A Novel Partnership for Advancing K-12 STEM Education & Entrepreneurship

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Biography: Mr. Boncek is Senior Principal Engineer at Raytheon. He holds a BSEE from Northeastern University and an MSEE from Georgia Tech. Mr. Boncek is actively involved in community activities related to STEM (Science, Technology, Engineering and Math) and enjoys working with students in middle and high school. He has partnered with several schools in Massachusetts as a guest speaker developing and facilitating units on topics such as remote sensing, feedback control systems and rocketry. In partnership with the educational branch of the New England Patriots, Mr. Boncek designed the 'Power to Hear' engineering design challenge to encourage students to explore areas of STEM especially those related to communications systems. Mr. Boncek has been a technical advisor in the "Science-of-Sports" program for four years.
A Novel Partnership for Advancing K-12 STEM Education

Abstract: By imparting expectations and behavioral norms for effective cooperation and teaming, effective study habits and by serving as role models of success-oriented behaviors it is our challenge to position the upcoming generation to preserve and further the gains of science and technology toward solving the challenges facing humanity. Many traditional paradigms exist such as apprenticeships, tutoring, job shadowing, internships and even ‘externships’ which bring teachers to industry for a summer of ‘on-the-job’ training. Even with the many successful efforts and paradigms which exist today, experts predict a shortfall in the future STEM workforce: the demand will not be met. Recognizing themselves as stakeholders, industries which employ and depend on a STEM-literate workforce have taken action --developing models and initiating efforts to enhance and augment the existing STEM-education infrastructure.

This paper will discuss two programs which have resulted from the collaboration between Raytheon Company --a leader in technology and innovation-- and the New England Patriots – a world class sports organization. This seemingly unlikely partnership has proven successful in advancing Science, Technology, Engineering and Mathematics (STEM) education in the middle and high school age groups.

The first program titled “Science-of-Sports” uses a science fair model and includes a third partner: the Boys & Girls Clubs of New England. The guidelines, operation and success-enablers will be described for those who may be interested in trying this model.

The second program is an engineering design challenge titled: “Power-to-Hear”. “Power-to-Hear” is an engineering design competition structured to represent the challenges faced by industry teams when designing and manufacturing devices for today’s highly competitive global marketplace.

The reasons for two programs will be explained and examples of students’ results will be shown. Metrics for the growth and sustainability of these programs will be presented.

Lastly, the paper provides an example of how the students’ work maps to a set of standards used by the state of Massachusetts for the comprehensive assessment of student learning for grades six through twelve. One example will be provided in the body of the paper. A larger mapping is included as an appendix.

It is our belief that these programs are adaptable for use by others interested in advancing STEM education and developing the next generation of engineers and entrepreneurs -- those who share our view --the view summarized by this year’s theme: “Engineering Education: Frankly, We Do Give a D*mn”.

Introduction: With the exception of a few notable events such as the moon landing, or an occasional medical break-through, the public’s interest and literacy in the sciences and technologies is low in proportion to amount of technology in common use in the last
thirty years. As a result, curricula historically did not allocate much time to the science and math behind the advanced technology of items like home computers, cell phones, GPS devices, and the wireless devices regularly used today. The non-existent or casual treatment of these topics positioned students only to be avid consumers or perhaps savvy end-users, but, fell short by failing to impart at least some understanding of what it takes to design, manufacture and bring such items to market. These topics have begun to appear in curricula driven by the demand for a technically competent work force at a time when a large population of the current work force prepares to retire. ¹

A simulation developed by Raytheon in partnership with the Business Higher Education Forum (BHEF) permits trade-off studies and analyses of hypotheses and parameters which are supposed to impact the strength of the projected STEM infrastructure. ²,³ Such parameters include: the aging and retirement of the STEM workforce, the current and proposed salaries for STEM educators, the current student interest and ability in STEM competencies and the expected demand for a STEM-competent workforce. Current projections using baseline parameters and existing data indicate a likely shortfall in the STEM infrastructure. ¹,²,³

Further, research has shown that student proficiency in math declines as students move from middle school to high school and existing data show that the number of students that are proficient or advanced in math at the 12th grade level is approximately equal to the number that declare their intent to pursue a STEM major freshman year in college ²,⁴,⁶

Graph 1: Declines in Student Math Proficiency by Grade ²
Changing the Image of STEM In The Eyes of Students

“Survey data collected as part of Raytheon’s MathMovesU program indicates that only 1/3 of middle school (6th to 8th grade) students like math a great deal, and, that by eighth grade, 45% are turned off to math, describing it as “boring”.” 2

Attempts to popularize and create a positive image of the scholastic endeavors of those with interests in math, science and technology include modifying the vernacular to include words like ‘mathlete’. Or, in holding events billed as academic ‘-athlons’ or ‘coli-piad’. These events build on the example, prestige and popularity of sports to capture the interest of students who may have the aptitude for STEM studies, but for whom science, technology, engineering and math studies may not yet have caught their interest.

The partnership between the Raytheon Company and the New England Patriots takes this idea further. In 2008, the Raytheon-Patriots collaboration created an educational branch of the New England Patriots organization for the purpose of promoting and holding STEM-centric events at Gillette stadium which encourage and reward student participation in STEM activities. Similar to the idea behind the U.S. Academic Decathlon --which by design includes students of several abilities 5 --, the Raytheon-Patriots idea was to capture the interest of the students who may not otherwise be interested in STEM topics, or who may have no STEM role models, and show them how STEM-based subjects and technologies influence society: everyday, everywhere, including the sports arena. Having caught the students’ interest, the programs --through mentoring associations with practicing engineers and scientists-- provide an educational experience which makes exploring STEM topics fun and exciting using topics and subjects directly chosen by the students in an atmosphere of support, reward and celebrity.

**Physics Rules the Game:** Working behind the scenes at each and every sporting event are the laws of physics, governing everything from the trajectory of a football, to the spin of an Olympic skater, to the drag on the hull of a world-class sailboat. Technology abounds in the modern sports arena from state-of-the-art displays to the latest in protective equipment. Developments in material science and electronic and computer technology impact the game in ways which when examined even casually, offer such a variety of STEM related topics it seems that there is something which could attract the curiosity and interest of almost every student.

Combine the opportunity to explore any topic within the theme of the ‘science of sports’ with the opportunity to win a scholarship, or, for the chance to be a VIP at Patriots’ training camp and a meaningful STEM-based competition is born. Add in the opportunity to be mentored by practicing, experienced engineers and our paradigm is defined.
Annual Competitions: Two competitions have resulted from the Raytheon-Patriots partnership.

The first is titled “The Science-of-Sports”. The “Science-of-Sports” is open to the Boys and Girls Clubs (herein B&G) across New England. The “Science of Sports” competition uses a science fair model. Raytheon engineers and scientists partner with staff members from the B&G clubs and over a period of approximately four months (mid-January to earlier May) to mentor and guide the students from topic selection, through prototype development to data collection finally culminating in a judging event at Gillette Stadium.

