A STEM BASED MODEL ROCKETRY CURRICULUM:
FOR THE TEAM AMERICA ROCKETRY CHALLENGE

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PROJECT

Submitted in partial satisfaction of
the requirements for the degree of

MASTER OF ARTS

in

EDUCATION
(Educational Leadership & Policy Studies)

at

CALIFORNIA STATE UNIVERSITY, SACRAMENTO

FALL
2009

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A Project

by

Thomas M. Sarradet Jr.

Approved by:

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Marilyn Winters, Ph.D.

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Date

ABSTRACT
of

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Brief Literature Review

The Team America Rocketry Challenge is a national competition that gives over 700 students nationwide an opportunity to win over $60,000 in scholarship money. While the contest has been in existence since 2003, the state of California does not have a representation in the contest in relation to the state's population. The researcher examined states that have a strong representation at the contest's finals and determined that students in those states may have more opportunities to acquire the skills needed to design, build, and fly model rockets through model rocketry education programs in their area.

The researcher discovered that creating a model rocket curriculum that taught the rocketry skills needed by the students may also serve a higher purpose of targeting science, technology, engineering, and math (STEM) standards. The researcher set out to determine what California and national STEM standards could be learned through model rocketry in addition to the rocketry skills.

Statement of Purpose

The purpose of this project is to create a STEM-based model rocketry curriculum that targets the basic model rocketry skills needed to succeed in the TARC. Because of its attention to the STEM standards, the curriculum may also serve as stand-alone elective

during the school day as a rocket club education program in an extracurricular setting, or as a two-week summer rocketry camp for middle and high school students.

Methodology

Questionnaires were developed and administered to parents and students to gauge the level of support for such a program. This information was compiled to determine whether further development of the curriculum was feasible. The results of the survey proved that the curriculum would have strong support among parents and students.

Conclusions and Recommendations

The data collected by the researcher suggests that there is a need for a STEM based model rocketry curriculum not only to train TARC students, but also as a means to teach science, technology, engineering, and math to middle and high school students. Model rocketry is hands-on, challenging and fun, that, when coupled with the curriculum developed by the researcher, becomes a very powerful teaching tool.

______________________________________, Committee Chair
Marilyn Winters, Ph.D.

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Date

DEDICATION

I dedicate this work to my three children, Michael, Stefanie, and Christopher. Through them I rediscovered my love of model rocketry.

ACKNOWLEDGEMENTS

I would like to thank my wife, Ina, who let me get out of a lot of "honeydos" in order to work on this project.

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INTRODUCTION

Background

The researcher became interested in the subject when he mentored Team 7009 of the 2009 Team America Rocketry Challenge. This was the first time that the researcher mentored a team and after much trial and error, the team managed to make two qualifying flights. Although the team did not make it to the final competition, the results of the first attempt were very promising. While researching the teams that were successful, the researcher found evidence to support the idea that a summer camp with its focus on this task, can improve the success rate of teams in the Team America Rocketry Challenge(Aerospace Industries Association, 2009).

The Team America Rocketry Challenge (TARC) is the world's largest rocket contest, sponsored by the Aerospace Industries Association (AIA) and the National Association of Rocketry (NAR). It was created in 2002 as a one-time celebration of the Centennial of Flight, but the enthusiasm about the event was so great that AIA and NAR were asked to hold the contest annually (Aerospace Industries Association, 2009). Approximately 7,000 students from across the nation compete in TARC each year. Teams design, build and fly a model rocket that reaches a specific altitude and duration determined by a set of rules developed each year. The top 100 teams, based on local qualification flights, are invited to Washington, DC in May for the national finals. Prizes include $60,000 in cash and scholarships split between the top 10 finalists (Aerospace Industries Association, 2009). NASA invites top teams to participate in their Student Launch Initiative, an advanced rocketry program. AIA member companies, such as Lockheed Martin and Raytheon have sponsored additional prizes such as scholarship money and a trip to an international air show.

Purpose of the Project

The purpose of this project is to develop a model rocketry curriculum that integrates math and science standards. In addition, it would target skills needed for students to be competitive in the Team America Rocketry Challenge.

California school participation in TARC is low. Out of the 653 teams registered to compete in the 2009 TARC, only 52 of those teams were from California. Of those 52, only 22 of the teams submitted a qualifying flight. A flight is considered successful if the egg payload is undamaged and the electronic altimeter records the rocket's highest altitude. By comparison, the State of Texas had 73 registered teams and 44 of those teams had a qualifying flight. In other words, 60% of Texas teams qualified for the 2009 competition. While Wisconsin only had 16 teams, 11 or 69%, of those teams qualified. One possible reason for higher success rates could be the availability of programs to the students in those areas that train the teams to be successful.

Wisconsin's Rockets for Schools program started in 1996 with 240 participating students. The current program involves middle and high school students from Wisconsin, Michigan, Illinois, and Iowa. One of its goals is to stimulate the academic interest in science, math and technology in students in grades 4 through 12(Rockets for Schools, 2008).

SystemsGo is a project-based rocketry program in Fredericksburg, Texas that serves over 40 schools and about 600 students. Its goal is to promote engineering studies through research, to develop work force skills, and encourage students to enter academic and career paths in STEM fields that lead to careers in the engineering industries. Each spring students and teachers gather in Fredericksburg to launch rockets that they designed and built. First-year students build and fly high-powered rockets carrying a scientific payload to a high altitude while students who participate in a second-year program develop a transonic sounding rocket. According to SystemGo's website, 80% of the students in the SystemsGo aero science program have continued on to study engineering in college (Ignite, 2007). The SystemsGo program inspired NASA's Marshall Space Center to create the Student Launch Initiative (Marshall Space Flight Center, 2002). SLI, involves middle and high school students in designing, building and testing reusable rockets with associated scientific payloads. Teams can qualify to participate by placing in the top level two teams at the Rockets for Schools competition held in Wisconsin or by placing in the top at the Team America Rocketry Challenge.

The 433rd Airlift Wing at the Kelly Annex on Lackland Air Force Base, Texas has sponsored Starbase Kelly, a hands-on educational program for San Antonio fourth, fifth, and sixth grade students. Starbase Kelly is part of DoD Starbase, a national initiative funded by the Department of Defense to interest school children in science, technology, engineering and mathematics, or STEM. The participating students come from five school districts surrounding Lackland for the five-day camp(Thompson, 2008).

Definition of Terms

AAPPT

American Association of Physics Teachers

AEX

The Civil Air Patrol’s Aerospace Excellence program

CAP

Civil Air Patrol, an auxiliary of the United States Air Force

CDE

California Department of Education

Curriculum

An operational plan for instruction that details what students need to know, how students are to achieve the identified curricular goals, what teachers are to do to develop their knowledge, and the context in which learning and teaching occur.

Elective

A class or course chosen by the student and is usually not one of the core subjects.

Elective Wheel

The organization of electives into a rotation of one elective per grading period. An example would be a trimester system with students rotating through computers, art, and model rocketry.

TARC

Team America Rocketry Challenge

NAESP

National Association of Elementary School Principals

NAR

National Association of Rocketry

NASA

National Aeronautics and Space Administration

SET

Science Engineering Technology

SBE

California State Board of Education

SLI

Student Launch Initiative

STEM

Science Technology Engineering Math

YMCA

Young Men's Christian Association

Significance of the Project

The STEM based model rocketry curriculum project will assist educators in preparing students to compete in the Team America Rocketry Challenge. The contest is designed to encourage students to ignite an interest in science, technology, engineering and math and to pursue careers in aerospace. Students who participate in the Team America Rocketry Challenge are required to use these academic disciplines in a hands-on manner in order to be successful in the contest. This project is focused on developing a program that addresses specific STEM standards that are engaged by TARC participants, as well as other students who study model rocketry in a class or club environment.

Administrators will find that the use of model rockets to teach to the STEM standards motivates the students to excel in these subjects. Model rocketry, when used as a tool to engage students in STEM education, may create an interest in the students of following a career path that they may not have considered before.

This project will provide a school or district with a curriculumthat can serve several purposes. The curriculum may be used as an extracurricular activity for a group of students who wish to compete in the Team America Rocketry Challenge, or as an enrichment program. The project may also serve as a curriculum in an elective rocketry class. Selected lessons may be used as a module in a science class as part of the curriculum on force and motion. The curriculum may also be used as a collaborative effort by math and science teachers in a team environment.

Organization of the Remainder of the Project

This paper is organized into four chapters. Chapter 1 includes the background, the statement of purpose, the significance of the project, definition of terms, and the limitations and organization of the project. Chapter 2 contains a review of related literature. This review includes the history and review of national and California STEM content standards, after school organizations and programs, including student team competitions, and on model rocketry, its history and its educational value.

Chapter 2

REVIEW OF RELATED LITERATURE

Introduction

On September 6, 2007 at 10:10 a.m., the third period rocketry class of E.V. Cain Middle School launched the first student-built rocket. The rocket, serial number S07001, was followed by over300 successful and safe rocket launches over the next two years. The model rocketry has become very popular with the students as well as the parents. Students rush into the classroom excitedly asking, “Are we launching rockets today?” The success and popularity of the class is owed to this simple fact: model rocketry is the “hook” that motivates and involves students in science. To put it plainly, model rocketry is fun!

Based on research and experience, the researcher firmly believes that using model rocketry as an educational tool creates energy and excitement about science and math among the students. Such enthusiasm is needed if the students are being encouraged to pursue math and science based careers. Yet adding model rocketry to the curriculum is not a simple matter. Model rocket motors, rocket kits or parts, and the equipment to build and fly them are expensive. There is also the matter of safety. While some rocketry programs use water and air powered rockets, this curriculum calls for the use of black power motors, which demand a degree of caution. Much like the scalpels used for dissection, rocket motors pose no great risk to students if used properly.

The review of related literature is divided into three subtopics. The first subtopic will be the math and science standards. The researcher examineshow standards came to be in education and a review of science, technology, engineering, and math standards that pertain to the project. The second subtopic coversa history and review of after-school programs and competitions that are currently available to middle and high school students. The third and final subtopic is an explanation of model rocketry. The researcher provides a history of the hobby, organizations that promote rocketry and previous publications that sought to promote model rocketry as an educational tool.

A History and Review of Academic Content Standards

National and California Content Standards in Math, Science, and Technology

President Ronald Reagan appointed Terrel H.Bell as secretary of education in 1981. Knowing that the president planned to abolish the Department of Education, Bell set out to change Reagan's mind. During his four years in the Departmentof Education, Bell established the National Commission on Excellence in Education in 1981 and directed it to examine the quality of education in the United States. The commission published *A Nation at Risk: the Imperative for Educational Reform*in 1983 (Miller Center of Public Affairs, 2009).

> The Commission was charged with paying particular attention to these areas:

assessing the quality of teaching and learning in our Nation's public and privateschools, colleges, and universities;

comparing American schools and colleges with those of other advanced nations;

studying the relationship between college admissions requirements and studentachievement in high school;

identifying educational programs which result in notable student success in

college;

assessing the degree to which major social and educational changes in the lastquarter century have affected student achievement; and

defining problems which must be faced and overcome if we are successfully topursue the course of excellence in education.(National Commission on Excellence in Education, 1983, p. 7)

The prognosis of the commission was bleak.

Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world. This report is concerned with only one of the many causes and dimensions of the problem, but it is the one that undergirds American prosperity, security, and civility.(National Commission on Excellence in Education, 1983, p. 9)

In its findings, the commission stated,“We conclude that declines in educational performance are in large part the result of disturbing inadequacies in the way the educational process itself is often conducted” (National Commission on Excellence in Education, 1983, p. 21).

The commission made eight recommendations based on the findings. Among the recommendations was to determine lower division course requirements in universities and colleges so that high school curricula may be aligned to them.

Though President Reagan did not abolish the Department of Education, he did continue to cut its funding and Bell eventually resigned. He returned to Utah, where he served as professor at the University of Utah before dying in 1996. Most educators cite Bell’s 1983 report as the starting point for the current emphasis on education standards (Marzano & Kendall, 1998).

The first academic standards for K12 education were published 20 years ago when mathematics educators and mathematicians addressed the subject of national standards with the publication of *Curriculum and Evaluation Standards for School Mathematics* in 1989 by the National Council of Teachers of Mathematics (National Committee on Science Education Standards & Assessment, 1996). The Standards did much for mathematics education by providing a consensus for what school mathematics should be (Yager, 2006). These standards are one facet of the mathematics education community's response to the call for reform in the teaching and learning of mathematics by*A Nation at*

Risk: the Imperative for Educational Reform(National Council of Teachers of Mathematics. Commission on Standards for School Mathematics, 1989).

Themathematics standards are divided into four categories: grades K-4, grades 5-8, grades 9-12, and evaluation. Each category lists a summary of changes in content and emphasis in mathematics. Increased and decreased attention for grades five through eight are suggested in the areas of problem solving, communication, reasoning, and connections, number/operations/computation, patterns and functions, algebra, statistics, probability, and geometry. Under connections, there is recommendation for increased attention for connecting mathematics to other subjects and to the world outside the classroom and decreased attention on learning isolated topics.

> In 1989, the American Association for the Advancement of Science (AAAS), through its Project 2061, published *Science for All Americans,* defining scientific literacy for all high school graduates. Later, the National Science Teachers Association (NSTA), through its Scope, Sequence & Coordination Project, published *The Content Core*. (National Committee on Science Education Standards & Assessment, 1996, p. 14)

The National Science Foundation (NSF) set out to develop its own set of standards modeled after the *Curriculum and Evaluation Standards for School Mathematics*. Seven million dollars and four years of debate later, the 262-page *National Science Education Standards*was published in 1996 (Yager, 2006).In acknowledging the document that started the shift toward standards based education, *A Nation at Risk*, the authors state that other countries are investing heavily to create scientifically and technically literate work forces. To keep pace in global markets, the United States needs to have an equally capable citizenry.The NSF standards are organized in six chapters that address standards for science teaching, professional development, assessment, science content, science education programs, and science education systems.According to the six teaching standards, effective teachers of science create an environment in which they and students work together as active learners. These standards call on teachers to place less emphasis on lecture, text, and demonstration and more on guiding students in active and extended scientific inquiry. On the subject of assessment, the document calls for less emphasis on assessing scientific knowledge and achievement and more emphasis on student understanding and rich, well structured knowledge (National Committee on Science Education Standards & Assessment, 1996).

The science content standards are organized by grades K-4, grades 5-8, and grades 9-12 and eight categories; unifying concepts and processes in science, science as inquiry, physical science, life science, earth and space science, science and technology, science in personal and social perspectives, and history and nature of science. In addressing the physical science standards, Content Standard D, for grades five through eight, the document states that the study of motions and the forces causing motion provide concrete experiences on which a more comprehensive understanding of force can be based in grades 9-12. By using simple objects, such as rolling balls and mechanical toys, students can move from qualitative to quantitative descriptions of moving objects and begin to describe the forces acting on the objects(National Committee on Science Education Standards & Assessment,1996).The researcher would like to point out that force and motion, a topic well coveredby model rocketry, is a standard in all three grade groupings.

As detailed as the *National Science Education Standards* are, the writers reminded all users and reviewers that the content described is not a science curriculum. On the topic of use of standards, they stated, “Content is what students should learn. Curriculum is the way content is organized and emphasized; it includes structure, organization, balance, and presentation of the content in the classroom” (National Committee on Science Education Standards & Assessment, 1996, p. 111).

By 1990, 42 of the 50 states had raised course requirements for high school graduation since the publication of A Nation at Risk. Forty-seven states had mandated student testing standards (Smith, 1994). Also, more students were taking algebra, geometry, trigonometry, and calculus as well as advanced science courses in chemistry and physics.

The California Department of Education oversees a public school system that is responsible for the education of more than seven million students attending 9,000 schools throughout the state. The department, and the State Superintendent of Public Instruction,enforce education law and regulations, reform and improve public elementary school programs, secondary school programs, adult education, some preschool programs, and child care programs (California Department of Education, 2009).

The State Board of Education is the governing and policy-making body of the California Department of Education. The responsibilities of the board include setting K-12 education policy for standards, instructional materials, assessment, and accountability, and also to adopt grades K-8 textbooks. The SBE has 11 members, appointed by the Governor (California State Board of Education, 2009).

The board has adopted content standards for mathematics (1997), English language arts (1997), science (1998), history-social science (1998), English language arts development (1999), visual and performing arts (2001), career technical education(2005), physical education (2005), and health education (2008).

In addition to the content standards, the CDE also publishes curriculum frameworks, which provide guidance for implementing the content standards. Frameworks are developed by the Curriculum Development and Supplemental Materials Commission, which also reviews and recommends textbooks and other instructional materials to be adopted by the SBE. Curriculum frameworks are provided for career technical education, foreign language, health, history-social science, mathematics, physical education, reading/language arts, science, and for the visual and performing arts (California State Board of Education, 2009).

The CDE document*Mathematics Content Standards for California Public Schools: Kindergarten Through Grade Twelve*is designed to “focus on essential content for all students and prepare students for the study of advanced mathematics, science and technical careers, and postsecondary study in all content areas” (Curriculum Development and Supplemental Materials Commission, 2005, Introduction). The mathematics content standards for seventh grade are presented in five strands: number sense; algebra and functions; measurement and geometry; statistics, data analysis, and probability; and mathematical reasoning. In addition, “Focus Statements” indicating the increasingly complex mathematical skills that will be required of students from kindergarten through grade seven. The focus statement for grade seven reads,

> By the end of grade seven, students are adept at manipulating numbers and equations and understand the general principles at work. Students understand and use factoring of numerators and denominators and properties of exponents. They know the Pythagorean Theorem and solve problems in which they compute the length of an unknown side. Students know how to compute the surface area and volume of basic three-dimensional objects and understand how area and volume change with a change in scale. Students make conversions between different units of measurement. They know and use different representations of fractional numbers (fractions, decimals, and percents) and are proficient at changing from one to another. They increase their facility with ratio and proportion,

> compute percents of increase and decrease, and compute simple and compound interest. They graph linear functions and understand the idea of slope and its relation to ratio. (California State Board of Education, 1999, p. 29)

Grades 8-12 do not use strands but rather the content is divided into disciplines such as algebra, geometry, trigonometry, and calculus.

The *Mathematics Framework for California Public Schools, Kindergarten Through Grade Twelve* was Developed by the Curriculum Development and Supplemental Materials Commission and adopted by the California State Board of Education in 2005. The framework focuses on the CBE content standards and calls for instructional programs and strategies, instructional materials, professional development, and assessments that are aligned with the standards. Its purpose is to guide the curriculum development and instruction that teachers provide in their efforts to ensure that all students meet or exceed the mathematics standards (Curriculum Development and Supplemental Materials Commission, 2005). A goal of this framework is to prepare all students to study algebra by the eighth grade. In 2000 the California legislation enacted a requirement for all California students to complete Algebra I as a condition of receiving a high school diploma as mandated in the California Education Code section 51224.5(b) (State of California, 2009).

California adopted *Science Content Standards for California Public Schools, Kindergarten through Grade Twelve*in 1998. The adoption of these standards marked a turning point in the education reform movement that began in 1983 with the report *A Nation at Risk: the Imperative for Educational Reform*, by the National Commission on Excellence in Education. The standards were adopted by the California State Board of Education as part of its commitment to provide a world-class science education for all California students (California State Board of Education, 2003).

The California State Board of Education and the Academic Standards Commission reviewed the *National Science Education Standards*, the Benchmarks for Science Literacy, and science standards and frameworks from numerous local school districts in California, from around the country, and from other nations with successful science education programs.

The standards include grade-level specific content for kindergarten through grade eight. Earth sciences are the focus in the sixth grade, life sciences in the seventh grade, and physical sciences in the eighth grade. The standards for grades nine through twelve are divided into four content strands: physics, chemistry, biology/life sciences, and earth sciences (California State Board of Education, 2003).

The International Technology Education Association (ITEA) released *Standards for Technological Literacy: Content for the Study of Technology* in 2000 as part of its Technology for All Americans Project. The project was funded by the National Science Foundation and the National Aeronautics and Space Administration. A companion document is *Advancing Excellence in*

Technological Literacy: Student Assessment, Professional Development, and Program Standards. The rationale behind the publications is the need for technological literacy and it is as fundamentally important as traditional core subject area knowledge and abilities. The 20 content standards are grouped under the nature of technology, technology and society, design, abilities for a technological world, and the designed world (International Technology Education Association, 2003).ITEA also produced*Standards for Technological Literacy: Content for the Study of Technology*, last published in 2007. It is the result of a four-year process, involving many levels of review and revisions.The document contains 20 content standards grouped into the nature of technology, technology and society, design, abilities for a technological world, and the designed world. Each standard is divided into Grades K-2, 3-5, 6-8, and 9-12. Each grade level has a narrative explaining the standard and offers suggestions for implementation. Also presented are vignettes that highlight a sample lesson that teaches to the standard (International Technology Education Association, 2007).

The American Society for Engineering Education was founded in 1893 to further education in engineering and engineering technology. The ASEE promotes activities that support increased student enrollments in engineering at the college level. The organization of the ASEE's K-12 STEM Standards, developed in 2006, are in five dimensions; engineering design, connecting engineering to science, technology, and mathematics, nature of engineering, communication and teamwork, and engineering and society (American Society for Engineering Education, 2009).

After School Programs, Clubs, and Competitions

In this subtopic, the researcher provides evidence that suggests that after school programs are not only beneficial, but they have become an essential part of the learning process. Programs available to students in an extracurricular setting are vast and therefore the researcher will concentrate on programs that target math, science, and technology. In the second part of the subtopic, national clubs and organizations that offer after school programs for youth will be examined. Finally, national science competitions will be discussed, including the contest's purpose and background, the requirements, and a description of what the students must do in order to be successful.

Extracurricular activities often appeal to student's special interests. They encourage peer interaction, promote cooperation, provide structure and challenge, and connect students to school. In addition, such activities can draw students, especially minorities and women, to science (Holloway, 2002). Afterschool programs can reinforce and supplement the core curriculum by offering new and different opportunities for learning that further engage students in school.

According to asurvey of K-8 principals by the National Association of Elementary School Principals, after schoolprograms are becoming an integral part of their schools (Afterschool Alliance, 2002). In the August 2001, the NAESP conducted a survey of 800 K-8 public school principals. Of those, 532 (67%) of the principals reported having after school programs. The programs included homework help (96%), literacy and reading enrichment (85%), math (85%) recreation sports (78%), computers (62%), science (69%) and art/music/drama/dance (63%) The after school programs were considered very important by 77% of respondents with 34% claiming that academic improvement was the biggest success (National Association of Elementary Principals, 2001).

The report *Afterschool Learning: a Study of Academically Focused After school Programs in New Hampshire*, the first statewide description of academically focused programs, reported positive effects on participating students, especially middle school students. More than half the students who attended regularly improved both academically and behaviorally (Frankel, Streitburger,& Goldman, 2005).

In the summer of 2003 the Afterschool Alliance conducted a survey of 18, 181 households, with funding from the J.C. Penney Afterschool Fund to find out what America's youth are doing once the normal school day ends. TheAmericaAfter 3 PMsurvey includes data on K-12 youth. The survey data revealed that families of 22 million children want after school programs yet only6.5 million of them are currently participating in them. Need is especially high for middle school children. Just 6% of middle school students are in after schoolprograms and another 34%are unsupervised in the afternoons. The America After 3 PM survey was broken down into each of the 50 states.

In California, public schools are the largest provider of after school programs. YMCAs, Boys andGirls Clubs, cities or towns, and private schools round out the top five providers of after school programs. Sixty-nine percent of California children spend some portion of the hours after school in the care of a parent or guardian and 22% of them are responsible for taking care of themselves. These children spend an average of nearly seven hours per week unsupervised after school. Two in five middle school children in working families (40%) are unsupervised in the afternoons (Afterschool Alliance, 2004).

Middle and high school students offer after school providers a special set of challenges. Teens are less interested in activities designed for the general audience. Afterschool programs must employ innovative strategies to attract and keep older youth engaged. Studies show that the peak hours for juvenile crime and experimentation with drugs, alcohol, cigarettes and sex are between 3:00 PM and 6:00 PM Studies also show that older youth that participate in after school programs demonstrate increased school attendance, improved homework completion, increased standardized test scores, problem solving skills, study habits, and have a lower risk of dropping out of school. In addition, the teens who participate in after school programs are more optimistic and have higher personal expectations, including an increased interest in attending college(The Afterschool Alliance & the Metlife Foundation, 2009). According to a survey of California teens conducted by the Online Research Corporation in May of 2006, 35% of surveyed teens said that there are not enough supervised after-school activities that interest them. Of these, 77% said they would be likely to participate if interesting activities were available to them (Online Research Corporation, 2006).

"The 21st century's information economy is creating more jobs that require not only a college education but also at least some expertise in the fields of science, technology, engineering and math, collectively known as STEM" (Coalition for Science After School, 2008, p. 1). By combining STEM learning with the expertise of after school professionals, both may benefit by combining each other's strengths. After school programs often teach communication, problem solving, and teamwork. They can become a positive addition for schools seeking more options for delivering science learning experiences (Coalition for Science After School, 2008).Eighty percent of future careers will demand knowledge of science and technology. Students who think that science and technology is not for them may find themselves out of most careers (Coalition for Science After School, 2009).

While the benefits of after school programs are proven, the challenge of every extracurricular program is funding. One source of funding is through the 21st Century Community Learning Center grants. The 21st Century Community Learning Centers Initiative is the only federal funding source dedicated exclusively to after school programs. It supports the creation of community learning centers that provide academic enrichment opportunities during non-school hours for children, particularly students who attend high-poverty and low-performing schools. The program helps students meet state and local student standards in core academic subjects, such as reading and math; offers students a broad array of enrichment activities that can complement their regular academic programs; and offers literacy and other educational services to the families of participating children. Some of the types of approved projects include remedial education activities and academic enrichment learning programs, including those which provideadditional assistance to students to allow the students to improve their academic achievement, as well as mathematics and science education activities (U.S. Department of Education, 2008, pp. 1-4). Only about one-third of programs that receive federal 21st Century Community Learning Center grants serve middle school students (Rinehart, 2008).

While after school programs are available to students from the school system, there are several national organizations that provide both similar and unique programs to youth. The researcher will now examine the most prominent of these organizations in order of their founding. A brief history of the organization will be presented, followed by a description of services that are targeted at youth. Services and programs targeted at adults will be omitted. A Few of these organizations offer rocketry programs. Where this does occur, the program will be discussed in detail.

The Young Men's Christian Association was founded by George Williams in London, England on June 6, 1844 as a response to the unhealthy social conditions arising in the big cities of England at the end of the industrial revolution. Many rural young men came to cities like London for jobs, where they worked for 10-12 hours a day, six days a week. These men often lived at the workplace in crowded rooms. Williams organized the first YMCA to substitute Bible study and prayer for life in the streets. The organization came to North America in 1851. There are 2,686 YMCAs in the United States today, and all offer different programs to meet the needs of their unique communities and for all age groups. Programs for youths include aquatics, arts and humanities, camping, sports, and team leadership(YMCA, 2009).

The Boys and Girls Clubs of America began in 1860 when several women in Hartford, Connecticut wanted to provide a positive alternative for boys who roamed the streets by founding the Boys Clubs. In recognition of the program serving girls as well, the organization's name was changed to Boys & Girls Clubs of America in 1990. Its mission is to enable all young people, especially those most in need, to reach their full potential as productive, caring, responsible citizens. The clubs serve some 4.5 million boys and girls at over 4,300 club locations. National programs are offered in the areas of education, the environment, health, the arts, careers, alcohol/drug and pregnancy prevention, gang prevention, leadership development and athletics (Boys and Girls Club of America, 2009).

The organization known as 4-H began at the start of the 20th century in the work of several people in different parts of the United States who were concerned about young people. The basic idea of the founders was to connect public school education with public life. The American farming community did not readily accept new agricultural discoveries of researchers at experiment stations of the land-grant college system so the United States Department of Agriculture decided to pass the new ideas to young students, who were more open to new ideas. Rural youth programs became a way to introduce new agriculture technology to the adults. In 1901, A.B. Graham, a school principal in Ohio, began to promote vocational agriculture in rural schools and a year later formed a club of boys and girls with officers, projects, meetings, and record requirements. Congress created the Cooperative Extension Service in 1914, which included boys and girls club work. The name 4-H represents Head, Heart, Hands, and Health. Today, after more than 100 years, 4-H offers youth opportunities in communications, leadership, career development, livestock, home improvement, and computer technology to 7 million American youth. Programs are found in rural and urban areas throughout the country and similar programs around the world. 4-H programs are divided into three core mission mandates, science, engineering, and technology (SET), healthy living, and citizenship. 4-H recognizes that the United States is falling behind other nations in developing its future workforce of scientists, engineers, and technology experts and has taken several steps to increase member interest in these fields. On October 8, 2008, the 4-H Youth Development Program launched the first 4-H National Youth Science Day as part of a larger effort to develop America's future workforce of scientists, engineers, and technology experts (4-H, 2009).

In May of 2007, 4-H initiated a partnership with the National Association of Rocketry. The partnership has several goals. Introducing 4-H members to model rocketry through NAR rocket clubs will eventually lead to more students participating in the Team America Rocketry Challenge. It also benefits 4-H's commitment to its SET mandate. Other activities promoted by this partnership include joint 4-H/NAR sport, contest, and TARC launches. 4-H members can also tap into NAR member expertise in the development of 4-H science fair projects involving rocketry(National Association of Rocketry, 2009).

The Civil Air Patrol (CAP) was created on December 1, 1941 as the United States was about to enter World War II. The CAP's purpose was to use America's civilian aviation resources to aid the war effort. Its missions during the war included anti-submarine and border patrols as well as courier services. It became the civilian auxiliary of the United States Air Force after the war. The CAP offers a cadet program to youths aged 12-18. Cadets meet two hours a week and one Saturday per month, on average. They also have opportunities to attend leadership encampments, career academies, and international exchanges during the summer. About 10% of the cadets at the United States Air Force Academy are former CAP cadets. The Civil Air Patrol offers aerospace education program for educators. The Aerospace Education EXcellence (AEX) program offers hands-on aviation and space-related student activities. Educators may also join the CAP as Aerospace Education Member (AEM). This program offers aerospace lesson plans, an orientation flight in one of the CAP's Cessna aircraft, and the opportunity to earn graduate credits for teaching aerospace lessons in the classroom (Civil Air Patrol, 2009). Model rocketry is an authorized extracurricular activity in the Civil Air Patrol. Cadet volunteer activities in model rocketry will supplement and enrich a cadet's aerospace education. The Civil Air Patrol provides a model rocketry handbook that guides instructors and cadets through each of the three stages, Redstone, Titan, and Saturn. Squadrons who conduct a model rocketry program are also encouraged to establish a National Association of Rocketry Section and to enter competitive NAR meets. Civil Air Patrol squadrons are also able to form teams and compete in the Team America Rocketry Challenge(Civil Air Patrol, 2004).

"Many educators encourage participation in extracurricular science activities, such as science fairs and science Olympiads, as a way for students to further develop science content knowledge, process skills, and interest" (Abernathy & Vinyard, 2001, p. 269). While science fairs are typically the presentation of the work of a single student, competitions like the Science Olympiad and the Team America Rocketry Challenge emphasize teamwork and covers a wide range of content areas(Abernathy & Vinyard, 2001).

The aerospace industry recognizes that its workforce is aging, and too few young people are being prepared for or are choosing engineering and science careers. In May of 2009, aerospace industry leaders met at the 2009 Inside Aerospace forum in Arlington, Virginia to discuss the challenges faced in recruiting future aerospace engineers and to create a plan to accomplish their goals. On average, aerospace companies invest about $8 million annually on STEM education programs with the larger companies spending even more (American Institute of Aeronautics and Astronautics, 2009). Many of the academic contests that focus on science are financially supported by the aerospace industry.

Academic contests for K-12 students in the STEM disciplines, science, technology, engineering, and mathematics, have been a part of education for many years. In the table of contents for the book *Competitions for Talented Kids*, there are 26 competitions listed for science, 15 for technology, 7 for technology, and 16 for math (Karnes & Riley, 2005). With the rise in interest of standards-based education, the growth of STEM-related competition could be seen as beneficial. High profile contests are often sponsored by distinguished organizations and well-known corporations that create student interest with travel and prizes. The better contests push students beyond the standard science and math curriculum to investigate specialized topics and practical applications. It is also beneficial for talented students with weak or unqualified math and science teachers. Academic contests can be used to guide and motivate students and serves as a recruitment tool for science and technology magnet schools (Trotter, 2008).

The *AAPPT Physics Bowl* is conducted by the American Association of Physics Teachers. For the 2008 competition, almost 4,000 students from 175 schools took a 40-question, 45-minute timed multiple-choice test under their school's supervision. The exam questions are based on topics and concept covered in a typical high school course. School team scores are determined be the summary scores of the top five competing students. Awards for the top scores are divided into two divisions for first and second-year physics students. Each division is divided into 15 regions in which schools within a region compete against each other. Prizes included gift certificates and calculators. The tests are administered in the spring (American Association of Physics Teachers, 2009).

The California Geographic Alliance Physics/Science/Math Teacher Steering Committee sponsors an annual roller coaster building contest in conjunction with the *Physics/Science/Math Days* held at California's Great America Amusement Park in Santa Clara, California. Schools may enter roller coaster models built by teams of students in one of two grade categories. Student teams composed of fifth to eighth graders compete against each other in one category and high school students, grades nine to twelve, compete in another. The roller coaster models must fit on a base 75 centimeters by 75 centimeters and be no higher than 100 centimeters. The model should be designed for a steel ball or glass marble. The models are given a technical, theme, and rider enjoyment score. 2009's competition was held in May(Physics Day Steering Committee, 2009).

