

DRAFT

A Thought Piece on the Future of America's S & E workforce
Spence M. (Sam) Armstrong; NASA HQ.

"To be or not to be; that is the question. Whether 'tis nobler in the mind to suffer the slings and arrows of outrageous fortune, or take up arms against a sea of troubles, and by opposing end them?" This very familiar soliloquy by Hamlet comes from Act III, scene 1 of one of Shakespeare's most famous plays. (Hamlet is filled with other quotes that we use today although many are unknowingly attributed to other sources—even the Bible!) He delivers this speech after he has come to the conclusion that his father, the late king of Denmark, was murdered by his own brother who within a month married the queen, Hamlet's mother. He is struck by an obligation to see justice done and atone the shame of his mother's hasty marriage that dishonored his father's memory. It has already been reported earlier in the play that Norway is arming to revenge an earlier victory by Hamlet's father. He thinks he has a crush on Ophelia but is not sure how she regards him at this time. In today's parlance Hamlet was having a "bad hair day".

A modern day reviewer would say that Hamlet was conducting a "risk assessment" process with himself. What, when and how could he redress the situation and what were the risks associated with any of his actions. He continues on in the soliloquy that if he does nothing he might as well die. He decides on action rather than inaction. However, there are many subsequent events in the play that he is not anticipating at this time and which cause him to alter his course of action. Whether these events caused him to go mad or whether it was a pretense on his part to gain some time is a debatable point. By the end of the play, there are dead bodies all over the place that could cause madness in all the remaining characters.

There are some similarities in the situation that Hamlet faced in the play and the situations we see on many fronts today. In October of 2001 the Government University Industry Research Roundtable (GUIRR) devoted the two-day session to examine the adequacy of the Science and Engineering (S & E) workforce now and for the next decade. It posed for itself three questions—unlike Hamlet's one question:

- What is the status of the S & E workforce now and for the next decade?
- If that workforce is inadequate for the nation's needs, what's the risk?
- If there is a risk, what can be done to mitigate it?

To deal with those three questions, some assumptions emerged:

1. The S & E workforce must be viewed as a **national pool**. Government, industry and academe each have their needs. If the pool is inadequate to meet all of those needs, then an impact occurs somewhere.
2. Foreign workers have been a talent source in the past to supplement the indigenous workforce. The trends in the past few years are for fewer

foreign persons to study in this country and for fewer of them to seek to stay. The events of 9/11 will only exacerbate the prospects of relying on foreign persons to take up any slack that might exist in the future.

The presentations made to the GUIRR by experts from government, industry and academe painted a dismal picture of the future. The number of U.S. citizens going into S & E (excluding life sciences) has recently dropped. The minority representation in the S & E workforce is only one third of the representation in the population at large. There seems to be no improvement in those ratios although they are forecast to grow as a larger percentage of the overall population. There is a wide spread concern over the adequacy of our S & E workforce but there is no concerted effort to address the remedy. As one participant said: "What we have are a thousand random innovations".

Subsequent to the October GUIRR meeting, there have been three more articles published. Kent Hughes of the Woodrow Wilson International Center for Scholars published a "Point of View" in the November 30 issue of The Chronicle of Higher Education. He points out the close coupling of federal spending for R & D and the production of S & E workers. The following is an excerpt from his piece:

"But since the cold war's end, the relative stability of total national spending on R & D has masked some key trends. According to the National Science Foundation, the federal share of the national research dollar has declined markedly over the past 15 years. In 1985, industry and government spent roughly equal amounts on R & D. By 1998, private-sector spending was 65 percent of the total while federal spending had slipped below 30 percent. Over the same 13 year period, federal support for the life sciences, relative to the size of America's economy (or gross national product), grew by just over 7 percent, while funds for the physical sciences were down 29 percent, engineering 21 percent and mathematics 15 percent.

Promising better health and longer life, the life sciences have gained public and political support. But the decrease in funds for the physical sciences and engineering has not been so much the product of a conscious strategy as the unintended consequence of the post-cold-war reduction in defense spending. The steady increase in private sector R & D has made American industry more competitive, but has not replaced federal support for non-biological basic research or high-risk technologies. Moreover, graduation rates for science and engineering graduates have roughly paralleled these spending trends—with life sciences degrees on the rise, and the number of new physicists, chemists and engineering falling"

Also from The Chronicle of Higher Education November 26 issue Elizabeth Farrell writes about the production of Ph.D.'s from data recently released by the University of Chicago. She notes that the number of doctorates awarded by American research universities rose slightly from

1999 to 2000 which reverses a slight dip in the previous year. She reports that life sciences registered the largest growth at 4.7 percent and physical sciences down the most at 4.1 percent. Her report adds confirmation to Kent Hughes' "Point of View".

The sub-heading of a November 21 article in The Washington Post reads: "12th-Graders' Skills Declining, Nationwide Study Reports". The opening paragraph sets the tone: *"More than 80 percent of the nation's high school seniors lack proficiency in science, according to test results released yesterday that provide another alarming sign of the huge task confronting educators as they seek to reform the nation's schools"*. This is slightly worse than four years ago which prompted Education Secretary Roderick R. Paige to comment in the same article: *"If our graduates know less about science than their predecessors four years ago, then our hopes for a strong 21st century are dimming just when we need them to improve most"*.

