Exploring the math behind the press release!

By Dr. Sten Odenwald (NASA/ADNET)

It is simply dreadful to be an astronomer who grew up in the pro-science era of the 1950s and 60s, only to read that our high schoolers now rank 21st in science and 25th in math in international competitions of the 21st Century (PISA). Yes I know our elite students in math and science are still world-class performers according to statistics from the International Science and Math Olympiads. But if you trust the news reports, it seems everyone else has badly lost ground in the international competition for future science careers. At the same time, Fermilab has been closed, the Space Shuttle is gone, while many politicians are demanding that the Department of Education be abolished, and still others decry global warming as a hoax. Not only are we living at a time when our math skills seem to be in decline in the face of trillion-dollar budgets, but the pernicious, Luddite calls for anti-science thinking are in strident ascendancy among our very politicians.

So what, if anything, can one astronomer possibly do about all of this?

I have always enjoyed being an astronomy popularizer, especially through the writing of numerous articles and books, and occasional appearances on radio and TV. With the birth of my two daughters in the 1990's, my professional interests turned from pure research to education. I began to realize that my unique skill was not that I could explain black holes or space weather to middle school students. It was that I could easily see the mathematics behind the science content itself. This singular realization completely re-directed my education efforts at NASA! No, I wasn't going to write still-more scientific boilerplate explaining quarks, and quasars to my next-door neighbor. I was going to try to make a bigger difference by lending my voice to formal education and

subtly influencing the 26 million K12 students in the ‘pipeline’. I saw first hand in the textbooks my children brought home, that their 'word-problems' were largely based upon commerce and economics. Where were the thrilling problems extolling the excitement of science, and specifically astronomy? There were 450 word problems in one Algebra 1 textbook and only 10 had anything to do with space science or astronomy.

In the 1990s I found myself working for NASA, and getting plugged-in to its manifold education activities. You may not know this but NASA has an annual budget for education that is third behind the Department of Education, and the National Science Foundation. Although I began by writing explanatory articles about space weather, and many other topics where science translation was deemed necessary, I realized that this was a waste of my time. Any knowledgeable amateur astronomer could write the same text. As a professional astronomer doing education, NASA wasn’t asking me to be profound, they just wanted me to explain ideas so that teachers could re-translate them for their students. Looking around at the massive collection of NASA E&PO products it dawned on me that one topic area was totally under-represented in the education products we were so busily creating – it was simple mathematics. For some reason, over the last few decades, virtually all mathematical content at the Algebra 1-level or higher had been quietly shorn from the discussions of science and scientific discovery. It wasn’t NASA’s fault. It’s just that teachers had demanded a certain kind of product from NASA, and NASA had obliged them. Teachers wanted heroic and inspiring wall posters to hang on the wall, so that’s what they got. Mathematics is hardly inspiring or visually dramatic to novice, but why was it that everyone was publishing gorgeous NASA images but not including basic scale information such as 'one centimeter = 10,000 km' ?

In 1997, as a new member of the IMAGE satellite education program, I decided to take a chance and create math enrichment resources for students and teachers rather than the traditional posters, bookmarks and other 'science content' products so common at NASA. Initially, I began by developing math

guides for middle school students in space weather - the area of research covered by the IMAGE mission. The popularity of these guides soon led to the idea of posting a new math problem each week featuring a different area of solar and space research. This online resource, *Space Science Problem of the Week*, included unusual problems for middle school students in solar science, auroras, magnetic storms and occasionally astrophysics and planetary science topics too. The problems in a one-page PDF format were eventually collected together into annual math guides beginning with *Exploring Space Science Mathematics* (2003), followed by Space Math I, II, III and so on through Space Math VII in 2011. Teachers and NASA mission educators soon began to request collections of problems on specific topics to support their particular mission, so math guides such as Solar Math, Earth Math, Black Hole Math and other topics quickly followed. Beginning in 2005, I re-named the Weekly Space Math program '*Space Math @ NASA*', with an entirely new website and its own URL (http://spacemath.gsfc.nasa.gov). Rather than one problem each week, I would often be inspired to write considerably more, especially if a particular topic area seemed popular and had readily identifiable math elements at the middle and high school level. But I had to do more than just create space-related math problems. They had to be tied to something dramatic that would catch the eye of a student, otherwise I would be writing the same old sterile math problems I previously complained about. The standard was very high, and the problems had to be authentic glimpses of real science. It did not do to simply take a standard textbook problem and swap the nouns for more spacey terms!

