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Strategic Improvement: A Systems Approach Using The Balanced Scorecard Methodology To Increase Federally Financed Research At The University Of Central Florida

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STRATEGIC IMPROVEMENT: A SYSTEMS APPROACH USING THE BALANCED SCORECARD METHODOLOGY TO INCREASE FEDERALLY FINANCED RESEARCH AT THE UNIVERSITY OF CENTRAL FLORIDA

by

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ABSTRACT

The University of Central Florida has many successful measures to reflect on as it celebrates its 50^{th} year in 2013. It is the university with the 2nd largest student population in the U. S. and its overall ranking in the U.S. News & World Report has improved 4 years in a row. However, with respect to research, the federally funded research and development for the University of Central Florida (UCF) has remained flat. In addition, when compared to other schools, its portion of those federal research dollars is small. This thesis lays the groundwork for developing a model for improving the federally financed academic research and development. A systems approach using the balanced scorecard methodology was used to develop causal loop relationships between the many factors that influence the federal funding process. Measures are proposed that link back to the objectives and mission of the university. One particular measure found in the literature was refined to improve its integration into this model. The resulting work provides a framework with specific measures that can be incorporated at the university to improve their share of the federally financed research and development. Although developed for UCF this work could be applied to any university that desires to improve their standing in the federal financed academic research and development market.

This work is dedicated to all those who appreciate that learning is a lifelong journey, and that taking the initiative to make things better is much better than letting things go or resigning to the idea that nothing can be done.

ACKNOWLEDGMENT

Let's face it. You cannot accomplish your goals without the help and encouragement of family, friends, colleagues, and mentors. Dr. Luis Rabelo, my committee chair, was enthusiastic about the topic and helped me refine the study to provide a more impactful body of work. Mr. Mark Calabrese, of my committee, provided significant feedback and encouragement to improve the quality of the work. GW and DC provided fresh eyes to improve the document's syntax.

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CHAPTER 1 : INTRODUCTION

This thesis applied lessons learned from the Masters Engineering Management program at the University of Central Florida's (UCF) College of Computer and Engineering to a real world situation. Approaching the problem from a systems approach and building on others' research, a potential solution was developed that could be used to increase UCF's awards level in the federally financed academic research market commensurate with their size. The problem is identified, and a potential solution is proposed. This work contributes uniquely to the body of research by applying system dynamics, the balanced scorecard methodology, and the portfolio management theory together to solve the problem.

1.1 Background

The federal government has been involved in the financial support of public education as early as 1785 (Jennings, 2011) . The early support was in the form of land grants that allowed states to benefit from the use and sale of land provided by the federal government to support public education. The federal support of education has grown since that time and comes in many forms. Jennings stated "These lands continue to generate revenues for education, through proceeds from agriculture, mining, commercial development, and other land uses" (Jennings & Center on, 2011) . The federal support evaluated in this thesis is the funding for academic research and development (R&D) obtained through the grant application process for the science and engineering disciplines. The National Science Foundation (NSF) reported that the the university system performs more than half of all basic research and the federal government remains the primary funding source for basic research (National Science Foundation, National Science Board, 2012a) .

Through the contracts and grant process universities build infrastructure, economic strength, and reputation (National Science Foundation, National Science Board, 2012a) . UCF has relied on contracts and grants (C&G) for a significant portion of its annual expenditures. As the university has grown in size the expenditures have also grown. Historically (1998-2011) the C&G comprised an average of 12.4% of UCF's annual expenditures (University of Central Florida, 2013). The reported expenditures for 2011 totaled $1,119 million with C&G accounting for $130 million, or 11.6% (University of Central Florida, 2013). Figure 1-1 shows UCF's expenditures related to contracts and grants as a percentage of yearly expenditures. The federally financed (FF) R&D expenditures were part of UCF's C&G expenditures. The UCF's reported FF R&D averaged 3.9% of the total expenditures from 1998 to 2011.

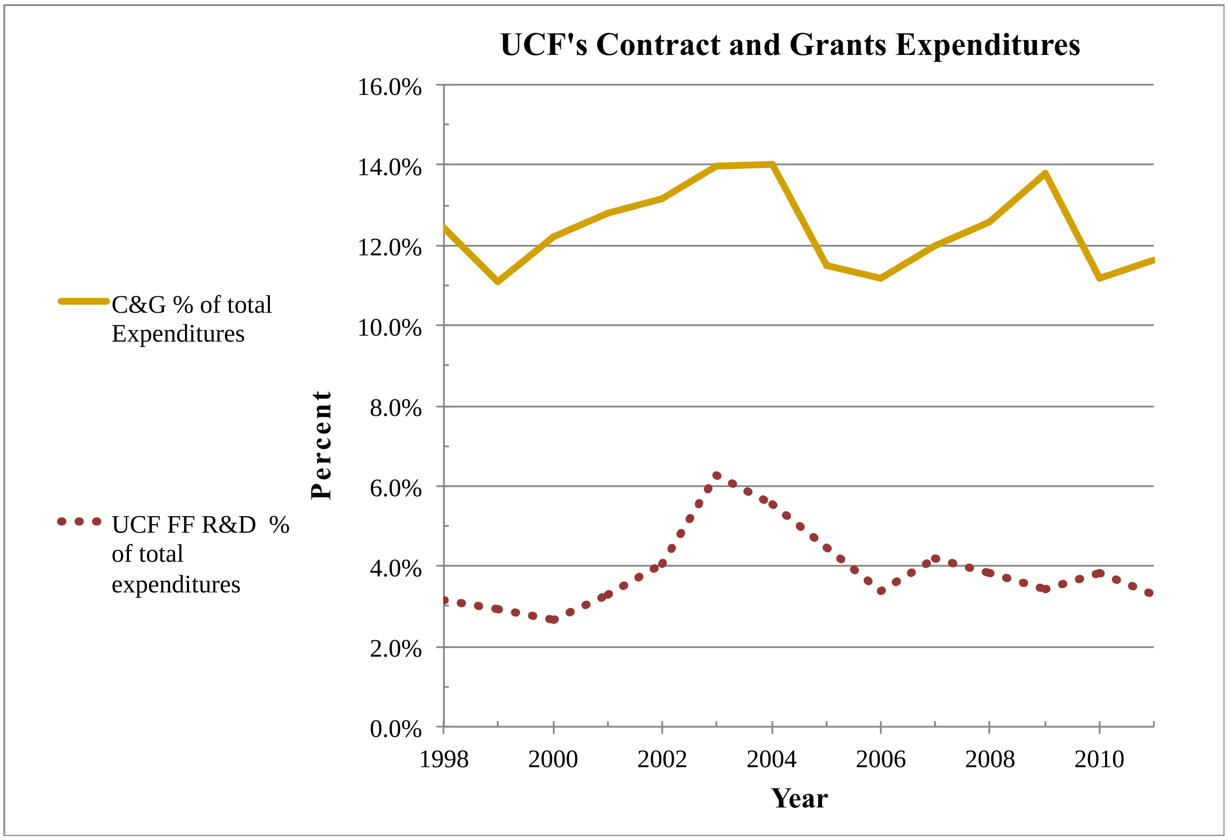

Figure 1-1: UCF's contracts & grants expenditures

As percentage of expenditures, both the C&G and the reported federally financed R&D expenditures have remained relatively flat over that time period.

One method to obtain grants is through funding opportunities supplied by the federal government. UCF, as well as many other universities, participate in this funding procurement process. Figure 1-2 shows UCF's position relative to seven other universities.

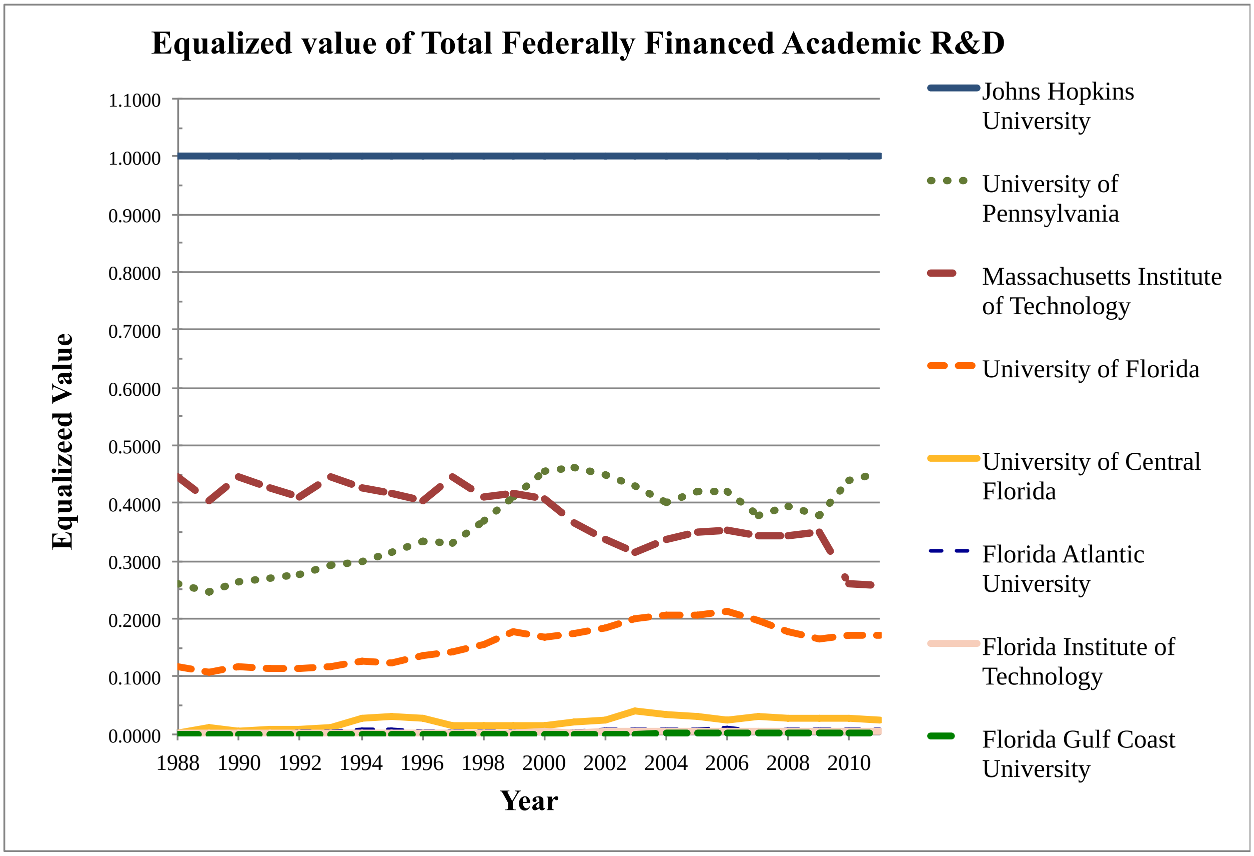

Figure 1-2: Equalized value of federally financed R&D

The data plotted is the equalized value of the reported federally financed R&D for Science and Engineering (S&E) disciplines for each university over the years 1988 through 2011. The equalized value was computed by first converting the reported expenditures into a percentage of the total expenditures for that year. Next, all the universities' percentages were divided by the largest percentage value for that year. The calculations were done for every year. The result provided the equalized value presented in Figure 1-2. In this case Johns Hopkins University had the largest reported federally financed R&D for all years, corresponding to a value is 1.0 across all years. The other universities had a number smaller than 1.0. Each university's value was relative to the university that held the largest percentage of the total expenditures. For 2011 the University of Pennsylvania had about 45%, MIT had about 25%, University of Florida had about 18%, and UCF was about 1% of what Johns Hopkins had. Three important items to observe from this figure are 1) Johns Hopkins University was the leader over this time frame, 2) UCF's performance is flat and low number, and 3) things can change. University of Pennsylvania's normalized value has increased from 0.25 to 0.45 while MIT's normalized value has decreased from 0.45 to 0.25. The equalized value introduced here becomes a significant component of analysis later in this work with other measures.

1.2 Problem Statement

The competition for federal funds through grant opportunities has never been stronger (The Research Universities Futures Consortium, June 2012). This has come about from reductions in state and federal funding, reduction in endowment values due to the recent recession, and increased reporting and compliance requirements (The Research Universities Futures Consortium, June 2012) Business as usual will not increase UCF's funding fortunes given these constraints. Deliberate action must be taken to overcome the barriers and increase the federal financed R&D expenditures.

1.3 Potential Solutions

The solution to the problem, of course, is to win more awards. That is much easier said than done. Figure 1-3 provides a diagram of the generic grant funding process flow.

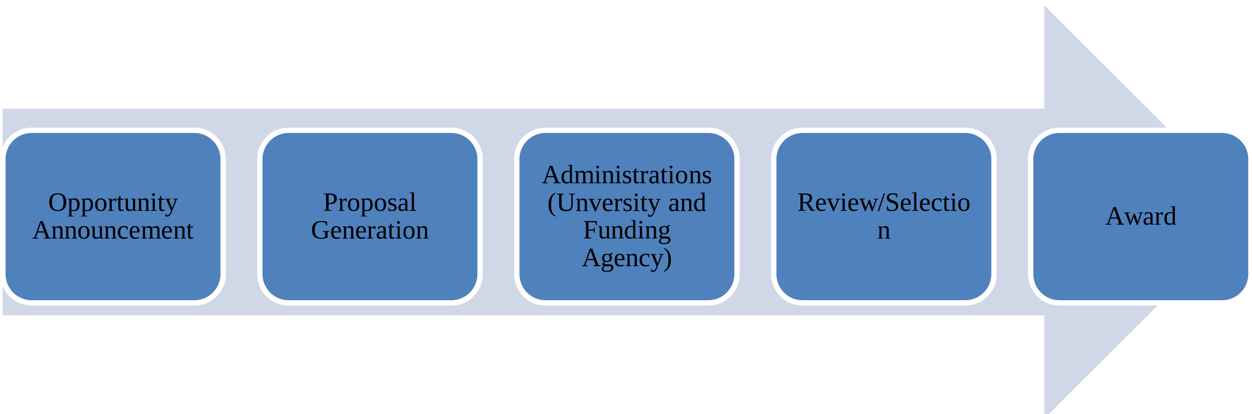

Figure 1-3: Process flow for grant process

The funding process is very complex. Each of the boxes in the figure has its own set of variables and processes that in turn interact with the variables and players in the other boxes. Although shown as a sequential process it has many interactive loops and dependencies that impact the outcome. It doesn't take long to appreciate the complexity of the endeavor to 'win more awards'. That complexity drove the investigation to a systems approach.

A system approach accounts for all the relevant pieces in the system and connects them in an interactive format to reveal relationships and behaviors (Senge, 2006). Introducing this type of feedback into the system provides a more realistic estimate of the outcome.

Success comes from developing a strategy that is linked to the organization's vision (Kaplan & Norton, 2001). In their book *The Strategy Focused Organization*, Kaplan and Norton (2001) described the importance of developing a strategy based on the organization's vision. They detailed how to form the connections between the strategy, the objectives, and the measures through the balanced scorecard methodology.

This methodology requires the development of objectives and measures to determine the progress towards achieving the organization's strategy. The scorecard lists the objectives and corresponding measures. Some of the objectives may be complementary with other objectives and some objectives may be in conflict with other objectives. In systems dynamic terms the balanced scorecard will have causal loops with reinforcing and balancing loops as described by Senge (2006). By building causal loops the preliminary models can be vetted and refined to move towards a systems dynamic modeling solution. The goal is to simplify the complex process and understand which 20% of the components provide 80% of the benefit.

The objective to gain academic research market share required the development of metrics to measure the position and growth of the market. Litwin (2009) had developed such a methodology. He specified strategic indicators that measured the market size by discipline, the growth of the market, the university's position in the market, and its competition's position in that market (Litwin, 2009). His work was based on portfolio management theory that looked at the university's portfolio as the disciplines of study they were involved in. He labeled his metrics strategic indicators reasoning that the position a university held in the market was a result of their strategy whether intended or unintended. In addition the market itself was a result of a strategy expressed by the funding agencies. He also reasoned the disciplines that held strong market positions in those disciplines that were being funded were strategically aligned. Any university could implement the methodology since the data is publically available.

Figure 1-4 provides a diagram on the proposed system to be implemented to solve the problem.

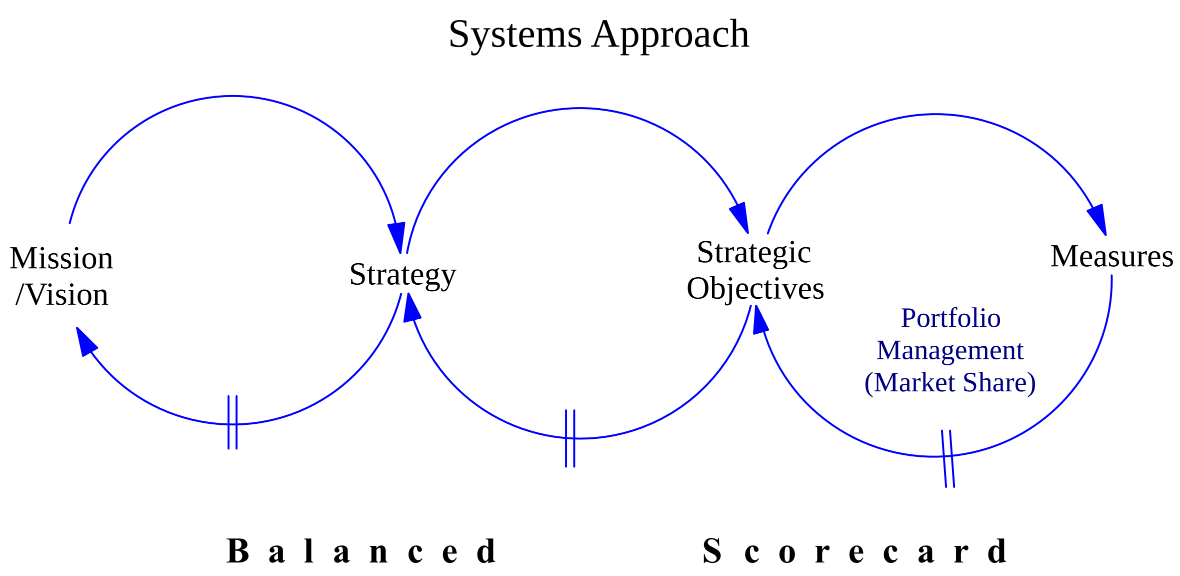

Figure 1-4: Systems approach diagram

With this framework a valuable model can be developed that incorporates the interactions of the measures and objectives that will lead to potential solution.

1.4 Potential Contributions

This work contributed to the body of knowledge in applying systems thinking, balanced scorecard methodology, portfolio management, and metric development for a unique problem in university funding. Because each university is unique in their mission, organizational structure, funding sources and constraints, and regional priorities this proposed solution was not a cookie cutter fix. Rather it used many of the well-documented theories and research to develop a potential solution for UCF. The unique contribution of refining the strategic alignment metric to a yearly measure provided an opportunity for it to be used in a model. This work has the potential to be used at other universities when they account for their unique circumstance.

1.5 Thesis Synopsis

The thesis begins with the introduction to the problem. The introduction describes a potential solution. Chapter 2, the literature review, provides information on the various theories, research, and strategies utilized in the work. A gap analysis was performed to highlight the need for this work to solve the problem. It revealed a few areas where unique contributions are needed that currently were not found in the literature. Chapter 3, discussing the methodology, shows the reader the path followed. Chapter 4 discusses the discoveries at each step in the process and presents UCF as a case study. Chapter 5 closes with restating the problem and showing how the proposed solution will potentially solve the problem. The thesis ends by pointing to two areas of research that could be followed to make this work more impactful.

CHAPTER 2 : LITERATURE REVIEW

One of the key themes to the Masters in Engineering Management at UCF's College of Computer Science and Engineering is to view opportunities from a systems perspective. This review presents the current literature in the order of these four topics; systems thinking, balanced scorecard, portfolio management, and the factors affecting the grant process. The four topics stand alone in their significance to affect the outcome. Systems thinking describe the holistic approach to viewing and scoping a problem. Balanced scorecard is a methodology that incorporates the four perspectives of a business model when developing and executing a strategy. Portfolio management is a method for determining a products or businesses' position and direction in the market. The factors affecting the grant process are the dependent and independent variables within the system that influence the ability to win an award.

2.1 Systems Thinking

System dynamics described in Peter Senge's (2006) *The Fifth Discipline: The Art and Practice of the Learning Organization* provided the perspective to view this research. Part philosophy, part application, the book provides the means and motivation to look at problems from a systems perspective to ensure long-term solutions to problems are developed (Senge, 2006). The book covers the four core disciplines; Personal Mastery, Mental Models, Shared Vision, and Team Learning. These disciplines provide a way to see opportunities from a new perspective and allow you to communicate and work proactively with your colleagues to formulate potential solutions to problems. He provides several examples and observations from his years of applying the principles to provide the reader sufficient skill to apply the techniques. Appendix 2 of his book provides an excellent reference to the 10 fundamental system archetypes. The fifth discipline is seeing it from a holistic approach through system thinking. That discipline provides the ability to capture a more robust solution.

A more application specific source for system dynamics applications was Stephanie Albin's (1997) *Building a Systems Dynamics Model Part 1: Conceptualization*. The document was prepared for MIT's System Dynamics in Education Project and provided sound instruction on defining the purpose of the model, setting the boundary conditions, creating the reference modes, and developing the basic mechanisms (Albin, 1997).

2.2 Balanced Scorecard

The balanced scorecard methodology introduced by Kaplan and Norton (2001) provided the framework for the systems approach to be implemented. Their book *The Strategy Focused Organization* provided a tutorial on moving from mission, to vision, to strategy, to objectives, to measures in a manner that tied it together using system dynamics philosophy (Kaplan & Norton, 2001) .

The article "Using systems thinking to enhance strategy maps" examined the balanced scorecard developed by Kaplan and Norton and discussed some of the criticisms of it (Kunc, 2008). Kunc (2008) continued with Senge's view of systems thinking and proposed how to tie systems thinking and causal loops into the balanced scorecard for improved performance.

Baker, Jones, Cao, and Song (2011) in their article "Conceptualizing the Dynamic Strategic Alignment Competency" takes a more quantitative approach where an equation was developed to measure strategic alignment. Although specific to the information technology industry the philosophy and developed formulas could be applicable to other fields.

2.3 Portfolio Management

The article "Corporate Portfolio Management: Appraising Four Decades of Academic Research" by Nippan, Pidun and Rubner (2011) took the reader through the economic conditions that moved portfolio management from a finance theory to the world of business management. It germinated from the economic conditions of the 1950s when corporate America began to diversify. Initially companies used diversification to their advantage by investing in businesses that played to their strengths. The result was that diversification demand grew due to early successes. The authors indicate it was not long before large corporations found themselves with holdings that were not in their core business. There was a need for a management tool that corporations could use to make business decisions about these diverse products and holdings. They discuss how Henderson, founder of the Boston Consulting Group, developed a simplified method for managers to analyze a company's businesses and/or product lines. It was based on the concept that cash flow related to market share and product or business growth. Henderson is attributed as writing "The portfolio composition is a function of the balance between cash flows. High-growth products require cash to grow. Low-growth products should generate cash."(Nippa et al., 2011, p. 52). Market growth becomes a substitute for cash demand. Relative market share becomes a substitute for cash generation (Nippa et al., 2011). It was this methodology that became known as the Boston Consulting Group growth-share matrix (Nippa et al., 2011).

Litwin (2009) presented the idea of using portfolio management as means of quantifying a university's strategic alignment with that of a funding source. He developed quantitative measures of the academic research market (ARM), the market share with respect to the different research disciplines, and market growth (or loss) of those research disciplines in the market. In a similar manner he developed quantitative measures for universities of interest to determine their position in the market, their research discipline's position in the market, and the market growth (or loss) of each discipline in the market. He named the quantitative measures the Market Strategic Indicator (MSI) and the Institutional Strategic Indicator (ISI). By using quadrant graphs he plotted the university's research discipline's position (ISI) against the overall market position for that discipline (MSI). The resulting plot provided a visual representation of the university's position in the market. He went further to hypothesize the university's market position was a measure of their strategic alignment with market (Litwin, 2008).

2.4 Factors affecting the grant award process

Improving UCF's federally financed R&D levels required researching the factors influencing the grant process outcome. There were scores of articles investigating this topic. Many drilled down to specific parameters; few provided a holistic approach on improving overall performance. The literature review discussed in the following pages provided perspective, facts, and factors influencing the grant processes.

2.4.1 Current funding facts

The Congressional Budget Office's (CBO) June 2007 report *Federal Support Research and Development* was a comprehensive report showing the funding trends for research and development from various sources from 1953 through 2004 (Campbell, 2007). This report showed the funding levels for research and development had grown from ~1.5% of gross domestic product (GDP) in 1953 to a peak of ~2.8% of GDP in 1964, the peak of the space race. There had been some ups and downs over the decades but the funding had leveled off at ~2.5% of GDP since the late 1990s. Industry had been the major source of funding of research and development since the early 1980s. The report differentiated research activity from development activity. It defined research as activity for the purpose of gaining knowledge without a commercial purpose in mind. Development, on the other hand, was specified as improving scientific understanding for a particular product or class of products. It also distinguished the difference between basic research and applied research. Basic research was defined as activity to increase knowledge without a specific target product in mind. Applied research was specified to connect the knowledge to a specific purpose. The activities were separated in the report because their funding sources were different. The report showed industry invested most heavily in development. Industry was concerned with getting the latest products to market. Government, however, had tended to fund basic research. In that report basic research was the largest sector funded by the federal government. The report also revealed, with the exception of the DoD, the federal government's total funding obligations for nondefense research and development in 2004 were partitioned as follows, basic research (46%), applied research (43%) and development (11%). Industry targeted 77% of its total research and development budget in 2004 to development. The DoD was a special case with respect to funding allocation because their focus was on development; all other federal agencies were not. Also reported, universities perform a significant amount of the federally funded research. It was reported ~$24 billion (2000 dollars) of federal spending for research was done by universities while the federal government spent ~$12 billion (2000 dollars) on research within its various agencies.

The CBO report pulled many of its statistics from the NSF, division of science resources statistics. The NSF periodically updates their statistics on research and development funding. The latest report available *Science and Engineering Indicators 2012: Chapter 4 – Research and Development: National Trends and International Comparisons* reported similar findings as the CBO report but used data through 2009 (National Science Foundation, National Science Board, 2012b). It reported that industry funded and performed the vast majority of development and a significant portion of applied research. The university system performed more than half of all basic research (53%). The federal government remained the primary funding source for basic research (53%). 2009 showed a slight decrease in overall spending on research and development from 2008 due to the great recession. The long-term trend showed a growth in spending on research and development.

The NSF published a comprehensive report in May 2013 titled *Report to the National Science Board on the National Science Foundation's Merit Review Process Fiscal Year 2012* (National Science Foundation, National Science Board, May 2013). This report provided details on the merit review process from the NSF for fiscal year 2012. The annual report described the details of many aspects of the grant award process. It revealed various statistics, sliced and diced, so the reader could see the grant process from various perspectives. It reported the NSF acted on 48,613 reviewed proposals in FY2012. It compared this level to historical data to provide trend charts. It also provided specific information on the demographics on the applicants, the winners, the success rates by demographics, the review process and some metrics related to the review process. The report provided a comprehensive understanding of the process and many of the factors associated with the grant application process.

Another report that provided insight into the grant process for universities was *The Current Health and Future Well-Being of the American Research University* published by The Research Universities Futures Consortium (The Research Universities Futures Consortium, June 2012). This report highlighted six key findings: 1) funding resource scarcity has increased the competiveness in the process, 2) increasing government regulations have increased the universities' costs associated with the grant application process, 3) measuring the success of research at the university needs an improved process so a university can fairly compare its research performance against others, 4) research activity needs to be data driven decisions that strategically align with the priorities of the local, national, and international desires, 5) the research story needs to be told by credible sources in manner that demonstrates its worth to our societal needs, and 6) the research administrative profession needs to come out of the shadows so the stakeholders understand the critical role they play in this complex process (The Research Universities Futures Consortium, June 2012, p. 11). This report raised these concerns as a way to rally support for improving the overall system. It suggested the solutions would come when more universities improve their internal process and improve the processes among the universities' interactions. It pointed to a larger view and encouraged more stakeholders to get involved to develop a sustainable American research university system.

2.4.2 Specific factors influencing the grant awards

The next set of articles presents findings from various researchers that investigated the grant process to reveal factors that influence the ability to win an award. Table 2-1 at the end of this chapter provides a summarized list of the factors with the corresponding the credited source(s). Following is the verbal rendition providing more context to the factors listed in the table.

The paper *Organizational and Institutional Factors Associated with National Institute of Health Research Grant Awards to Social Work Programs* by Corvo, Zlotnik, and Chen (2008) demonstrated there was more to winning a grant than having a competitive proposal. Their study, specific to the social work programs, indicated an asymmetrical distribution of awards among the schools. Their analysis showed NIH grant success was not evenly distributed among the schools of social work. Their analysis showed that 75% of the awards went to 25% of the schools. Further analysis revealed there could be organizational differences among the schools that impact a university's grant success rate.

In his article about a library's relationship with foundations, Herkovic (2004) revealed a few salient points that also apply to funding from the federal government. One key point, the grant was not there to serve the applicant; the applicant was there to serve the funding source. He argued it was critically important that the proposal be structured to align lock step with the goals and expected outcome of the funding source. He indicated this was true for both foundations and the federal government. A second point he stressed was that grants were not 'free money'. There was a certain amount of work that needed to be done prior to the award. Often the work associated with grant proposals consumed a significant portion of time and resources. A real cost was incurred by spending time and resources on the proposal. Depending on the opportunity the investigator's time and the administrative staff's time could be a significant cost burden. These indirect costs need to be accounted for in research administration.

He also argued the grants are not 'free money' in a second way. The grant was very much like a contract. A relationship was created where a specific outcome was expected by a certain date for a specific price. The awardee was held to meet the requirements.

Herkovic (2004) also discussed the need for teamwork and a champion for the project to ensure organizational leadership support. Communication was a key difference mentioned between foundation funding and federal government funding. The foundation relationship was very collaborative during the proposal process. They wanted to make sure the applicant understood their needs and they understood the proposal. The foundation proposal process tended to be an iterative process resulting in higher satisfaction fewer surprises for both parties. The federal grant process was just the opposite. That process was typically a single proposal submittal by the announcement deadline. The federal process discouraged iterative communication once an opportunity submittal deadline had passed (Herkovic, 2004).

Budd (2012) investigated the reason behind the fact that some colleges had an overwhelming higher success rate at winning grants than other colleges of similar characteristics. His study of two successful colleges found that strong organizational leadership and good organizational structure that supported the grant application process were two key reasons for their success at obtaining grants. The organizational leadership was demonstrated by the enthusiasm and support from the college president level all they way down to the investigator. The organizational structure was observed in the formal processes and the informal processes present within the colleges to promote information, potential opportunities, status of investigations, and collaboration among different departments.

Several articles pointed to the inadequacies of the grant evaluation process. Graves, Barnett, and Clarke (2011) investigated the scoring variability found in the grant review panels. The study relating to the National Health and Medical Research Council of Australia reviewed just over 2700 grant proposals from 2009. Forty-five review panels evaluated and scored between 42 to 92 proposals each. The panels comprised of 7 to 13 members. The investigators estimated the variability in the panel members' scores and examined how the variability influences the variability in the proposal's rank, which in turn, affected the decision on funding. The analysis of the variability put the proposals into 3 categories; never funded, sometimes funded, and always funded. The only group not affected by the variability was the never funded group. All panels could clearly distinguish what proposals did not merit funding. The variability in scoring among the panels pointed to the variability in proposals that got funded. The investigators showed the funding ranged from 9% to 38% across all the panels. That implied that a proposal's ability to win funding depended on what panel reviewed it (Graves et al., 2011a). The investigators researched the variability to determine its effect on funding. Another aspect of the funding process investigated in the study was the cost of grants proposals. They presented an estimated the total cost per proposal at $A 17,744 with 85% being incurred by the applicant. They referenced a study that estimated the cost of proposals in the United Kingdom at $A 15,676 per proposal (Graves et al., 2011a).

Table 2-1: Grant process factors and attributed source

Factor(s)	Source(s)
Credentials of the proposer and team	(Graves et al., 2011a; Lynn, 6/21/2013)
Previous grant winner	(Lynn, 6/21/2013)
Size of university	(Corvo et al., 2008)
Grant aligns with funding source goal	(HERKOVIC, 2004; Lynn, 6/21/2013)
Number of faculty	(Corvo et al., 2008)
Teaching load	(HERKOVIC, 2004)
Number of endowed chairs	(Corvo et al., 2008)
Amount of seed money	(The Research Universities Futures Consortium, June 2012)
Presence of internal research centers	(The Research Universities Futures Consortium, June 2012)
Presences of PhD programs	(Corvo et al., 2008)
Previously awarded grants	(National Science Foundation, National,Science Board, May 2013)
Opportunity costs (can it afford to apply)	(HERKOVIC, 2004)
Academic origin (do grants follow researcher)	(National Science Foundation, National,Science Board, May 2013)
University culture promotes grant apps	(Budd, 2012)
Career award system tied to grants	(Capaldi, Lombardi, Abbey, & Craig, 2010)
Size of research administration department	(The Research Universities Futures Consortium, June 2012)
Financial incentives for scholarship	(Capaldi et al., 2010)
Number of doctoral students available for research	(Corvo et al., 2008)
Organizational structure to promote interdisciplinary research	(Budd, 2012; Corvo et al., 2008)

Factor(s)	Source(s)
Strategic alignment of grant apps with university strategy and Funding source strategy	(Graves et al., 2011a; Lynn, 6/21/2013)
Competition level for funds	(Brainard, 2007; National Science Foundation, National,Science Board, 2012a; Van Noorden & Brumfiel, 2010)
Historical success of university	(Corvo et al., 2008)
Capability to meet financial requirements	(Capaldi et al., 2010; Graves, Barnett, & Clarke, 2011b)
Capability to meet legal requirements.	(Capaldi et al., 2010)
Investigators first win with respect to the time since their last degree	(National Science Foundation, National,Science Board, May 2013)
Regulation barriers (high or low)	(HERKOVIC, 2004)
Proposal quality	(HERKOVIC, 2004)
Proposal alignment with agency goals	(HERKOVIC, 2004)
Review methodology (peer, blind, etc.)	(Demicheli, 2008)
Level of extenuating circumstances	(Lynn, 6/21/2013; National Science Foundation, National,Science Board, May 2013)
Quality of review panel	(Graves et al., 2011a)
Reviewer's ability to work with others	(Graves et al., 2011a)

2.5 Gap Analysis

The literature review demonstrated the capacity of systems thinking, balanced scorecard, and portfolio management to solve problems. The last topic, factors affecting the grant process, demonstrated the complexity of solving the problem. The uniqueness to this master's thesis is the combination of the three disciplines in a manner that connects all the grant process factors to provide the framework for solving the problem. Table 2-2 summarizes the literature citations by the topic.