Several success-enablers are provided. Each team is assigned a Technical Advisor – an experienced engineer (many of whom are Engineering Fellows with advance degrees) to provide oversight and ensure success. The Tech Advisors provide support and guidance to the team mentors. A formal “mid-term” review is held midway through the program (approx mid-March) during which the Tech Advisors review each team’s project. The projects are reviewed for the current status and for any problems with the hypothesis or setup. The ability of the team to collect the data needed to test their stated hypothesis is evaluated. The mid-term review is an opportunity to strengthen the projects and to offer constructive feedback early enough to allow the teams to make adjustments or enhancements before the judging event. The judging is a full-day event which takes place at Gillette Stadium using the open floor space of the Putnam Club (Appendix A) in a festive and celebrity-like environment.

The first round of judging is done by the Raytheon Technical Advisors. The Tech Advisors rotate among the student displays and interview the teams for approximately five minutes per booth according to a formal schedule.

The Tech Advisors rank the teams using the scoring guidelines provided in Appendix B.

Each team is seen by three pairs of Tech Advisors. The Tech Advisor scores are averaged to determine the top six teams who go on to present to the executive judges consisting of Raytheon CEO Bill Swanson, Patriots Chairman and CEO Robert Kraft, a Patriot football player and Raytheon’s Engineering Director and Director of Corporate Affairs, Bob Filosa.

Additional success-enablers provided to the teams include: team-building and ice breaker exercises, a formal kick-off event at Gillette stadium complete with scientists performing ‘science magic’, a scoring rubric, and a budget for project materials. The staff from the Boys’ &Girls’ clubs provides support to the Raytheon mentors by helping with team management, access to B&G facilities, and during project development and testing.

Additional parameters for the Science-of-Sports model can be found in Appendix C.
Analysis of “Science-of-Sports” Metrics: Growth, Sustainability, and Impact

Watching a barbell-weight turn a wheel that rotates a Barbie-doll gymnast while four middle-school girls describe how linear momentum is converted into angular momentum, my intuition can’t but tell me that our programs are making STEM topics accessible to students. Seeing a group of students carrying a hand-built four foot parabolic microphone almost as big as the students themselves conveys the same.

Photo 1: Las Ultimate Twirlers, the 2012 Science-of-Sports 1st Place Team Explain to the Executive Judging Team How Their Gymnastics Simulation Converts Linear Momentum to Angular Momentum. Photo provided by and used with written permission from the New England Patriots.

Since our STEM initiatives are privately funded and a largely volunteer-based, after-hours effort, the demand for metrics and proof-of-efficacy is perhaps less than the demand for such metrics on other initiatives such as charter schools or innovative public school programs which need to regularly report progress to ensure continued funding and access to research dollars and grants. Therefore collecting and analyzing such metrics has not received significant attention to date. In fact one objective of attending the ASEE 2013 conference will be to survey evaluation methodologies to see which may work for our programs. Graph 2 (below) presents the metrics we do have. It shows the trends for the Science-of-Sports science fair since its beginning in 2009. Student and volunteer mentor participation have been increasing steadily. The increase in the number of volunteer mentors is keeping pace with the student participation and the program has averaged a 2:1 student-to-mentor ratio over its life. At an average 28 meeting-hours over four months this translates into an average of 14 mentoring-hours per student. This is quite significant, in that many of our students have few opportunities to interact with professional engineers and scientists.
Based on team surveys and attendance record many students stay with the program for at least two years. Some have stayed for at least four years.\textsuperscript{17} Since participation is voluntary it seems evident that the students are finding their involvement fun, worthwhile and beneficial.

Lastly this section will infer some favorable impact of the programs described in this paper by comparing them to another Raytheon program called “Stand and Deliver”. The Stand & Deliver program predates the collaboration described in this paper so it was not described in detail. Stand & Deliver volunteers provide one-on-one mentoring with Raytheon employees meeting with students who come from a town where only 40\% of the students graduate from high school. Of the 110 students who come to Raytheon annually to be tutored weekly from October to May (approx 40 hours face-time) 95\% go on to college.\textsuperscript{7,8} By inference, Science-of-Sports provides an average of 14 hours of face-time per student with practicing engineers so it does not seem unreasonable to expect at least a proportional impact. As our programs evolve we can consider a more formal study by including the schools with proper controls in an attempt to measurement any statistically significant changes in student academics, STEM interest, or other positive changes which may results from their students participating in our programs.
**Competition Two: “The Power-to-Hear”**

The second competition is titled: “The Power to Hear: Engineering Design Challenge”.

“The Power to Hear” challenges students to create functional parabolic microphones on a budget of $50.00. Throughout the competition, students apply their knowledge and understanding of the engineering design process and science, technology, engineering and mathematics concepts (STEM) to design, fabricate, test and present their microphone.

“The Power-to-Hear” uses a different model than “Science-of-Sports”. It is more competitive and participation in the final measurement play-off at Gillette is not guaranteed. The competition is structured more like the business world. It begins will a “call for participation” which announces the date of the competition and the source of the guidebook which governs all aspects of the competition.

The Coach’s Guide discusses all aspects of the competition. At thirty three pages, the guide is too large to be included in this paper even as an appendix. The table-of-contents, the requirements list, the general scoring guide and the test setup are included in Appendix D. Reference 9 provides the URL for those who would like to review the full document.

Participation in the final measurement playoff is only allowed for teams who provide artifacts which meet the requirements and are on time. Similar to a request for proposal (RFP) in industry, it is left to the teams to contact the competition’s sponsor if there are any questions or ambiguities in the requirements or in the rules. It is part of the competition to have the teams understand the requirements and meet all deadlines along the way.

Four teams of middle school students participated in the 2012 playoff event for a chance to be honored guests at one of the Patriot training camps. Rather than use a pseudo parabolic reflector like a wok or a bowl, the middle school students actually calculated the equations of the parabola and hand-fabricated true parabolic reflectors, some as large as four feet in diameter -- the maximum allowed by the rules.

The results of the competition were truly surprising for work done at the middle school grade level. Not only did the students deliver functioning products within the time and budget allowed, but their devices were true works-of-art with surprisingly sophisticated and aesthetically pleasing designs. The 2012 results exceeded all expectations.

Teams give a timed PowerPoint presentation and an accounting of the cost of each component. Then the teams take part in a “measurement play-off” to see which microphone picks up the reference signal at the furthest distance. The received signal is recorded and checked for quality, amplitude and frequency response.

A side-by-side comparison of the parameters for both the “Power-to-Hear” competition and the “Science-of-Sports” can be found in Appendix C.
Analysis of STEM Content: Some may be tempted to think that competitions designed around sports, cosponsored by a professional sports organization, and hosted at a major sports venue may more about public relations than educational content. This is certainly not the case for the ‘Science of Sports’ science fair or ‘The Power to Hear’ design challenge.

In the “Science of Sports” each team works with two or three Raytheon engineers from project conception to the final competition. It is the students who choose the topic. The challenge for the engineers is to lead the students from concept through the design, fabrication, testing, and presentation phases while imparting real learning all while keeping it fun. To help ensure technical depth, engineers with post graduate degrees including many engineering fellows with doctorates are assigned as ‘technical advisors’ who act in a consulting role.

For the ‘Power-to-Hear’ competition the mentoring and advising is done by teachers, usually someone who is responsible for one or more of the school’s STEM subjects and/or parents, or by volunteers with technical backgrounds. One team had a volunteer from the RESEED \textsuperscript{18} (Retirees Enhancing Science Education through Experiments and Demonstrations) program.