The *Intel International Science and Engineering Fair* is the world's largest international pre-college science competition. 1,500 ninth to twelfth students from over 50 countries showcase their independent research. Participants are selected from the millions of school-sponsored science fairs to compete for nearly $4 million in prizes and scholarships. This contest is for students who wish to compete individually(Society for Science & the Public, 2008).

Odyssey of the Mind is creative problem-solving team competition for students from kindergarten through college. It is an international competition that engages thousands of teams throughout the United States and about 25 other countries. Teams are given open-ended problems that appeal to a wide range of interests. The students must think creatively to solve the problems by thinking "outside the box.” Competing teams of up to seven members are divided into four divisions; grades K-5, grades 6-8, grades 9-12, and collegiate. The competition's problems change yearly and fall into five general categories: mechanical/vehicle, technical performance, classics, and structure & performance. Teams have a cost limit, typically $125 –$150, for their materials and the solution must be presented by the team members in an entertaining performance. The competition also has spontaneous problems, which require quick thinking. Only five of the seven team member may participate in this part of the competition. Teams are given a score out of 350 points with 200 possible points for the long-term problem, 100 for the spontaneous, and 50 for style. American teams who win their state finals and international teams who have won their national finals meet for the world finals at a university in the United States. Over the course of three days, teams present their long-term solution and complete one spontaneous problem. Time is given for the finalists to meet and interact. The cost for registering a team for the 2009-2010 competition is $135 (Micklus & Micklus, 2008).

BEST Robotics Inc. sponsors a robotics competition for middle and high school students. *BEST*, an acronym for *Boosting Engineering, Science, and Technology*, is a non-profit, volunteer-based organization that promotes student interest in engineering, science, and technology careers through the competition. Recent competitions have drawn 10,000 students from over 700 middle and high schools. *BEST* features two parallel competitions; a theme-based robotics game with four teams competing in a round-robin competition. Each team designs and builds a radio-controlled machine to accomplish defined tasks in a game-type format. The BEST Award is presented to the team that best embodies the concept of *BEST*. There is no cost to compete in the program, but a school must join a local competition site, called a hub, in order to compete. The average first year cost for running a 24-team hub is about $28,000 and can be funded by colleges/universities, corporations, or individuals. While considered a national competition, most local hubs are located in the states of Texas, Arkansas, and Alabama. Currently, the westernmost hub is located in Las Cruces, New Mexico (Best Robotics Inc., 2009).

Another team-oriented robotics competition is *Botball*. The Botball Educational Robotics Program integrates science, technology, engineering, and math with robotics. The competition begins with a professional development workshop, where educators and team leaders receive training and information about the competition. Students are given about seven weeks to design, build, and program a team of mobile, autonomous robots as well as document the engineering process online. The robots are programmed to maneuver on a game board. *Botball* events are held in 12 regions in the United States, including northern and southern California. Participation in *Botball* costs $2,500 per team, which includes the robotics equipment and the participation fee. Over 6,000 middle and high school students compete in the program (KISS Institute for Practical Robotics, 2009).

The *Science Olympiad* started in 1984 as an alternative to science fairs and will celebrate its 25th anniversary in 2009. It is a national non-profit organization whose mission of improving the quality of K-12 science education is achieved in *Science Olympiad* tournaments and non-competitive events. Currently, *Science Olympiad* holds 240 regional competitions in 47 states with close to 200,000 students on 5,300 secondary school teams. Over 10,000 more schools participate in grades K-6. Middle school students compete against each other in Division B and High School students do the same in Division C. Science Olympiad competitions are run like academic track meets, consisting of a series of 23 team events in each division. Every year, a portion of the events are rotated and cover topics in genetics, earth science, chemistry, anatomy, physics, geology, astronomy, mechanical engineering and technology. Emphasis is placed on active, hands-on, group participation and teamwork is a required skill. Medals and trophies are awarded to competitors as well as cash and scholarship awards in excess of $5 million (Science Olympiad Inc., 2008).

The *Team America Rocketry Challenge* was conceived originally as a way to promote interest in science and aerospace careers among high school students, and to celebrate the 100th anniversary of the Wright brothers' 1903 flight. (Horst, 2004) The response was so great that it became an annual event. Approximately 7,000 students from across the nation compete in TARC each year. The challenge for 2010 finals is to design a safe and stable model rocket flight vehicle and use it to lift a fragile payload (one hen's egg) to an altitude of exactly 825 feet and also for a total flight duration score of 40-45 seconds, and return this payload safely and undamaged (Aerospace Industries Association, 2009).Three- to 15-member teams are formed at middle schools, high schools, 4-H and Civil Air Patrol units at the beginning of the new school year and plane, design, and build flying rockets using mid-power rocketry techniques. The teams must fly qualifying flights locally before the announced deadline and submit scores to the national headquarters. Qualification requires a successful flight observed by a local National Association of Rocketry Senior member observer. In preparation for this event, teams must conduct practice launches. For the 2004 event, two Goshen High School TARC teams flew more than 50 practice flights. (Horst, 2004)The top 100 teams, based on the local qualification flights, are invited to Virginia for the national finals. Prizes include $60,000 in cash and scholarships split between the top 10 finishers. (Aerospace Industries Association, 2009)The most vital ingredient is the ability of a team of young TARC rocketeers to succeed in qualifying (Barber, 2006).

The top 25 TARC teams go on to participate in National and Aeronautics Space Administration's Student Launch Initiative. The SLI involves middle and high school students in designing, building and testing reusable rockets with associated scientific payloads. This unique hands-on experience allows students to demonstrate proof-of-concept for their designs and gives previously abstract concepts tangibility. Both new and returning teams construct the vehicle that is designed to reach an altitude of one mile. In addition to actual vehicle performance, teams are also evaluated on design and other criteria. This educational experience culminates with a launch at Marshall Space Flight Center in the spring (National Aeronautics and Space Administration, 2009).

Model Rocketry

Rocketry is a broad field that includes children building and flying inexpensive model rockets to national space programs that put satellites and astronauts into space. Aside from cost, the differences between a child's model rocket and the rockets used by NASA are small. Both are subject to Newton's Laws of Motion and the forces of flight. Lessons learned from a child's first rocket can be built upon with each successive, more complicated model and possibly leading to a career at NASA designing and building the rockets that will propel the next generation of astronauts back to the Moon and beyond. Rocketry can be divided into three categories, professional, amateur, and model(Cannon & Banks, 1987).

There are thousands of men and women who design and build rockets in the professional field and most of them work for NASA. The National Aeronautics and Space Administration was established by President Dwight D. Eisenhower in 1958 in response to the Soviet Union's successful launch of Sputnik on October 4, 1957. President John F. Kennedy focused NASA on sending astronauts to the moon by the end of the 1960s, which was accomplished on July 20, 1969 when astronauts Neil Armstrong and Buzz Aldrin became the first of 12 men to walk on the moon. Since that time, the organization has concentrated on Earth orbit missions with the space shuttle program as well as the construction and operation of the International Space Station, due for completion in 2010, in cooperation with sixteen nations. NASA also conducts unmanned exploration, such as the Mars Rovers *Spirit* and *Opportunity*, and operates weather and communications satellites in Earth orbit(National Aeronautics and Space Administration, 2009).NASA employed 16,923 people in 2008 and is ranked the third best federal agency to work for out of thirty agencies (Partnership for Public Service & Institute for the Study of Public Policy Implementation, 2009).

The second type of rocketeer is the amateur rocketeer.

> Amateur rocketry is the art of studying, building, experimenting with and launching rockets of various descriptions (heavy and light), often using metallic components, where the user or experimenter is usually required to

handle, formulate or load his own propellant or other explosive compound. (Estes, 1961, p. 3)

Many amateur rocketeers were inspired by the launch of Sputnik in 1957. Homer Hickam, author of the book *The Rocket Boys*, which is the basis for the movie *October Sky*, is an example of an amateur rocketeer inspired by the early achievements of space flight(Hickam, 1998).Unfortunately, many of these home-made rockets failed. In 1956, the American Rocket Society, since renamed the American Institute of Aeronautics and Astronautics, estimated that one out of seven amateur rocketeers were killed or hurt while engaged in amateur rocketry (Stine, 2004). Yet modern rocketry started with amateurs.

Dr. Robert H. Goddard (1882-1945), an American scientist and amateur rocketeer, is considered the Father of Modern Rocketry. Experimenting with solid-fueled rockets and ultimately converting to liquid fueled rockets, Dr. Goddard launched the first liquid-fueled rocket on March 16, 1926. Although the flight only lasted two and a half seconds and climbed to only 121/2meters, it marked a new era in rocket flight (Nielsen, 1997).

Hermann Oberth (1894–1989), inspired by the works of Jules Verne, devoted his life to promoting space travel. His dissertation for the University of Heidelberg was rejected, but became the basis for his book *Die Rakete zu den Planetenräumen* (By Rocket to Space). Rocket societies were formed around the world by fans of his writings, including a Berlin amateur rocket group called Verein für Raumschiffarht (Society for Space Travel). One young member of the society was Werner von Braun (1912 – 1977). As a doctoral candidate at the University of Berlin in the early 1930s, von Braun was recruited by the German government to develop a rocketry program, which ultimately led to the development of the V-2, the world's first tactical military rocket. After World War II, von Braun moved to the Unites States to help develop a fledgling rocket program and was the chief architect and engineer for the largest rocket ever launched; the Saturn V Moon rocket (Shearer & Vogt, 2008).

Model rocketry represents the third type. The hobbyists involved in model rocketry design and build model rockets out of light weight, non-metallic materials and use commercially available rocket motors for propulsion(Cannon & Banks, 1987). The creation of this safe and inexpensive form of rocketry paved the way for rocketry to be used in the classroom.

Several events transformed amateur rocketry, a dangerous activity banned in most states, into the safer hobby of model rocketry. Orville H. Carlisle, an amateur pyrotechnician, and his brother Robert, a model airplane enthusiast, combined their skills to build the first model rockets in 1954. After reading articles written by G. Harry Stine, a range safety officer at White Sands Missile Range about the dangers of rocketry, they sent him samples of their rockets to fly and evaluate. Stine used his missile range experience to write the *Handbook of Model Rocketry* to be used as a safety handbook. In 1957, the National Association of Rocketry (NAR) was founded to further promote the safety of model rocketry. The NAR’s Model Rocket Safety Code is well known and followed by its members.

Another important breakthrough was the invention of an unwieldy machine named Mabel. In May of 1958, G. Harry Stine was looking for a reliable supplier for his fledging model rocket company called Model Missiles. He contacted the three fireworks companies in the Denver, Colorado area, which included "Mile High Fireworks.” This led to the first meeting of two legends in model rocketry, Stine and Verne Estes. The order called for the manufacture of 5,000 rocket motors a day and no machine was available to make them. Estes went to work to create such a machine and the end result was christened Mabel by its operators. By the time that Mabel was ready, model missiles realized that their rocket motor sales estimate was too high and cut back the order for 5,000 motors a day. With a considerable investment and time in the machine, Verne and his wife Gleda decided to create their own model rocket company and named it Estes Industries. During model rocketry's golden years in the 1960s, Estes Industries was the premier manufacturer of model rockets and engines in the country (Beach, 2007). In February 1961, Estes Industries conducted a survey to establish the relative safety of model rocketry and amateur rocketry. Of the 340 respondents, none said that they were aware of any accidents using Estesrocket motors and rockets. But when asked if the same is true for home made propellants, 58% answered yes. Fifty of the 198 yes answers had first-hand accounts and offered details of these accidents. Injuries ranged from lost fingers, eyes, hands, and a few deaths were reported (Estes, 1961). Model rocketry is a much safer alternative to amateur rocketry for students as well as adults. By 2003, nearly 600 million model rockets had been flown safely and successfully in the United States alone. The hobby is far safer than swimming, boating, baseball, football, and cycling(Stine, 2004).

From its earliest beginnings, model rocketry was recognized as a powerful learning tool for the hands-on teaching of math and science. The largest source of educational material on model rocketry is from the major model rocket manufacturers. Estes Industries produced several documents that focused on the use of math and science in model rocketry design, construction and flight.

Estes began publishing *Model Rocketry News* in 1961. The newsletter was published approximately four times annually and was distributed free of charge to its mail order customers. Its purpose was to advertise and promote a safe form of youth rocketry (Estes, 1961). The newsletters featured information on company products, rocket construction and flying tips, and letters about model rocketry that were sent by young model rocketry hobbyists and answered by Verne Estes. Although Estes sold the company in 1969, *Model Rocketry News* continued to be published until the mid-1990s. The company also published technical reports and notes. The technical notes covered topics such as rocket stability, altitude tracking, and building a wind tunnel. Technical Note TN-5, entitled *Elementary Mathematics of Model Rocket Flight*, is an example of how model rocketry is an excellent tool for the learning of math and science. TN-5 is a collection of articles written by Robert L. Cannon that originally appeared in *Model Rocket News* from 1969 to 1970. The first article detailed the procedure for determining how high a rocket traveled using the Pythagorean Theorem. Other articles provided equations for determining a rocket's velocity and acceleration (Cannon, 1970). Estes published a 38-page educator’s guide the year after Apollo 11's historic mission to the moon. In their introduction, the authors point out the importance of aerospace education as an important step to student learning in a variety of subjects and increases student interest in aerospace careers. The booklet provides basic information on rocket construction and launching. There are 12 experiments that demonstrate the properties of air using basic items. While written by two elementary school principals, the authors do not address the connection of the experiments to content standards or curriculum(Saltrick & Kubota, 1970). The definitive document, *A Nation at Risk*, was 13 years away.

Estes Industries created the *Estes Educator* series in the early 1990s targeted directly at teachers who wished to use model rocketry in the classroom. Many of the topics were covered in the company’s technical notes over twenty years before, but these publications organize the content in the form of lesson plans. Four publications covering model rocketry were produced,*Science and Model Rockets* (1992), *Physics and Model Rockets,* (1992) *Mathematics and Model Rockets* (1994), and *Industrial Technology and Model Rockets* (1995). It is worth noting that these subjects are now packaged as the Science Technology Engineering Math (STEM) standards of today.

Science and Model Rockets is a curriculum guide for teachers experienced in rocketry as well as those who are not. The guide is directed to teachers of fifth through eighth grade and contains six lessons that cover motion and flight, rocket stability, altitude calculation, recovery, safety, and launch procedures. Also included in the publication are activity sheets for the students and overhead transparencies for the teacher. The authors make no mention of content standards as the guide was published four years before the National Science Foundation's publication of the National Science Education Standards (Nolte & Stoops, 1992).

Another teacher guide developed for the *Estes Educator* series in 1992 was *Physics and Model Rockets*. The seven lessons cover topics on aerodynamic forces, Newton's Laws of Motion, safety, and launching. A 24-page student book is included for distribution to the students and includes all of the lesson information. An extended math extension was added as an appendix and covers two-station tracking of rocket flights for a more accurate calculation of altitude (Nolte, 1992).

Mathematics and Model Rockets offers a more demanding set of unit plans that demonstrate the mathematical equations that help determine arocket's center of pressure, techniques for finding the rocket's center of mass (gravity), advanced procedures for determining altitude, as well as velocity and acceleration calculations. The publication also supplies student worksheets with the formulas for making the required calculations. *Curriculum and Evaluation Standards for*

School Mathematics was published in 1989, but no content standards were addressed by the author (Nolte, 1994).

Industrial Technology and Model Rockets was published in 1995 and was designed to give the educator a selection of materials that can be chosen to meet particular grade, maturity, and interest levels. The book is divided into nine sections; introduction to spaceflight, research, payload and recovery, model construction, design and engineering, dynamic testing, propulsion, electronics, and communications applications. Each section organized into eight-step lesson plans. Many of these lesson plans rely on the other Estes publications and products for reference and several of these are now out of print. While specific standards are not addressed, objectives are listed for each lesson (Kalk & Wash, 1995).

The *Estes Educator* guides were sold by Estes as were their other publications for a few years after their publication. Currently, electronic versions of the guides as well as some of the technical reports and notes are available as a free download from the Estes Industries web site (Estes Industries, 2009).

A few books on model rocketry have been published by the education community. Robert L. Cannon, education director and consultant of Estes Industries, co-authored *The Rocket Book* with model rocket hobbyist Michael A. Banks in 1987 as part of the Prentice-Hall Science Education Series.The comprehensive 224-page book covers the basics in model rocket construction and flight, altitude tracking, basic physics, aerodynamics, and advanced techniques such as two-stage and cluster engine rockets and payloads. Much of the content is similar to the Estes publications, but the professional layout of text and images make it easier to read and understand. Of note is Chapter 10, which addresses classroom activities in specific areas such as math, physics, language arts, consumer education, general science, industrial arts, and aerospace education (Cannon & Banks, 1987). *The Rocket Book* could serve as a student textbook if it were still in print.

Experimenting with Model Rockets Teacher's Guide is part of a series of the Great Explorations in Math and Science guides published by the University of California at Berkeley's Lawrence Hall of Science. The stated purpose of the guide is to serve as a strong support to the National Science Education Standards. Its content is most useful to the teacher with little or no experience with model rocketry. The guide provides detailed information on teacher preparation and supply lists. Activities include observation of rocket flight paths, calculating altitude, and rocket construction. Of the five listed student outcomes in the assessment suggestions, none are taken from the content standards. The guide is targeted at grades 6-10(Sneider, 1989).

The National Aeronautics and Space Administration has been very active in supporting teachers who use model rocketry in the classroom. *Rockets: Educator's Guide with Activities in Science, Technology, Engineering, and Mathematics* was first published in the mid-1990s and has undergone several revisions. The guide was created as a two- to six-week classroom unit depending on grade level or as stand-alone classroom experiences. The 2008 revision includes a national curriculum standards matrix for science and math. Each activity is matched to a specific standard. The book contains activities for grades K-12 and a matrix identifies which activities are appropriate for specific grade levels. The activities use various forms of inexpensive propulsion such as air, chemical reaction, and water. This publication is in the Public Domain and teachers are free to download and copy it (Shearer & Vogt, 2008).

Blast Off! Rocketry for Elementary and Middle School Students was authored by California teacher Lee Brattland Nielsen and is based on her experience incorporating model rocketry in her classroom since 1980. Nielson's book contains NASA lessons from their Rockets Educator Guide. Chapters cover rocket history, Newton's Laws of Motion, basic parts of a model rocket, rocket construction and rocket launch procedures. Unique to this book is a script for students to recite at a school assembly prior to conducting rocket launches (Nielsen, 1997).

The book that many model rocket hobbyists consider the definitive authority on model rocketry is the *Handbook of Model Rocketry*. First published in 1965 and currently in its seventh edition, its 363 pages cover practically every aspect of model rocketry in detail. The subjects covered include, but are not limited to, model rocket construction, motor, launch equipment, stability, aeronautics, altitude determination, and payloads (Stine & Stine, 2004). Author G. Harry Stine was one of the founders of the National Association of Rocketry and has been active in model rocketry since its inception. While this book may not serve as a textbook to all but the most advanced student, it is an essential reference book for educators who are teaching model rocketry.

Rationale of the Project

There is a strong need to excite students about math and science. The industry sectors who rely on trained engineers and mathematicians know that a large portion of their work force is about to retire while fewer students are entering college in pursuit of careers in these fields. There is also the need by schools to embrace the national and state standards and build curriculums to meet those standards. Finally, many of the creators of the reviewed standards called for integrating the disciplines of math and science and to move away from the lecture hall and into the laboratory. Students who have hands-on experience have a greater understanding of the subject than those who listen to a lecture, study notes, and take a written test for assessment. Model rocketry can serve all of those needs in a fun, exciting and challenging way. When used in conjunction with STEM driven lessons, launching model rockets in a school environment is a very effective educational tool.

The Team America Rocketry Challenge is the next logical step for students who have taken basic rocketry and want to progress in knowledge, challenge and experience. The promotion of this competition by schools will be of great benefit to all involved, student, teacher, and mentor. The person who first steps on the surface of Mars may be building a model rocket today.

Summary

The push for standards based education can be traced back to 1981 with the publication of the definitive document *A Nation at Risk: The Imperative for Educational Reform* by the U.S. Department of Education. The nation's first standards appeared in 1989 when the National Council of Teachers of Mathematics published *Curriculum and Evaluation Standards of Mathematics.* The National Science Foundation invested $7million and four years of debate to produce the National Education Standards in 1996.

The California Department of Education, responsible for the education of more that 7 million students in over 9,000 schools published its first content standards in 1997 for mathematics. The CDE has since established standards in language arts, science, history-social science, English language arts development, visual and performing arts, career technical education, physical education and health education.

After school programs can reinforce and supplement the core curriculum by offering new and different opportunities. Research supports that many schools are offering after school programs because of their value to students. There are a few organizations of note that offer programs to school-aged children. The YMCA began in London, England in 1844 and has grown to 2,686 locations throughout the United States. 4-H, born in the rural areas of the United States as a means of educating farmers on new farm techniques through their children, is now a partner with the National Association of Rocketry for the purpose of fielding teams for the Team America Rocketry Challenge. The Civil Air Patrol is an auxiliary of the United States Air Force and its cadet program includes aerospace training through model rocketry. This organization is also involved in the TARC and sponsors CAP teams who participate.

There are several national competitions for middle and high school students in the field of science and math. The aerospace industry invests about $8 million annually in STEM education programs and competitions in order to attract future employees. Competitions like the AAPPT Physics Bowl, the Intel International Science and engineering Fair, Odyssey of the Mind, Botball, Science Olympiad and the Team America Rocketry Challenge offer science and math scholarships as prizes to participants.

Rocketry is a broad field that falls into three categories, professional, amateur, and model rocketry. Model rocketry is a safe hobby in that participants use commercially build rocket motors rather than the homemade types used in amateur rocketry.

Modern rocketry can be traced back to pioneers in the field such as Dr. Robert H. Goddard, Hermann Oberth, and Werner von Braun. The early work of these men led to the German V2 missile program of World War II and ultimately the U.S. and Russian space programs. Model rocketry emerged from the more dangerous amateur rocketry when G. Harry Stine and Orville H. Carlisle founded the National Association of Rocketry for the purpose of promoting safe forms of rocketry. The dream of safe rocket motors was realized when Verne Estes created a machine that could manufacture large amounts of black powder motors and eliminating the need for rocket hobbyists to make their own.

The concept of model rocketry as a teaching tool for math and science came early in its history and Verne Estes produced newsletters containing science experiments and the mathematical equations for determining velocity and altitude for model rockets. Estes Industries produced several documents over the years promoting math and science-based activities and lessons including technical reports, technical notes, and the Estes Educator Series, which included lessons in math, science, and industrial technology. The National Aeronautics and Space Administration has also supported rocketry education and has produced several publications to aid the teacher in teaching rocketry in the classroom.

Chapter 3

METHODOLOGY

Introduction

The development of a STEM based curriculum for model rocketry took place over the course of two years of experience teaching model rocketry as a thirteen week elective to middle school students, mentoring a middle school team in the 2009 Team America Rocketry Challenge, and research on the subject. The researcher saw the benefits of using model rocketry to teach science, technology, engineering, and math concepts using an engaging, motivational method. After the first year of successfully teaching a basic curriculum, the research sought a more challenging path for the students who were motivated by model rocketry. That led to the first participation of E.V. Cain students in the Team America Rocketry Challenge. The 2009 TARC team made several successful launches of their model rocket and submitted qualifying scores to the TARC headquarters. The scores did not qualify the team to go to the TARC finals and that led the researcher to investigate the teams that did have scores close enough to make the cut. It was determined that the percentage of schools in Texas and Wisconsin that made the finals were higher than those from California. Further research revealed that those states with higher success rates also have programs that provide rocketry programs that teach the basic skills needed to succeed in building and flying model rockets. The researcher decided to create such a program here in

California that would serve the students of the state who wish to compete in future competitions.

Research Design

Setting

Edgar Virgil Cain Middle School educates the six, seventh, and eighth grade students of the Auburn Union Elementary School District in Auburn, California. It is the only middle school in the district and the city of Auburn. The district's student population in 2008 was 2,230 students with 718 of them attending E.V. Cain. Students have an opportunity to participate in extracurricular activities such as theater and Boys and Girls Club. The school is a charter member of the Foothill Intermediate Schools Athletic League and competes with thirteen other middle schools in cross country, flag football, boys and girls volleyball, boys and girls basketball, boys and girls soccer, wrestling, girls softball and track and field(Axiom Management Advisors & Consultants, 2008).

On December 21, 1950, the voters of Auburn, California approved a bond for $215,000 for the construction of a new school. The passing of the bond was largely due to the efforts of Auburn Union School District Superintendent Edgar Virgil Cain. The school was needed to overcome the overcrowded conditions in the school district. The district had more than 750 students at one school(Weidel, 2000). In December of the next year, they approved an additional $41,000 for additional units for the school (Auburn Sesquicentennial Research Committee, 1998). In 1952, the Palm Avenue School opened its doors. It was a fifth grade to eighth grade school with one fourth grade class added soon after its opening(Delana Ruud, personal communication, November 26, 2007). Cain died in 1952, three years after the school was built and nine years after coming to Auburn. Palm Avenue School was renamed E.V. Cain School after his death.

E.V. Cain Middle School has undergone several transformations since then. It served as a sixth -eighthgrade school for a time before changing into a seventh – eighthgrade configuration. The sixth grade classes were located to the district's four elementary schools. In 2001, the sixth graders were returned to the campus and enrollment blossomed from an enrollment of 644 to 1,031 students. E.V. Cain's enrollment has declined since then as district enrollment numbers continue to fall. The current school year has only 757 students registered in the school, a drop of 274 students(Educational Data Partnership, 2007).When the student population is broken down into ethnic groups, the data reveals that the loss is mainly in the European student population.

The Educational Data Partnership has also posted the following data about E.V. Cain on their site, Ed-Data. The 1998 to 1999 school year is the earliest data posted. The American Indian population has been as high as 2.3% of the population to a low in the 2002 to 2003 school year of only two students who belonged to that group, only .2% of the total student population. The Asian population has seen a high of 26 students (2002 to 2003) and a low number of 3 students in the 1999 to 2000 session. Pacific Islanders have never been higher that five and the only group to have 0%, which occurred in the 2003 to 2004 year. The Filipino student ranks swelled to nine students in that same school year, which is the highest number for that group. The percentage of E.V. Cain students who reported an African American heritage was 2% in the 2004 – 2005 school year and dipped to 1% in 1999 to 2000 when only six reported for school.

The European population has always been the largest group, but the highest percentage of students with European ancestry was 91.5% in the first school year that is reported (1998 to 1999). It is from this group that E.V. Cain is seeing a noticeable drop in numbers. In the 2000 to 2001 school year, the first year that included sixth graders, 938 out of 1, 031 students were of European decent, or 91%. For the current school year only 599 European students are enrolled, representing 79.1% of the total student population.

There is one group that has shown steady growth from 1998 to 2007. The Hispanic population had only 27 in that group in the first year of the data reporting. By the 2001 to 2002 year it had grown to 50, representing 4.8% of the total student population. The next year it went to 67, then 86, 92, and for the 2005 to 2006 school year there were 107 Hispanic students at E.V. Cain. That number dropped to 100 for the 2008-2009 school year, but that was still enough to account for 13.4% of the student population.

The Auburn Union Elementary School District is comprised of three K-5 elementary schools and one grade six to eight middle school. The district's students move on to the Placer Union High School District upon completion of the 8th grade.

Population and Sample

The surveys were given to sixth and seventh grade teachers for distribution to random students in their classroom. The survey for the parents (see Appendix A) was sent home with the selected students. The survey and consent form (see Appendix B) was included in the packet. The researcher explained to the parents through the students and in writing the purpose of the survey. The packets were given out on a Tuesday with instructions to return them on Thursday. Ten packets were distributed to the sixth grade Gate class, 20 packets to the seventh grade Gate class, and 20 given to random students in the rocketry class. Twenty-six parent surveys were completed and returned. Students who returned the surveys were given candy as a reward.

The consent form for students (see Appendix C) was included in a packet containing the survey (see Appendix D) and consent form along with the parent survey and the parent consent form, which was written permission to administer the survey to their children. Twenty-six of the 50 packets sent out were returned by the Thursday deadline. The survey was administered on Friday in the classes in which packets had been passed out. Each student was given a survey and unlimited time to fill in the responses. Upon completion of the survey, each student was given candy.

Data and Data Collection

The researcher's intent was to survey parents and teachers about their interest in creating an after school rocketry club for the purpose of supporting the math and science programs, developing teamwork and problem solving skills and competing in rocket contests.

The consent forms and surveys from the parents were collected from the GATE teachers and placed in folders. Consent forms for students were detached from the parent surveys and collected in a separate folder in preparation for administering the student survey. One hundred percent of the surveys collected were used as data and analyzed. The data was transferred to an Excel spreadsheet.Student surveys were collected and separated by grade level.

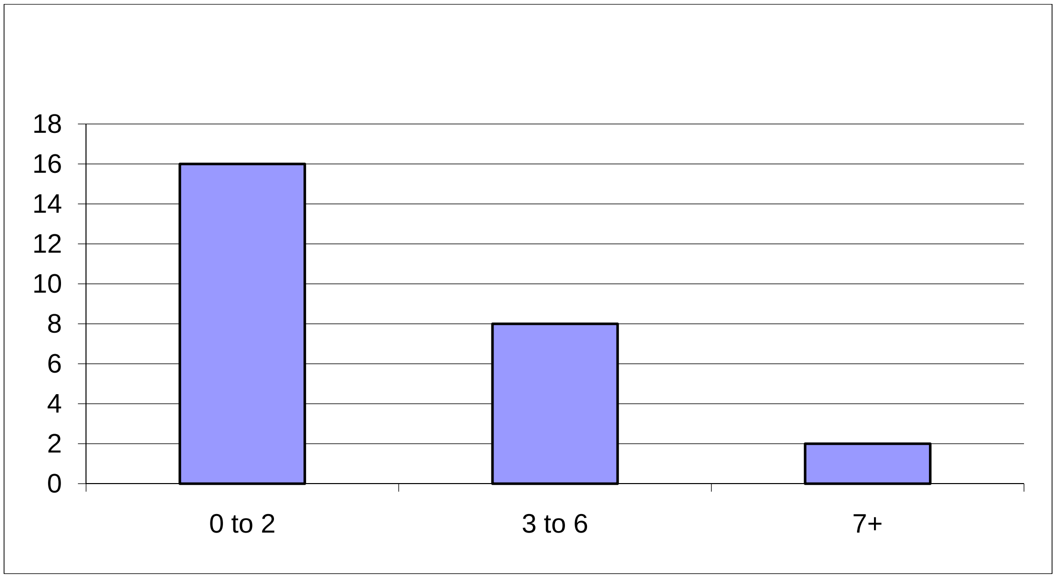
Analysis of the Data

Findings – Parent Survey

Question 1 ascertained the number of years each parent had a child enrolled at E.V. Cain. This information helped to determine the parent experience level with the school.

How long have you had children at E.V. Cain?

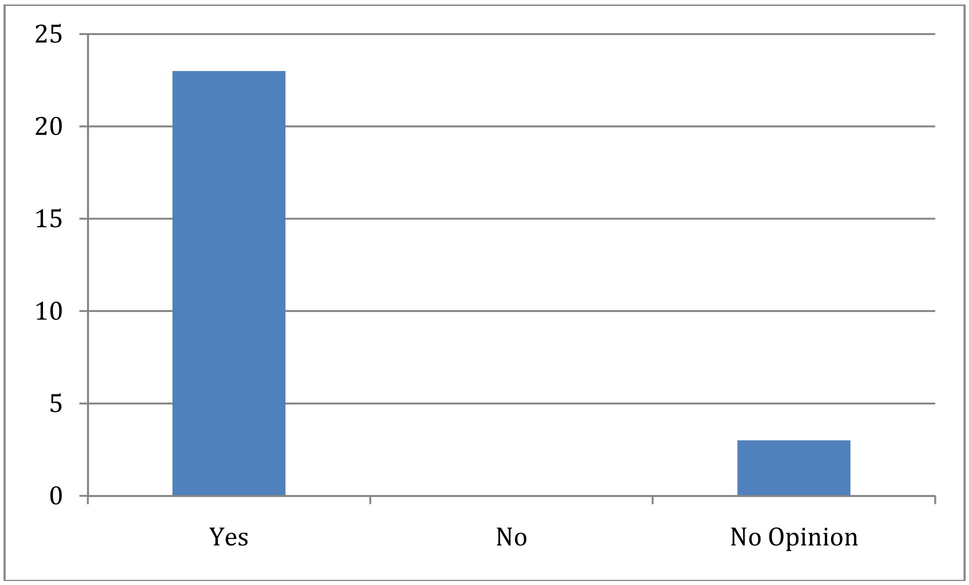
Figure 1 Parent question oneresults



The parent responses indicate that 62% of the respondents have had a child at E.V. Cain for two years or less, 31%, had children at the school for as long as six years and only two, representing 8%,had an association with the school for seven or more years (see Figure 1).

Question 2 asked the participants if they felt that there was a need for after school activities at E.V. Cain.