Table 2-2: Source by topic analysis.

Source	Systems thinking	Balanced Scorecard	Portfolio Management	Factors affecting grant outcome
Table 2-1 contains 13 unique sources for the 32 different factors				✓
(Albin, 1997)	✓			
(Baker et al., 2011)	✓	✓		
(Kaplan & Norton, 2001)	✓	✓		
(Kunc, 2008)	✓	✓		
(Litwin, 2009)	✓		✓	✓
(Nippa et al., 2011)			✓	
(Senge, 2006)	✓			

2.5.1 Uniqueness

The literature survey did not reveal any articles that used all four topics in the university setting to solve this problem. Senge (2006) and Albin (1997) discussed the application of systems thinking and system dynamics in a wide range of problems. Kaplan and Norton (2001) gave a nod to Senge's work but applied a unique methodology that moved from strategy to a broad range of objectives and measures. Kunc (2008) introduced causal loops into the balanced scorecard methodology to formally introduce feedback loops into the system. Baker et al (2011) discussed strategic alignment in the balanced scorecard method with the introduction of specific metrics for the information technology industry. Nippa et al (2011) provided a treatise on the state of the corporate portfolio management research in academia and suggestions for continued work. Litwin (2009) was the only source found that used 3 of the 4 topics. Litwin's (2008) work discussed the systems approach and then moved to portfolio management as a way of measuring a university's market position. He proposed further work suggesting more time sensitive measures since his work had been based on measurement of the market change over a 10-year time period. It was Litwin's work that pointed to specific measures that could be implemented to measures a university's market position.

2.5.2 Concurrence

The four topics from the literature review presented unique features that could work together to solve the problem. The system thinking philosophy requires a holistic view of the problem. It requires a broad view to ensure a permanent solution is found. The balanced scorecard incorporates a systems approach by categorizing the objectives into one of the four business perspectives; the financial perspective, the customer perspective, the internal process perspective, and the growth and learning perspective. The methodology develops strategic objectives and measures that are intended to accomplish the overall strategy. The causal loop diagram provides a means of showing a picture of the system with all its interactions. The strategic indicators introduced by Litwin, in his application of portfolio management, were the starting point to measuring a university's market position. A modification of his metric was required for its introduction into the metrics within the balanced scorecard system. Taken alone each of the topics can address a pieces of the problem. Put together they provided a potential solution to the problem.

CHAPTER 3 : METHODOLOGY

This chapter introduces the research methodology used for this applied research activity. The work is a combination of qualitative and quantitative research. The qualitative portion investigates systems and factors that influence the problem. The quantitative portion investigates performance measures and the improvement of those measures to solve the problem.

3.1 Research methodology

The research methodology used for this work is provided graphically in Figure 3-1. It started with the problem formulation. From there the literature survey was done. A framework was proposed to solve the problem. Validation of the framework was performed to determine its integrity. The validation step produced an iterative process with the framework development step. The successful validation resulted in the final framework developed to solve the problem. The final framework was completed using UCF as the case study. An analysis was performed on the findings. A conclusion was developed from the analysis.

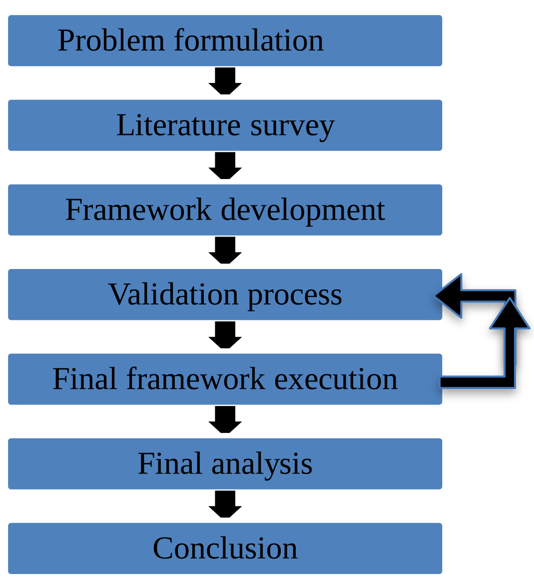

Figure 3-1: Research methodology process flow

3.1.1 Problem formulation

My experience at UCF exposed me to the grant funding process. A review of UCF's Office of Research and Commercialization's (ORC) annual report provided a glossy display of increased funding over the years (University of Central Florida, 2012). A preliminary analysis of the data within the report revealed the win rate had gone down over the years. Although the monetary value of contracts and grants had increased over the years, the percentage of proposals that won an award had gone down. That observation was the seed to the problem statement for this thesis. Discussions with my advisor and a more background investigation refined the problem statement for this work.

> *How can UCF increase their federally financed academic research expenditures commensurate with their mission and size?*

3.1.2 Literature survey

A literature survey was undertaken to understand the problem, learn from the latest research results, and find potential solutions. The articles were grouped and reported in the four categories described in Chapter 2. It was found that system thinking, the balanced scorecard methodology, and portfolio management techniques could be used to develop a potential solution. It was also found that the grant process is a very complex process with many interactions that would have to be accounted for if a successful solution was to be developed. The research had not discovered the use of systems thinking, the balanced scorecard methodology, and portfolio management theory together to address a university's need to increase its federally financed R&D expenditures.

3.1.3 Framework development

The framework development activity formulated a proposed solution. Sufficient information and plans were developed to present the idea for validation. The proposed framework utilized different disciplines covered in this Masters curriculum; systems engineering, operations management, engineering management, project management, and economics, to name a few.

3.1.4 Validation process

The validation was performed to determine the soundness of the proposed framework. The idea was presented to an ad hoc committee of experts for feedback. These experts included the thesis committee and faculty members from outside the committee. Their expertise was in program management, the grant award process, data mining, business operations, statistics, technology strategies, system dynamics, and the balanced scorecard methodology.

The resulting critique fed back into the framework development stage. This process resulted in a final framework that provided a potential solution to the problem and met the Master's criteria of complexity, and originality.

3.1.5 Final framework

The final framework was a multi-step process that yielded the results of the study. Figure 3-2 presents that framework visually.

Figure 3-2: Final framework for investigation

The process was succinctly presented in Rohm's article "A Balancing Act" that was based on writings from Kaplan & Norton and others (Rohm, undated). The details of each step follow.

3.1.5.1 Assessment

Three areas relating to the problem statement were assessed. UCF's current position with respect to the federally financed academic R&D was measured. The current Mission and Vision for UCF's ORC was reviewed and evaluated for its alignment with research initiatives. The factors affecting grant awards found in the research literature were cataloged.

The NSF's WebCASPAR database (https://webcaspar.nsf.gov) was a primary source for the academic research market information. The publicly available database had a wide range of funding information related to colleges and universities that have received funding from any federal agency going back decades. This database was used to document the academic research market, UCF's position in the research market, and its position with respect to the other universities. Additionally it was used to measure the activity by research discipline.

The ORC's mission and vision statements were evaluated for their alignment with a strong research initiative. The content and construction was compared to those recommended in current studies on the topic.

The last area of assessment determined the factors reported as affecting the grant award process. Several sources were consulted to catalog the factors reported having an influence the ability to win grants.

3.1.5.2 Develop Strategy

A strategy was developed specific to the research initiative for UCF. The knowledge gained from the literature review, the classes taken as part of this UCF's Master's program, and my professional experiences were used to propose a strategy for UCF's research initiative.

3.1.5.3 Develop Objectives from Strategy

The factors influencing the grant award process were listed and categorized by the four perspectives as noted by Kaplan & Norton (2001). Those were the financial perspective, the customer perspective, the internal process perspective, and the learning and growing perspective. For each perspective the question was asked, "What needs to happen to maximize the positive factors and minimize the negative factors?" The answer to those questions developed the strategic objectives needed to attain the strategy. The strategic objectives were then listed by perspective.

3.1.5.4 Develop Strategy Map

The strategy map was developed using the philosophy and techniques described by Kaplan and Norton (2001). The strategic objectives were inserted into the strategy map at the different perspective positions. Arrows were drawn to show how the objective strategy in one perspective was connected to strategic objectives in other perspectives. The strategy map was presented.

3.1.5.5 Develop Performance Measures

A set of performance measures was developed from the strategic objectives. Asking the question, "How do we achieve that objective" or "What do we measure to ensure we meet the objective?" developed the set of performance measures.

A causal loop diagram was built containing all the developed measures. The resulting diagram was presented that showed the interaction among the various measures.

The performance measure relating to academic market share was investigated further. Litwin's (2008) strategic indicators were analyzed for applicability to UCF's situation and the proposed solution. Those strategic indicators were uniquely modified to provide a timelier, more accurate representation of a university's market position.

3.1.6 Final analysis

The final analysis evaluated the findings from the study. The analysis relating to the market share performance measure was presented. The analysis of the systems approach to solving the problem statement was presented.

3.2 Conclusions

The conclusion was presented that tied all the work together to point to a potential solution to the problem statement. It also provided potential areas of further research.

3.3 Definitions

This definitions section is specific to the academic research market performance measures presented in this work. The terms relate to measuring the academic research market, a university's position in the market and quantifying its position relative to the market. These definitions were presented in Litwin's work "The efficacy of strategy in the competition for research funding in higher education" (Litwin, 2008). They are repeated here to let the reader see how his strategic indicators were formulated and calculated. The definitions are notated with a "(Litwin, 2008)" citation following the term name to indicate this definition is verbatim or nearly verbatim to the definition in his work. Definitions in his work contained examples of how the terms were calculated using data found in his appendices. In those cases I have modified the definition to use data found in appendices in this work. Terms without the Litwin citing were developed from this work.

The terms are grouped by topic, not listed alphabetically. General terms related to the academic research market are presented first. Then terms related to the basic calculations are presented.

The third definition group is related to the Market Strategic Indicator (MSI). The fourth definitions group is related to the Institutional Strategic Indicator (ISI).

3.3.1 Market related terms

ARM (Litwin, 2008): The Academic Research Market is defined as the total of all federally financed research and development expenditures in colleges and universities, as reported by the colleges and universities that received those funds, regardless of which federal agency provided those funds. Even though universities receive research funds from other sources, for the purposes of this study these sources have been excluded. Federally financed research expenditures in non-science and engineering fields have also been excluded from this definition. Non-science and engineering fields include "Education, Law, Humanities, Visual & Performing Arts, Business and Management, Communications, Journalism, and Library Science, Social Work, and Other Non-S&E fields" (NSF, 2006, p. 6). In addition, amounts from NSF fields entitled "Engineering, Other, nec, Physical Sciences, Other, nec, Environmental Sciences, Other, nec, Life Sciences, Other, nec, Social Sciences, Other, nec, Other Sciences, nec, and Engineering, Bioengineering/biomedical" (NSF, 1994-2001) were excluded (Litwin, 2008). The basic reason the nec was excluded was because the categorizing in the reporting scheme was not clean enough to prevent double reporting or other unintended consequences.

Discipline: The area of research as categorized by the NSF in the WebCASPAR database. There were 21 disciplines of study in the S&E fields are found in Appendix A. Litwin had referred to these as ‘fields’ in his work (Litwin, 2008).

RIU (Litwin, 2008): Research Intensive University. An RIU is a university that was a member of the Association of American Universities from 1988 to 2002 inclusive (Association of American Universities, 2005), that was classified by the NSF as one of the top 100 recipients of federal research funding from 1988 to 2002 inclusive, and that was categorized by the Carnegie Foundation as a Research University I in its 1987 and 1994 surveys and as a Doctoral/Research University-Extensive in its 2000 survey (Carnegie Foundation for the Advancement of Teaching, 1987, 1994, 2000). The final filter used to define an RIU relates to the consistency of the data that each RIU reported in the annual NSF surveys. All institutions that met the first three conditions had to further qualify by passing a reporting consistency test called the Ratio Variance test. The Ratio Variance test was used to determine whether an RIU's reporting history was sufficiently consistent so that its reported data could be reliably used in the study (Litwin, 2008).

ΔMS (Litwin, 2008): The Change in Share of ARM (ΔMS) is the percentage difference in the share of the ARM held by an RIU compared over different time periods. The ARM share held by an RIU in 1990a is determined by dividing the Total Reported for 1990a by the ARM in 1990a. Dividing UCF's Total Reported of $4.537 million (Appendix G) by the ARM in 1990a of $8,635.580 (Appendix D) million produces a market share of 0.05% (Appendix G) in 1990a. Litwin stated, "ΔMS is the critical measurement of strategic success in this *(his)* study since it measures the actual performance of an RIU in relation to all other RIUs and in relation to the ARM. An RIU that has increased its market share to a greater degree than its competitors has achieved a better strategic outcome" (Litwin, 2008).

3.3.2 Basic calculation terms

1990a (Litwin, 2008): 1990a is the arithmetic mean of data from the years 1989, 1990, and 1991 inclusive. The purpose for using an average of years is to mitigate the risk that 1990 was an anomaly. For greater certainty, when the term 1990 is hereafter used, it refers to that actual year. In the circumstances described in the Exceptions Method within the definition below, 1990a is the arithmetic mean of data from the 5 years 1988 to 1992 inclusive (Litwin, 2008).

2000a (Litwin, 2008): 2000a is the arithmetic mean of data from the years 1999, 2000, and 2001 inclusive. As in the case of 1990a, the purpose for using an average of years is to mitigate the risk that 2000 was an anomaly. For greater certainty, when the term 2000 is hereafter used, it refers to that actual year. When the exception method is invoked, 2000a is the arithmetic mean of the 5 years 1998 through 2002 inclusive (Litwin, 2008).

2008a: Defined for this study the 2008a term is intended to replicate the definition set for 1990a and 2000a above but or a different span of years. 2008a is the arithmetic mean of data from the years 2007, 2008, and 2009 inclusive. As in the case of 1990a, the purpose for using an average of years is to mitigate the risk that 2008 was an anomaly. For greater certainty, when the term 2008 is hereafter used, it refers to that actual year. When the exception method is invoked, 2008a is the arithmetic mean of the 5 years 2006 through 2010 inclusive.

Exceptions Method (Litwin, 2008): The procedure was undertaken for each discipline in the ARM and UCF. The exception method was implemented to smooth data when outliers were present. Appendix B presents the academic research market data used for this study. Appendix C presents the academic research data related to the exceptions method. Appendix E presents the academic research market data for UCF. Appendix F presents the academic research market data for UCF related to the exceptions method. The step-by-step process showing how the exception method is tested and implemented is presented in Appendix W.

Rolling: In this work rolling refers to the moving 3-year span for a particular parameter. The rolling average refers to a 3-year span where the stated year is latest of the 3-year span. For instance, 2000 rolling average institutional spending was the average spending for the years 1998, 1999, and 2000. This allowed the newest NSF data to be incorporated and labeled with the most current year. When the 2012 data was released a researcher could calculate the new parameters by incrementing all the rolling metrics by one year. The 2012 data would become an average of the years 2010, 2011, and 2012.

3.3.3 Market Strategic Indicator (MSI)

The following terms define the market share indicator and its components. The data is presented in Appendix D.

$$MSI = EMS + \Delta EMS \tag{1}$$

EMS (Litwin, 2008): The Equalized Value for Percent of ARM (EMS) is an indicator, as seen in Appendix D, which corresponds to the equalized values for the proportion that each discipline represented of the ARM in 2000a or 2008a. EMS comprises one of two equal parts of the Market Strategic Indicator, the second equal part being ΔEMS.

The first step in generating EMS for a discipline is to determine the percentage that each field represented of the ARM in 2000a. For example, in 2000a Mathematics was 1.43 % of the $15,895 million ARM. This datum can be found in the column entitled "2000a % of ARM" in the Mathematics and Statistics row. The next step used to ensure that EMS was an equally weighted component of MSI was to determine that largest value of "2000a % of ARM." This value was then used as the denominator for all other values in for "2000a % of ARM" to determine EMS. For example, at 34.74 %, Medical Sciences was the field that was the largest proportion of the ARM in 2000a. "2000a % of ARM" for Medical Sciences was used as the denominator. Astronomy was 1.60 % of the ARM in 2000a. ("2000a % of ARM" for Astronomy was 1.60). When divided by 34.74, the value of EMS for Astronomy equaled 0.046.

Litwin stated “EMS manifests the earlier described portfolio theory, which stipulates that the greater the proportion that a market segment represents of a market's total value, the greater will be its strategic importance to the competitors operating in that market. EMS can be used to rank 2000a federally financed R&D expenditures by discipline as a proportion of the ARM. Disciplines that have a greater value for EMS represent fields that are a larger proportion of the ARM. Disciplines that are a larger proportion of the ARM provide better opportunities for the strategic advancement of RIUs than do disciplines that are a smaller proportion of the ARM” (Litwin, 2008, p.118). The same methodology to calculate the EMS was used for all disciplines over both the 1990a to 2000a time frame and the 2000a to 2008a time frame.

ΔEMS (Litwin, 2008): The Equalized Value for Change in ARM (ΔEMS) represents the equalized values for the change that occurred in the proportion that each discipline represented of the ARM between 1990a and 2000a.

The first step in determining ΔEMS was to find the percentage change in "2000a % of ARM" from "1990a % of ARM." For example, Civil Engineering was 1.32 % of the ARM in 1990a and 1.51 % in 2000a, which means that its share grew by 14 % during the period. (1.51 is 14 % larger than 1.32.) Agricultural Sciences share was 4.18 % in 1990a and 3.65 % in 2000a, representing a decline in share of expenditures of 13 %. Declines in market share are represented as negative numbers while growth in market share is represented as positive number.

In order to ensure that ΔEMS was equally weighted to EMS, the largest value of ΔEMS was equated to one. In the ARM, Political Science had the largest ΔEMS at 29.56 % for the time span 1990a to 2000a. This value was used as the denominator for all values of "% Change in ARM 1990a-2000a". The ΔEMS values are found in Appendix D for the two time spans, 1990a to 2000a, and 2000a to 2008a. The column labels are "Equalized Value of Change in ARM (ΔEMS 1990a-2000a)" and "Equalized Value of Change in ARM (ΔEMS 2000a-2008a)".

Litwin stated, "The concept of ΔEMS reflects the earlier described portfolio theory attribute, in which a market's fastest growing segments provide greater strategic opportunities than do slower growing or contracting market segments. The greater the value of ΔEMS, the faster a market segment has grown as a proportion of the ARM. The larger the value of the ΔEMS, the greater the opportunity for strategic advancement there is for the RIUs" (Litwin, 2008, p. 119). The same methodology is used to for all disciplines over both the 1990a to 2000a time frame and the 2000a to 2008a time frame.

MSI (Litwin, 2008): The Market Strategic Indicator (MSI) is the sum of EMS and ΔEMS. Litwin stated "Market segments that are both the largest and the fastest growing should be considered as those segments that provide the greatest opportunities for competitors. MSI is an indicator that represents the relative size and change in relative size of each of the 21 market segments that comprise the ARM. The greater the value of MSI, the larger and faster growing is that market segment and the greater is the strategic opportunity provided to the RIUs. For example, the market segments of Medical and Biology provide better opportunities for RIUs to generate strategic advancement than do the fields of Mathematics or Economics" (Litwin, 2008, p. 119).

3.3.4 Institutional Strategic Indicator (ISI)

The following terms define the institutional strategic indicator and its components. The data is presented in Appendix G.

$$ISI = EIS + \Delta EIS \qquad (2)$$

EIS (Litwin, 2008): The Equalized Value for Percent of Institutional Spending (EIS) indicates the equalized values for the proportion that each discipline represented of an RIU's federally financed research expenditures in 2000a or 2008a.

The first step in generating EIS for a discipline is to determine the percentage that each discipline represented of the institution's research expenditures in 2000a or 2008a. For example, Chemistry was 7.90% of the $11.789 million spent by the UCF in 2000a. This datum can be seen in the column entitled "2000a % of Institutional

Spending" in Appendix G in the Chemistry row. Since EIS comprises one of two equal parts of the Institutional Strategic Indicator, all values of "2000a % of Institutional Spending" were adjusted by the factor that equated the largest value to one. At UCF, Physics had the largest share in 2000a at 27.03%, and this value was used as the denominator for all values of "2000a % of Institutional Spending." For example, Chemistry was 7.90 % of the University of Central Florida's expenditures in 2000a. When divided by 27.03, the value of EIS for Chemistry equals 0.2923. This result can be observed in Appendix G, column "Equalized Value of % Institutional Spending (EIS, 2000a) in the Chemistry row.

Litwin stated, "EIS parallels the portfolio theory attribute in which the largest components of a multiunit enterprise's total portfolio are more strategically important to it than are its smaller components. In this methodology, the larger the value of EIS, the more strategically important those disciplines are to the RIU" (Litwin, 2008, p. 120).

The same methodology is used for all disciplines over both the 1990a to 2000a time frame and the 2000a to 2008a time frame.

ΔEIS (Litwin, 2008): The Equalized Value for Change in Share of Spending (ΔEIS) represents the equalized values for the change that occurred in the proportion that each discipline represented of the RIU's federally financed research expenditures between 1990a and 2000a or between 2000a and 2008a.

ΔEIS is determined by finding the percentage change from "2000a % of Institutional Spending" to "1990a % of Institutional Spending." For example, at UCF the Biological Sciences was 2.40% of spending in 1990a and 5.52% of spending in 2000a, which means that its share of institutional expenditures grew by 130% from 1990a to 2000a. Computer Science was 7.35% of 1990a spending and 2.60% of 2000a spending which means its share changed by -65% for that time period.

In order to equally weight the ΔEIS with EIS, the largest value of "% Change in Institutional Spending" was equated to one. At UCF, Sociology was the largest "% Change in Institutional Spending (1990a-2000a) at 1724%. This value was used in the denominator for all values of "% Change in Institutional Spending (1990a-2000a). Completing the Computer Science example, the change of -65% in share, divided by 1724% produced a ΔEIS for Computer Science of -0.038. This value is found in Appendix G, column "Equalized Value of Change in share of spending (ΔEIS 2000a)" in the Computer Science row. The same methodology is used for all disciplines over both the 1990a to 2000a time frame and the 2000a to 2008a time frame.

Litwin stated, "Portfolio theory states that in any multiunit enterprise, faster growing portfolio components are more strategically important than slower growing ones. The concept is that, in limited resource environments, portfolio components that grow relatively rapidly are absorbing resources faster than the other component components. RIU research operations exist in a limited resource environment. The decisions that enable resource allocations represent strategic activation. Those components that are receiving a disproportionate share of resources are strategically more important than other components in a RIU's portfolio. The greater the value of ΔEIS, the faster growing is the proportion that field (discipline) represents of an RIU" (Litwin, 2008, p. 121).

ISI (Litwin, 2008): The Institutional Strategic Indicator (ISI) is the sum of EIS and ∆EIS. Litwin stated, “Portfolio components that are both the largest and fastest growing should be considered as the most strategically important to an organization. ISI is an indicator that represents the relative size, and change in relative size, of every component in an RIU’s portfolio. The greater the value of ISI in any RIU, the more strategically important is that discipline to it” (Litwin, 2008, p. 122).

CHAPTER 4 : CASE STUDY AND ANALYSIS

The results of the research methodology are presented in this chapter. The research methodology provided a proposed solution that, when applied to the problem, could improve the condition. This chapter provides the potential answer on how UCF can increase its federally financed academic R&D expenditures.

4.1 Framework Development

The systems approach ensured a broader picture of the problem was encompassed when the initial problem definition was being developed. The literature review revealed the complexity of the problem by revealing that a high number of variables were involved in the grant award process. The literature review also provided examples of how different methodologies and theories could be integrated for a possible solution. The iterative approach to framework development using a validation process ensured a sound investigation could proceed. The research using the final framework provided a systems solution using the balanced scorecard methodology. The resulting strategic objectives with their associated measures integrated into the causal loop diagrams provided a view of the system with the interactions. The development of the real-time market share metric based on the portfolio management theory is believed to improve upon the market position metric reported in the literature. The result of using this applied research methodology was a solution with specific outcomes that could be tested to solve the problem.

4.2 UCF Case Study

The proposed framework was applied to UCF for the purpose of improving their position in the federally financed academic R&D market.

4.2.1 Problem defined

It is critical to have the problem definition scoped properly in order to move forward with meaningful research and provide a plausible solution. A problem defined too broadly leaves a researcher with a lifelong effort and very little to show for it. A problem defined too narrowly may provide a solution but with limited application or impactful result. The problem defined for this work was narrow enough to develop a potential solution and broad enough to have a meaningful impact for UCF or other universities that may want to study the approach.

> *How can UCF increase their federally financed academic R&D expenditures commensurate with their mission and size?*

The '*federally funded academic R&D expenditures'* was chosen because the data is publicly available, updated yearly, has decades of history, is reported using specified guidelines, and is consistent in their definition of terms (Litwin, 2008). Another benefit of using this parameter is the competition's performance can be measured as well as your own performance (Litwin, 2008). The potential solution to improving the federally financed R&D expenditures may translate to increased funding from other sources. In that respect the problem is defined narrowly enough to provide a potential solution but has the ability to provide a more impact result.

The '*UCF increase*' was sufficiently narrow to provide focus and implies real-time measurement with corrective action in order to achieve the goal of '*commensurate with their mission and size*'. As the mission and size change the targets should also change. This speaks to the dynamics of the problem.

4.2.2 Literature revelation

The literature review provided the justifications for the basic framework to solve the problem. The combination of Senge's (2006) philosophy of systems dynamics with Kaplan and Norton's (2001) specific balanced scorecard methodology provided rough structure to proceed.

The complexity of the grant award process was realized when the literature revealed over 32 different factors that influenced the grant award process. The summarized list of factors in Table 2-1 revealed their breadth. The controllable items like quality of the proposal or the credentials of the authors were to be expected. The less obvious, but just as important, were the factors related to the application review process. The make-up of the review panel, their size, and the review method used were reported to potentially affect the award. The literature review highlighted the complexity of the problem and that a broader view would need to be taken in order to impact change.

The work by Kunc (2008) and Baker et al., (2011) showed the incorporation of system dynamics and causal loops into the balanced scorecard for improved results.

Litwin's (2008) work specific to the federally funding of university academic research became the focus for measuring a university's performance.

The literature survey provided the building blocks to develop a potential solution to the problem.

4.2.3 Iterative framework developed

With the building blocks in hand they were arranged in various ways and tested for integrity through the use of a validation process. In the early stages the proposed framework was presented to the advisor for comment. It was refined and presented to an ad hoc panel of experts for their comment. Their feedback was considered and the framework was modified to improve its integrity. This iterative process continued for 2 cycles before the framework was finalized. This resulted in a more sound solution framework that had the potential to solve the problem.

4.2.4 Framework applied

The final framework applied to this problem used a 5-step process with the balanced scorecard methodology incorporating causal loops. The first step assessed the situation to determine the as found condition. From that starting point a strategy was developed for the organization responsible for the university's grant awards process. The balanced scorecard methodology was used to develop strategic objectives and measures for this proposed strategy. That led to the strategy map that provided a visual representation of the system. Further work led to the development of the measures needed to determine the status of meeting the strategic objectives. The developed solution had a set of 19 measures. These metrics were incorporated into a causal loop diagram to show interconnectivity. Further work focused on one measure, UCF's position in the market. The metric currently reported in the literature was applied to UCF's case. It was modified to so that it could be used in the developed solution such that it provided a real-time metric, weighted properly, to reveal a university's market position. A graphical representation of the result was presented for single view of the market, its direction, and the university's position in it.

4.2.4.1 As found condition

An assessment was performed for three areas: the mission statement, the market position, and the factors affecting the grant process. The findings formed the direction of the developed solution.

From a systems approach the assessment started with the mission statement. The lead finding was that UCF's Mission did not highlight the importance of academic research.

The mission covered seven of the eight main characteristics judged relevant to a good statement: location, self-concept, products/services, customers, technology, philosophy, concern for public image, and concern for survival (D'Souza, Clower, Nimon, Oldmixon, & Tassell, 2011). UCF's lacked the concern for survival characteristic. The ORC's mission and vision statements were reviewed and compared against the attributes listed above. Neither speaks to the suggested attribute of concern for survival. Since mission and vision statements need to be developed by a team, I do not provide a definitive statement here (Mowry, 2012). For the purpose of moving this work forward, however, I provide a potential starting point for the ORC mission that speaks to eight main characteristics.

> *Drive reputable, sustainable research programs commensurate with the university's mission and size.*

The ORC has responsibilities other than research. For that reason I do not suggest this one statement can be a substitute for their entire organization's current mission. I suggest this statement could be the focus for improving their federally financed academic R&D expenditures.

The introduction provided UCF's relative position to other universities with respect to a subset of universities. Additional assessment was done to provide UCF's position relative to its regional competition, the other Florida universities. Figure 4-1 provides the equalized value of the total federally financed R&D reported by each university. The equalized value was calculated as discussed in the introduction. Johns Hopkins University had a value of 1.0, but not shown on this graph. The graph was scaled to provide separation among the universities at the bottom.

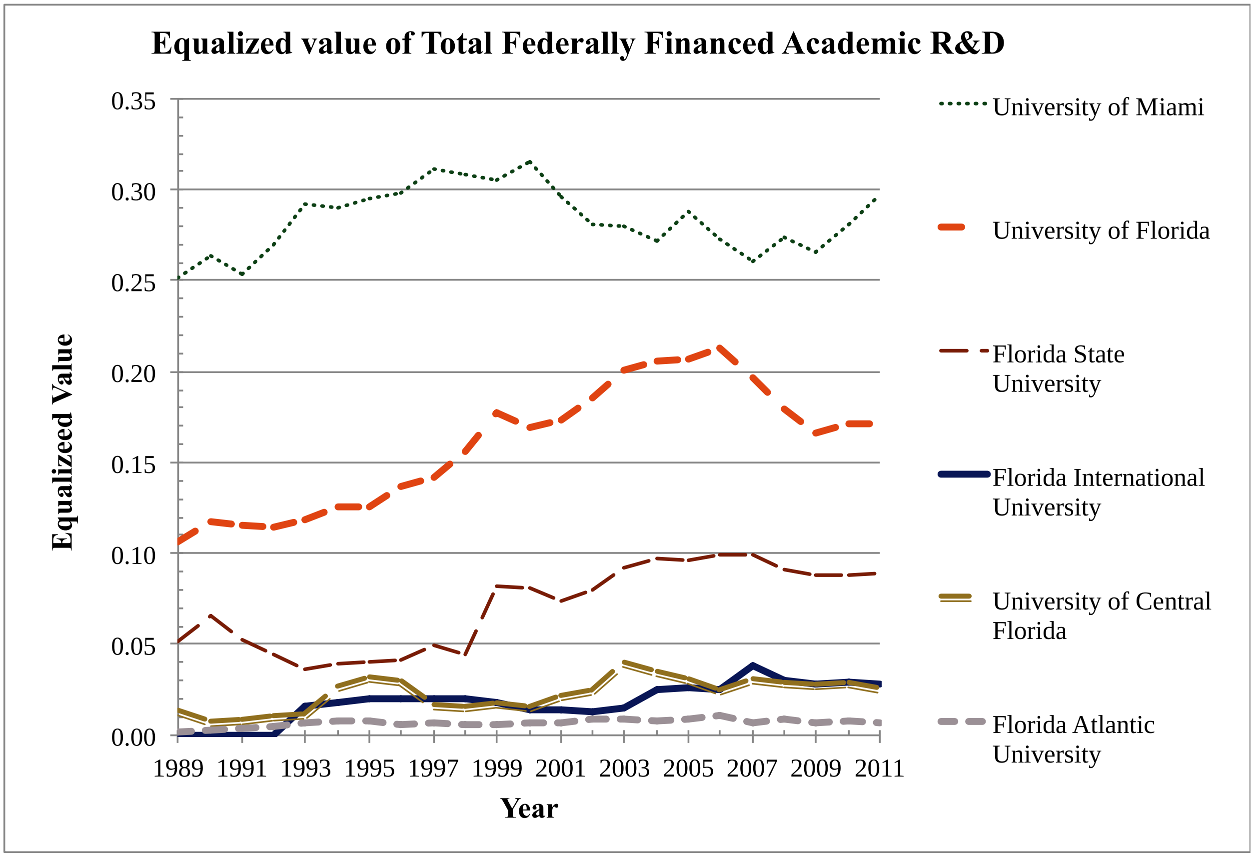

Figure 4-1: Equalized value of total FF R&D for some Florida universities

The NSF webCASPAR database presents the data in many formats and categories. It can provide the data by research discipline. They have defined 21 different disciplines in the S&E category. Those disciplines are listed in Appendix A. UCF participated in 16 of the 21 disciplines. The 5 disciplines UCF did NOT participate in were Agricultural Sciences, Astronomy, Chemical Engineering, Earth Sciences, and Oceanography.

As the literature review mentioned there are a myriad of factors found to influence the grant award process. The assessment of those factors, their relationship from a systems perspective, and their integration into a strategy from the balanced scorecard methodology allowed them to be grouped into the four perspectives developed by Kaplan and Norton (2001). Table 4-1 presents the factors arranged by their respective perspectives.

Table 4-1: Factors grouped by balance scorecard perspectives

Financial perspective (Financial Strength)	
	Research market share and growth in the research market
	Number of endowed chairs
	Amount of seed money
	Opportunity costs (can university afford expense and diversion of efforts)
	Capability to meet financial requirements
	Size of university
	University history of keeping promises (Reputation)
Customer perspective (Recruitment)	
	Financial incentives for scholarship
	Recruitment strategy of University
	Size of university
	University history of keeping promises
	Number of endowed chairs
Internal Processes (Administrative Performance)	
	Career award system tied to grants
	Size of research administration department
	Strategic alignment of grant apps with U strategy and funding source strategy
	Competition level for funds
	Historical success of university
	Capability to meet the legal requirements
	Investigators first win with respect to the time since their last degree
	Proposal quality
	Proposal alignment with agency goals
	University history of keeping promises
Learning and Growing (Organizational Structure)	
	Number of faculty
	Teaching load
	Presence of internal research centers
	Presences of PhD programs
	University culture promotes grant apps
	Number of doctoral students available for research
	Organizational structure to promote interdisciplinary research
	Size of university
	Previous grant winner
	Credentials of the proposer and team
	Proposal quality

4.2.4.2 Develop strategy

The assessment in the previous section provided sufficient information to propose a strategy for UCF's ORC to answer the thesis question of how UCF can increase their federally financed academic R&D expenditures commensurate with its mission and size.