The topics and amount of STEM content in both of these competitions is high, surprisingly high in fact for middle school.

The conservation of angular momentum is a challenging enough concept for high school students and perhaps even some college students but that was the topic taken on by the 2012 ‘Science of Sports’ winning team comprised of students in 7\textsuperscript{th} and 8\textsuperscript{th} grades.

How about the Bernoulli principle or buoyancy? These too have been taken up by teams in previous ‘Science of Sports’ fairs.

The concept of antenna gain is another concept traditionally not encountered before high school and often not until college, and then primarily by electrical engineering students.

How about calculating the equations of a parabolic surface and then hand-fabricating a true parabolic reflector by hand from cardboard or aluminum wedges?

These last two concepts are taken up by those who compete in the ‘Power-to-Hear’ competition.
The Test of Understanding:  Do the students really understand the concepts they deal with in these competitions?

One test of understanding is the ability to extend and apply a concept to other topics and new situations. Applying this test to the team whose topic was angular and linear momentum and the effect on the rotations of a gymnast on the uneven bars, the team was asked “do these concepts apply to other sports like ice skating?” by one of the Tech Advisor judges. Without hesitation the student explained how skaters change the rate at which they spin “by moving their arms inward to speed up or outward to slow down”.

“Why would she speed up?” the student was asked by another Tech Advisor.

“To conserve angular momentum”, was the answer.

The students changed the position of the Barbie-doll gymnast from straight to pike position and demonstrated the result for the Tech Advisor judges.

After showing the gain equation for antennas, one of the middle school teams competing in the 2012 ‘Power to Hear’ was asked “if you had a chance to measure the sound of a bull frog or a chirping bird, which would you pick to try to measure the maximum sound assuming the bird and the frog were at the same distances and emitting the same amplitude sound wave?”

The teammates consulted and correctly understood that the frequency of the sound source was the key variable behind the question. Because wavelength is related to frequency they demonstrated their understanding of how frequency related to expected output of the microphone based on the wavelength term in the gain equation they had just presented.

Although anecdotal, these stories convey some of the depth of STEM topics covered in our competitions.

In the next sections we will let the students’ work speak for itself, especially as it relates to key items in the assessment system in use by the state of Massachusetts.
Student Results: This section will present some of the results produced by the student teams in the 2012 ‘The Power To Hear’ competition. The figures are mapped to some of the Massachusetts MCAS standards in the next section. All photos and student work are used with written permission. All referenced work cited in the student examples is used with written permission obtained by the author directly from the copyright owners.

The presentation by the students at McCall Middle School\textsuperscript{10} emphasized the mathematical aspects of designing their reflector. Their work included recursive applications of the Pythagorean Theorem and trigonometric equations.

\textbf{Comparing a Parabola to a Circle}

As you can see, the curve of a Parabola and circle differentiate after (10,2) and (10,2). The dimensions are in inches.

\textbf{What is a Parabola?}

- It is a curve generated by the formula $y = x^2 / 4f$. Where $f$ is the location of the FOCUS point.
- If you spin a parabola about its center axis, you generate a parabolic surface that can be used as a reflector.

\textbf{Figure 1a Circle vs. Parabola Trade-Off}

\textbf{Figure 1b Representative a Parabola}

\textit{From the 2012 presentation by McCall Middle School 6th Grade Team, Winchester, MA, [10]}

\textbf{The Spacing between Folds Change Because the Surface is Tilted}

But don’t worry, Microsoft Excel can help us to calculate all this without a lot of work.

\textbf{How We Constructed a Segment}

This is the basic layout math. More details will come. The spacing between folds is not uniform. The edges are not straight lines.

\textbf{Figure 2a Recursive Pythagorean Theorem}

\textbf{Figure 2b Trigonometry in 6th Grade!}

Figures 2a and 2b are cited in [10] and are used with written permission from Mayes, Lawrence [11]

\textbf{Figure 2c Reflector Segment}
Figure 3a,b  Students’ Spreadsheet Calculations Used To Make The Reflector Segments to a Parabolic Shape and Seamless Edges!

Figure 3c,d  Manufacturing the Reflector Based on the Calculations

Figure 4a  Presenting their outstanding and hi-performing design to a live audience.
Figure 4b  McCall’s Poster Board was part of a Multimedia Presentation which included photos, a video, the poster board, an example wedge and the final product.
The presentation by the Walsh Middle School “Sound Cats” emphasized engineering design process. The “Sound Cats” documented their activities from requirements, through a trade-off study, and manufacture. The “Sound Cats” presentation also included test results. Test results are not required for the middle school division of the “Power To Hear” competition so by completing a trade-off study and including the test results some ‘extra credit’ was awarded to this team.

Objective: Design and Build a Cost Effective Parabolic Microphone

- Design criteria
  - $50.00 maximum budget
  - 4.8” maximum dimension
  - 3/8” mini microphone jack
  - No amplifier circuits
- Deadline: April 13, 2012

Brainstorming

- Materials – Metal (e.g., aluminum, steel), plastic, paper mâché
- Pre-formed parabolas – Bowls, woks, satellite dishes
- Microphones – Lap top mics, stereo mics
- Structural support – Wire, PVC pipe, dowels, knitting needles, wood, plastic utensils
- Assembly materials – Glue, tape, screws/bolts
- Consider trade-off of quality for price

Budget

<table>
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<tr>
<th>Component Description</th>
<th>Source/Vendor</th>
<th>Package Cost</th>
<th>Units per Pack</th>
<th>Cost per Unit</th>
<th>Units Used</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8” aluminum sheeting</td>
<td>Home Depot</td>
<td>$1.57/ft</td>
<td>50</td>
<td>$4.35/ft</td>
<td>25</td>
<td>$51.44</td>
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<td>Earphone jack</td>
<td>Walmart</td>
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<td>$5.00</td>
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<td>$5.00</td>
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<tr>
<td>3/8” PVC conduit</td>
<td>Home Depot</td>
<td>$1.76/ft</td>
<td>10</td>
<td>$17.60/ft</td>
<td>1</td>
<td>$17.60</td>
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<tr>
<td>PVC pipe</td>
<td>Home Depot</td>
<td>$1.38/ft</td>
<td>90</td>
<td>$125.72</td>
<td>2</td>
<td>$251.44</td>
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<tr>
<td>Test results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We only spent ~50% of the allowable budget!

Selecting the Best Options

- Tested and selected the best microphone by measuring AC voltage output
  - Walmart laptop mic - $5.00
- Decided on size over simplicity
  - Opted to build our own parabola
    - Aluminum sheeting - $0.35 per foot
    - Bent PVC pipe - $0.12 per foot
- Glue, tape, and hardware - various costs

Figure 5 The Engineering Design Process

Figures 5a – 5d

From the 2012 presentation by Walsh Middle School ‘Sound Cats’ Team Framingham, MA, [12]
Prototype Construction

- Cut and punched flashing
- Bent the PVC
- Assembled PVC
- Assembled flashing
- Glued flashing
- Taped flashing
- Mounted microphone

Background

- A parabolic shape will bounce sound waves to the same point in space
- This spot is the focus of the parabola, the ideal location to place the microphone
- The larger the parabola, the more sound will be reflected

Experimentation & Results

- Initially, we had troubles with the laptop, but we resolved the problems
- We tested eight microphones
- We selected the best based on voltage output and cost
- Measurements were taken both indoors and outdoors
- Unfortunately, the assembled parabolic microphone performed poorly in comparison to our hopes (but it looks fantastic!)