Through its many images, videos and on-line products, NASA has a huge copyright-free resource base that can be called upon to stimulate student learning. What astonished me as an astronomer was just how vast NASA's implicit math resources were. All that was needed was someone to serve as a guide and translator - the perfect role for an astronomer wishing to help the cause of education! But which NASA resource would be the most engaging for students?

NASA has one resource that it updates daily, and that has an enormous public distribution – its press releases! You will find them not only at the main NASA website, but paraphrased in stories covered by online news organizations (e.g. cnn.com) and numerous other outlets (newspapers, TV, radio). By the time you hear, or read, about a dramatic discovery by NASA, it has largely been expunged of its quantitative information. Thankfully, NASA press releases are not completely devoid of mathematical content. In fact, they often contain a wealth of numerical information, occasional graphs in many forms, and of course the dazzling imagery returned by NASA's many space assets. In a moment of inspiration I realized that all one needs to do to re-connect the excitement of space exploration with mathematics is to essentially reverse-engineer NASA press releases! Here's a recent example.

September 24, 2011 **-** NASA's UARS Re-Enters Earth's Atmosphere

"…NASA's decommissioned Upper Atmosphere Research Satellite (UARS) fell back to Earth between 11:23 p.m. EDT Friday, Sept. 23 and 1:09 a.m. Sept. 24, 20 years and nine days after its launch on a 14-year mission that produced some of the first long-term records of chemicals in the atmosphere. The precise re-entry time and location of debris impacts have not been determined."

SpaceMath@NASA Problem 442: The student is provided with a table of the orbit perigees for UARS between July 20 (291 km) and September 23 (160 km). The student plots the data and obtains the classical decay curve shown in Figure 2. The student then calculates the rate of change (slope) of the altitude loss on August 19, September 17 and September 22 in meters per hour. For advanced students in Algebra-2, they are asked to find a function that exactly fits the data, and estimates the re-entry date. For the last step they will readily confirm that the slope changes are not linear in time but follow a more complex 'exponential' decay represented by an equation such as

$h = 291 - 6e^{3x^{3/2}}$ where x is the time since July 20 normalized to 65 days so x = t/65days. This is a challenging empirical function to match to the data, and students are free to discover other functions that fit the data better. They will find among other things that common linear regressions are useless. Teachers may also provide students with only the data between July 20 and September 17 so that they can make their own extrapolations for the re-entry date.

Thanks to the coupling of mathematics with press releases, I have been successful in promoting mathematics within NASA. Its many science missions understand that 'STEM' education requires mathematical content, and so I have developed a growing partnership with all of the operating NASA missions to help them create more math-ready products. It's a great symbiotic relationship. I get to create lots of very fun math problems for mission press releases, and students get exposed to the math behind-the-scenes. The NASA missions get some engaging math problems to offer their teachers during workshops. Teachers get to use these problems as a supplement to all the boring economics problems they find in their textbooks. Let's face it, would a student rather use NASA's Chandra Observatory data to estimate the diameter of a black hole in a distant galaxy, or calculate the distance their family car traveled to get to Grandmas house? Would they rather use NASA's Kepler mission data to estimate the number of Earth-like planets in their habitable zones in the Milky Way, or would they prefer to calculate the number of Hip Hop Music DVDs published in 2007? It's a no-brainer to me, and to young students who are interested in science.

Even though maintaining *SpaceMath@NASA* is a stimulating activity for me and I am seldom bored by it, I honestly have to say that I do have my darker moments despite the huge support I have from thousands of teachers across the country, and on the international scene. I distress over the fact that I have been at this effort for a decade or more, but I still feel that I am walking on the 'Third

Rail' of education in the US. I often feel outside the main-stream of education resource development. My NASA colleagues are happy that I provide them resources free-of-charge, but I know that once my grants expire, and with no renewal to be expected, my experiment in math education will vanish into oblivion. Luckily, I have many more good days that darker ones and here's why.

