Project Group 5: Cross-Agency Effectiveness

Final Report

SYST/OR 699 Master's Project

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Project Sponsor:

The MITRE Corporation

Project Team:
Jeff Chittim
Paul Dolan
Syed Jaffery

Executive Summary

The United States Government has established Cross-Agency Priority (CAP) goals as a method to accelerate progress towards Presidential priority areas. In fiscal year 2015 Presidential Budget, the Whitehouse outlined 15 CAP goals. Among these is a goal to improve Science, Technology, Engineering and Mathematics (STEM) education. One of the goals in the STEM CAP is to create 1,000,000 additional STEM graduates between 2010 -2020. This project was created to evaluate the cross-agency effectiveness in achieving that goal using a model-driven approach.

One of the major challenges that faced this project is the lack of student-level effectiveness data reported by STEM programs. The absence of this data requires a model to aggregate assumed and calculated effects of several STEM programs across multiple agencies.

Using a Systems Dynamics model approach, the Project Team modeled Government STEM program effects on the STEM undergraduate pipeline. System Dynamics modelling is an ideal methodology to for this project because it allows assumptions, causality and delayed effects to be integrated into the model.

The project team performed sensitivity analysis to calculate the Return On Investment (ROI) of investment of STEM scholarships and research programs for undergraduates. Among these two options, the analysis found that investment in STEM scholarships will cause a greater number of students persisting in the STEM pipeline per dollar spent than STEM research programs.

Table of Contents

Table of Figures

Table of Tables

1 Introduction

1.1 Government Performance and Accountability Challenges

In fiscal year (FY) 2014 the United States Government will oversee a discretionary spending budget of over $1.2 trillion (OMB, 2014). Given this large sum of money and limited oversight and program performance gathering resources, they face significant management challenges in the way this budget is obligated and spent.

The Government uses goals to improve performance and accountability to the American people. The Government Performance and Results Act (GPRA), implemented in 1993, was designed to make improvements in the way that Federal Government conducts its business. The GPRA Modernization Act of 2010 requires Federal agencies to identify priority goals, assign officials responsibility for accomplishing them, and report the progress towards these goals on regular basis using performance measures. These performance measures help the agencies to evaluate the efficiency and effectiveness of their programs.

To improve and promote cross agency harmonization and best practice sharing, Federal Government has adopted a limited number of Cross Agency Priority (CAP) goals. The Office of Management and Budget (OMB) with the help of CAP goal leaders identify the agencies that can contribute to these selective goals. The participating agencies develop strategic plans every four years and set priority goals every two years. Current Cross-Agency Priority Goals are show in Table 1.

Table 1- Cross Agency Goals (Performance.gov, 2014)

Mission	Management	
Cybersecurity	Effectiveness	Customer Service
Climate Change		Smarter IT Delivery
Insider Threat and Security Clearance	Efficiency	Strategic Sourcing
Job-Creating Investment		Shared Services
Infrastructure Permitting Modernization		Benchmark and Improve Mission-Support Operations
STEM Education	Economic Growth	Open Data
Service Members and Veterans Mental Health		Lab-To-Market
		People and Culture

1.2 Project Objectives

The project sponsor (The MITRE Corporation) established a set of objectives for the Project Team to follow in order to provide value to the sponsor and create a challenging topic for SYST/OR 699:

- This project will develop a prototype, rigorous data driven approach to evaluate Government performance and provide insight to support program and funding decisions related to a significant cross agency goal—increase the proportion of U.S. graduates in STEM.
- The project will advise agencies regarding opportunities to improve their investments (i.e. allocation of resources to existing or new activities) and their performance management to increase government effectiveness in achieving this goal.
- The project also will identify the challenges in developing an effective methodology, data inadequacies and critical needs, and recommended methodology improvements.

1.3 STEM Background

Domestic science, technology, engineering, and mathematics (STEM) expertise is central to the economic prosperity of the United States (US). Specialized STEM knowledge is critical to continual development in manufacturing, health care, energy production, environmental preservation, a modern national defense and many other areas. The United States must maintain a robust education system to prepare the next generation of American workers for careers in STEM fields (Carnevale, Smith, & Melton, 2011).

During the period from 2000 to 2010, STEM jobs grew at a rate of 7.9 percent while non-STEM jobs grew at 2.6 percent. During the period from 2008-2018 the Department of Commerce projects that STEM jobs will grow at a 17.0 percent rate, while non-STEM jobs will grow at a 9.8 percent rate (Department of Commerce, 2011).

Currently, the US is struggling to prepare students for careers and higher education in STEM fields. In 2012, the Program for International Student Assessment (PISA) showed that "teenagers in the U.S. slipped from 25th to 31st in math since 2009 [and] from 20th to 24th in science (Banchero, 2013)…"

This problem also extends to postsecondary education. Only 38 percent of bachelor's degree students enter a STEM field during their postsecondary education (National Center for Education Statistics, 2012). Furthermore, approximately half of all students who intend to major in STEM fields ultimately leave STEM programs (Chen, 2013).

In support of this goal, he U.S. Federal Government has established a CAP with education partners to improve the quality of STEM education at all levels. Specifically, the Government has set a performance goal to increase the number of STEM graduates by one-third by 2020, which results in an additional 1 million graduates with degrees in STEM subjects (Performance.gov, 2014). In FY14 fourteen Federal Agencies will administer 110 investments with approximately $3.1 Billion in STEM program funding as shown in Figure 1.

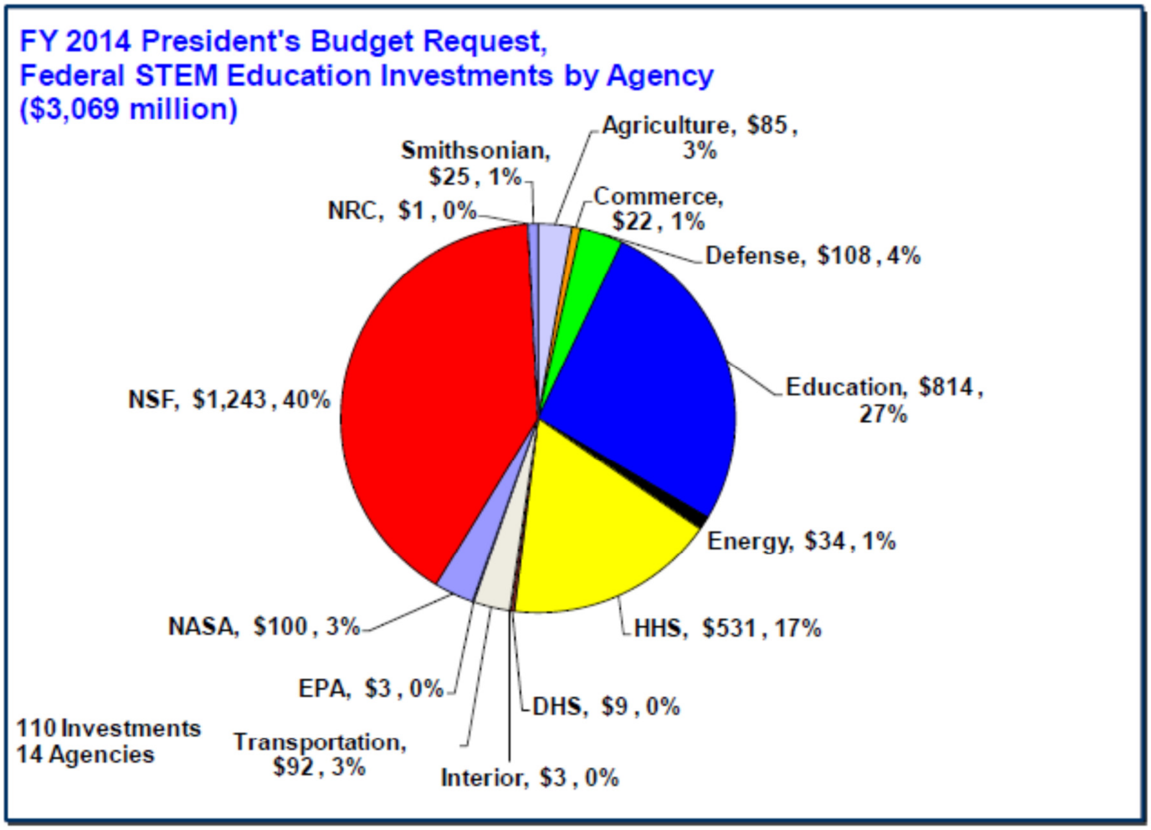

Figure 1 – FY 2014 Budget Request, STEM Education Investments by Agency (National Science and Technology Council, 2013)

An overarching area of opportunity in reaching this performance goal is increasing retention of STEM students. A report by the President's Council of Advisors on Science and Technology (PCAST) concluded that a strategy which focuses on retention of STEM students would be the lowest-cost and most efficient policy (PCAST, 2012)

The PCAST study found the following reasons that affect STEM retention:

- Uninteresting introductory courses and lack of effective teaching practices;
- Lack of access to research;
- Difficulty with required mathematics; and
- Insufficient focus on women and minorities.

Currently, the Federal Government lacks methods of assessing effectiveness of CAP goals such as STEM as discussed by the GAO, 2012.

1.4 Scope

The scope of this project is to model the impact of Federal agency funding priorities and goals on the STEM workforce pipeline. In support of model development, the Project Team must gather data and information regarding various aspects of the problem and the contributing agencies' programs, functions, investments, performance and program evaluations. Simulations of the model will be performed to measure the effects different funding policies. Based on the results of this analysis, recommendations will be made for performance measures, data and research to improve the effectiveness in achieving STEM CAP goals and serve as a proof of concept for CAP modelling in general. To be in alignment with the selected STEM CAP goal, the project will restrict the project to only study and model the undergraduate phase of the STEM pipeline as shown in Figure 2.

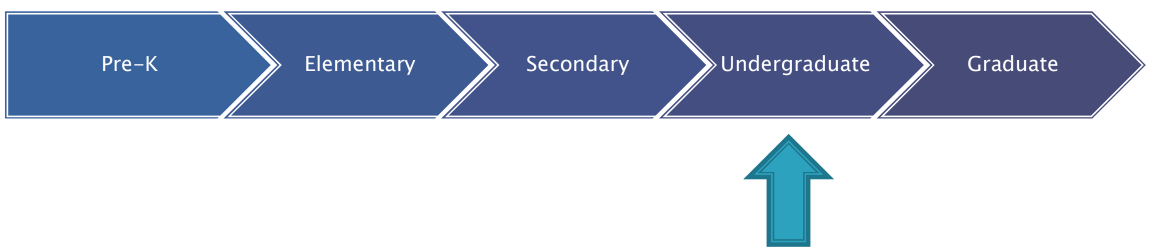

Figure 2- STEM Pipeline Scoping

2 Data Collection and Literature Review

Our approach began with the literature review because our technical solution depends in part on what is learned in this review. The sections below provide focus areas for our effort pertaining to literature review.