Competition Results – May 6, 2012

Figure 6a
Safely Assembling The Prototype

Figure 6b
Wave Reflections and the Underlying Theory

Figure 6c
How It Measured Up

Figures 6a-6c
From the 2012 presentation by Walsh Middle School ‘Sound Cats’ Team Framingham, MA, [12]
Figures 6c and 7a document the “Sound Cats” testing and results. Although Figure 6c states that they did not have good performance in their testing, their design, in fact, delivered excellent performance. On competition day the Sound Cats’ design achieved the highest voltage reading. The data also exhibits the correct shape for the voltage fall-off with distance. Theory states that the voltage should decrease by half each time the distance is doubled.

The author’s conclusion: the Sound Cats’ device looked and performed ‘fantastic’! This team also documented the lessons-learned and ideas for improvements – a very good engineering practice to be learned at such an early age.

**Figure 7a**  The Walsh Sound Cats’ Voltage vs. Range Measurements  
**Figure 7b** The Author’s Comparison of the Students’ Results to Theory

**Future Improvements**
- Improve dimensions
- Better controlled parabolic shape
- Better location of microphone
- Deeper parabola
- Improve construction
  - Use thicker aluminum
  - Use a single, formed aluminum piece instead of sections
- Improve microphone sensitivity

**Figure 8** Documented ‘Lessons-Learned’  
**Figure 9** The Walsh ‘Sound Cats’ Team Photo and the 2012 Winning Entry

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Figures 7a, 8, 9  
From the 2012 presentation by Walsh Middle School ‘Sound Cats’ Team Framingham, MA, [12]
Mapping Student Results to the Massachusetts MCAS Standards

In both the “Science of Sports” and “The Power to Hear” students learn and apply many of skills required by the state of Massachusetts’ Comprehensive Assessment of Student learning –herein MCAS standards. ¹³

An example mapping of the student results from the 2012 “Power-To-Hear” competition is provided. A more extensive mapping is included in Appendix B. Reference 9 provides additional resources for performing mappings to the standards.

Example mapping:

Figures 1a, 1b and 6b taken from the students’ presentations provide evidence that the students identified the focus of the parabola. Finding and placing the microphone at the focus is fundamental to success in this competition. In figure 1b and 6b the parabolas are represented both in graphical and different algebraic forms, thus meeting a majority of the text of the MCAS Mathematics standard listed below. Given this is a grade 11 standard and these are 6th and 7th grade students it is reasonable to conclude that the students are being exposed to, and working with, STEM concepts above grade level and applying those concepts to practical problems.

<table>
<thead>
<tr>
<th>Framework</th>
<th>Text of The Standard</th>
<th>Grade/Strand</th>
<th>Domain/Topic</th>
<th>Code</th>
<th>Grades</th>
<th>Power To Hear Figure(s)</th>
<th>Significance to 'Power to Hear' and to the Standard</th>
<th>Power to Hear Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004 Mathematics</td>
<td>Identify and discuss features of conic sections: axes, foci, asymptotes, and tangents. Convert between different algebraic representations of conic sections.</td>
<td>Patterns, Relations, and Algebra</td>
<td>Patterns, Relations, and Functions</td>
<td>PC.P.8</td>
<td>Grade:11-12</td>
<td>1a 1b 3a 3b 3c 3d 6b</td>
<td>Students calculated the focus of a parabola using a spreadsheet and different representations of a parabola --a conic section are shown algebraic and graphic. The results were applied to the practical problem of building a functioning parabolic microphone.</td>
<td>The students' demonstrated work ABOVE grade level</td>
</tr>
</tbody>
</table>

"This excerpt from the Science & Technology/Engineering and Mathematics Curriculum Framework and is included by permission of the Massachusetts Department of Elementary and Secondary Education. The Science & Technology/Engineering Curriculum Framework is posted at www.doe.mass.edu/frameworks/current.html"
**Why Two Programs?** The reason is that they serve different student populations. Each program has a different objective and operates with different run-rules. The differences between the programs are summarized in Appendix C.

**Conclusion:** It is this author’s conclusion that evidence from the student results, from the feedback of the Tech Advisors and judging panels, and, from feedback provided by the students themselves in the form of unsolicited e-mails and impromptu conversations that the competitions sponsored by this novel collaboration between Raytheon and The New England Patriots have helped to foster enthusiasm for participation in STEM-based activities. Along with the support and encouragement from the schools’ leadership and the learning imparted by the mentoring and guidance of the team coaches, the students demonstrated their ability to understand and apply STEM concepts in solving real world problems presented in a competitive format. The evidence provided also shows student work at and above grade level as requirement by the Massachusetts MCAS standard.

Given the anticipated demand for a strong STEM infrastructure at a time when budgets are under ever-increasing pressure, it is the author’s hope that interested teachers, principals, administrators or parents can take this model forward as an example, using it to establish additional collaborations and partnerships between hi-tech companies and professional sports organizations along perhaps with additional Boys’ & Girls’ clubs. Such collaborations if embraced with the same enthusiasm and passion as the one we have established and documented in this paper could provide additional private funding for STEM-based educational experiences.

Thus, this novel and unlikely collaboration between a high-tech leader and a world-class professional sports organization is presented as a tool in the tool box of those interested in furthering STEM education consistent with the view summarized by this year’s conference theme: “Engineering Education: Frankly, We Do Give a D*mn”.

**References:**

1. “RISING ABOVE THE GATHERING STORM Energizing and Employing America for a Brighter Economic Future”, National Academies Press, 500 Fifth Street, N.W., Lockbox 285, Washington, DC 20055; Copyright 2007 by the National Academy of Sciences


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7. Munson, T., “Stand & Deliver Corporate Campus Academic Mentoring”, internal Raytheon presentation, February 2013

8. “Stand & Deliver At Fenway Park: Video” [http://www.youtube.com/watch?v=L0zFEvweZ7Q] Time section: 00:55 to 01:10


10. Varahunan Mathiyalakan Roy Xing, Manav Kumar, James Viglas, Jennifer Kim, Ethan Wong, “Parabolic Microphone Project”, unpublished presentation, May 2012, McCall Middle School, Winchester MA


18. RESEED Retirees Enhancing Science Education through Experiments and Demonstrations [https://sites.google.com/site/bostonreseedcenter]
Acknowledgements

To the Patriots organization and the folks at Gillette Stadium and The Hall at Patriot Place for co-sponsoring and hosting the ‘Science-of-Sports’ and ‘Power-To-Hear’ events.

To the Boys & Girls Clubs, families, teachers and mentors of our participants and to our students themselves for taking on these competitions and delivering outstanding results.

“Las Ultimate Twirlers”: Rosa Reynoso, Jailene Garcia, Latiny Ke, Arlese Silva

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McCall Middle School 6th Grade Engineering Design Team: Varahunan Mathiyalakan Roy Xing, Manav Kumar, James Viglas, Jennifer Kim, and Ethan Wong.