> *Drive reputable, sustainable research programs commensurate with university's mission and size.*

It is important to note a team of stakeholders that have ownership in solving the problem best develops a strategy. This proposed strategy developed here provides the focus needed for the rest of framework to proceed.

4.2.4.3 Develop objectives from strategy

From the strategy the strategic objectives were developed. They were created from analyzing the findings and applying the principles taught by Kaplan and Norton (2001). They were centered on the factors and their categorization presented in Table 4-1. The resulting 12 strategic objectives are listed below:

1. Ensure the competition in the academic research market has holistic approach;
2. Increase UCF academic research market share commensurate with its size;
3. Win funding opportunities to align with funding agency and university strategy;
4. Ensure policies and procedures promote grant application winning with interdisciplinary activity in mind;
5. Ensure policies and procedures recruit and reward faculty and staff in accordance with winning funding opportunities;

6. Ensure research administration’s operational efficiency accounts for resource load required to support competing in the academic research market (opportunity costs, seed money, personnel);
7. Ensure policies and procedures for student recruitment include significant scholarship opportunities, discipline variety, and research opportunities that align with university’s mission;
8. Recruit quality faculty and staff;
9. Recruit quality students;
10. Develop faculty and staff;
11. Develop culture that promotes research participation and wins funding; and
12. Promote accomplishments to improve reputation.

It is important to note a team of stakeholders that are close to the problem best creates the strategic objectives developed from the strategy. The strategic objectives presented here are believed to be applicable to solving the problem based on the research findings. Their implementation, however, will take involvement from stakeholders to refine and apply.

4.2.4.4 Develop strategy map

The strategic objectives were grouped by perspective and presented graphically in Figure 4-2 as the strategy map. This followed the balanced scorecard development protocol (Kaplan & Norton, 2001).

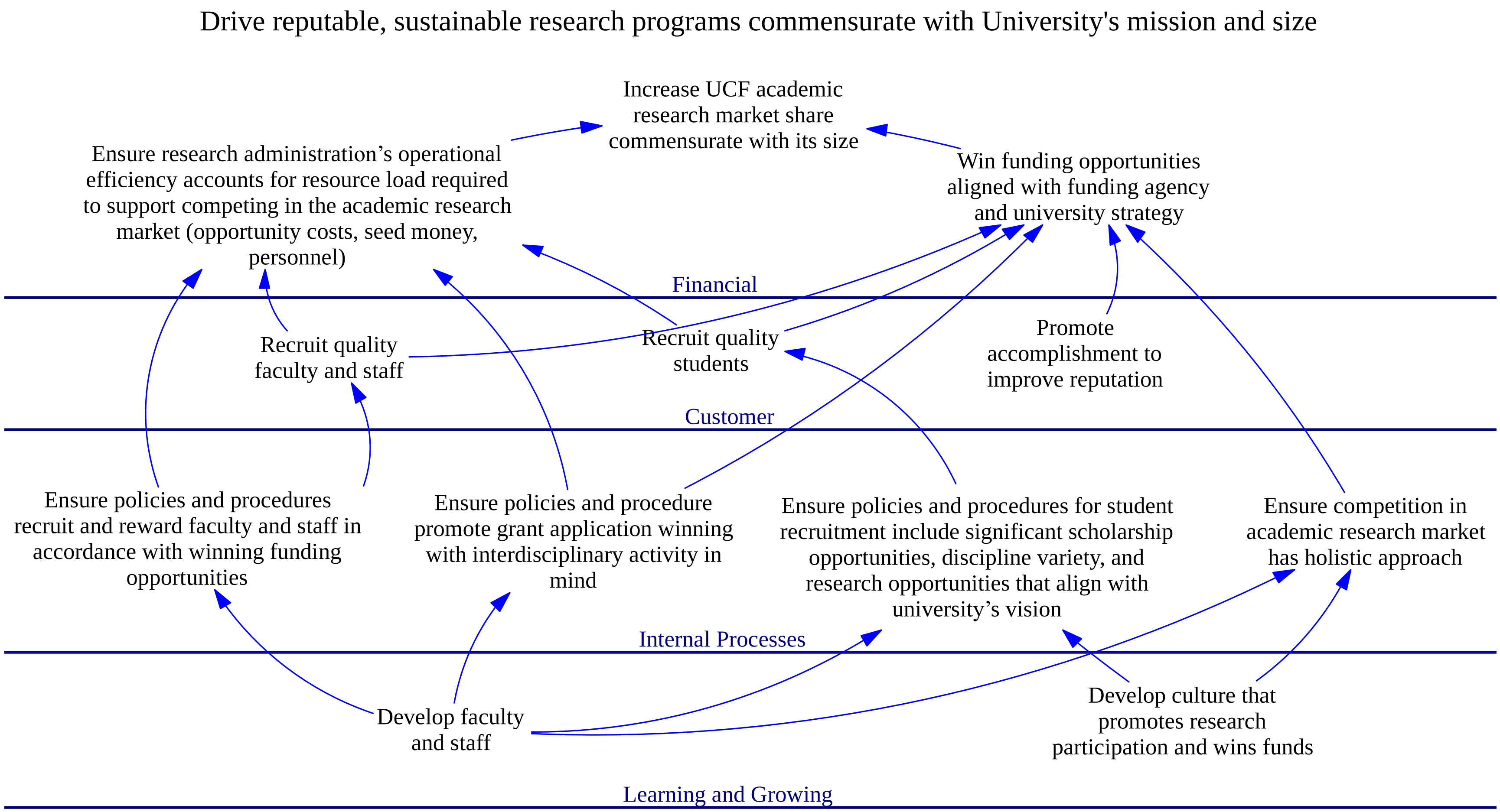

Figure 4-2: Proposed Strategy Map for improving UCF's R&D funding

4.2.5 Develop Performance Measures

The strategy map provides the strategic objectives necessary to accomplish the main strategy. The measures are those things that need to be quantified to determine if the strategic objectives are being met. They were developed by asking the question(s) "How can we obtain the *strategic objective*?" or "What do we measure to ensure we have the *strategic objective*?" for each strategic objective in the strategy map. As an example, the question "What do we measure to confirm we *promote accomplishments to improve reputation?*" was asked. The proposed metric was to measure the "*Number of promotional articles published*". For each objective found in the strategy map in Figure 4-2 a metric or set of metrics was proposed to determine if the objective was met or on its way to being met. Remember this is a dynamic process and will require feedback and refreshing to maintain the currency of the objectives. The list of strategic objectives and corresponding measures are presented in Appendix X.

It is important to note this list was not intended be the definitive list of measures that will solve the problem. The strategic objectives and associated measures are best generated from a team of stakeholders close to the problem. These measures were developed as a starting point to give structure to the potential solution.

A key aspect of this work was developing the causal loops associated with the measures. The measures do not stand-alone in systems view. They are interconnected with other measures within the system. The resulting causal loops shown in Figure 4-3 are the visual relationship of that connectivity.

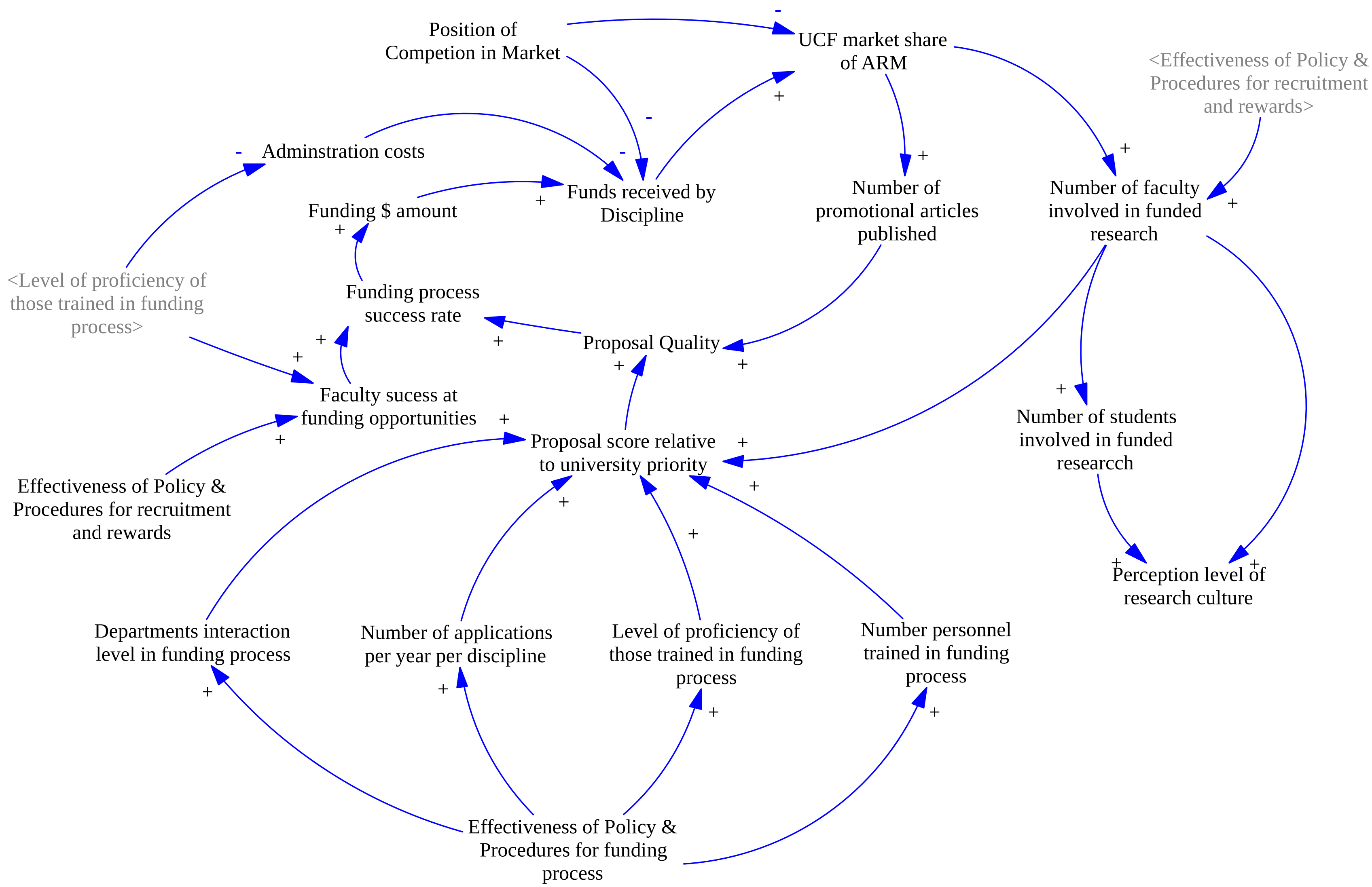

Figure 4-3: Causal loops of objectives and measures

An example of the causal relationship that the *UCF market share of ARM* has with the other measures is presented as follows. When the *UCF market share of ARM* increases, it is proposed it will increase the *Number of faculty involved in funded research* and *Number of promotional articles published*. As the *Number of promotional articles published* increases the *Proposal Quality* will improve. The reason for the proposal quality improvement is the proposal reviewer looks at a university's reputation as a factor during their assessment. The more *Number of promotional articles published* the more likely the university's reputation will increase. As the *Proposal Quality* increases the *Funding process success rate* goes up. This will increase the *Funding $ amount* which increases the *Funds received by Discipline* which increases *UCF market share*. The loop is completed and the causal relationship among the different measures can be observed.

Standard nomenclature in Figure 4-3 shows a '+' at the tip of the arrow indicates that an increased value of the preceding measure will increase the value of the measure the arrow head is pointing to. A '-' symbol at the tip of the arrow indicates the increasing value of the preceding measure will decrease the value of the measure the arrow is pointing to. As you can see, very few measures stand by themselves. Their values will influence the outcome of other measures.

The proposed causal loops presented in Figure 4-3 address only increasing the federally funded R&D expenditures.

4.2.6 Metrics for Market Position

The rest of this work is focused on the measures related to the academic research market and UCF's position in that market. First the strategic indicators developed by Litwin are presented for UCF's case (Litwin, 2008). Applicability of these measures to UCF's case is discussed. Modifications to those metrics are presented for them to fold into the balanced scorecard. The resulting indicators are presented. It was argued the new measures did not accurately reflect the change in the market share, so an alternative measure was developed and presented. The final metric propose provide a more accurate representation of the market share and its change in its market position. Examples of the metrics are presented in the quadrant plot from Litwin's work but in time sequence and by discipline (Litwin, 2008).

4.2.6.1 Existing performance measures

UCF's relative market position through the equalized value of the total federally financed academic R&D expenditures is shown in Figure 5. The total was the summation of all the participating disciplines' contributions. UCF's case was explored in more detail by investigating the contributions by academic discipline as presented by Litwin (Litwin, 2008). Litwin's work proposed a university's strategic alignment could be measured through measuring the ARM and measuring the university's position in the ARM (Litwin, 2008). See section 3.3 Definitions, in Chapter 3, Research Methodology. Through the Market Strategic Indicator (*MSI*) and the Institutional Strategic Indicator (*ISI*) Litwin (2008) presented metrics that could be calculated for any university. Those metrics were calculated for UCF's case. UCF's positions are presented for two time spans, 2000a and 2008a using Litwin's (2008) methodology. The data used to develop the results using Litwin's (2008) methodology are contained in Appendices B through G.

Litwin's (2008) approach used portfolio management theory to measure market share and market share growth. Calculations for each academic discipline were made. The *MSI* combined the market share position and the market share growth for a discipline as detailed in the section 3.3.3. The *ISI* combined the market share position and the market share growth for each discipline at the university as defined in section 3.3.4. Quadrant plots were developed where the

ISI was plotted on the x-axis, and the *MSI* plotted on the y-axis. The origin point for the quadrants was the mean of the *MSI* and the grand mean of the *ISI* of all RIUs, For Litwin's (2008) work the origin point was *MSI* =0.01, and *ISI* =0.18. Figure 4-4 presents the results graphically and Table 4-2 presents them numerically for 2000a.

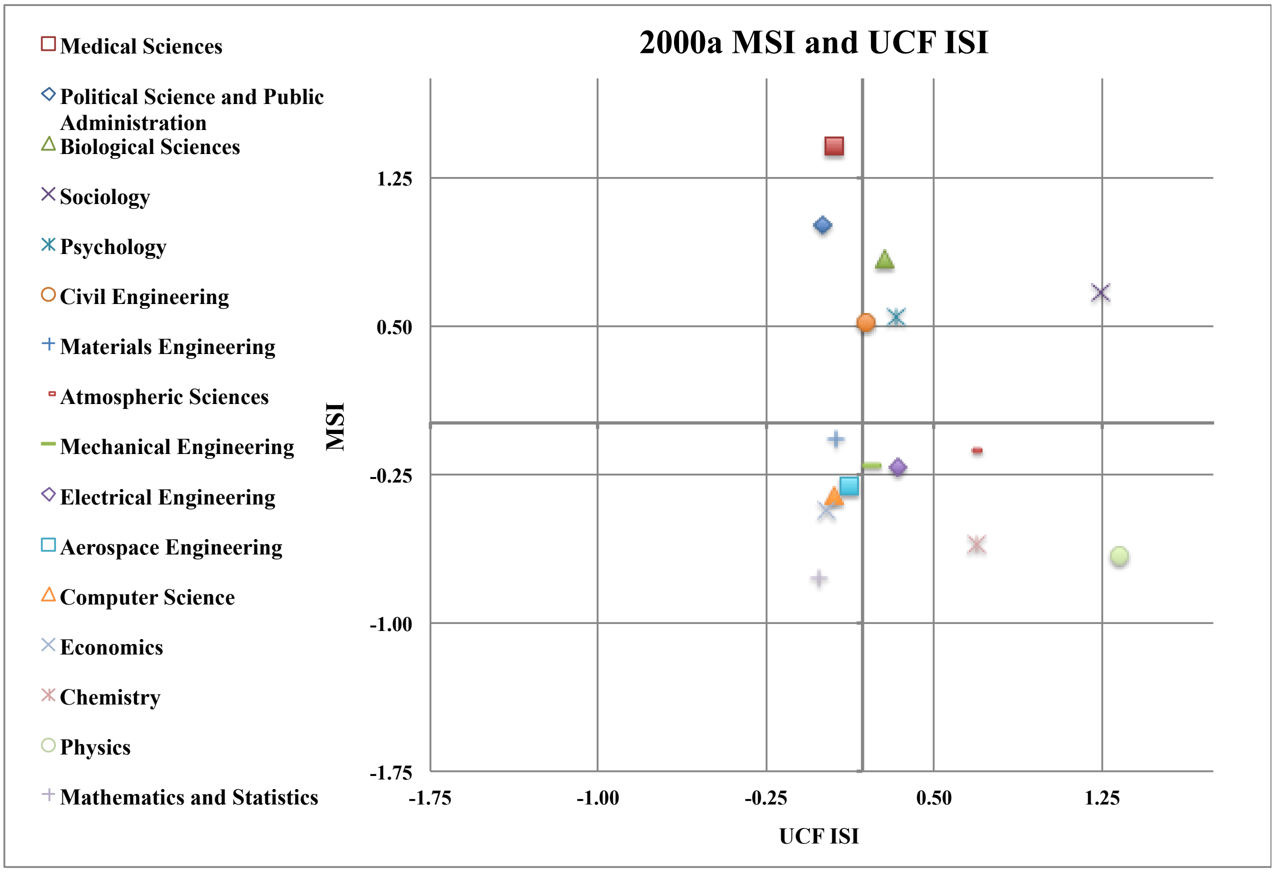

Figure 4-4: 2000a MSI and UCF ISI

Table 4-2: 2000a MSI and UCF ISI - ordered by descending MSI

University of Central Florida	ISI (2000a)	MSI (2000a)
Medical Sciences	0.06	1.41
Political Science and Public Administration	0.01	1.01
Biological Sciences	0.28	0.84
Sociology	1.24	0.67
Psychology	0.33	0.55
Civil Engineering	0.20	0.51
Materials Engineering	0.06	-0.07
Atmospheric Sciences	0.68	-0.13
Mechanical Engineering	0.22	-0.21
Electrical Engineering	0.33	-0.21
Aerospace Engineering	0.12	-0.30
Computer Science	0.06	-0.36
Economics	0.02	-0.43
Chemistry	0.69	-0.61
Physics	1.32	-0.66
Mathematics and Statistics	-0.02	-0.78

Litwin described the quadrant plot succinctly by saying positive *MSI* values represented disciplines the funding agencies had interest in while negative *MSI* values represented disciplines the funding agencies were less supportive of (Litwin, 2008). In a similar fashion positive ISI values represented disciplines where the university had won grants while negative ISI values represented disciplines where the university was not successful. From a portfolio management perspective the goal was for a university to have a high count of occurrences in the upper right quadrant of the plot. That position represented the disciplines where the university was successful in disciplines the funding agencies supported (Litwin, 2008). The lower right quadrant indicated positions where the university was strong but the funding agencies were no longer as supportive of those disciplines (Litwin, 2008). The lower left quadrant represented occurrences where the university was less successful in areas that had lost support (Litwin, 2008). Occurrences in the upper left indicated a position where the university was losing position in a market that was supported by the funding agencies (Litwin, 2008).

Figure 4-4 shows UCF had 4 disciplines with upper right quadrant, 5 in the lower right, 5 in the lower left, and 2 in the upper left. In alignment parlance that indicated UCF had 4 disciplines that aligned with the funding agency's strategy. Remember the year 2000a is the position of the discipline in 2000a plus the change in market share between 1990a and 2000a

Table 4-2 provides the 2000a values for UCF's *ISI* and the *MSI* values sorted by the *MSI* in descending order. The highest *MSI* values from the table show the disciplines that have strong position in the market and have grown in market share over that 10-year time span. In a like manner the highest *ISI* values show the disciplines where UCF held and gained market share over the same 10-year period.

The same analysis was performed for the year 2008a. Figure 4-5 presents the findings graphically and Table 4-3 presents the results numerically.

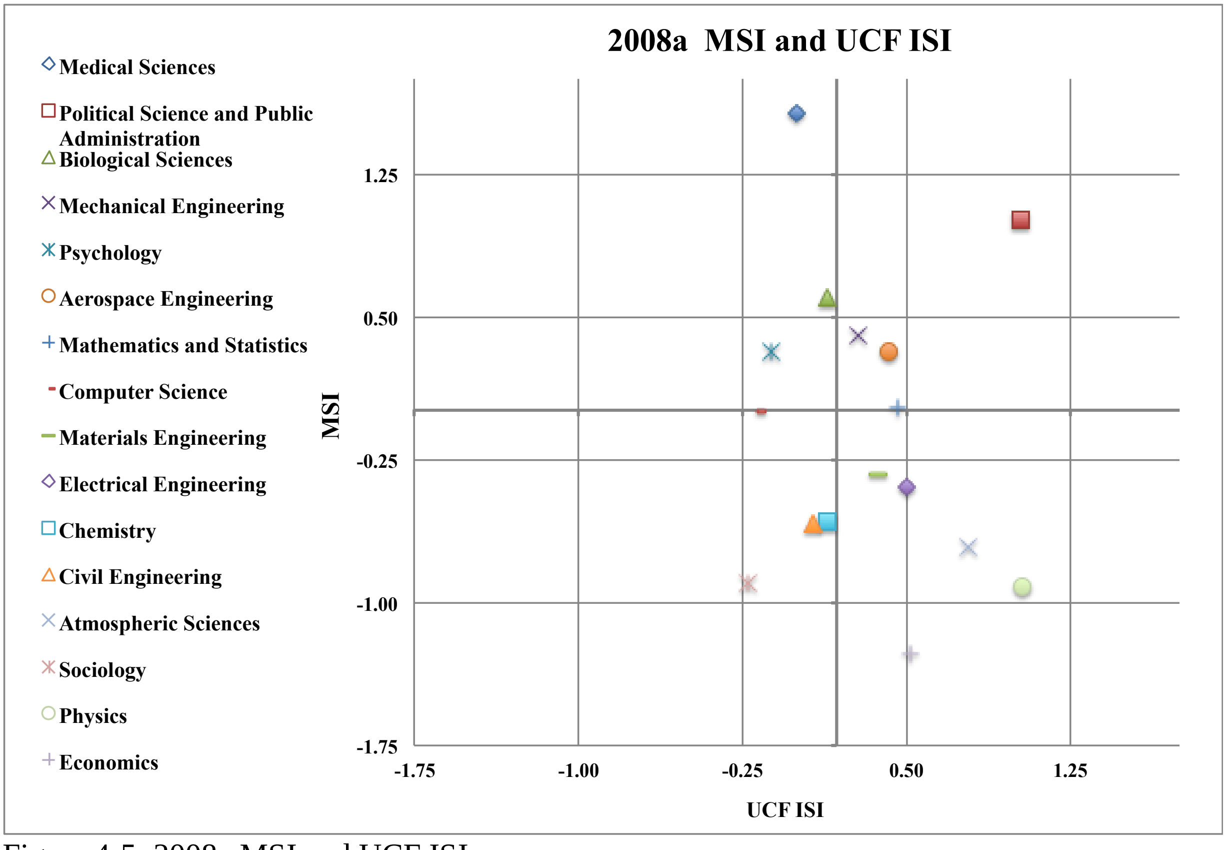

Figure 4-5: 2008a MSI and UCF ISI

Table 4-3: 2008a MSI and UCF ISI - ordered by descending MSI

University of Central Florida	ISI (2008a)	MSI (2008a)
Medical Sciences	0.00	1.57
Political Science and Public Administration	1.03	1.01
Biological Sciences	0.14	0.60
Mechanical Engineering	0.28	0.40
Psychology	-0.12	0.32
Aerospace Engineering	0.42	0.31
Mathematics and Statistics	0.46	0.02
Computer Science	-0.19	0.00
Materials Engineering	0.37	-0.33
Electrical Engineering	0.50	-0.40
Chemistry	0.14	-0.58
Civil Engineering	0.07	-0.59
Atmospheric Sciences	0.78	-0.71
Sociology	-0.22	-0.89
Physics	1.03	-0.92
Economics	0.52	-1.26

For 2008a the quadrant plot in Figure 4-5 shows 4 disciplines are in the upper right quadrant, 5 in the lower right, 4 in the lower left, and 3 in the upper left..

Table 4-3 lists UCF's *ISI* values and corresponding *MSI* values sorted by *MSI* in descending order. The *MSI* descending order reveals the priorities of the funding agency.

Analysis of the two figures and the two tables resulted in the following observations

- The *MSI* for the top 3 disciplines remain unchanged over a 18-year (10 + 8) time span
    - Medical Sciences, Political Science, and Biological Sciences
- The *MSI* values for the other disciplines moved in relative position
- UCF's 2000a *ISI* indicated strategic alignment in 4 disciplines
    - Sociology, Biological Sciences, Psychology, and Civil Engineering
- UCF's 2008a *ISI* indicated strategic alignment is 4 disciplines

- Political Science, Mechanical Engineering, Aerospace Engineering, and Mathematics

The disciplines that showed alignment in 2000a were not the same disciplines that showed alignment in 2008a. This observation prompted an investigation of how to measure the strategic indicators more frequently. If the metric was going to be used in a balanced scorecard methodology it would have to be calculated and reviewed on a yearly basis as new NSF data became available. That realization led to the metric modification described in the next section.

4.2.6.2 Real-time performance measures

This section describes the modification of Litwin's methodology to a yearly calculation of the *MSI* and the *ISI*. Rolling averages were introduced that led to the elimination of using the exceptions method. The other modification changed the time span for measuring the change in market share from a 10-year span to a 1-year span.

The first modification changed the label of 3-year average value from being centered on the year to have it labeled for the latest year of the 3 years. The second change was to calculate the differences yearly instead of using larger time periods like 10 years or 8 years. Figure 4-6 provides a visual representation of these changes.

The top section of the Figure 4-6 shows Litwin's definition with the 2000a label centered under the 3-year average for 1999, 2000, and 2001. Similarly the 2008a label is centered under the 3-year average for 2007, 2008, and 2009.

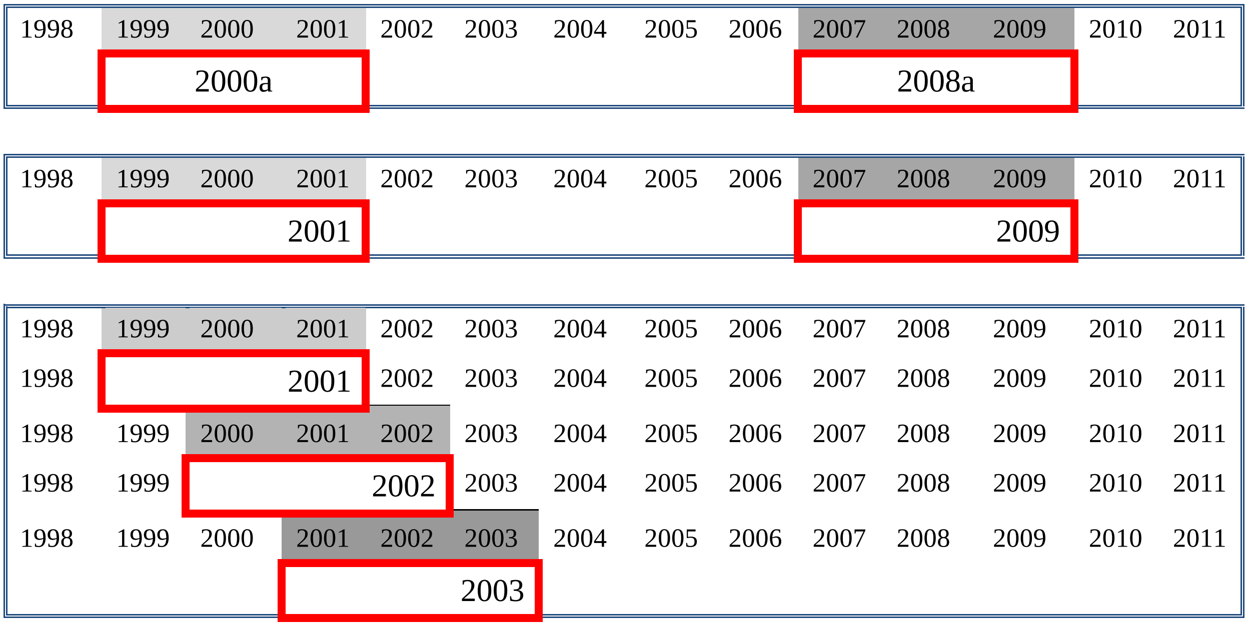

Figure 4-6: Visual presentation of changes in calculations

The middle section of Figure 4-6 shows the label under the most recent year of the 3-years. The label 2001 represents the 3-year average for the years 1999, 2000, and 2001. Likewise the 2009 label represents the 3-year average for the years 2007, 2008, and 2009. You are correct to realize the numerical difference between the 2008a value and the 2000a value are the same as the difference between the 2009 value and the 2001 value. The difference in the methodology is the label. It becomes important when the user wants to update the calculations on a yearly basis. When 2014 data becomes available, for instance, it is thought the user would want to label the most current data as 2014 and calculate the values using the 2012, 2013, and 2014 data.

The bottom section of Figure 4-6 shows how the years are grouped when calculating the averages. Taking the average of sequential years uses two of the numbers from the previous year. This creates smoothing effect from year to year. Figure 4-7 presents an example of the smoothing effect for the Chemical Engineering discipline. The data was obtained from Appendix B for the unsmoothed data and Appendix H for the smoothed data.

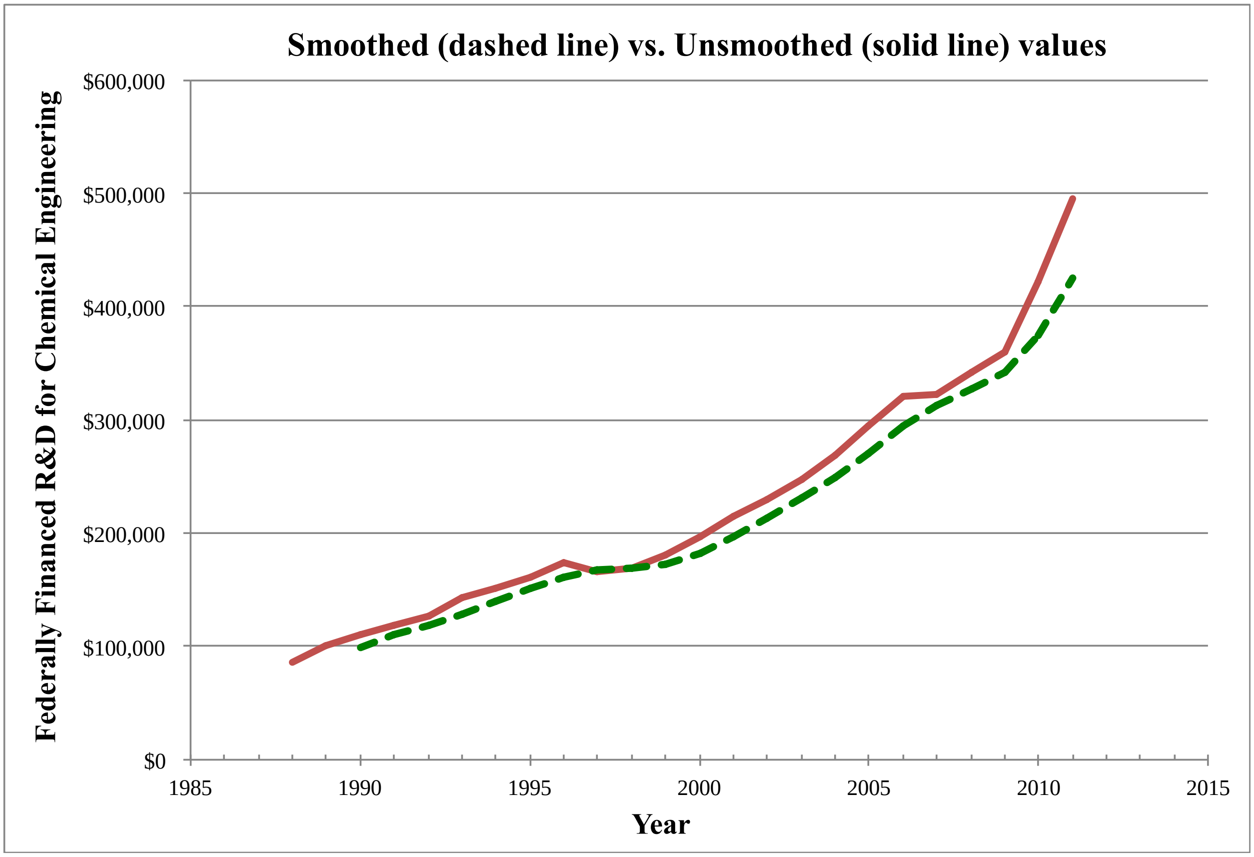

Figure 4-7: Smoothed vs. unsmoothed data

Adding the smoothing method into the process eliminated the need to use the Exception Method utilized in Litwin's methodology. The Chemical Engineering discipline had the most 2-σ outliers with 4 from 1990 through 2011, as shown in Appendix C. The smoothing effect created by using the 3-year rolling average eliminates the need to implement the exceptions method.

The basic methodology developed by Litwin remained the same for calculating the components of the *MSI* and the *ISI*. The *EMS* was calculated using rolling averages by year, Appendix K based on data in Appendix I. The *ΔEMS* was calculated using the yearly differences from the rolling average data, Appendix L based on data in Appendix J. In the same manner the *EIS* was calculated from the rolling average data, Appendix Q based on data in Appendix O. The *ΔEIS* was calculated using the rolling average data, Appendix R based on data in Appendix P.

The *MSI* components, *EMS* and *ΔEMS,* for different disciplines were compared against the yearly rolling method and Litwin's method. Figure 4-8 presents those results for Physics.