2.1 STEM Programs

In order to implement an efficient and effective STEM framework, there are 13 agencies who are participating in the STEM CAP. After a GAO report in 2012 which stated the duplications in the STEM programs, the STEM administration proposed a comprehensive streamlining of these programs, reducing them to 114 across 11 agencies as part of FY15 budget proposal (GAO, 2012). The primary and secondary of objectives of these programs are shown in the Figure below.

Primary Objective	Total	Secondary Objective: Institutional Capacity	Engagement	Learning	Pre- and In-Service Educator/ Education Leader Performance	Postsecondary STEM Degrees	Education Research and Development	STEM Careers	STEM System Reform	Other
Institutional Capacity	20		50%	55%	25%	55%	10%	20%	5%	25%
Engagement	42	21%		79%	62%	31%	14%	33%	7%	14%
Learning	48	42%	77%		56%	54%	29%	40%	19%	13%
Pre- and In-Service Educator/Education Leader Performance	24	38%	71%	71%		42%	17%	29%	8%	21%
Postsecondary STEM Degrees	71	46%	54%	72%	18%		15%	77%	8%	13%
Education Research and Development	12	42%	50%	50%	50%	17%		17%	25%	8%
STEM Careers	35	34%	43%	54%	11%	71%	9%		6%	11%
Total		14	81	137	101	26	48	36	48	23

Figure 3- STEM Programs' primary and secondary objective (Policy, 2011)

Due to project constraints, the Project Team's focus was research on the following STEM program categories:

- Institutional Grants;
- Scholarships to Students and Engagement; and
- Learning/Skill Development.

2.2 Literature Findings

Through research we found out that the stakeholder agency performance plans are mostly not aligned with STEM CAP goals. Figure 4 is from a GAO report of 2012, which shows a summary of STEM performance plan data completion data (GAO, 2012). Although 38 percent of agencies mentioned STEM education in their performance plans and 20 percent in their performance reports, fewer cited outcome measures related to STEM education. More specifically, in reporting their progress toward meeting their performance goals, 11 percent of the agencies mentioned STEM education as contributing to one of these goals in their performance reports. In some cases, the program's agency does not track the number of students served by the program. Often programs give grants to institutions or states and not directly to students. This presents an obstacle in finding performance information for these types of programs. Typically, programs that use this methodology often report on how effective they are in awarding money.

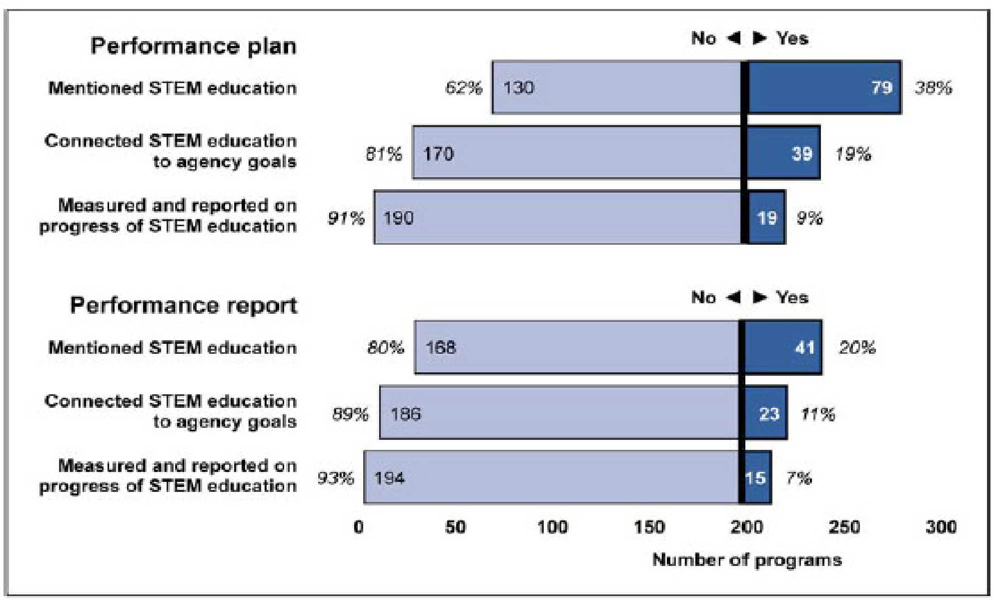

Figure 4- 2012 GAO report on STEM Education

Programs provide performance data often using different methods across agencies. This inconsistency presents a challenge to aggregate the number of students, teachers, and institutions served and to assess the effectiveness of the overall federal effort.

Agencies' limited use of common performance measures and student-level evaluations hinders their ability to assess the effectiveness of their individual programs as well as the overall STEM education effort. Data from the GAO report shows that only 29% of the agencies have conducted comprehensive evaluations. These evaluations were often of varying methods and designs (GAO, 2012). For instance, some agencies used surveys as an evaluation method, but the evaluation criteria was different although these agencies were participating in the same STEM program. Realistically, being able to perform a very detailed level of data collection is costly. Asking a STEM program to collect this type of data would almost certainly increase their overhead and reduce their investment in the STEM pipeline.

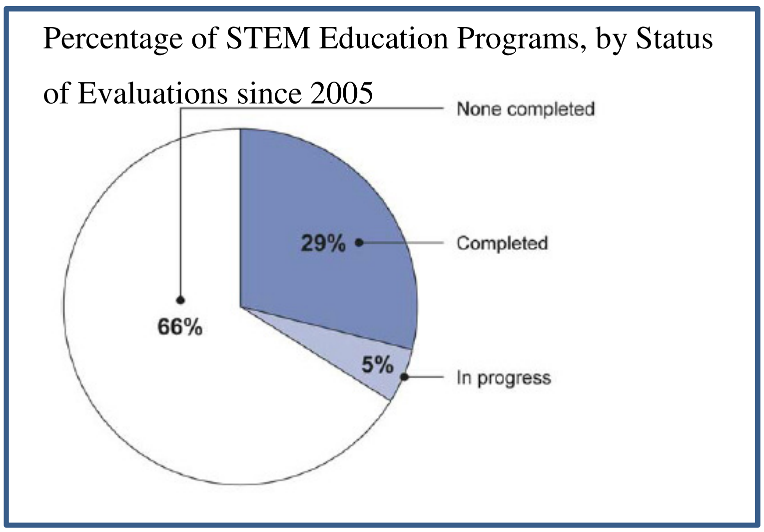

Figure 5- 2012 GAO report data for STEM Program Evaluation

Agencies will be better in assessing their effectiveness if a greater proportion of STEM performance data is linked to student-level factors. This also aid assessment in of cross-agency effectiveness.

3 Technical Approach

The technical approach used in this project is meant to be a proof of concept to model cross-agency goals. This approach is built on publically available data. Ultimately, the aim of this approach is to acquire "business intelligence" to help agencies better progress towards a cross-agency goal.

3.1 Model Approach

One of the major objectives for this project was to develop a model that uses Government performance to provide insight to support program and funding. One approach that was suggested by the Project Sponsor is Systems Dynamics (SD). As noted by the MIT Sloan School of Management:

> *"System dynamics is designed to avoid such policy resistance and identify high leverage policies for sustained improvement. We develop formal mathematical models, grounded in empirical evidence, to build theoretical understanding of complex systems and seek to use those models to design and implement policies that yield lasting benefits for businesses and society"* (MIT Sloan, 2014).

As mentioned in this quotation, SD modelling is used to build a theoretical understanding of complex systems and to identify leverage policies for improvement. SD model attributes lend very nicely to a complex approach such as the STEM pipeline. After an early review of the data challenges facing this project, the project team selected SD as an optimal modelling approach.

The SD approach allowed the Project Team to develop and understanding of a complex attrition and persistence based model. SD performs well at capturing non-linearity and considers causality and delayed effects.

3.2 Causality Analysis

An important part of the technical approach was to establish a method to link attrition and persistence factors affecting the STEM pipeline. The Project Team completed a cognitive exercise mapping with the Project Sponsor to better understand the cause and effect related to

STEM attrition and to further scope the project to an appropriate level. The results of a group brainstorming session with the Project Sponsor are shown in Figure 6.

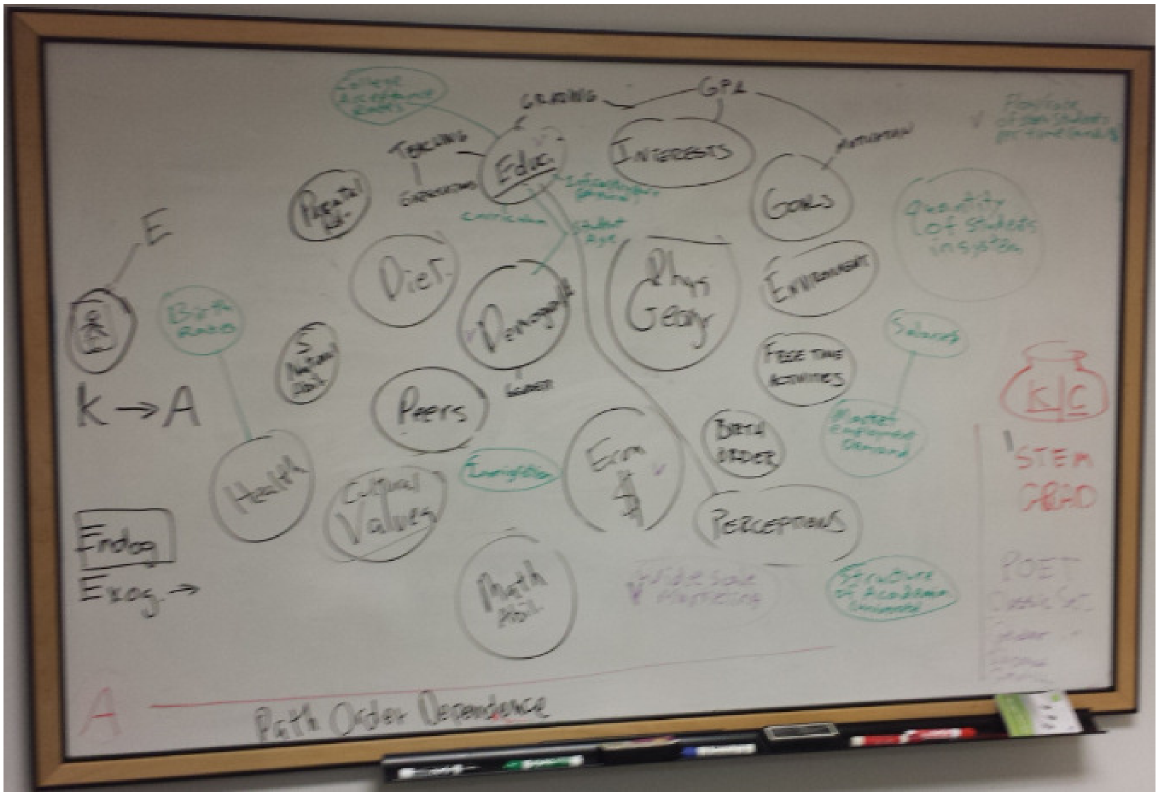

Figure 6 – Brainstorming session with the Sponsor for Cognitive Mapping

During this session we brainstormed factors (from birth to graduation) that would affect the number of STEM graduates. These factors are listed below:

- Birth Rate;
- Health;
- Parental Involvement;
- Natural Ability;
- Quality of Education;
- Diet;
- Peers;
- Demographics;
- Immigration Policies;
- Cultural Values;
- Mathematics Ability;
- Interests;
- Goals;
- Physical Geography;
- Free Time Activities;
- Birth Order;
- Quantity of Students in Education System;

- STEM Salaries;
- Market Employment Demand;
- Structure of Academia;
- Marketing;
- Perceptions;
- Economic Factors; and
- College Acceptance Rates.