Advisers: Will Becker, Rich Monagle, Joe DeMarinis (RESEED) and Thomas Awiszus.

Walsh Middle School Teams

Team 1 QUERTY: Chris Thierauf, Kevin Thierauf, Gilad Waldman, Sajal Akipeddi, Jason Landes

Team 2: Walsh Sound Cats: Graylen Chickering, Ellen Burton, Jillian Shapiro, Joey Wolpert, Varun Akur, Priyanka Roy.

Team #3: Parabolic Cats: Shristi Varshnay and Anna Parra.

Advisors: Don Chickering, Stephen Thierauf

Biography: Mr. Boncek is Senior Principal Engineer at Raytheon. He holds a BSEE from Northeastern University and an MSEE from Georgia Tech. Mr. Boncek is actively involved in community activities related to STEM (Science, Technology, Engineering and Math) and enjoys working with students in middle and high school. He has partnered with several schools in Massachusetts as a guest speaker developing and facilitating units on topics such as remote sensing, feedback control systems and rocketry. In partnership with the educational branch of the New England Patriots, Mr. Boncek designed the ‘Power to Hear’ engineering design challenge to encourage students to explore areas of STEM especially those related to communications systems. Mr. Boncek has been a technical advisor in the “Science-of-Sports” program for four years.
Appendix A  “Science-of-Sports” Science Fair Floor Map

Science of Sports
Science Fair
East Club
Proposed Floor Plan

Booths (18)
- Booth Size: 8’ x 10’
- Table Size: 96” (8’) wide x 30” deep x 30” tall
- Black Draping, 1 Table per each Booth.

(Center)
50 Yard Line

Awards Ceremony
Theater Style-Seating 256 pp
3 (8’) Tables for Awards

On Stage
Podium
6 Club Chairs for Judges

Lunch
20 (72”) Rounds
18 chairs each

Registration
2 (8’) Tables
4 Chairs

Note:
Electrical Requirements — TBD.
Standard 110-125 volt electrical power (A.C., single phase, 60 cycle) to be available on a pre-order basis.
Appendix B  Scoring Rubric

Creativity and Innovation  35 points

Is the project interesting and creative?

Description
The project is unique and innovative as a result of one or more of the following: (1) the subject is interesting and important, (2) the team's approach is creative and resourceful, (3) the solution captures the imagination and provides real insight, (4) the overall project provides important and relevant information to athletes and/or coaches.

Criteria
- Project introduced new or unique ideas, approaches, analysis, data interpretation, and/or results
- Team was creative, efficient, and effective in its use of equipment and/or materials used to conduct the project

Questions to Consider
- What does this mean for an athlete or coach? Why should an athlete or coach care about this project?
- What is unique about the team's approach to the project?
- Was the team creative in the way it analyzed and presented data? Did the team's analysis produce new insights?
- Are the project results innovative? Did the team uncover a new discovery or at least identify a promising new idea that can be pursued?
- Did the team select an interesting topic, or at least consider an interesting aspect of a common topic?
Appendix B  Scoring Rubric (continued)

Scientific Approach and Demonstrated Knowledge   25 points

Was the team thorough in completing the project, and – as a result – did the team demonstrate a deep understanding of the subject matter?

Description
The team clearly identified a realistic goal or hypothesis, and then developed a procedural plan to accomplish the project objectives. The team's progression from observations and analysis to conclusions is consistent, logical, and unbiased. The team demonstrates that it has researched -- and understands -- the relevant scientific literature, as evidenced by appropriate references and citations. The team can describe alternative approaches to the problem, and understands what further research could be conducted to build on the results of the project.

Criteria
- Clearly stated scientific hypothesis or engineering goal
- Problem is sufficiently limited to allow a plausible approach
- Procedural plan was developed and followed through to completion
- Setup and follow-through of project is orderly and logical
- Thorough use of data and observations
- Conclusions are consistent with data that was collected
- Team demonstrates knowledge of relevant content matter
- Team members understand the scope and limitations of the project, and have an idea of what further research is warranted
- Team conducted sufficient research, as evidenced by appropriate citation of scientific literature and reference sources

Questions to Consider
- Has the team identified a clear, bounded problem statement and/or objective?
- Did the team follow a logical plan for completing the project?
- Did the team collect and analyze data?
- Are the project conclusions consistent with the data and analysis?
- Do the team members understand the subject matter?
- Did the team consider alternative approaches to project, and (if so) can it explain the advantages and disadvantages of different approaches?
- Did the team conduct research to help guide their experiment(s)?
Appendix B  Scoring Rubric (continued)

Presentation and Display  20 points

Is the project displayed in an organized and clear fashion? Did the team make effective use of visuals (charts, tables, pictures, etc.)?

Description
Team members can describe the project -- its objective, method, and conclusions -- in a clear and precise manner. The team's description is supported by appropriate charts and graphs that are understandable, insightful, and professional-looking.

Criteria
- Project explanation was clear and precise
- Project was displayed in a logical and organized manner
- Charts and graphs were used appropriately and effectively
- Display and posters effectively convey the message in an understandable manner

Questions to Consider
- Is the team's presentation organized, clear, and logical?
- Do the visuals (tables, charts, pictures, etc.) support the project, and do they help convey information efficiently and effectively?
- Overall, does the project have an orderly, aesthetic appearance?
Teamwork and Team Spirit  20 points

Does the team exhibit a shared, contagious enthusiasm about the project and their achievement?

Description
Each team member demonstrates a contagious enthusiasm for the project, its results, and the shared learning experience. Each team member discusses his/her role with passion and excitement, and understands how the team worked together to achieve a shared success.

Criteria
- Each member was fully involved in the project and can demonstrate his/her role
- The final product reflects the coordinated effort of all team members
- Each team member exhibits noticeable enthusiasm for the project, the results achieved, and the underlying scientific principles
- Team members demonstrate contagious energy and passion for the project

Questions to Consider
- Do the team members get excited when they discuss the project and their roles?
- Do the team members feel proud of their accomplishments?
- Do the team members appear to be enjoying the opportunity to showcase their work?
<table>
<thead>
<tr>
<th>Appendix C   Comparison of the Programs Discussed in the Paper</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td><strong>Science-of-Sports</strong></td>
</tr>
<tr>
<td>Subject Matter:</td>
</tr>
<tr>
<td>Program Focus:</td>
</tr>
<tr>
<td>Time Period:</td>
</tr>
<tr>
<td>Rules and Handbook:</td>
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<tr>
<td>Success Enablers:</td>
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<tr>
<td>Winner Evaluation Methods:</td>
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<td>Formal Presentations:</td>
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<td>Objective Measures:</td>
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<td>Budget Objectives:</td>
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<td>Is Participation in Final Event Guaranteed?</td>
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<tr>
<td>Awards and Prizes:</td>
</tr>
</tbody>
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(continued)  

Design Requirements  

Appendix 1: “The Power to Hear” Engineering Design Challenge  

Study the basics of sound and the math of conic sections. Calculate the focus of the 
parabola so you know where to put the microphone to capture sound. Build and test 
your own parabolic microphone just like they use during the game.  

Competition is open to all students in grades 6 – 12. It will take place at Gillette Stadium.  