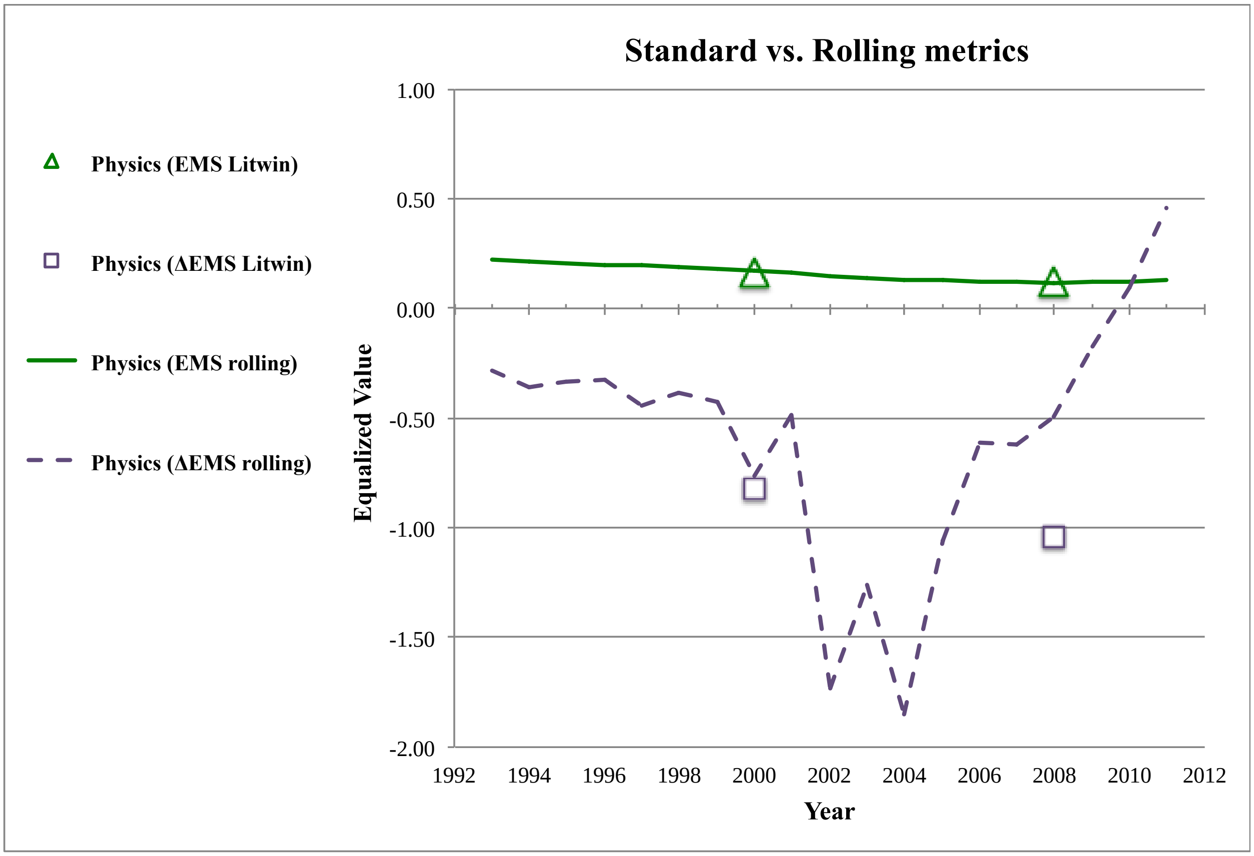

Figure 4-8: Equalized values - standard vs. rolling method- Physics

Since the *EMS* Litwin and *EMS* rolling are equalized values based on 3-year average at a specific time the finding showed the values were nearly the same at years labeled 2000 and 2008 in Figure 4-8.

However, this was not the case for the *ΔEMS* Litwin and the *ΔEMS* rolling. There was a significant difference in values for those metrics. The source of the difference was the time span over which the values were calculated. Litwin's methodology calculated the change in the market position from 1990a to 2000a or from 2000a to 2008a. The yearly rolling method calculated the change in the market position from the previous year.

Figure 4-8 provides the components of the *MSI* for physics using the Litwin methodology and the rolling average methodology. It's evident the yearly calculations reveal information about the change in the market position (*ΔEMS*) that the larger time span calculation did not. The data used to generate these graphs are found in Appendix D (*EMS* and *ΔEMS*), Appendix K (*EMS*, rolling), and Appendix L (*ΔEMS*, rolling).

In a similar manner the ISI components, *EIS* and *ΔEIS*, were compared between the Litwin method and the rolling year method. Figure 4-9 presents the components of UCF's *ISI* in Physics for both the Litwin method and the rolling method. The components in the *ISI* showed the same characteristic as the components of the *MSI* when comparing the Litwin methodology to the rolling methodology. The *EIS* values were similar because the rolling averages were very similar for that specific year. The *ΔEIS* do not match because the Litwin method calculated the delta over 10 or 8 years and the rolling method calculated the delta over one year. The data used to generate these graphs is found in Appendix G (*EIS* and *ΔEIS* Litwin), Appendix Q (*EIS* rolling), and Appendix R (*ΔEIS* rolling).

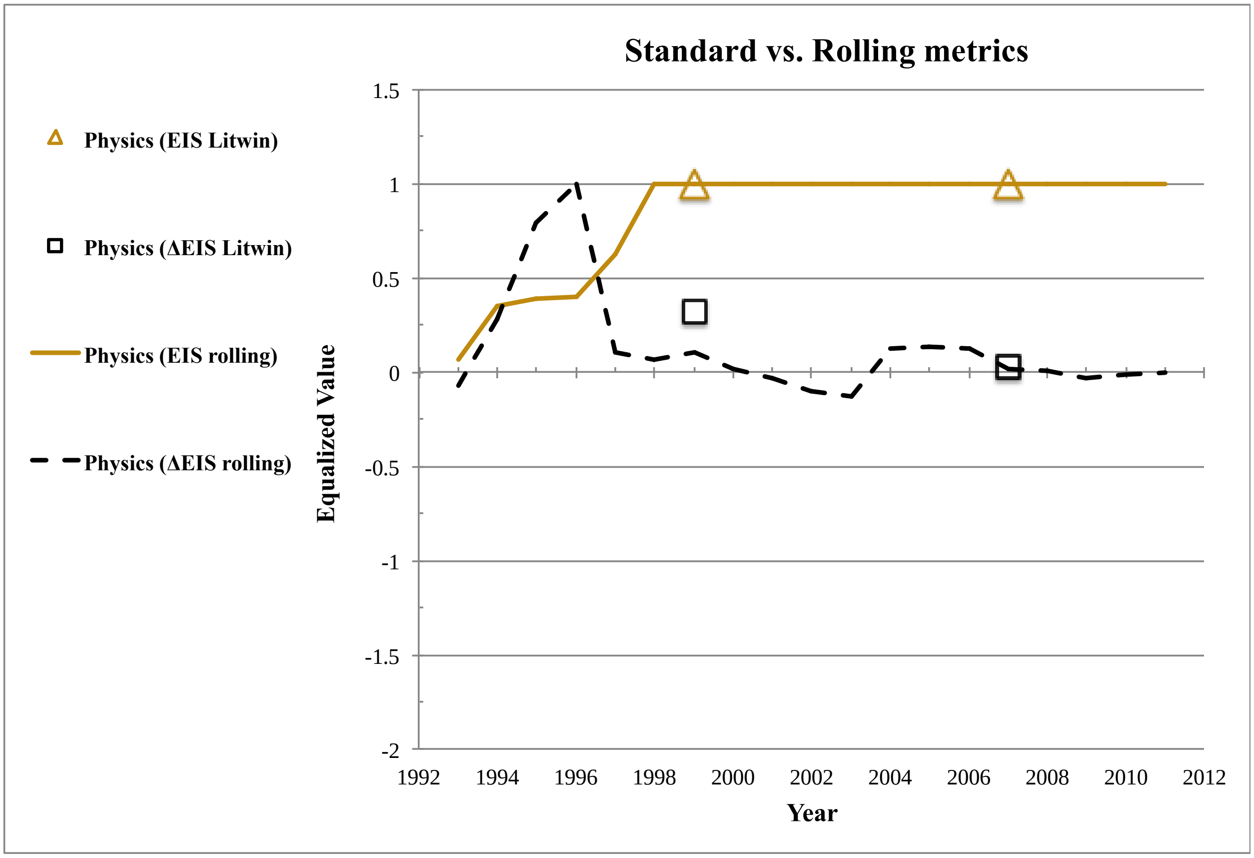

Figure 4-9: Equalized values- standard vs. rolling – UCF Physics

It is argued here the rolling method provided more information about the market because it can be updated every year. The trends in the position of the market and the trends related to the change in the market can be observed as new data becomes available. Metrics that can be updated yearly could be more readily integrated into the balanced scorecard.

4.2.6.3 Providing weight

During the development and analysis of the *MSI* and *ISI* using the rolling method it was observed their values were often driven by the *ΔEMS* value and the *ΔEIS* value, respectively. The change in market share relative to other disciplines produced large swings in those *Δ* terms that drove the *MSI* and the *ISI* values. The significance of those swings was investigated. A modification to the *MSI* and *ISI* formulas is presented. The modification changed the weight of the *Δ* term to scale it to the share of the market it held. The results of the weighted terms are presented.

The ARM consisted of 21 disciplines. UCF participated in 16 of those disciplines. The *EMS*, *ΔEMS*, *EIS*, and *ΔEIS* were calculated for each discipline from 1990 through 2011. The standard deviations of each discipline for each of the four components were calculated to measure the width of the distributions. The standard deviations and the average of those standard deviations are presented in Table 4-4.

Table 4-4: Standard deviation of components of the *MSI* & the *ISI*

	Sample Standard Deviation by Discipline			
	EMS	*ΔEMS*	*EIS*	*ΔEIS*
Aerospace Engineering	0.01	0.80	0.06	0.30
Chemical Engineering	0.00	0.57		
Civil Engineering	0.00	0.57	0.05	0.15
Electrical Engineering	0.02	0.58	0.33	0.39
Mechanical Engineering	0.01	0.49	0.08	0.47
Materials Engineering	0.01	0.70	0.04	0.31
Astronomy	0.01	1.19		
Chemistry	0.03	0.36	0.12	0.22
Physics	0.05	0.56	0.38	0.29
Atmospheric Sciences	0.01	0.69	0.30	0.42
Earth Sciences	0.01	0.64		
Oceanography	0.02	0.60		
Mathematics and Statistics	0.01	0.66	0.01	0.31
Computer Science	0.01	0.41	0.09	0.73
Agricultural Sciences	0.02	0.55		
Biological Sciences	0.03	0.26	0.08	0.18
Medical Sciences	0.00	0.29	0.05	0.47
Psychology	0.00	0.43	0.08	0.21
Economics	0.00	0.94	0.02	0.46
Political Science and Public Administration	0.00	0.97	0.01	0.48
Sociology	0.00	0.59	0.10	0.54
Count (n)	**21**	**21**	**16**	**16**
Mean	**0.01**	**0.61**	**0.11**	**0.37**

The average of the standard deviations for the *ΔEMS* and *ΔEIS* terms was larger than the average of the standard deviations for the *EMS* and *EIS* terms. These results support the statement that the *Δ* terms drove the swings in the *MSI* and *ISI* numbers.

The *MSI* and the *ISI* for Computer Science using the rolling method are presented in Figure 4-10. This discipline was presented because the *MSI* values and the *ISI* values show different characteristics.

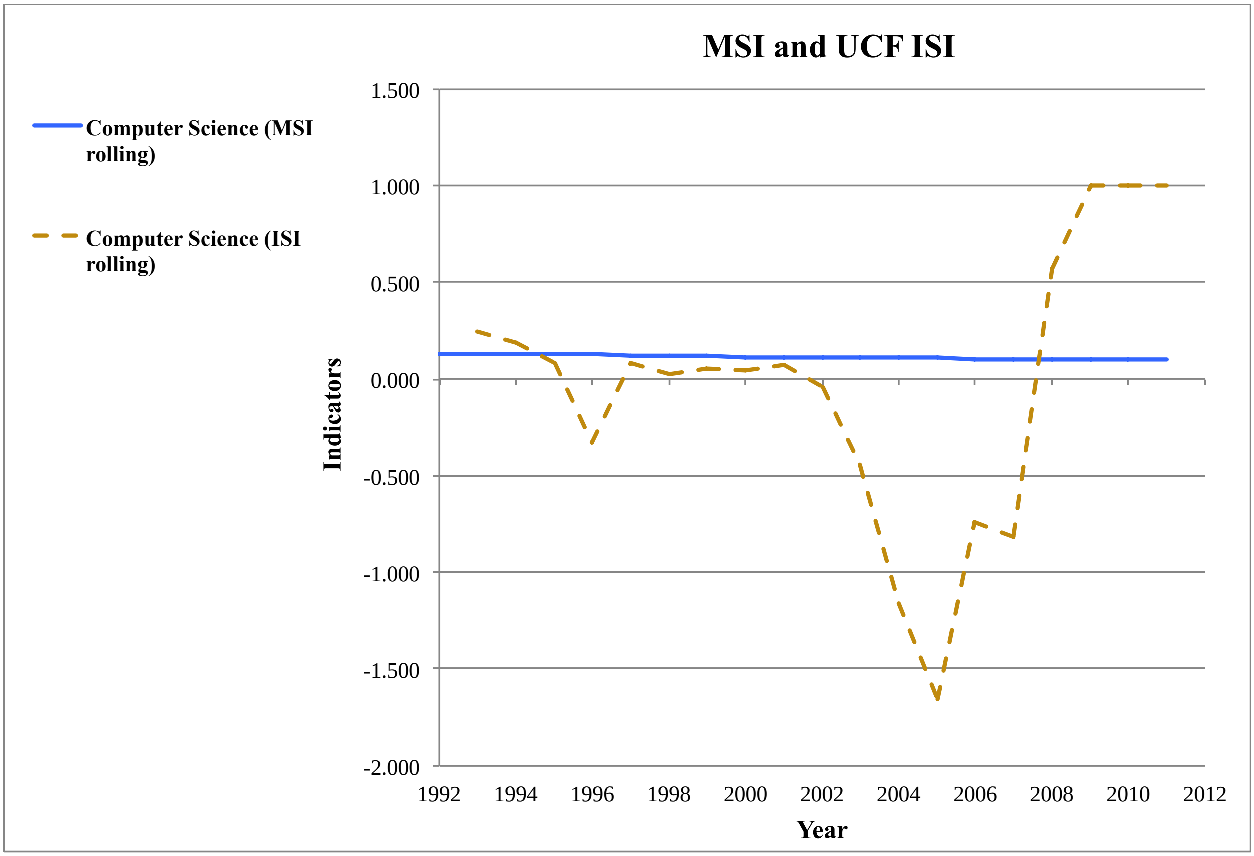

Figure 4-10: MSI and UCF ISI rolling-Computer Science

Figure 4-10 shows the *MSI* for Computer Science is relatively flat over the years. The implication is that the combination of its market share and change in market share had not changed much over many years ($MSI = EMS + \Delta EMS$).

The *ISI* on the other hand showed more change over time. From the years 2002 through 2010 there were large swings in the *ISI* values. The data was reviewed to determine the source of the swings. Table 4-5 summarizes many of the parameters for UCF's Computer Science discipline.

Table 4-5: UCF Computer Science market parameters

Parameter	Appendix	2005	2011
Rolling average expenditures ($ in thousands)	N	9	370
Percentage of institutional expenditures (%)	O	0.03	1.01
Percentage change in institutional expenditures (%)	P	-63.92	66.27
EIS, rolling	Q	0.00	0.33
ΔEIS, rolling	R	-1.73	1.00
ISI, rolling	S	-1.73	1.33

The large swing in the Computer Science *ISI* from 2005 (-1.73) and 2011 (+1.33) was driven by the *ΔEIS* values in those years.

The actual expenditures and their percentages of the total institutional spending revealed relatively small values. As a percentage of all UCF federally financed R&D expenditures Computer Sciences comprised only 1% of its expenditures in 2011.

The fundamentals of portfolio management use the market share as a proxy for cash usage and the market share growth as a proxy for cash generation (Srivastava & Prakash, 2011). UCF's Computer Science discipline's *EIS* value of 0.33 was the proxy for cash usage $370,000. As stated earlier this accounted for 1% of their R&D expenditures that year. The large *ΔEIS* value of 1.00 was the proxy for cash generation. The underlying percentage change of 66% in 2011 translated to increase of $107,000 from the previous year. That dollar amount value is < 0.5 % of the total UCF federal financed R&D expenditures in 2011. The small amount of total dollar change, in my view, did not warrant that large *ΔEIS* value. The market share of 1% did not appear to represent large cash generation opportunity. It is argued the *ΔEIS* value overstated its cash generation position.

A modification of the *Δ* term calculation that represents the change in the market is presented.

$$\Delta EIS_w = (EIS * \Delta EIS) \quad (3)$$

Equation 3 weights the change in the market to the relative position it holds in the market. This changed the ISI equation to a weighted version.

$$ISI_w = EIS + \Delta EIS_w \quad (4)$$

It is argued the weighted *ISI* (ISI_w) in Figure 4-11 for Computer Science provides a more accurate representation of the Computer Science discipline for UCF.

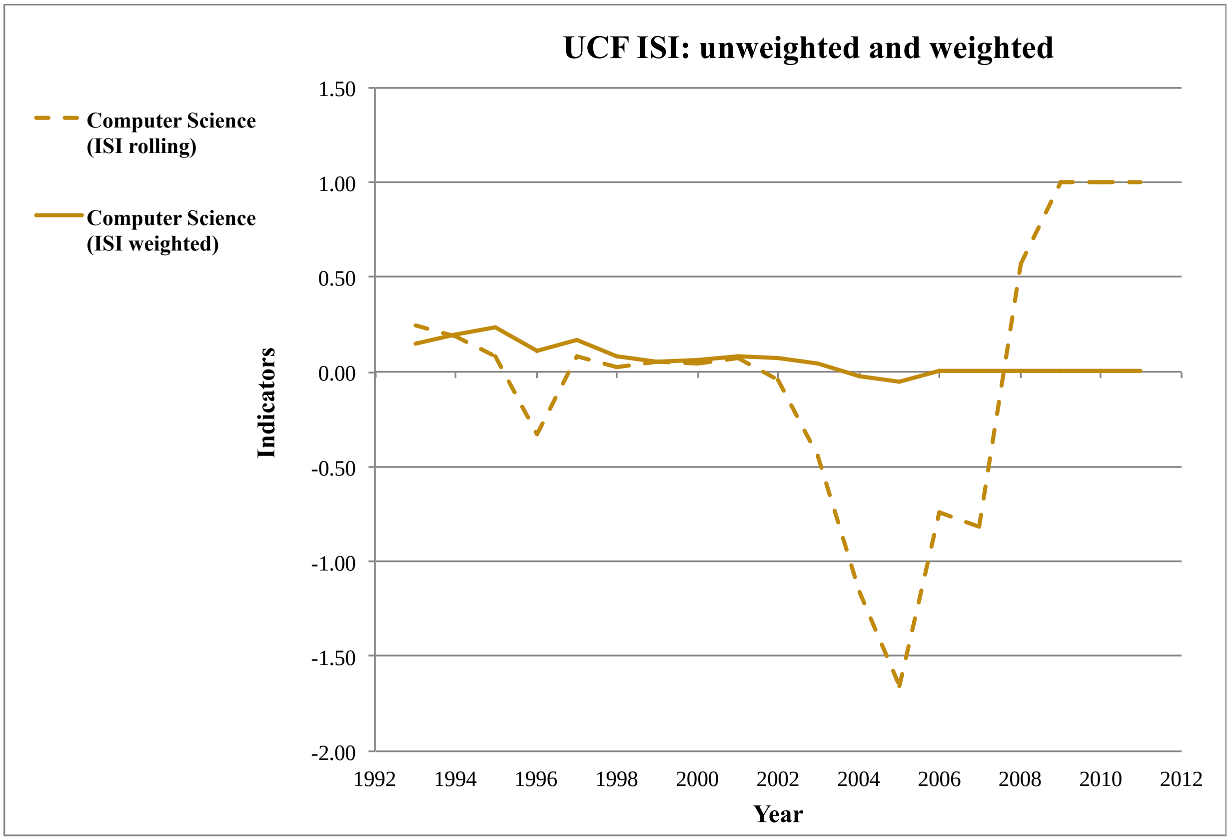

Figure 4-11: Indicators- unweighted vs. weighted- Computer Science

The curve for the unweighted *ISI* (dashed line) in Figure 4-11 shows a drop in 2002 and a rebound in 2006 with it holding a strong position within the UCF disciplines from 2009 on. From the definition of *ISI* it could have been due to its position in the market or the change of its position in the market. We learned earlier the large *ISI* value was due to the large yearly percentage changes, not its market share position.

The graph for the weighted *ISI* (solid line) in Figure 4-11 presents a different picture. This curve shows an overall decline for Computer Science at UCF. The graph shows it does not hold a strong market position. The data presented in Table 4-5 supports that story line.

Another example showing the weighted vs. unweighted *ISI* is found in Figure 4-12 for UCF's Physics discipline. Physics was chosen because it had the opposite characteristics of Computer Science. Physics had a large *ISI* value because it held the largest proportion of federally financed R&D expenditures at UCF in 2011. The unweighted *ISI* (dashed line) increase was due to changes in the percentage of market share year to year. The weighted *ISI* line (solid) shows an increase in expenditures over time with it currently accounting for a major proportion of the UCF federally financed R&D expenditures.

The same type of weighted modification is proposed for the *MSI* equation.

$$MSI_w = EMS + \Delta EMS_w \qquad (5)$$

$$\text{where} \quad \Delta EMS_w = (EMS * \Delta EMS) \qquad (6)$$

Appendix T presents the MSI_w values and Appendix U presents the UCF ISI_w from 1993 to 2011.

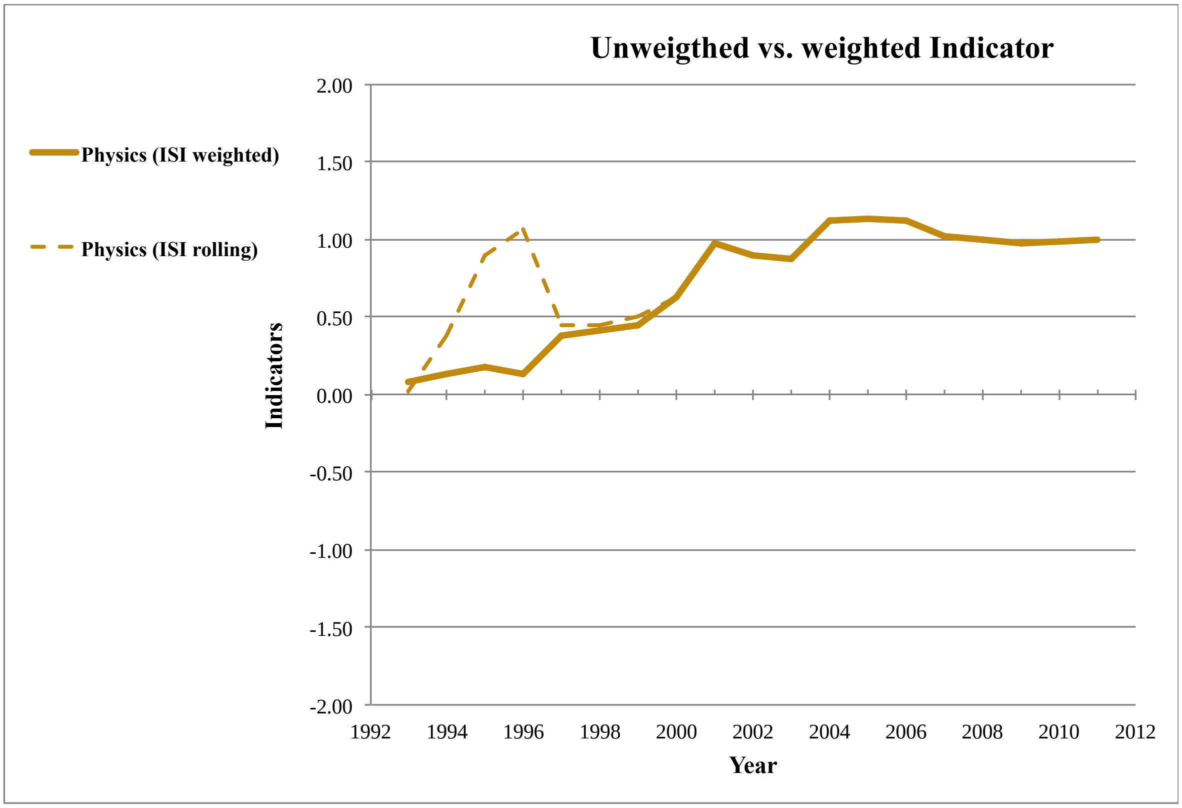

Figure 4-12: Unweighted vs. weighted indicators- Physics

4.2.6.4 Real-time weighted strategic indicators

The introduction of the weighted strategic indicators required an evaluation of its effect on the quadrant plot. It was determined the origin of quadrants had shifted. The quadrant plot was modified to present each discipline in time series. The resulting visual allowed the reader to see in one figure, the history of the strategic alignment for all disciplines over a 10-year time span.

The application of the weight to the *MSI* and the UCF *ISI* calculation changed their distribution characteristics. Table 4-6 shows the change in the distribution through the median, mean, the standard deviation, and percentage of negative and positive numbers.

The weighting method resulted in predominantly positive numbers. In addition, the breadth of values had decreased as observed in smaller standard deviations. These changes correspond with the earlier discussions that the strategic indicators were heavily influenced by the Δ terms, and the weighting of the Δ terms to their market position would scale them. The results were that weighted strategic indicators had less swing and are more positive values than the unweighted version.

Table 4-6: Distribution characteristics of strategic indicators

	Median	Mean	Std. dev.	Count with Negative ISI values	Total Count	% negative	% positive
MSI Litwin	-0.21	-0.07	0.69	26	42	62%	38%
MSI rolling	-0.03	-0.05	0.75	209	399	52%	48%
MSI weighted	0.05	0.14	0.30	42	399	11%	89%
ISI Litwin	0.25	0.34	0.40	5	32	16%	84%
ISI rolling	0.19	0.25	0.44	68	289	24%	76%
ISI weighted	0.07	0.16	0.25	3	289	1%	99%

The other significant finding was the difference between the mean and the median. The large difference between the mean and the median indicated the set was not normally distributed. This had implication for selecting the origin point of the quadrant plot.

4.2.6.5 Quadrant plot refined

The intent of the quadrant plot was to locate a university discipline's relative position in the research market. The origin point for the quadrant plot should locate the center of the research market (MSI_w) and the university's participation (ISI_w). The analysis determined the median was a more suitable metric than the mean for that purpose.

An MSI_w value or ISI_w value greater than the median meant the value was larger than half the values in the distribution. Likewise an MSI_w value or ISI_w value less than the median placed it in the lower half of the distribution. The resulting plotted point provided information on the distance away from the center of the distribution. For skewed distributions, using the mean value would not provide the relative position with respect to the center of the distribution. For that reason the MSI_w median and ISI_w median were chosen for the origin point of the quadrant plot.

Analysis was performed to determine the behavior of the medians and means for the MSI_w values and the ISI_w values over time. Figure 4-13 presents the mean and median values for the MSI_w and ISI_w over an 18-year period.

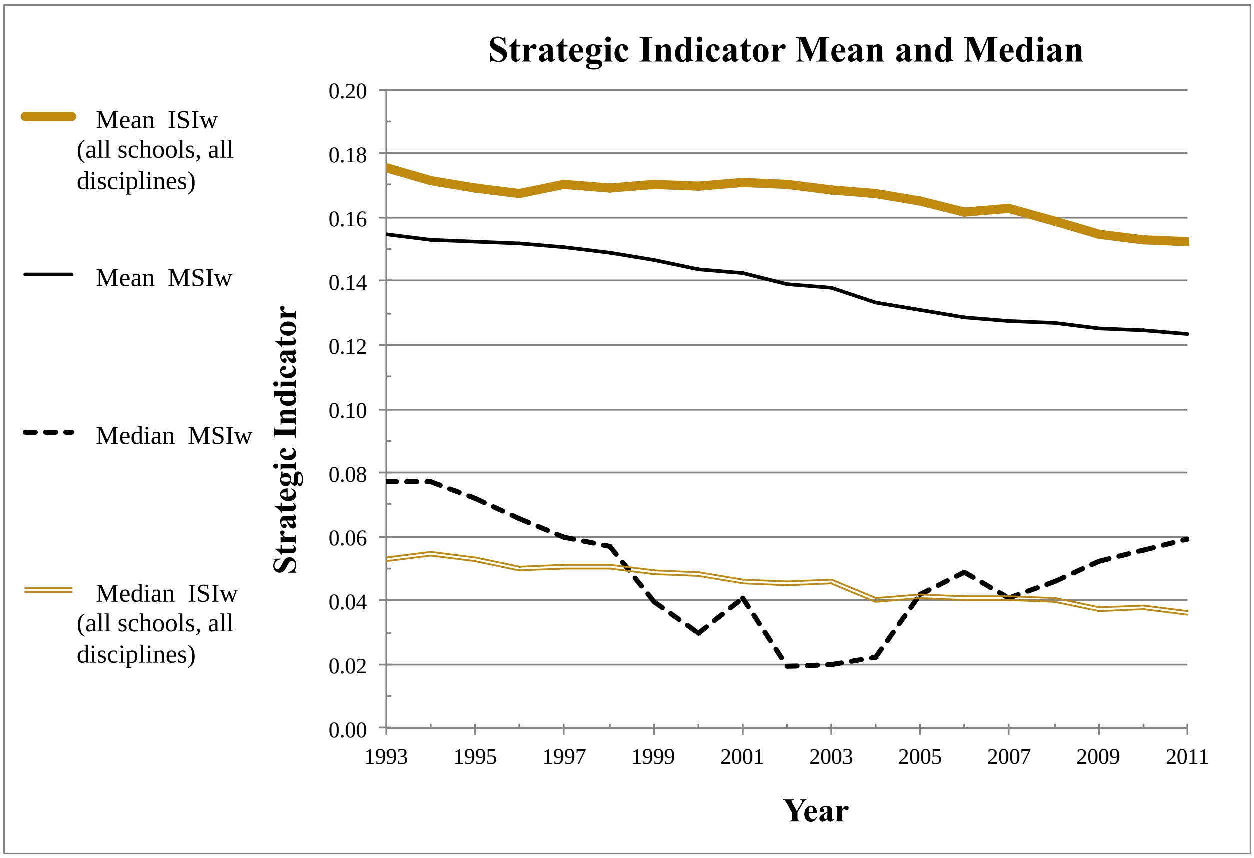

Figure 4-13: Mean and median of strategic indicators

The mean and median values were calculated for each year. The MSI_w data set were the rolling weighted values for each of the 21 disciplines for each year. For a single year the MSI_w consisted of 21 data points. The ISI_w data set were the rolling weighted values for all disciplines for all schools for each year. For a single year the average number of ISI_w data points was 719. The list of schools used for the analysis is presented in Appendix Z.

Figure 4-13 shows the movement of the strategic indicators over time. The large separation of the mean and median indicate a skewed distribution. For skewed distributions the median is located in the center of a distribution.

The second observation from Figure 4-13 was the yearly change in the median values of the MSI_w and the ISI_w. The yearly changes in the median reflected the dynamics of the market. The implication was an origin point would have to be selected each year in order to accurately place the strategic indicators.

The last effort for this work combined the results of the prevision analysis into a modified quadrant plot. A miniaturized quadrant plot (mini-quad) was developed to present all the university's disciplines over a 10 year time period. Figure 4-14 presents the miniaturized quadrant plot. The quadrants are color coded to provide easy visual clues.

The MSI_w and ISI_w values are summarized in Appendix V by discipline. For the mini-quad their values were compared to the median MSI_w and median ISI_w values for that year. The result determined what quadrant that discipline belonged in that year. The quadrant location and color coding is presented below.

$MSI_w >$ median MSI_w and $ISI_w >$ median ISI_w , upper right, green cell.

$MSI_w \leq$ median MSI_w and $ISI_w >$ median ISI_w , lower right, pink cell.

$MSI_w \leq$ median MSI_w and $ISI_w \leq$ median ISI_w , lower left, yellow cell.

$MSI_w >$ median MSI_w and $ISI_w \leq$ median ISI_w , upper left, red cell.

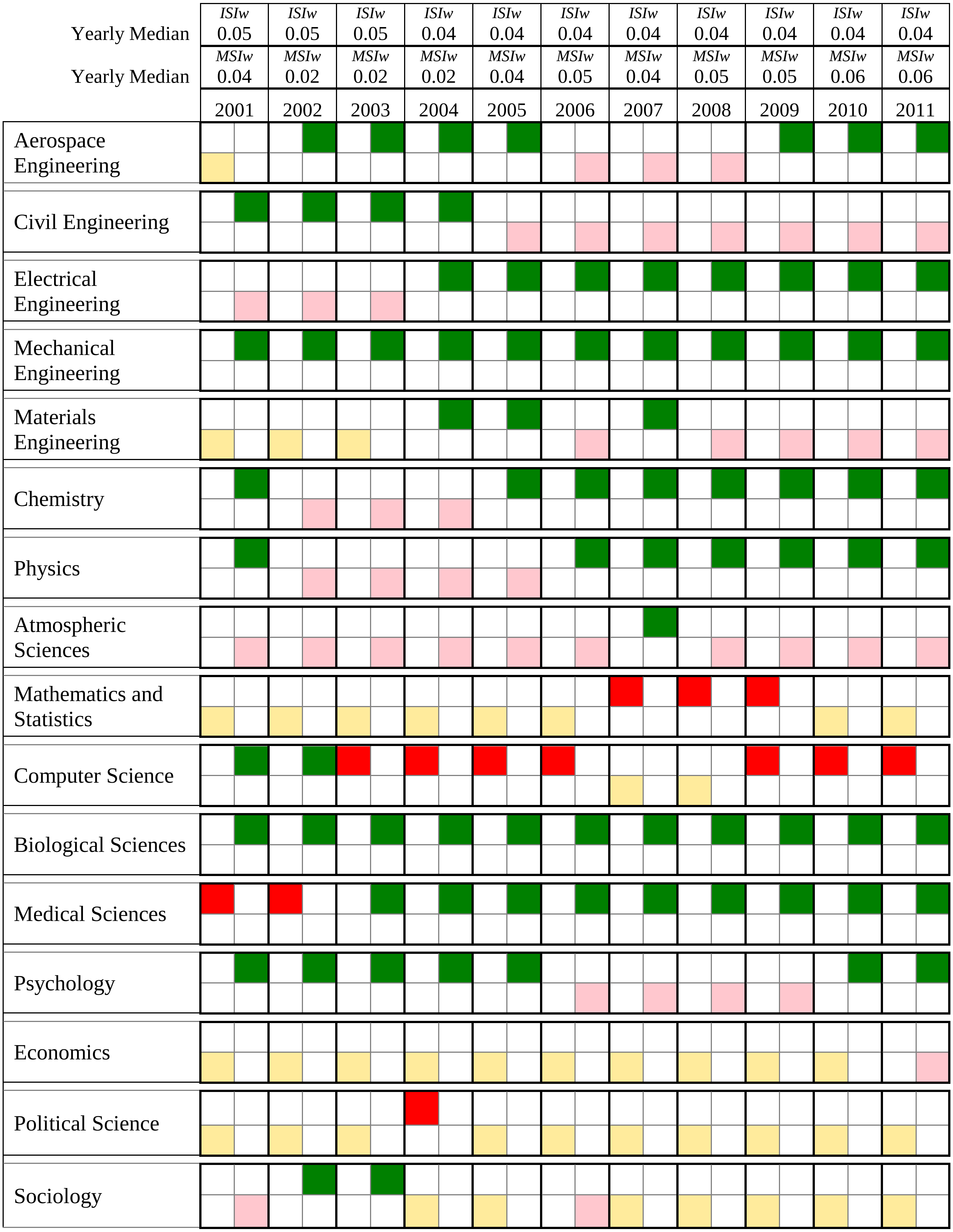

Figure 4-14: Mini-quad time series

The mini-quad provided a broad stroke view of the academic research market and the university's position in the market by discipline. The intent of the strategic indicators was to provide metrics that can be compared to targets set by the university strategy. The mini-quad and the strategic indicators provided a starting point for further analysis, drilling down into the data to answer fundamental performance questions. Although not shown here this analysis can be applied to any university since the data is publically available.