I used to write dozens of popular-level articles about big bang cosmology, string theory, space weather and many other exciting topics. I never got a single impassioned letter from a reader that said I had changed their life or point-of-view. Today I get almost weekly emails from teachers who tell me about students who used my math problems and got very excited about astronomy. I think back to my own formative years in grade school; passionately interested in astronomy but struggling in mathematics. I never got to see in my K-12 experience just how math was connected to astronomy.

As I sit and pen my latest math problem from a NASA press release, I get that wonderful warm feeling that I have finally come full circle. This problem will inspire that long-ago child in me, and students in other classrooms around the world. It will help them make the math-science connection as they dream about being the next generation of scientists. I can think of no better legacy!

Figure 1 – A screen shot of part of the SpaceMath@NASA home page showing a few of its many offerings (http://spacemath.gsfc.nasa.gov)

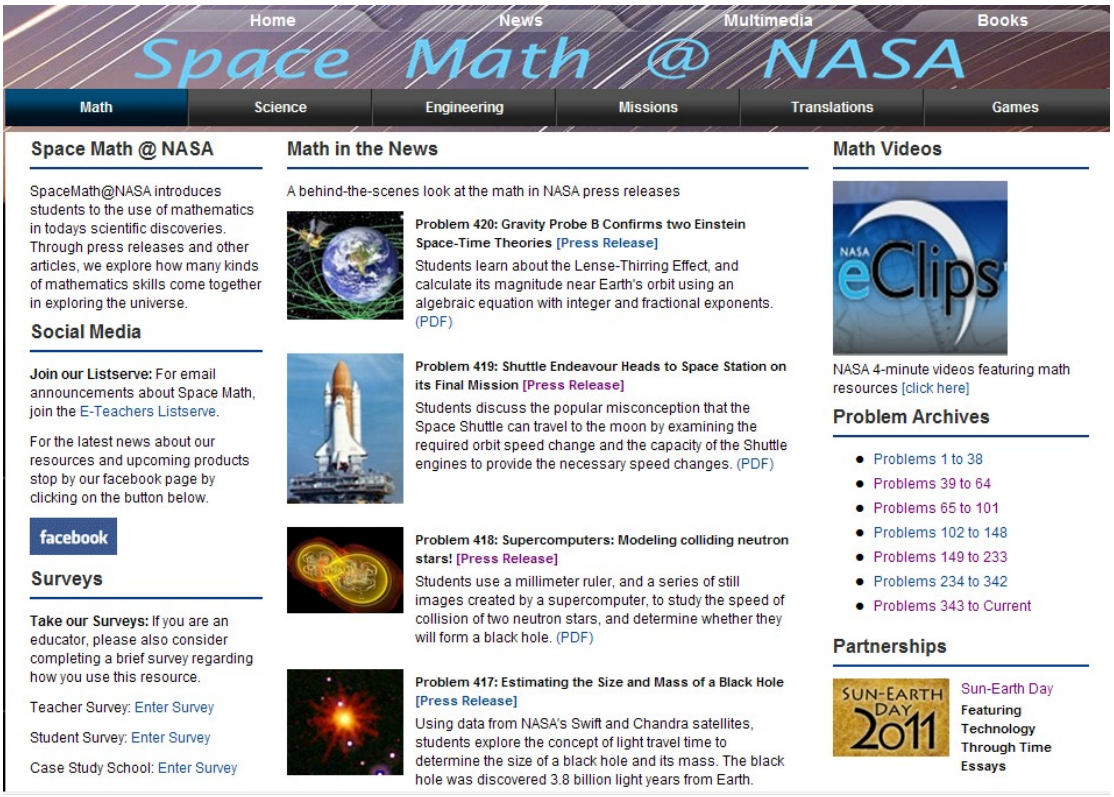

Figure 2 - Decay of the UARS satellite between July 20 and September 23, 2011.