Figure 2 Parent question tworesults

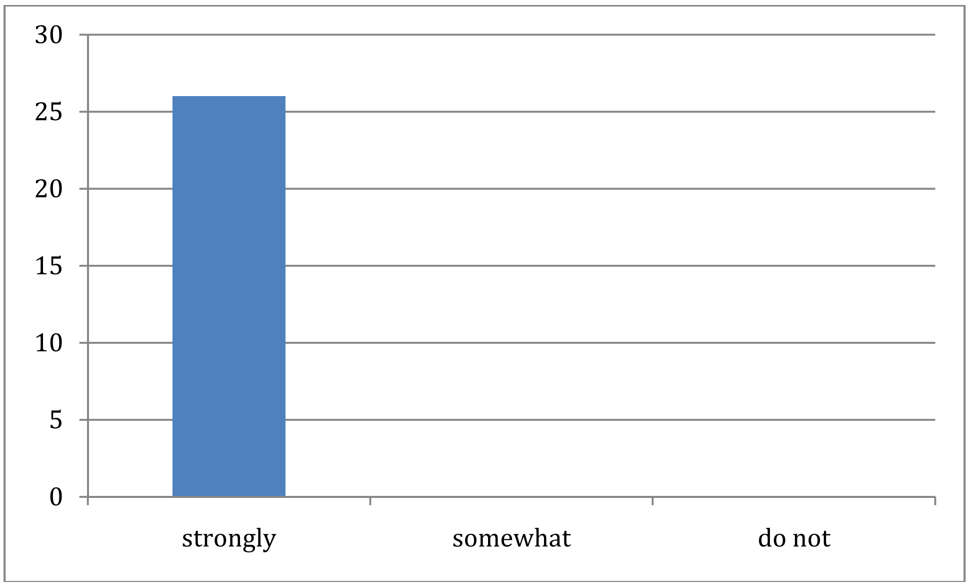


The most frequently selected choice was “yes” at 88%. Three respondents, 26% out of 26 surveyed had no opinion on the need for after school activities (see Figure 2).

Question 3 was designed to ascertain if the parents view science and math as important subjects in the curriculum.

3. Do you agree that there is a need for a strong curriculum in science and math?

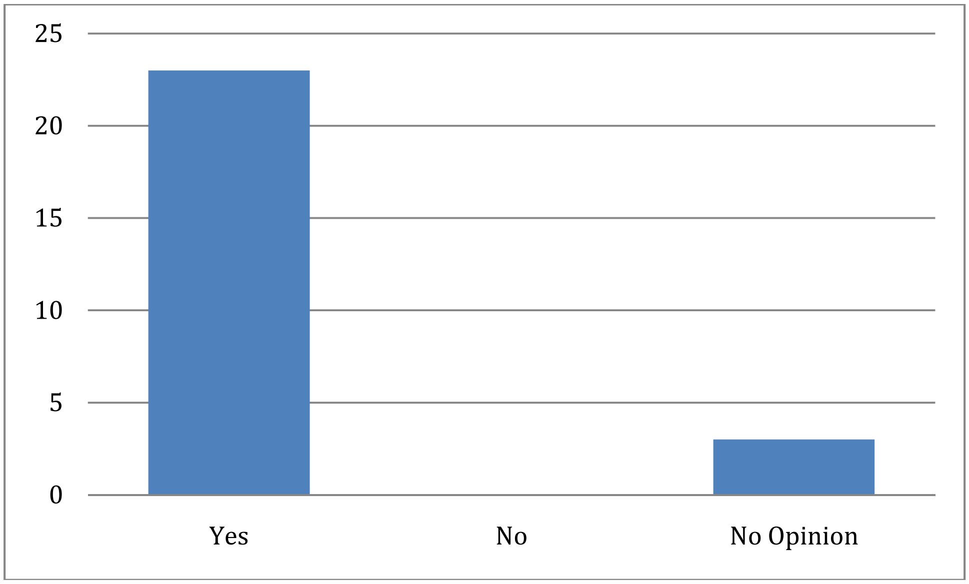
Figure 3 Parent question threeresults



One hundred percent of the respondents strongly agreed that a strong science and math curriculum is important to them (see Figure 3).

Question 4 asked the parents in they think that their child would participate in an after school academic program.

Figure 4 Parent question fourresults

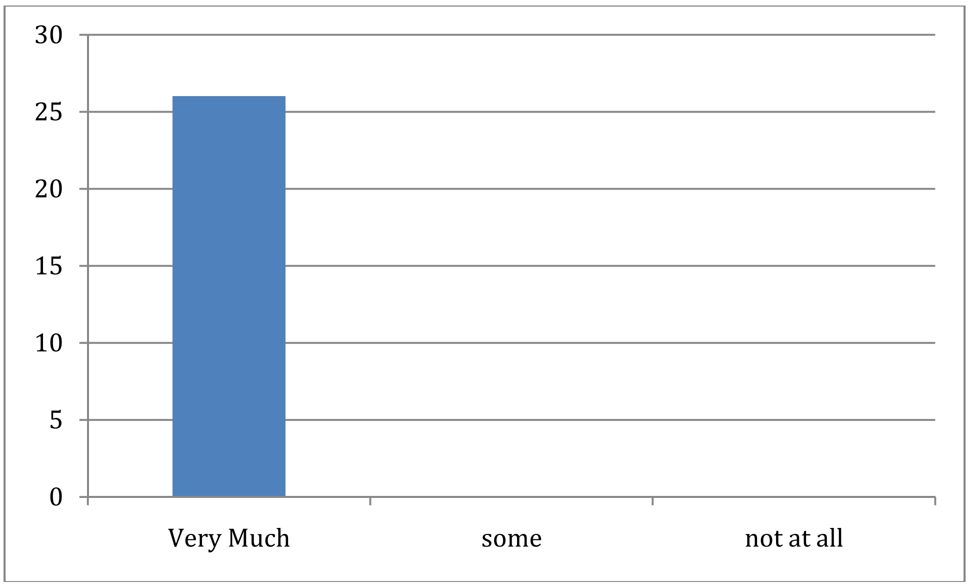


The most frequently selected choice was “yes” at 88%. Only three of the 26 respondents had no opinion and none chose “no”(see Figure 4).

Question 5 solicited the opinion of the parents if their child would benefit from hands on activities related to science and math.

5. Do you feel that students learn science and math better when it is learned through hands-on activities?

Figure 5 Parent question fiveresults

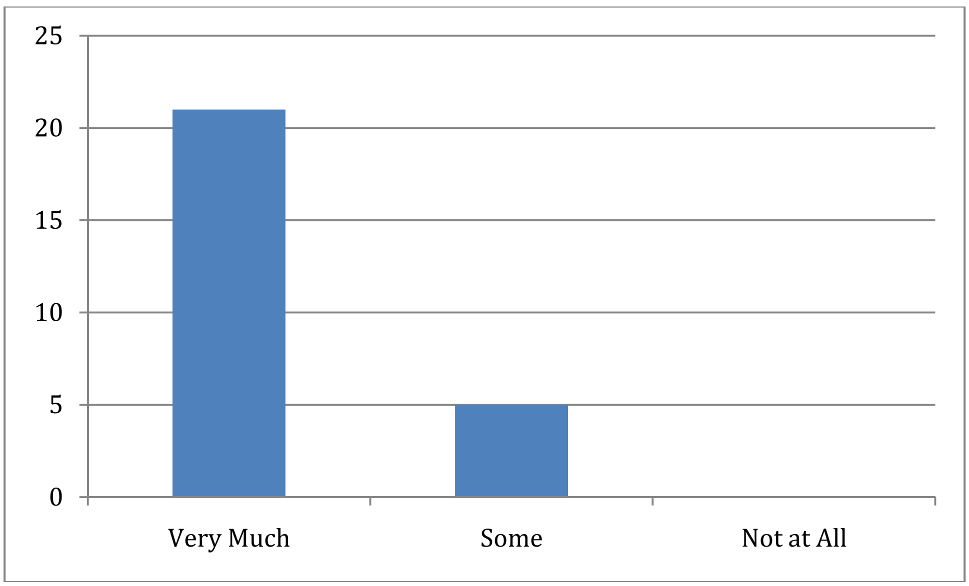


One hundred percent of the parents selected “very much” as their choice about the benefit of a hands-on approach to learning (see Figure 5).

Question 6 asked the parents about their opinion on the benefits of teamwork and problem solving skills for their child's education.

6. Would your child benefit from a program that requires teamwork and problem solving skills?

Figure 6 Parent question sixresults

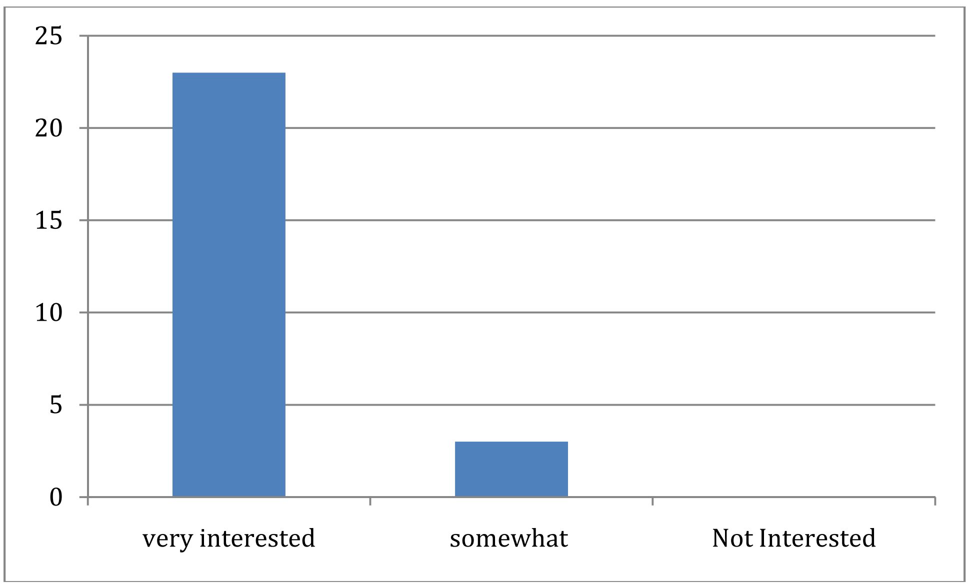


The most frequently selected choice was "very much" with 81% of the parents selecting it with 100% of the respondents seeing at least some need for teamwork and problem solving skills for their children (see Figure 6).

Question7 queried the parents' interest in college scholarships for their children.

7. Would you be interested in your child participating in a contest that could win them a college scholarship?

Figure 7 Parent question sevenresults

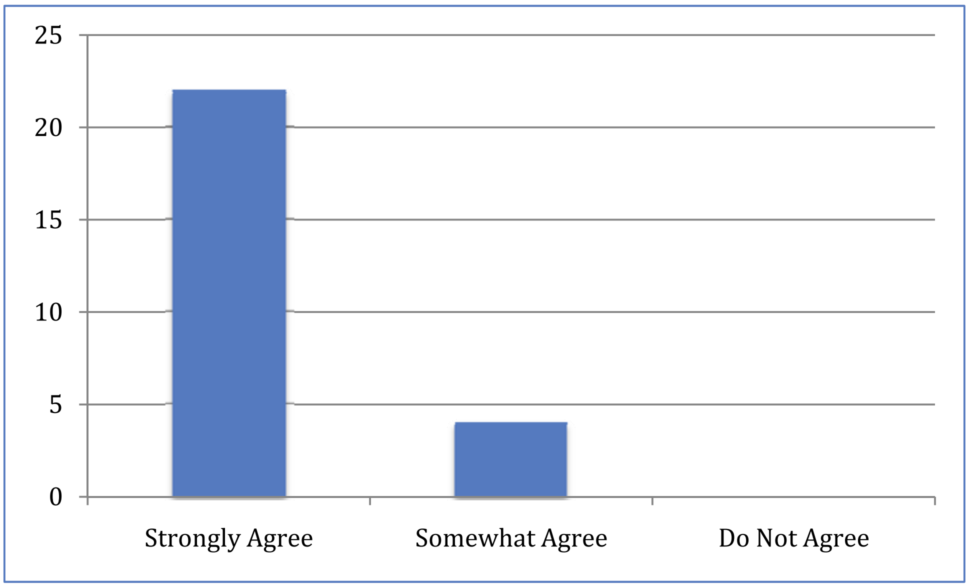


The most frequently selected choice was "very interested" with 88% of the 26respondents selecting it and only two indicating that they were "somewhat interested" in their child obtaining a scholarship through competition (see Figure 7).

Question 8 focused on soliciting the parents' opinion about the safety and fun factor of model rocketry.

8. Do you agree that model rocketry is a safe and fun way for students to learn about science and math?

Figure 8 Parent question eightresults

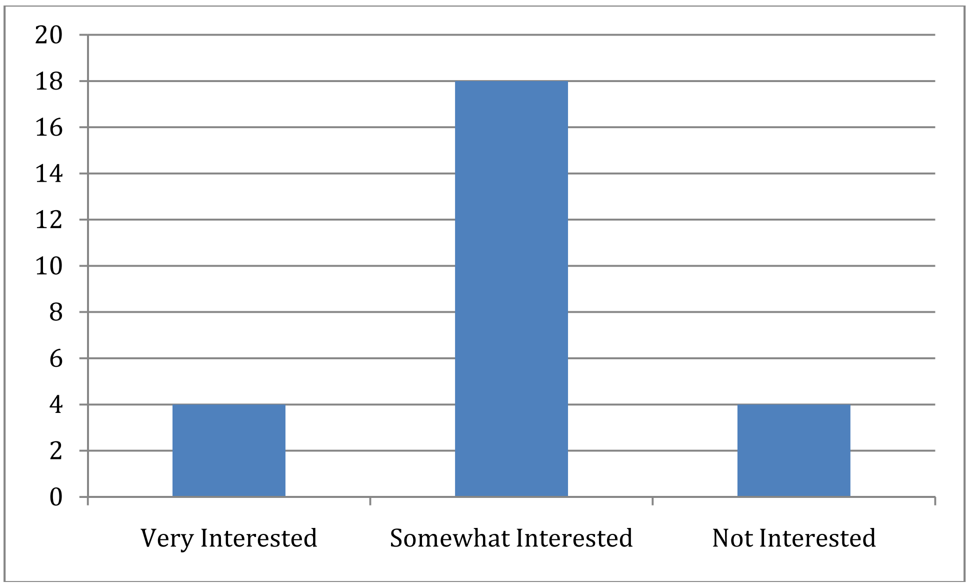


Out of the 26 parents surveyed, none felt that model rocketry was not a safe activity.

Question 9 gauged the respondents on their willingness to assist in the creation of an after school model rocketry club.

9. Would you be interested in helping to create and assist an after school advanced model rocketry club?

Figure 9 Parent question nineresults



Eighty-five percent of the respondents expressed a willingness to assist in the creation of an after school program dedicated to model rocketry.

Question 10 asked if the parent had anything to add.

10. Please provide additional comments.

Great idea! I know nothing about rocketry but it would be fun to learn.

I am not able to assist at this time but I think it is an excellent idea.

Anytime we can do creative “outside of the box” learning/thinking. I am all for it!! This type of learning is exactly what we need to have available – especially as a continuing high end learning experience. That can be fun too!

I don’t have enough information to determine how ‘safe’ rocketry is; also I believe it is important to educate our young girls in science and math as much as possible.

I would love to help in an after school program. I am available on Wednesdays and every other Friday.

Great elective, my child enjoys it.

Learning something and having fun. What could be better?

This would be great for kids who are in band! I know my son would love this.

Re #9 Work schedule is flexible if enough planning/notice, If I know 8 weeks in advance when I am needed, will be there!!!

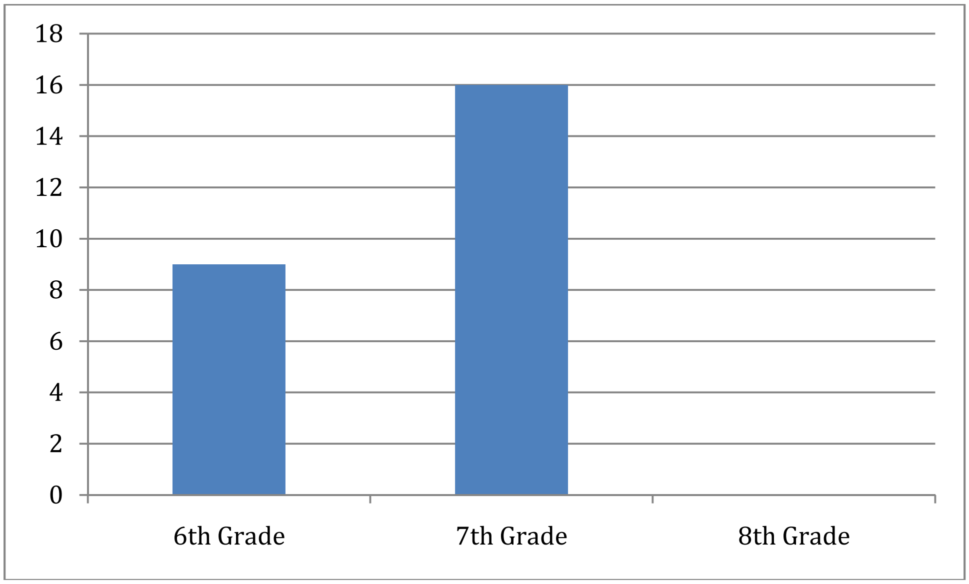
Would be able to donate. As of now, I am in the science club. Sierra College, also attending.

Findings: Student Survey

Question 1 ascertained the grade level of participants.

1. What grade are you in at E.V. Cain?

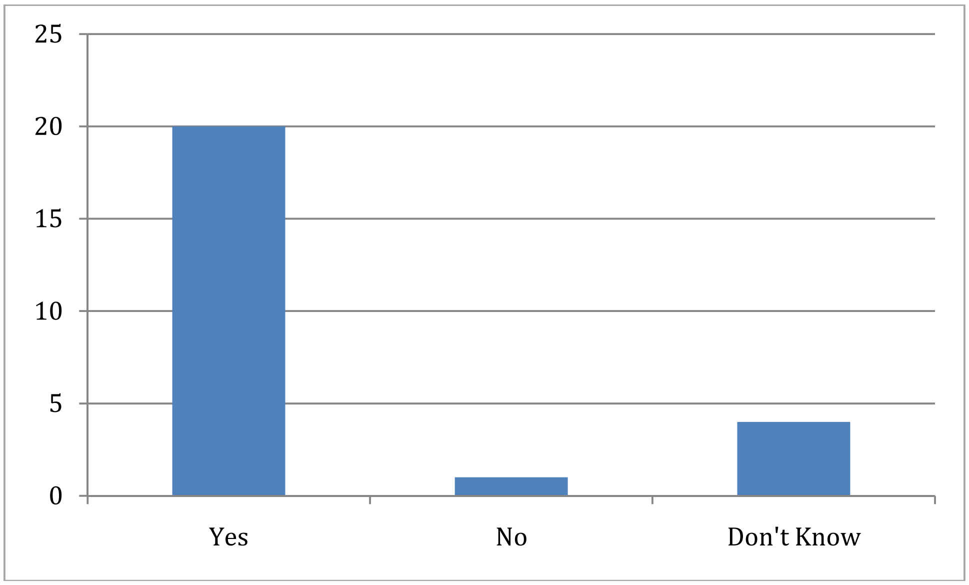
Figure 10   Student question oneresults



Sixty-four percent of the participants were in the seventh grade and the remainder were sixth graders. None of the participants were eighth graders (see Figure 10).

Question 2 asked the participants if they see a need for after school activities at E.V. Cain.

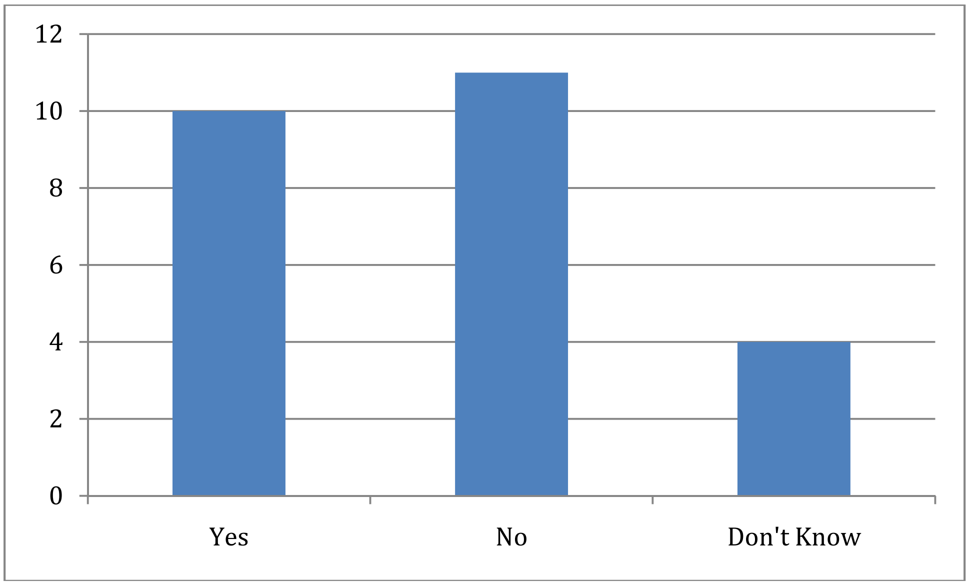
Figure 11 Student question tworesults



Eighty percent of the respondents chose yes, 4%, or one out of 25 said no, and 16% chose don't know (see Figure 11).

Question 3 inquired if the students felt that they would like more help in science and math.

Figure 12   Student question threeresults

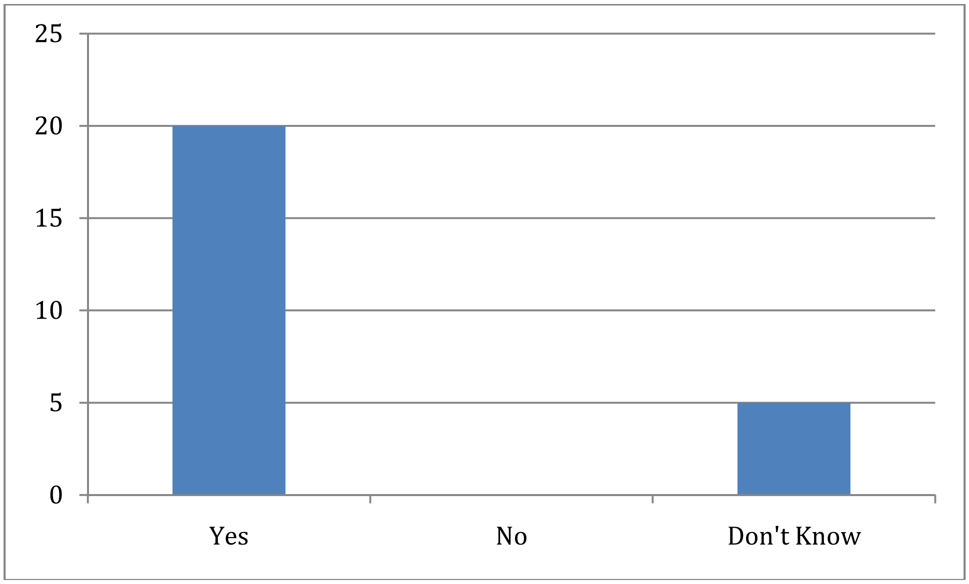


Forty-four percent of the respondents stated they did not need help with science and math, while 40% picked “yes.” Four of the 25respondents picked “Don’t Know” (see Figure 12)

Question 4 asked the participants if they thought the school should have after school clubs.

4. Do you feel that there should be after school clubs at E.V. Cain?

Figure 13   Student question fourresults

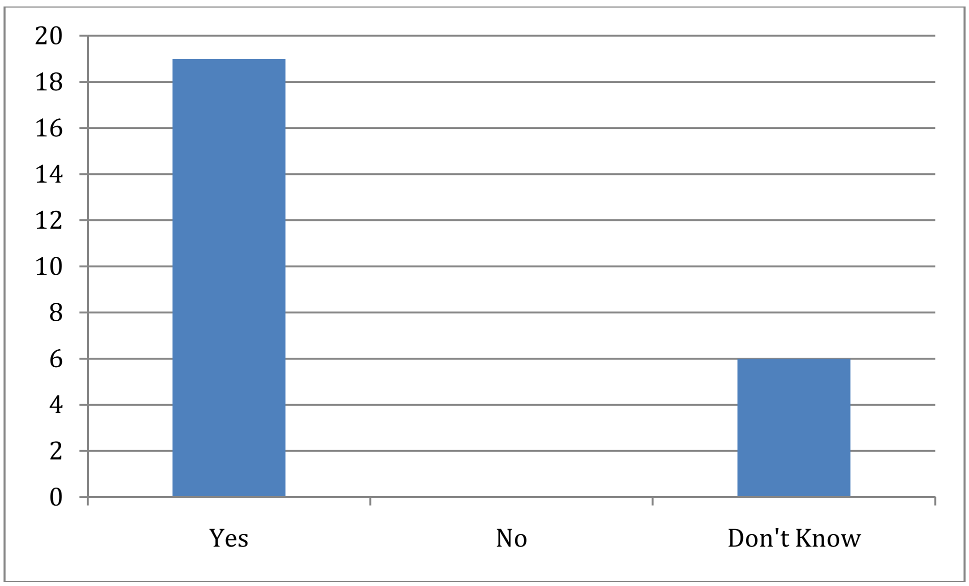


The most frequently chosen answer was “yes” at 80%, none selected “no,” and 20% stated they did not know (see Figure 13).

Question 5 asked the participants about learning through hands on activities.

5. Do you feel that you would learn science and math better through a hands-on experience?

Figure 14   Student question fiveresults

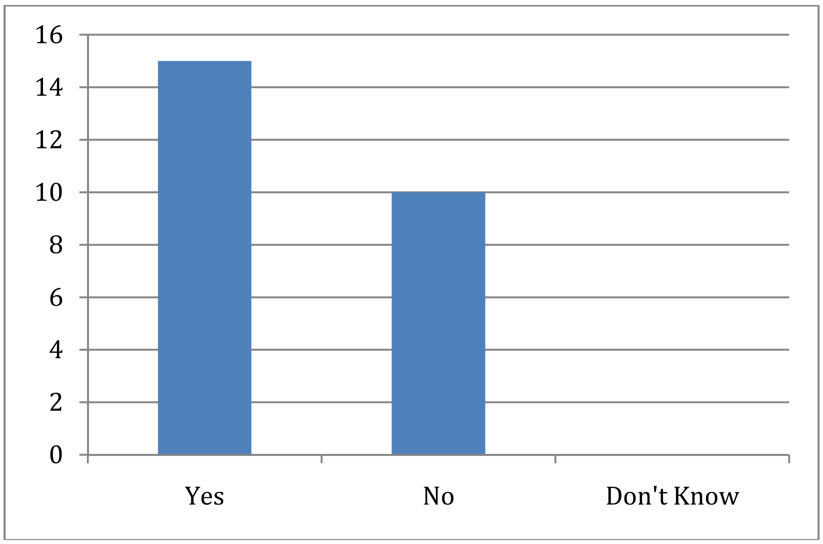


Seventy-six percent of the respondents answered “yes,” no respondent picked “no,” and 24% stated that they did not know (see Figure 14).

Question 6 was designed to inquire if the respondents enjoy working with others.

6. Do you enjoy working with others to solve a challenging problem?

Figure 15 Student question sixresults

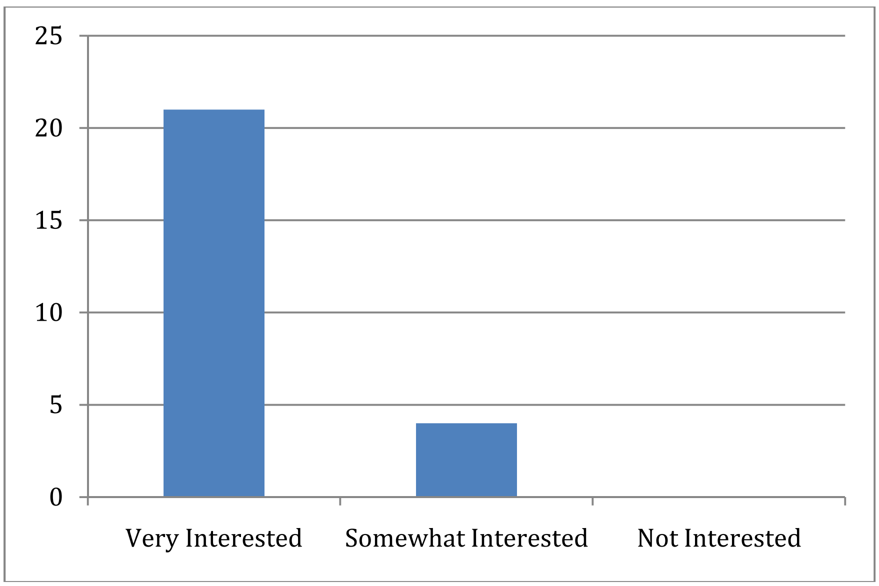


Sixty percent of the students said yes to Question 6 and 40% picked no (see Figure 15).

Question 7 asks the participants about their interest in college scholarships.

7. Would you be interested in participating in a contest that you could win a college scholarship?

Figure 16 Student question sevenresults

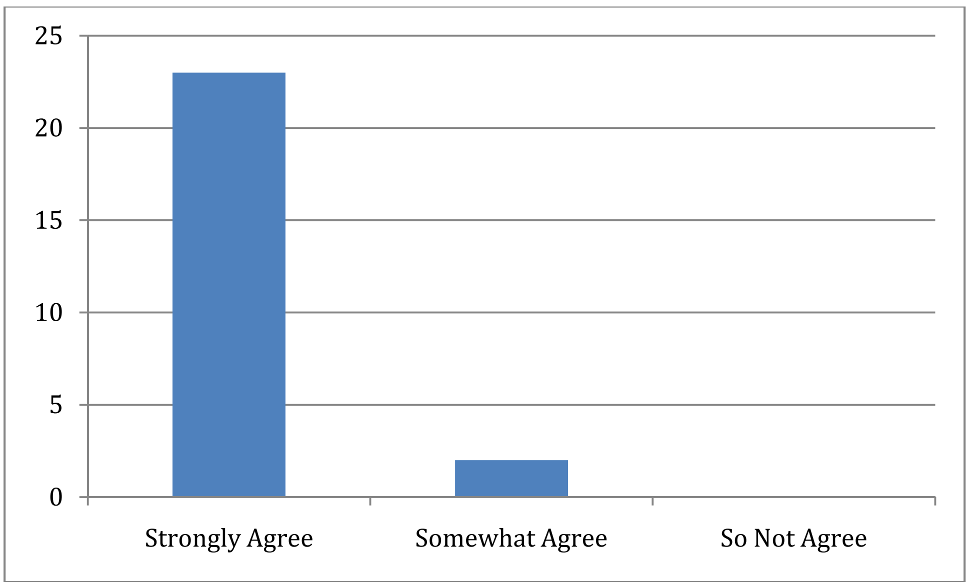


One hundred percent of respondents indicated that they are interested in winning a scholarship (see Figure 16).

Question 8 focused on soliciting the students' opinion about the safety and fun factor of model rocketry.

8. Do you agree that model rocketry is a safe and fun way to learn about science and math?

Figure 17   Student question eightresults

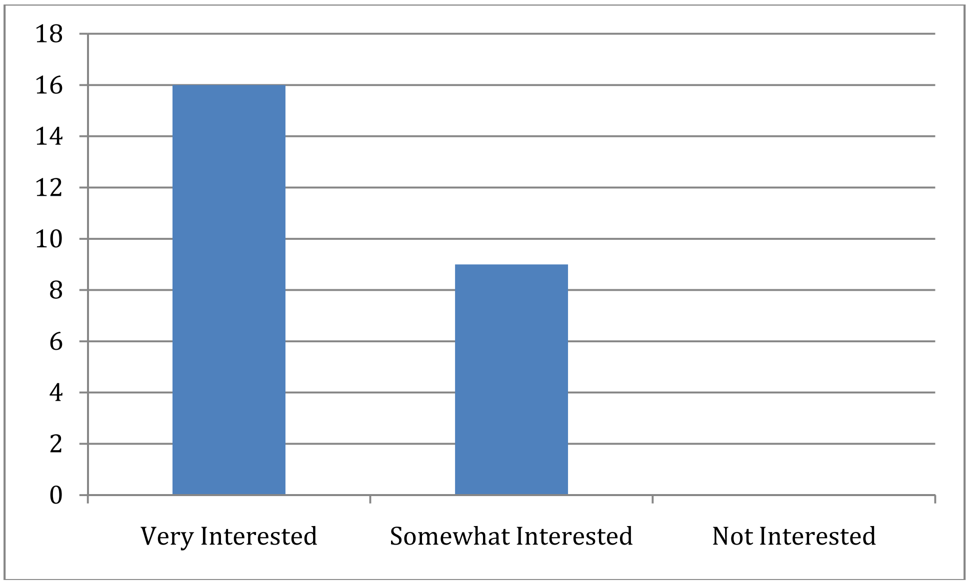


The most frequently chosen answer was "strongly agree" with 92% of the respondents choosing it. None of the 25 respondents view model rocketry as unsafe or boring (see Figure 17).

Question 9 solicited the respondent interest in participating in an after school model rocketry club.