Using these factors we created a cognitive map. This map helped us see which factors had the widest influence. The cognitive map allowed the Project Team to better focus on the research required to build the model.

The scope of our approach is aligned to the STEM goal to produce 1 million additional STEM graduates by 2020 in STEM fields. According to a report published by the Whitehouse Office of Science and Technology Policy, "Increasing the retention of STEM majors to just 50 percent would generate approximately three-quarters of the targeted 1 million additional STEM graduates over the next decade." in addition the report stated, "retaining more students in STEM majors is the lowest cost, fastest policy option to providing the STEM professionals that the nation needs for economic and societal well-being." (Technology, 2012) Therefore, we believe it is important to study the impact of these high contributing factors.

The focus of our approach was to create a SD model that has the ability to simulate different interventions that can improve the total number of STEM graduates to meet the primary goal of the STEM CAP initiative. For this purpose, we focused on the following interventions to research and study their impact on undergraduate students as they move through the STEM undergraduate pipeline:

- **Parent Perception –** According to a study conducted by Microsoft, "Nearly 4 in 5 STEM college students (78%) say that they decided to study STEM in high school or earlier" (Harris Interactive, 2011). Student perception of STEM is a vital intervention that needs to be studied thoroughly.

- **Scholarships –** In general, the tuition cost for STEM degree programs are more than the other majors due to laboratory charges, textbooks, other technical services charges etc. Scholarships that are offered in the first year of college develop positivity in STEM students for degree completion (DesJardins, Ahlburg, & McCall, 2002).
- **H.S. Preparation –** High school is a crucial time for a student as most students would be thinking about colleges and their career decisions around this time. Developing interest level in STEM during high school years is a key factor to have higher STEM enrollment rate which would fuel STEM graduate rates. According to a study conducted by Microsoft, "Only 1 in 5 STEM college students feel that their K–12 education prepared them extremely well for their college courses in STEM" (Harris Interactive, 2011). To that end, we include the following preparation measures in the SD model:
  - **H.S. GPA**
  - **H.S. Calculus Percentage**

- **Research Experience –** We focused on The Research Experiences for Undergraduates (REU) programs that are funded by the National Science Foundation (NSF). These programs support research activities by the Undergraduate students in areas that are supported by NSF in ongoing research programs or other projects that are specifically tailored for REU purposes. Based on our extensive research, we found that students who are actively involved in REUs are more likely to graduate with a STEM degree thus significantly increasing the retention rate of the STEM students (Eagan, Hurtado, & Chang, 2010) (MIT Washington, 2013)

These interventions are linked to STEM pipeline model through the use of three persistence rates:

- **Enrollment Rate –** The proportion of postsecondary enrollees that become STEM Majors
- **Net Switching Rate** – The proportion of Non-STEM Majors that become STEM Majors.
- **Retention Rate –** The proportion of STEM Majors that ultimately graduate.

The integration of these rates and interventions on the STEM pipeline are shown in Figure 7. Based on our literature review, we found that Scholarships (DesJardins, Ahlburg, & McCall, 2002) and Parent Perception (Harris Interactive, 2011)would most likely affect the Enrollment Rate and High School Preparation (Harris Interactive, 2011) and Research Experience (Eagan, Hurtado, & Chang, 2010) would mostly likely affect the Net Switching Rate and Retention Rate. Also shown in Figure 7 is the STEM undergraduate pipeline model.

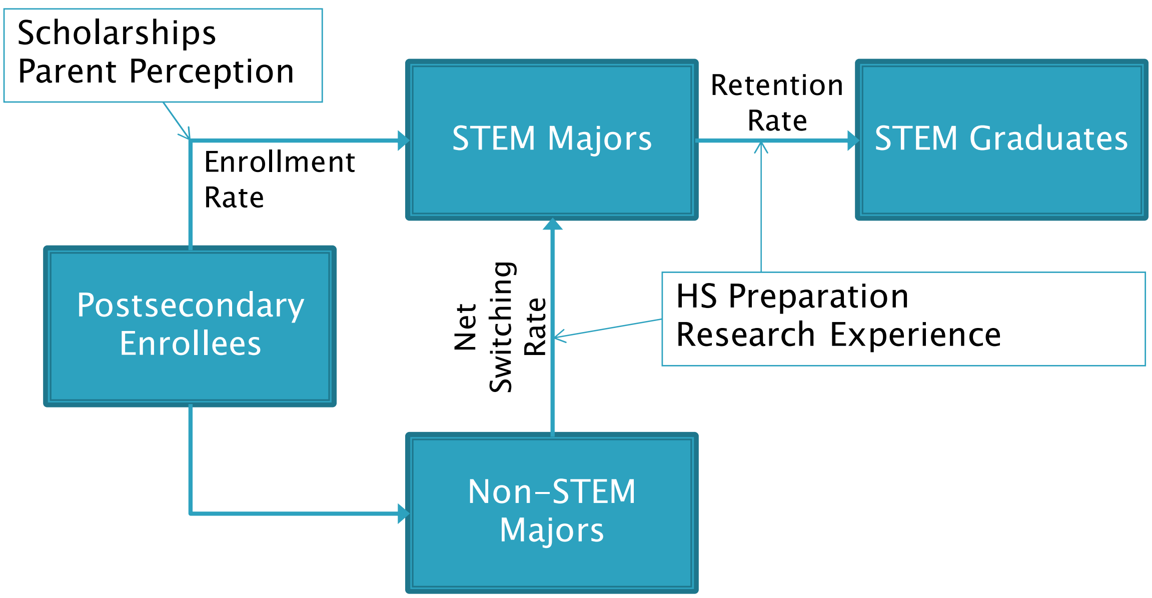

Figure 7 – Model Summary

The full model and specification of all nodes is shown in Appendix A.

3.3 Factor Determination

The Project Team used a three tiered approach to calculate how interventions and other factors in the SD model would affect rates of students through the STEM Pipeline. A visualization of this approach is shown in Figure 8.

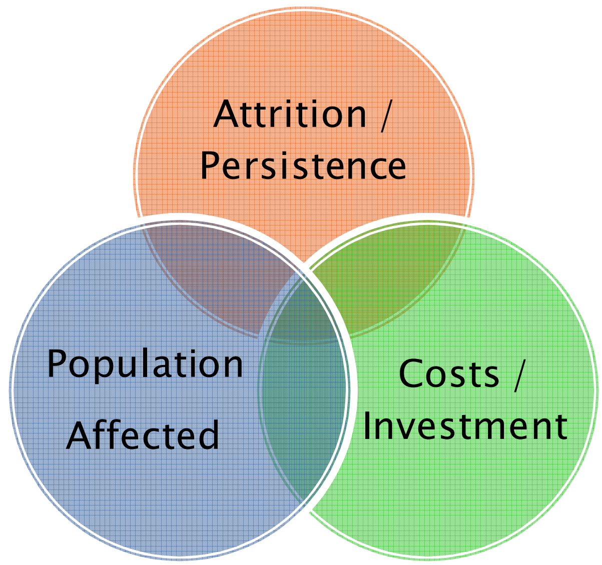

Figure 8 – Factor Research Approach

Generally, our data gathering focused on finding how an intervention or factor would affect a model rates in terms of attrition or persistence. The Project Team found these factors in research areas related to general postsecondary education. This approach was necessary given the lack of performance data provided by STEM programs.

The Project Team defined persistence rate as a function of investment. The final input into a factor determination calculation is how much of a population in the STEM pipeline would be affected by an intervention. Generally this is found or derived by researching program descriptions. The general format for the factor rate equation is shown in Figure 9.

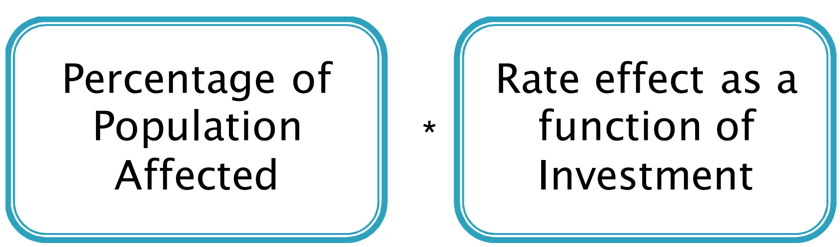

Figure 9 – Rate Affect General Form

As an example, Figure 10 summarizes how scholarship programs would affect persistence in the STEM pipeline.

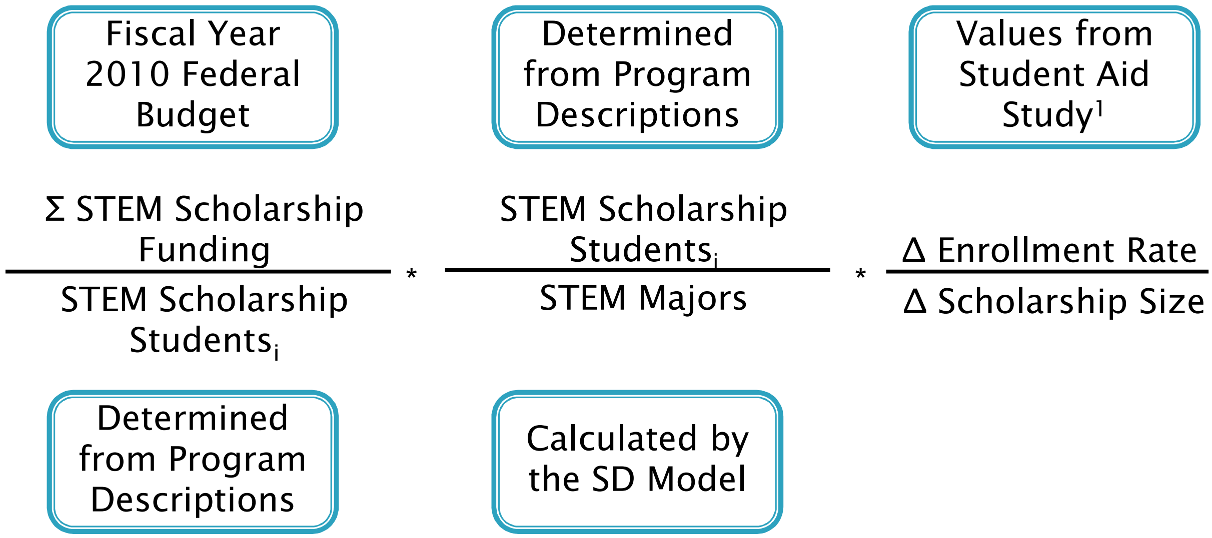

Figure 10 – Enrollment Rate Affect Due to STEM Scholarships

The middle and left terms in this equation correspond to the calculation of the percentage of students affected by STEM scholarships. The rate term gives the change in the STEM major enrollment rate affects as a function of scholarship size, which is related to investment.