4.2.7 Case Study Summary

UCF's position in the academic research market was evaluated. A literature review revealed the complexity of the problem due to the vast number of variables affecting the grant award process. The literature review also pointed to potential sources for a solution. A systems approach using the balanced scorecard methodology was the framework chosen to solve the problem. A proposed mission to *drive reputable, sustainable research programs commensurate with the university's mission and size drive* was developed. From the mission, the strategic objectives were developed and from that, the measures to achieve those objectives were proposed. Strategic indicators were investigated and applied to UCF's case in order to measure their position in the market. It was refined for better applicability to the balanced scorecard methodology. The result was real-time weighted strategic indicators that provided the university's market position, its competitor's market position and its alignment with the funding agency's strategy. The strategic indictors were a few of many measures that will need to be rolled into the balanced scorecard feedback loops to measure the success at meeting the strategic objectives.

CHAPTER 5 : CONCLUSION

This work concludes with a discussion of the key findings. The work resulted in a solid framework using the balanced scorecard methodology to address the problem. The portfolio management concept for measuring a university's position in the market was refined to improve its applicability to the balanced scorecard. These strategic indicators provided a yearly measure of the university's position and growth in the academic research market by discipline. These and the other metrics provided in the causal loop diagram provided the means to gauge the success of meeting the strategic objectives that were developed to improve the university's federally financed R&D expenditures.

5.1 Validated Framework

This work provided a path for UCF, and other universities, to follow in order to improve their position in the academic research market. The literature survey revealed the complexity of the problem. The systems approach took a broad view of the problem to develop a more comprehensive solution. The balanced scorecard methodology focused the attention on the strategy to accomplish the goal. The strategic objectives developed from that method brought focus to achieving the mission. The metrics developed from those objectives created the scorecard to measure the success. The portfolio management theory, applied to the university's market position, was investigated for a few of the measures in the scorecard. Previously reported metrics using this technique were applied to UCF's case. The strategic indicators were modified to provide metrics that would be applicable to the scorecard. The scope of this work provided the framework to solve the problem with specific measures to gauge the university's strategic alignment with the funding agencies.

The literature survey revealed 32 factors that contributed to the ability of a university to win a grant. The breadth of these factors required a wide view in developing a potential solution. The balanced scorecard methodology was selected because it incorporated the systems view to achieve the organizations strategy.

The mission of UCF's ORC was evaluated and refined to bring focus to the research component of their work.

> *Drive reputable, sustainable research programs commensurate with the university's mission and size.*

This mission statement became the proxy for the strategy to improve UCF's federally financed academic R&D expenditures. Using the balanced scorecard methodology a strategy map was developed having 12 strategic objectives across the four perspectives of Financial, Customer, Internal Process, and Growth and Learning. The sources of the objectives were the 32 factors found to influence a university's ability to win an award. These strategic objectives were used to develop a causal loop diagram containing 19 measures. These metrics became the scorecard to measure the university's success of achieving the strategy.

Metrics based on the portfolio management theory measured the university's position and growth in the academic research market. The method was found in the literature and applied to this problem. It was successful at calculating the Market Strategic Indicator (*MSI*) and the Institutional Strategic Indicator (*ISI*). The time span, however, for the market growth was not appropriate for the developed scorecard. The literature used a 10-year span to measure changes in the market. The balanced scorecard anticipated yearly metrics.

The strategic indicators were successfully modified to yearly measures. Additionally the components of the measures were weighted to provide a more accurate representation of the market position and the market growth. The strategic indicators that resulted provided yearly measures of the academic research market, UCF's position in the market, and its competition's position in the market. All three metrics were to be used in the balanced scorecard.

Others have established the balanced scorecard as a sound methodology applicable to problems where strategy is the focus. Its application in the university setting was applied for the purpose of increasing UCF's federally financed R&D expenditures. Through the balanced scorecard, a set of objectives and measures were developed to potentially reach that goal. The strategic indicators previously found in the literature were refined to meet the scorecard's needs.

5.2 The Framework (Step by Step)

Figure 3-2 shows the framework steps used for this problem. Other universities faced with a similar problem could use the framework. The first step, assessment, revealed the current condition for the university. Documenting the current state provided a baseline to gauge the success of future initiatives. The strategy development step provided the action theme to focus and motivate the organization. It's important to realize each university has its unique talent, perspective, and mission that will drive the specific strategy to solve their particular problem. The objectives were developed after the strategy was set. The strategy map was created to connect the strategy and the objectives with the four business perspectives of financial, customer, internal processes, and growing & learning. The resulting diagram provided insight into the interconnectivity of the objectives developed to achieve the strategy. The last step was the development of the performance measures used to determine if an objective was met. The resulting balanced scorecard provided metrics, tied to the objectives used to attain the strategy.

Again a visual diagram through causal loops was used to show the interconnectivity of the measures. For this work a set of strategic indicators was modified to measure the university's position in the academic research market and their alignment with the funding agency's strategy. Utilizing the framework resulted in a balanced scorecard with specific metrics corresponding to certain objectives for a unified plan on attaining the developed strategy.

5.3 Contributions

This work contributed to the body of knowledge encompassing systems approach to solving problems, the balanced scorecard methodology, the portfolio management theory, causal loops and the complexity of the grant award process. The literature survey touched on these topics individually or in combination but not inclusive of all.

This work cataloged the factors that influenced the ability to win grants that were discovered and researched by others. This work contributed by providing a summarized list with citation to the source.

The application of portfolio management to the university's research market position was reported in the literature. This work contributed by modifying the strategic indicators to yearly measures and changing the weight of the components to more accurately represent the significance of a discipline's market growth.

The balanced scorecard was introduced in the 1970's and has been used successfully and unsuccessfully as reported in the literature. This work contributed by providing a pathway for UCF to solve its problem of low academic research market share. It also contributed in the respect that other universities could use it as a template to start a similar investigation at their schools.

Causal loops and system dynamics are well-documented methodologies for modeling. This work contributed by setting up the basic causal loop diagram for a university to improve its grant funding.

5.4 Further Research

This work provided a framework to begin a more thorough investigation to solve the complex problem of increasing federally financed R&D.

One area of interest would be to move the causal loop diagram to the stock and flow format to develop systems dynamics model. The complexity of this problem deserves a more visual representation to allow people to see the interactions and test where the levers are in the system.

A second area of study to move this work forward would be to qualify or quantify the importance of the 32 factors identified as influencing the ability to win an award. Currently they are incorporated into the causal loop diagram. To assist in improving the system dynamics model their importance needs to be gauged so the proper response curve can be put into the model.

The last area of further study would be the presentation of the strategic indicators. The miniaturized quadrant plot was helpful in providing a broad stroke assessment of the market and the university's position in the market. Further work could provide a more automated generation of the plot with the ability to drill down to specific areas to see the data behind the plot.

APPENDIX A: NSF SCIENCE AND ENGINEERING DISCIPLINES

NATIONAL SCIENCE FOUNDATION S&E DISCIPLINES

NSF Disciplines (alphabetically)	UCF participation
Aerospace Engineering	X
Agricultural Sciences	
Astronomy	
Atmospheric Sciences	X
Biological Sciences	X
Chemical Engineering	
Chemistry	X
Civil Engineering	X
Computer Science	X
Earth Sciences	
Economics	X
Electrical Engineering	X
Materials Engineering	X
Mathematics and Statistics	X
Mechanical Engineering	X
Medical Sciences	X
Oceanography	
Physics	X
Political Science and Public Administration	X
Psychology	X
Sociology	X

APPENDIX B: ARM, 1988 to 2011

The following four pages present the ARM from the years 1988 through 2011 for the 21 disciplines defined by the NSF.

	Federally Financed Higher Education R&D Expenditures for S&E (Sum)					
Year	1988	1989	1990	1991	1992	1993
Discipline						
Aerospace Engineering	$93,681	$114,988	$127,116	$137,638	$150,859	$159,839
Chemical Engineering	$85,530	$100,907	$110,362	$118,006	$126,225	$142,815
Civil Engineering	$102,168	$102,148	$116,987	$123,626	$143,623	$154,325
Electrical Engineering	$330,379	$386,713	$431,904	$435,962	$449,459	$458,418
Mechanical Engineering	$192,647	$214,203	$238,203	$251,329	$268,870	$310,007
Materials Engineering	$121,611	$130,372	$139,133	$153,099	$143,259	$150,438
Astronomy	$83,744	$87,941	$112,714	$136,018	$158,350	$165,031
Chemistry	$403,189	$422,254	$445,216	$451,436	$479,671	$505,260
Physics	$579,590	$606,332	$652,285	$679,786	$708,030	$708,167
Atmospheric Sciences	$112,318	$128,805	$131,110	$129,384	$140,073	$160,633
Earth Sciences	$174,493	$186,851	$204,635	$218,147	$238,424	$243,557
Oceanography	$238,276	$259,959	$262,159	$263,616	$306,583	$329,612
Mathematics and Statistics	$149,959	$157,315	$160,910	$170,544	$183,262	$203,122
Computer Science	$289,129	$323,909	$342,380	$371,608	$379,798	$423,319
Agricultural Sciences	$322,563	$350,140	$353,509	$378,004	$417,787	$450,030
Biological Sciences	$1,608,398	$1,736,474	$1,844,674	$1,950,610	$2,137,564	$2,310,910
Medical Sciences	$2,212,866	$2,502,586	$2,671,393	$2,848,670	$3,113,369	$3,369,507
Psychology	$140,465	$153,081	$163,807	$186,284	$214,905	$234,389
Economics	$49,171	$54,316	$54,348	$59,671	$65,947	$77,304
Political Science and Public Administration	$25,163	$25,885	$25,365	$28,542	$35,046	$42,828
Sociology	$47,782	$53,980	$60,002	$72,045	$81,736	$91,108
ARM	$7,363,122	$8,099,159	$8,648,212	$9,164,025	$9,942,840	$10,690,619

Dollar amounts are in thousands.

Federally Financed Higher Education R&D Expenditures for S&E (Sum)

Year	1994	1995	1996	1997	1998	1999
Discipline						
Aerospace Engineering	$165,423	$183,731	$171,283	$183,425	$171,475	$184,691
Chemical Engineering	$150,495	$161,117	$173,770	$165,856	$169,276	$179,939
Civil Engineering	$163,753	$185,920	$197,777	$200,405	$197,146	$217,136
Electrical Engineering	$490,188	$543,720	$599,878	$624,323	$692,606	$651,207
Mechanical Engineering	$327,764	$339,627	$334,913	$322,462	$350,741	$388,553
Materials Engineering	$155,565	$175,508	$190,455	$222,456	$221,691	$218,231
Astronomy	$181,074	$207,119	$182,533	$183,190	$188,220	$272,719
Chemistry	$517,957	$533,336	$553,799	$551,904	$587,342	$617,588
Physics	$727,474	$761,867	$757,397	$803,404	$818,088	$868,791
Atmospheric Sciences	$161,349	$163,717	$176,050	$186,750	$209,709	$223,356
Earth Sciences	$271,699	$273,996	$268,105	$269,179	$312,256	$321,297
Oceanography	$323,125	$331,526	$371,416	$355,508	$362,214	$405,334
Mathematics and Statistics	$205,346	$204,928	$208,197	$202,208	$214,289	$210,224
Computer Science	$461,836	$483,473	$501,691	$506,473	$513,612	$583,370
Agricultural Sciences	$493,165	$531,505	$559,673	$548,427	$533,569	$545,755
Biological Sciences	$2,438,344	$2,490,606	$2,530,783	$2,685,552	$2,939,143	$3,225,351
Medical Sciences	$3,537,444	$3,826,943	$4,023,910	$4,226,957	$4,559,333	$4,866,063
Psychology	$240,721	$249,020	$258,697	$271,716	$299,030	$309,850
Economics	$76,277	$80,029	$90,660	$89,804	$92,252	$90,162
Political Science and Public Administration	$49,850	$59,667	$62,276	$51,803	$53,157	$54,101
Sociology	$96,334	$104,556	$119,096	$120,707	$119,075	$122,086
ARM	$11,235,183	$11,891,911	$12,332,359	$12,772,509	$13,604,224	$14,555,804

Dollar amounts are in thousands.

Federally Financed Higher Education R&D Expenditures for S&E (Sum)

Year	2000	2001	2002	2003	2004	2005
Discipline						
Aerospace Engineering	$183,376	$257,255	$250,255	$309,405	$334,153	$335,261
Chemical Engineering	$196,325	$214,719	$229,985	$247,939	$268,128	$295,483
Civil Engineering	$237,073	$264,434	$300,127	$326,465	$347,627	$337,310
Electrical Engineering	$701,038	$725,417	$818,812	$925,067	$971,038	$1,047,169
Mechanical Engineering	$383,421	$416,200	$507,501	$532,093	$587,450	$626,353
Materials Engineering	$226,743	$240,875	$262,898	$313,547	$352,152	$369,362
Astronomy	$276,766	$260,002	$277,644	$271,580	$289,271	$310,897
Chemistry	$631,606	$659,822	$736,518	$819,118	$920,749	$952,197
Physics	$902,149	$926,057	$974,496	$1,087,480	$1,168,717	$1,225,968
Atmospheric Sciences	$223,240	$233,229	$250,302	$297,790	$320,856	$361,862
Earth Sciences	$331,718	$328,941	$369,929	$439,604	$536,716	$615,785
Oceanography	$422,521	$449,180	$485,767	$537,255	$546,973	$545,509
Mathematics and Statistics	$230,025	$242,021	$268,430	$294,623	$317,764	$345,942
Computer Science	$583,714	$643,233	$769,336	$935,873	$1,024,363	$1,020,758
Agricultural Sciences	$578,787	$616,649	$689,286	$764,261	$866,940	$844,413
Biological Sciences	$3,658,744	$3,873,561	$4,423,258	$5,018,179	$5,743,194	$6,198,215
Medical Sciences	$5,441,910	$6,259,575	$7,206,642	$8,242,517	$9,389,023	$9,896,496
Psychology	$350,851	$398,496	$475,407	$552,984	$586,204	$609,456
Economics	$89,185	$89,761	$99,783	$106,433	$109,044	$108,956
Political Science and Public Administration	$62,906	$73,278	$79,594	$96,853	$112,110	$112,124
Sociology	$137,075	$148,591	$178,367	$179,617	$181,771	$193,689
ARM	$15,849,173	$17,321,296	$19,654,337	$22,298,683	$24,974,243	$26,353,205

Dollar amounts are in thousands.

Year	2006	2007	2008	2009	2010	2011
	Federally Financed Higher Education R&D Expenditures for S&E (Sum)					
Discipline						
Aerospace Engineering	$287,779	$340,324	$399,582	$431,583	$466,991	$502,959
Chemical Engineering	$320,214	$322,568	$341,267	$359,939	$421,323	$495,907
Civil Engineering	$334,927	$355,898	$385,610	$400,543	$461,233	$545,002
Electrical Engineering	$1,077,270	$1,065,707	$1,111,783	$1,200,699	$1,375,872	$1,513,764
Mechanical Engineering	$686,074	$696,357	$737,583	$801,249	$954,918	$1,031,810
Materials Engineering	$386,338	$377,842	$377,073	$389,439	$429,412	$455,275
Astronomy	$317,423	$305,545	$353,111	$387,819	$405,252	$408,153
Chemistry	$968,134	$975,723	$992,275	$1,037,490	$1,199,882	$1,244,103
Physics	$1,215,517	$1,219,721	$1,215,264	$1,360,833	$1,557,455	$1,661,831
Atmospheric Sciences	$406,606	$354,500	$337,720	$322,239	$338,465	$384,761
Earth Sciences	$591,714	$601,428	$603,223	$645,126	$735,518	$798,560
Oceanography	$560,990	$671,710	$686,106	$711,758	$666,930	$705,174
Mathematics and Statistics	$374,931	$408,608	$447,399	$368,729	$417,758	$458,568
Computer Science	$1,018,483	$1,025,809	$1,036,436	$1,106,960	$1,174,024	$1,288,912
Agricultural Sciences	$883,383	$897,109	$862,443	$863,378	$956,447	$1,041,298
Biological Sciences	$6,246,792	$6,188,668	$6,361,214	$6,621,528	$7,576,590	$8,227,188
Medical Sciences	$10,438,130	$10,563,250	$10,748,831	$11,057,633	$12,070,667	$13,199,569
Psychology	$629,253	$603,423	$634,857	$656,196	$758,507	$816,492
Economics	$120,316	$124,401	$127,685	$121,542	$127,748	$150,391
Political Science and Public Administration	$106,991	$134,811	$124,970	$137,282	$152,542	$148,672
Sociology	$216,449	$206,882	$202,619	$201,872	$226,457	$231,507
ARM	$27,187,714	$27,440,284	$28,087,051	$29,183,837	$32,473,991	$35,309,896

Dollar amounts are in thousands.

APPENDIX C: ARM EXCLUSION DATA

This appendix contains the results from the calculations for percent change by year in each discipline and the summary statistics. The first 3 pages present the yearly percentage changes and the fourth page presents the average, standard deviation and associated 2-sigma (σ) range. Shaded cell indicates a percentage change outside the ± 2σ for that discipline's yearly % change in funding.

	Percent Change by Year [(Discipline Year 2-Discipline Year1)/Discipline Year 1]							
	1989	1990	1991	1992	1993	1994	1995	1996
Aerospace Engineering	22.74%	10.55%	8.28%	9.61%	5.95%	3.49%	11.07%	-6.78%
Chemical Engineering	17.98%	9.37%	6.93%	6.96%	13.14%	5.38%	7.06%	7.85%
Civil Engineering	-0.02%	14.53%	5.67%	16.18%	7.45%	6.11%	13.54%	6.38%
Electrical Engineering	17.05%	11.69%	0.94%	3.10%	1.99%	6.93%	10.92%	10.33%
Mechanical Engineering	11.19%	11.20%	5.51%	6.98%	15.30%	5.73%	3.62%	-1.39%
Materials Engineering	7.20%	6.72%	10.04%	-6.43%	5.01%	3.41%	12.82%	8.52%
Astronomy	5.01%	28.17%	20.68%	16.42%	4.22%	9.72%	14.38%	-11.87%
Chemistry	4.73%	5.44%	1.40%	6.25%	5.33%	2.51%	2.97%	3.84%
Physics	4.61%	7.58%	4.22%	4.15%	0.02%	2.73%	4.73%	-0.59%
Atmospheric Sciences	14.68%	1.79%	-1.32%	8.26%	14.68%	0.45%	1.47%	7.53%
Earth Sciences	7.08%	9.52%	6.60%	9.30%	2.15%	11.55%	0.85%	-2.15%
Oceanography	9.10%	0.85%	0.56%	16.30%	7.51%	-1.97%	2.60%	12.03%
Mathematics and Statistics	4.91%	2.29%	5.99%	7.46%	10.84%	1.09%	-0.20%	1.60%
Computer Science	12.03%	5.70%	8.54%	2.20%	11.46%	9.10%	4.68%	3.77%
Agricultural Sciences	8.55%	0.96%	6.93%	10.52%	7.72%	9.58%	7.77%	5.30%
Biological Sciences	7.96%	6.23%	5.74%	9.58%	8.11%	5.51%	2.14%	1.61%
Medical Sciences	13.09%	6.75%	6.64%	9.29%	8.23%	4.98%	8.18%	5.15%
Psychology	8.98%	7.01%	13.72%	15.36%	9.07%	2.70%	3.45%	3.89%
Economics	10.46%	0.06%	9.79%	10.52%	17.22%	-1.33%	4.92%	13.28%
Political Science and Public Administration	2.87%	-2.01%	12.53%	22.79%	22.21%	16.40%	19.69%	4.37%
Sociology	12.97%	11.16%	20.07%	13.45%	11.47%	5.74%	8.53%	13.91%

	Percent Change by Year [(Discipline Year 2-Discipline Year1)/Discipline Year 1]							
	1997	1998	1999	2000	2001	2002	2003	2004
Aerospace Engineering	7.09%	-6.51%	7.71%	-0.71%	40.29%	-2.72%	23.64%	8.00%
Chemical Engineering	-4.55%	2.06%	6.30%	9.11%	9.37%	7.11%	7.81%	8.14%
Civil Engineering	1.33%	-1.63%	10.14%	9.18%	11.54%	13.50%	8.78%	6.48%
Electrical Engineering	4.07%	10.94%	-5.98%	7.65%	3.48%	12.87%	12.98%	4.97%
Mechanical Engineering	-3.72%	8.77%	10.78%	-1.32%	8.55%	21.94%	4.85%	10.40%
Materials Engineering	16.80%	-0.34%	-1.56%	3.90%	6.23%	9.14%	19.27%	12.31%
Astronomy	0.36%	2.75%	44.89%	1.48%	-6.06%	6.79%	-2.18%	6.51%
Chemistry	-0.34%	6.42%	5.15%	2.27%	4.47%	11.62%	11.21%	12.41%
Physics	6.07%	1.83%	6.20%	3.84%	2.65%	5.23%	11.59%	7.47%
Atmospheric Sciences	6.08%	12.29%	6.51%	-0.05%	4.47%	7.32%	18.97%	7.75%
Earth Sciences	0.40%	16.00%	2.90%	3.24%	-0.84%	12.46%	18.83%	22.09%
Oceanography	-4.28%	1.89%	11.90%	4.24%	6.31%	8.15%	10.60%	1.81%
Mathematics and Statistics	-2.88%	5.97%	-1.90%	9.42%	5.22%	10.91%	9.76%	7.85%
Computer Science	0.95%	1.41%	13.58%	0.06%	10.20%	19.60%	21.65%	9.46%
Agricultural Sciences	-2.01%	-2.71%	2.28%	6.05%	6.54%	11.78%	10.88%	13.44%
Biological Sciences	6.12%	9.44%	9.74%	13.44%	5.87%	14.19%	13.45%	14.45%
Medical Sciences	5.05%	7.86%	6.73%	11.83%	15.03%	15.13%	14.37%	13.91%
Psychology	5.03%	10.05%	3.62%	13.23%	13.58%	19.30%	16.32%	6.01%
Economics	-0.94%	2.73%	-2.27%	-1.08%	0.65%	11.17%	6.66%	2.45%
Political Science and Public Administration	-16.82%	2.61%	1.78%	16.28%	16.49%	8.62%	21.68%	15.75%
Sociology	1.35%	-1.35%	2.53%	12.28%	8.40%	20.04%	0.70%	1.20%

	2005	2006	2007	2008	2009	2010	2011	Outliers
Aerospace Engineering	0.33%	-14.16%	18.26%	17.41%	8.01%	8.20%	7.70%	1
Chemical Engineering	10.20%	8.37%	0.74%	5.80%	5.47%	17.05%	17.70%	4
Civil Engineering	-2.97%	-0.71%	6.26%	8.35%	3.87%	15.15%	18.16%	1
Electrical Engineering	7.84%	2.87%	-1.07%	4.32%	8.00%	14.59%	10.02%	
Mechanical Engineering	6.62%	9.53%	1.50%	5.92%	8.63%	19.18%	8.05%	2
Materials Engineering	4.89%	4.60%	-2.20%	-0.20%	3.28%	10.26%	6.02%	1
Astronomy	7.48%	2.10%	-3.74%	15.57%	9.83%	4.50%	0.72%	1
Chemistry	3.42%	1.67%	0.78%	1.70%	4.56%	15.65%	3.69%	3
Physics	4.90%	-0.85%	0.35%	-0.37%	11.98%	14.45%	6.70%	3
Atmospheric Sciences	12.78%	12.36%	-12.81%	-4.73%	-4.58%	5.04%	13.68%	1
Earth Sciences	14.73%	-3.91%	1.64%	0.30%	6.95%	14.01%	8.57%	1
Oceanography	-0.27%	2.84%	19.74%	2.14%	3.74%	-6.30%	5.73%	1
Mathematics and Statistics	8.87%	8.38%	8.98%	9.49%	-17.58%	13.30%	9.77%	1
Computer Science	-0.35%	-0.22%	0.72%	1.04%	6.80%	6.06%	9.79%	2
Agricultural Sciences	-2.60%	4.62%	1.55%	-3.86%	0.11%	10.78%	8.87%	
Biological Sciences	7.92%	0.78%	-0.93%	2.79%	4.09%	14.42%	8.59%	
Medical Sciences	5.40%	5.47%	1.20%	1.76%	2.87%	9.16%	9.35%	
Psychology	3.97%	3.25%	-4.10%	5.21%	3.36%	15.59%	7.64%	2
Economics	-0.08%	10.43%	3.40%	2.64%	-4.81%	5.11%	17.72%	2
Political Science and Public Administration	0.01%	-4.58%	26.00%	-7.30%	9.85%	11.12%	-2.54%	1
Sociology	6.56%	11.75%	-4.42%	-2.06%	-0.37%	12.18%	2.23%	

Percent Change by Year [(Discipline Year 2-Discipline Year1)/Discipline Year 1]

The summary statistics show the number of outliers for each discipline, the average % change per year, the standard deviation for the distribution, the 2-sigma, and the ±2σ range around the calculated average.

	Years 1988 to 2009				RANGE - 20 years	
	Outliers	Mean % Diff.	Std Dev (s)	2 sigma	Low	High
Aerospace Engineering	1	8.17%	12.07%	24.13%	-15.96%	32.30%
Chemical Engineering	4	7.17%	4.43%	8.86%	-1.69%	16.03%
Civil Engineering	1	6.86%	5.45%	10.90%	-4.04%	17.75%
Electrical Engineering		6.47%	5.44%	10.87%	-4.40%	17.35%
Mechanical Engineering	2	7.17%	5.80%	11.60%	-4.43%	18.77%
Materials Engineering	1	5.88%	6.30%	12.60%	-6.72%	18.47%
Astronomy	1	8.21%	12.50%	25.01%	-16.80%	33.22%
Chemistry	3	4.66%	3.48%	6.96%	-2.30%	11.62%
Physics	3	4.21%	3.60%	7.19%	-2.99%	11.40%
Atmospheric Sciences	1	5.42%	7.72%	15.45%	-10.03%	20.87%
Earth Sciences	1	6.65%	7.22%	14.44%	-7.78%	21.09%
Oceanography	1	5.51%	6.09%	12.19%	-6.67%	17.70%
Mathematics and Statistics	1	4.59%	6.58%	13.17%	-8.58%	17.76%
Computer Science	2	6.78%	6.41%	12.82%	-6.04%	19.60%
Agricultural Sciences		4.92%	5.21%	10.42%	-5.49%	15.34%
Biological Sciences		7.06%	4.47%	8.94%	-1.89%	16.00%
Medical Sciences		8.04%	4.32%	8.65%	-0.60%	16.69%
Psychology	2	7.76%	5.75%	11.50%	-3.73%	19.26%
Economics	2	4.56%	5.99%	11.98%	-7.42%	16.55%
Political Science and Public Administration	1	9.01%	11.45%	22.90%	-13.89%	31.91%
Sociology		7.33%	7.14%	14.28%	-6.95%	21.61%

APPENDIX D: ARM *MSI* COMPONENTS, 2000a & 2008a

These two pages contain the results of the calculations for the percentage each discipline has in the ARM over the three time periods (1990a, 2000a, 2008a), the percentage change in the ARM for each discipline, the resulting equalized value in the percentage of the ARM (EMS), the equalized value for the change in the ARM (ΔEMS), and the MSI for the two time periods.

	1990a	1990a % of ARM	2000a	2000a % of ARM	2008a	2008a % of ARM	% Change in ARM 1990a-2000a	% Change in ARM 2000a-2008a
Aerospace Engineering	$126,581	1.47%	$209,410	1.32%	$390,496	1.38%	-10.12%	4.78%
Chemical Engineering	$108,206	1.25%	$196,994	1.24%	$341,258	1.21%	-1.09%	-2.66%
Civil Engineering	$114,254	1.32%	$239,548	1.51%	$380,684	1.35%	13.91%	-10.71%
Electrical Engineering	$418,193	4.84%	$692,554	4.36%	$1,126,063	3.98%	-10.03%	-8.64%
Mechanical Engineering	$234,578	2.72%	$396,058	2.49%	$745,063	2.63%	-8.27%	5.70%
Materials Engineering	$140,868	1.63%	$228,616	1.44%	$381,451	1.35%	-11.83%	-6.25%
Astronomy	$112,224	1.30%	$255,070	1.60%	$348,825	1.23%	23.48%	-23.16%
Chemistry	$439,635	5.09%	$636,339	4.00%	$1,001,829	3.54%	-21.36%	-11.54%
Physics	$646,134	7.48%	$898,999	5.66%	$1,313,758	4.64%	-24.41%	-17.89%
Atmospheric Sciences	$129,766	1.50%	$226,608	1.43%	$351,906	1.24%	-5.13%	-12.74%
Earth Sciences	$203,211	2.35%	$327,319	2.06%	$616,592	2.18%	-12.49%	5.84%
Oceanography	$261,911	3.03%	$425,678	2.68%	$659,499	2.33%	-11.70%	-12.95%
Mathematics and Statistics	$162,923	1.89%	$227,423	1.43%	$403,485	1.43%	-24.16%	-0.31%
Computer Science	$345,966	4.01%	$603,439	3.80%	$1,056,402	3.73%	-5.24%	-1.64%
Agricultural Sciences	$360,551	4.18%	$580,397	3.65%	$874,310	3.09%	-12.54%	-15.36%
Biological Sciences	$1,843,919	21.35%	$3,585,885	22.56%	$6,390,470	22.59%	5.65%	0.13%
Medical Sciences	$2,674,216	30.97%	$5,522,516	34.74%	$10,789,905	38.14%	12.19%	9.78%
Psychology	$167,724	1.94%	$353,066	2.22%	$656,447	2.32%	14.36%	4.47%
Economics	$56,112	0.65%	$89,703	0.56%	$124,543	0.44%	-13.15%	-21.99%
Political Science and Public Administration	$26,597	0.31%	$63,428	0.40%	$132,354	0.47%	29.56%	17.25%
Sociology	$62,009	0.72%	$135,917	0.86%	$203,791	0.72%	19.08%	-15.75%
ARM =	$8,635,580	100 %	$15,894,969	100 %	$28,289,131	100 %		

Dollar values are in thousands

	Equalized Value of % ARM (EMS 2000a)	Equalized Value of Change in ARM (ΔEMS 1990a-2000a)	MSI (2000a)	Equalized Value of % ARM (EMS 2008a)	Equalized Value of Change in ARM (ΔEMS 2000a-2008a)	MSI (2008a)
Aerospace Engineering	0.038	-0.342	-0.304	0.036	0.277	0.313
Chemical Engineering	0.036	-0.037	-0.001	0.032	-0.155	-0.123
Civil Engineering	0.043	0.470	0.514	0.035	-0.621	-0.586
Electrical Engineering	0.125	-0.339	-0.214	0.104	-0.501	-0.397
Mechanical Engineering	0.072	-0.280	-0.208	0.069	0.331	0.400
Materials Engineering	0.041	-0.400	-0.359	0.035	-0.362	-0.327
Astronomy	0.046	0.794	0.841	0.032	-1.343	-1.311
Chemistry	0.115	-0.723	-0.607	0.093	-0.669	-0.576
Physics	0.163	-0.826	-0.663	0.122	-1.037	-0.916
Atmospheric Sciences	0.041	-0.173	-0.132	0.033	-0.739	-0.706
Earth Sciences	0.059	-0.423	-0.363	0.057	0.339	0.396
Oceanography	0.077	-0.396	-0.319	0.061	-0.751	-0.690
Mathematics and Statistics	0.041	-0.817	-0.776	0.037	-0.018	0.019
Computer Science	0.109	-0.177	-0.068	0.098	-0.095	0.003
Agricultural Sciences	0.105	-0.424	-0.319	0.081	-0.891	-0.810
Biological Sciences	0.649	0.191	0.841	0.592	0.008	0.600
Medical Sciences	1.000	0.413	1.413	1.000	0.567	1.567
Psychology	0.064	0.486	0.550	0.061	0.259	0.320
Economics	0.016	-0.445	-0.428	0.012	-1.275	-1.264
Political Science and Public Administration	0.011	1.000	1.011	0.012	1.000	1.012
Sociology	0.025	0.646	0.670	0.019	-0.914	-0.895

APPENDIX E: UCF REPORTED FEDERAL FINANCED R&D, 1988-2011

These three pages present the University of Central Florida's federally financed R&D expenditures as reported to the NSF from the years 1988 through 2011 for the 16 disciplines they participated in as of 2011.