9. Would you be interested in joining an after school advanced model rocketry club?

Figure 18 Student question nineresults



Of the 25 surveyed students, 100% indicated at least some interest in joining a rocketry club after school (see Figure 18).

Question 10 asked for additional comments.

Rocketry is fun.

Rocketry is very fun.

I always was fascinated by remote control things. But my problem is whether to do band or rocketry. So now I don't have to give up either.

I would most definitely want to join an after school rocketry club or group.

Interpretation

Based on the responses by the surveyed parents, there is strong support for a model rocketry program. They see a need for after school activities at E.V. Cain and that math and science is important in the education of their children. The parents agree with the statement that students learn science and math better if taught through hands-on activities and that model rocketry would be a safe and fun way to teach those disciplines. The strongest endorsements came from the additional comments, where the parents offered support and enthusiasm.

The data that was collected and analyzed from the student surveys showed several distinct trends.Students are very interested in an after school rocketry club and were eager to participate. The hands-on aspect of model rocketry appealed to them and they viewed the hobby as fun and safe.

The researcher believes that data supports the creation of an after school rocketry program and that select students of the program attempt to compete in the Team America Rocketry Challenge.

Description of the Project

The project is a STEM-based curriculum (see Appendix E) that teaches identified skills required by students to become successful in the Team America Rocketry Challenge. The curriculum is designed to be used in a middle school as an elective model rocketry class. Educators may also select portions of the curriculum to use in an eighth grade physical science class as a hands-on activity for forces and motion lessons. It can also be used as a curriculum for an extracurricular program, either before or after school.

The curriculum lists skills that the researcher identified as being essential for TARC team success and content standards that the lessons teach, both on the federal and state level.

The lessons are divided into four lesson types. The lecture and demonstration lessons comprise PowerPoint lectures on rocketry, the model rocket, Newton's Laws of Physics, aeronautics, rocket stability, model rocket launch procedures, and the TARC rules. The design and engineering lessons are on the design and construction of model rockets capable of carrying egg and electronic altimeter payloads. These lessons also teach the students how to safely launch their rockets. The construction lessons offer a step-by-step approach to guiding the students in building a low power payload rocket in order to obtain the basic construction skills required to build a TARC rocket. Finally, the investigation and discovery lessons provide experience in data collection and the analysis of that data for the purpose of altering a model rocket's altitude and total time of flight in order to obtain a qualifying TARC score that will be competitive.

Chapter 4

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The push for standards based education can be traced back to 1981 with the publication of the definitive document *A Nation at Risk: The Imperative for Educational Reform* by the U.S. Department of Education. The nation's first standards appeared in 1989 when the National Council of Teachers of Mathematics published *Curriculum and Evaluation Standards of Mathematics.* The National Science Foundation invested $7million and four years of debate to produce the National Education Standards in 1996.

The California Department of Education, responsible for the education of more that 7 million students in over 9,000 schools published its first content standards in 1997 for mathematics. The CDE has since established standards in language arts, science, history-social science, English language arts development, visual and performing arts, career technical education, physical education and health education.

After school programs can reinforce and supplement the core curriculum by offering new and different opportunities. Research supports that many schools are offering after school programs because of their value to students. There are a few organizations of note that offer programs to school-aged children. The YMCA began in London, England in 1844 and has grown to 2,686 locations throughout the United States. 4-H, born in the rural areas of the United States as a means of educating farmer on new farm techniques through their children, is now a partner with the National Association of Rocketry for the purpose of fielding teams for the Team America Rocketry Challenge. The Civil Air Patrol is an auxiliary of the United States Air Force and its cadet program includes aerospace training through model rocketry. This organization is also involved in the TARC and sponsors CAP teams who participate.

There are several national competitions for middle and high school students in the field of science and math. The aerospace industry invests about $8 million annually in STEM education programs and competitions in order to attract future employees. Competitions like the AAPPT Physics Bowl, the Intel International Science and engineering Fair, Odyssey of the Mind, Botball, Science Olympiad and the Team America Rocketry Challenge offer science and math scholarships as prizes to participants.

Rocketry is a broad field that falls into three categories; professional, amateur, and model rocketry. Model rocketry is a safe hobby in that participants use commercially build rocket motors rather than the home made types used in amateur rocketry.

Modern rocketry can be traced back to pioneers in the field such as Dr. Robert H. Goddard, Hermann Oberth, and Werner von Braun. The early work of these men led to the German V2 missile program of World War II and ultimately the U.S. and Russian space programs. Model rocketry emerged from the more dangerous amateur rocketry when G. Harry Stine and Orville H. Carlisle founded the National Association of Rocketry for the purpose of promoting safe forms of rocketry. The dream of safe rocket motors was realized when Verne Estes created a machine that could manufacture large amounts of black powder motors and eliminating the need for rocket hobbyists to make their own.

The concept of model rocketry as a teaching tool for math and science came early in its history and Verne Estes produced newsletters containing science experiments and the mathematical equations for determining velocity and altitude for model rockets. Estes Industries produced several documents over the years promoting math and science-based activities and lessons including technical reports, technical notes, and the Estes Educator Series, which included lessons in math, science, and industrial technology. The National Aeronautics and Space Administration has also supported rocketry education and has produced several publications to aid the teacher in teaching rocketry in the classroom.

E.V. Cain Middle School educates over 700 students in the Auburn Union Elementary School District and has done so since 1950. The demographics of the district are shifting as the Hispanic population increases and the number of European students decreases.

According to the results of a survey given to random parents and students, there is a strong indication that an after school model rocketry program would be well supported by both groups. The majority of respondents felt that model rocketry was a good way to teach math and science standards in a safe and fun way.

Conclusions

Since the publication of *A Nation at Risk* in 1981, there has been a steady progression toward standards based education. The researcher found common language in many of the standards publications. The authors of those documents saw a need for integrated curricula that taught several disciplines, such as math and science, in one curriculum. They saw a benefit not only in time management but also in a better understanding of the content by the students. The authors also saw the advantages of more hands-on activities instead of classroom lectures. Math and science is about using those disciplines to make things and to solve problems. It is not about taking tests and hearing lectures.

There is a strong need for the educational community to embrace these concepts and move out of the classrooms into the field for a real-world learning experiences. The popularity of national competitions may be offered as proof that students are just as willing to embrace an interactive approach to learning.

Model rocketry is a powerful tool for teachers who wish to incorporate science, technology, engineering, and math into a fun, engaging, and challenging activity. When designing model rockets in the computer lab, the students have an opportunity to match their ingenuity with the limits of Newton's Laws of Physics in order to design their own model rocket that is aerodynamically sound. Fine motor skills are honed during the construction of the rockets as they measure, cut, and glue their rocket parts to the specifications that they themselves determined. Teamwork is a skill that they acquire and they organize into a group with many specialized responsibilities for the purpose of launching their rockets and collecting valuable data to be processed and analyzed in the classroom. Suddenly, the Pythagorean Theorem makes sense as they visualize the giant triangle formed by the flight path of their rocket. Newton's Laws are in full enforcement right before their very eyes. Through the activities of model rocketry, science and math not only exist, they "come to life."

Recommendations

For the sake of brevity, the research restricted the studies of model rocketry to solid propellant models, which are model rockets that use black powder as the means of propulsion. Many of the lessons developed in the project could easily be converted for rockets that use other forms of propulsion such as water, air, and hydrogen. The researcher recommends that future research be done to investigate other types of safe rocket propulsion.

The researcher would like to recommend that the curriculum be accepted as a course of elective study at E.V. Cain Middle School. In addition, that the curriculum be used as a summer program that involves middle and high school students from the Auburn area to train students in the skills needed to successfully participate in the TARC.

As the Team America Rocketry Challenge involves over 7,000 students yearly, it is hoped by the researcher that this curriculum, in whole or in part, may be of benefit to any educator who mentors a TARC team. Such a program would be an asset to a school that seeks to offer more hands-on science and math activities to their students both in the classroom and in their extracurricular programs.

APPENDICES

APPENDIXA

Rocket Club Parent Survey

1. How long have you had children at E.V. Cain?
____0-2 years ____ 3 – 6 years ____ 7+ Years

2. Do you see a need to have after-school academic activities at E.V. Cain?
____ Yes ____ No ____ No Opinion

3. Do you agree that there is a need for a strong curriculum in science and math?
___ Strongly Agree ___ Somewhat Agree ____ Do Not Agree

4. Would your child participate in an after school academic program?
____ Yes ____ No ____ No Opinion

5. Do you feel that students learn science and math better when it is learned through hands-on activities?
____ Very Much ____ Some ____ Not at All

6. Would your child benefit from a program that requires teamwork and problem solving skills?
____ Very Much ____ Some ____ Not at All

7. Would you be interested in your child participating in a contest that could win them a college scholarship?
____ Very Interested ____ Somewhat Interested ____ Not Interested

8. Do you agree that model rocketry is a safe and fun way for students to learn about science and math?
___ Strongly Agree ___ Somewhat Agree ____ Do Not Agree

9. Would you be interested in helping to create and assist an after school advanced model rocketry club?
____ Very Interested ____ Somewhat Interested ____ Not Interested

10. Please provide additional comments

____
____
____
____
____
____
____

APPENDIX B

Parent Survey Consent Form

E.V. Cain Middle School
150 Palm Avenue
Auburn, CA 95603
(530) 823-6106

Randy Ittner, Principal Shawn Shaw, Vice Principal

Consent to Participate in Research
At E.V. Cain Middle School

Dear Parent,

You are being asked to participate in a research study conducted by Mr. Thomas Sarradet, a teacher at E.V. Cain Middle School and a graduate student in Educational Leadership and Policy Studies at California State University, Sacramento. The California Department of Education supports the practice of informed consent and protection for subject participating in research.

The purpose of this study is to evaluate the possibility of the creation of an after school model rocketry club that may participate in a rocketry challenge competition.

Please fill out the attached survey of questions and return it with your student to the class in which it was issued.

There are no risks to you or your privacy if you decide to participate in the survey. The completed surveys will be completely anonymous. Potential benefits from participation in this study may lead to the creation of an after school program dedicated to model rocketry that your child may participate in.

Participation is entirely voluntary. If you have questions or concerns about this study, please contact me at 823-6106 ext 227 or by email at: tsarradet@auburn.k12.ca.us

You may indicate your consent by filling out the attached survey and returning it to school with your student. Thank you very much for your time and support.

Sincerely,

Tom Sarradet
E.V. Cain Middle School

APPENDIX C

Student Survey Consent Form

E.V. Cain Middle School
150 Palm Avenue
Auburn, CA 95603
(530) 823-6106

Randy Ittner, Principal Shawn Shaw, Vice Principal

Consent to Participate in Research
At E.V. Cain Middle School

Dear Parent,

Your child is being asked to participate in a research study conducted by Mr. Thomas Sarradet, a teacher at E.V. Cain Middle School and a graduate student in Educational Leadership and Policy Studies at California State University, Sacramento. The California Department of Education supports the practice of informed consent and protection for subject participating in research.

The purpose of this study is to evaluate the possibility of the creation of an after school model rocketry club that may participate in a rocketry challenge competition. Participation in this study will require about 10 minutes of your/your child's time answering 10 survey questions.

There are no risks to your child's privacy if you decide to participate in the survey. The completed surveys will be completely anonymous. Potential benefits from participation in this study may lead to the creation of an after school program dedicated to model rocketry that your child may participate in.

Participation is entirely voluntary. The survey will not be administered until this consent form is signed and returned. If you have questions or concerns about this study, please contact me at 823-6106 ext 227 or by email at: tsarradet@auburn.k12.ca.us

You may indicate your consent by filling out the attached survey and returning it to school with your student. Thank you very much for your time and support.

I consent to my child, ____ (child's name) participating in this survey

Signed ____

Sincerely,
Tom Sarradet

E.V. Cain Middle School

APPENDIX D

Rocket Club Student Survey

1. What grade are you in at E.V. Cain?

____6th grade ____ 7th grade ____ 8th grade

2. Do you see a need to have after-school academic activities at E.V. Cain?

____ Yes ____ No ____ Don't Know

3. Would you like more help in science and math?

___ yes ___ no ____ Don't Know

4. Do you feel that there should be after school clubs at E.V. Cain?

___ yes ___ no ____ Don't Know

5. Do you feel that you would learn science and math better through a hands-on experience?

___ yes ___ no ____ Don't Know

6. Do you enjoy working with others to solve a challenging problem?

____ Very Much ____ Some ____ Not at All

7. Would you be interested in participating in a contest that you could win a college scholarship?

____ Very Interested ____ Somewhat Interested ____ Not Interested

8. Do you agree that model rocketry is a safe and fun way to learn about science and math?

___ Strongly Agree ___ Somewhat Agree ____ Do Not Agree

9. Would you be interested in joining an after school advanced model rocketry club?

____ Very Interested ____ Somewhat Interested ____ Not Interested

10. Please provide additional comments

____

____

____

____

____

____

APPENDIX E

STEM Based Rocketry Curriculum

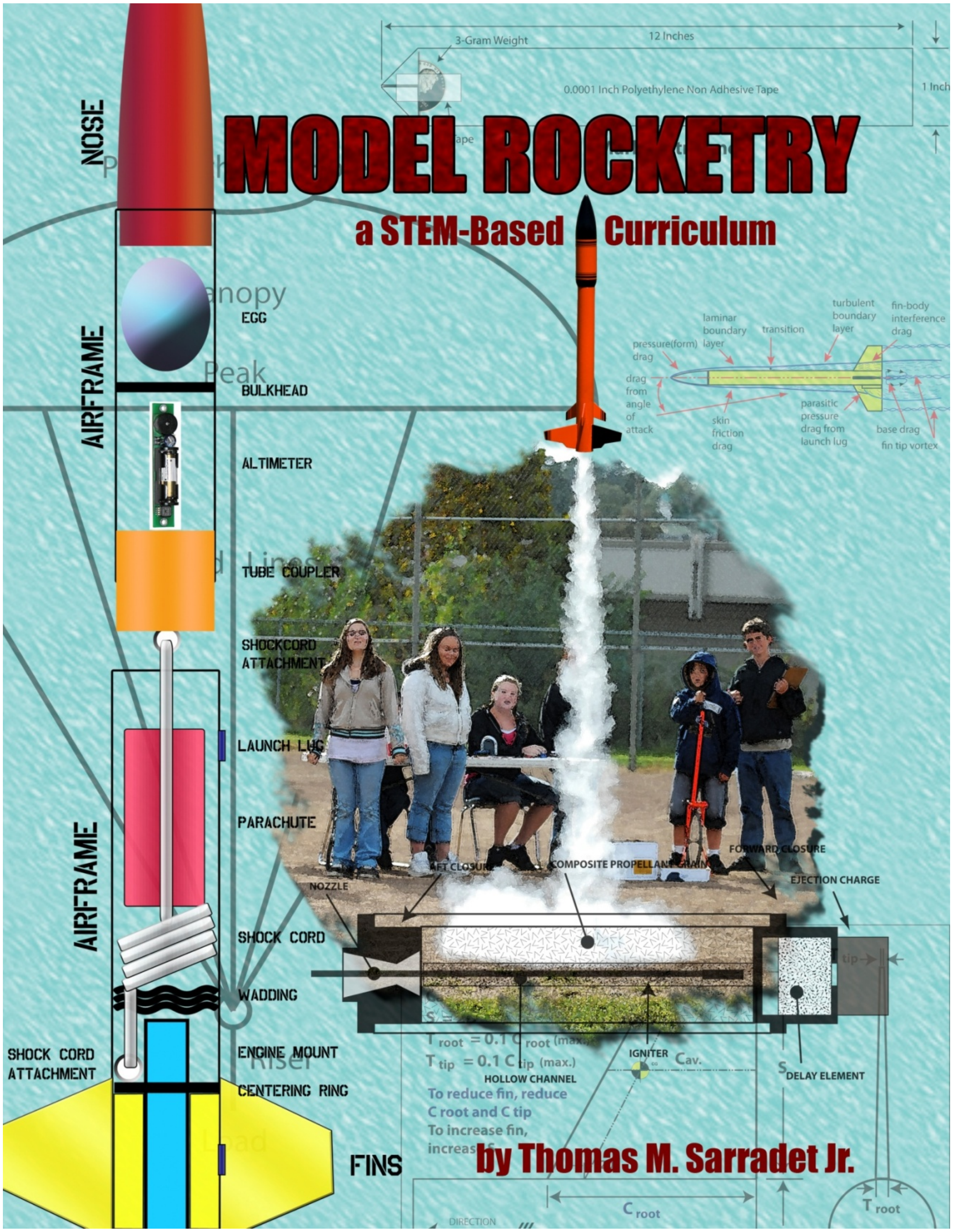

MODEL ROCKETRY
a STEM-Based Curriculum
by Thomas M. Sarradet Jr.
NOSE
AIRFRAME
EGG
BULKHEAD
ALTIMETER
TUBE COUPLER
SHOCKCORD ATTACHMENT
LAUNCH LUG
PARACHUTE
AIRFRAME
SHOCK CORD
WADDING
SHOCK CORD ATTACHMENT
ENGINE MOUNT
CENTERING RING
FINS
3-Gram Weight
12 Inches
0.0001 Inch Polyethylene Non Adhesive Tape
1 Inch
laminar boundary layer
transition
turbulent boundary layer
fin-body interference drag
pressure(form) drag
drag from angle of attack
skin friction drag
parasitic pressure drag from launch lug
base drag
fin tip vortex
AFT CLOSURE
COMPOSITE PROPELLANT GRAIN
FORWARD CLOSURE
EJECTION CHARGE
NOZZLE
IGNITER
HOLLOW CHANNEL
DELAY ELEMENT
To reduce fin, reduce
C root and C tip
To increase fin,

TABLE OF CONTENTS

Questions or comments may be sent to

Tom Sarradet
E.V. Cain Middle School
150 Palm Ave.
Auburn, CA 95603

Email: tsarradet@auburn.k12.ca.us

CHAPTER 1 INTRODUCTION

Description

The primary purpose of this curriculum is to teach the STEM skills necessary for middle and high school students to successfully compete in the Team America Rocketry Challenge.

Setting

The curriculum may also be used, in whole or in part as:

- a training program for TARC member.
- an elective class in middle and high school.
- an extracurricular course.
- A model rocket club curriculum.
- a hands-on activity for a middle or high school science or math class.
- a summer camp program.

Limitations of Model Rocketry

Launching model rockets require access to a launch area that meets the size requirements in accordance with the Model Rocket Safety Code. Schools typically have athletic fields that meet Type A and B model rocket motor requirements of 122 square meters. The Educator may also contact their local National Association of Rocketry club for access to the club's launch sites. NAR clubs support local rocketry education efforts and will usually welcome students on their launch sites with proper notification and preparation. Educators may find club information on the NAR website (National Association of Rocketry, 2009). The local fire laws should be investigated prior to the use of solid propellants. If laws do prohibit them, the curriculum may be altered to use water or air as a means of propulsion. Water rockets can be set up to deploy a recovery system and to carry payloads and electronic altimeters. Educators who use this curriculum for training a TARC team should conduct the training prior to the teams beginning their design and build. Once the students begin the contest, educators and mentors are prohibited from aiding in the design and construction of a TARC rocket.

CHAPTER 2 SKILLS AND STANDARDS

Introduction

The first step in creating a STEM based model rocketry curriculum was to identify the skills students need in order to be successful in the Team America Rocketry Challenge and group them into a skill set. Lessons were designed to teach the targeted skills. The final step was to review federal and state STEM content standards that would be addressed be the lessons.

Skills Set

The following matrix matches specific skills with the lessons that target them.

TARC SKILL SET		
SET		**LESSON**
Students should have knowledge of:		
1.	the rules and regulations governing the Team America Rocketry Challenge.	LD07
2.	the parts of a model rocket and their function: a. Rocket parts b. Rocket motors c. Recovery systems	LD02
3.	Newton's Laws of Motion.	LD03
4.	basic aerodynamics pertaining to rocket flight.	LD04, LD05
5.	math concepts that pertain to the design, construction, and flight of a model rocket.	DE02, DE03, ID03, ID06, ID08, ID12, ID13
6.	basic meteorology and its influence on rocket flight.	ID01, ID10
7.	construction tools and adhesives used to build and repair model rockets.	C01-04
8.	model rocket construction materials and techniques.	C01-04
9.	the math and science of parachute and streamer recovery.	ID02, ID09
10	rocketry safety rules and how to adhere to them.	LD08

Students should have the skills to:	

11	operate and succeed in a team environment.	LD08
12	design a payload model rocket using Rocksim.	DE01
13	run computer simulations of the rocket's flight to ensure sound design and that the design meets the requirement of the TARC.	DE01
14	calculate the proper size and dimensions of rocket parts and manufacture them to those specifications.	LD04, LD05, DE02, DE03
15	build an aerodynamically sound booster section, to include a recovery system, to the specifications of the design that withstands the stresses of multiple mid-power flight.	LD04, LD05, DE02, DE04, CO1-06
16	build an aerodynamically sound, multi-chambered payload section to the specifications of the design that is capable of protecting the egg and electronic payload.	LD04, LD05, DE02, DE04
17	determine and adjust model rocket stability.	LD05
18	safely launch a model rocket and recover it.	DE07, LD06
19	calculate a rocket's velocity in flight.	ID06
20	calculate the altitude attained by a rocket in flight.	ID03
21	install and use parachutes and streamers to recover the payload and booster sections.	DE06, ID02, ID09
22	record and analyze flight data in order to make adjustments.	LD04, ID01, ID04
23	predict and adjust a rocket's altitude by using rocket motors with various Newtons of force.	LD03, DE05, ID03, ID07
24	predict and adjust the rocket's altitude by adjusting the rockets mass.	LD03, ID03, ID08
25	predict and adjust the flight times by adjusting the recovery system.	LD04, DE06, ID02, ID05, ID09
26	use the proper equipment to collect, interpret and predict the effects of atmospheric conditions on rocket flight.	ID01
27	calculate a rocket's altitude and flight time based on atmospheric conditions.	IDO1, ID10
28	analyze preliminary flights to redesign and improve their model rocket as needed.	ID01-13

List of Lessons

STEM Standards

Listed are national and state standards that the researcher has identified as standards that may be taught through the use of this curriculum. Each listed standard is matched with the TARC skills and the lessons that apply to it. Some standards are addressed by most of the lessons, but for the sake of clarity the researcher chose to identify a select few as examples. Standards that the researcher determined do not directly apply to model rocketry have been omitted; therefore this is not a complete list of the standards.
The model rocketry curriculum is not intended to replace science or math courses, but rather to enhance and reinforce them.

NATIONAL AND CALIFORNIA STEM STANDARDS: SCIENCE			
National Science Education Standards		**Skill**	**Lesson**
	Content Standards: 5-8 As a result of activities in grades 5-8, all students should develop		
A	• Abilities necessary to do scientific inquiry • Understand about scientific inquiry	11- 28	
B	an understanding of • Motions and forces • Transfer of energy	3 4 17 23	LD03 LD04 LD05 DE05 ID03 ID07
E	• Abilities of technological design • Understandings about science and technology	All	All
G	an understanding of • Science as a human endeavor • Nature of science • History of science	All	All
	Content Standards: 9 - 12 As a result of activities in grades 9 - 12, all students should develop		
A	• Abilities necessary to do scientific inquiry • Understandings about scientific inquiry	19 20 22- 28	ID06 ID03 ID07 ID08
B	an understanding of • Motions and forces	3 4 5 17 23 24 25 27	LD03 LD04 LD05 DE05 ID03 ID07
E	• Abilities of technological design • Understanding about science and technology	12 13 15 16	DE01 LD04 LD05 DE02 DE04 C01-06

G	develop an understanding of • Science as a human endeavor • Nature of scientific knowledge • Historical perspectives	All	All
	Program Standards		
B	The program of study in science for all students should be developmentally appropriate, interesting, and relevant to students' lives; emphasize student understanding through inquiry; and be connected with other school subjects.	All	All
C	The science program should be coordinated with the mathematics program to enhance student use and understanding of mathematics in the study of science and to improve student understanding of mathematics.	All	All
California State Standards for Grade 8 SCIENCE (Physical Science)			
	Standard Set 1. Motion		
1.	The velocity of an object is the rate of change or its position.		
a.	position is defined relative to some choice of standard reference point and a set of reference directions.	4	LD04
b.	average speed is the total distance traveled divided by the total time elapsed.	19	ID06
c.	The speed of an object along the path traveled can vary.		
d.	how to solve problems involving distance, time, and average speed.	19	ID06
e.	to describe the velocity of an object one must specify both direction and speed.	4	LD04
f.	changes in velocity can be changes in speed, direction, or both.	4	LD05
g.	how to interpret graphs of position versus time and speed versus time for motion in a single direction.	4	LD04
	Standard Set 2. Forces		
2.	Unbalanced forces cause changes in velocity. Students know		
a.	a force has both direction and magnitude.	3 4	LD02 LD03
b.	when an object is subject to two or more forces at once, the effect is the cumulative effect of all the forces.	4	LD04
c.	when the forces on an object are balanced, the motion of the object does not change.	3 17	LD03 LD05
d.	how to identify separately two or more forces acting on a single static object, including gravity, elastic forces due to tension or compression in matter, and friction.	3	LD03
e.	when the forces on an object are unbalanced the object will change its motion (that is, it will speed up, slow down, or change direction).	3, 4, 17	LD03 LD04 LD05
f.	the greater the mass of an object the more force is needed to achieve the same change in motion.	3 23 24	LD03 DE05 ID03 ID07 ID08
	Standard Set 9. Investigation and Experimentation		
9.	As a basis for understanding this concept, and to address the content the other three strands, students should develop their own questions and perform investigations. Students will:		
a.	plan and conduct a scientific investigation to test a hypothesis.	All	All

b.	evaluate the accuracy and reproducibility of data.	23 24 25 26	LD03 LD04 DE05 DE06 ID02 ID03 ID05 ID07 ID08 ID09
c.	distinguish between variable and controlled parameters in a test.	23 24 25 26	LD03 LD04 DE05 DE06 ID02 ID03 ID05 ID07 ID08 ID09
d.	recognize the slope of the linear graph as the constant in the relationship y=kx and apply this to interpret graphs constructed from data.	2	LD07
e.	construct appropriate graphs from data and develop quantitative statements about the relationships between variables.	26	ID01
f.	apply simple mathematical relationships to determine one quantity given the other two (including speed = distance/time, density = mass/volume, force = pressure x area, volume=area x height).	20	ID03
	High School Physics		
	Motion and Forces		
1.	Newton's laws predict the motion of most objects. As a basis for understanding this concept:	3	LD03
a.	Students know how to solve problems that involve constant speed and average speed.	19	ID06
b.	Students know that when forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton's first law).	18	DE07 LD06
c.	Students know how to apply the law F = MA to solve one-dimensional motion problems that involve constant forces (Newton's second law).	3 19 26	LD03 ID01 ID06
d.	Students know that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's third law).	3 4	LD03 LD04 LD05
e.	Students know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth.	4 20 21	LD04 LD05 ID03 DEO 6 ID02 ID09

f.	Students know applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed).	4	ID10
g.	Students know circular motion requires the application of a constant force directed toward the center of the circle.	17	LD05
h.	Students know Newton's laws are not exact but provide very good approximations unless an object is moving close to the speed of light or is small enough that quantum effects are important.	3 23	LD03 ID04
i.	Students know how to solve two-dimensional trajectory problems.	19	ID06
	Conservation of Energy and Momentum		
2.	The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects. As a basis for understanding this concept:		
a.	Students know how to calculate kinetic energy by using the formula $E = 1/2mv^2$.	23	LD03 DE05 ID03 ID07
c.	Students know how to solve problems involving conservation of energy in simple systems, such as falling objects.	25	LD04 DE06 ID02 ID05 ID09
d.	Students know how to calculate momentum as the product mv.	19	ID06
e.	Students know momentum is a separately conserved quantity different from energy.	23	ID04
f.	Students know an unbalanced force on an object produces a change in its momentum.	4 17 26	LD04 LD05 ID01
NATIONAL STEM STANDARDS: TECHNOLOGY			
	International Technology Education Association Standards		
Standard 8: Students will develop an understanding of the attributes of design. Students should learn that			
E.	Design is a creative planning process that leads to useful products and systems**.** • The design process typically occurs in teams whose members contribute different kinds of ideas and expertise.	All	All
F.	There is no perfect design. • All designs can be improved.	28	C01-C06 ID01-ID13
G.	Requirements for design are made up of criteria and constraints.	1	LD07
H.	The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.	All	All

J.	The design needs to be continually checked and critiqued, and the ideas of the design must be refined and improved.	22-27	ID01-13
K.	Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.	All	All
Standard 9: Students develop an understanding of engineering design. Students should learn that			
F.	design involves a set of steps, which can be performed in different sequences and repeated as needed. • Each design problem is unique and may require different procedures or demand that the stops be performed in a different sequence. In addition, engineers and designers also have their preferences and problem-solving styles and may choose to approach the design process in different ways.	15 16	C01-C06
G.	brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum. • In this process, no person is allowed to criticize anyone else's ideas regardless of how inane they may seem. After all of the ideas are recorded, the group selects the best ones, and then further develops them.	11	LD08
H.	modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions. • Historically, this process has centered on creating and testing physical models. Models are especially important for the design of large items, such as cars, spacecraft, and airplanes because it is cheaper to analyze a model before the final products and systems are actually made. Evaluation is used to determine how well the designs meet the established criteria and to provide direction for refinement. Evaluation procedures range from visually inspecting to actual operating and testing products and systems.	11-28	DE01-07 C01-06 ID01-13
I.	Established design principles are used to evaluate existing designs, to collect data, and to guide the design process. • The design principles include flexibility, balance, function, and proportion. These principles can be applied in many types of design and are common to all technologies	12 14 15 16	DE01 DE02 DE03 LD04 LD05 C01-06
J.	Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly. •Individuals and groups of people who possess combinations of these characteristics tend to be good at generating numerous alternative solutions to problems. The design process often involves a group effort among individuals with varied experiences, backgrounds, and interests. Such collaboration tends to enhance creativity, expand the range of possibilities, and increase the level of expertise directed toward design problems.	1	LD07
K.	A prototype is a working model used to test a design concept my making actual observations and necessary adjustments. Prototyping helps to determine the effectiveness of a design be allowing a design to be tested before it is built. Prototypes are vital to the testing and refinement of a product or system with complicated operations	11-28	DE01-07 C01-06 ID01-13

Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. Students should learn that			
F.	Troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system.	28	ID01-13
G.	Invention is a process of turning ideas and imagination into devices and systems. Innovation is the process of modifying an existing product or system to improve it.	All	All
H.	Some technological problems are best solved through experimentation.	18-28	ID01-13
J.	Technological problems must be researched before they can be solved.	18-28	ID01-13
Standard 11: Students will develop abilities to apply the design process. Students should be able to			
H.	Apply a design process to solve problems in and beyond the laboratory-classroom.	15 16	C01-C06
I.	Specify criteria and constraints for the design.	1	LD07
J.	Make two-dimensional and three dimensional representations of the designed solution. • Two-dimensional examples include sketches, drawings, and computer-assisted designs (CAD).	12 15 16	DE01 C01-C06
K.	Test and evaluate the design in relation to pre-established requirements, such as criteria and constraints, and refine as needed.	1 23 25	LD07 DE03 ID04
L.	Make a product or system and document the solution.	2 3 15 16 24 25	C01-C06 LD04 LD07 DE05 DE06 ID02-ID09
M.	Identify the design problem to solve and decide whether or not to address it.	28	ID01-13
N.	Identify criteria and constraints and determine how these will affect the design process.	1	LD07
O.	Refine a design be using prototypes and modeling to ensure quality, efficiency, and productivity of the final product. Evaluate proposed or existing designs in the real world. Modify the design solution so that it more effectively solves the problem.	28	ID01-13
P.	Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.	2 12 22	LD02 DE01 ID01 ID04
Standard 13: Students will develop the abilities to assess the impact of products and systems. Students should be able to			
F.	Design and use instruments to gather data.	22	ID01

G.	Use data collected to analyze and interpret trends in order to identify the positive or negative effects of technology.	28	ID01-ID13
I.	Interpret and evaluate the accuracy of the information obtained and determine if it is useful.	28	ID01-ID13
J.	Collect information and evaluate its quality.	28	ID01-ID13
NATIONAL STEM STANDARDS: ENGINEERING			
	NATIONAL CONTENT STANDARDS K-12 ENGINEERING/ENGINEERING TECHNOLOGY		
Dimension 1: Engineering Design Students will apply concepts of engineering design to solve problems Students will:			
	Apply a structured approach to solving problems including: defining a problem, brainstorming, researching and generating ideas, identifying criteria and constraints, exploring possibilities, making a model or prototype, evaluating the design using specifications, and communicating results.	11-28	C01-06
	Ask questions and make observations to help figure out how things work.	All	All
	Learn that all products and systems are subject to failure and that many products and systems can be fixed.	28	ID01-13
	Troubleshoot as a way of finding out why something does not work so that it can be fixed.	18	DE07 LD06
	Analyze and break down complex systems into their component parts and explain the relationship and interdependency of the part and the system.	2	LD02
Dimension 2: Connecting Engineering to Science, Technology, and Mathematics Students will develop an understanding of the essential concepts of and how to apply science, technology, and mathematics as they pertain to engineering. Students will			
	Apply their knowledge of science, technology, engineering, and mathematics to define, analyze, and solve problems	All	All
	Apply contemporary engineering tools in the application of science, mathematics and technology to define analyze, model and prototype solutions to problems.	All	All
	Analyze a device and explain the principles of math and science used in the design.	28	ID01-ID13
Dimension 3: Nature of Engineering Students will be creative and innovative in the thought and in their actions. Students will be able to:			
	Use a logical process for inquiry, solving practical problems, critical thinking, and innovation.	1	LD07
Dimension 4: Communication and Teamwork Students will be able to use effective communication and teamwork skills to acquire information and convey outcomes to a variety of stakeholders. Students will be able to:			
	Use appropriate communication procedures, including oral presentations and written documentation using guidelines and style standards.	11	
	Communicate effectively using multiple media.	11 18	DE07
	Practice interpersonal and group dynamic skills, such as: cooperate with others, advocate, influence, resolve conflict, and negotiate.	11	
	Function on multidisciplinary and crossfunctional teams.	11	
NATIONAL AND CALIFORNIA STEM STANDARDS: MATH			
	National Council of Teachers of Mathematics Standards		
Standard 1: Mathematics and Problem Solving In grades 5-8, the mathematics curriculum should include numerous and varied experiences with problem solving as a method of inquiry and application so that the students can –			