Competition groups:  
  Group 1: grades 6, 7 and 8  
  Group 2: grades 9, 10, 11, and 12  

Design Requirements:  

REQ101  The parabolic microphone SHALL have no dimension exceeding 48 inches.  

REQ102  The total cost of all components and materials SHALL be less than $50.01 US dollars  

REQ103  The parabolic microphone SHALL plug into the microphone jack on a laptop or PC. The microphone and the feed to the PC SHALL NOT contain any amplifiers or preamp circuits.  

REQ104  Each entry for grades 9-12 SHALL be accompanied by a graph plotting distance on the x-axis and your measured output for 6, 12, 24, and 48 yards on the y-axis.  

REQ105  The team SHALL provide a design report and a complete parts list with costs. Documented cost estimates are required for all borrowed or scavenged items. Provide receipts, pages from a catalog or price lists from online vendors.  

REQ105  The team SHALL give a 10 to 12 minute PowerPoint presentation explaining the design, costs and building process.  

REQ 106  Each entry SHALL provide a fixture that plugs into the headphone jack on a laptop or PC. The fixture SHALL have leads of at least 12 inches and SHALL have alligator clips attached to one end. This fixture SHALL be passive, i.e. no active components like amplifiers.  

Entries must meet all requirements to participate in the Measurement Playoff Round.  

The winning team will be invited to use its parabolic microphone on the field during training camp.  

1. See Appendix 1 for scoring rubric.
### C. General Scoring Guidelines

*The decisions by the judges are final!*

#### The New England Engineering Design Challenge Scoring Guidelines

Overall scoring will be based on the following deliverables:
- Engineering Design Challenge Detail Budget
- Engineering Design Challenge PowerPoint Presentation
- Participation in the Measured Play Off

**Scoring Guidelines:**
- EDC Detail Budget - 1000 points \( - (20\times \text{cost}) \)
- EDC PowerPoint Challenge – 1000 points (see Appendix 3 for scoring rubric)
- Measurement Play Off
\[ X_{\text{M}@12\text{ yds}} + Y_{\text{m}@24\text{ yds}} + W_{\text{m}@48\text{ yds}} + Z_{\text{m}@72\text{ yds}} + \text{Bonus round} \]

1. **Design solution**
   - **To what degree did your team meet all the design requirements?**
   - Design requirements: See Appendix 1
   - Entries must meet all requirements to go on to the Measurement Playoff Round.

2. **Engineering Design Presentation**
   - The presentation shall:
     - Describe in detail the engineering design process as outlined in appendix 1
     - Describe the thinking and learning that took place within the team
     - Demonstrate an understanding of the science and math used to design the parabolic microphone
     - Provide an overview of the costs associated with the design
     - Last a minimum of 10 minutes and no more than 12 minutes.

A detailed outline of the Scoring Guidelines can be found in Appendix 3.
Appendix D  Excerpts from Reference 9: “Power-to-Hear” Coaches’ Guide (continued)

Test Setup Used For Measurement Play Off

Testing Set Up for Measurement Playoff
Each team must provide a parabolic mic and a test fixture. We will provide all of the remaining test equipment.

Your parabolic microphone must be able to plug into the mic jack on a PC or laptop.

Your test fixture must plug into the headphone jack of the PC and have alligator clips on the other end.
Appendix E  Additional Mappings of Student Results to MCAS Standards

In this section additional student results from the 2012 “Power To Hear” competition are mapped to a subset of the MCAS standards. The examples included in this paper are representative of the work seen from eight student teams in two years of competitions, but not all inclusive. Occasionally the table below mentions a student result observed in the competition but not shown in one of this paper’s figures. If necessary the supporting data can be provided upon request if the proper permissions can be obtained. Interested readers can extend this exercise by reviewing the full set of MCAS standards while looking at the examples of the students’ work in section seven above. Additional resources for mapping student results to MCAS standard are provided in reference 9.