3.4 STEM Programs

The Project Team was able to integrate 18 different STEM programs into the SD model. These programs represent greater than $750 million of STEM funding. The programs were grouped in the model to facilitate linking to common nodes:

- Scholarships for Service
  - Hollings Undergraduate Scholarship Program
  - Stokes Educational Scholarship Program
  - Aeronautics Scholarship
  - Federal Cyber Service
- Research Experiences for Undergraduates (REU)
  - Awards to Stimulate & Support Undergraduate Research Experiences (ASSURE)
  - Naval Research Enterprise Program (NREIP)
  - Science Undergraduate Laboratory Internships (SULI)

[1] (Bettinger, 2004)

    - Undergraduate Student Research Project (USRP)
    - Summer Undergraduate Research Fellowship Program (SURF)
- STEM Scholarships
    - DoD SMART Scholarships
    - Dept. of ED SMART Scholarships
    - Undergraduate Scholarship Program for Individuals from Disadvantaged Backgrounds
    - NSF STEM Scholarships (S-STEM)
- Other STEM Programs
    - Upward Bound Math Science Program
    - Global Climate Change Education
    - Motivating Undergraduates in Science & Technology
    - University Transportation Centers Program

3.5 Model Limitations

As mentioned in Section 2, the Project Team was limited to only publicly available information to build this model. Furthermore, the project was limited by the following factors:

- Project scope does not include data collection
- Program effectiveness and performance generally not reported in terms of STEM goals
- Model was limited to factors affecting attrition and persistence. For example, the model did not consider ways to increase the number of undergraduates enrolling.

3.6 Model Assumptions

In order to assemble this model without the proper data, many complicating factors had to be omitted from the analysis including:

- STEM Teacher Pipeline;
- Demographics;
- Cultural aspects; and
- K-12 Experiences.

The Project Team acknowledges that there are likely areas of Government investment not labeled as "STEM Programs" that affect the STEM pipeline, however these programs were omitted. Similarly, private sector investments were also omitted.

Several assumptions regarding calculated and collected data were made to ensure simplicity of the modelling approach:

- Stability of STEM 2010 program inventory;
- Constant factor effects during simulation;
- Combined data across recent fiscal years to build model; and
- Omission of seasonality effects.

The project tested the assumption of "Constant factor effects during simulation", which is discussed in Section 4.

4 Analysis and Results

4.1 Analysis Methods

In order to test both hypotheses, three variant models had to be developed. Two model variants were created to calculate return on investment (ROI) for two groups of federal programs targeting undergraduate STEM students: federal STEM student scholarship programs and federal programs whose primary purpose (as determined by the literature review) was to provide research experiences for undergraduates (REU programs). The third model variant was developed to test the sensitivity of the model outputs to whether or not the size of a STEM scholarship has variable effects on the model. An assumption (in the base model) was made that the size of a STEM scholarship added to STEM persistence as it increases.

4.1.1 ROI General Calculation

To calculate the ROI of federal STEM student scholarship programs and REU programs, federal funding for the scholarship and REU programs was increased for one year and the effect on the number of STEM students persisting was observed. The effect of this increase in funding had to be not significantly different from zero in order to result in a non-trivial ROI. Therefore, by design, the increase in funding for STEM programs that year had to be large. The immediate effect of the increase in funding was a change in the STEM student persistence rate for that year. Additional funds were applied to a future year in the model simulation so the ROI calculation could be framed in terms of potential action for the Government to undertake.

2016 was chosen as the year for which ROI would be calculated in both the scholarship and REU model variants. This had the added benefits of allowing the simulation to have a warm up period and being able to further test if the effects of the added funding would perpetuate until 2020 in terms of total STEM graduates when compared to the base model. The Project Team assumed that for both calculations of ROI, the funding that was added went directly to student related costs and assumed no increase in overhead costs for any of the programs administering that funding. This simplifying assumption was made due to the lack of data on program overhead costs. Because of this assumption, the ROI values found can be thought of as a lower bound of actual ROI.

Each model variant was run 30 times to ensure large enough sample sizes for statistical tests. All random variables included in each model were ensured to be independent as a necessary assumption of the Tukey comparison test. Because federal STEM student scholarship programs were specified in the model to act on a different part of the STEM student timeline than federal REU programs, model outputs were framed in terms of the number of students persisting in STEM. This allowed federal initiatives to be compared without regard to where they impact the STEM undergraduate pipeline. The Tukey test was conducted to compare the mean difference between the output of each model variant (REU and Scholarship) and the base model, as well as give a 95% confidence interval on this mean. To find the ROI for each set of programs, the amount of funding added was then divided by the 95% confidence interval to obtain a 95% confidence interval on the average federal dollars per STEM student persisting for each federal initiative. The ROI calculation is shown in the equation below:

$$ROI(\$/STEM\ Students\ Persisting) = \frac{Funding\ added\ from\ base\ model}{\#\ Persisters\ in\ variant\ model - \#Persisters\ in\ base\ model}$$

4.1.2 ROI Scholarship Model

The effect of federal scholarship programs on STEM student persistence was specified in the base model as:

$$\binom{Scholarship\ programs'}{effect\ on\ persistence} = \sum_{i}^{\text{All Scholarship Programs}} \overbrace{\frac{\begin{pmatrix} Scholarship \\ program \\ funding \end{pmatrix}_i}{\$/_{Student_i}}}^{\text{\# of students affected by program } i} \times \frac{1}{(Total\ \#ofStudents)} \times \overbrace{\frac{\$}{Student_i} \times \frac{Normal(0.033, 0.0016)}{\$1000}}^{\text{Effect of program } i \text{ on persistence}}$$

The average scholarship amount given to each student cancels for each term in the sum and the total funding going to students is summed over all scholarship programs. The scholarship funding input into this equation already had overhead and nonrelated costs for each program (inferred from FY10 funding) subtracted out. The scholarship model variant included the added funding into the above sum during 2016 and added zero for all other years. After some testing of the model to the sensitivity of the output to the added funding amount, $\$4.17092 * 10^8$ was decided as the amount to be added.

Outputs for the comparison of the base model to the scholarship variant were the number of post-secondary enrollees multiplied by the enrollment rate of STEM majors. Since quarterly time steps were used in all model simulation runs, the product for each quarter in 2016 was summed to obtain the 2016 total number of STEM students persisting. Comparing this result using the Tukey 95% confidence intervals produced the number of STEM students persisting <u>due to the funding difference</u> between the base and scholarship variant models.

4.1.3 ROI REU Model

The effect of federal REU programs on STEM student persistence was specified in the REU model as:

$$\begin{pmatrix} Effect\ of\ REU \\ programs\ on\ persistence \end{pmatrix} = Normal(0.24, 0.009) \times \frac{(Base\ model\ \#of\ REU\ students + added\ REU\ students)}{Total\ STEM\ majors}$$

Added REU students were calculated by dividing the funding added by the average REU student stipend across programs ($5000). After some testing of the model to the sensitivity of the output to the added funding amount, $4.501308 $*10^7$ was decided as the amount to be added.

Outputs for the comparison to the base model were the total number of STEM majors multiplied by the effect of REU programs on persistence. Similar to the scholarship calculation, quarterly STEM student numbers were summed to obtain the total number of STEM students persisting in 2016. Comparing this result using the Tukey 95% confidence intervals produced the number of STEM students persisting due to the funding difference between the base and REU variant models.

4.1.4 Assumption Testing

The node equation for the effect of scholarship programs on persistence was changed from the base model to have the persistence effect depend only on the number of students receiving scholarships and not on scholarship size.

$$\begin{pmatrix} Scholarship\ programs' \\ effect\ on\ persistence \end{pmatrix} = \frac{0.16}{(Total\ \#of Students)} \times \sum_{i}^{\substack{All\ Scholarship \\ Programs}} \frac{\begin{pmatrix} Scholarship \\ program \\ funding \end{pmatrix}_i}{\$/_{Student_i}}$$

This implies that each student receiving a scholarship would have their likelihood of persisting in STEM increased by 16%.

The 16% likelihood was calculated by relating the minimum STEM scholarship size to the average student debt size. In 2010, the average student debt size was $25,250 (Lewin, 2011), which corresponds to a need size of $6,312 per year. The minimum scholarship size found in the literature review is approximately $2,000, which corresponds to about 30% of need met. A study by (Noel-Levitz, Inc., 2011), relates between 30-40% of need met to a persistence rate of 55.0%. This represents a 16% increase above the base rate of %39 (National Center for Education Statistics, 2012).

This model was simulated for 30 runs and the total number of STEM students in 2020 was compared to the base model using the Tukey test to obtain a 95% confidence interval on the mean of the difference.

4.2 Results

4.2.1 Base Model Results

In calibrating the base model, the number of time steps needed per year was tested. One time step per year was determined as too little to allow the model to reach a steady state. Next, four time steps per year and eight time steps per year were tested and it was clear that both allowed the model to reach a steady state quickly. Therefore four time steps per year were chosen as suitable. The base model generally showed a near linear increase in the total number of STEM students from 2010 to 2020 (Figure 11).

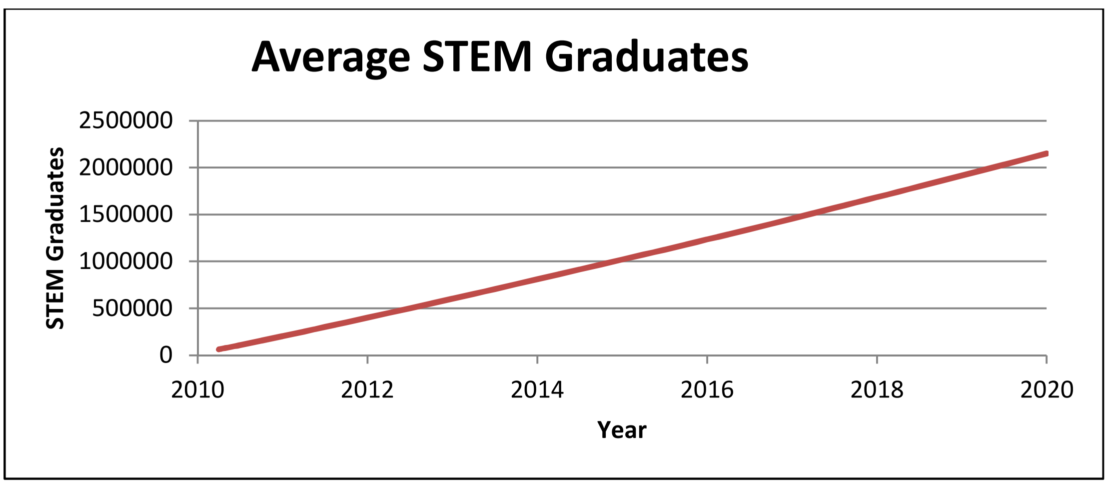

Figure 11 – Average STEM Graduates in the Base Case

This is because the rate of STEM graduates per year was fairly stable after a short warm up period of about two years.