	Use problem-solving approaches to investigate and understand mathematical content;	19 20 24	ID06 ID03 ID04

	Formulate problems from situations within and outside mathematics;	5	DE02 DE03 ID03 ID06
	Develop and apply a variety of strategies to solve problems, with emphasis on multistep and non routine problems;	23 24 27	ID04
	Verify and interpret results with respect to the original problem situation;	28	ALL
	Generalize solution and strategies to new problem situations;	12	DE01
	Acquire confidence in using mathematics meaningfully.	5	ALL
Standard 2: Mathematics and Communication In grades 5-8, the study of mathematics should include opportunities to communicate so that students can –			
	Model situations using oral, written, concrete, pictorial, graphical, and algebraic methods.	19	ID06
	Reflect on and clarify their own thinking about mathematical ideas and situations.	28	All
	Develop common understandings of mathematical ideas, including the role of definitions.	5	All
	Use the skills of reading, listening, and viewing to interpret and evaluate mathematical ideas.	All	All
	Discuss mathematical ideas and make conjectures and convincing arguments;	23 24	IDO3 ID07
	Appreciate the value of mathematical notation and its role in the development of mathematical ideas.	20	ID03
Standard 3: Mathematics as Reasoning In grades 5-8, reasoning shall permeate the mathematics curriculum so that students can –			
	Recognize and apply deductive and inductive reasoning.	28	All
	Understand and apply reasoning processes, with special attention to spatial reasoning and reasoning with proportions and graphs.	23	ID07
	Make and evaluate mathematical conjectures and arguments.	22	ID04
	Validate their own thinking.	23	ID04
	Appreciate the pervasive use and power of reasoning as a part of mathematics.	5 28	All
Standard 4: Mathematical Connections In grades 5-8, the mathematics curriculum should include the investigation of mathematical connections so that students can –			
	See mathematics as an integrated whole.	5	All
	Explore problems and describe results using graphical, numerical, physical, algebraic, and verbal mathematical models or representations.	19 20 22	ID03 ID04 ID07
	Use a mathematical idea to further the understanding of other mathematical ideas.	5	All
	Apply mathematical thinking and modeling to solve problems that arise in other disciplines, such as art, music, psychology, science, and business.	4	LD05 ID12 ID13
	Value the role of mathematics in our culture and society.	5	All

Standard 5: Number and Number Relationships In grades 5-8, the mathematics curriculum should include the continued development of number and number relationships so that students can –			
	Understand, represent, and use numbers in a variety of equivalent forms (integer, fraction, decimal, percent, exponential, and scientific notation) in real-world and mathematical problem situations.	5 15 16 6	DE02 DE03 ID14
	Develop number sense for whole numbers, fractions, decimals, integers, and rational numbers.	15 16	DE02 DE03
	Understand and apply ratios, proportions, and percents in a wide variety of situations.	14 24	LD04 ID04
	Investigate relationships among fractions, decimals, and percents.	14	C03
	Represent numerical relationships in one- and two- dimensional graphs.	23	DE05
Standard 7: Computation and Estimation In grades 5-8, the mathematics curriculum should develop the concepts underlying computation and estimation in various contexts so that students can –			
	Compute with whole numbers, fractions, decimals, integers, and rational numbers;	8	C01- C05
	Develop, analyze, and explain procedures for computation and techniques for estimation;	12	DE01
	Develop, analyze, and explain methods for solving proportions;	22	ID04
	Select and use an appropriate method for computing from among mental arithmetic, paper-and-pencil, calculator, and computer methods;	22	ID04
	Use computation, estimation, and proportions to solve problems;	22	ID04
	Use estimation to check the reasonableness of results.	23	ID07
Standard 8: Patterns and Functions In grades 5-8, the mathematics curriculum should include exploration of patterns and functions so that students can –			
	Describe, extend, analyze, and create a wide variety of patterns;	28	ID04
	Describe and represent relationships with tables, graphs, and rules;	2	ID07
	Analyze functional relationships to explain how a change in one quantity results in a change in another;	2.b	ID05
	Use patterns and functions to represent and solve problems.	19	ID06
Standard 9: Algebra In grades 5-8, the mathematics curriculum should include explorations of algebraic concepts and processes so that students can –			
	Understand the concepts of variable, expression, and equation;	19	ID06
	Represent situations and number patterns with tables, graphs, verbal rules and equations and explore the interrelationships of these representations;	2b	ID07
	Analyze tables and graphs to identify properties and relationships;	2b	ID07
	Apply algebraic methods to solve a variety of real-world and mathematical problems.	4	LD04 DE02
Standard 10: Statistics In grades 5-8, the mathematics curriculum should include exploration of statistics in real-world situations so that students can –			
	Systematically collect, organize, and describe data; Construct, read, and interpret tables, charts, and graphs.	19 20	ID06 ID03

		23	ID07
	Make inferences and convincing arguments that are based on data analysis.	28	ID01-ID13

	Develop an appreciation for statistical methods as powerful means of decision making.	28	ID01-ID13
Standard 11: Probability Model situations by devising and carrying out experiments or simulations to determine probabilities.			
	Appreciate the power of using a probability model by comparing experimental results with mathematical expectations;	20	ID11
	Make predictions that are based on experimental or theoretical probabilities;	20 23	ID11I ID07
	Develop an appreciation for the pervasive use of probability in the real world.	20	ID07
Standard 12: Geometry In grades 5-8, the mathematics curriculum should include the study of the geometry of one, two, and three dimensions in a variety of situations so that students can –			
	Indentify, describe, compare, and classify geometric figures;	12 4	DE01 ID08
	Visualize and represent geometric figures with special attention to developing spatial sense;	20	ID03
	Explore transformations of geometric figures;	2a	ID08
	Represent and solve problems using geometric models;	20	ID03
	Understand and apply geometric properties and relationships;	20	ID03
Standard 13: Measurement In grades 5-8, the mathematics curriculum should include extensive concrete experiences using measurement so that students can –			
	Extend their understanding of the process of measurement;	8	C01-C06
	Estimate, make, and use measurements to describe and compare phenomena;	21 25	ID02 ID05
	Select appropriate units and tools to measure to the degree of accuracy required in a particular situation;	8	C01-C06
	Understand the structure and use of systems and measurements;	8 12	C01-C06 DE01
	Extend their understanding of the concepts of perimeter, area, volume, angle measure, capacity, and weight and mass;	10 20 24	ID08 ID03 ID04
	Develop the concepts of rates and other derived and indirect measurements;	19 20	ID06 ID03
	Develop formulas and procedures for determining measures to solve problems.	28	ID01-ID13
California State Math Standards			
Grade 7 Math			
	Number Sense		
1.0 Students know the properties of, and compute with, rational numbers expressed in a variety of forms:			
1.1	Read, write, and compare rational numbers in scientific notation (positive and negative powers of 10) with approximate numbers using scientific notation.	15	DE02 DE04

1. 2	Add, subtract, multiply, and divide rational numbers (integers, fractions, and terminating decimals) and take positive rational numbers to whole-number powers.	12	DE01
1. 3	Convert fractions to decimals and percents and use these representations in estimations, computations, and applications.	9	ID05
1. 5	Know that every rational number is either a terminating or repeating decimal and be able to convert terminating decimals into reduced fractions.	5 12 15 16	DE01 DE02 DEO 3 CO2- C04
1. 6	Calculate the percentage of increases and decreases of a quantity.	24	ID04
2.0 Students use exponents, powers, and roots and use exponents in working with fractions:			
2. 1	Understand negative whole-number exponents. Multiply and divide expressions involving exponents with a common base.		
2. 2	Add and subtract fractions by using factoring to find common denominators.	14 15 16	DE02 DE03 C03
2. 3	Multiply, divide, and simplify rational numbers by using exponent rules.	2a	ID08
2. 4	Use the inverse relationship between raising to a power and extracting the root of a perfect square integer; for an integer that is not square, determine without a calculator the two integers between which its square root lies and explain why.	10	LD08
2. 5	Understand the meaning of the absolute value of a number; interpret the absolute value as the distance of the number from zero on a number line; and determine the absolute value of real numbers.	24	ID04
Algebra and Functions			
1.0 Students express quantitative relationships by using algebraic terminology, expressions, equations, inequalities, and graphs:			
1. 1	Use variables and appropriate operations to write an expression, an equation, an inequality, or a system of equations or inequalities that represents a verbal description (e.g., three less than a number, half as large as area A).	20	ID04
1. 2	Use the correct order of operations to evaluate algebraic expressions such as $3(2x + 5^2)$.	4	ID12
1. 4	Use algebraic terminology (e.g., variable, equation, term, coefficient, inequality, expression, constant) correctly.	4	LD04
1. 5	Represent quantitative relationships graphically and interpret the meaning of a specific part of a graph in the situation represented by the graph.	2b	ID07
2.0 Students interpret and evaluate expressions involving integer powers and simple roots:			
2. 1	Interpret positive whole-number powers as repeated multiplication and negative whole-number powers as repeated division or multiplication by the multiplicative inverse. Simplify and evaluate expressions that include exponents.	4	ID12
2. 2	Multiply and divide monomials; extend the process of taking powers and extracting roots to monomials when the latter results in a monomial with an integer exponent.	4	ID12
3.0 Students graph and interpret linear and some nonlinear functions:			

3. 2	Plot the values from the volumes of three-dimensional shapes for various values of the edge lengths (e.g., cubes with varying edge lengths or a triangle prism with a fixed height and an equilateral triangle base of varying lengths).	4	ID12

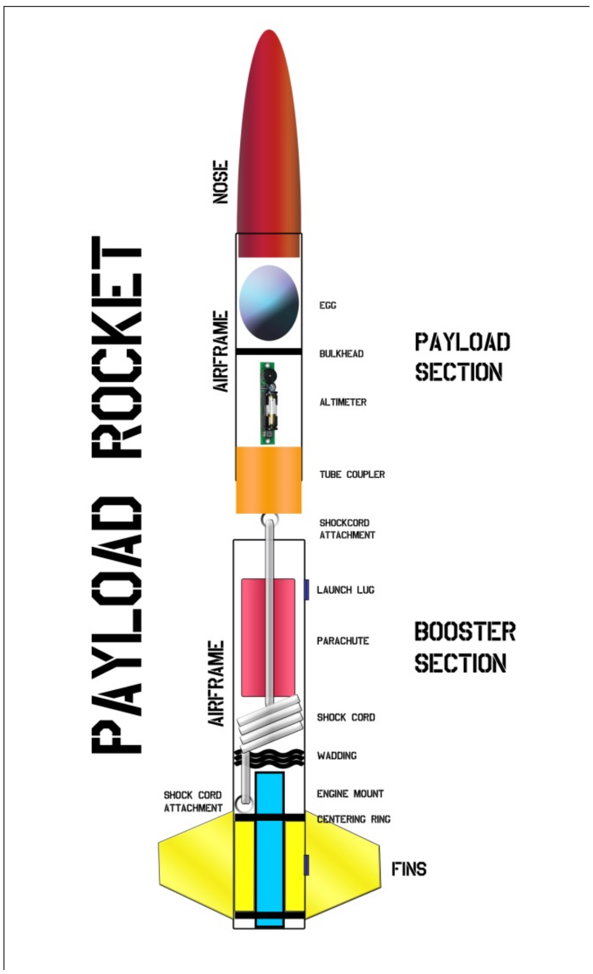
3. 3	Graph linear functions, noting that the vertical change (change in *y*-value) per unit of horizontal change (change in *x*-value) is always the same and know that the ratio (“rise over run”) is called the slope of a graph.	19 20	ID06 ID03
3. 4	Plot the values of quantities whose ratios are always the same (e.g., cost to the number of an item, feet to inches, circumference to diameter of a circle). Fit a line to the plot and understand that the slope of the line equals the quantities.	19 20	ID06 ID03
4.0 Students solve simple linear equations and inequalities over the rational numbers:			
4. 2	Solve multistep problems involving rate, average speed, distance, and time or a direct variation.	19 23 24	ID06 ID03 ID04
Measurement and Geometry			
1.0 Students choose appropriate units of measure and use ratios to convert within and between measurement systems to solve problems:			
1. 1	Compare weights, capacities, geometric measures, times, and temperatures within and between measurement systems (e.g., miles per hour and feet per second, cubic inches to cubic centimeters).	19	ID06
1. 2	Construct and read drawings and models made to scale.	12	DE01
2.0 Students compute the perimeter, area, and volume of common geometric objects and use the results to find measures of less common objects. They know how perimeter, area, and volume are affected by changes of scale:			
2. 1	Use formulas routinely for finding the perimeter and area of basic two-dimensional figures and the surface area and volume of basic three-dimensional figures, including rectangles, parallelograms, trapezoids, squares, triangles, circles, prisms, and cylinders.	2a 4	ID08 ID12
2. 2	Estimate and compute the area of more complex or irregular two- and three-dimensional figures by breaking the figures down into more basic geometric objects.	4	ID12
3.0 Students know the Pythagorean theorem and deepen their understanding of plane and solid geometric shapes by constructing figures that meet given conditions and by identifying attributes of figures:			
3. 1	Identify and construct basic elements of geometric figures (e.g., altitudes, midpoints, diagonals, angle bisectors, and perpendicular bisectors; central angles, radii, diameters, and chords of circles) by using a compass and straightedge.		
3. 2	Understand and use coordinate graphs to plot simple figures, determine lengths and areas related to them, and determine their image under translations and reflections.	2a 15	DE01 LD02 C03
3. 3	Know and understand the Pythagorean theorem and its converse and use it to find the length of the missing side of a right triangle and the lengths of other line segments and, in some situations, empirically verify the Pythagorean theorem by direct measurement.	20	ID03
3. 5	Construct two-dimensional patterns for three-dimensional models, such as cylinders, prisms, and cones.	12	DE01

Statistics, Data Analysis, and Probability			
1.0 Students collect, organize, and represent data sets that have one or more variables and identify relationships among variables within a data set by hand and through the use of an electronic spreadsheet software program:			
1.1	Know various forms of display for data sets, including a stem-and-leaf plot or box-and-whisker plot; use the forms to display a single set of data or to compare two sets of data.	22	ID04 ID05
1.2	Represent two numerical variables on a scatter plot and informally describe how the data points are distributed and any apparent relationship that exists between the two variables (e.g., between time spent on homework and grade level).	20	ID03
1.3	Understand the meaning of, and be able to compute, the minimum, the lower quartile, the median, the upper quartile, and the maximum of a data set.	19 20	ID06 ID03

CHAPTER 3LESSONS

Lecture and Demonstration

The lecture and demonstration series of lessons are designed to give the students a basic understanding of the model rocket, Newton's Laws of Motion, aeronautics, rocket stability, the rules of the Team America Rocketry Challenge, and model rocketry safety rules. The lectures are given with a PowerPoint Presentation with the students taking notes. The lectures should occur early in the class as knowledge gained by the students will be used throughout the curriculum.



LECTURE & DEMONSTRATION

Topic:	*LD01: Introduction to Rocketry*
Content:	Overview of class, Introduction to the Team America Rocketry Challenge
Materials	Student: Student Handbook Teacher: PowerPoint presentation: LL01; Introduction to Rocketry, TARC DVD, equipment to show presentation
Procedures:	1. Welcome, Introduction of instructors & students. 2. Hand out student handbook . 3. Lecture on the class outline, the Team America Rocketry Challenge 4. View a portion of the 2007 TARC finals DVD
Practice:	None
Activities:	**Group Activities:** **Individual Activities:**
Assessment:	Teacher will ask questions and engage in discussion to check for understanding.
Modification:	As needed for individual students
References:	Class Outline (Aerospace Industries Association, 2009) (National Association of Rocketry, 2008)

Lecture & Demonstration

Topic: *LD02: The Model Rocket*

Content: The parts of a model rocket and their function.
Materials LL02 PowerPoint Presentation, Equipment to show presentation, a model rocket with a payload section, rocket engine, parachute.
Procedures: 1. The teacher will give the PowerPoint presentation of the model rocket using a built model rocket as an example.
Practice: The students will handle various model rockets and identify the parts.
Activities: **Group Activities:** none
Individual Activities: Students will enter notes in their student handbook for use during design and construction lessons.
Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be given a written test on the information.
Modification: As needed for individual students
References: (Van Milligan, 2008) (Canepa, 2005) (Stine & Stine, 2004)

Lecture & Demonstration

Topic: *LD03: Newton's Laws of Motion*

Content: An explanation of Newton's three laws of motion.
Materials (Aids/AV/Software/Student Supplies): PowerPoint presentation on Newton's Laws of Motion, NASA video clip on Newton's Laws of Motion, computer, projector, sound system, Student Handbook
Procedures:
1. The teacher will give a lecture using the following PowerPoint presentation while students take notes in their handbook:
2. If needed, the students will view a short video on the Wright brothers and the laws of motion.

Practice: Students will engage in hands-on activities that demonstrate the laws of motion.
Activities: **Group Activities:** Balloon Thrust Experiment
Individual Activities: Students will study their notes for homework in preparation of taking the written test.
Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.
Modification: As needed for individual students
References: (National Aeronautics and Space Administration, 2005) (Robertson, 2002) (Cannon, 1998) (Nolte, 1994) (Cannon, 1970) (Shearer et al., 2007)

Lecture & Demonstration

Topic: *LD04: Aerodynamics*

Content: four forces of flight: lift, drag, weight (gravity), thrust

Materials (Aids/AV/Software/Student Supplies): PowerPoint presentation on Newton's Laws of Motion, NASA video clip on four forces of flight, computer, projector, sound system, Student Handbook

Procedures:
1. The teacher will give a lecture LD04, Aerodynamics.
2. If needed, the students will view a short video on the Wright brothers and the four forces of flight.

Practice: The students will use knowledge gained from this lesson to successfully fly their model rocket.

Activities: **Group Activities:** Students will fly their model rockets as a group.
Individual Activities: Toy Balloon Experiment; adding fins.

Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students

References: (National Aeronautics and Space Administration, 2005) (Stine & Stine, 2004) (Nolte, 1992) (Mandell, Caporaso & Bengan, 1973) (Cannon, 1970)

Lecture & Demonstration

Topic: *LD05: Rocket Stability*

Content: Center of gravity, rocket rotations, center of pressure, rocket stability, weathercocking

Materials (Aids/AV/Software/Student Supplies): PowerPoint presentation on Rocket Stability, computer, projector, model rocket for demonstrative purposes, Student Handbook

Procedures:
1. The teacher will give a lecture LD05, Rocket Stability

Practice: The students will use knowledge gained from this lesson to successfully fly their model rocket.

Activities: **Group Activities:** Toy Balloon Experiment – adding fins
Individual Activities:

Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students

References: (National Aeronautics and Space Administration, 2005) (Stine & Stine, 2004) (Estes, 1999) (Mandell, Caporaso & Bengan, 1973) (Nolte, 1994)

Lecture & Demonstration

Topic: *LD06: Launch Procedures*

Content: Students learn and practice the launch procedures for the class.

Materials Launch Equipment, Data Collection Instruments, Launch procedures script, flight log, meteorology log, tracking station log, two way radios.

Procedures:

1. Assign students to positions.
2. In Class Walkthrough – (Day 1)
    1. Hand out Appendix C, Countdown procedures.
    2. The class will read the procedures out loud while the teacher pauses the reading to elaborate what is occurring at that point of the countdown.
    3. Repeat as necessary.
3. Dry Run with Equipment – (Day 2)
    1. Issue the equipment to the students.
    2. Set up the equipment in a small area so that all students may hear the teacher without the two-way radios.
    3. Walk through the countdown with the students, explaining each step.
    4. Repeat the launch procedures in real time while simulating a launch.
4. First Launch – (Day 3)
    1. Conduct a launch using one rocket. Ensure that all students are familiar with their assignments.
    2. Conduct a post launch discussion about the launch, answer questions, and clarify procedures.

Practice: The students will set up the launch equipment and data collection instruments and conduct a dry run.

Activities: **Group Activities:** The students will conduct a dry run of the launch procedures.
Individual Activities: Each student will have a specific assignment and must learn to operate any instruments or equipment pertaining to the assignment.

Assessment: Teacher will ask questions and engage in discussion to check for understanding.

Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students

References: Model Rocketry Safety Rules

Lecture & Demonstration

Topic:	*LD07: TARC Rules*
Content:	A review of the Team America Rocketry Challenge Rules
Materials	Current TARC rules
Procedures:	1. The teacher will discuss the TARC rules for the current competition. 2. The teacher will lead a discussion of the rules and assist the students in interpreting them.
Practice:	1. The students will design, build, and fly their rocket based on the TARC rules.
Activities:	**Group Activities:** The students will brainstorm ideas about rocket designs that would be successful under the TARC rules. **Individual Activities:**
Assessment:	Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.
Modification:	As needed for individual students
References:	(Aerospace Industries Association, 2009)

Lecture & Demonstration

Topic:	*LD08: Model Rocketry Rules*
Content:	Safety rules from the National Association of Rocketry
Materials	Rocketry rules in Student Handout
Procedures:	1. The class will review the Model Rocketry Safety Rules.
Practice:	The students will adhere to the model rocketry safety code during all class activities.
Activities:	**Group Activities:** **Individual Activities:**
Assessment:	Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.
Modification:	As needed for individual students
References:	(National Association of Rocketry, 2009)

Notes to Lecture & Demonstration Lessons

LD01: Introduction to Model Rocketry

The Team America Rocketry Challenge

The Team America Rocketry Challenge (TARC) was conceived originally as a way to promote interest in science and aerospace careers among high school students, and to celebrate the 100th anniversary of the Wright brothers' 1903 flight. The response was so great that it became an annual event. Approximately 7,000 students from across the nation compete in TARC each year.

The Team America Rocketry Challenge is an aerospace design and engineering event for teams of US secondary school students (7th through 12th grades) run by the NAR and the Aerospace Industries Association (AIA). Teams can be sponsored by schools or by non-profit youth organizations such as Scouts, 4-H, or Civil Air Patrol (but not the NAR or other rocketry organizations). The goal of TARC is to motivate students to pursue aerospace as an exciting career field, and it is co-sponsored by the American Association of Physics Teachers, 4-H, the Department of Defense, and NASA. The event involves designing and building a model rocket (2.2 pounds or less, using NAR-certified model rocket motors totaling no more than 80.0 Newton-seconds of total impulse) that carries a payload of 1 Grade A Large egg for a flight duration of 40 - 45 seconds, and to an altitude of exactly 825 feet (measured by an onboard altimeter), and that then returns the egg to earth undamaged using only a streamer as a recovery device. Onboard timers are allowed; radio-control and pyrotechnic charges are not.

The first seven Team America Rocketry Challenges, held in 2003 through 2009, were the largest model rocket contests ever held. Co-sponsored by the NAR and the Aerospace Industries Association (AIA), the five events together attracted about 5,100 high-school teams made up of a total of over 50,000 students from all 50 states. These students had a serious interest in learning about aerospace design and engineering through model rocketry. The top 100 teams each year came to a final fly-off competition in late May near Washington, DC, to compete for $60,000 in prizes. These teams were selected based on the scores reported from qualification flights that they conducted locally throughout the US.

Team America Rocketry Challenge 2010's target flight duration of 40-45 seconds is measured from the moment of rocket liftoff until the egg payload lands. The target flight altitude of 825 feet is measured by an onboard altimeter. The top 100 teams from among all those who have entered will meet in a final fly-off competition on May 15, 2010 at Great Meadow, The Plains, VA. These top 100 teams will be selected based on the duration and altitude scores reported from local qualification flights that they conduct in front of an NAR Senior (adult) member observer at their choice of time, up until the flight deadline of April 5, 2010.

NAR

The National Association of Rocketry (NAR) is the organized body of rocket hobbyists. Chartered NAR sections conduct launches, connect modelers and support all forms of sport rocketry. NAR was founded in 1957 to help young people learn about science and math through building and safely launching their own models.

4H

4-H has grown into a community of 6 million young people across America learning leadership, citizenship and life skills. 4-H can be found in every county in every state, as well as the District of Columbia, Puerto Rico and over 80 countries around the world. The 4-H community also includes 3,500 staff, 518,000 volunteers and 60 million alumni. 4-H'ers participate in fun, hands-on learning activities, supported by the latest research of land-grant universities, that are focused on three areas called Mission Mandates: Science, Engineering and Technology, Healthy Living and Citizenship.

The NAR 4H partnership

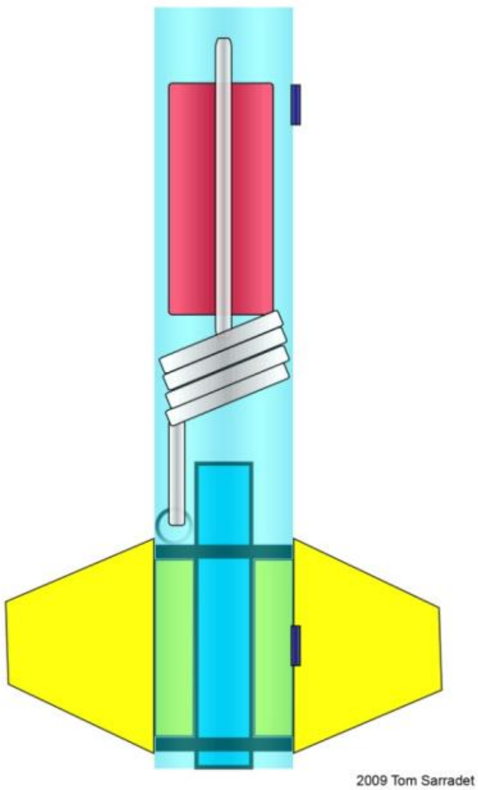
In May 2007 the NAR and 4-H initiated a national partnership. The purpose of this alignment is to get more kids to fly rockets and form rocket clubs which will lead to more TARC teams, more people joining NAR and more kids becoming scientists and engineers

Together 4H clubs and NAR sections can hold sport, contest or TARC launches. They can have training and building sessions, or work on science fair and engineering challenges using rocketry. 4H has many 'state fair' events that need innovative ideas for student projects. In serving young people 4H and NAR can both elevate the visibility of one another in their mutual community.

The NAR has a wide range of online resources that are immediately useful to 4-H youth group leaders in organizing and running rocketry programs.

NAR board members have had several planning meetings with the 4H National Council and Headquarters Directors. The first steps to implementing these plans are to establish connections between the organizations, such as this web link. Members from both groups need to get familiar with each other. As a few joint rocketry activities get started and promoted in some regions, other areas will get the idea and follow. 4H teams will eventually become big players in TARC. The goal is that in five years the partnership will have engaged over 100,000 students in a rocketry event.

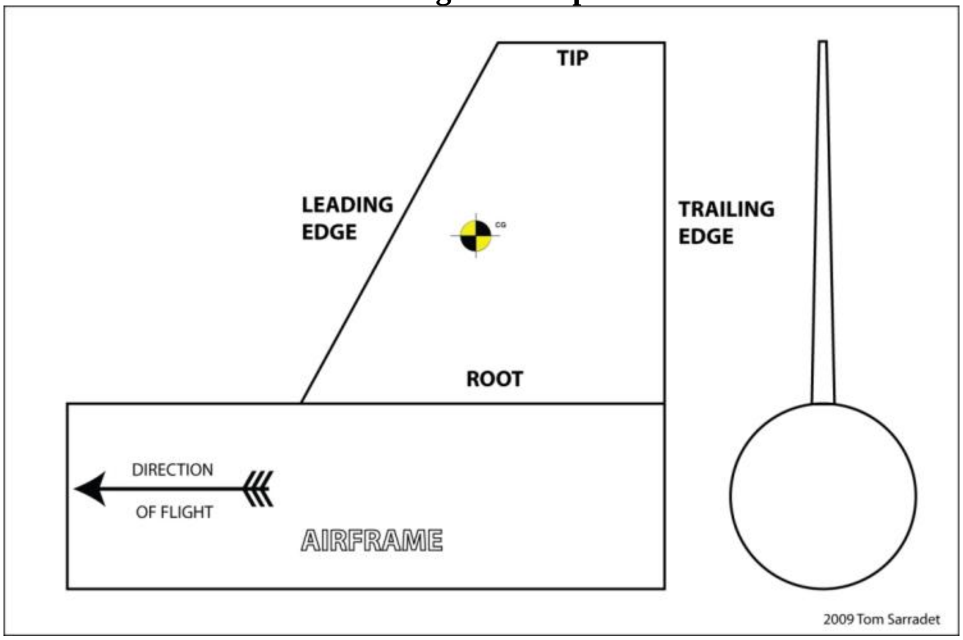
LD02: The Model Rocket

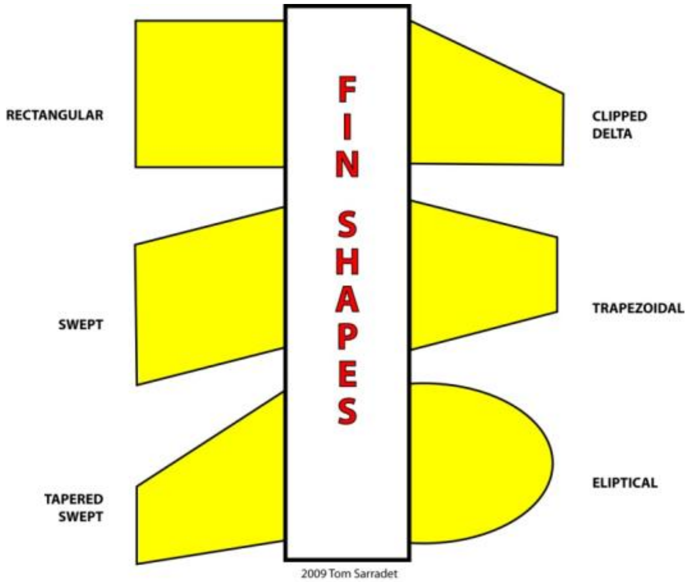


THE BOOSTER SECTION

- **Launch Lug –** helps to guide the rocket upward until it reaches enough velocity for the fins to engage.
- **Parachute –** assists in the safe recovery of the rocket.
- **Shock Cord –** connects the parachute and nosecone to the booster. It absorbs the shock of ejection charge.
- **Shock Cord Attachment –** attaches the shock cord to the booster section.
- **Centering Rings –** attach the engine mount (and sometimes the fins) to the airframe.
- **Engine Mount –** holds the rocket engine inside the rocket.
- **Engine Retainer –** prevents the engine from being ejected by the ejection charge.
- **Fins –** guides the rocket in a straight path.

Fin Edges & Shapes





Rectangular: Simple to make, least aerodynamic

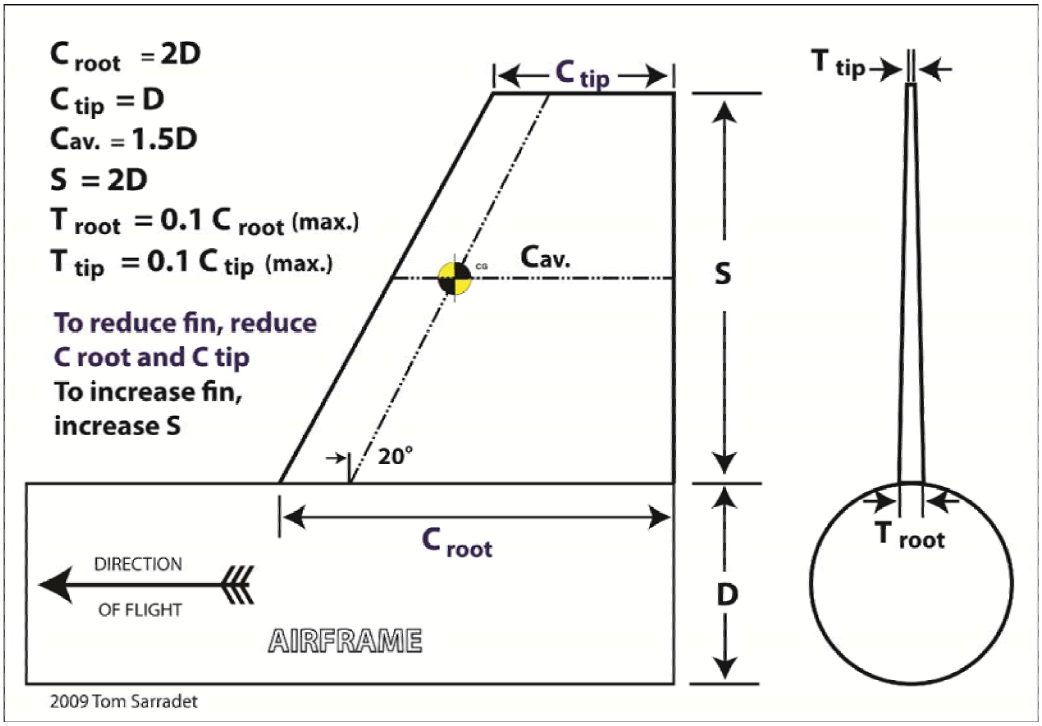
Swept: Simple to make, slightly better aerodynamics

TaperedSwept: Moves Center of Pressure back, good design for fast moving rockets.