<table>
<thead>
<tr>
<th>Framework</th>
<th>Text of The Standard</th>
<th>Grade/Strand Domain/Topic Code</th>
<th>Grades</th>
<th>Power To Hear Figure</th>
<th>Significance to 'Power to Hear' and to the Standard</th>
<th>Power to Hear Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004 Mathematics</td>
<td>Solve everyday problems that can be modeled using linear, reciprocal, quadratic, or exponential functions. Apply appropriate tabular, graphical, or symbolic methods to the solution. Include compound interest, and direct and inverse variation problems. Use technology when appropriate. (AI.P.11)</td>
<td>Patterns, Relations, and Algebra</td>
<td>Models</td>
<td>10.P.7 Grade:9-10</td>
<td>1a 3a 6a 7a</td>
<td>McCall students used a recursive Pythagorean algorithm to create the wedges used in their microphone. This is a grade 9-10 standard. While the students did not derive the algorithm they implemented in a spreadsheet and used it to solve a technical problem.</td>
</tr>
<tr>
<td>2004 Mathematics</td>
<td>Relate geometric and algebraic representations of lines, simple curves, and conic sections.</td>
<td>Geometry</td>
<td>Transformations and Symmetry</td>
<td>12.G.4 Grade:11-12</td>
<td>1a 1b 2a 2b 3a 3b 6b</td>
<td>Students calculated the focus of a parabola using a spreadsheet and different representations of parabola -- a conic section</td>
</tr>
<tr>
<td>2004 Mathematics</td>
<td>Solve everyday problems that can be modeled using polynomial, rational, exponential, logarithmic, trigonometric, and step functions, absolute values, and square roots. Apply appropriate graphical, tabular, or symbolic methods to the solution. Include growth and decay; joint (e.g., ( I = Prt )) and combined (( F = G(m_1m_2)/d^2 )) variation, and periodic processes. (AII.P.11)</td>
<td>Patterns, Relations, and Algebra</td>
<td>Models</td>
<td>12.P.11</td>
<td>2b, 3b, 7a</td>
<td>McCall team used trig and a spreadsheet to tabulate the sizes for their wedges. One middle school team and two high school teams used the antenna &quot;Gain Equation&quot; ( G = 4\pi A/\lambda^2 ) to calculate the expected output based on size.</td>
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</tr>
<tr>
<td>2004 Mathematics</td>
<td>Demonstrate an understanding of the trigonometric, exponential, and logarithmic functions. (AII.P.4)</td>
<td>Patterns, Relations, and Algebra</td>
<td>Functions</td>
<td>11.P.4</td>
<td>2b, 2c, 3a, 3b, 7a</td>
<td>Trigonometric functions were used to properly shape the parabolic wedge sections. The students gave an explanation of the edge differences when using linear and tangent based segments.</td>
</tr>
<tr>
<td>2004 Mathematics</td>
<td>Identify, measure, and describe circles and the relationships of the radius, diameter, circumference, and area (e.g., ( d = 2r ), ( p = C/d )), and use the concepts to solve problems.</td>
<td>Measurement</td>
<td>Techniques and Tools</td>
<td>6.M.5</td>
<td>1a, 6a</td>
<td>Demonstrated and used in all student presentations. It is fundamental to successfully doing the project for the students to understand the difference between a circle and a parabola.</td>
</tr>
<tr>
<td>2004 Mathematics</td>
<td>Use a ruler, protractor, and compass to draw polygons and circles.</td>
<td>Geometry</td>
<td>Transformations and Symmetry</td>
<td>7.G.5</td>
<td>1a, 6a</td>
<td>The supports for several entries were circular. Students were required to scribe circles and form the circles from plywood or other materials.</td>
</tr>
<tr>
<td>Year</td>
<td>Subject</td>
<td>Description</td>
<td>Course</td>
<td>Grade</td>
<td>Submissions</td>
<td>Level</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>2004 Mathematics</td>
<td>Translate between different representations of functions and relations: graphs, equations, point sets, and tabular.</td>
<td>Patterns, Relations, and Algebra</td>
<td>Patterns, Relations, and Functions</td>
<td>1a b c d e f g</td>
<td>Used in all student presentations. The spreadsheets used by the students turned the equations into graphs and numbers suitable for the manufacturing step.</td>
<td>students' demonstrated work ABOVE grade level</td>
</tr>
<tr>
<td>2004 Mathematics</td>
<td>Demonstrate an understanding of the relationship between geometric and algebraic representations of circles.</td>
<td>Geometry Course</td>
<td>Geometry</td>
<td>1a b c d e f g</td>
<td>Demonstrated and used in several student presentations. It is fundamental to successfully doing the project for the students to understand the difference between a circle and a parabola.</td>
<td>students' demonstrated work ABOVE grade level</td>
</tr>
<tr>
<td>2004 Mathematics</td>
<td>Translate between geometric, algebraic, and parametric representations of curves. Apply to the solution of problems.</td>
<td>Precalculus</td>
<td>Patterns, Relations, and Functions</td>
<td>1a b c d e f g</td>
<td>Students calculated the focus of a parabola using a spreadsheet and different representations of parabola -- a conic section. They used the results to build a functioning parabolic microphone.</td>
<td>students' demonstrated work ABOVE grade level</td>
</tr>
<tr>
<td>2004 Mathematics</td>
<td>Identify and discuss features of conic sections: axes, foci, asymptotes, and tangents. Convert between different algebraic representations of conic sections.</td>
<td>Patterns, Relations, and Algebra</td>
<td>Patterns, Relations, and Functions</td>
<td>1a b c d e f g</td>
<td>Students calculated the focus of a parabola using a spreadsheet and different representations of parabola -- a conic section. They used the results to build a functioning parabolic microphone.</td>
<td>students' demonstrated work ABOVE grade level</td>
</tr>
<tr>
<td>2006 Science and Technology/Engineering</td>
<td>Identify and explain the steps of the engineering design process: identify the problem, research the problem, develop possible solutions, select the best possible solution(s), construct prototypes and/or models, test and</td>
<td>Technology/Engineering Design</td>
<td>Engineering Design</td>
<td>1.1</td>
<td>The students demonstrated this in their presentations, poster boards and discussions. They actually live through the engineering design process as part of the contest. All aspects are evident in the student presentations.</td>
<td>students' demonstrated work ABOVE grade level</td>
</tr>
<tr>
<td>Given a design task, identify appropriate materials (e.g., wood, paper, plastic, aggregates, ceramics, metals, solvents, adhesives) based on specific properties and characteristics (e.g., strength, hardness, and flexibility).</td>
<td>Technology/Engineering (preK-8)</td>
<td>Materials, Tools, and Machines</td>
<td>Trade off and material selection studies were demonstrated and documented in the student presentations. McCall’s presentation introduced the term ‘tensile’ strength’ as they were concerned about how their design would hold up under windy conditions.</td>
<td>students' demonstrated work AT grade level</td>
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<tr>
<td>Identify and explain appropriate measuring tools, hand tools, and power tools used to hold, lift, carry, fasten, and separate, and explain their safe and proper use.</td>
<td>Technology/Engineering (preK-8)</td>
<td>Materials, Tools, and Machines</td>
<td>The students demonstrated this in their presentations, poster boards and discussions. Some of the figures included in this paper show the students manufacturing their devices and the tools they used.</td>
<td>students' demonstrated work AT grade level</td>
<td></td>
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</tr>
<tr>
<td>Identify and explain the safe and proper use of measuring tools, hand tools, and machines (e.g., band saw, drill press, sander, hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) needed to construct a prototype of an engineering design.</td>
<td>Technology/Engineering (preK-8)</td>
<td>Materials, Tools, and Machines</td>
<td>The students demonstrated this in their presentations, poster boards and discussions. Some of the figures included in this paper show the students manufacturing their devices wearing safety glasses, etc.</td>
<td>students' demonstrated work AT grade level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td>School Course</td>
<td>Standard</td>
<td>Description</td>
<td></td>
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</tr>
<tr>
<td>HS</td>
<td>Technology/Engineering High School Course</td>
<td>1.5</td>
<td>The students developed drawings and built prototypes based on the equations of a parabola. The quality of the results is proportional to getting the parabolic shape correct and placing the microphone at the focus.</td>
<td></td>
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</tr>
<tr>
<td>6-8</td>
<td>Technology/Engineering (preK-8)</td>
<td>2.1</td>
<td>This is required for the competition. All teams demonstrated the steps as part of the required presentation. Prototype development is shown in the figures. Teams give oral presentations. A few teams documented lessons-learned and ideas for an improved product.</td>
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<tr>
<td>6-8</td>
<td>Technology/Engineering (preK-8)</td>
<td>2.2</td>
<td>Some drawing and sketches were used by the teams. Projections and multiviews were not evident in the presentations.</td>
<td></td>
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</tr>
<tr>
<td>6-8</td>
<td>Technology/Engineering (preK-8)</td>
<td>2.3</td>
<td>The Sound Cats and a couple of other teams used several prototypes in a trade study to determine their final selection of a microphone demonstrating that they understanding of using prototypes to solve an engineering problem.</td>
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</tbody>
</table>
### 2006 Science and Technology/Engineering

#### Explain how such design features as size, shape, weight, function, and cost limitations would affect the construction of a given prototype.

<table>
<thead>
<tr>
<th>Technology/Engineering (preK-8)</th>
<th>Engineering Design</th>
<th>Grade: 6-8</th>
<th>4a</th>
<th>4b</th>
<th>5d</th>
<th>6a</th>
<th>6b</th>
<th>6c</th>
<th>7a</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>There was an upper bound on size. The Sound Cat presentation clearly states that output is related to size. Two other groups used the antenna &quot;Gain Equation&quot; ( G=\frac{4\pi A}{\lambda^2} ) to calculate the expected output based on reflector size and sound frequency.</td>
<td>students' demonstrated work AT &amp; ABOVE grade level. Especially the use of the 'Gain' equation</td>
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</tbody>
</table>

#### Describe the measurable properties of waves (velocity, frequency, wavelength, amplitude, and period) and explain the relationships among them. Recognize examples of simple harmonic motion.