Federally Financed Higher Education R&D Expenditures for S&E (Sum)

Year	1988	1989	1990	1991	1992	1993	1994	1995
Aerospace Engineering	$0	$0	$0	$0	$222	$221	$626	$519
Civil Engineering	$140	$201	$94	$97	$72	$58	$537	$704
Electrical Engineering	$84	$128	$115	$58	$142	$838	$9,249	$10,840
Mechanical Engineering	$272	$257	$392	$431	$545	$639	$29	$119
Materials Engineering	$0	$0	$0	$0	$0	$0	$0	$0
Chemistry	$0	$0	$41	$96	$68	$127	$216	$270
Physics	$69	$171	$194	$194	$98	$102	$3,336	$4,620
Atmospheric Sciences	$0	$4,225	$791	$653	$606	$577	$0	$0
Mathematics and Statistics	$0	$24	$4	$61	$8	$2	$44	$22
Computer Science	$33	$236	$388	$497	$514	$761	$599	$573
Biological Sciences	$61	$125	$103	$99	$147	$10	$167	$222
Medical Sciences	$0	$0	$0	$0	$49	$64	$2	$7
Psychology	$9	$12	$112	$344	$406	$274	$448	$701
Economics	$0	$0	$0	$0	$0	$0	$33	$0
Political Science and Public Administration	$0	$0	$0	$0	$0	$0	$0	$0
Sociology	$65	$0	$0	$49	$5	$0	$110	$108

Dollar amounts are in thousands.

Federally Financed Higher Education R&D Expenditures for S&E (Sum)

Year	1996	1997	1998	1999	2000	2001	2002	2003
Aerospace Engineering	$393	$0	$95	$333	$279	$513	$1,931	$942
Civil Engineering	$548	$250	$556	$343	$574	$667	$739	$2,672
Electrical Engineering	$10,413	$101	$355	$724	$611	$856	$737	$3,262
Mechanical Engineering	$161	$560	$485	$719	$770	$742	$698	$852
Materials Engineering	$0	$0	$0	$101	$138	$315	$367	$606
Chemistry	$293	$102	$347	$736	$824	$1,234	$1,581	$3,890
Physics	$4,326	$4,272	$3,953	$3,148	$2,282	$4,129	$5,579	$8,580
Atmospheric Sciences	$0	$1,320	$2,117	$2,420	$1,543	$2,803	$3,543	$7,374
Mathematics and Statistics	$13	$15	$16	$37	$33	$42	$94	$207
Computer Science	$375	$484	$162	$291	$346	$283	$231	$26
Biological Sciences	$192	$276	$227	$366	$596	$992	$1,142	$2,295
Medical Sciences	$97	$33	$41	$178	$62	$288	$856	$1,322
Psychology	$759	$580	$264	$536	$844	$1,146	$1,756	$2,368
Economics	$0	$0	$0	$0	$59	$88	$149	$267
Political Science and Public Administration	$0	$44	$57	$0	$19	$36	$40	$72
Sociology	$2	$1,775	$1,140	$774	$490	$1,058	$617	$896

Dollar amounts are in thousands.

Federally Financed Higher Education R&D Expenditures for S&E (Sum)

Year	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	$1,026	$1,569	$948	$1,423	$2,143	$2,445	$816	$631
Civil Engineering	$798	$1,020	$629	$1,525	$1,062	$1,070	$1,990	$1,054
Electrical Engineering	$3,342	$2,951	$2,262	$3,430	$2,886	$3,875	$4,841	$5,414
Mechanical Engineering	$620	$765	$798	$1,702	$3,879	$1,677	$1,171	$1,826
Materials Engineering	$854	$535	$378	$708	$1,238	$1,244	$1,526	$1,565
Chemistry	$1,718	$1,442	$848	$1,744	$1,601	$2,715	$4,358	$3,291
Physics	$13,405	$9,428	$8,656	$10,429	$9,410	$10,289	$12,597	$10,505
Atmospheric Sciences	$6,209	$7,577	$7,398	$8,096	$6,996	$7,280	$7,388	$6,358
Mathematics and Statistics	$186	$402	$265	$262	$288	$310	$458	$322
Computer Science	$0	$0	$93	$0	$0	$535	$254	$321
Biological Sciences	$2,553	$2,798	$817	$2,160	$1,710	$1,112	$1,408	$1,157
Medical Sciences	$1,592	$1,185	$893	$0	$616	$624	$267	$1,911
Psychology	$1,969	$1,528	$1,219	$1,192	$599	$235	$356	$823
Economics	$139	$158	$326	$195	$354	$655	$552	$1,098
Political Science and Public Administration	$118	$282	$476	$282	$175	$315	$374	$372
Sociology	$274	$22	$20	$155	$188	$111	$74	$119

Dollar amounts are in thousands.

APPENDIX F: UCF MARKET, EXCLUSION DATA

This appendix contains the results from the calculations for percent change by year in each discipline and the summary statistics for the University of Central Florida. The first 3 pages present the yearly percentage changes and the fourth page presents the average, standard deviation and associated 2-sigma (σ) range. Shaded cell indicates a percentage change outside the ± 2σ for that discipline's yearly % change in funding.

	Percent Change by Year [(Discipline Year 2-Discipline Year1)/Discipline Year 1]							
	1989	1990	1991	1992	1993	1994	1995	1996
Aerospace Engineering					0%	183%	-17%	-24%
Civil Engineering	44%	-53%	3%	-26%	-19%	826%	31%	-22%
Electrical Engineering	52%	-10%	-50%	145%	490%	1004%	17%	-4%
Mechanical Engineering	-6%	53%	10%	26%	17%	-95%	310%	35%
Materials Engineering								
Chemistry			134%	-29%	87%	70%	25%	9%
Physics	148%	13%	0%	-49%	4%	3171%	38%	-6%
Atmospheric Sciences		-81%	-17%	-7%	-5%	-100%		
Mathematics and Statistics		-83%	1425%	-87%	-75%	2100%	-50%	-41%
Computer Science	615%	64%	28%	3%	48%	-21%	-4%	-35%
Biological Sciences	105%	-18%	-4%	48%	-93%	1570%	33%	-14%
Medical Sciences					31%	-97%	250%	1286%
Psychology	33%	833%	207%	18%	-33%	64%	56%	8%
Economics							-100%	
Political Science and Public Administration								
Sociology	-100%			-90%	-100%		-2%	-98%

	Percent Change by Year [(Discipline Year 2-Discipline Year1)/Discipline Year 1]							
	1997	1998	1999	2000	2001	2002	2003	2004
Aerospace Engineering	-100%		251%	-16%	84%	276%	-51%	9%
Civil Engineering	-54%	122%	-38%	67%	16%	11%	262%	-70%
Electrical Engineering	-99%	251%	104%	-16%	40%	-14%	343%	2%
Mechanical Engineering	248%	-13%	48%	7%	-4%	-6%	22%	-27%
Materials Engineering				37%	128%	17%	65%	41%
Chemistry	-65%	240%	112%	12%	50%	28%	146%	-56%
Physics	-1%	-7%	-20%	-28%	81%	35%	54%	56%
Atmospheric Sciences		60%	14%	-36%	82%	26%	108%	-16%
Mathematics and Statistics	15%	7%	131%	-11%	27%	124%	120%	-10%
Computer Science	29%	-67%	80%	19%	-18%	-18%	-89%	-100%
Biological Sciences	44%	-18%	61%	63%	66%	15%	101%	11%
Medical Sciences	-66%	24%	334%	-65%	365%	197%	54%	20%
Psychology	-24%	-54%	103%	57%	36%	53%	35%	-17%
Economics					49%	69%	79%	-48%
Political Science and Public Administration		30%	-100%		89%	11%	80%	64%
Sociology	88650%	-36%	-32%	-37%	116%	-42%	45%	-69%

	Percent Change by Year [(Discipline Year 2-Discipline Year1)/Discipline Year 1]						
	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	53%	-40%	50%	51%	14%	-67%	-23%
Civil Engineering	28%	-38%	142%	-30%	1%	86%	-47%
Electrical Engineering	-12%	-23%	52%	-16%	34%	25%	12%
Mechanical Engineering	23%	4%	113%	128%	-57%	-30%	56%
Materials Engineering	-37%	-29%	87%	75%	0%	23%	3%
Chemistry	-16%	-41%	106%	-8%	70%	61%	-24%
Physics	-30%	-8%	20%	-10%	9%	22%	-17%
Atmospheric Sciences	22%	-2%	9%	-14%	4%	1%	-14%
Mathematics and Statistics	116%	-34%	-1%	10%	8%	48%	-30%
Computer Science			-100%			-53%	26%
Biological Sciences	10%	-71%	164%	-21%	-35%	27%	-18%
Medical Sciences	-26%	-25%	-100%		1%	-57%	616%
Psychology	-22%	-20%	-2%	-50%	-61%	51%	131%
Economics	14%	106%	-40%	82%	85%	-16%	99%
Political Science and Public Administration	139%	69%	-41%	-38%	80%	19%	-1%
Sociology	-92%	-9%	675%	21%	-41%	-33%	61%

The summary statistics show the average % change per year, the standard deviation for the distribution, the 2-sigma, and the ±2σ range around the calculated average for the University of Central Florida.

		10-year stats 1990-2000			Range	
	Outliers	Average year % change	Std. dev.	2-sigma	Low	High
Aerospace Engineering		39%	127%	254%	-214%	293%
Civil Engineering	1	76%	255%	509%	-433%	585%
Electrical Engineering	1	167%	324%	648%	-481%	815%
Mechanical Engineering	2	59%	117%	234%	-175%	292%
Materials Engineering		37%	50%	100%	-63%	137%
Chemistry	1	59%	89%	178%	-119%	237%
Physics	1	283%	958%	1916%	-1633%	2199%
Atmospheric Sciences	2	-22%	51%	103%	-124%	81%
Mathematics and Statistics	2	303%	740%	1480%	-1177%	1783%
Computer Science	1	13%	44%	87%	-74%	100%
Biological Sciences	1	152%	473%	945%	-793%	1097%
Medical Sciences	1	212%	461%	922%	-710%	1134%
Psychology	1	112%	250%	500%	-387%	612%
Economics		-100%				
Political Science and Public Administration		-35%	92%	183%	-218%	148%
Sociology	1	11032%	31362%	62725%	-51693%	73757%

APPENDIX G: UCF *ISI* COMPONENTS, 2000a and 2008a

These three pages contain the information for the University of Central Florida. It provides the dollar amount of reported federally financed R&D by discipline as well the calculated percentages for the institutional spending, its percentage in the ARM, its percentage change in share of the institutional spending, and its percentage change in the share of the ARM for the three time periods (1990a, 2000a, 2008a). In addition the equalized value in the percentage of the institutional spending (EIS), the equalized value for the change in institutional spending (ΔEIS), and the ISI for the two time periods 2000a and 2008a are presented.

	1990a	1990a % Institutional Spending	1990a U% of ARM	2000a	2000a % of Institutional Spending	2000a U% of ARM	2008a	2008a % of Institutional Spending	2008a U% of ARM
Aerospace Engineering	$0	0.00%	0.00%	$375	3.18%	0.18%	$2,004	5.96%	0.51%
Civil Engineering	$131	2.88%	0.11%	$528	4.48%	0.22%	$1,219	3.62%	0.32%
Electrical Engineering	$100	2.21%	0.02%	$730	6.19%	0.11%	$3,397	10.10%	0.30%
Mechanical Engineering	$360	7.94%	0.15%	$744	6.31%	0.19%	$2,419	7.19%	0.32%
Materials Engineering	$0	0.00%	0.00%	$185	1.57%	0.08%	$1,063	3.16%	0.28%
Chemistry	$46	1.01%	0.01%	$931	7.90%	0.15%	$2,020	6.00%	0.20%
Physics	$186	4.11%	0.03%	$3,186	27.03%	0.35%	$10,043	29.85%	0.76%
Atmospheric Sciences	$1,890	41.65%	1.46%	$2,255	19.13%	1.00%	$7,457	22.16%	2.12%
Mathematics and Statistics	$19	0.43%	0.01%	$37	0.32%	0.02%	$287	0.85%	0.07%
Computer Science	$334	7.35%	0.10%	$307	2.60%	0.05%	$178	0.53%	0.02%
Biological Sciences	$109	2.40%	0.01%	$651	5.52%	0.02%	$1,661	4.94%	0.03%
Medical Sciences	$0	0.00%	0.00%	$176	1.49%	0.00%	$413	1.23%	0.00%
Psychology	$177	3.89%	0.11%	$842	7.14%	0.24%	$675	2.01%	0.10%
Economics	$0	0.00%	0.00%	$49	0.42%	0.05%	$401	1.19%	0.32%
Political Science and Public Administration	$0	0.00%	0.00%	$18	0.16%	0.03%	$257	0.76%	0.19%
Sociology	$16	0.36%	0.03%	$774	6.57%	0.57%	$151	0.45%	0.07%
Total Reported	$4,537	1.00	0.05%	$11,789	1.00	0.07%	$33,647	1.00	0.12%

Dollar amounts are in thousands.

	% Change in Share of ARM (1990a-2000a)	% Change in Institutional Spending (1990a-2000a)	% Change in Share of ARM (2000a-2008a)	% Change in Institutional Spending (2000a-2008a)
Aerospace Engineering			187%	87%
Civil Engineering	93%	55%	45%	-19%
Electrical Engineering	340%	180%	186%	63%
Mechanical Engineering	22%	-21%	73%	14%
Materials Engineering			245%	102%
Chemistry	1309%	685%	38%	-24%
Physics	1129%	558%	116%	10%
Atmospheric Sciences	-32%	-54%	113%	16%
Mathematics and Statistics	38%	-26%	333%	169%
Computer Science	-47%	-65%	-67%	-80%
Biological Sciences	207%	130%	43%	-11%
Medical Sciences			20%	-18%
Psychology	126%	83%	-57%	-72%
Economics			490%	187%
Political Science and Public Administration			573%	392%
Sociology	2062%	1724%	-87%	-93%

The empty fields in some of the disciplines indicated were there was $0 reported federal financed expenditures in that time frame.

	Equalized Value of % Institutional Spending (EIS, 2000a)	Equalized Value of Change in share of spending (ΔEIS 2000a)	ISI (2000a)	Equalized Value of % Institutional Spending (EIS, 2008a)	Equalized Value of Change in share of spending (ΔEIS 2008a)	ISI (2008a)
Aerospace Engineering	0.118		0.118	0.200	0.223	0.422
Civil Engineering	0.166	0.032	0.198	0.121	-0.049	0.073
Electrical Engineering	0.229	0.104	0.334	0.338	0.161	0.499
Mechanical Engineering	0.233	-0.012	0.221	0.241	0.036	0.277
Materials Engineering	0.058		0.058	0.106	0.260	0.366
Chemistry	0.292	0.397	0.690	0.201	-0.061	0.140
Physics	1.000	0.324	1.324	1.000	0.027	1.027
Atmospheric Sciences	0.708	-0.031	0.676	0.743	0.040	0.783
Mathematics and Statistics	0.012	-0.015	-0.003	0.029	0.431	0.460
Computer Science	0.096	-0.037	0.059	0.018	-0.203	-0.185
Biological Sciences	0.204	0.075	0.280	0.165	-0.027	0.138
Medical Sciences	0.055		0.055	0.041	-0.045	-0.004
Psychology	0.264	0.048	0.313	0.067	-0.183	-0.116
Economics	0.015		0.015	0.040	0.477	0.517
Political Science and Public Administration	0.006		0.006	0.026	1.000	1.026
Sociology	0.243	1.000	1.243	0.015	-0.238	-0.223

The empty fields in some of the disciplines indicated were there was $0 reported federal financed expenditures in that time frame.

APPENDIX H: ROLLING AVERAGE OF ARM

These three pages present the total federally funded academic R&D in thousands by discipline from 1990 through 2011 using a 3 year rolling average for smoothing.

	Rolling Average Total Federally Funded Academic R&D by Discipline by Year						
	1990	1991	1992	1993	1994	1995	1996
Aerospace Engineering	$111,928	$126,581	$138,538	$149,445	$158,707	$169,664	$173,479
Chemical Engineering	$98,933	$109,758	$118,198	$129,015	$139,845	$151,476	$161,794
Civil Engineering	$107,101	$114,254	$128,079	$140,525	$153,900	$167,999	$182,483
Electrical Engineering	$382,999	$418,193	$439,108	$447,946	$466,022	$497,442	$544,595
Mechanical Engineering	$215,018	$234,578	$252,801	$276,735	$302,214	$325,799	$334,101
Materials Engineering	$139,133	$146,116	$145,164	$148,932	$149,754	$160,504	$173,843
Astronomy	$94,800	$112,224	$135,694	$153,133	$168,152	$184,408	$190,242
Chemistry	$423,553	$439,635	$458,774	$478,789	$500,963	$518,851	$535,031
Physics	$612,736	$646,134	$680,034	$698,661	$714,557	$732,503	$748,913
Atmospheric Sciences	$124,078	$129,766	$133,522	$143,363	$154,018	$161,900	$167,039
Earth Sciences	$188,660	$203,211	$220,402	$233,376	$251,227	$263,084	$271,267
Oceanography	$253,465	$261,911	$277,453	$299,937	$319,773	$328,088	$342,022
Mathematics and Statistics	$156,061	$162,923	$171,572	$185,643	$197,243	$204,465	$206,157
Computer Science	$318,473	$345,966	$364,595	$391,575	$421,651	$456,209	$482,333
Agricultural Sciences	$342,071	$360,551	$383,100	$415,274	$453,661	$491,567	$528,114
Biological Sciences	$1,729,849	$1,843,919	$1,977,616	$2,133,028	$2,295,606	$2,413,287	$2,486,578
Medical Sciences	$2,462,282	$2,674,216	$2,877,811	$3,110,515	$3,340,107	$3,577,965	$3,796,099
Psychology	$152,451	$167,724	$188,332	$211,859	$230,005	$241,377	$249,479
Economics	$52,612	$56,112	$59,989	$67,641	$73,176	$77,870	$82,322
Political Science and Public Administration	$25,471	$26,597	$29,651	$35,472	$42,575	$50,782	$57,264
Sociology	$53,921	$62,009	$71,261	$81,630	$89,726	$97,333	$106,662

Dollars are in thousands

Rolling Average Total Federally Funded Academic R&D by Discipline by Year

	1997	1998	1999	2000	2001	2002	2003
Aerospace Engineering	$179,480	$175,394	$179,864	$179,847	$208,441	$230,295	$272,305
Chemical Engineering	$166,914	$169,634	$171,690	$181,847	$196,994	$213,676	$230,881
Civil Engineering	$194,701	$198,443	$204,896	$217,118	$239,548	$267,211	$297,009
Electrical Engineering	$589,307	$638,936	$656,045	$681,617	$692,554	$748,422	$823,099
Mechanical Engineering	$332,334	$336,039	$353,919	$374,238	$396,058	$435,707	$485,265
Materials Engineering	$196,140	$211,534	$220,793	$222,222	$228,616	$243,505	$272,440
Astronomy	$190,947	$184,648	$214,710	$245,902	$269,829	$271,471	$269,742
Chemistry	$546,346	$564,348	$585,611	$612,179	$636,339	$675,982	$738,486
Physics	$774,223	$792,963	$830,094	$863,009	$898,999	$934,234	$996,011
Atmospheric Sciences	$175,506	$190,836	$206,605	$218,768	$226,608	$235,590	$260,440
Earth Sciences	$270,427	$283,180	$300,911	$321,757	$327,319	$343,529	$379,491
Oceanography	$352,817	$363,046	$374,352	$396,690	$425,678	$452,489	$490,734
Mathematics and Statistics	$205,111	$208,231	$208,907	$218,179	$227,423	$246,825	$268,358
Computer Science	$497,212	$507,259	$534,485	$560,232	$603,439	$665,428	$782,814
Agricultural Sciences	$546,535	$547,223	$542,584	$552,704	$580,397	$628,241	$690,065
Biological Sciences	$2,568,980	$2,718,493	$2,950,015	$3,274,413	$3,585,885	$3,985,188	$4,438,333
Medical Sciences	$4,025,937	$4,270,067	$4,550,784	$4,955,769	$5,522,516	$6,302,709	$7,236,245
Psychology	$259,811	$276,481	$293,532	$319,910	$353,066	$408,251	$475,629
Economics	$86,831	$90,905	$90,739	$90,533	$89,703	$92,910	$98,659
Political Science and Public Administration	$57,915	$55,745	$53,020	$56,721	$63,428	$71,926	$83,242
Sociology	$114,786	$119,626	$120,623	$126,079	$135,917	$154,678	$168,858

Dollars are in thousands

Rolling Average Total Federally Funded Academic R&D by Discipline by Year

	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	$297,938	$326,273	$319,064	$321,121	$342,562	$390,496	$432,719	$467,178
Chemical Engineering	$248,684	$270,517	$294,608	$312,755	$328,016	$341,258	$374,176	$425,723
Civil Engineering	$324,740	$337,134	$339,955	$342,712	$358,812	$380,684	$415,795	$468,926
Electrical Engineering	$904,972	$981,091	$1,031,826	$1,063,382	$1,084,920	$1,126,063	$1,229,451	$1,363,445
Mechanical Engineering	$542,348	$581,965	$633,292	$669,595	$706,671	$745,063	$831,250	$929,326
Materials Engineering	$309,532	$345,020	$369,284	$377,847	$380,418	$381,451	$398,641	$424,709
Astronomy	$279,498	$290,583	$305,864	$311,288	$325,360	$348,825	$382,061	$400,408
Chemistry	$825,462	$897,355	$947,027	$965,351	$978,711	$1,001,829	$1,076,549	$1,160,492
Physics	$1,076,898	$1,160,722	$1,203,401	$1,220,402	$1,216,834	$1,265,273	$1,377,851	$1,526,706
Atmospheric Sciences	$289,649	$326,836	$363,108	$374,323	$366,275	$338,153	$332,808	$348,488
Earth Sciences	$448,750	$530,702	$581,405	$602,976	$598,788	$616,592	$661,289	$726,401
Oceanography	$523,332	$543,246	$551,157	$592,736	$639,602	$689,858	$688,265	$694,621
Mathematics and Statistics	$293,606	$319,443	$346,212	$376,494	$410,313	$408,245	$411,295	$415,018
Computer Science	$909,857	$993,665	$1,021,201	$1,021,683	$1,026,909	$1,056,402	$1,105,807	$1,189,965
Agricultural Sciences	$773,496	$825,205	$864,912	$874,968	$880,978	$874,310	$894,089	$953,708
Biological Sciences	$5,061,544	$5,653,196	$6,062,734	$6,211,225	$6,265,558	$6,390,470	$6,853,111	$7,475,102
Medical Sciences	$8,279,394	$9,176,012	$9,907,883	$10,299,292	$10,583,404	$10,789,905	$11,292,377	$12,109,290
Psychology	$538,198	$582,881	$608,304	$614,044	$622,511	$631,492	$683,187	$743,732
Economics	$105,087	$108,144	$112,772	$117,891	$124,134	$124,543	$125,658	$133,227
Political Science and Public Administration	$96,186	$107,029	$110,408	$117,975	$122,257	$132,354	$138,265	$146,165
Sociology	$179,918	$185,026	$197,303	$205,673	$208,650	$203,791	$210,316	$219,945

Dollars are in thousands

APPENDIX I: PERCENTAGE OF ARM

These two pages present the percentage of the 3-year average market the discipline had relative to the 3-year ARM for that year..

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Aerospace Engineering	1.39%	1.46%	1.50%	1.50%	1.49%	1.50%	1.47%	1.46%	1.36%	1.32%	1.23%
Chemical Engineering	1.23%	1.27%	1.28%	1.30%	1.31%	1.34%	1.37%	1.35%	1.32%	1.26%	1.24%
Civil Engineering	1.33%	1.32%	1.38%	1.41%	1.45%	1.49%	1.54%	1.58%	1.54%	1.50%	1.48%
Electrical Engineering	4.75%	4.84%	4.76%	4.52%	4.39%	4.41%	4.60%	4.77%	4.95%	4.82%	4.66%
Mechanical Engineering	2.67%	2.71%	2.73%	2.78%	2.84%	2.89%	2.83%	2.70%	2.61%	2.59%	2.56%
Materials Engineering	1.62%	1.63%	1.57%	1.51%	1.41%	1.42%	1.47%	1.59%	1.64%	1.62%	1.52%
Astronomy	1.18%	1.29%	1.46%	1.54%	1.58%	1.63%	1.61%	1.55%	1.43%	1.56%	1.67%
Chemistry	5.28%	5.10%	4.97%	4.83%	4.72%	4.61%	4.53%	4.43%	4.38%	4.29%	4.18%
Physics	7.63%	7.48%	7.36%	7.05%	6.74%	6.50%	6.34%	6.28%	6.15%	6.09%	5.89%
Atmospheric Sciences	1.54%	1.51%	1.45%	1.44%	1.45%	1.44%	1.41%	1.42%	1.48%	1.51%	1.49%
Earth Sciences	2.35%	2.35%	2.38%	2.35%	2.36%	2.33%	2.30%	2.20%	2.19%	2.20%	2.20%
Oceanography	3.16%	3.04%	3.00%	3.01%	3.01%	2.92%	2.89%	2.86%	2.82%	2.74%	2.70%
Mathematics and Statistics	1.95%	1.89%	1.85%	1.87%	1.86%	1.82%	1.75%	1.66%	1.62%	1.53%	1.49%
Computer Science	3.96%	4.00%	3.94%	3.94%	3.96%	4.05%	4.08%	4.03%	3.94%	3.92%	3.82%
Agricultural Sciences	4.26%	4.18%	4.14%	4.18%	4.27%	4.36%	4.47%	4.43%	4.25%	3.99%	3.77%
Biological Sciences	21.54%	21.35%	21.37%	21.47%	21.61%	21.42%	21.06%	20.83%	21.05%	21.60%	22.28%
Medical Sciences	30.61%	30.96%	31.10%	31.31%	31.44%	31.73%	32.10%	32.63%	33.08%	33.35%	33.76%
Psychology	1.90%	1.94%	2.03%	2.13%	2.17%	2.14%	2.11%	2.11%	2.14%	2.15%	2.18%
Economics	0.66%	0.65%	0.65%	0.68%	0.69%	0.69%	0.70%	0.70%	0.71%	0.67%	0.62%
Political Science and Public Administration	0.32%	0.31%	0.32%	0.35%	0.40%	0.45%	0.48%	0.47%	0.43%	0.39%	0.39%
Sociology	0.67%	0.72%	0.77%	0.82%	0.84%	0.86%	0.90%	0.93%	0.93%	0.89%	0.86%

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	1.30%	1.31%	1.38%	1.33%	1.33%	1.22%	1.19%	1.24%	1.38%	1.45%	1.45%
Chemical Engineering	1.24%	1.22%	1.17%	1.12%	1.10%	1.12%	1.16%	1.19%	1.21%	1.25%	1.31%
Civil Engineering	1.50%	1.52%	1.51%	1.46%	1.38%	1.30%	1.27%	1.30%	1.35%	1.39%	1.45%
Electrical Engineering	4.36%	4.26%	4.17%	4.07%	4.00%	3.94%	3.94%	3.93%	3.99%	4.10%	4.21%
Mechanical Engineering	2.50%	2.47%	2.46%	2.44%	2.37%	2.42%	2.48%	2.56%	2.64%	2.77%	2.87%
Materials Engineering	1.44%	1.39%	1.38%	1.38%	1.41%	1.41%	1.40%	1.38%	1.35%	1.33%	1.32%
Astronomy	1.71%	1.55%	1.38%	1.26%	1.19%	1.17%	1.15%	1.18%	1.23%	1.28%	1.24%
Chemistry	4.01%	3.85%	3.74%	3.70%	3.66%	3.62%	3.58%	3.55%	3.55%	3.59%	3.59%
Physics	5.67%	5.33%	5.06%	4.84%	4.74%	4.60%	4.52%	4.41%	4.48%	4.60%	4.72%
Atmospheric Sciences	1.43%	1.34%	1.32%	1.30%	1.33%	1.38%	1.39%	1.33%	1.20%	1.12%	1.08%
Earth Sciences	2.07%	1.96%	1.92%	2.00%	2.15%	2.22%	2.23%	2.17%	2.18%	2.21%	2.25%
Oceanography	2.68%	2.58%	2.49%	2.36%	2.22%	2.11%	2.19%	2.32%	2.44%	2.31%	2.16%
Mathematics and Statistics	1.43%	1.40%	1.36%	1.32%	1.30%	1.32%	1.39%	1.49%	1.45%	1.38%	1.28%
Computer Science	3.80%	3.77%	3.94%	4.07%	4.06%	3.91%	3.79%	3.72%	3.74%	3.70%	3.69%
Agricultural Sciences	3.65%	3.57%	3.50%	3.47%	3.37%	3.31%	3.24%	3.20%	3.10%	2.99%	2.95%
Biological Sciences	22.54%	22.65%	22.46%	22.67%	23.01%	23.16%	23.02%	22.73%	22.63%	22.89%	23.11%
Medical Sciences	34.63%	35.71%	36.59%	37.08%	37.37%	37.85%	38.15%	38.39%	38.22%	37.78%	37.48%
Psychology	2.21%	2.31%	2.40%	2.42%	2.38%	2.32%	2.28%	2.26%	2.24%	2.28%	2.30%
Economics	0.57%	0.53%	0.50%	0.47%	0.44%	0.43%	0.44%	0.45%	0.44%	0.42%	0.41%
Political Science and Public Administration	0.40%	0.41%	0.42%	0.43%	0.44%	0.42%	0.44%	0.44%	0.47%	0.46%	0.45%
Sociology	0.85%	0.88%	0.86%	0.81%	0.76%	0.75%	0.76%	0.76%	0.72%	0.70%	0.68%

APPENDIX J: ROLLING PERCENTAGE OF CHANGE IN MARKET

These two pages contain the percent change by year for the federally funded academic R&D from the years 1990 through 2011.

Rolling % Change in Market Spending is a 3-year average (lag, not centered) of the % change in Institutional spending.

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aerospace Engineering	2.61%	0.66%	0.17%	-0.82%	-0.87%	-3.29%	-3.49%	-5.55%	-1.26%
Chemical Engineering	1.83%	1.21%	1.70%	1.77%	0.92%	-0.71%	-2.74%	-2.90%	-2.00%
Civil Engineering	2.07%	3.08%	2.49%	2.96%	2.90%	1.03%	-0.90%	-2.14%	-0.71%
Electrical Engineering	-1.75%	-3.21%	-2.44%	0.73%	2.92%	3.91%	1.40%	-0.91%	-4.15%
Mechanical Engineering	1.40%	1.59%	1.89%	0.47%	-1.75%	-3.40%	-2.86%	-1.82%	-1.48%
Materials Engineering	-4.61%	-5.90%	-3.24%	-0.66%	4.20%	4.81%	3.14%	-1.56%	-4.24%
Astronomy	9.22%	6.60%	3.69%	1.42%	-0.72%	-4.27%	-0.78%	2.81%	5.66%
Chemistry	-2.90%	-2.50%	-2.46%	-2.08%	-2.06%	-1.69%	-1.76%	-1.96%	-2.91%
Physics	-2.59%	-3.43%	-4.04%	-3.45%	-2.29%	-1.84%	-1.34%	-2.13%	-2.73%
Atmospheric Sciences	-2.20%	-1.18%	-0.16%	-0.70%	-0.62%	1.00%	2.34%	1.54%	-1.22%
Earth Sciences	0.07%	0.19%	-0.68%	-0.77%	-2.46%	-2.04%	-1.34%	0.01%	-2.08%
Oceanography	-1.42%	-0.22%	-0.98%	-1.41%	-1.69%	-1.12%	-1.75%	-1.86%	-1.67%
Mathematics and Statistics	-1.24%	-0.51%	-0.73%	-2.25%	-3.57%	-3.83%	-4.24%	-3.66%	-3.98%
Computer Science	-0.13%	-0.28%	0.90%	1.16%	0.52%	-0.95%	-1.36%	-1.79%	-1.18%
Agricultural Sciences	-0.56%	0.79%	1.75%	2.24%	1.23%	-0.90%	-3.74%	-5.25%	-4.95%
Biological Sciences	-0.04%	0.43%	0.05%	-0.68%	-1.22%	-0.54%	0.93%	2.34%	2.26%
Medical Sciences	0.77%	0.54%	0.68%	0.85%	1.26%	1.40%	1.26%	1.15%	1.62%
Psychology	4.06%	3.67%	1.67%	-0.35%	-0.91%	0.02%	0.64%	1.16%	1.18%
Economics	1.39%	2.00%	2.10%	0.75%	0.73%	0.66%	-1.49%	-4.19%	-7.08%
Political Science and Public Administration	4.29%	9.44%	12.05%	10.54%	5.15%	-1.31%	-6.92%	-6.43%	-2.76%
Sociology	7.03%	5.51%	3.82%	3.18%	3.30%	2.36%	-0.66%	-2.60%	-2.72%

Rolling % Change in Market Spending is a 3-year average (lag, not centered) of the % change in Institutional spending.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	-0.27%	3.96%	0.63%	0.54%	-3.93%	-3.76%	-2.33%	4.49%	6.73%	4.98%
Chemical Engineering	-1.20%	-1.93%	-3.41%	-3.18%	-1.27%	1.31%	2.58%	2.39%	2.59%	3.49%
Civil Engineering	0.35%	0.51%	-1.11%	-3.21%	-4.72%	-4.51%	-1.83%	1.27%	3.07%	3.70%
Electrical Engineering	-4.04%	-3.63%	-2.32%	-2.03%	-1.83%	-0.98%	-0.53%	0.38%	1.44%	2.35%
Mechanical Engineering	-1.56%	-1.26%	-0.79%	-1.40%	-0.50%	0.69%	2.64%	2.93%	3.88%	3.91%
Materials Engineering	-5.15%	-3.14%	-1.18%	0.55%	0.77%	0.29%	-0.62%	-1.43%	-1.63%	-1.62%
Astronomy	-0.65%	-6.33%	-9.63%	-8.60%	-5.17%	-2.76%	-0.11%	1.90%	3.47%	1.59%
Chemistry	-3.63%	-3.63%	-2.59%	-1.62%	-1.07%	-1.13%	-0.98%	-0.66%	0.21%	0.38%
Physics	-4.42%	-5.00%	-5.15%	-3.80%	-3.03%	-2.16%	-2.28%	-0.87%	0.63%	2.30%
Atmospheric Sciences	-3.98%	-4.07%	-3.09%	-0.16%	1.75%	2.20%	-0.08%	-4.63%	-7.01%	-6.88%
Earth Sciences	-3.94%	-4.40%	-0.78%	3.59%	4.94%	3.48%	0.14%	-0.57%	-0.35%	1.15%
Oceanography	-2.14%	-2.77%	-4.27%	-4.81%	-5.36%	-2.25%	1.63%	5.09%	1.51%	-2.42%
Mathematics and Statistics	-2.91%	-2.99%	-2.71%	-2.46%	-0.89%	2.00%	4.64%	2.92%	-0.46%	-4.74%
Computer Science	-1.20%	1.26%	2.47%	2.28%	-0.50%	-2.44%	-2.76%	-1.41%	-0.79%	-0.39%
Agricultural Sciences	-3.59%	-2.50%	-1.69%	-1.95%	-1.82%	-2.23%	-1.69%	-2.14%	-2.65%	-2.64%
Biological Sciences	1.52%	0.21%	0.22%	0.59%	1.03%	0.47%	-0.45%	-0.77%	-0.15%	0.59%
Medical Sciences	2.40%	2.73%	2.24%	1.46%	1.11%	0.93%	0.88%	0.31%	-0.35%	-0.81%
Psychology	2.55%	3.37%	2.78%	0.79%	-1.15%	-1.94%	-1.68%	-1.28%	0.13%	0.64%
Economics	-7.44%	-6.89%	-5.83%	-5.81%	-4.85%	-2.56%	0.73%	0.77%	-1.26%	-2.90%
Political Science and Public Administration	1.69%	2.90%	2.64%	2.19%	0.04%	0.46%	0.56%	3.60%	1.86%	0.64%
Sociology	-0.22%	-0.19%	-1.85%	-4.90%	-4.17%	-1.93%	0.13%	-1.42%	-2.63%	-3.50%

APPENDIX K: *EMS*, ROLLING

These 3 pages contain the Equalized value of the Market Share from the rolling averages dataset for academic research federally funded R&D provided by government sources.