ClippedDelta: Good aerodynamic fin, used on low-drag, high-performance rockets

Trapezoidal: Good aerodynamic fin for payload rockets, moves the Center of Pressure forward.

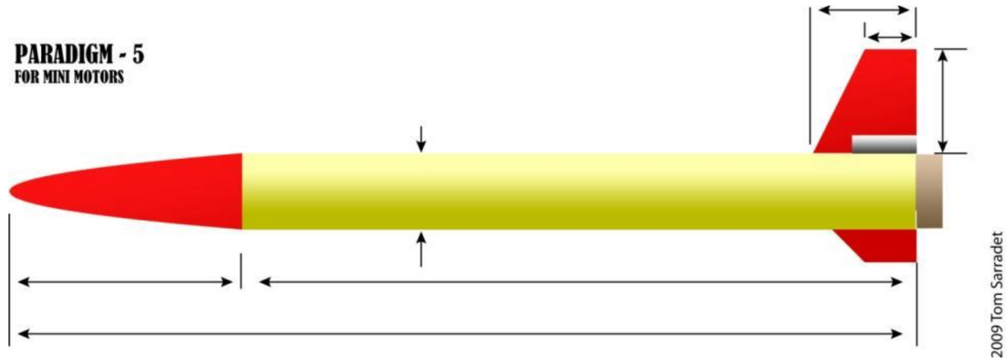
Elliptical: Best aerodynamic fin, difficult to construct.



Low Drag Clipped Delta Fin

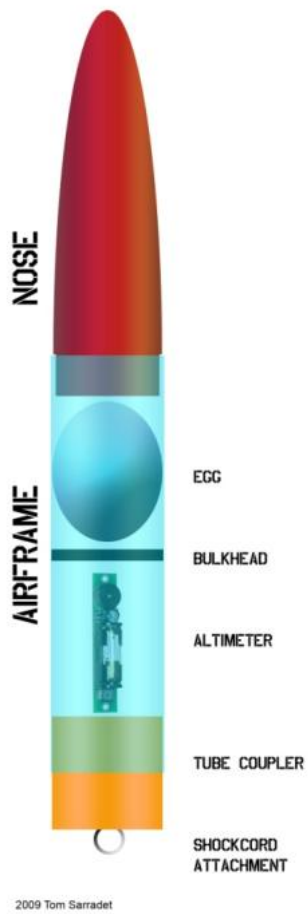
To determine the dimensions of a low drag fin:

1. Determine the diameter of the airframe.
2. Multiply it by 2 to determine the root length and the span (C_{root} and S)
3. The length of the tip (C_{tip}) is equal to the airframe diameter.
4. The thickness of the fin at the root (T_{root}) = 0.1 of the root length (C_{root}).
5. The thickness of the fin at the tip (C_{tip}) = 0.1 of the tip length (C_{tip})
6. To reduce the fin, reduce the C root and C tip only.
7. To increase the fin, increase the span (S) only.



Low Drag, High Performance Rocket

The Paradigm–5 is an example of a **low-drag, high performance** model rocket design that uses a low-drag clipped delta fin.

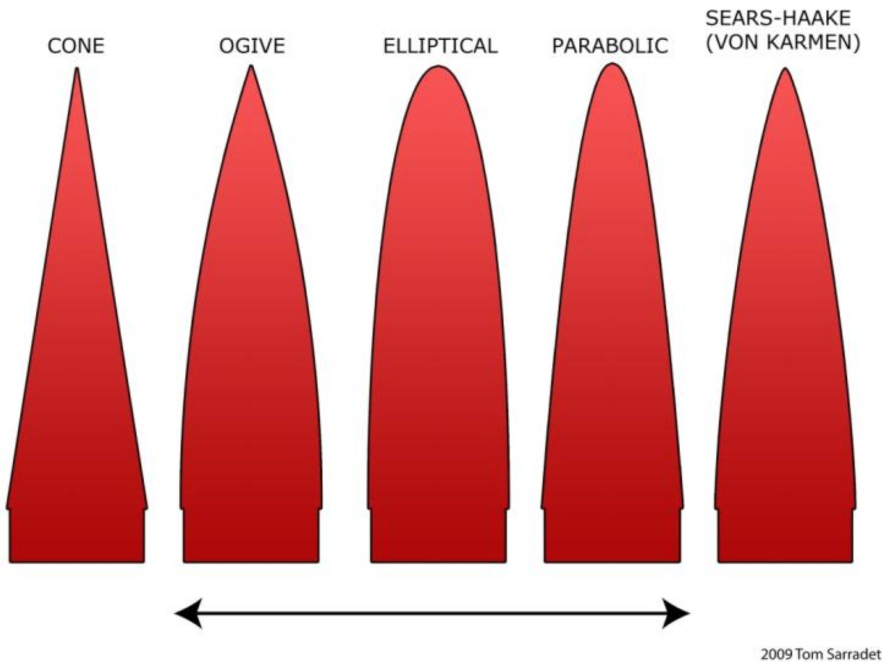


Payload Section

- **Nose –** creates an aerodynamic shape. May also hold a payload.
- **Airframe –** holds the payloads in place.
- **Bulkhead –** separates the egg section from the electronics section, preventing vortex effect and causing a false altimeter reading.
- **Altimeter –** measures the changing air pressure to calculate apogee. Must have vent holes in airframe in order to operate properly.
- **Tube Coupler –** connects the payload section to the booster section by means of the shock cord. Also protects the payload from the ejection gases.
- **Shock Cord Attachment –** a metal eye for the secure attachment of the shock cord.

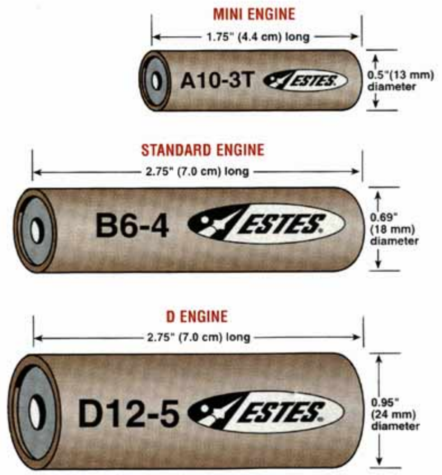
The Egg

- Eggs have an '**arch structure**' at each end that transfers pressure to the sides.
- About **35 Newtons** of force is required to break an egg on its end and about **25N** to break it on its side.



Nose Shape

Rocket noses are made of balsa, plastic, or fiberglass.For aircraft and rockets, below Mach .8, the nose pressure drag is essentially zero for all shapes and the major significant factor is friction drag. Having a smooth finish on the nose is more important than nose shape for rockets flying under the speed of sound.

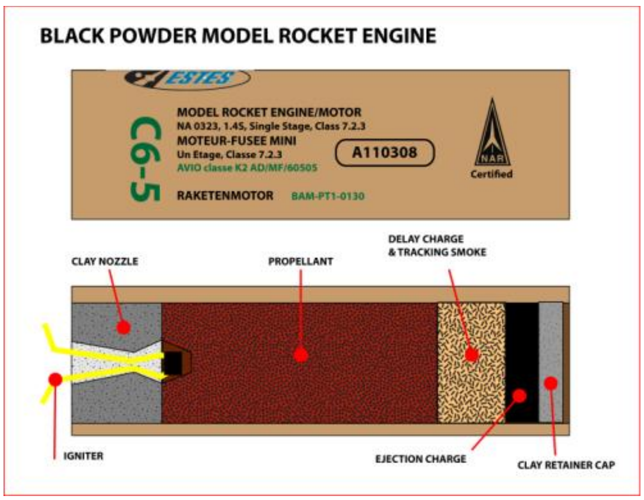


Rocket Motor Sizes

- **Motor diameter is measured in millimeters.**
- **Sizes for low to mid-power rockets are 13mm, 18mm, 24mm, and 29mm.**

Engine or Motor?

- Something that **imparts** motion is called a **motor**.
- An **engine** is a machine that **convertsenergy** into mechanical motion.
- While referring to the propulsion system of a model rocket as a **motor is more accurate**, the use of the term engine is common.

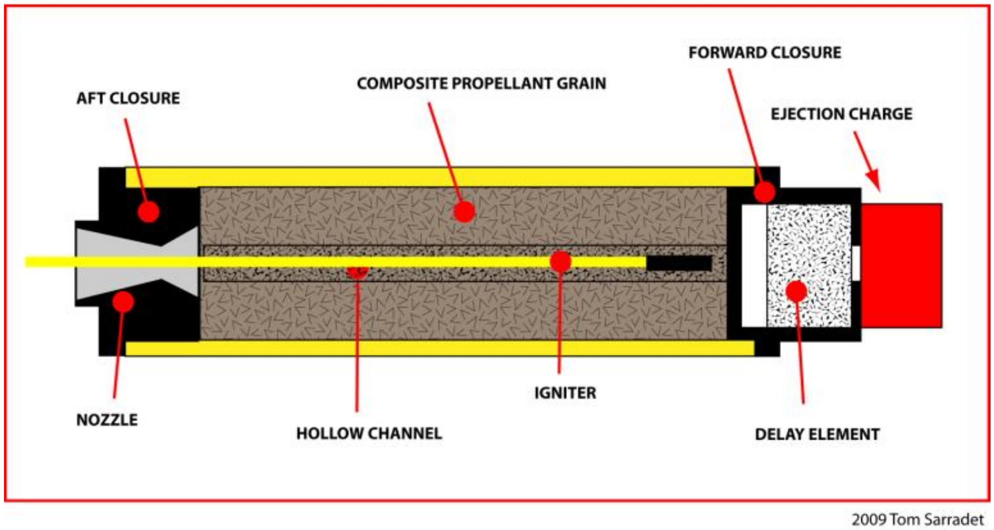


Black Powder Motor

- **B**– The letter indicates the total impulse power produced by the motor. Each letter doubles the power.
- **6** – The first number gives the average thrust of the motor in Newtons.
- **4** – The last number indicates the delay seconds between the end of thrust and the ejection charge.

Black Powder Motor Burn

- Black powder motors burn from the **rear forward**.
- When the propellant is spent, it ignites the **delay charge**.
- The delay charge burns forward and ignites the **ejection charge**.
- The clay nozzle forces the pressure **forward**, expelling the nose cone and recovery system.

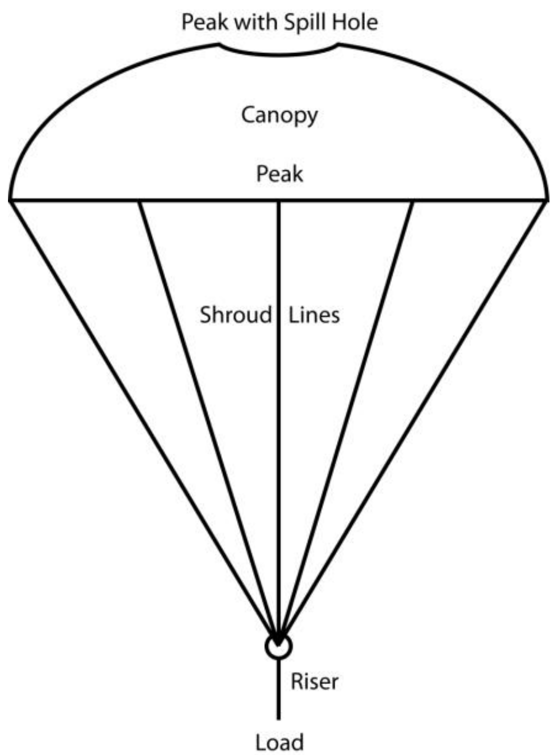


The parts of a Composite Reloadable Engine:

- The case is a reusable part that holds the propellant. Also reusable are the forward and aft closure.
- The nozzle is only used once and directs the thrust rearward.
- The composite propellant grain is a spongy material that does not break if dropped. It is the same type of propellant used in the NASA Space Shuttle boosters.
- The igniter is pushed all the way forward into the propellant grain.
- The delay element is installed inside the forward closure.
- The black powder ejection charge is held in place by a plastic cap.

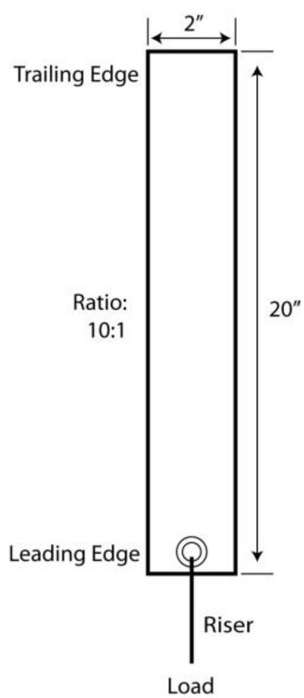
Composite Motor Burn

- Composite motors burn from the inner core out.
- The delay element is ignited with the propellant and burns forward. Because of this, tracking smoke is produced immediately.
- The delay element ignites the ejection charge.



Parachute

- Parachutes are made out of plastic, Mylar, or rip-stop nylon.
- Shroud lines can be carpet thread or Kevlar chord.
- The spill hole reduces oscillation and increased descent rate.
- Oscillation is a swaying motion as the parachute spills air from its sides.
- Adding a riser lifts the parachute out of the turbulence of the rocket, but increases the risk of parachute failure.



Streamers

- Streamers are made out of crepe paper, Mylar, Dura-Lar, or rip-stop nylon.
- The best length to width radio is 10:1 to create the most drag as the streamer flaps in the wind.
- Streamer recovery is faster than parachute recovery and reduces the recovery area.

LD03: Newton’s Laws of Motion

Sir Isaac Newton was an English physicist, mathematician, astronomer, natural philosopher, and alchemist.
In 1666, he witnessed an apple fall from its tree and he began to ponder why it fell down. This led to his Three Laws of Motion.

First Law of Motion: The Law of Inertia

Every body perseveres in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by force impressed.

Objects at rest will stay at rest (inertia) and objects in motion will stay in motion in a straight line unless acted upon be an unbalanced force.
There is a natural tendency of objects to keep on doing what they're doing. All objects resist changes in their state of motion. In the absence of an unbalanced force, an object in motion will maintain this state of motion.

Second Law of Motion: The Law of Force

The change of momentum of a body is proportional to the impulse impressed on the body, and happens along the straight line on which that impulse is impressed.

Acceleration is produced when a force acts on a mass. The greater the mass (of the object being accelerated) the greater the amount of force needed (to accelerate the object).
F = MA
Force = Mass times Acceleration

A car that weighs 1,000 kg runs out of gas. The driver pushes the car to a gas station at a speed of 0.05 meters per second. How much force is the driver applying to the car to go that speed?
F = 1,000 kg x 0.05 m/s/s
F = 50 Newtons of force

What the heck is a Newton?
The Newton is a unit of force.
It is equal to the amount of force required to accelerate a mass of one kilogram at a rate of one meter per second per second.
What the heck is a kilogram?

1 Kilo = 2.2 pounds

You Know The 2nd Law Already!

Everyone knows the Second Law: heavier objects require more force to move the same distance as lighter objects.

We know that we don’t need the same amount of force to lift a feather that is needed to lift a bowling ball.

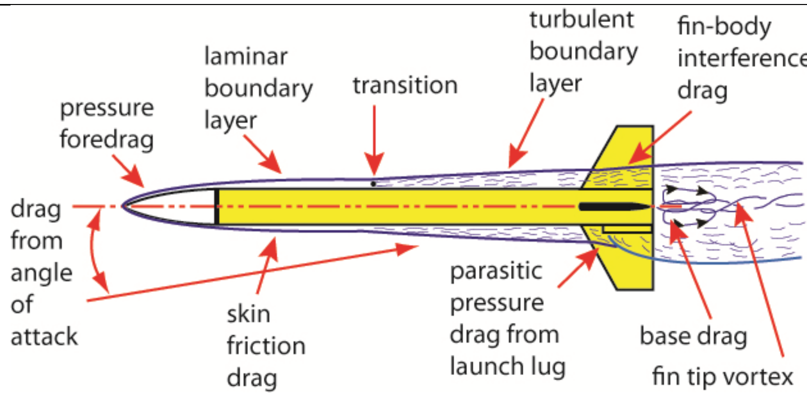
Third Law of Motion: The Law of Reciprocal Actions

For a force there is always an equal and opposite reaction: or the forces of two bodies on each other are always equal and are directed in opposite directions.

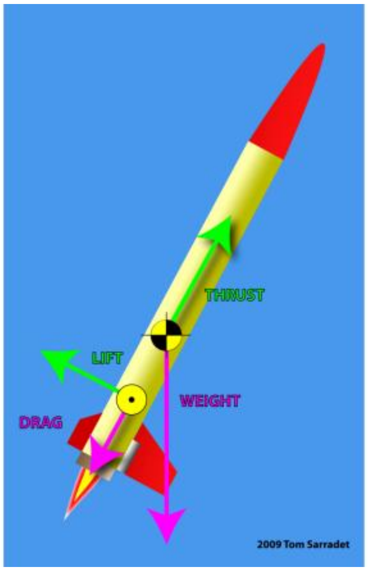
For every action, there is an equal and opposite reaction.

This means that for every force there is a reaction force that is equal in size, but opposite in direction. Whenever an object pushes another object it gets pushed back in the opposite direction with equal force.

LD04: Aerodynamics



Aerodynamics is the study of the motion of air, particularly when it interacts with a moving object. In physics the term dynamics customarily refers to the time evolution of physical processes.



Factors that Affect Aerodynamics
The Object: shape and size
The Motion: velocity and the inclination to flow
The Air: mass, viscosity, compressibility

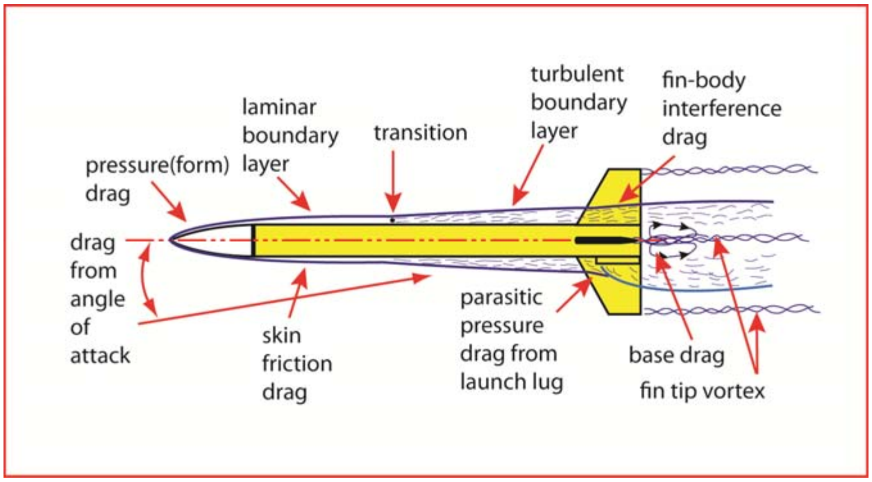
Four Forces of Flight
Liftis a force used to stabilize and control the direction of flight.
Drag is the aerodynamic force parallel to the relative wind.
Weightis the force generated by gravity on the rocket.
Thrust is the force which moves the rocket forward.

Aerodynamic Forces
Aerodynamic forces are generated and act on a rocket as it **flies through** the air.
The lift and drag act through the **center of pressure** which is the average location of the aerodynamic forces on an object.
Aerodynamic forces are **mechanicalforces**. They are generated by the interaction and contact of the rocket with the air.
For **lift** and **drag** to be generated, the rocket must be moving through the air.

- **Lift** occurs when a flow of **gas** (the air) is turned by a **solid object**(the rocket).
- The flow is turned in one direction, and the lift is generated in the opposite direction.

For a model rocket, the **nose**, **airframe**, and **fins** can become a source of **lift** if the rocket's flight path is at an **angle**
When a solid body (**the rocket**) moves through a fluid (**gas or liquid**), the fluid **resists**

the motion. The rocket is subjected to an **aerodynamicforce**in a direction opposed to the motion which we call **drag**.



drag is **aerodynamic friction**, and one of the sources of drag is the **skin friction** between the molecules of the air and the solid surface of the moving rocket.

A **boundary layer** is the layer of air in the immediate vicinity of the rocket's surface. Boundary layers can be **laminar** (smooth flow) or **turbulent** (swirling).

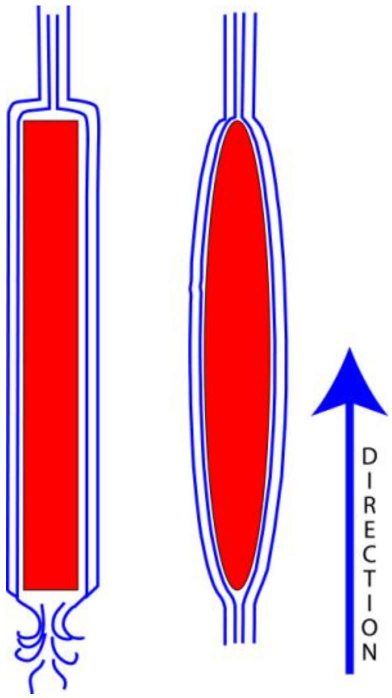
The **point** in which a laminar boundary layer becomes turbulent is called the **transition**.

drag is also **aerodynamic resistance** to the motion of the object through the fluid. This source of drag depends on the **shape** of the rocket and is called **pressure or form drag**.

Interference drag occurs whenever two surfaces meet at sharp angles, such as at the fin roots. Interference drag creates a **vortex** which creates drag. Fin fillets reduce the effects of this drag.

Air passing by the tips of the fins form a **fin tip vortex**. Accelerating the air into this vortex causes **drag** on the fins, and a **low** pressure area behind them. Tapered fin tips reduce this drag.

Parasitic Drag is produced by objects like the launch lug. The launch lug can account for **30%** of all drag. Cutting the lug's leading edge to 45 degrees reduces drag.



A model rocket's fin that is **square** on the edges creates a lot of **drag** and **turbulence**. If the fin's leading and trailing edges are sanded in a **roundshape**, called an **airfoil**, it reduces the drag.

airfoil shape fins creates high pressure behind the fin and **pushes it forward**, cancelling out most of the pressure drag caused by the fins. This is called **pressure recovery**.

Weight is the force generated by the **gravitational** attraction on the rocket.
The gravitational force is a **field force**; the source of the force does **not** have to be in physical contact with the object.
Gravity affects the rocket whether it is **stationary** or **moving** (up or down).

Thrust is the force applied to the rocket to **move it** through the air, and through space.
Thrust is generated by the **propulsion system** of the rocket through the application of Newton's Third Law of Motion.
The direction of the thrust is normally along the **longitudinal axis** of the rocket through the rocket's **center of gravity**.

LD05: Rocket Stability

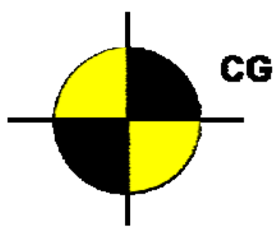
During the flight of a model rocket, gusts of **wind** or thrust instabilities, can cause the rocket to "**wobble**", or change its attitude in flight.

Poorly built or designed rockets can also become **unstable** in flight.
This lesson is about what makes a rocket unstable in flight and what can be done to improve its stability.

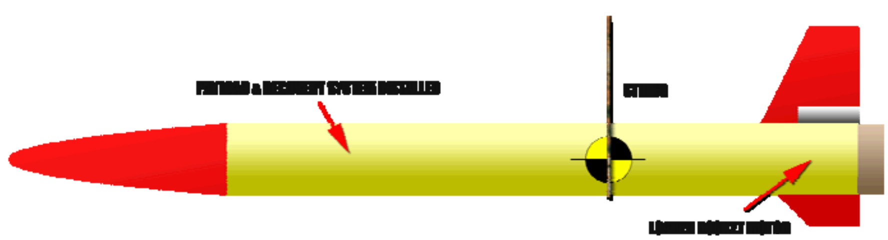
Translation and Rotation
A rocket in flight can move two ways; it can **translate**, or change its location from one point to another, and it can **rotate**, meaning that it can roll around on its axis.

Roll
Most rockets are symmetric about a line from the tip of the nose to the center of the nozzle exit. We will call this line the **roll axis** and motion about this axis is called a **rolling motion**.
The **center of gravity** lies along the roll axis.

Yaw and Pitch
When a rocket wobbles from **side to side**, this movement is called a **yaw motion.**
A **pitch motion** is an **up or down** movement of the nose of the rocket.

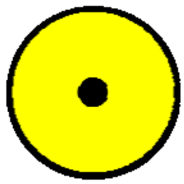


Center of Gravity – CG
As a rocket flies through the air, it both **translates** and **rotates**. The rotation occurs about a point called the **center of gravity**, which is the average location of the weight of the rocket.



How to Determine the Center of Gravity

1. Load the motor, recovery system, and payload.
2. Tie a string around the airframe and adjust it until the rocket is horizontally balanced.
3. The location of the string is the center of gravity.

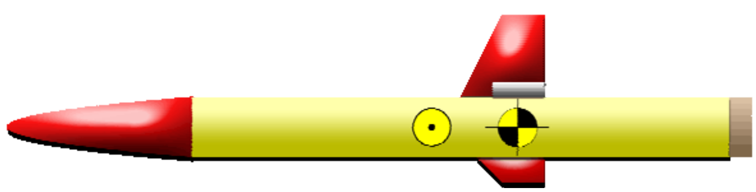


Center of Pressure – CP
The average location of the pressure on the rocket is called the center of pressure.
The parts of the rocket that influences the location of the center of pressure the most are the fins.

Building a Stable Rocket

If the center of gravity is in front of the center of pressure, the rocket will return to its initial flight conditions if it is disturbed. This is called a **restoring force** because the forces "restore" the rocket to its initial condition and the rocket is said to be **stable**.

If the center of gravity and the center of pressure are in the same location, it is called **neutral stability**.
A rocket with neutral stability may make a **stable** or **unstable** flight depending on the forces acting on it.



If the **center of pressure is behind the center of gravity**, the lift and drag forces maintain their directions but the direction of the torque generated by the forces is reversed. This is called a **de-stabilizing force**. Any small displacement of the nose generates forces that cause the displacement to increase. Such a flight condition is **unstable** .

Correcting Unstable Flight
To move the Center of Gravity:

- Add or remove weight in the nose cone.
- Redistribute the Payload
- Increase or decrease airframe length.

To move the Center of Pressure:

- Increase or reduce the fin size.
- Change the shape of the fins.
- Change the location of the fins.
- Increase or decrease airframe length/diameter

One Caliber Stability
The best separation between the center of gravity is for the CP to be at least one body tube diameter in front of the CG. This is called **one caliber stability**.

Weather Cocking

- Following the liftoff of a model rocket, it often **turns into the wind**. This maneuver is called **weather cocking** and it is caused by forces, such as a strong wind, pushing on the side of the rocket's fins.

Causes of Weather Cocking

- Rockets with long airframes experience weather cocking, especially during the coast phase.
- Large fins present a larger surface area for the wind.
- Rockets with a center of gravity that is far in front of the center of pressure.

Tube Fins

- Using tube fins reduce weather cocking because of the aerodynamic side profile.
- Tube fins should be used carefully because these types of rockets tend to be unstable.

Design and Engineering

During the design and engineering phase, the students will learn how to design and run flight simulations on Rocksim, a model rocket computer program available from Apogee Components. The student will also receive a detailed hands-on presentation of the booster and payload section of the model rocket to include information on materials and construction, how to paint a rocket, rocket engines, the types of recovery systems used on model rockets, and how to safely launch rockets.

Figure E1 Student designing a rocket on Rocksim

Design & Engineering

Topic:

DE01: Introduction to Rocksim

Content: Designing a model rocket on the computer

Materials Computer and a copy of Rocksim for each student, Student Handbook

Procedures:

1. The teacher will demonstrate in a step by step process how to design a model rocket, load and engine, and run flight simulations.
2.

Practice: Students will run simulations and make changes to their rocket design to improve performance.

Activities: **Group Activities:** The students can have a virtual model rocketry contest with their Rocksim designs.

Individual Activities: Students will design their own rocket and test the design in flight simulations.

Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: Rocksim Help Manual

Design & Engineering

Topic: *DE02: The Booster Section*

Content: Fin design and construction, through the tube fins, fin fillets, body tubes, engine mounts, shock code attachment, launch lugs and rails

Materials Examples of fins and fin material, craft, HD, and phenolic tubes, engine mount parts; engine mounts, centering rings, engine blocks, engine hooks and retention systems, launch lugs and rails, epoxy, glue, ca glue, card stock, wood filler

Procedures:

1. The teacher will present each part of the booster section and demonstrate construction techniques. To include:
   - Fin design and construction
   - Fin reinforcement methods
   - Engine mount design and construction
   - How to select and use epoxy and other adhesives
   - Through the Tube Fins (TTF)
   - Shock cords and their attachment

2. Demonstration of cutting body tubes for “through the body” fins

Practice: Students will use skills to built the own rocket.

Activities: **Group Activities:** TARC team members will work as a group in the design and construction of their TARC rocket.
Individual Activities: Students will use knowledge gained from lesson in the construction of their own rockets.

Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Van Milligan, 2008) (Canepa, 2005) (Stine & Stine, 2004)

Design & Engineering

Topic:

DE03: The Payload Section

Content: Construction of a payload section on a model rocket.

Materials Examples of nose cones, body tubes of various sizes and materials, bulkheads, altimeter, egg, cushion materiel, hardware.

Procedures:

1. The teacher will present each part of the payload section and demonstrate construction techniques.
    - Nose cone shapes, materials, and selection
    - Body tube sizes and selection. Cutting body tubes.
    - Bulkhead selection and installation.
    - Vent hole placement and drilling.
2. Altimeter installation and operation.
3. A review of the chicken egg.

Practice: Students will use skills to built the own rocket.

Activities: **Group Activities:** TARC team members will work as a group in the design and construction of their TARC rocket.
Individual Activities: Students will use knowledge gained from lesson in the construction of their own rockets.

Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Van Milligan, 2008) (Canepa, 2005) (Stine & Stine, 2004)

Design & Engineering

Topic: *DE04: Painting and Finishing*

Content: The best methods for creating aerodynamic surfaces.

Materials: Unfinished model, wood filler, wood sealer, spray cans of primer and enamel paint, clear coat, model rockets in various stages of finish.

Procedures:
1. The teacher will demonstrate the process of applying a finish to a model rocket. For the sake of time, discuss the technique and show examples.
2. Supervise the students throughout the finishing process.

Practice: Students will apply a finish to their own rockets during construction.

Activities: **Group Activities:** TARC team members will work as a group in the design and construction of their TARC rocket.
Individual Activities: Students will use knowledge gained from lesson in the construction of their own rockets.

Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Van Milligan, 2008) (Canepa, 2005) (Stine & Stine, 2004)

Design & Engineering

Topic: *DE05: Rocket Engines*

Content: A detailed look at model rocket engines

Materials: Examples of rocket engine, model rocket engine static display.

Procedures: 1. Give lessons and demonstrations that include:

- the types of available rocket engines
- motor nomenclature
- single use and reloadable engines
- how to read a thrust curve
- how to build a reloadable engine, engine retainer systems
- clustering
- staged rockets

Practice: The students will choose and load rocket motors into their own rockets.

Activities: **Group Activities:** TARC teams will use this information to design and build their competition rocket.
Individual Activities: Students will use knowledge gained from lesson in the construction of their own rockets.

Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Van Milligan, 2008) (Stine & Stine, 2004) (Estes, 1999)

Design & Engineering

Topic:	*DE06: Recovery Systems*
Content:	Types of recovery, parachutes and streamers
Materials:	Examples of recovery systems including, parachutes with and without spill holes and of different material, examples of streamers.
Procedures:	1. The teacher will describe and discuss each type of recovery system. 2. The teacher will demonstrate the various types of parachutes and streamers.
Practice:	The students will practice the use of recovery systems during lesson ID02, Investigating Parachutes, ID09, Investigating Streamers, and ID05, Adjusting Descent Rate Using Parachutes & Streamers
Activities:	**Group Activities:** TARC teams will use this information to design and build their competition rocket. **Individual Activities:**
Assessment:	Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.
Modification:	As needed for individual students.
References:	(Van Milligan, 2008) (Stine & Stine, 2004)

Design & Engineering

Topic:	*DE07: Model Rocket Launch Equipment*
Content:	A review of available launch equipment.
Materials:	Example of launch pads using rods and rails, 6v and 12v ignition systems
Procedures:	1. The teacher will describe and discuss various types of launch equipment to include launch 1/8”, 3/8”, and ¼” launch rods, launch pads, launch rail, 6 volt and 12 volt ignition systems.
Practice:	The students will gain experience with the launch equipment during launches.
Activities:	**Group Activities:** TARC teams will use this information to select a launch system for their competition rocket. **Individual Activities:** none
Assessment:	Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.
Modification:	As needed for individual students.
References:	(Van Milligan, 2008) (Stine & Stine, 2004) (Estes, 1999) (Wayne, 1996)

Construction

The construction of the students' model rockets may occur simultaneously with the design and engineering lessons. A good sequence is to give the design and engineering lesson specific to the part of construction that the students are about to begin.
Because of the volume of rockets that the students will create, it is recommended that the educator devise some form of identification nomenclature for each rocket. The system that the researcher uses has worked well. The first digit is an S, for student or a T, for teacher. The next two digits are the last two numbers of the year. The last two to three digits represent the rocket number for the year. So the 51^{st} rocket build by a student in 2009 would be S0951. The teacher's rocket may omit the year and start from the first rocket the teacher built and is written as T055 for the 55^{st} rocket. The numbers are types on small adhesive mailing labels and affixed on the airframe. This is the number that the Chief Engineer will verify with Flight Control prior to launch.