Figure 12- Yearly rate of STEM graduates +/- one standard deviation

After 2012, the graduation rate seems to increase slightly every year until 2018. The system may have reached a steady state of STEM graduates by 2018, because there is no significant increase in the graduation rate afterwards. However, this could not be tested. The model was not built to simulate past 2020 because projecting that far into the future would likely cause some assumptions to break down.

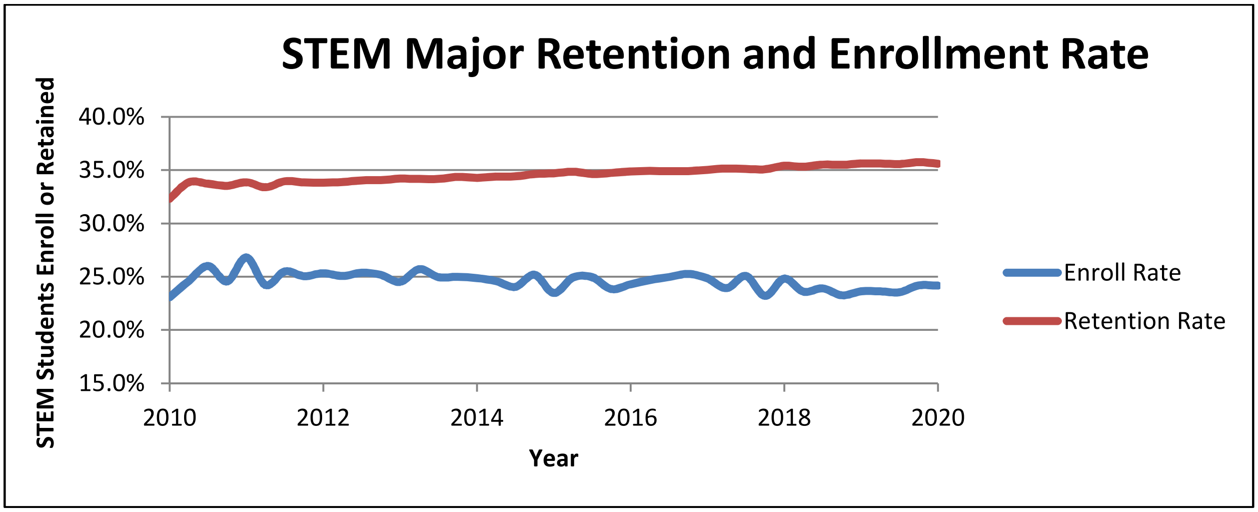

Figure 13- STEM persistence rates for the base case

After some fluctuations, Figure 13 shows that the retention rate steadily increases linearly. This is because the average high school GPA of STEM college enrollees were modeled as slowly increasing over the next decade. The other main factor affecting the retention rate is the component added by the federal REU programs. Additionally, the STEM student enrollment rate slightly decreased over the time period. This drove the percentage of STEM students affected by REU programs to increase slightly, thereby pushing the retention rate up. The cause of the increase in retention rate may have been that the REU programs included in the model have been keeping the number of students they accept each year steady. Although the retention rate seemed fairly linear, figure 13 showed that the enrollment rate had some distinct nonlinearities. The National Center for Education Statistics Science and Engineering Indicators 2014 Appendix table 2-17 (National Center for Education Statistics, 2012) shows the percentage of STEM Bachelor's graduates (percentage of total graduates) stayed around 30% from 2001-2011. Although this was contingent on graduation, it is close to the retention rate given by the base model throughout the timeframe that was examined.

4.2.2 ROI Results

The results of the 95% Tukey confidence interval on the mean of the difference between the REU/scholarship and the base model outputs (in terms of STEM students persisting) are:

Table 2 - 95% Tukey confidence interval results

2016	Mean	L Bound	U Bound
REU-Base	9114	8546	9683
Sch-Base	152073	127056	177090

The p-values for both intervals were significant (less than 0.001).

Dividing each row by the amount of added funding in the respective alternate model to obtain:

Table 3 – ROI results

	Dollars per STEM Student Persisting		
	Mean	L Bound	U Bound
ROI REU	$ 4,938.74	$ 4,648.76	$ 5,267.30
ROI SCH	$ 2,742.70	$ 2,355.25	$ 3,282.74

The mean ROI of REU programs was larger than the mean ROI of scholarship programs. Because the 95% confidence intervals do not overlap, the difference in ROI is significant. These results support the idea that funding federal STEM student scholarship programs would be preferable to adding funding to federal REU programs. Levene's test was conducted on both data sets and neither p-value was significant:

Table 4 – Levene's Test Results

Levene's Test	
Comparison	**p-value**
REU - Base	0.2613
Scholarship - Base	0.556

Therefore the assumption of equal variances was not rejected.

4.2.3 Assumption Testing Results

The results of the Tukey test showed that the fixed scholarship persistence model produced more students persisting in STEM by a mean of 293,983 STEM students. The 95% confidence interval on this mean was ($2.6*10^5$, $3.27*10^5$). This amounted to about one additional year worth of STEM graduates. The p-value was significant (less than 0.001). Levene's test was conducted on the data and a non-significant result was obtained (p-value=0.2385). Therefore the assumption of equal variances made by Tukey's test was not rejected.

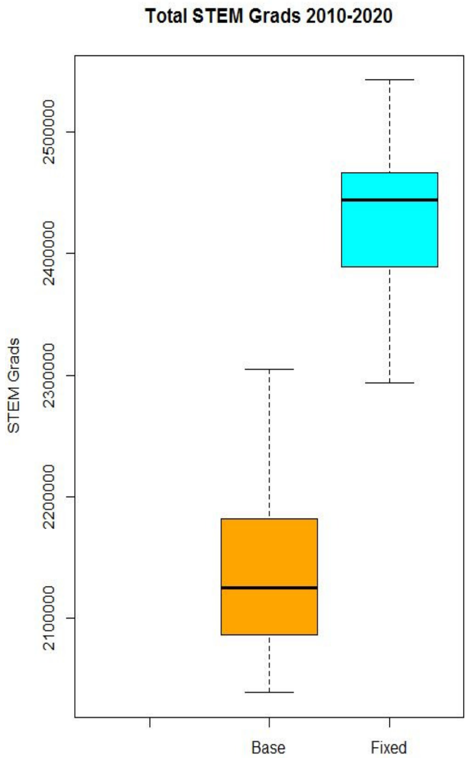

Figure 14 – Assumption test box plot

The box plot in Figure 14 shows a comparison of the total number of STEM grads by 2020 for each of the base and fixed scholarship persistence models. The total STEM grads given by the fixed model is significantly higher than in the base model. This may be because the proportion of STEM students receiving scholarships was around 70%. Nevertheless, the majority of scholarships awarded (due to the SMART grants program) were only a few thousand dollars. This situation explained why the fixed persistence model produced more STEM graduates.

5 Conclusions

5.1 Literature Conclusions

The literature review that informed the model gave many insights into the availability of data relevant to factors and federal programs affecting the STEM student pipeline. The most essential data sources were the National Center for Education Statistics and the GAO. The GAO's reports were crucial to isolating STEM education focused programs across agencies. The availability of data varied widely across agencies for federal STEM education programs. Classifying STEM programs into categories of federal initiatives (e.g. REU programs, STEM student scholarship programs…) greatly facilitated the specification of program effects on student level outcomes (i.e. persistence in the STEM pipeline). The classification process was necessary due to the lack of publicly available data on national level, yearly, student level program outcomes.

No programs had processes in place where programs published annual assessments of STEM performance with relation to undergraduate outcomes. Therefore most model parameters relied heavily on one-time assessments that produced a single, national level, parameter estimate. Although these estimates were generally of high quality, samples were too small to derive distributions for these important parameters. Conveniently, the SD approach allowed the importance of these parameters to be tested relative to model outputs. Nevertheless, the research generally showed that programs were more likely to report performance measures relevant to STEM when the agency goals they addressed intersected with the cross agency STEM goals.

Performance reporting is generally tailored to agency objectives. Cross-agency data reporting suffers when CAP goals are not exactly aligned with agency objectives. This situation suggests that agencies should more clearly identify how much money they are investing in specific STEM education initiatives. Clarifying the investments in STEM education initiatives within programs would allow the federal government to more clearly track STEM education spending. Questions that frequently arose in the literature review were: For STEM student scholarship programs, how much money is actually going to students? And what percentage of total REU program funding is going to supporting the undergraduates involved? An additional suggestion could be to have programs focus on specific interventions such as the NSF REU program. Two major STEM education programs by the NSF (Catalyzing Advances in Undergraduate STEM Education & STEM Talent Expansion Program) were unable to be included in the model because of a dearth of publicly available information about how funding is allocated among STEM student interventions (i.e. curriculum enhancing initiatives, teacher training, STEM student mentoring, pilot studies…).

5.2 Modeling Conclusions

A system dynamics model of the STEM student pipeline that includes links from federal program funding to effects of that funding on rates that regulate flow works well to test how differences in funding allocation might affect national level outcomes. The SD modeling approach leant itself to using the effects of federal interventions to determine rates of flow.

Moreover, the approach gives decision makers the opportunity to calculate ROI per time interval to see how funding decisions might change over time. Modeling how federal initiatives affect rates through a pipeline also facilitated the comparison of ROI measures across the pipeline. Because ROI could be measured in terms of augmented flow, impacts on different points of the pipeline are directly comparable. Additionally, if final model outputs (in this case, STEM graduates per year or total STEM graduates at simulation end) had not shown significant differences from the base model to the alternative (funding added) models, then that would have provided insight into the importance of later parts of the pipeline in shaping the outputs. Had that been the case, insight would have been given about how subsections of the pipeline should be prioritized for federal investment. However, the current results indicated that, although research experiences are known to increase the likelihood of persistence in STEM by a greater amount than scholarships, scholarships to undergraduate STEM students provide a less costly way of increasing the flow of the STEM student pipeline.