	Equalized Value of % Market Spending (EMS) by year						
	1990	1991	1992	1993	1994	1995	1996
Aerospace Engineering	0.045	0.047	0.048	0.048	0.048	0.047	0.046
Chemical Engineering	0.040	0.041	0.041	0.041	0.042	0.042	0.043
Civil Engineering	0.043	0.043	0.045	0.045	0.046	0.047	0.048
Electrical Engineering	0.156	0.156	0.153	0.144	0.140	0.139	0.143
Mechanical Engineering	0.087	0.088	0.088	0.089	0.090	0.091	0.088
Materials Engineering	0.057	0.055	0.050	0.048	0.045	0.045	0.046
Astronomy	0.039	0.042	0.047	0.049	0.050	0.052	0.050
Chemistry	0.172	0.164	0.159	0.154	0.150	0.145	0.141
Physics	0.249	0.242	0.236	0.225	0.214	0.205	0.197
Atmospheric Sciences	0.050	0.049	0.046	0.046	0.046	0.045	0.044
Earth Sciences	0.077	0.076	0.077	0.075	0.075	0.074	0.071
Oceanography	0.103	0.098	0.096	0.096	0.096	0.092	0.090
Mathematics and Statistics	0.063	0.061	0.060	0.060	0.059	0.057	0.054
Computer Science	0.129	0.129	0.127	0.126	0.126	0.128	0.127
Agricultural Sciences	0.139	0.135	0.133	0.134	0.136	0.137	0.139
Biological Sciences	0.703	0.690	0.687	0.686	0.687	0.674	0.655
Medical Sciences	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Psychology	0.062	0.063	0.065	0.068	0.069	0.067	0.066
Economics	0.021	0.021	0.021	0.022	0.022	0.022	0.022
Political Science and Public Administration	0.010	0.010	0.010	0.011	0.013	0.014	0.015
Sociology	0.022	0.023	0.025	0.026	0.027	0.027	0.028

	Equalized Value of % Market Spending (EMS) by year						
	1997	1998	1999	2000	2001	2002	2003
Aerospace Engineering	0.045	0.041	0.040	0.036	0.038	0.037	0.038
Chemical Engineering	0.041	0.040	0.038	0.037	0.036	0.034	0.032
Civil Engineering	0.048	0.046	0.045	0.044	0.043	0.042	0.041
Electrical Engineering	0.146	0.150	0.144	0.138	0.125	0.119	0.114
Mechanical Engineering	0.083	0.079	0.078	0.076	0.072	0.069	0.067
Materials Engineering	0.049	0.050	0.049	0.045	0.041	0.039	0.038
Astronomy	0.047	0.043	0.047	0.050	0.049	0.043	0.037
Chemistry	0.136	0.132	0.129	0.124	0.115	0.107	0.102
Physics	0.192	0.186	0.182	0.174	0.163	0.148	0.138
Atmospheric Sciences	0.044	0.045	0.045	0.044	0.041	0.037	0.036
Earth Sciences	0.067	0.066	0.066	0.065	0.059	0.055	0.052
Oceanography	0.088	0.085	0.082	0.080	0.077	0.072	0.068
Mathematics and Statistics	0.051	0.049	0.046	0.044	0.041	0.039	0.037
Computer Science	0.124	0.119	0.117	0.113	0.109	0.106	0.108
Agricultural Sciences	0.136	0.128	0.119	0.112	0.105	0.100	0.095
Biological Sciences	0.638	0.637	0.648	0.661	0.649	0.632	0.613
Medical Sciences	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Psychology	0.065	0.065	0.065	0.065	0.064	0.065	0.066
Economics	0.022	0.021	0.020	0.018	0.016	0.015	0.014
Political Science and Public Administration	0.014	0.013	0.012	0.011	0.011	0.011	0.012
Sociology	0.029	0.028	0.027	0.025	0.025	0.025	0.023

	Equalized Value of % Market Spending (EMS) by year							
	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	0.036	0.036	0.032	0.031	0.032	0.036	0.038	0.039
Chemical Engineering	0.030	0.029	0.030	0.030	0.031	0.032	0.033	0.035
Civil Engineering	0.039	0.037	0.034	0.033	0.034	0.035	0.037	0.039
Electrical Engineering	0.109	0.107	0.104	0.103	0.103	0.104	0.109	0.113
Mechanical Engineering	0.066	0.063	0.064	0.065	0.067	0.069	0.074	0.077
Materials Engineering	0.037	0.038	0.037	0.037	0.036	0.035	0.035	0.035
Astronomy	0.034	0.032	0.031	0.030	0.031	0.032	0.034	0.033
Chemistry	0.100	0.098	0.096	0.094	0.092	0.093	0.095	0.096
Physics	0.130	0.126	0.121	0.118	0.115	0.117	0.122	0.126
Atmospheric Sciences	0.035	0.036	0.037	0.036	0.035	0.031	0.029	0.029
Earth Sciences	0.054	0.058	0.059	0.059	0.057	0.057	0.059	0.060
Oceanography	0.063	0.059	0.056	0.058	0.060	0.064	0.061	0.057
Mathematics and Statistics	0.035	0.035	0.035	0.037	0.039	0.038	0.036	0.034
Computer Science	0.110	0.108	0.103	0.099	0.097	0.098	0.098	0.098
Agricultural Sciences	0.093	0.090	0.087	0.085	0.083	0.081	0.079	0.079
Biological Sciences	0.611	0.616	0.612	0.603	0.592	0.592	0.607	0.617
Medical Sciences	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Psychology	0.065	0.064	0.061	0.060	0.059	0.059	0.060	0.061
Economics	0.013	0.012	0.011	0.011	0.012	0.012	0.011	0.011
Political Science and Public Administration	0.012	0.012	0.011	0.011	0.012	0.012	0.012	0.012
Sociology	0.022	0.020	0.020	0.020	0.020	0.019	0.019	0.018

APPENDIX L: *ΔEMS*, ROLLING

These two pages present the Equalized value of the Yearly Change in Market Share (ΔEMS)

	Equalized Value of Change in share of spending (ΔEMS) by year								
	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aerospace Engineering	0.283	0.070	0.014	-0.078	-0.168	-0.685	-1.113	-1.976	-0.222
Chemical Engineering	0.199	0.128	0.141	0.168	0.178	-0.149	-0.873	-1.032	-0.354
Civil Engineering	0.225	0.326	0.207	0.281	0.563	0.215	-0.288	-0.761	-0.126
Electrical Engineering	-0.189	-0.340	-0.203	0.070	0.567	0.813	0.446	-0.324	-0.734
Mechanical Engineering	0.152	0.168	0.156	0.045	-0.340	-0.707	-0.913	-0.648	-0.262
Materials Engineering	-0.500	-0.625	-0.269	-0.063	0.815	1.000	1.000	-0.555	-0.749
Astronomy	1.000	0.699	0.306	0.135	-0.139	-0.889	-0.249	1.000	1.000
Chemistry	-0.315	-0.264	-0.204	-0.197	-0.400	-0.351	-0.561	-0.699	-0.514
Physics	-0.281	-0.363	-0.335	-0.327	-0.445	-0.384	-0.429	-0.760	-0.482
Atmospheric Sciences	-0.239	-0.125	-0.013	-0.066	-0.121	0.208	0.746	0.549	-0.215
Earth Sciences	0.007	0.020	-0.057	-0.074	-0.478	-0.424	-0.427	0.003	-0.367
Oceanography	-0.154	-0.024	-0.081	-0.134	-0.329	-0.233	-0.558	-0.663	-0.295
Mathematics and Statistics	-0.135	-0.054	-0.060	-0.214	-0.694	-0.797	-1.353	-1.303	-0.703
Computer Science	-0.015	-0.030	0.074	0.110	0.100	-0.198	-0.433	-0.638	-0.209
Agricultural Sciences	-0.061	0.084	0.145	0.213	0.239	-0.188	-1.192	-1.869	-0.873
Biological Sciences	-0.004	0.045	0.004	-0.064	-0.236	-0.112	0.296	0.835	0.400
Medical Sciences	0.083	0.057	0.056	0.080	0.245	0.292	0.403	0.408	0.285
Psychology	0.440	0.389	0.138	-0.033	-0.177	0.005	0.204	0.412	0.209
Economics	0.151	0.212	0.174	0.071	0.142	0.137	-0.476	-1.493	-1.250
Political Science and Public Administration	0.466	1.000	1.000	1.000	1.000	-0.273	-2.205	-2.289	-0.488
Sociology	0.762	0.583	0.317	0.302	0.640	0.491	-0.212	-0.926	-0.481

	Equalized Value of Change in share of spending (ΔEMS) by year									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	-0.105	1.000	0.227	0.149	-0.797	-1.081	-0.501	0.881	1.000	1.000
Chemical Engineering	-0.470	-0.486	-1.227	-0.885	-0.257	0.378	0.556	0.468	0.385	0.701
Civil Engineering	0.138	0.130	-0.398	-0.894	-0.955	-1.297	-0.395	0.250	0.456	0.742
Electrical Engineering	-1.583	-0.916	-0.836	-0.564	-0.370	-0.281	-0.114	0.075	0.213	0.473
Mechanical Engineering	-0.613	-0.319	-0.283	-0.390	-0.101	0.197	0.568	0.576	0.576	0.785
Materials Engineering	-2.018	-0.792	-0.425	0.154	0.156	0.084	-0.133	-0.282	-0.242	-0.325
Astronomy	-0.253	-1.598	-3.463	-2.392	-1.047	-0.795	-0.024	0.374	0.516	0.319
Chemistry	-1.424	-0.915	-0.931	-0.451	-0.218	-0.325	-0.212	-0.129	0.031	0.076
Physics	-1.731	-1.263	-1.852	-1.056	-0.615	-0.622	-0.492	-0.170	0.094	0.461
Atmospheric Sciences	-1.559	-1.028	-1.111	-0.044	0.355	0.633	-0.017	-0.909	-1.041	-1.380
Earth Sciences	-1.544	-1.110	-0.279	1.000	1.000	1.000	0.030	-0.112	-0.052	0.231
Oceanography	-0.839	-0.700	-1.535	-1.339	-1.087	-0.648	0.351	1.000	0.224	-0.485
Mathematics and Statistics	-1.140	-0.755	-0.974	-0.684	-0.180	0.574	1.000	0.574	-0.068	-0.951
Computer Science	-0.470	0.317	0.889	0.635	-0.101	-0.702	-0.595	-0.277	-0.117	-0.077
Agricultural Sciences	-1.406	-0.632	-0.608	-0.543	-0.369	-0.641	-0.364	-0.420	-0.394	-0.529
Biological Sciences	0.596	0.053	0.079	0.165	0.209	0.134	-0.097	-0.152	-0.022	0.118
Medical Sciences	0.939	0.688	0.805	0.405	0.225	0.267	0.189	0.061	-0.053	-0.162
Psychology	1.000	0.851	1.000	0.220	-0.234	-0.557	-0.362	-0.252	0.020	0.128
Economics	-2.916	-1.741	-2.098	-1.616	-0.983	-0.735	0.158	0.152	-0.187	-0.582
Political Science and Public Administration	0.664	0.733	0.950	0.610	0.009	0.132	0.122	0.707	0.277	0.128
Sociology	-0.085	-0.047	-0.665	-1.364	-0.845	-0.554	0.027	-0.278	-0.390	-0.702

APPENDIX M: *MSI*, ROLLING

These two pages present the Market Strategic Indicator (MSI) for the federal funded academic R&D from 1993 through 2011 using data from Appendices K and L.

	Market Strategic Indicator (MSI) by Year								
	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aerospace Engineering	0.328	0.117	0.062	-0.030	-0.120	-0.638	-1.067	-1.931	-0.181
Chemical Engineering	0.239	0.169	0.182	0.209	0.220	-0.106	-0.830	-0.991	-0.314
Civil Engineering	0.268	0.368	0.251	0.326	0.609	0.262	-0.240	-0.713	-0.079
Electrical Engineering	-0.034	-0.183	-0.050	0.214	0.706	0.952	0.590	-0.177	-0.584
Mechanical Engineering	0.239	0.256	0.244	0.134	-0.250	-0.616	-0.825	-0.566	-0.183
Materials Engineering	-0.443	-0.571	-0.219	-0.015	0.860	1.045	1.046	-0.507	-0.699
Astronomy	1.039	0.741	0.353	0.184	-0.089	-0.838	-0.199	1.047	1.043
Chemistry	-0.143	-0.100	-0.044	-0.043	-0.250	-0.206	-0.420	-0.563	-0.382
Physics	-0.032	-0.122	-0.099	-0.102	-0.231	-0.179	-0.231	-0.568	-0.297
Atmospheric Sciences	-0.189	-0.076	0.033	-0.020	-0.075	0.254	0.790	0.593	-0.170
Earth Sciences	0.084	0.096	0.020	0.002	-0.402	-0.351	-0.356	0.070	-0.301
Oceanography	-0.051	0.074	0.015	-0.037	-0.233	-0.141	-0.468	-0.575	-0.210
Mathematics and Statistics	-0.072	0.007	-0.001	-0.154	-0.635	-0.740	-1.298	-1.252	-0.654
Computer Science	0.115	0.099	0.201	0.236	0.227	-0.071	-0.305	-0.514	-0.090
Agricultural Sciences	0.078	0.219	0.278	0.346	0.375	-0.050	-1.053	-1.733	-0.745
Biological Sciences	0.698	0.735	0.691	0.621	0.451	0.563	0.951	1.473	1.036
Medical Sciences	1.083	1.057	1.056	1.080	1.245	1.292	1.403	1.408	1.285
Psychology	0.502	0.452	0.204	0.035	-0.108	0.072	0.269	0.476	0.274
Economics	0.172	0.233	0.195	0.093	0.164	0.158	-0.454	-1.471	-1.229
Political Science and Public Administration	0.476	1.010	1.010	1.011	1.013	-0.259	-2.190	-2.275	-0.475

Sociology	0.784	0.606	0.342	0.328	0.667	0.518	-0.184	-0.898	-0.453

	Market Strategic Indicator by Year									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	-0.066	1.036	0.265	0.186	-0.760	-1.045	-0.466	0.913	1.031	1.032
Chemical Engineering	-0.433	-0.449	-1.192	-0.851	-0.225	0.408	0.586	0.498	0.415	0.732
Civil Engineering	0.183	0.174	-0.355	-0.852	-0.914	-1.258	-0.359	0.284	0.489	0.776
Electrical Engineering	-1.439	-0.778	-0.710	-0.445	-0.257	-0.172	-0.007	0.180	0.317	0.575
Mechanical Engineering	-0.535	-0.244	-0.212	-0.321	-0.034	0.263	0.632	0.640	0.641	0.852
Materials Engineering	-1.969	-0.747	-0.383	0.192	0.194	0.121	-0.096	-0.244	-0.205	-0.289
Astronomy	-0.206	-1.549	-3.414	-2.349	-1.010	-0.762	0.007	0.405	0.546	0.350
Chemistry	-1.295	-0.792	-0.816	-0.343	-0.115	-0.225	-0.114	-0.033	0.125	0.169
Physics	-1.549	-1.088	-1.689	-0.908	-0.477	-0.492	-0.365	-0.049	0.212	0.576
Atmospheric Sciences	-1.514	-0.984	-1.070	-0.006	0.391	0.668	0.018	-0.872	-1.004	-1.346
Earth Sciences	-1.478	-1.045	-0.219	1.055	1.052	1.054	0.088	-0.054	0.006	0.288
Oceanography	-0.757	-0.620	-1.458	-1.268	-1.019	-0.584	0.411	1.056	0.281	-0.425
Mathematics and Statistics	-1.094	-0.711	-0.933	-0.644	-0.143	0.610	1.035	0.609	-0.032	-0.912
Computer Science	-0.352	0.430	0.999	0.741	0.008	-0.592	-0.487	-0.174	-0.017	0.020
Agricultural Sciences	-1.287	-0.521	-0.503	-0.443	-0.273	-0.548	-0.274	-0.333	-0.309	-0.446
Biological Sciences	1.244	0.714	0.728	0.797	0.822	0.746	0.520	0.460	0.581	0.710
Medical Sciences	1.939	1.688	1.805	1.405	1.225	1.267	1.189	1.061	0.947	0.838
Psychology	1.065	0.916	1.064	0.285	-0.168	-0.492	-0.299	-0.190	0.079	0.187
Economics	-2.897	-1.723	-2.082	-1.601	-0.969	-0.723	0.169	0.163	-0.175	-0.570
Political Science and Public Administration	0.675	0.744	0.961	0.621	0.020	0.143	0.133	0.718	0.288	0.140
Sociology	-0.058	-0.022	-0.641	-1.340	-0.822	-0.532	0.047	-0.258	-0.370	-0.682

APPENDIX N: UCF ROLLING AVERAGE INSTITUTIONAL SPENDING

These three pages contain the rolling average for the University of Central Florida federally financed R&D for the years 1990 through 2011. As discussed in the definition, rolling 1990 is the average value from 1988, 1989, and 1990 and so forth for the other years.

	Institutional Spending by Year, rolling average						
	1990	1991	1992	1993	1994	1995	1996
Aerospace Engineering			$74	$148	$356	$455	$513
Civil Engineering	$145	$131	$88	$76	$222	$433	$596
Electrical Engineering	$109	$100	$105	$346	$3,410	$6,976	$10,167
Mechanical Engineering	$307	$360	$456	$538	$404	$262	$103
Materials Engineering							
Chemistry	$14	$46	$68	$97	$137	$204	$260
Physics	$145	$186	$162	$131	$1,179	$2,686	$4,094
Atmospheric Sciences	$1,672	$1,890	$683	$612	$394	$192	
Mathematics and Statistics	$9	$30	$24	$24	$18	$23	$26
Computer Science	$219	$374	$466	$591	$625	$644	$516
Biological Sciences	$96	$109	$116	$85	$108	$133	$194
Medical Sciences			$16	$38	$38	$24	$35
Psychology	$44	$156	$287	$341	$376	$474	$636
Economics					$11	$11	$11
Political Science and Public Administration							
Sociology	$22	$16	$18	$18	$38	$73	$73
Institutional Spending Total	$3,450	$4,566	$4,168	$5,062	$8,833	$13,357	$17,224

Dollar amounts are in thousands.

	Institutional Spending by Year, rolling average						
	1997	1998	1999	2000	2001	2002	2003
Aerospace Engineering	$304	$163	$143	$236	$375	$908	$1,129
Civil Engineering	$501	$451	$383	$491	$528	$660	$1,359
Electrical Engineering	$7,118	$3,623	$393	$563	$730	$735	$1,618
Mechanical Engineering	$280	$402	$588	$658	$744	$737	$764
Materials Engineering			$34	$80	$185	$273	$429
Chemistry	$222	$247	$395	$636	$931	$1,213	$2,235
Physics	$4,406	$4,184	$3,791	$3,128	$3,186	$3,997	$6,096
Atmospheric Sciences	$440	$1,146	$1,952	$2,027	$2,255	$2,630	$4,573
Mathematics and Statistics	$17	$15	$23	$29	$37	$56	$114
Computer Science	$477	$340	$312	$266	$307	$287	$180
Biological Sciences	$230	$232	$290	$396	$651	$910	$1,476
Medical Sciences	$46	$57	$84	$94	$176	$402	$822
Psychology	$680	$534	$460	$548	$842	$1,249	$1,757
Economics				$20	$49	$99	$168
Political Science and Public Administration	$15	$34	$34	$25	$18	$32	$49
Sociology	$628	$972	$1,230	$801	$774	$722	$857
Institutional Spending Total	$15,363	$12,400	$10,111	$9,997	$11,789	$14,907	$23,628

Dollar amounts are in thousands.

	Institutional Spending by Year, rolling average							
	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	$1,300	$1,179	$1,181	$1,313	$1,505	$2,004	$1,801	$1,297
Civil Engineering	$1,403	$1,497	$816	$1,058	$1,072	$1,219	$1,374	$1,371
Electrical Engineering	$2,447	$3,185	$2,852	$2,881	$2,859	$3,397	$3,867	$4,710
Mechanical Engineering	$723	$746	$728	$1,088	$2,126	$2,419	$2,242	$1,558
Materials Engineering	$609	$665	$589	$540	$775	$1,063	$1,336	$1,445
Chemistry	$2,396	$2,350	$1,336	$1,345	$1,398	$2,020	$2,891	$3,455
Physics	$9,188	$10,471	$10,496	$9,504	$9,498	$10,043	$10,765	$11,130
Atmospheric Sciences	$5,709	$7,053	$7,061	$7,690	$7,497	$7,457	$7,221	$7,009
Mathematics and Statistics	$162	$265	$284	$310	$272	$287	$352	$363
Computer Science	$86	$9	$31	$31	$31	$178	$263	$370
Biological Sciences	$1,997	$2,549	$2,056	$1,925	$1,562	$1,661	$1,410	$1,226
Medical Sciences	$1,257	$1,366	$1,223	$693	$503	$413	$502	$934
Psychology	$2,031	$1,955	$1,572	$1,313	$1,003	$675	$397	$471
Economics	$185	$188	$208	$226	$292	$401	$520	$768
Political Science and Public Administration	$77	$157	$292	$347	$311	$257	$288	$354
Sociology	$596	$397	$105	$66	$121	$151	$124	$101
Institutional Spending Total	$30,165	$34,032	$30,830	$30,330	$30,825	$33,647	$35,356	$36,581

Dollar amounts are in thousands.

APPENDIX O: UCF PERCENTAGE OF INSTITUTIONAL SPENDING

These two pages contain the percentage of institutional spending by discipline for the University of Central Florida for the reported years 1988 through 2011. The percentages are based on the rolling average reported in Appendix N.

	Percent of Institutional rolling average spending by year.										
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Aerospace Engineering	0.00%	0.00%	1.78%	2.92%	4.03%	3.41%	2.98%	1.98%	1.31%	1.41%	2.36%
Civil Engineering	4.20%	2.86%	2.10%	1.49%	2.52%	3.24%	3.46%	3.26%	3.64%	3.79%	4.91%
Electrical Engineering	3.16%	2.20%	2.52%	6.83%	38.60%	52.22%	59.03%	46.33%	29.22%	3.89%	5.64%
Mechanical Engineering	8.90%	7.88%	10.94%	10.63%	4.58%	1.96%	0.60%	1.82%	3.24%	5.82%	6.58%
Materials Engineering	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.33%	0.80%
Chemistry	0.40%	1.00%	1.64%	1.92%	1.55%	1.53%	1.51%	1.44%	1.99%	3.91%	6.36%
Physics	4.19%	4.08%	3.89%	2.59%	13.34%	20.11%	23.77%	28.68%	33.74%	37.49%	31.29%
Atmospheric Sciences	48.47%	41.38%	16.39%	12.09%	4.46%	1.44%	0.00%	2.86%	9.24%	19.31%	20.27%
Mathematics and Statistics	0.27%	0.65%	0.58%	0.47%	0.20%	0.17%	0.15%	0.11%	0.12%	0.22%	0.29%
Computer Science	6.35%	8.18%	11.19%	11.67%	7.07%	4.82%	2.99%	3.11%	2.74%	3.09%	2.66%
Biological Sciences	2.79%	2.39%	2.79%	1.69%	1.22%	1.00%	1.12%	1.50%	1.87%	2.86%	3.96%
Medical Sciences	0.00%	0.00%	0.39%	0.74%	0.43%	0.18%	0.21%	0.30%	0.46%	0.83%	0.94%
Psychology	1.29%	3.42%	6.89%	6.74%	4.26%	3.55%	3.69%	4.43%	4.31%	4.55%	5.48%
Economics	0.00%	0.00%	0.00%	0.00%	0.12%	0.08%	0.06%	0.00%	0.00%	0.00%	0.20%
Political Science and Public Administration	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.27%	0.33%	0.25%
Sociology	0.63%	0.36%	0.43%	0.36%	0.43%	0.54%	0.43%	4.09%	7.84%	12.16%	8.02%

Percent of Institutional rolling average spending by year.	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	3.18%	6.09%	4.78%	4.31%	3.46%	3.83%	4.33%	4.88%	5.96%	5.09%	3.55%
Civil Engineering	4.48%	4.43%	5.75%	4.65%	4.40%	2.65%	3.49%	3.48%	3.62%	3.89%	3.75%
Electrical Engineering	6.19%	4.93%	6.85%	8.11%	9.36%	9.25%	9.50%	9.28%	10.10%	10.94%	12.88%
Mechanical Engineering	6.31%	4.94%	3.23%	2.40%	2.19%	2.36%	3.59%	6.90%	7.19%	6.34%	4.26%
Materials Engineering	1.57%	1.83%	1.82%	2.02%	1.95%	1.91%	1.78%	2.51%	3.16%	3.78%	3.95%
Chemistry	7.90%	8.14%	9.46%	7.94%	6.91%	4.33%	4.43%	4.53%	6.00%	8.18%	9.44%
Physics	27.03%	26.81%	25.80%	30.46%	30.77%	34.05%	31.34%	30.81%	29.85%	30.45%	30.43%
Atmospheric Sciences	19.13%	17.64%	19.36%	18.93%	20.73%	22.90%	25.36%	24.32%	22.16%	20.42%	19.16%
Mathematics and Statistics	0.32%	0.38%	0.48%	0.54%	0.78%	0.92%	1.02%	0.88%	0.85%	1.00%	0.99%
Computer Science	2.60%	1.92%	0.76%	0.28%	0.03%	0.10%	0.10%	0.10%	0.53%	0.74%	1.01%
Biological Sciences	5.52%	6.10%	6.25%	6.62%	7.49%	6.67%	6.35%	5.07%	4.94%	3.99%	3.35%
Medical Sciences	1.49%	2.70%	3.48%	4.17%	4.01%	3.97%	2.28%	1.63%	1.23%	1.42%	2.55%
Psychology	7.14%	8.38%	7.43%	6.73%	5.74%	5.10%	4.33%	3.25%	2.01%	1.12%	1.29%
Economics	0.42%	0.66%	0.71%	0.61%	0.55%	0.67%	0.75%	0.95%	1.19%	1.47%	2.10%
Political Science and Public Administration	0.16%	0.21%	0.21%	0.25%	0.46%	0.95%	1.14%	1.01%	0.76%	0.81%	0.97%
Sociology	6.57%	4.84%	3.63%	1.97%	1.17%	0.34%	0.22%	0.39%	0.45%	0.35%	0.28%

APPENDIX P: ROLLING PERCENTAGE CHANGE IN INSTITUTIONAL SPENDING

These 2 pages contain the yearly percentage change in institutional spending for the University of Central Florida federally financed R&D for the years 1990 through 2011. As discussed in the definition, rolling change, the difference between years is 3-year average of year 2 minus the 3-year average of year 1 divided by the 3-year average of year 1. As an example the

Rolling % Change for 1997 = [Ave.(1997,1996,1995)-Ave.(1996, 1995, 1994)] / Ave.(1996,1995, 1994)

Rolling % Change in Institutional Spending is a % yearly change in the 3-year average spending

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aerospace Engineering	164.30%	85.97%	18.72%	0.57%	-19.72%	-25.07%	-24.98%	8.05%	36.79%
Civil Engineering	-29.54%	-5.33%	18.62%	27.12%	8.05%	4.00%	3.14%	15.46%	6.80%
Electrical Engineering	46.66%	315.14%	103.65%	53.44%	5.16%	-14.60%	-40.97%	-51.23%	-59.43%
Mechanical Engineering	6.26%	-11.22%	-34.32%	-58.43%	-38.59%	29.15%	92.14%	43.74%	19.60%
Materials Engineering								239.33%	138.63%
Chemistry	50.07%	12.09%	-2.15%	-8.18%	-2.36%	10.38%	48.51%	66.93%	48.17%
Physics	-13.15%	87.70%	81.83%	58.74%	26.80%	18.79%	15.92%	2.61%	-6.55%
Atmospheric Sciences	-34.24%	-52.84%	-45.39%	-67.19%	-27.10%	181.22%	159.53%	55.42%	20.26%
Mathematics and Statistics	13.09%	-26.21%	-32.99%	-37.41%	-18.10%	-11.93%	18.78%	39.53%	31.53%
Computer Science	20.68%	-3.58%	-21.27%	-36.81%	-26.63%	-19.03%	1.08%	-4.95%	-1.69%
Biological Sciences	-13.89%	-16.96%	-31.50%	-14.38%	8.21%	24.12%	38.77%	39.60%	42.04%
Medical Sciences	189.87%	38.20%	-13.36%	-39.62%	-16.65%	40.54%	65.03%	40.29%	46.38%
Psychology	47.07%	4.93%	-18.68%	-20.96%	1.47%	6.50%	6.90%	7.94%	19.75%
Economics			66.13%	30.87%	-45.99%	-56.32%	-100.00%		211.27%
Political Science and Public Administration						284.40%	90.73%	22.56%	-13.52%
Sociology	-19.22%	6.66%	9.18%	5.26%	260.44%	144.23%	94.97%	16.29%	-4.56%

The empty fields in some of the disciplines indicated were there was $0 reported federal financed expenditures in that time frame.

	Rolling % Change in Spending is a 3-year average of the % change in Institutional spending									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	67.31%	20.81%	8.03%	-17.29%	-7.54%	0.19%	12.19%	16.29%	5.04%	-8.38%
Civil Engineering	4.85%	6.09%	1.18%	-0.20%	-20.99%	-9.94%	-8.74%	10.17%	3.76%	2.47%
Electrical Engineering	6.60%	7.25%	10.67%	22.28%	9.87%	5.19%	-0.29%	3.02%	4.99%	11.88%
Mechanical Engineering	-4.67%	-18.78%	-27.00%	-26.01%	-11.16%	17.13%	57.83%	37.60%	15.58%	-12.92%
Materials Engineering	55.65%	24.31%	8.67%	2.13%	1.61%	-4.04%	9.90%	20.14%	26.79%	15.20%
Chemistry	23.29%	13.85%	0.17%	-4.82%	-21.09%	-18.30%	-15.13%	12.56%	25.01%	26.23%
Physics	-11.15%	-6.44%	4.31%	4.76%	9.47%	0.92%	0.05%	-4.36%	-0.96%	-0.43%
Atmospheric Sciences	-2.84%	-1.61%	-0.37%	5.52%	6.01%	10.28%	5.21%	-1.02%	-6.86%	-7.71%
Mathematics and Statistics	18.57%	20.09%	18.79%	28.63%	24.34%	21.56%	3.77%	-2.49%	-0.92%	4.10%
Computer Science	-13.96%	-26.46%	-43.84%	-63.92%	-61.73%	-44.34%	32.91%	141.59%	87.56%	66.27%
Biological Sciences	26.22%	14.65%	6.12%	7.30%	2.07%	-1.31%	-11.81%	-9.58%	-14.43%	-12.28%
Medical Sciences	57.23%	49.59%	34.86%	12.75%	4.19%	-15.49%	-23.21%	-34.75%	-16.78%	21.52%
Psychology	22.28%	9.30%	-1.78%	-11.67%	-11.73%	-13.68%	-16.41%	-24.38%	-33.44%	-30.80%
Economics	108.09%	40.36%	11.05%	-5.51%	-2.00%	7.23%	19.97%	21.94%	25.14%	31.96%
Political Science and Public Administration	-16.25%	-7.18%	17.11%	37.00%	79.80%	53.43%	21.42%	-5.88%	-11.26%	-1.63%
Sociology	-27.37%	-22.60%	-30.54%	-35.18%	-48.53%	-50.47%	-44.91%	11.37%	12.77%	-9.68%

APPENDIX Q: UCF *EIS*, ROLLING

These two pages present the equalized institutional spending for the University of Central Florida from the years 1990 through 2011.