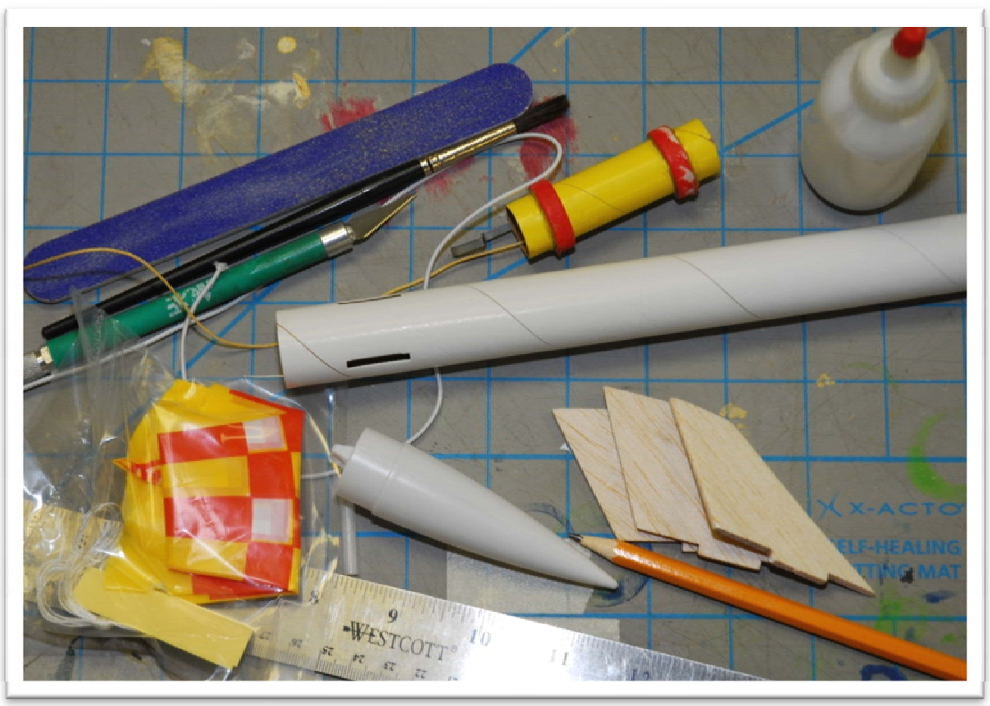


Figure E2 The Model Rocket Workstation

CONSTRUCTION

Topic:

C01: Model Rocket Parts Inventory

Content: Opening and inspecting a model rocket kit prior to assembly.
Demo Models: none
Perishable Materials: Model rocket kits
Durable Materials: Scissors to cut packaging.
Teacher Instruction/ Guided Construction:

1. Carefully open kit package and lay out model rocket parts.
2. Use the instruction sheet to inspect and inventory all parts.
3. Mark each package with student's name.
4. Repackage items or continue on to Lesson C02.

Independent Construction:

1. The students will follow the teacher's lead in inspecting the parts.

Clean Up : Kits will be collected and stored if not continuing with Lesson C02
Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.
Modification: As needed for individual students.
References: Model rocket kit instructions.

Construction

Topic:

C02: Model Rocket Construction: The Motor Mount

Content: Building the motor mount
Demo Models: Example of completed motor mount.
Perishable Materials: Model rocket kits, glue, tape
Durable Materials: Hobby knife, scissors, ruler, pencil
Teacher Instruction/ Guided Construction:

1. The teacher will demonstrate the construction of the rocket's motor mount in accordance with the kit instructions.

Independent Construction:

1. The students will construct their motor mounts in accordance with the lecture and kit instructions.
2. Return completed motor mount to the package once dry or continue to Lesson C03

Clean Up: Kits will be collected and stored if not continuing with Lesson C03, tools cleaned and stored.
Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.
Modification: As needed for individual students.
References: Kit instructions, (Van Milligan, 2008) (Stine & Stine, 2004)

Construction

Topic:

C03: Model Rocket Construction: Fins, Airframe, Nose

Content: Construction techniques for the fins, airframe, and nose cone.
Demo Models: Examples of fins to include balsa, plywood, laminate, and fiberglass. Examples of rocket noses are various shapes and materials.
Perishable Materials: Wood glue, wood filler, sandpaper, disposable cups, popsicle sticks
Durable Materials: Hobby knife, scissors, ruler, pencil
Teacher Instruction/ Guided Construction:
1.
- Applying wood filler on balsa fins and nose cones.
- Laminating paper on fins for strength.
- Filling airframe seams with filler.
- Airframe construction (fins, motor mount, shock cord, nose)
- Wet and dry sanding techniques.

Independent Construction:
1. The students will replicate the demonstrated techniques on their own model rockets.
2. Complete the construction of the airframe according to the kit directions.
3. Return parts to the package or continue to Lesson C04

Clean Up: Kits will be collected and stored if not continuing with Lesson C03, tools cleaned and stored.
Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.
Modification: As needed for individual students.
References: Kit instructions, (Van Milligan, 2008) (Stine & Stine, 2004)

Construction

Topic:

C04: Model Rocket Construction: Payload Bays

Content: Adding a payload bay to a model rocket.
Demo Models: Examples of completed payload bays
Perishable Materials: Model rocket kits, glue, tape, airframe tubes similar to kit.
Durable Materials: Hobby knife, scissors, ruler, pencil, airframe cutting jig
Teacher Instruction/ Guided Construction:

1. The teacher will demonstrate how to scratch build a payload bay. Instruction includes:
    - Designing a payload bay
    - Cutting airframes
    - Bulkheads
    - Vent holes for altimeter

Independent Construction:

1. to build their own bays.
2. Return parts to the package or store on model rocket stand.

Clean Up: Clean and store materials, pick up trash.
Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.
Modification: As needed for individual students.
References: (Van Milligan, 2008) (Canepa, 2005) (Stine & Stine, 2004)

Construction

Topic:

C05: Model Rocket Construction: Finishing

Content: Finishing a model rocket for improved drag coefficient.
Demo Models: Examples of properly and poorly finished model rockets.
Perishable Materials: Spray cans of sandable primer, flat white enamel paint, gloss white, red, and yellow enamel paint,
Durable Materials: Filter mask rated for paint, model rocket drying stand.
Teacher Instruction/ Guided Construction:

1. The teacher will demonstrate each step of finishing a model rocket:
   - Apply and sand 2-3 coats of primer, ending with a wet sand.
   - Apply flat white enamel spray paint, wet sand
   - Apply gloss white enamel spray paint
   - Apply red or yellow to fins and nose.

Independent Construction:

1. The students will replicate the demonstrated techniques
2. Set rockets on stand to dry.

Clean Up: Store unused paint, rockets
Assessment: Student competence is demonstrated by successful completion of the task.
Modification: As needed for individual students.
References: (Van Milligan, 2008) (Stine & Stine, 2004)

Construction

Topic:

C06: Recovery Systems

Content: The students will construct parachutes and streamers for their model rocket.
Demo Models: A variety of completed streamers and parachutes.
Perishable Materials: Plastic, Mylar, carpet thread, page hole reinforcing rings, launch lugs
Durable Materials: Hobby knife, scissors, ruler, pencil
Teacher Instruction/ Guided Construction:

1. Give a hands –on demonstration of various forms of parachutes and streamers.
    - Examples should include parachutes made of plastic, Mylar, and rip-stop nylon, parachutes with and without spill holes, and streamers made out of crepe paper, Dura Lar, and Mylar.
    - Discuss the pros and cons of each design.
    - Demonstrate how to construct a parachute and a streamer.
    - If time is available, conduct a launch that demonstrates each recovery system.

Independent Construction:

1. Students will each construct a parachute and a streamer for their model rocket.

Clean Up: Tools and materials will be stored away be the students.
Assessment Student competence is demonstrated by successful completion of the task.
Modification: As needed for individual students.
References: (Van Milligan, 2008) (Stine & Stine, 2004)

Investigation and Discovery

The most exciting time for the students is when they get to fly their model rockets. It is during these launches that the previous lessons will be reinforced by the investigation and discovery lessons. It is an exciting time for the teacher as well. Students will work independently as they prepare the rockets for launch and to collect valuable flight data. The knowledge gained on the field during launch day will enrich the post-flight activities as the students analyze and decipher the collected data in the classroom.
There are three distinct phases of each investigation and discovery lesson:

- <u>Preflight Activities</u> - occur the day before launch day.
  - teacher briefing on lesson goals.
  - selection and preparation of rockets,
  - inspection of all equipment
  - equipment training
  - launch day weather report from the meteorologists.
- <u>Launch Day</u> -
  - transport equipment and rockets to launch site
  - set up equipment and conduct launches
  - record data
  - recover equipment and rockets to class room
  - conduct quick post-flight debriefing if possible
- <u>Post-Flight Activities</u> -
  - analyze and discuss collected data
  - assessment of student understanding

Investigation & Discovery

Topic:

ID01: Data Collecting Instruments

Content: A introduction to instruments used to collect data on wind, humidity, temperature, air pressure, flight times, distances and altitude.

Statement of Investigation: Data on the weather conditions and of the rocket's flight can be collected with the proper instruments.

Equipment: Sling psychrometer (humidity), anemometer (wind speed), barometer (air pressure), thermometer (air temperature), stopwatch (time), and Estes Altitrak or similar device (altitude), Flight Data Logs

Teacher Instruction/ Guided Construction:

1. Demonstrate the operation of each instrument.
2. Demonstrate how to record data on the Flight Log.

Guided Practice:

1. Divide the students into enough group to rotate through each instrument as they gain hands-on experience.

Discovery:

1. Collect and record data and analyze results.

Independent Practice: Students will collect data as assigned during rocket launches.

Assessment: Student competence is demonstrated by successful completion of the task.

Modification: As needed for individual students.

References: Instrument manuals (Exline, Arlene & Levine, 2008)

Investigation & Discovery

Topic:

ID02: Investigating Parachutes

Content: Parachute design

Statement of Investigation: Students launch rockets with parachutes of different sizes, shapes, and spill holes and collect data for analysis..

Equipment: A single rocket or rockets of equal design, engine and weight, a variety of parachutes of different diameters and spill holes.

Preflight Procedures:

1. Lesson LD02, The Model Rocket
2. Preparation of Equipment
3. Safety Briefing

Guided Practice:

1. Set up Equipment
2. Conduct activity and collect data
3. Recover equipment

Discovery:

1. Collect and record data:
    - Descent times from apogee for each parachute.
    - Observe for oscillation, spinning, and deployment.
    - Record times and observation on the Flight Log.

2. Group analysis of results:
    - Class will discuss and compare data and determine the best parachute design among those that were deployed.

Independent Practice: Students will collect data as assigned during rocket launches.

Assessment: Student competence is demonstrated by successful completion of the task. Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Van Milligan, 2008) (Stine & Stine, 2004)

Investigation & Discovery

Topic:

ID03: Calculating Apogee

Content: Students learn how to use the Pythagorean Theorem, marker streamers, and electronic altimeters to determine the rocket's altitude at apogee.

Statement of Investigation: Rocket altitude can be determined by various methods.

Equipment: Rocket with payload section, launch equipment, two Estes Altitraks, measuring wheel, stopwatches, marker streamers, and electronic altimeter.

Preflight Procedures:

1. Assignment of duties
2. Preparation of Equipment:
    1. Prepare rocket with motor and recovery system.
    2. Make marker streamers as instructed in Appendix I, Marker Streamers.
    3. Install marker streamer over the recovery system and the electronic altimeter in the payload bay.

3. Safety Briefing

Guided Practice:

1. Set up Equipment
    - Two students are placed with the Altitraks with one student placed halfway between the other tracker and the launch pad.
    - Timers are assigned to time the drop of the marker streamers.
    - The electronic altimeter is activated by the pad crew.

2. Launch rocket with all 3 apogee calculation methods deployed.
3. Recover equipment

Discovery:

1. Collect and record data: All data is recorded on the Flight Log
2. Group analysis of results
    1. Students compare the results of the different methods.
    2. How close are the 3 methods in apogee calculation?

Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Nolte, 1994) (Cannon, 1970) Appendix I, Marker Streamers

ID03: Marker Streamer Construction and Use

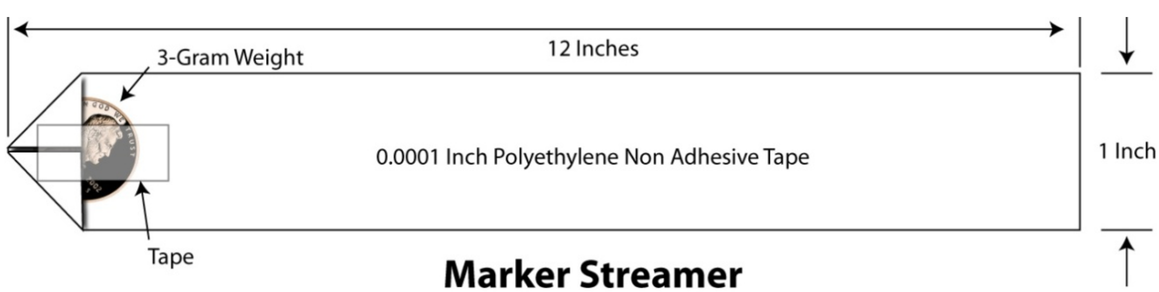
Marker streamers are used as an inexpensive method of determining how high a model rocket flew by timing the streamer's return to Earth. These measuring devices are constructed by taping a 3 gram weight, such as a penny, on the end of a 1 inch wide by 12 inches long polyethylene tape that is .0001" of an inch thick. The purpose of the tape is not to produce drag, but to aid visibility of the streamer. High visibility colors such as florescent orange are a good choice. The streamer will fall at a constant rate of 18 feet per second. By timing the streamer's drop from apogee to the ground, the rocket's altitude can be determined by multiplying that number by 18.

Construction

1. Cut a 1 inch polyethylene tape to 12 inches
2. Place a penny (or other 3 gram flat object) on one end and fold the side of the tape around it to from a "V."
3. Tape the penny in place.
4. Fold the marker streamer.

Use

1. Place the marker streamer into the body tube after the recovery system and shock cord has been packed.
2. Instruct the timer to begin timing when the streamer is ejects out of the body tube and to stop timing when the streamer lands.
3. To determine altitude, multiply the number of seconds from apogee to landing by 18. The result is the altitude in feet.



Marker Streamer

Investigation & Discovery

Topic:

ID04: Adjusting Apogee

Content: Adjusting the mass of the rocket to change the apogee.
Statement of Investigation: The students will reduce the altitude of a model rocket by 25% using Newton's Second Law of Motion as a guide: $F = MA$.
Equipment: Rocket with payload section, launch equipment, two Estes Altitraks, measuring wheel, stopwatches, marker streamers, electronic altimeter, clay or lead weights.
Preflight Procedures:

1. Assignment of duties
2. Preparation of Equipment
3. Safety Briefing

Guided Practice:

1. Set up Equipment
2. Launch rocket and determine its apogee.
3. By using F = MA, calculate the additional mass needed to reduce the apogee to 25% lower.
4. Prepare rocket with adjusted mass and launch again.
5. Repeat process until apogee has been reduced by 25% from the first flight.

Discovery:

1. Collect and record data: All data is recorded on the Flight Log
2. Students determine mass adjustment.

Independent Practice: TARC teams will adjust apogees in their own rockets.
Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.
Modification: As needed for individual students.
References: (Stine & Stine, 2004) (Nolte, 1994) (Cannon, 1970)

Investigation & Discovery

Topic:

ID05: Adjusting Descent Rate Using Parachutes & Streamers

Content: Adjusting descent rate of model rocket by changing drag coefficient.

Statement of Investigation: Students will use different types of streamers to alter the payload section's time of descent.

Equipment: Rocket used in Lesson ID04 including added mass, two parachutes two sizes larger that original parachute without spill holes and two of the largest size with two different sized spillholes.

Preflight Procedures:

1. Assignment of duties
2. Preparation of Equipment: Prepare rocket with recommended parachute.
3. Safety Briefing

Guided Practice:

1. Set up Equipment
2. Launch rocket and determine its apogee.
3. By using knowledge gained by Lessons ID02 and ID09, increase the time of flight by 25% of first flight. NOTE: If adding 25% more time to time of flight may cause the rocket to leave the recovery area, target a lower percentage.
4. Repeat the process using streamers of different sizes and materials.

Discovery:

1. Collect and record data
2. Students determine adjustment.

Independent Practice: TARC teams will adjust apogees in their own rockets.

Assessment: Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Van Milligan, 2008) (Stine & Stine, 2004)

Investigation & Discovery

Topic:

ID06: Investigating Average Velocity

Content: Measuring Velocity of model rockets after determining altitude.
Statement of Investigation: Students will determine the average velocity of a model rocket in flight by using the equation $v = d/t$.
Equipment: Rockets with similar mass and motors, launch equipment, two Estes Altitraks, measuring wheel, stopwatches, marker streamers, electronic altimeter
Preflight Procedures:

1. Assignment of duties
2. Preparation of Equipment
3. Safety Briefing

Guided Practice:

1. Set up Equipment
2. Launch several rockets. Time flights from launch to apogee and calculate altitude.
3. Recover equipment

Discovery:

1. Collect and record data: record times and determine altitude.
2. Group analysis of results: Using the formula $v=d/t$, determine the average velocity of each rocket.
3. Determine the combined average velocity of all launched rockets.

Independent Practice: TARC students are able to determine the average velocity of their own rockets.
Assessment: Student competence is demonstrated by successful completion of the task.
Teacher will ask questions and engage in discussion to check for understanding.
Students will be assessed using appropriate STEM content standards.
Modification: As needed for individual students.
References: (Stine & Stine, 2004)

Investigation & Discovery

Topic:

ID07: Investigating Energy

Content: Predicting the apogee of a model rocket based on the rocket motor.

Statement of Investigation: The altitude of a model rocket can be predicted based on the mass of the rocket and the energy of the motor.

Equipment: Rockets with similar mass and motors, launch equipment, two Estes Altitraks, measuring wheel, stopwatches, marker streamers, electronic altimeter

Preflight Procedures:

1. Assignment of duties
2. Preparation of Equipment
3. Safety Briefing

Guided Practice:

1. Set up Equipment
2. Launch rocket with an A motor and determine its altitude.
3. Lead class in a discussion about the predicted altitude of the rocket with a B motor. Record predictions.
4. Launch rocket with a B motor and determine its altitude.
3. Recover equipment

Discovery:

1. Collect and record data
2. Group analysis of results: How accurate was the prediction verses the actual altitude? Where there any unbalanced forces that could have effected the results?

Independent Practice:

Assessment: Student competence is demonstrated by successful completion of the task. Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Stine & Stine, 2004)

Investigation & Discovery

Topic:

ID08: Investigating Nose Drag Co efficiency

Content: The investigation and discovery of model rocket noses.

Statement of Investigation: Students will determine drag co efficiency of various nose shapes.

Equipment: Model rocket, noses that fit the rocket of the following shapes: Elliptical, parabolic, conical, ogive. Hemisphere, launch and data equipment.

Preflight Procedures:
1. Assignment of duties
2. Preparation of Equipment
3. Safety Briefing

Guided Practice:
1. Set up Equipment
2. Students will fly the model rocket under the following conditions:
   - Each flight uses the same motor
   - Each flight uses a different nose
3. Recover equipment

Discovery:
1. Collect and record data:
   The altitude of each flight is recorded either from an electronic altimeter or an Estes Altitrak. The results are entered on the Flight Log.
2. Group analysis of results:
   Students will determine which cones flew the highest with minimum pitch and yaw.

Independent Practice: TARC students will determine the best nose shape for their rocket.

Assessment: Student competence is demonstrated by successful completion of the task. Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Van Milligan, 2008) (Stine & Stine, 2004)

Investigation & Discovery

Topic:

ID09: Investigating Streamers

Content: The investigation and discovery of streamer recovery for model rockets.
Statement of Investigation: Students will discover the drag coefficients of streamers constructed of different material and of different lengths.
Equipment:

1. A low power model rocket with ample space for streamers.
2. The following streamers::one each 1”, 2”, and 4” x 10” made of Mylar or polyethylene and one each A 1”, 2”, and 4” x 10” made of crepe paper

Preflight Procedures:

1. Assignment of duties
2. Preparation of Equipment
3. Safety Briefing

Guided Practice:

1. Set up equipment
2. Conduct activity and collect data as described below.
3. Break down equipment

Discovery:

1. Collect and record data:
   - Students will collect and record the times from apogee to landing (to measure descent rate) and the distance from the launch pad (to measure drift)
   - Information will be recorded on a graph showing descent rate and drift.

2. Group analysis of results
   - The class will determine the best streamer for the test rocket; that being the streamer with the highest drag yet still durable enough to give consistent results.

Independent Practice: TARC student will adjust the recovery of their rocket.
Assessment: Student competence is demonstrated by successful completion of the task.
Teacher will ask questions and engage in discussion to check for understanding.
Students will be assessed using appropriate STEM content standards.
Modification: As needed for individual students.
References: (Van Milligan, 2008) (Stine & Stine, 2004)

Investigation & Discovery

Topic:

ID10: Investigating Weathercocking

Content: Students study the effects of wind on rocket flight.

Statement of Investigation: The wind is an unbalanced force that affects a rockets trajectory and altitude.

Equipment: For classroom demonstration: model rocket with large fins suspended by the nose with string, fan with strong and focused current.
For field demonstration: model rockets with different types of fins, launch equipment, windy day.

Preflight Procedures:

1. Give a demonstration of weathercocking by placing the model rocket in the fan's current.
2. Assignment of duties
3. Preparation of Equipment
4. Safety Briefing

Guided Practice:

1. Set up Equipment
2. Students observe and record effects of weathercocking during rocket flight.
3. Recover equipment

Discovery:

1. Collect and record data
2. Group analysis of results: Classroom discussion of observations. Which fin performed the best?

Independent Practice: TARC students will select the best fin design for their rocket.

Assessment: Student competence is demonstrated by successful completion of the task.
Teacher will ask questions and engage in discussion to check for understanding.
Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Van Milligan, 2008) (Stine & Stine, 2004)

Investigation & Discovery

Topic:
ID11: Entering and Analyzing Flight Data in Rocksim

Content: Students will begin designing their TARC rocket
Statement of Investigation: Rocksim flight simulations are more accurate with proper data.
Equipment: Copy of Rocksim, computer, model rocket with Rocksim file, launch equipment.
Preflight Procedures:

1. Assignment of duties
2. Preparation of Equipment
3. Safety Briefing

Guided Practice:

1. Set up Equipment
2. Launch rockets and collect data on flight and weather.
3. Recover equipment

Discovery:

1. Collect and record data
2. Group analysis of results: Enter data into Rocksim and run simulations.
3. Compare the results of the simulation with the actual flight.

Independent Practice: TARC students will be able to enter data into Rocksim and analyze the results.
Assessment: Student competence is demonstrated by successful completion of the task.
Teacher will ask questions and engage in discussion to check for understanding.
Students will be assessed using appropriate STEM content standards.
Modification: As needed for individual students.
References: Rocksim Manual, (Van Milligan, 2008)

Investigation & Discovery

Topic:

ID12: Determining the Center of Pressure

Content: Calculating CP using Rocksim, the cardboard cutout method, and the Barrowman method.

Statement of Investigation: The center of pressure can be determined with several methods.

Equipment: Model rocket as an example, caliper and ruler for measurements, cardboard, copy of Rocksim on a computer Barrowman equation found in the appendix of the *Handbook of Model Rocketry*.

Procedures:

1. Review lesson LD05, Rocket Stability, with the class.
2. Give a demonstration of using the cardboard cutout method:
    1. Draw an outline of the sample rocket on the piece of cardboard using accurate measurements.
    2. Cut out the rocket's outline from the cardboard.
    3. Balance the cutout on the edge of a ruler to determine the center of pressure.
    4. Mark the CP's location on the cutout.

3. Give a demonstration of using the Barrowman equation to determine the CP using the same cardboard cutout.
4. Using the same model rocket as the design, point out the location of the CP as determined by Rocksim. Measure and mark the Rocksim CP on the cardboard cutout.
5. Compare the three CP locations from the 3 different methods and discuss the findings with the class.

Guided Practice:

1. Guide the students as they repeat the processes with their own rocket design.

Discovery:

1. Collect and record center of pressure results.
2. Group analysis of results

Independent Practice: Students will be able to determine the CP of their own rocket.

Assessment: Student competence is demonstrated by successful completion of the task.
Teacher will ask questions and engage in discussion to check for understanding.
Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Stine & Stine, 2004) (Kalk & Wash, 1995)

Investigation & Discovery

Topic:

D13: Determine the Center of Gravity and Stability of a Rocket

Content: Determine the center of gravity using a string and tape.

Statement of Investigation: The center of pressure of a model rocket can be determined by balancing the rocket with a string.

Equipment: Model rocket with engine installed, sturdy nylon string at least 8 feet long, masking tape

Procedures:

1. Review lesson LD05, Rocket Stability, with the class.
2. Taking a model rocket with an installed engine and parachute, tie a string around the airframe and slide the rocket back and forth until it balances on the string.
3. Explain to the class that the rocket balances at the location of the center of gravity.
4. Mark the location of the center of gravity with a pen.
5. Tape string onto airframe at the center of gravity.
6. In a clear area outdoors or in the gym, rotate the rocket in a circle above head. Tell students to look for any pitch, which will indicate an unstable rocket.
7. If an unstable rocket is available, repeat the process so that the students may see the difference.

Guided Practice:

1. Have the students repeat the procedures demonstrated to them during the demonstration.
2. Conduct activity and collect data
3. Recover equipment

Discovery:

1. Collect and record data
2. Group analysis of results

Independent Practice: Students will be able to determine the stability of their own rockets.

Assessment: Student competence is demonstrated by successful completion of the task. Teacher will ask questions and engage in discussion to check for understanding. Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Estes, 1999) (Kalk & Wash, 1995)

Investigation & Discovery

Topic:

ID14: Basic Meteorology

Content: Collecting samples of temperature, humidity, pressure, and wind.

Statement of Investigation: Samples of temperature, humidity, air pressure, and wind can be collected using a variety of instruments.

Equipment: Thermometer, anemometer, sling psychrometer, barometer, compass, stop watch, Meteorologist Log, cloud chart

Procedures:

1. Give a lecture on basic meteorology
2. Demonstrate how to collect and record meteorological data.

Guided Practice:

1. Students practice collecting data with each instrument.
2. Share and discuss collected samples with the class.

Discovery:

1. Collect and record data
2. Group analysis of results

Independent Practice: Students will collect data during rocket launches.

Assessment: Assess the accuracy of the data collection.
Teacher will ask questions and engage in discussion to check for understanding.
Students will be assessed using appropriate STEM content standards.

Modification: As needed for individual students.

References: (Exline, Arlene & Levine, 2008)

CHAPTER 4 TRAINING, ORGANIZATION, AND EQUIPMENT

Launch Procedures

Launching model rockets with a middle or high school class requires procedures that maintain control by keeping all students actively involved in a meaningful activity. It also maintains a high level of safety, which is of paramount importance to the teacher. The following procedures meet those needs and are designed for a class of twenty to thirty students.

These launch procedures are loosely based on the actual count procedures used for the Pershing 1a missile operated by the United States Army in Germany. The MGM-31 Pershing was a solid-fueled two-stage medium-range ballistic nuclear missile designed and built by Martin Marietta. The Pershing systems lasted over 30 years from the first test version in 1960 through final elimination in 1991 (The Cold War Museum, 2008). Theresearcherserved for over three years in a United States Army Pershing firing battery from 1981 to 1984 and was assigned as a flight controller on a Combat Alert Site (CAS) in southern Germany. Over a four-month period, the researcher took part in many simulated launches of the missiles on the remote site. The spirit of speed, efficiency, and safety of the Pershing launch procedures were preserved.

Thecurriculum was developed from two years of experience teaching a 13-week model rocketry elective to middle school students at E.V. Cain Middle School in Auburn, CA. The model rocketry elective is very popular with students and parents. Students take launches very seriously and behavior problems have been rare. This is a very powerful teaching tool.

Figure E3 a Quest Courier

Organization

Upon completion of the model rocket construction phase, the students must be given launch assignments and trained in procedures and equipment before conducting the first launch.

The class organization is set up to accommodate a compliment of 29 students.

Table of Suggested Launch Duty Assignments		
Assignment	*# of Positions*	*Total Positions*
FLIGHT CONTROL SECTION		4
Student Flight Director	1	
Flight controller	1	
Launch control specialist	1	
Communications Officer	1	
ENGINEERING SECTION		5
Chief Engineer	1	
Engineer	4+	
SCIENCE SECTION		14
Chief Scientist	1	
Meteorologist	3+	
Flight Timer	4+	
Tracking Station OIC	1	
Tracker	2+	
Surveyor	2	
Observer	2+	
SECURITY/RECOVERY SECTION		5
Chief Security	1	
Security/Recovery	4+	
	TOTAL:	29
Note: numbers followed by the + sign are positions that additional students may be assigned to.		

The educator may assign positions dependent on the size of the class by combining responsibilities in smaller classes or assigning more than the suggested number of timers or security members. If the class is composed of 10 or less students, it is recommended that the educator use a more informal method of conducting launches that meet the requirements of the Model Rocket Safety Code(National Association of Rocketry, 2009).

The assignments are grouped into four sections; flight control, engineering, science, and security/recovery. Each position and a description of the responsibilities are listed followed by recommendations of how to fill the positions.

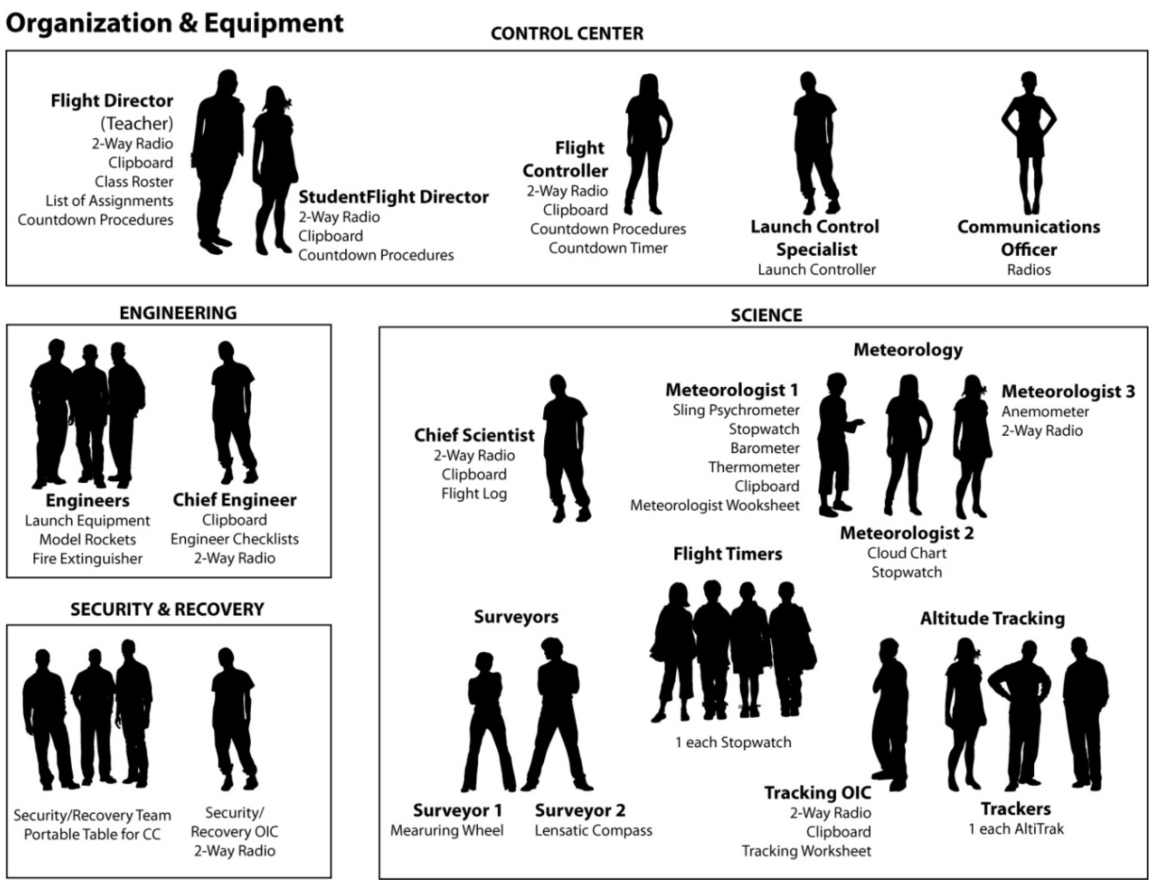


Figure E4 Organization & Equipment

Description of Positions

- Flight Control – The fight control is the command section and has the overall responsibility of conducting productive and safe flights.
  - Flight Director - The Flight Director is the teacher and is responsible for insuring that all students are trained in their positions and that all launches are conducted in a safe manner.
  - Student Flight Director - The Student Flight Director is the highest ranking student during flights. While it may seem obvious that placing the most responsible student in the position is best, the author has had the most success with putting students who need to be challenged and given responsibility.