The return on investment comparison between REU programs and STEM student scholarships was reasonable for several reasons. Most importantly, giving out more scholarships or larger scholarships requires less infrastructure and overhead investment than setting up new laboratories or renting existing high-tech facilities for undergraduate opportunities. REU programs generally require a larger number of high paid researchers or faculty to mentor each student during the program. Whereas scholarship administrators may not be as highly paid as their work is of a less specialized nature. Thirdly, the overall effect of REU programs within the model is understated due to the large number of both federal and non-federal programs that provide REU opportunities but do not report the number of students involved. Another important factor to be included in the calculation of ROI for REU programs would be the costs associated with idle or underused facilities (or, conversely, the benefit of permitting REU students access to facilities that would otherwise be idle or underused). Although the REU programs produced a significantly lower ROI than the scholarship programs, it is worth noting that both ROIs are on the same order of magnitude. This provides some assurance that federal REU initiatives are still providing a reasonable ROI. Despite the smaller ROI of REU programs, the results given in this report indicate that they are a viable solution to the cross agency goal of increasing the total number of STEM students by one million in 2020. Using only STEM student scholarships to increase persistence would result in the cross-agency goal being met if an additional $2.7 Billion were invested in providing STEM student scholarships over ten years.

The ability to test assumptions within the model provided an advantage of the SD framework. The discussion of effects of scholarships on undergraduate persistence found in the literature motivated an examination of whether or not that particular parameter's variation significantly affected model outputs. The Tukey test's significant result suggests two things. It is unclear if the significant result was because the effect of the fixed persistence added by a scholarship being too high (relative to the true value), or scholarship size significantly affects the amount added to STEM persistence. Besides raising more questions, the Tukey test did indicate that the current STEM student scholarship situation, in which 70% of STEM students receive some federal scholarship money, is biased towards the fixed persistence rate model. This explains why the fixed persistence model produced nearly 300,000 additional STEM students when compared to the base model.

6 Future Research

Several questions were raised during both the literature review and the modeling effort that could constitute grounds for future studies. If programs aimed at undergraduate STEM students instituted processes by which they routinely evaluated performance based on national averages of student level outcomes that controlled for ethnicity and socio-economic background, then the distributions of parameters included in this model could replace the point estimates currently in place. This would greatly enhance the predictive power of the model by mirroring the stochastic nature of variables in the system. Additional federal initiatives such as bridge programs, curriculum enhancements, and extracurricular activities could be included in the model for ROI comparisons against STEM student scholarships and REU programs. Introducing these interventions might give a better insight into the optimal funding allocation to achieve the cross agency STEM goal using a combination of intervention techniques. Possible data sets that could be collected could show the long term effects of STEM infrastructure investments on both STEM student persistence and wider perception of STEM, the social factors influencing STEM attrition, or compare public vs. private sector ROI for STEM education investments. Future research might also add more sections of the STEM pipeline so that more federal programs could be introduced to the model. Also future studies may be interested in the subset of federal STEM education programs that aim to increase the proportion of minority classes of STEM students. Although these studies would need to include complex interactions between background sociocultural factors and other factors which would typically be included in an analysis of STEM student attrition

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Appendix A - Model Specification

The following appendix displays the node and node description for the model referenced in this report. Node descriptions excluded from this appendix represent nodes to facilitate data gathering and model settings.

STEM Pipeline View is shown in Figure 15.

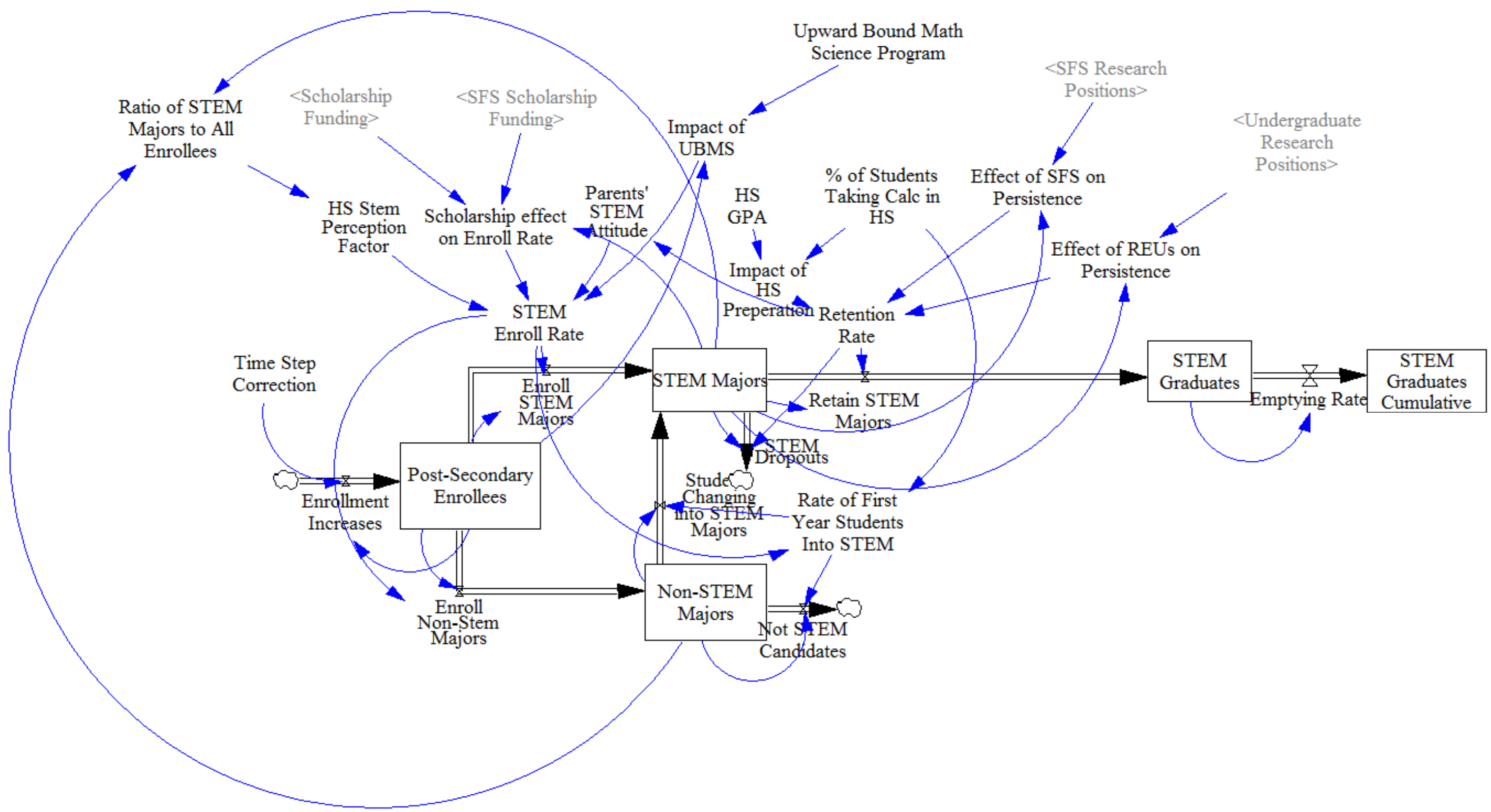

Figure 15 – STEM Pipeline Model View

A view of the STEM programs used in the model is shown in Figure 16.

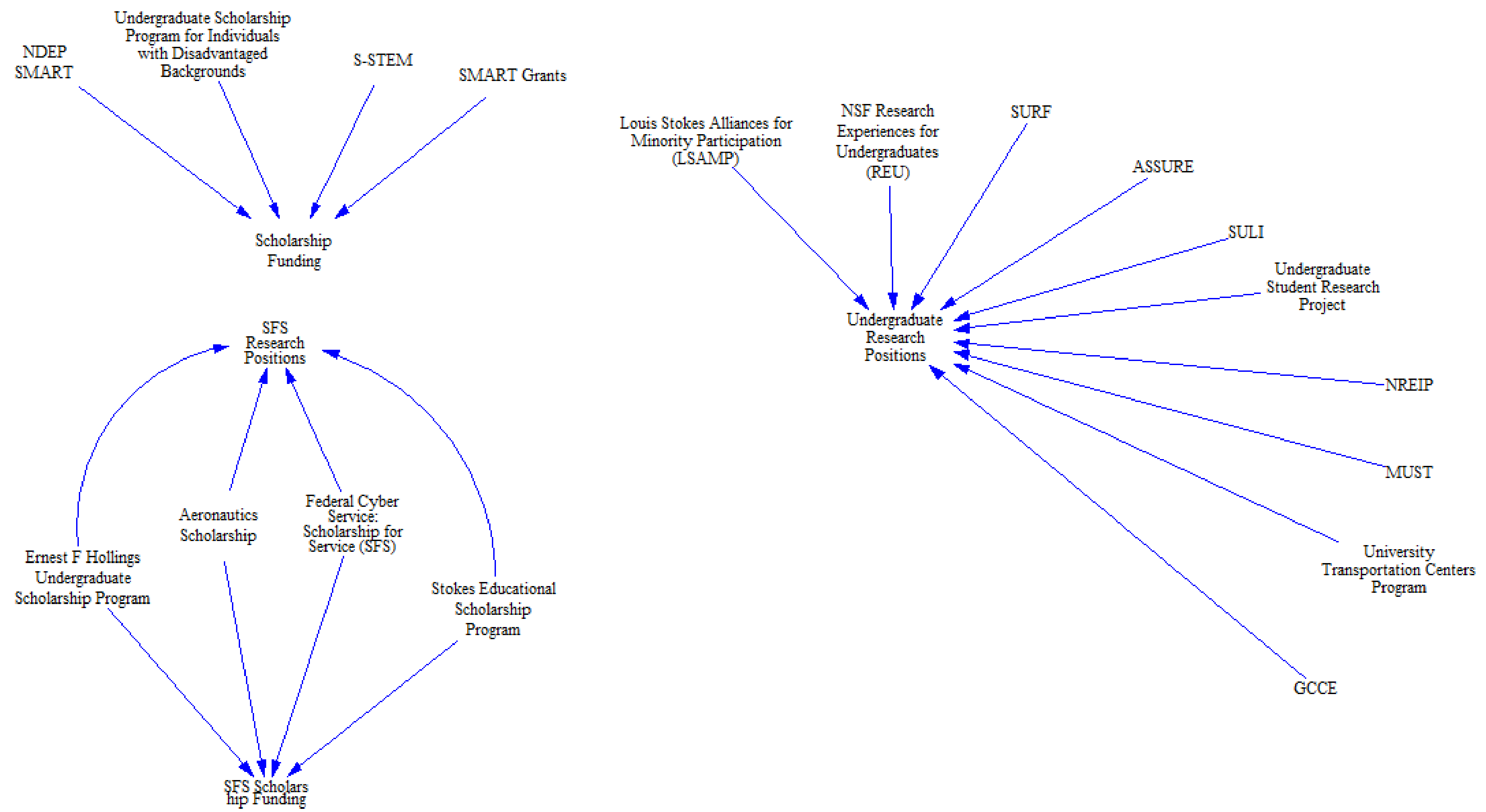

Figure 16 – STEM Program Model View

Node Specification

STEM Pipeline Nodes

Node Name: % of Students Taking Calc in HS
Value: 0.1586
Note: Approximately 15.86% of High Schools take Calculus (National Center for Education Statistics, 2012)

Node Name: Effect of REUs on Persistence
Value: RANDOM NORMAL(0.2, 0.3 , 0.24, 0.04, 0)*INTEGER(Undergraduate Research Positions)/STEM Majors
Note: The percentage of students involved with REUs is multiplied by the percentage increase in STEM persistence due to the REU experience. Random normal distribution of this effect was added per (MIT Washington, 2013).

