for America's entrepreneurs and innovators. CONNECT stands ready to assist you as the bill advances in the House and strongly encourages Majority Leader Reid to promptly place the bill on the Senate floor calendar.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Unspecified location

CONGRESSIONAL RECORD—SENATE October 31, 2013

> My bill would fertilize America's innovation ecosystems so that scientific breakthroughs can more effectively navigate the so-called valley of death between the lab and the factory and reach their commercial potential. America's universities and research institutions are truly national treasures, and our venture capitalists and entrepreneurs are the sharpest in the world. When we sprinkle the right mix of scientific brainpower and capitalist drive, we get something uniquely American and extremely potent in terms of its economic impact.

Occurrences of 'Valley of Death': 1 (0 repetitions)
Coding: Funding gap, Location Described

CONGRESSIONAL RECORD—SENATE November 13, 2013

> In those sectors, we need to look at ways of partnering with our innovators on proof-of-concept and demonstration projects so that more breakthroughs can bridge the so-called Valley of Death between the lab bench and commercialization of a new technology.

Occurrences of ‘Valley of Death’: 1 (0 repetitions)
Coding: Development gap, Unspecified location

APPENDIX H

CODING RESULTS FOR THE DIMENSIONS OF A FUNDING SHORTFALL DRAWN FROM CITATIONS OF THE VALLEY OF DEATH CONTAINED TO INNOVATION AND TECHNOLOGY DEVELOPMENT

Date of Congressional Record Examined	Dimensions for a Funding Shortfall						Identified Funding Shortfall Content	Number of Valley of Death References
	Funding	Financing	Capital	Money	Investment	Loans/Credit/Grants		
3/7/2001								
7/20/2001	1	1	4		3		✓	1
9/10/2001	4	1	1				✓	1
9/24/2001					2		✓	2
2/25/2004	3		2	2			✓	4
6/9/2005								
7/29/2005	2		2			1	✓	2
9/14/2005 (1)	1		2	2	1		✓	1
9/14/2005 (2)			1				✓	1
10/21/2005								
12/14/2005 (1)	1						✓	1
12/14/2005 (2)	2						✓	1
12/14/2005 (3)			1				✓	2
12/14/2005 (4)								
2/15/2006		1					✓	1
5/4/2006				1			✓	2
9/26/2006 (1)		1					✓	1
9/26/2006 (2)								
12/27/2006								
1/4/2007				1			✓	2
1/17/2007	1		1		1		✓	1
5/3/2007	1		2			1	✓	2
8/2/2007 (1)	1						✓	1
8/2/2007 (2)			1		1		✓	1
9/27/2007			1				✓	1
4/30/2008		1					✓	1

Date of Congressional Record Examined	Dimensions for a Funding Shortfall						Identified Funding Shortfall Content	Number of Valley of Death References
	Funding	Financing	Capital	Money	Investment	Loans/Credit/Grants		
5/7/2008 (1)								
5/7/2008 (2)								
7/8/2008	1		1				✓	1
4/28/2009	3						✓	1
5/6/2009	1		1			2	✓	1
7/8/2009 (1)						1	✓	1
7/8/2009 (2)								
7/8/2009 (3)	1						✓	1
7/13/2009						1	✓	1
9/16/2009								
10/20/2009 (1)				1	1		✓	1
10/20/2009 (2)								
10/20/2009 (3)								
10/30/2009		1					✓	1
11/18/2009			1		1		✓	1
12/15/2009	2		1		1		✓	1
3/19/2010	1			1			✓	2
5/12/2010 (1)								
5/12/2010 (2)			1				✓	1
5/12/2010 (3)			1				✓	1
12/21/2010						1	✓	2
2/2/2011					1		✓	3
3/15/2011 (1)	1						✓	2
3/15/2011 (2)			2		1		✓	1
3/15/2011 (3)	1		2			1	✓	1
5/27/2011								
7/14/2011	1		1		1		✓	4
12/6/2011	2						✓	1
6/14/2012					1		✓	2
5/15/2013			3				✓	1
10/31/2013			2				✓	1
11/13/2013								

APPENDIX I

CODING RESULTS FOR THE DIMENSIONS FOR LOCATION PARAMETERS DRAWN FROM CITATIONS OF THE VALLEY OF DEATH CONTAINED TO INNOVATION AND TECHNOLOGY DEVELOPMENT

Date of Congressional Record Examined	Dimensions for Location						Identified Location Content	Number of Valley of Death References
	Commercialization	Applied Research	Ideas	Products	Between/Bridge	Market		
3/7/2001			1	1			✓	1
7/20/2001	2		2	1	3	1	✓	1
9/10/2001								
9/24/2001		2	1	1	3	1	✓	2
2/25/2004	1	1		6	2	5	✓	4
6/9/2005			1				✓	1
7/29/2005			1		1		✓	2
9/14/2005 (1)	2			1	3	1	✓	1
9/14/2005 (2)	1		1		2		✓	1
10/21/2005	2			1			✓	2
12/14/2005 (1)				2			✓	1
12/14/2005 (2)								
12/14/2005 (3)			1	1			✓	2
12/14/2005 (4)								
2/15/2006	1		1				✓	1
5/4/2006								
9/26/2006 (1)				1			✓	1
9/26/2006 (2)								
12/27/2006								
1/4/2007								
1/17/2007	1						✓	1
5/3/2007					1		✓	2
8/2/2007 (1)								
8/2/2007 (2)			1	1			✓	1
9/27/2007	1		2	1	1		✓	1
4/30/2008								

Date of Congressional Record Examined	Dimensions for Location: Commercialization	Applied Research	Ideas	Products	Between/Bridge	Market	Identified Location Content	Number of Valley of Death References
5/7/2008 (1)	2				2	1	✓	1
5/7/2008 (2)	1			1	1		✓	2
7/8/2008	1					2	✓	1
4/28/2009					1		✓	1
5/6/2009			1				✓	1
7/8/2009 (1)	2					2	✓	1
7/8/2009 (2)					1		✓	1
7/8/2009 (3)					1		✓	1
7/13/2009				1	1	1	✓	1
9/16/2009	1					1	✓	1
10/20/2009 (1)	1		1				✓	1
10/20/2009 (2)	2			1	1	4	✓	4
10/20/2009 (3)				1			✓	3
10/30/2009								
11/18/2009	1		1				✓	1
12/15/2009			1				✓	1
3/19/2010			2				✓	2
5/12/2010 (1)	2					1	✓	1
5/12/2010 (2)			1			1	✓	1
5/12/2010 (3)								
12/21/2010								
2/2/2011			2		1		✓	3
3/15/2011 (1)			3				✓	2
3/15/2011 (2)								
3/15/2011 (3)			1				✓	1
5/27/2011	1				2		✓	1
7/14/2011	4		1		1		✓	4
12/6/2011				1	3		✓	1
6/14/2012	3		4	2	1		✓	2
5/15/2013								
10/31/2013	1				1		✓	1
11/13/2013	1				2		✓	1
Count	34	3	30	23	35	21	44	66

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