    Duties include:
    - in charge of the Flight Control area.
    - ensures that all stations are properly set up
    - collects all data and records it on the Flight Data Sheet
    - Equipment: clipboard, Launch Procedures script, Flight Data Sheet, two-way radio
  - Flight Controller - The Flight Controller manages the count procedures and speaks to the teams on behalf of the Flight Director. The student picked for this position must be able to speak clearly over the two way radio. Duties include:
    - leads the launch procedures over the radio
    - operates the countdown timer and announces the countdown
    - monitors and records the total time of flight
    - Equipment: portable table, Launch Procedures script, countdown timer, clipboard, two-way radio

Figure E5 The Flight Controller and Launch Controller

- Launch Controller – The launch controller specialist operates the launch controller, which launches the rockets. A student good at troubleshooting misfires and malfunctioning equipment. Sits next to the flight controller. Duties include:
    - ensures that the launch controller is operational and ready for launches
    - ensures the safety of students by monitoring the location of the launch safety key
    - operates both switches of the launch controller during launches of teacher-built rockets
    - operates the safety switch during launches of student rockets
    - trains students on the launch controller
    - Equipment: launch controller
- Communications Officer – The Communications Officer is responsible for the two way radios. The assignment may be combined with another if the class size is small.
  Duties:
    - conduct maintenance on the radios on pre-flight days
    - assign radios to the proper personnel
    - Ensure that all radios are accounted for after the launch.
    - Equipment: tool box with radios and spare batteries

- Engineering – The engineers prepare rockets for launch using the Pre-Launch Checklist. On launch day, they set up the launch pad and rockets.
    - Chief Engineer – The chief engineer ensures that the engineering section is following proper procedures in a safe manner.
      Duties:
        - Follows Pre-Flight Checklist
        - Oversees the setup of the launch pad
        - Communicates with flight control over the two way radio
        - Controls safety key
        - Equipment: clipboard, Launch Procedures script, pre-launch checklist,two way radio, fire extinguisher

Figure E6 An engineer prepares a rocket

- Rocket Engineer – The rocket engineers are responsible for prepping the rockets for flight. There can be as few as one or as many as four students assigned to this position. Duties:
- inspect and prep rockets for launch
- maintain and clean launch equipment
- set up and break down launch equipment
- maintain control of prepped rockets
- provide safety and security on the launch pad
- ensure that rocket engines are secure
- Equipment: Ready box, tool box with launch pads and launch controller
- Science – The science section is the largest section and has the most important job of collecting the data that will be used in the classroom.
  - Chief Scientist– The chief scientist is responsible for the accurate collection of data during rocket launched. Duties:
    - collect data on weather conditions from the meteorologists, times from the timers, the degrees reported by the tracking station(s), measurements and compass readings from the surveyors, and flight characteristics from the observers.
    - record data on the Science Data Sheet.
    - Equipment: clipboard, launch procedures script, science data sheet, two way radio
  - Meteorologist– The meteorologists obtain weather reports for launch day and collect real-time data of conditions during launch. At least two students share these duties.
    - Check online weather sources and brief the class on weather predictions for launch activities
    - Determine humidity, barometric pressure, temperature, wind speed and direction, cloud conditions, dew point
    - Equipment: sling psychrometer, barometer, wind speed gauge or anemometer, cloud chart, toolbox for equipment, clipboard

Figure E7 A meteorologist operates the sling psychrometer

- Flight Timer – The flight timers time whatever part of the flight that the lesson calls for. There should be at least two timers for each time needed, three is better. More than one timed event, such as launch to apogee and apogee to landing, may be recorded on the same flight.
  - Equipment: one stopwatch for each timer
- Tracking Station OIC – The tracking station officer is responsible for ensuring that trackers are in place for launches and to record and report readings in degrees. This student may also act as an altitude tracker if needed.
  - Equipment: clipboard, Tracking Station Record Log, two way radio

Figure E8 Two students track a model rocket's flight with the Estes Altitrak

- Altitude TrackeTracker – The altitude trackers measure the altitude of the rocket in degrees using an Estes AltiTrak or similar device. The trackers are positioned by the surveyors using the measuring wheel.
  - Equipment – Estes AltiTrak, two way radio if stationed at a distance from the tracking station officer
- Surveyor– The surveyors measure ground distance using a measuring wheel, and determine the direction of rocket landing from launch pad in degrees. They are also responsible for helping the meteorologists determine wind direction.
  - Measure distance for trackers to stand
  - Determine direction of landing in degrees.
  - Determine distance of landing
  - Determine wind direction.
  - Equipment: measuring wheel, lensatic compass

- Observer– The observers watch the rocket's flight and look for roll or pitch. They also assist the recovery team in locating rockets if the team loose site of the returning rocket. This responsibility may be assigned to security/recovery if the class is small.

- Security & Recovery – Safety is the number one priority and students assigned to this section must be mature and dependable. They are very important in the likely event that the launch field is being shared with other types of classes, such as physical education.
    - Chief of Security– The security officer is in charge of the security section and communicates with the control center over the two way radio. Duties:
        - Create a security perimeter around the launch pad of at least 20 feet
        - Position security personnel around the perimeter
        - Take note of wind direction and position personnel for rocket recovery
        - Communicate security status to the control center
        - Ensure that no one enters the perimeter while the pad is hot
        - Secures the rocket at its landing site until the surveyors have determined distance and direction
    - Security/Recovery **-** Members of security/recovery follow the directions of the security officer and maintain security around the launch pad. They are also responsible for the recovery of the rocket.

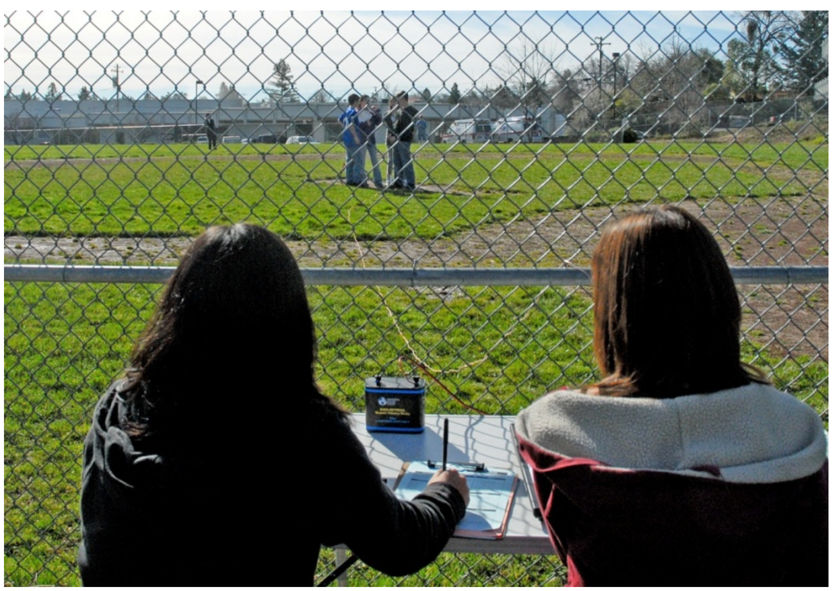


Figure E9 View of the Launch Pad from Control Center

Assignment Recommendations

Care should be taken in assigning students to the duties that they will perform during the launches. The most challenging positions are the ones that require leadership and management skills. Those positions, the student flight director, chief scientist, chief engineer should be filled by students who have demonstrated leadership qualities. Because of their importance to the success of the launches and data collection obtained by them, these positions should be filled first. Consideration for the remaining positions, in the order of importance, is as follows:

- Student Flight Director – This is a position that can really bring out the best in the right student. The best student flight director that the researcher ever has was a student who was disruptive and unmotivated in class until given this assignment. That student not only transformed into a model student, he went on to participate in the Team America Rocketry Challenge and was instrumental in his team’s success. Some students are just waiting for the opportunity to prove themselves.
- Flight Controller - As the student who will be the center of communications during the launch, flight controllers should speak in a loud, clear voice.
- Engineers – engineers will carefully follow procedures in the preparation of the rockets for flight. Students who do best in this role are careful and methodical.
- Meteorologists – These students will be active collecting data and are using equipment that is expensive and fragile. Students selected as meteorologists should be responsible enough to collect weather data accurately with minimum supervision.
- Launch Control Specialist – While this position is not very challenging, it is one of the most rewarding. The launch control specialist gets to press the launch button, making it a much sought after job.
- Tracking OIC/ Trackers – The students tracking the rocket flights will be 75 or more meters away from the teacher. Students selected must be responsible enough to work independently.
- Security/Tracking – The perfect assignment for high energy students who will get plenty of movement as they follow and recover the rockets.
- Flight Timers – These students must be focused in order to gather accurate flight times.
- Surveyors – Students assigned to these positions need to be accurate in their measurements and directions. Surveyors do the most walking among the students during the launches.

- Communications Officer – This position can easily be filled by the flight controller as most of the responsibilities occur during pre-launch procedures. Assign to another student if the class is large and a student is available.

Duty Rotation

Rotation of students is recommended in order to maximize student learning and to maintain interest. The frequency is left to the discretion of the educator. If time permits, the class may be retrained using the procedures outlined in Lesson LD06, Launch Procedures. Another technique is to rotate a portion of the students and have them receive "on the job" training by the students who did not rotate. Much of the learning will occur during the post-flight activities when the collected data is analyzed and discussed.

Training

Taking the time to train the students on the launch procedures and how to properly the equipment before the first rocket launch will ensure an efficient and safe launch. Train the students on launch procedures using lesson LD06, Launch Procedures.

Because of the volume of rockets that the students will create, it is recommended that the educator devise some form of identification nomenclature for each rocket. The system that the researcher uses has worked well. The first digit is an S, for student or a T, for teacher. The next two digits are the last two numbers of the year. The last two to three digits represent the rocket number for the year. So the 51st rocket build by a student in 2009 would be S0951. The teacher's rocket may omit the year and start from the first rocket the teacher built and is written as T055 for the 55st rocket. The numbers are types on small adhesive mailing labels and affixed on the airframe. This is the number that the Chief Engineer will verify with Flight Control prior to launch.

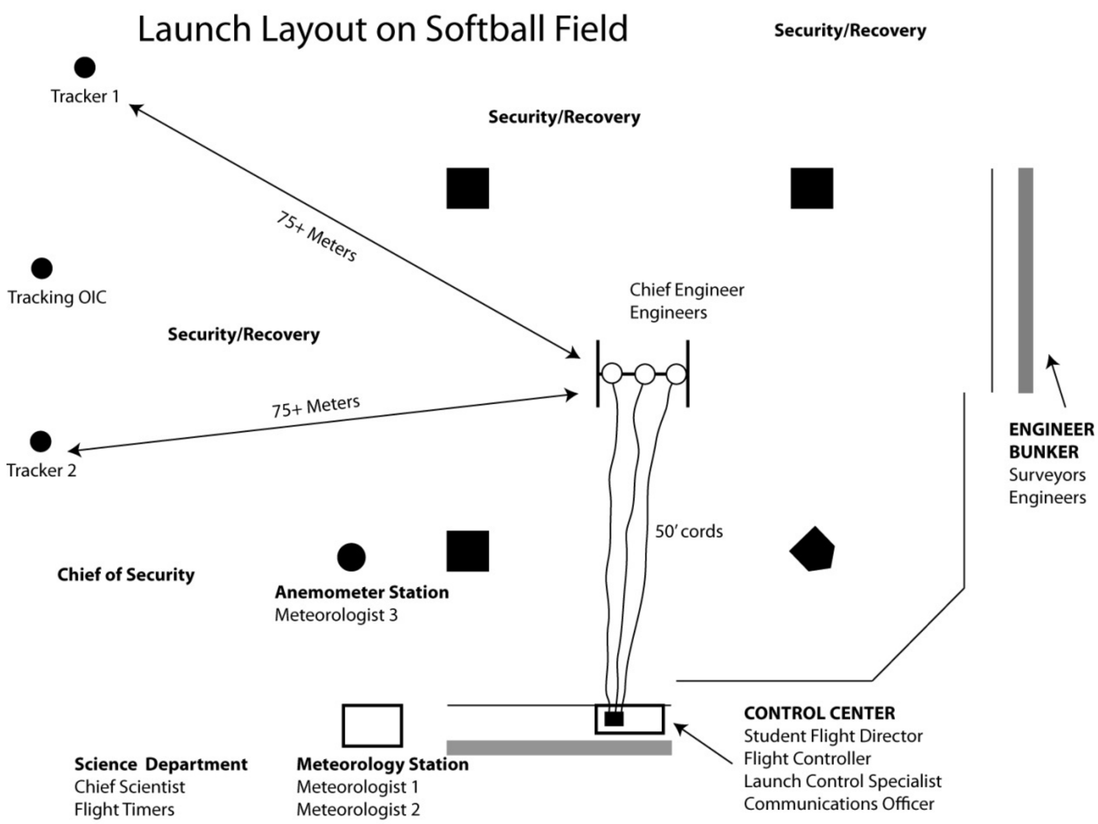


Figure E10 Launch Layout

Launch Site

A good location to conduct launches in on the school's baseball or softball field. Placing the launch pad on the pitcher's mound and locating most of the students behind the fencing creates a controllable and safe environment.

Equipment

During launches, many of the students will be responsible for the collection of data to be used for in-class activities. While professional grade equipment may give very accurate results, there is an opportunity for the instructor to add to student knowledge by building some of the equipment in the classroom and by using equipment that require the students to manually collect and interpret data, thus increasing student understanding of the collection process. A student who builds a cup anemometer, counts the number of rotations, and multiplies that number with the diameter of the cup assembly to determine wind velocity will have a much greater understanding of the process than the student who simply reads the wind speed from an electronic device.

Design and Engineering Equipment

The recommended setup for the teaching of Rocksim software is to have a copy of Rocksim and a computer for each student. As of this writing, Apogee offers an education discount on the software available on their website. Since most middle and high schools now possess a computer lab, it is assumed that the software would be installed there. The teacher will also need built examples of model rockets to use as demonstration models. Constructing the models prior to the lessons helps the teacher to better understand the work required.

Construction Equipment and Material

Durable equipment will last for many years if properly maintained.

Rulers – Used for measuring parts for cutting and gluing.

Hobby Knives – These knives dull quickly in the hands of inexperienced builders, so a supply of replacement blades is a must.

Cutting Mats – help to extend the life of the hobby knife blade not to mention the class tables.

Pencils – to mark fin and launch lug locations.

Scissors – are handy for several of the construction steps.

Consumable Supplies will need to be restocked after their use.

Rocket Kits – The easiest choice for the educator is to purchase a complete model rocket kit for each student. It is also the most expensive. Another method is to purchase the model rocket parts in bulk and give the students the added challenge of building from scratch. Making the Paradigm 5 found in *The Handbook of Model Rocketry* is simple and inexpensive. Students may also design their own model rocket on Rocksim, print the templates and parts lists, and build it.

Glue – Wood glue is perfect for small rockets. Students who will build a mid-powered rocket to compete in the Team America Rocketry Challenge will need to become familiar with ca glue and epoxy as well.

Tape – Masking tape is used to mask off areas of the model rocket for multi color paint schemes. The tape is also used to friction fit rocket motors into the motor mount.

Paint – The most efficient method of painting the model rockets is to use the enamel spray cans found in all hardware stores. Painting should be done outdoors for enough away from the class so that the fumes don't make their way back in. With generous funding, a program could set up airbrush stations and use water-based paint.

Launch Equipment

- Launch Pad – There are several commercially made launch pads that will work. The challenge with most of them is that they sit very low the ground, making it difficult for the students to set up the rockets and for the instructor to inspect the work. A simple pad for three rockets can be made with a saw horse or custom built with PVC pipe and connectors.
- Electronic Launcher – As with launch pads, commercial launchers will work fine. Most are 6 volt systems that have only a 15 foot electrical cord. For maximum safety, a 12 volt system with 50 foot cords will move the students to a distance that makes visual tracking of the flight much easier. A custom launch controller made of Radio Shack parts that allow the preparation of three rockets at a time is recommended. Such a system will allow all three rockets to be launched simultaneously or in sequence. This will shorten the launch times and provide more time for post flight lessons. Electronic Model Rocket Launcher Construction Plans and Tips by Tony Wayne offer several electronic launcher plans for the classroom and is available from Apogee Components.

Figure E11 a PVC launch pad for 3 rockets made by the author. The rockets from left to right are the Apogee Avion, the Estes Loadstar, and a scratch built Paradigm 5.

- Two-Way Radios - A very important feature of the launch procedures is communication. Two-way radios allow the students to conduct a smooth launch while spread over 5625 square meters or more. The radios also allow the teacher get give instruction. The researcher has given a portion of a altitude calculation lesson by standing at the launch pad and pointing out the parts of the triangle formed by the rocket's flight over the radio to the class spread out over the field. Inexpensive radios can be found on eBay and on sale at department and sporting goods stores. Another source is to obtain the school's old radios when they purchase new ones. For two-way radios, the required range of operation is very small. Another dimension that the radios give is an additional "wow" factor to the activity. The students love using the radios. It is recommended that the radios be distributed and returned at the launch site for control purposes. The students should be instructed that all transmissions are in the public domain and are under the control of the Federal Communications Commission.
- Fire Extinguisher– As an added safety precaution, a portable fire extinguisher is recommended.
- Countdown Timer – a simple kitchen battery operated timer can be used by the flight controller for the countdown.
- Portable Tables – for the Control Center and the Meteorologists.

Data Collection Equipment

- Sling Psychrometer – The sling psychrometer is used by the meteorologists to determine the relative humidity during the launch. The data can also be used to determine the dew point. The *Taylor 1330PJ Sling Psychrometer* is a good inexpensive choice. It also uses a nontoxic red liquid rather than mercury, making it a safer choice for student use.
- Thermometer – While the meteorologists can use the dry thermometer on the sling psychrometer to record the temperature, an inexpensive thermometer can provide a more accurate reading of the launch site's temperature.
- Wind Meter/Anemometer – The teacher has several options for determining wind speed.
    - Cup anemometers rotate in the wind and can be used to determine the wind velocity in feet per minute. While commercial versions are available, the students can make their own cup anemometers using paper cups and straws. The plans for a student built cup anemometer and instructions on its use are located in the appendix.
    - Electronic hand held anemometers such as the *La Crosse EA-3010 Anemometer*. This model uses a small fan to determine wind speed,

temperature, and wind chill, but there are others who utilize a small cup anemometer for reading.

  - Wind socks, a common sight at small airfields, is another effective methods for measuring wind speed and direction. A 15 knot (17mph) wind will fully extend the windsock. A 3 knot (3.5mph) breeze is required to cause the windsock to orient itself according to the wind. Wind direction is the opposite of the direction in which the windsock is pointing. The Federal Aviation Administration (FAA) specifications for windsock use are located in the appendix.
  - Windmill anemometers are also available for use for wind speed and direction readings. This type is expensive and is usually affixed permanently to the tops of buildings. Portable versions are available as well, but are too fragile for student use.

- <u>Barometer</u> – A barometer is used to measure atmospheric pressure. A hand held barometer is recommended. These types of barometers have a manual adjustment ring to adjust for the altitude of the launch site.
- <u>Altimeter</u> - Knowing the altitude of the launch site in required for accurate calculation of barometric pressure. The least expensive way for determining launch site altitude above sea level is to use Google Earth, or a similar program, to get that information. Hand held altimeters and GPS devices will also provide that information.
- <u>Trackers</u> – The typical tracker is a simple pointing device that requires the tracker to follow the rocket’s flight and measure the apogee in degrees. That data, combined with the measured distance of the tracker from the launch pad will be used during post flight lessons to determine the highest altitude of the rocket’s flight. An example of one of these devices is the Estes Altitrak, which is a plastic tracker that requires the tracker to depress the trigger during flight and release it at apogee. This action locks a weighted arm into position and the degrees can be read through a small opening in the arm. Plans for a triple-track tracker is provided in the appendix of the *Handbook of Model Rocketry*. Simple, but accurate trackers can be made out of typical classroom materials.
- <u>Marker Streamer</u> – A simple method of determining maximum altitude of a model rocket is the use of a marker streamer. Details on constructing and using marker streamers are in the appendix.
- <u>Lensatic Compass</u> – Also known as a military compass, this inexpensive compass is used to determine magnetic North on the launch site, and to determine the direction of rocket landing from the launch pad and of the tracking stations.

- Measuring Wheel – Measuring wheels operate by rolling the wheel on the ground from one spot to another and the distance is either mechanically or electronically displayed. A wheel that measures in meters is preferred. Electronic versions measure in meters as well as feet.
- Digital Scale – a digital kitchen scale large enough to weigh the rockets, motors, and parts in grams. Weigh rocket parts to enter an accurate mass weight in Rocksim. The engineers will use the scale to weigh the rocket before and after flight.

APPENDIX 1: COUNTDOWN PROCEDURES

Long Count:

Speaker	**Says**
Flight Director	*Flight Control, commence launch procedures.*
Flight Control	*Attention all launch personnel; the Flight Director has given permission to begin countdown preparations. All teams report a GO – NO GO on launch commencements:*
Note: teams are to report GO if their equipment is functional and they are in position. Report a NO GO if there are any problems with equipment or personnel. If a team reports a NO GO, Recorder is to continue with the team check, then hold countdown preparations until NO GO team reports a GO.	
Flight Control	*Tracking?*
Tracking Station OIC	*Go Flight* (or NO GO Flight, then state reason for NO GO)
Flight Control	*Security?*
Security OIC	*Go Flight* (or NO GO Flight, then state reason for NO GO)
Flight Control	*Engineers?*
Engineer OIC	*Go Flight* (or NO GO Flight, then state reason for NO GO)
Flight Control	Weather?
Meteorologist	*Go Flight* (or NO GO Flight, then state reason for NO GO)
Flight Control	*Science?*
Science OIC	*Go Flight* (or NO GO Flight, then state reason for NO GO)
Flight Control	(If all report GO) *All Teams report GO, commence launch procedures.*
All teams prepare for launch in accordance with special instructions.	
Quick Count	
Pad OIC	*Flight Control,* *Verify rocket number* _______ (rocket SN) *on Pad # 1.* (Note: The Pad OIC will verify all remaining rockets in the same manner.)
Flight Control	*Rocket number ________ is verified for launch.* (repeat #)
Meteorologist	*Flight Control, Wind Speed is at ___ miles per hour. Conditions are GO for launch.*
Flight Control	*Understand. Wind speed is at ___ miles per hour; GO for launch.*
Engineer OIC	*Flight Control, Pad OIC requests permission to clear pad. Pad checklist is complete with the exception of removal of the Launch Key on Rocket number __________*
Flight Director	*Understand. Pad OIC stand by. Flight Control; give a final status check of teams.*
Flight Control	*Understand. All teams report a GO – NO GO on launch commencements.*
Flight Control	*Tracking*
Tracking Station OIC	*GO Flight* (or NO GO Flight, then state reason for NO GO)
Flight Control	*Security*
Security OIC	*Go Flight* (or NO GO Flight, then state reason for NO GO)
Flight Control	*Engineers*
Engineer OIC	*Go Flight* (or NO GO Flight, then state reason for NO GO)

Flight Control	*Weather*
Meteorologist	*Go Flight* (or NO GO Flight, then state reason for NO GO)
Flight Control	*Science*
Science OIC	*Go Flight* (or NO GO Flight, then state reason for NO GO)
Flight Control	*All teams stand by for launch.*
Flight Director	*Pad OIC, you have permission to remove Launch Key and clear pad.*
Engineer OIC	(After crew has left pad and entered the Engineer Bunker) *Pad is clear*.
The Pad OIC brings the Launch Key to Flight Control and delivers it to the Launch Control Specialist. The Launch Control Specialist will conduct a hot test on the launch system.	
Launch Control Specialist	(Without a radio to Recorder) *Hot Test is complete, pad (1,2,3) is hot.*
Flight Control	*Pad is hot.*
Flight Director	*Flight Control, begin 15 second countdown on my mark ….mark.*
Flight Control	(on radio) *10, 9, 8, 7, 6, 5, 4, 3, 2, 1, Ignition!*
Flight Control	(on radio if liftoff successful) *Liftoff!*
Security OIC	(on radio when rocket touches down) *Touchdown !*
DATA/ ROCKET RECOVERY	
Data Collection : Student Flight OIC collects and records flight data on the Flight Data Sheet. Transmission of data over the two way radios should be reserved for students who are at a distance from fight control, such as the tracking station. Nearby stations may pass data directly to the Student Flight OIC.	
Flight Control	*All stations report data.*
Flight Control	*Tracking*
Tracking Station OIC	*Tracking Station Alpha reports ____ degrees.* *Tracking Station Bravo reports ____ degrees.* *Tracking Station Charlie reports ____ degrees.*
Flight Control	*Science OIC report to Flight Control with data.*
Science Officer	Science OIC will collect data from timers, observers, meteorologists, and surveyors and turn in the completed Science Data sheet to the Student Flight Director.

APPENDIX 2: ENGINEER CHECKLIST

ROCKET SERIAL # ____________________

BUILDER: ____

PRE-FLIGHT SAFETY CHECK

GO	NO GO	
		All glue and paint on model is completely dry
		Model is complete and all parts are present
		Nose cone fits properly and is not tight
		Nose cone is securely attached to the airframe
		Shock cord is secure
		Airframe is straight with no bends or warps
		Fins are present, securely attached and properly aligned
		Fins are undamaged
		Launch lug is securely attached to the airframe
		Motor mount is secure and operational
		ROCKET IS READY FOR FLIGHT!

PRE-FLIGHT PREPARATION

		ROCKET WEIGHT EMPTY: ________ grams
		Wadding installed
		Recovery system installed
		Rocket motor nomenclature: ____________
		Rocket motor undamaged
		Rocket motor installed
		Igniter and igniter plug installed
		Payload description: ____
		Payload installed
		ROCKET WEIGHT LOADED: _________ grams

POST-FLIGHT INSPECTION

		Rocket successfully recovered
		Rocket nose, airframe, and fins are intact and undamaged
		Recovery system is reusable
		ROCKET POST-FLIGHT WEIGHT : _________ grams (Including engine casing & recovery system)

APPENDIX 3: FLIGHT LOG

	Rocket Name: ______________________________ Serial # ________________ Builder:__________________________________

LAUNCH INFORMATION	FLIGHT DATA	
Date:	**Liftoff**	**Recovery**
Launch Time:	Successful:	Recovery System Deployment
Location:	***Misfire***	***Stage 1***
Launch Pad Elevation:	Stage 1:	Before Apogee:
	Stage 2:	At Apogee:
ROCKET DATA	**Pitch & Roll**	During Descent:
Fin Design:	***Thrust Phase***	Partial Deployment:
Fin #	No Pitch/Roll:	Failed to Deploy:
Engine	Pitched:	***Stage 2***
Stage 1:	Rolled:	Before Apogee:
Stage 2:	Tumbled:	At Apogee:
	Weathercock:	During Descent:
Recovery System	***Coast Phase***	Partial Deployment:
Stage 1:	Straight Trajectory:	Failed to Deploy:
Parachute -	Weathercock:	
Diameter:	Tumbled:	Recovery System Performance
Spill Hole Diameter:		***Stage 1***
Streamer -	**ALTITUDE**	Stable Descent:
Size:	***Tracking Station***	Oscillation:
Material:	Track. 1 Distance from pad:	Spinning:
Stage 2:	Track.2 Distance from pad:	***Stage 2***
Parachute -	Track.3 Distance from pad:	Stable Descent:
Diameter:	Tracker 1 Degrees:	Oscillation:
Spill Hole Diameter:	Tracker 2 Degrees:	Spinning:
Streamer -	Tracker 3 Degrees:	
Size:		**Landing**
Material:	***Marker Streamer***	Soft:
	Timer 1:	Hard:
Mass	Timer 2:	Crash:
Empty:		Distance from Pad:
Loaded:	***Electronic Altimeter***	Direction from Pad:
Post:	Reading:	
	FLIGHT TIMES	**Post Flight Inspection**
METEOROLOGY	***To Apogee***	***Damage***
Temperature:	Timer 1:	Nose:
Humidity:	Timer 2:	Airframe:
Barometer:	***Apogee to Landing***	Fins:
Wind Speed:	Timer 1:	Shock Cord:
Wind Direction:	Timer 2:	Recovery System:
Conditions:	***Total Time of Flight***	Can be reflown?
Cloud Type:	Timer 1:	
	Timer 2:	

APPENDIX 4: METEOROLOGIST WORKSHEET

Date: _______________ Time of Collection: ________________

Air Temperature (^{o}F):	^{o}	Wind Speed Range	KPH
Dry Bulb Temperature:	^{o}	Wind Direction:	
Wet Bulb Temperature:	^{o}	Barometric Pressure:	In Hg
Dry Bulb Temp. – Wet Bulb Temp. =	^{o}	Visibility:	^{o}
Relative Humidity:	^{o}	Cloud Type:	
Dew Point:			

Dry Bulb ^{o}	**Sling Psychrometer Worksheet Difference between Dry and Wet Bulbs in degrees**														
	1 ^{o}	**2 ^{o}**	**3 ^{o}**	**4 ^{o}**	**5 ^{o}**	**6 ^{o}**	**7 ^{o}**	**8 ^{o}**	**9 ^{o}**	**10 ^{o}**	**11 ^{o}**	**12 ^{o}**	**13 ^{o}**	**14 ^{o}**	**15 ^{o}**
32	90	79	70	60	50	40	31	22	13	4					
34	91	81	72	62	53	44	35	26	18	9	1				
36	91	52	74	65	56	48	39	31	22	14	6				
38	92	83	75	67	59	51	42	35	27	19	11	4			
40	92	84	76	68	61	53	46	38	31	23	16	9	2		
42	92	85	77	70	62	55	48	41	34	28	21	14	7		
44	93	85	78	71	64	57	50	44	37	31	24	18	12	5	
46	93	86	79	72	65	59	52	46	40	34	28	22	16	10	4
48	93	86	80	73	67	61	54	48	42	36	31	25	19	14	11
50	94	87	81	74	68	62	56	50	45	39	33	28	22	17	12
52	94	87	81	75	69	63	58	52	47	41	36	31	25	20	15
54	94	88	82	76	70	65	59	54	49	43	38	33	28	23	20
56	94	88	83	77	71	66	61	56	51	45	40	36	31	26	22
58	94	89	83	78	71	67	62	57	52	47	42	38	33	29	24
60	94	89	84	78	73	68	63	58	54	49	44	40	35	34	27
62	95	89	84	79	74	69	64	60	55	51	46	42	38	34	29
64	95	90	84	79	74	70	65	60	56	51	47	43	38	34	30
66	95	90	85	80	75	71	66	61	57	53	48	44	40	36	32
68	95	90	85	80	75	71	67	62	58	54	50	46	42	38	34
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36
72	95	91	86	82	77	73	69	65	61	57	53	49	45	42	38
74	95	91	86	82	78	74	69	65	61	58	54	50	47	43	39
76	96	91	87	82	78	74	70	66	62	59	55	51	48	44	41
78	96	91	87	83	79	75	71	67	63	60	56	53	49	46	43
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44
82	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45
84	96	92	88	84	80	76	73	69	66	62	59	56	52	49	46
86	96	92	88	84	81	77	73	70	66	63	60	57	53	50	47
88	96	92	88	85	81	77	74	70	67	64	61	57	54	51	48
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49
92	96	92	89	85	82	78	75	72	68	65	62	59	56	53	50
94	96	92	89	85	82	79	75	72	69	66	63	60	57	54	51

APPENDIX 5: RECOMMENDED REFERENCE LIBRARY

The researcher used a wide variety of resources to compile this curriculum. For the educator who wishes to use this curriculum to its fullest potential, the following books are recommended as a reference library.

Books available for purchase:
The Handbook of Model Rocketry by G. Harry Stine
Model Rocket Design and Construction by Timothy S. Van Milligan.

Available for free from Estes at http://www.esteseducator.com/
*Science and Model Rockets*by Sylvia Nolte, Ed. D.
Physics and Model Rockets Curriculum by Sylvia Nolte, Ed. D.
Mathematics and Model Rockets by Sylvia Nolte, Ed.D.
*Industrial Technology & Model Rockets Curriculum*by Richard Kalk, Ed. D and Steve Walsh.

Available free from NASA:
Rockets Educator Guide by Deborah A. Shearer & Gregory L. Vogt, Ed.D.http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html

Adventures in Rocket Science by Deborah Shearer, Greg Vogt, Carla Rosenberg, Vince Huegele, Kristy Hill,& Benda Terry
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Adventures_in_Rocket_Science.html

*Meteorology: an Educator's Resourcefor Inquiry-Based Learning for Grades 5-9*byDr. Joseph D. Exline, Dr. Arlene S. Levine&Dr. Joel S. Levine
http://www.nasa.gov/centers/langley/science/met-guide.html

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