	Equalized Value of % Institutional Spending (EIS) by year										
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Aerospace Engineering	0.000	0.000	0.046	0.073	0.105	0.065	0.050	0.043	0.039	0.038	0.075
Civil Engineering	0.087	0.069	0.055	0.038	0.065	0.062	0.059	0.070	0.108	0.101	0.157
Electrical Engineering	0.065	0.053	0.066	0.171	1.000	1.000	1.000	1.000	0.866	0.104	0.180
Mechanical Engineering	0.184	0.191	0.284	0.267	0.119	0.038	0.010	0.039	0.096	0.155	0.210
Materials Engineering	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.025
Chemistry	0.008	0.024	0.043	0.048	0.040	0.029	0.026	0.031	0.059	0.104	0.203
Physics	0.087	0.099	0.101	0.065	0.346	0.385	0.403	0.619	1.000	1.000	1.000
Atmospheric Sciences	1.000	1.000	0.426	0.303	0.116	0.028	0.000	0.062	0.274	0.515	0.648
Mathematics and Statistics	0.006	0.016	0.015	0.012	0.005	0.003	0.003	0.002	0.004	0.006	0.009
Computer Science	0.131	0.198	0.291	0.293	0.183	0.092	0.051	0.067	0.081	0.082	0.085
Biological Sciences	0.058	0.058	0.073	0.042	0.032	0.019	0.019	0.032	0.055	0.076	0.127
Medical Sciences	0.000	0.000	0.010	0.019	0.011	0.003	0.003	0.006	0.014	0.022	0.030
Psychology	0.027	0.083	0.179	0.169	0.110	0.068	0.063	0.096	0.128	0.121	0.175
Economics	0.000	0.000	0.000	0.000	0.003	0.002	0.001	0.000	0.000	0.000	0.006
Political Science and Public Administration	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.008	0.009	0.008
Sociology	0.013	0.009	0.011	0.009	0.011	0.010	0.007	0.088	0.232	0.324	0.256

	Equalized Value of % Institutional Spending (EIS) by year										
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	0.118	0.227	0.185	0.141	0.113	0.113	0.138	0.158	0.200	0.167	0.117
Civil Engineering	0.166	0.165	0.223	0.153	0.143	0.078	0.111	0.113	0.121	0.128	0.123
Electrical Engineering	0.229	0.184	0.265	0.266	0.304	0.272	0.303	0.301	0.338	0.359	0.423
Mechanical Engineering	0.233	0.184	0.125	0.079	0.071	0.069	0.115	0.224	0.241	0.208	0.140
Materials Engineering	0.058	0.068	0.070	0.066	0.064	0.056	0.057	0.082	0.106	0.124	0.130
Chemistry	0.292	0.304	0.367	0.261	0.224	0.127	0.141	0.147	0.201	0.269	0.310
Physics	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Atmospheric Sciences	0.708	0.658	0.750	0.621	0.674	0.673	0.809	0.789	0.743	0.671	0.630
Mathematics and Statistics	0.012	0.014	0.019	0.018	0.025	0.027	0.033	0.029	0.029	0.033	0.033
Computer Science	0.096	0.072	0.030	0.009	0.001	0.003	0.003	0.003	0.018	0.024	0.033
Biological Sciences	0.204	0.228	0.242	0.217	0.243	0.196	0.203	0.164	0.165	0.131	0.110
Medical Sciences	0.055	0.101	0.135	0.137	0.130	0.117	0.073	0.053	0.041	0.047	0.084
Psychology	0.264	0.312	0.288	0.221	0.187	0.150	0.138	0.106	0.067	0.037	0.042
Economics	0.015	0.025	0.028	0.020	0.018	0.020	0.024	0.031	0.040	0.048	0.069
Political Science and Public Administration	0.006	0.008	0.008	0.008	0.015	0.028	0.036	0.033	0.026	0.027	0.032
Sociology	0.243	0.181	0.141	0.065	0.038	0.010	0.007	0.013	0.015	0.012	0.009

APPENDIX R: UCF *ΔEIS*, ROLLING

These two pages contain the equalized value of yearly change in institutional spending (ΔEIS) for the University of Central Florida from the years 1993 through 2011.

	Equalized Value of Change in share of spending (ΔEIS) by year								
	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aerospace Engineering	0.865	0.273	0.181	0.010	-0.076	-0.088	-0.157	0.034	0.174
Civil Engineering	-0.156	-0.017	0.180	0.462	0.031	0.014	0.020	0.065	0.032
Electrical Engineering	0.246	1.000	1.000	0.910	0.020	-0.051	-0.257	-0.214	-0.281
Mechanical Engineering	0.033	-0.036	-0.331	-0.995	-0.148	0.102	0.578	0.183	0.093
Materials Engineering								1.000	0.656
Chemistry	0.264	0.038	-0.021	-0.139	-0.009	0.036	0.304	0.280	0.228
Physics	-0.069	0.278	0.789	1.000	0.103	0.066	0.100	0.011	-0.031
Atmospheric Sciences	-0.180	-0.168	-0.438	-1.144	-0.104	0.637	1.000	0.232	0.096
Mathematics and Statistics	0.069	-0.083	-0.318	-0.637	-0.070	-0.042	0.118	0.165	0.149
Computer Science	0.109	-0.011	-0.205	-0.627	-0.102	-0.067	0.007	-0.021	-0.008
Biological Sciences	-0.073	-0.054	-0.304	-0.245	0.032	0.085	0.243	0.165	0.199
Medical Sciences	1.000	0.121	-0.129	-0.675	-0.064	0.143	0.408	0.168	0.220
Psychology	0.248	0.016	-0.180	-0.357	0.006	0.023	0.043	0.033	0.093
Economics			0.638	0.526	-0.177	-0.198	-0.627		1.000
Political Science and Public Administration						1.000	0.569	0.094	-0.064
Sociology	-0.101	0.021	0.089	0.090	1.000	0.507	0.595	0.068	-0.022

The empty fields in some of the disciplines indicated were there was $0 reported federal financed expenditures in that time frame.

	Equalized Value of Change in share of spending (ΔEIS) by year									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	0.623	0.420	0.230	-0.467	-0.094	0.003	0.211	0.115	0.058	-0.126
Civil Engineering	0.045	0.123	0.034	-0.005	-0.263	-0.186	-0.151	0.072	0.043	0.037
Electrical Engineering	0.061	0.146	0.306	0.602	0.124	0.097	-0.005	0.021	0.057	0.179
Mechanical Engineering	-0.043	-0.379	-0.774	-0.703	-0.140	0.321	1.000	0.266	0.178	-0.195
Materials Engineering	0.515	0.490	0.249	0.057	0.020	-0.076	0.171	0.142	0.306	0.229
Chemistry	0.215	0.279	0.005	-0.130	-0.264	-0.343	-0.262	0.089	0.286	0.396
Physics	-0.103	-0.130	0.124	0.129	0.119	0.017	0.001	-0.031	-0.011	-0.006
Atmospheric Sciences	-0.026	-0.032	-0.010	0.149	0.075	0.192	0.090	-0.007	-0.078	-0.116
Mathematics and Statistics	0.172	0.405	0.539	0.774	0.305	0.404	0.065	-0.018	-0.011	0.062
Computer Science	-0.129	-0.534	-1.258	-1.727	-0.774	-0.830	0.569	1.000	1.000	1.000
Biological Sciences	0.243	0.295	0.176	0.197	0.026	-0.025	-0.204	-0.068	-0.165	-0.185
Medical Sciences	0.529	1.000	1.000	0.345	0.053	-0.290	-0.401	-0.245	-0.192	0.325
Psychology	0.206	0.188	-0.051	-0.315	-0.147	-0.256	-0.284	-0.172	-0.382	-0.465
Economics	1.000	0.814	0.317	-0.149	-0.025	0.135	0.345	0.155	0.287	0.482
Political Science and Public Administration	-0.150	-0.145	0.491	1.000	1.000	1.000	0.370	-0.042	-0.129	-0.025
Sociology	-0.253	-0.456	-0.876	-0.951	-0.608	-0.945	-0.777	0.080	0.146	-0.146

APPENDIX S: UCF *ISI*, ROLLING

These two pages contain the Institutional Strategic Indicator (ISI) for the University of Central Florida from 1993 through 2011.

	Institutional Strategic Index by Year								
	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aerospace Engineering	0.865	0.273	0.227	0.083	0.029	-0.023	-0.106	0.076	0.213
Civil Engineering	-0.069	0.052	0.234	0.499	0.096	0.076	0.078	0.135	0.140
Electrical Engineering	0.311	1.053	1.066	1.081	1.020	0.949	0.743	0.786	0.585
Mechanical Engineering	0.217	0.155	-0.047	-0.728	-0.030	0.140	0.588	0.222	0.189
Materials Engineering								1.000	0.656
Chemistry	0.272	0.063	0.022	-0.091	0.031	0.066	0.330	0.311	0.287
Physics	0.017	0.377	0.891	1.065	0.449	0.451	0.502	0.630	0.969
Atmospheric Sciences	0.820	0.832	-0.012	-0.840	0.012	0.665	1.000	0.293	0.370
Mathematics and Statistics	0.075	-0.067	-0.303	-0.625	-0.064	-0.039	0.120	0.168	0.153
Computer Science	0.240	0.186	0.086	-0.334	0.081	0.025	0.057	0.046	0.073
Biological Sciences	-0.016	0.004	-0.231	-0.202	0.063	0.104	0.262	0.198	0.254
Medical Sciences	1.000	0.121	-0.119	-0.656	-0.053	0.146	0.411	0.175	0.233
Psychology	0.274	0.098	-0.001	-0.188	0.116	0.091	0.106	0.129	0.221
Economics			0.638	0.526	-0.173	-0.196	-0.626		1.000
Political Science and Public Administration						1.000	0.569	0.096	-0.056
Sociology	-0.088	0.030	0.100	0.099	1.011	0.518	0.603	0.156	0.211

The empty fields in some of the disciplines indicated were there was $0 reported federal financed expenditures in that time frame.

	Institutional Strategic Index by Year									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	0.660	0.495	0.348	-0.240	0.091	0.145	0.323	0.228	0.196	0.032
Civil Engineering	0.146	0.280	0.199	0.160	-0.040	-0.033	-0.008	0.150	0.154	0.150
Electrical Engineering	0.165	0.326	0.535	0.786	0.389	0.363	0.299	0.293	0.360	0.480
Mechanical Engineering	0.112	-0.168	-0.541	-0.519	-0.015	0.399	1.071	0.335	0.292	0.029
Materials Engineering	0.524	0.516	0.307	0.126	0.091	-0.009	0.235	0.198	0.363	0.311
Chemistry	0.320	0.482	0.297	0.173	0.102	-0.082	-0.037	0.216	0.427	0.543
Physics	0.897	0.870	1.124	1.129	1.119	1.017	1.001	0.969	0.989	0.994
Atmospheric Sciences	0.489	0.616	0.697	0.807	0.826	0.814	0.764	0.666	0.731	0.673
Mathematics and Statistics	0.178	0.414	0.551	0.788	0.324	0.421	0.091	0.010	0.022	0.090
Computer Science	-0.047	-0.449	-1.161	-1.656	-0.744	-0.821	0.570	1.003	1.003	1.003
Biological Sciences	0.319	0.422	0.380	0.425	0.268	0.193	0.039	0.128	0.038	-0.021
Medical Sciences	0.552	1.030	1.055	0.445	0.187	-0.153	-0.271	-0.129	-0.119	0.378
Psychology	0.328	0.363	0.213	-0.003	0.141	-0.035	-0.097	-0.022	-0.244	-0.359
Economics	1.000	0.820	0.332	-0.124	0.003	0.155	0.363	0.175	0.311	0.513
Political Science and Public Administration	-0.141	-0.137	0.496	1.008	1.008	1.008	0.385	-0.014	-0.092	0.008
Sociology	0.071	-0.199	-0.633	-0.770	-0.468	-0.880	-0.739	0.090	0.153	-0.133

APPENDIX T: *MSI*, WEIGHTED

These two pages present the weighted MSI to treat the percent change in the share of market with the size of its share.

	MSI weighted								
	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aerospace Engineering	0.058	0.051	0.049	0.044	0.040	0.015	-0.005	-0.044	0.032
Chemical Engineering	0.048	0.046	0.047	0.048	0.049	0.036	0.005	-0.001	0.026
Civil Engineering	0.053	0.057	0.054	0.058	0.072	0.057	0.034	0.012	0.041
Electrical Engineering	0.125	0.103	0.122	0.154	0.219	0.252	0.208	0.099	0.040
Mechanical Engineering	0.100	0.102	0.102	0.093	0.060	0.027	0.008	0.029	0.058
Materials Engineering	0.038	0.026	0.037	0.045	0.081	0.090	0.092	0.022	0.012
Astronomy	0.077	0.071	0.062	0.056	0.043	0.006	0.038	0.095	0.086
Chemistry	0.117	0.120	0.127	0.124	0.090	0.094	0.062	0.041	0.064
Physics	0.178	0.153	0.157	0.151	0.119	0.126	0.113	0.046	0.096
Atmospheric Sciences	0.038	0.042	0.046	0.043	0.041	0.055	0.077	0.068	0.035
Earth Sciences	0.077	0.077	0.072	0.070	0.039	0.042	0.041	0.067	0.042
Oceanography	0.087	0.095	0.089	0.084	0.064	0.070	0.040	0.030	0.060
Mathematics and Statistics	0.055	0.058	0.056	0.047	0.018	0.012	-0.019	-0.015	0.015
Computer Science	0.127	0.125	0.136	0.140	0.139	0.102	0.072	0.045	0.094
Agricultural Sciences	0.130	0.146	0.152	0.162	0.168	0.112	-0.027	-0.118	0.016
Biological Sciences	0.697	0.719	0.690	0.642	0.525	0.599	0.849	1.171	0.891
Medical Sciences	1.080	1.055	1.056	1.080	1.245	1.292	1.403	1.408	1.285
Psychology	0.089	0.087	0.074	0.066	0.057	0.068	0.079	0.091	0.078
Economics	0.025	0.025	0.024	0.023	0.025	0.025	0.011	-0.011	-0.005
Political Science and Public Administration	0.015	0.020	0.021	0.023	0.025	0.010	-0.018	-0.019	0.007
Sociology	0.039	0.037	0.033	0.034	0.044	0.041	0.022	0.002	0.015

	MSI weighted									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	0.035	0.073	0.046	0.042	0.008	-0.003	0.018	0.061	0.062	0.065
Chemical Engineering	0.020	0.019	-0.008	0.004	0.024	0.041	0.046	0.044	0.042	0.053
Civil Engineering	0.051	0.050	0.026	0.004	0.002	-0.012	0.022	0.043	0.048	0.059
Electrical Engineering	-0.084	0.012	0.021	0.052	0.072	0.079	0.095	0.112	0.125	0.151
Mechanical Engineering	0.030	0.051	0.051	0.042	0.060	0.078	0.099	0.101	0.102	0.119
Materials Engineering	-0.049	0.009	0.024	0.045	0.044	0.041	0.033	0.027	0.028	0.024
Astronomy	0.035	-0.030	-0.120	-0.060	-0.002	0.007	0.031	0.042	0.046	0.041
Chemistry	-0.055	0.010	0.008	0.059	0.080	0.067	0.077	0.083	0.097	0.100
Physics	-0.133	-0.046	-0.139	-0.008	0.053	0.049	0.064	0.101	0.130	0.168
Atmospheric Sciences	-0.025	-0.001	-0.005	0.036	0.049	0.057	0.035	0.003	-0.001	-0.013
Earth Sciences	-0.036	-0.007	0.043	0.109	0.105	0.108	0.060	0.052	0.055	0.070
Oceanography	0.013	0.024	-0.041	-0.024	-0.006	0.022	0.080	0.111	0.070	0.031
Mathematics and Statistics	-0.006	0.011	0.001	0.012	0.030	0.056	0.070	0.055	0.034	0.002
Computer Science	0.062	0.149	0.206	0.173	0.097	0.033	0.044	0.075	0.088	0.090
Agricultural Sciences	-0.048	0.041	0.041	0.046	0.060	0.034	0.057	0.051	0.052	0.039
Biological Sciences	1.035	0.696	0.700	0.737	0.741	0.693	0.557	0.519	0.590	0.662
Medical Sciences	1.939	1.688	1.805	1.405	1.225	1.267	1.189	1.061	0.947	0.838
Psychology	0.129	0.120	0.128	0.079	0.050	0.029	0.041	0.046	0.061	0.066
Economics	-0.038	-0.014	-0.018	-0.009	0.000	0.003	0.014	0.013	0.009	0.005
Political Science and Public Administration	0.019	0.020	0.022	0.018	0.012	0.013	0.013	0.019	0.015	0.013
Sociology	0.024	0.024	0.008	-0.009	0.004	0.010	0.021	0.014	0.012	0.006

APPENDIX U: UCF *ISI*, WEIGHTED

These two pages present the weighted ISI for the University of Central Florida from 1993 through 2011.

	Institutional Strategic Indicator (ISI) weighted by Year								
	1993	1994	1995	1996	1997	1998	1999	2000	2001
Aerospace Engineering	0.000	0.000	0.055	0.074	0.097	0.060	0.043	0.044	0.046
Civil Engineering	0.073	0.068	0.065	0.055	0.067	0.063	0.060	0.075	0.111
Electrical Engineering	0.081	0.106	0.131	0.328	1.020	0.949	0.743	0.786	0.622
Mechanical Engineering	0.190	0.184	0.190	0.001	0.101	0.041	0.016	0.047	0.105
Materials Engineering								0.000	0.000
Chemistry	0.010	0.025	0.042	0.041	0.040	0.030	0.033	0.040	0.073
Physics	0.081	0.126	0.181	0.130	0.381	0.410	0.443	0.626	0.969
Atmospheric Sciences	0.820	0.832	0.240	-0.044	0.104	0.045	0.000	0.076	0.300
Mathematics and Statistics	0.006	0.014	0.010	0.004	0.005	0.003	0.003	0.003	0.004
Computer Science	0.145	0.195	0.231	0.109	0.164	0.086	0.051	0.066	0.081
Biological Sciences	0.053	0.055	0.051	0.032	0.033	0.021	0.024	0.038	0.066
Medical Sciences	0.000	0.000	0.009	0.006	0.011	0.004	0.005	0.007	0.017
Psychology	0.033	0.084	0.147	0.109	0.111	0.070	0.065	0.099	0.140
Economics			0.000	0.000	0.003	0.001	0.000		0.000
Political Science and Public Administration						0.000	0.000	0.002	0.008
Sociology	0.012	0.009	0.012	0.010	0.022	0.016	0.012	0.094	0.227

The empty fields in some of the disciplines indicated were there was $0 reported federal financed expenditures in that time frame.

	Institutional Strategic Indicator (ISI) weighted by Year									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aerospace Engineering	0.061	0.107	0.145	0.121	0.168	0.142	0.136	0.125	0.146	0.138
Civil Engineering	0.106	0.176	0.171	0.164	0.164	0.124	0.121	0.083	0.116	0.117
Electrical Engineering	0.110	0.206	0.299	0.294	0.298	0.292	0.303	0.277	0.320	0.355
Mechanical Engineering	0.148	0.131	0.053	0.055	0.108	0.104	0.142	0.088	0.135	0.180
Materials Engineering	0.013	0.038	0.072	0.072	0.072	0.061	0.074	0.064	0.074	0.100
Chemistry	0.127	0.260	0.294	0.264	0.270	0.171	0.166	0.139	0.182	0.205
Physics	0.897	0.870	1.124	1.129	1.119	1.017	1.001	0.969	0.989	0.994
Atmospheric Sciences	0.501	0.627	0.700	0.756	0.807	0.741	0.734	0.668	0.746	0.697
Mathematics and Statistics	0.007	0.013	0.018	0.025	0.024	0.025	0.027	0.027	0.032	0.030
Computer Science	0.072	0.040	-0.025	-0.052	0.007	0.002	0.001	0.006	0.007	0.007
Biological Sciences	0.095	0.164	0.240	0.273	0.248	0.212	0.194	0.183	0.169	0.134
Medical Sciences	0.034	0.060	0.110	0.135	0.142	0.097	0.078	0.088	0.059	0.070
Psychology	0.146	0.208	0.251	0.214	0.246	0.164	0.134	0.124	0.085	0.057
Economics	0.000	0.011	0.020	0.021	0.027	0.023	0.024	0.023	0.031	0.046
Political Science and Public Administration	0.008	0.007	0.009	0.016	0.016	0.017	0.021	0.027	0.032	0.032
Sociology	0.242	0.139	0.030	0.009	0.055	0.004	0.008	0.011	0.008	0.011

APPENDIX V: WEIGHTED *MSI* AND UCF's *ISI* COMPARISON BY DISCIPLINE

These four pages present the weighted MSI and UCF's weighted ISI

Year	Aerospace Engineering (ISI weighted)	Aerospace Engineering (MSI weighted)	Civil Engineering (ISI weighted)	Civil Engineering (MSI weighted)	Electrical Engineering (ISI weighted)	Electrical Engineering (MSI weighted)	Mechanical Engineering (ISI weighted)	Mechanical Engineering (MSI weighted)
1993	0.000	0.058	0.073	0.053	0.081	0.125	0.190	0.100
1994	0.000	0.051	0.068	0.057	0.106	0.103	0.184	0.102
1995	0.055	0.049	0.065	0.054	0.131	0.122	0.190	0.102
1996	0.074	0.044	0.055	0.058	0.328	0.154	0.001	0.093
1997	0.097	0.040	0.067	0.072	1.020	0.219	0.101	0.060
1998	0.060	0.015	0.063	0.057	0.949	0.252	0.041	0.027
1999	0.043	-0.005	0.060	0.034	0.743	0.208	0.016	0.008
2000	0.044	-0.044	0.075	0.012	0.786	0.099	0.047	0.029
2001	0.046	0.032	0.111	0.041	0.622	0.040	0.105	0.058
2002	0.061	0.035	0.106	0.051	0.110	-0.084	0.148	0.030
2003	0.107	0.073	0.176	0.050	0.206	0.012	0.131	0.051
2004	0.145	0.046	0.171	0.026	0.299	0.021	0.053	0.051
2005	0.121	0.042	0.164	0.004	0.294	0.052	0.055	0.042
2006	0.168	0.008	0.164	0.002	0.298	0.072	0.108	0.060
2007	0.142	-0.003	0.124	-0.012	0.292	0.079	0.104	0.078
2008	0.136	0.018	0.121	0.022	0.303	0.095	0.142	0.099
2009	0.125	0.061	0.083	0.043	0.277	0.112	0.088	0.101
2010	0.146	0.062	0.116	0.048	0.320	0.125	0.135	0.102
2011	0.138	0.065	0.117	0.059	0.355	0.151	0.180	0.119

Year	Materials Engineering (ISI weighted)	Materials Engineering (MSI weighted)	Chemistry (ISI weighted)	Chemistry (MSI weighted)	Physics (ISI weighted)	Physics (MSI weighted)	Atmospheric Sciences (ISI weighted)	Atmospheric Sciences (MSI weighted)
1993		0.038	0.010	0.117	0.081	0.178	0.820	0.038
1994		0.026	0.025	0.120	0.126	0.153	0.832	0.042
1995		0.037	0.042	0.127	0.181	0.157	0.240	0.046
1996		0.045	0.041	0.124	0.130	0.151	-0.044	0.043
1997		0.081	0.040	0.090	0.381	0.119	0.104	0.041
1998		0.090	0.030	0.094	0.410	0.126	0.045	0.055
1999		0.092	0.033	0.062	0.443	0.113	0.000	0.077
2000	0.000	0.022	0.040	0.041	0.626	0.046	0.076	0.068
2001	0.000	0.012	0.073	0.064	0.969	0.096	0.300	0.035
2002	0.013	-0.049	0.127	-0.055	0.897	-0.133	0.501	-0.025
2003	0.038	0.009	0.260	0.010	0.870	-0.046	0.627	-0.001
2004	0.072	0.024	0.294	0.008	1.124	-0.139	0.700	-0.005
2005	0.072	0.045	0.264	0.059	1.129	-0.008	0.756	0.036
2006	0.072	0.044	0.270	0.080	1.119	0.053	0.807	0.049
2007	0.061	0.041	0.171	0.067	1.017	0.049	0.741	0.057
2008	0.074	0.033	0.166	0.077	1.001	0.064	0.734	0.035
2009	0.064	0.027	0.139	0.083	0.969	0.101	0.668	0.003
2010	0.074	0.028	0.182	0.097	0.989	0.130	0.746	-0.001
2011	0.100	0.024	0.205	0.100	0.994	0.168	0.697	-0.013

Year	Mathematics and Statistics (ISI weighted)	Mathematics and Statistics (MSI weighted)	Computer Science (ISI weighted)	Computer Science (MSI weighted)	Biological Sciences (ISI weighted)	Biological Sciences (MSI weighted)	Medical Sciences (ISI weighted)	Medical Sciences (MSI weighted)
1993	0.006	0.055	0.145	0.127	0.053	0.697	0.000	1.080
1994	0.014	0.058	0.195	0.125	0.055	0.719	0.000	1.055
1995	0.010	0.056	0.231	0.136	0.051	0.690	0.009	1.056
1996	0.004	0.047	0.109	0.140	0.032	0.642	0.006	1.080
1997	0.005	0.018	0.164	0.139	0.033	0.525	0.011	1.245
1998	0.003	0.012	0.086	0.102	0.021	0.599	0.004	1.292
1999	0.003	-0.019	0.051	0.072	0.024	0.849	0.005	1.403
2000	0.003	-0.015	0.066	0.045	0.038	1.171	0.007	1.408
2001	0.004	0.015	0.081	0.094	0.066	0.891	0.017	1.285
2002	0.007	-0.006	0.072	0.062	0.095	1.035	0.034	1.939
2003	0.013	0.011	0.040	0.149	0.164	0.696	0.060	1.688
2004	0.018	0.001	-0.025	0.206	0.240	0.700	0.110	1.805
2005	0.025	0.012	-0.052	0.173	0.273	0.737	0.135	1.405
2006	0.024	0.030	0.007	0.097	0.248	0.741	0.142	1.225
2007	0.025	0.056	0.002	0.033	0.212	0.693	0.097	1.267
2008	0.027	0.070	0.001	0.044	0.194	0.557	0.078	1.189
2009	0.027	0.055	0.006	0.075	0.183	0.519	0.088	1.061
2010	0.032	0.034	0.007	0.088	0.169	0.590	0.059	0.947
2011	0.030	0.002	0.007	0.090	0.134	0.662	0.070	0.838

Year	Psychology (ISI weighted)	Psychology (MSI weighted)	Economics (ISI weighted)	Economics (MSI weighted)	Political Science and Public Administration (ISI weighted)	Political Science and Public Administration (MSI weighted)	Sociology (ISI weighted)	Sociology (MSI weighted)
1993	0.033	0.089		0.025		0.015	0.012	0.039
1994	0.084	0.087		0.025		0.020	0.009	0.037
1995	0.147	0.074	0.000	0.024		0.021	0.012	0.033
1996	0.109	0.066	0.000	0.023		0.023	0.010	0.034
1997	0.111	0.057	0.003	0.025		0.025	0.022	0.044
1998	0.070	0.068	0.001	0.025	0.000	0.010	0.016	0.041
1999	0.065	0.079	0.000	0.011	0.000	-0.018	0.012	0.022
2000	0.099	0.091		-0.011	0.002	-0.019	0.094	0.002
2001	0.140	0.078	0.000	-0.005	0.008	0.007	0.227	0.015
2002	0.146	0.129	0.000	-0.038	0.008	0.019	0.242	0.024
2003	0.208	0.120	0.011	-0.014	0.007	0.020	0.139	0.024
2004	0.251	0.128	0.020	-0.018	0.009	0.022	0.030	0.008
2005	0.214	0.079	0.021	-0.009	0.016	0.018	0.009	-0.009
2006	0.246	0.050	0.027	0.000	0.016	0.012	0.055	0.004
2007	0.164	0.029	0.023	0.003	0.017	0.013	0.004	0.010
2008	0.134	0.041	0.024	0.014	0.021	0.013	0.008	0.021
2009	0.124	0.046	0.023	0.013	0.027	0.019	0.011	0.014
2010	0.085	0.061	0.031	0.009	0.032	0.015	0.008	0.012
2011	0.057	0.066	0.046	0.005	0.032	0.013	0.011	0.006

APPENDIX W: EXCEPTIONS METHOD

The exceptions method processes the research market data to determine if there were outliers in the data used to calculate averages. If one of the data points was outside the 2σ boundary condition a 5-year average was implemented for that average rather than the standard 3-year average. The exception process was developed by Litwin in his work and is copied here for the reader's convenience and understanding (Litwin, 2008). The step-by-step process follows.

1. The percentage change from one year to the next year was determined for all years, beginning with the percentage difference from 1988 to 1989 and ending with the percentage difference from 2010 to 2011.
2. The arithmetic mean of the percentage changes was determined. There were 23 percentage changes.
3. An amount equal to 2σ of the percentage changes was determined.
4. A range equal to the mean ± 2σ was established.
5. Each percentage change was compared with the range, and all values outside the 2σ range were identified. They are identified with a shaded cell as found in Appendix C for the ARM and Appendix F for UCF.
6. If any of the identified amounts were from the years 1989,1990, or 1991, then an adjustment was triggered.
7. The adjustment affected 1990a only in the specific field in which the exception occurred. The adjustment was that, instead of using the arithmetic mean of data from the years 1989,1990, and 1991 to establish 1990a, the arithmetic mean of the 5 years of 1988 to 1992 inclusive was used to establish the value for 1990a.
8. Likewise, if any of the identified outliers were from 1999, 2000, or 2001, then an adjustment was triggered such that 2000a became the arithmetic mean of data from the 5 years of 1998

to 2002 inclusive (Litwin, 2008). The same is true for identified outliers from 2007, 2008, or 2009. In those cases the 2008a was the arithmetic means of data from the years 2006 through 2010 inclusive.

APPENDIX X: DEVELOPED OBJECTIVES AND MEASURES

These pages present the objectives and measures developed for UCF in order to meet the research strategy to increase the federally financed academic R&D expenditures. Asking how the objective could be met developed the performance measures. This list is not intended to be definitive for the solution. It is meant to be a guideline for others to follow and build upon.

Perspective	Objective	Measure
Financial	Increase UCF academic research market share commensurate with its size	UCF market position
		Competition's market position
		Federally financed R&D expenditures by discipline
		Gap between target position and measured position
	Ensure research administration's operational efficiency accounts for resource load required to support competing in the academic research market (opportunity costs, seed money, personnel)	Research administration costs
		Faculty success at funding opportunities
		Internal metrics that track operation efficiencies
		Compare measures against target values
	Win funding opportunities to align with funding agency and university strategy	Measure discipline's position in the ARM
		Funding success rate
		Measure proposal's target discipline against university's priority discipline
		Measure quality of proposals (several metrics to track, this is a body of work all by itself)
		Track faculty's publishing rankings
		Track the proposal budgets are in alignment with todays' anticipated expenses for similar work
		Compare measures against target values

Perspective	Objective	Measure
Customer	Recruit quality faculty and staff	Compare recruitment quality against target values
	Recruit quality students	Number of students involved in funded research Compare measures against target values Number of promotional articles published by success weighted by reputation of publication and $ amount of research
	Promote accomplishments to improve reputation	Distribution and number of papers published by faculty Number of patents Compare measures against target values
Internal Processes	Ensure policies and procedures recruit and reward faculty and staff in accordance with winning funding opportunities	Measure faculty win rate and $ amount Measure staff influence on win rate and $ amount Report on yearly survey that measures the effectiveness of the policy and procedures that recruit and reward faculty and staff Compare measures against target values Report on yearly survey that measures the effectiveness of the policies and procedures for funding process Compare measures against target values
	Ensure policies and procedures promote grant application winning with interdisciplinary activity in mind	Report on yearly survey that measures the level of interaction among different university departments related to this topic
	Ensure policies and procedures for student recruitment include significant scholarship opportunities, discipline variety, and research opportunities that align with university's mission	Compare measures against target values
	Ensure the competition in the academic research market has holistic approach	Measure funding process success rate

Perspective	Objective	Measure
Learning and Growing	Develop faculty and staff	Measure the number of personnel that have been trained in grant application process
		Measure their level of proficiency at with their role in the process
		Measure proficiency against target values
		Report on yearly survey that measures the perceptions of the research culture being promoted
	Develop culture that promotes research participation and wins funding	Measure results against target values.

APPENDIX Y: IDENTIFYING BALANCED SCORECARD INITIATIVES

Identify new initiatives based the proposed objectives and measures.

From this layout of performance measures (metrics) a causal loop could be developed for the loop related to increasing market share.

1. Measure where UCF is in market
2. Measure position in the market for the different disciplines
    a. Compare to target
3. Measure where your competition is in the market
    a. Compare to target
4. Funds received by discipline
5. Score proposal against university discipline priority
6. Measure quality of proposal
    a. Proposal meets all application requirements
    b. Number of papers or patents the researchers have in area of research
    c. University's overall reputation
    d. University's reputation for research in the field of interest
    e. Labor rates, construction costs, equipment costs within norm.
7. Measure number of application per year per discipline and amount of awards funded.
8. Measure % faculty involved in funded research
    a. Compare against targets
9. Measure % students involved in funded research

    a. Compare against targets

10. Measure number articles published on successes weighted by publication and $ amount of research.
    a. Compare publication count to targets
11. Report on yearly survey that measures the effectiveness of the policies and procedures for funding process.
12. Report on yearly survey that measures the level of interaction among different university departments related to this topic.
13. Measure the number of personnel that have been trained in aspects of this topic.
    a. Compare measures against targets.
14. Measure their level of proficiency at with their role in the process.
    a. Compare measures against targets.
15. Report on yearly survey that measures the perceptions of the research culture being promoted.
    a. Compare measures against targets.
16. Measure research administration costs
17. Measure UCF's market share
18. Measure competition's market share
19. Measure funding process success rate
20. Measure faculty win rate and $ amount

21. Measure staff influence on win rate and $ amount

22. Report on yearly survey that measures the effectiveness of the policy and procedures that recruit and reward faculty and staff.

APPENDIX Z: UNIVERSITY LIST FOR CALCULATING *ISIw*

The following university list was identified as Research Intensive Universities (RIU) in Litwin's work (Litwin, 2008). For this study two universities were added for the ISI_w; Florida State University and the University of Central Florida.

Research intensive university list (modified for this study)

California Institute of Technology	University of Central Florida
Carnegie Mellon University	University of Chicago
Case Western Reserve University	University of Colorado, All Campuses
Columbia University in the City of New York	University of Florida
Duke University	University of Iowa
Florida State University	University of Maryland at College Park
Harvard University	University of Michigan, All Campuses
Indiana University, All Campuses	University of Minnesota, All Campuses
Johns Hopkins University	University of Missouri, Columbia
Massachusetts Institute of Technology	University of Missouri, Kansas City
Michigan State University	University of Missouri, St Louis
New York University	University of North Carolina at Chapel Hill
Northwestern University	University of North Carolina at Charlotte
Ohio State University, All Campuses	University of Pennsylvania
Princeton University	University of Rochester
Purdue University, All Campuses	University of Southern California
Rutgers the State Univ. of NJ, All Campuses	University of Virginia, All Campuses
Stanford University	University of Wisconsin-Madison
University of Arizona	Vanderbilt University
University of California-Berkeley	Washington University
University of California-Los Angeles	Yale University
University of California-San Diego	

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