<table>
<thead>
<tr>
<th>Introductory Physics High School Course</th>
<th>Waves</th>
<th>Grade: HS</th>
<th>1b</th>
<th>6b</th>
<th>6c</th>
<th>7a</th>
</tr>
</thead>
<tbody>
<tr>
<td>One middle school team used the antenna &quot;Gain Equation&quot; ( G=\frac{4\pi A}{\lambda^2} ) to calculate the expected output based on size. When quizzed they were able to explain the change in the gain of their design based on frequency.</td>
<td>students' demonstrated work ABOVE grade level by researching and using the 'Gain' equation ( G=4\pi A/\lambda^2 )</td>
<td></td>
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</tr>
</tbody>
</table>

#### Describe qualitatively the basic principles of reflection and refraction of waves.

<table>
<thead>
<tr>
<th>Introductory Physics High School Course</th>
<th>Waves</th>
<th>Grade: HS</th>
<th>1b</th>
<th>4a</th>
<th>4b</th>
<th>6b</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>This understanding is a key element of the competition. All students groups explained how the parabola reflects and focuses the sound waves which gives the microphone the ability to pick up sounds from far away</td>
<td>students' demonstrated work AT &amp; ABOVE grade level. Especially the use of the 'Gain' equation</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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**Note:** The table above is a simplified representation of a larger document that discusses various aspects of science and engineering. The table outlines specific tasks, equations, and explanations provided in the document. Each cell in the table corresponds to a specific task or concept, along with the relevant grade levels and additional comments. The table helps in organizing the information to make it easier to understand the content.
2006 Science and Technology/Engineering

Explain basic processes in manufacturing systems, e.g., cutting, shaping, assembling, joining, finishing, quality control, and safety.

Technology/Engineering (preK-8)

Manufacturing Technologies

The students went through the process of cutting, shaping and assembling, joining and finishing their prototypes based on the equations of a parabola. The McCall team used a poly finish on their design to increase the strength and reflectivity of the cardboard reflector.

2006 Science and Technology/Engineering

Explain how to measure and calculate voltage, current, resistance, and power consumption in a series circuit and in a parallel circuit. Identify the instruments used to measure voltage, current, power consumption, and resistance.

Technology/Engineering High School Course

Energy and Power Technologies-Electrical Systems

Grade:HS

Students in the competition used voltage meters to record the output of their prototypes. The Sound Cats presentation included a set of voltage measurements taken at increasing ranges from the parabolic microphone. The students' presentations were graded and passed, indicating the expected behavior of the system.

Students' work at grade level.

The basic microphone circuit was included in some student presentations however the content owner was not available so the information could not be included here. In the high school division one group did a nice job of explaining the operation of noise cancelling microphones.

2006 Science and Technology/Engineering

Identify and explain the components of a circuit including sources, conductors, circuit breakers, fuses, controllers, and loads. Examples of some controllers are switches, relays, diodes, and variable resistors.

Technology/Engineering High School Course

Energy and Power Technologies-Electrical Systems

Grade:HS

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Students' work at grade level.

2006 Science and Technology/Engineering

Explain basic processes in manufacturing systems, e.g., cutting, shaping, assembling, joining, finishing, quality control, and safety.
<table>
<thead>
<tr>
<th>Task</th>
<th>Grade</th>
<th>Description</th>
<th>Students' demonstrated work AT &amp; ABOVE grade level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define and use functions of a spreadsheet application (e.g., sort, filter, find).</td>
<td>6-8</td>
<td>Most teams used a spreadsheet to do some calculations for the project. The McCall team employed a spreadsheet to solve the recursive and trig calculations needed to shape each wedge of the reflector.</td>
<td>Students' demonstrated work AT &amp; ABOVE grade level</td>
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<td>Use a variety of applications to plan, create, and edit multimedia products (e.g., slide presentations, videos, animations, simulations, podcasts).</td>
<td>HS</td>
<td>Several student entries used Powerpoint, digital photos, videos and poster board displays to capture their experience. The progression was from requirements, design, test and final presentation.</td>
<td>Students' demonstrated work ABOVE grade level</td>
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<td>Use a variety of media to present information for specific purposes (e.g., reports, research papers, presentations, newsletters, Web sites, podcasts, blogs), citing sources.</td>
<td>HS</td>
<td>Several student entries used Powerpoint, digital photos, videos and poster board displays to capture their experience. The progression was from requirements, design, test and final presentation.</td>
<td>Students' demonstrated work ABOVE grade level</td>
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<td>Develop and use guidelines to evaluate the content, organization, design, use of citations, and presentation of technologically enhanced projects.</td>
<td>6-8</td>
<td>Many teams showed included elements of research in the work. Student presentations properly cited their references and included URLs, Web sites when using existing materials. The teams used the contest guidelines in conducting their project.</td>
<td>Students' demonstrated work AT grade level</td>
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<tr>
<td>Subject</td>
<td>Standard</td>
<td>Grade</td>
<td>Objective</td>
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<td><strong>2011 English Language Arts</strong></td>
<td>ELA.9-10.SL.2.04</td>
<td>9-10</td>
<td>Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.</td>
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<td><strong>2011 English Language Arts</strong></td>
<td>ELA.9-10.SL.2.05</td>
<td>9-10</td>
<td>Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.</td>
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<td><strong>2011 English Language Arts</strong></td>
<td>ELA.9-10.SL.2.04</td>
<td>9-10</td>
<td>Solve real-world and mathematical problems involving the measurements of circles.</td>
</tr>
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<td><strong>2011 Mathematics</strong></td>
<td>Mathematics.6.G.1.01.b</td>
<td>6</td>
<td>Apply the Pythagorean Theorem to determine unknown side lengths in right triangles in real-world and mathematical problems in two and three dimensions.</td>
</tr>
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<td><strong>2011 Mathematics</strong></td>
<td>Mathematics.8.G.2.07</td>
<td>8</td>
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<td>Write a function that describes a relationship between two quantities.*</td>
<td>Determine an explicit expression, a recursive process, or steps for calculation from a context.*</td>
<td>Combine standard function types using arithmetic operations. <em>For example, build a function that models the temperature of a cooling body by adding a constant function to a decaying exponential, and relate these functions to the model.</em></td>
<td>Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.*</td>
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<td>6b 6c 7a</td>
<td>2a 2b 2c 3a 3b 3c 3d</td>
<td>6c 7a</td>
<td>1b 6b</td>
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<td>The Sound Cats' presentation included a graph of voltages versus distance. While the students did not actually write the equation $v = k/r^2$ plotting the relationship was a good first step in meeting this High School level requirement and connecting the physics of the problem to the math.</td>
<td>McCall students used a recursive Pythagorean algorithm to create the wedges used in their microphone.</td>
<td>Two student groups including one middle school team used the antenna &quot;Gain Equation&quot; $G = 4\pi A/\lambda^2$ to calculate the expect output based on size.</td>
<td>Students identified the location for the microphone by plotting the equation of the parabola and identifying the focus</td>
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<td><strong>Geometry</strong></td>
<td><strong>Expressing Geometric Properties with Equations</strong></td>
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<td>2011 Mathematics</td>
<td>Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.*</td>
<td>Geometry</td>
<td>This was done by some student entries. The McCall MS students in particular demonstrated this standard.</td>
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<td>2006 Science and Technology/Engineering</td>
<td>Distinguish among tension, compression, shear, and torsion, and explain how they relate to the selection of materials in structures.</td>
<td>Technology/Engineering High School Course</td>
<td>The McCall MS students in particular demonstrated this standard. Their reflector was made from cardboard strips and the students investigated concepts of mechanical strength as part of their research and design.</td>
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