Node Name: Effect of SFS on Persistence
Value: SFS Research Positions/STEM Majors*0.39
Note: The percentage of students involved with a SFS is multiplied by the percentage increase in STEM persistence due to the scholarships for service experience (MIT Washington, 2013).

Node Name: Enroll Non-Stem Majors"=
Value: Post-Secondary Enrollees"*(1-STEM Enroll Rate)
Note: Non-STEM major enrollment rate is assumed to be 1 – STEM Major Enrollment rate

Node Name: Enrollment Increases
Value: INTEGER(RANDOM NORMAL(-0.0975 , 0.1578 , 0.0218, 0.0665 ,0)*"Post-Secondary Enrollees"/Time Step Correction)+"Post-Secondary Enrollees"
Note: Population of Students entering the STEM Undergraduate pipeline (US Census, 2012). Modeled as a random normal distribution to introduce variability into the model.

Node Name: HS GPA
Value: 3.02 + RAMP(0.020686/4 , 0 , 40)
Note: Average high school GPA rose linearly from 1990-2011 and is expected to continue that trend at least through 2020 (National Center for Education Statistics, 2012).

Node Name: HS Stem Perception Factor
Value: 0.02*(Ratio of STEM Majors to All Enrollees-0.384)
Note: Uses the ratio of STEM enrollment to approximate HS student STEM Perceptions. This is an assumed factor that amplify STEM as becoming more or less popular. The

Project Team assumes that things that are increasing in popularity will have an additional effect with high school students and vice versa.

Node Name: Impact of HS Preparation
Value: 0.059*((HS GPA-1)/0.42857)+"% of Students Taking Calc in HS"*0.123
Note: Analysis of STEM high school preparation W.R.T. to retention. Included in this calculation are:

- 5.9% of students are increased with a GPA above a calculated threshold (Oseguera & Rhee, 2009).
- 12.3% of STEM majors who take calculus in high school graduate as STEM students (Chen, 2013).

Node Name: Impact of UBMS
Value: Upward Bound Math Science Program/1663*1/"Post-Secondary Enrollees"
Note: Factor was calculated using (US Depatment of Education, 2010).

Node Name: Non-STEM Majors
Value: INTEG ("Enroll Non-Stem Majors"-Not STEM Candidates-Students Changing into STEM Majors
Initial Value: (2.058e+006 *0.614)/Time Step Correction)
Note: STEM Pipeline stock node. Initial values researched from (National Center for Education Statistics, 2012)

Node Name: Parents' STEM Attitude
Value: 0.205*Retention Rate + RANDOM UNIFORM(0, 0.355*0.384 ,0)
Note:

- 38.4%= original estimate of what enrollment rate should be (National Center for Education Statistics, 2012)
- 35.5% of Parents influencing kids to pursue STEM (Harris Interactive, 2011)
- 20.5% is a model calibration factor to allow for the model to be in line with estimate base values.

Node Name: Post-Secondary Enrollees
Value: INTEG (Enrollment Increases-"Enroll Non-Stem Majors"-Enroll STEM Majors,
Initial Value: 2.058e+006 / Time Step Correction)
Note: Post-Secondary Enrollee data from (National Center for Education Statistics, 2012)

Node Name: Rate of First Year Students into STEM
Value: % of Students Taking Calc in HS*0.17*(1-STEM Enroll Rate)+0.01
Note: Rate at which Non-STEM students switch into STEM. Found that 17% of Non-STEM majors who took calculus in high school would switch into a STEM field (Chen,

2013). This was multiplied by 1-STEM Enroll Rate to translate into a rate factor effect. 0.01 was added as a calibration factor.

Node Name: Ratio of STEM Majors to All Enrollees
Value: STEM Majors/("Non-STEM Majors" + STEM Majors)
Note: Node to calculate the ratio of STEM Students

Node Name: Retention Rate
Value: Impact of HS Preparation + Effect of REUs on Persistence + Effect of SFS on Persistence
Note: Summation of rate effects.

Node Name: Scholarship effect on Enroll Rate
Value: (Scholarship Funding + SFS Scholarship Funding)/(STEM Majors)*(RANDOM NORMAL (0.024, 0.042 , 0.033 , 0.004 , 0)/1000)
Note: This rate effect is calculated as an increase of 2-4% to the enroll rate per $1,000 of scholarship funding (Bettinger, 2004). This factor was modeled as a random normal distribution to introduce variability.

Node Name: STEM Dropouts
Value: STEM Majors*(1-Retention Rate)
Note: Drop rate is 1 - retention rate.

Node Name: STEM Enroll Rate
Value: HS Stem Perception Factor + Parents' STEM Attitude + Scholarship effect on Enroll Rate + Impact of UBMS
Note: Summation of enrollment rate effects

Node Name: STEM Graduates
Value: INTEG (Retain STEM Majors-Emptying Rate)
Initial Value: 0
Note: STEM pipeline stock node.

Node Name: STEM Majors
Value: INTEG (Enroll STEM Majors + Students Changing into STEM Majors-Retain STEM Majors-STEM Dropouts)
Initial Value: (2.058e+006*0.384)/Time Step Correction)
Note: STEM pipeline stock node. Initial values from (National Center for Education Statistics, 2012)

STEM Program Nodes

Node Name: Aeronautics Scholarship
Value: 1.8e+006
Units: $
Note: FY10 budget for the NASA Aeronautics Scholarship Program (Executive Office of the President, 2011).

Node Name: ASSURE
Value: 4.5e+006
Units: $
Note: FY10 budget for Awards to Stimulate & Support Undergraduate Research Experiences (ASSURE) (Executive Office of the President, 2011)

Node Name: Ernest F Hollings Undergraduate Scholarship Program
Value: 5.6e+006
Units: $
Note: FY10 budget (Executive Office of the President, 2011)

Node Name: Federal Cyber Service: Scholarship for Service (SFS)
Value: 1.487e+007
Note: $1663 per student involved is the 2010 amount estimated as spent per student[2] who enrolled in college after participating in the program. This doesn't include overhead costs because that data was not available. Assumption was that these students enrolled as STEM majors due to the impact of the program (US Depatment of Education, 2010)

Node Name: Louis Stokes Alliances for Minority Participation (LSAMP)
Value: 1301
Note: This is number of undergrad students confirmed in REU programs for the baseline year. Relation to funding is unclear as this program sponsors a number of institutional grants that neither contribute to sponsoring additional REU students nor overhead for REU opportunities[3].

Node Name: NDEP SMART
Value: (4.7e+007*0.51)
Note: FY10 budget for National Defense Education Program (NDEP) (Executive Office of the President, 2011). 49% Overhead Rate and Grad Student Spending derived from program description (DTIC, 2012)

[2] The number of students involved was given via phone call with Kathy Roberson - SFS Program Manager (5-6-14, 13:45)

[3] The following document was reviewed and numbers of REU students explicitly mentioned were added to obtain the total. Grants producing REU opportunities that did not report the number of REU students involved were unfortunately unable to be included in the analysis. http://www.uab.edu/alsamp/LSAMP_%2709.pdf

Node Name: NREIP
Value: 1.9e+006
Note: FY10 budget for Naval Research Enterprise Program (NREIP) (Executive Office of the President, 2011).

Node Name: NSF Research Experiences for Undergraduates (REU)
Value: 1.0047e+008
Note: FY10 budget for NSF Research Experiences for Undergraduates (REU) (Executive Office of the President, 2011).

Node Name: S-STEM
Value: (7.596e+007*0.75)
Note: Assumed 25% Overhead Rate. FY10 budget for NSF STEM Scholarships (S-STEM) (Executive Office of the President, 2011).

Node Name: Scholarship Funding
Value: NDEP SMART+"S-STEM"+SMART Grants + Undergraduate Scholarship Program for Individuals with Disadvantaged Backgrounds
Note: Summation of scholarship summation nodes.

Node Name: SFS Research Positions
Value: Aeronautics Scholarship*0.11/10000+"Federal Cyber Service: Scholarship for Service (SFS)"*0.11/10000+Ernest F Hollings Undergraduate Scholarship Program*0.12/6500+ (Stokes Educational Scholarship Program*0+15)
Note: Number of students involved with SFS programs. This is calculated by dividing the budget for stipends by the stipend size or directly inputting the value if unknown. Stipend budget size and stipend size was available via program descriptions.

Node Name: SFS Scholarship Funding=
Value: Aeronautics Scholarship*0.33+Ernest F Hollings Undergraduate Scholarship Program*0.6+"Federal Cyber Service: Scholarship for Service (SFS)"*0.21+Stokes Educational Scholarship Program*0.28
Note: Coefficients reflect percentage of program budget allocated for undergraduate scholarships. This percentage is calculated by dividing total FY10 funding by number of students in the base scenario * scholarship size.

Node Name: SMART Grants
Value: (3.41e+008 * 0.7)
Note: Assume 30% Overhead Rate. FY10 budget for Department of Education SMART grants (Executive Office of the President, 2011).

Node Name: Stokes Educational Scholarship Program
Value: 1.6e+006
Note: FY10 budget (Executive Office of the President, 2011).

Node Name: SULI
Value: 5.224e+006
Note: FY10 budget for Science Undergraduate Laboratory Internships (SULI) (Executive Office of the President, 2011).

Node Name: SURF
Value: 287000
Note: FY10 budget for Summer Undergraduate Research Fellowship Program (SURF) (Executive Office of the President, 2011).

Node Name: Undergraduate Research Positions
Value: ("NSF Research Experiences for Undergraduates (REU)"*(1-.2027)+ASSURE*(1-0.2778)+SULI*0.77+NREIP*(1-0.4026)+(1-0.4906)*Undergraduate Student Research Project)/5000+404[4]*(SURF*0+1)+100[5]*(0*MUST+1)+480[6]*(1+0*University Transportation Centers Program)+224[7]*(0*GCCE+1)+"Louis Stokes Alliances for Minority Participation (LSAMP)"
Note: Calculation of the number of undergraduate researchers. Programs whose primary purpose was to provide REU opportunities had their total funding allocated to students divided by the average stipend per student of $5000[8]. All other programs providing REU opportunities simply summed the number of students involved per year (as calculated individually based on information about that particular program). The result is the total number of REU positions.

Node Name: Undergraduate Scholarship Program for Individuals with Disadvantaged Backgrounds
Value: (2.4e+006*0.5)
Note: Calculated 50% overhead rate from program description. FY10 budget (Executive Office of the President, 2011).

Node Name: Undergraduate Student Research Project=
Value: 2.975e+006
Note: FY10 budget (Executive Office of the President, 2011).

Node Name: University Transportation Centers Program
Value: 8.36706e+007
Note: FY10 budget (Executive Office of the President, 2011).

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[4] Phone call with Program Manager (at 626-395-2886) on 5-6-14
[5] http://www.nasa.gov/sites/default/files/525243main_2010_MUREP_MUST.pdf
[6] http://www.rita.dot.gov/utc/sites/rita.dot.gov.utc/files/UTCperformance_Indicators2014.pdf
[7] http://www.nasa.gov/sites/default/files/522294main_2010_HE_GCCE.pdf
[8] http://www.nsf.gov/pubs/2013/nsf13542/nsf13542.htm

Node Name: Upward Bound Math Science Program
Value: 3.5204e+007
Note: FY10 budget (Executive Office of the President, 2011).

Appendix B – Earned Value Management Analysis

An important component project management for this project was the establishment of a schedule and a progress tracking tool early in the project lifecycle. The project schedule is shown in Figure 17.

WBS	Task Name	Duration	Start	Finish
1	Project Starts	1 day	Tue 1/21/14	Tue 1/21/14
2	**Project Meetings**	**123 days?**	**Tue 1/21/14**	**Sat 5/10/14**
2.1	Project Meetings	0 days?	Tue 1/21/14	Tue 1/21/14
2.2	Project Meetings	0 days?	Sat 5/10/14	Sat 5/10/14
2.3	**Sponsor Meetings**	**110.25 days**	**Thu 1/23/14**	**Thu 5/1/14**
3	**Define Project Scope & Proposal**	**25 days?**	**Tue 1/21/14**	**Wed 2/12/1**
3.1	Define Project Scope & Proposal	0 days?	Tue 1/21/14	Tue 1/21/14
3.2	Define Project Scope & Proposal	0 days?	Wed 2/12/1	Wed 2/12/1
3.3	Develop Problem & Scope	11 days	Tue 1/21/14	Tue 2/4/14
3.4	Develop Project Proposal	6 days	Tue 2/4/14	Tue 2/11/14
4	**Develop STEM Model**	**56 days**	**Fri 2/7/14**	**Sat 3/29/14**
4.1	Gather Data about STEM Programs	21 days	Fri 2/7/14	Tue 2/25/14
4.2	Analyze Data for use in Model	7 days	Wed 2/26/1	Tue 3/4/14
4.3	Generate Model Network	7 days	Tue 3/4/14	Mon 3/10/14
4.4	Generate Node Interactions	14 days	Tue 3/4/14	Sun 3/16/14
4.5	Analyze Model	14 days	Sun 3/16/14	Sat 3/29/14
5	**Develop Class Deliverables**	**73.13 days**	**Wed 3/5/14**	**Fri 5/9/14**
5.1	Develop Progress Report #1 Brief	7 days	Wed 3/5/14	Tue 3/11/14
5.2	Develop Progress Report #2 Brief	7 days	Wed 3/19/1	Tue 3/25/14
5.3	**Develop Project Report**	**50 days**	**Sat 3/22/14**	**Mon 5/5/14**
5.3.1	Develop Draft Report	23 days	Sat 3/22/14	Fri 4/11/14
5.3.2	Release Draft for Sponsor Review	7 days	Sat 4/19/14	Fri 4/25/14
5.3.3	Complete Final Draft	11 days	Sat 4/26/14	Mon 5/5/14
5.4	**Develop Final Presentation**	**46.13 days**	**Sat 3/29/14**	**Fri 5/9/14**
5.4.1	Develop Presantion Draft	14 days	Sat 3/29/14	Thu 4/10/14
5.4.2	Perform Presentation Dry Run	8 days	Sun 4/20/14	Sun 4/27/14
5.4.3	Complete Final Brief	11 days	Sun 4/27/14	Wed 5/7/14
5.4.4	Present to Faculty	0 days	Fri 5/9/14	Fri 5/9/14
5.5	Develop Website	16 days	Mon 4/21/14	Mon 5/5/14

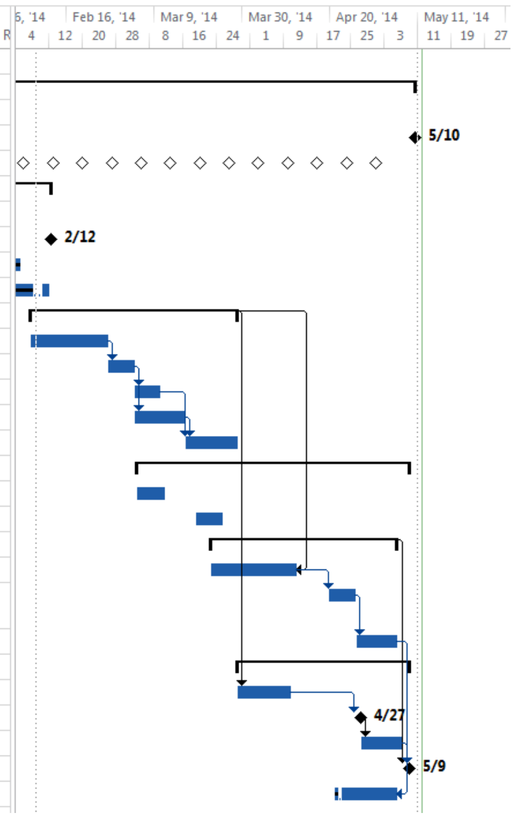

Figure 17 – Project Schedule

The project team used Earned Value Management (EVM) in order to track progress. The project team established this schedule as the project schedule baseline to track progress. Each team member was expected to report their work hours in an activity log using the Work Breakdown Structure (WBS) format shown in Figure 17.

The project team estimated a cost baseline by using the course expectation of 10 hours per week per team member outside of class. The hours were divided among tasks based on past experience in timeframes needed to complete similar tasks.

Using the weekly activity log data, the Project Team calculated the following EVM metrics:

- Budgeting Cost of Work Scheduled (BCWS)
- Actual Cost of Work Performed (ACWP)
- Budgeted Cost of Work Performed (BCWP) or Earned Value
- Cost Variance (CV)
- Schedule Variance (SV)
- Cost Performance Index (CPI)
- Schedule Performance Index (SPI)

Calculation of these metrics is shown in Table 5

Table 5- Final Earned Value Register

	Week 1	***Week 2***	***Week 3***	***Week 4***	***Week 5***	***Week 6***	***Week 7***	***Week 8***
BCWS	30	60	90	120	150	180	210	240
ACWP	27	63	103	142	179.5	224.5	254.5	276.5
BCWP	30	60	84	113	140.5	176.5	188.5	218.5
CV	3	-3	-19	-29	-39	-48	-66	-58
SV	0	0	-6	-7	-9.5	-3.5	-21.5	-21.5
CPI	111.1%	95.2%	81.6%	79.6%	78.3%	78.6%	74.1%	79.0%
SPI	100.0%	100.0%	93.3%	94.2%	93.7%	98.1%	89.8%	91.0%

	Week 9	**Week 10**	**Week 11**	**Week 12**	**Week 13**	**Week 14**	**Week 15**
BCWS	270	300	330	360	390	420	450
ACWP	306.5	352	398	445	491	575	629
BCWP	233.5	251.5	272.5	283.5	303.5	385.5	436.5
CV	-73	-100.5	-125.5	-161.5	-187.5	-189.5	-192.5
SV	-36.5	-48.5	-57.5	-76.5	-86.5	-34.5	-13.5
CPI	76.2%	71.4%	68.5%	63.7%	61.8%	67.0%	69.4%
SPI	86.5%	83.8%	82.6%	78.8%	77.8%	91.8%	97.0%

A graph of BCWS, ACWP and BCWP growth over the course of the project is shown in Figure 18. An import note from Table 5 and Figure 18 is that project ended over 150 hours over budget. The project team was able to absorb the overage to complete the project by the agreed upon deadline.

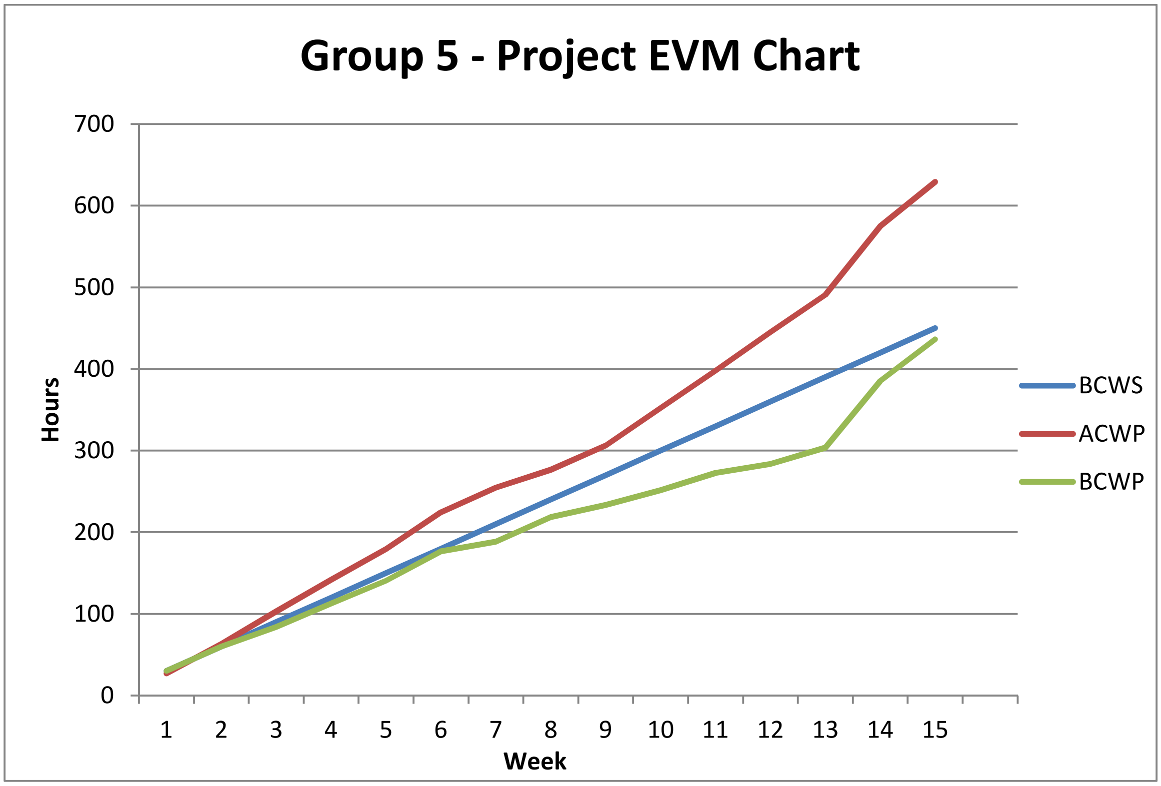

Figure 18- Final EVM Chart