Hamlet would see the alarms expressed in these three articles as "a sea of trouble". Ernest Thayer expressed the same dismal outlook in his 1888 poem Casey at the Bat *"The outlook wasn't brilliant for the Mudville nine that day"*.

The GUIRR's first question was answered in convincing tones—it certainly looks like we are headed for a shortage of S & E talent in the coming decade. It didn't take much discussion or imagination to conclude that we don't like the answer to the second question concerning the impact of a shortage. Will this result in a further imbalance of trade? Will our quality of life decline? Dare we risk these eventualities and others that we wouldn't like? It might be appropriate to commission a study to forecast the impact in more specific detail.

This brings us to the third question the GUIRR posed for itself: What can we do to mitigate that risk? Or as Hamlet said: *"take arms against"*. Under its charter, the GUIRR cannot make recommendations. This principle was deemed necessary to permit a wider exchange at the roundtable. In lieu of recommendations, the GUIRR ensured that there were complete minutes of the meeting that can be made available to individual members for their individual/collective use in mitigating the risk. In the meeting, this was addressed in the closing session entitled: "The Way Ahead". It is hoped that the March 2002 GUIRR will be devoted to a follow-up of the last roundtable where members can bring forward their mitigation efforts for all to consider.

In the meantime, NASA intends to take some action on its own and in collaboration with other agencies who have similar concerns. It is assumed that the minutes from the October roundtable are useful as a basis for establishing the answer to the first two questions. NASA's intent is to proceed on two fronts.

The first front is a broad gauge one. Keying to the comment "a thousand random innovations" there are already initiatives underway which promote generating a larger S & E workforce. This must be recognized as a

positive thing. What needs to be done is to create an initiative to get everybody “generally headed west”. The NSF has the charter that makes it the obvious leader of the initiative. The initiative will have to be promoted and acknowledged as a national imperative that involves the whole nation. All of the stakeholders—government (Congress and the Administration), industry and academia—need to reach a consensus on the process. There needs to be developed a set of metrics to highlight the most cost effective innovations. NSF should provide a periodic forum for the sharing of best practices.

The above front does not single out specific S & E needs over the next decade. Under the theory that “*a rising tide lifts all ships*” the objective is to restore the appreciation of R & D that has traditionally existed in this nation. The overall talent pool must be high enough to provide 240,000 new mathematics and science teachers to the K-12 system over the next decade. Otherwise any gains realized at the higher education level cannot be sustained by the next generation.

The second front is much narrower and specific. There are some disciplines for which the government “makes the market”. For example there is no industrial need for hypersonic aerodynamic unless a government requirement exists. Other examples are nuclear thermal rocketry, planet sample protection, interferometry, and others that can be extracted from government strategic plans.

The process that NASA intends to follow is as follows:

- Estimate the 10-year **requirement** for the workforce needed in each specific discipline.
 - List the technology required for that period.
 - Derive the specific disciplines required for the development, application and execution of those technologies.
 - Ask other agencies to do likewise for their requirements and aggregate those at the government level.
 - From past programs, estimate the number in each discipline that private industry will need to respond to government assuming that there will be competition rather than a sole provider.
 - Summing the above, estimate the discipline resources that academia will need to sustain the pipeline for that number.
 - The summation of all of the above provides an estimate of the national pool **required** by discipline.
- Estimate the **supply** for each discipline.
 - Engage the professional societies that represent these disciplines to obtain the current demographics (including academia) by level of education and experience, and future working potential
 - This may require some surveying of members.
 - Determine which universities are foremost in these disciplines.
 - For the above, tally the level of research current and anticipated.

- The summation of the above will provide an estimate of the **supply** by discipline.

NASA will match the requirements against the supply to include all of the stakeholders and institute a comprehensive program to close the gap. The NSA “Cyber Force” model which was briefed to the GUIRR is a good starting point.

The fallacy of the NSA model is that it doesn’t deal at the national level of requirements. Can industry and academia’s requirements be factored into the equation in an equitable way? The answer is yes but not easily. If a combination of the ROTC and the National Football League (NFL) were to be employed, it could work. For the former, students who get scholarships will have to serve in the summer with one of the sponsors and will incur a service obligation of a year for each year of support. The NFL part has to do with draft rights and free agency.

Take the example of hypersonic aerodynamics. If the requirement for all of the stakeholders is estimated to be 100 for a given year but the estimated supply by the various educational levels is only 50, then there is a 50 person shortfall. Because it is a comparison of two estimates, provisions are not made to cover the total shortfall. Rather some percentage of the shortfall becomes the target. In the above example, one choice would be to expect at least 50 percent production after attrition could be a reasonable objective.

Using the NSA model, NASA will solicit proposal from universities who wish to provide the disciplines. After those are selected, some government investment in research will be required to prime the pump. A solicitation would be issued (probably by the individual universities) for scholarships at the various educational levels. If one industry partner would like to have the draft rights to 5 graduates, it would have to provide the scholarship money and summer employment for that number. The universities would support their needs through methods that are available to them to include fellowships from organizations like AIAA.

For all of this to work, there will need to be some policy and legislative actions taken by the government. OPM would provide the enabling legislation as in the NSA model. OMB would especially identify the funds necessary for research and scholarship required. This may be new money or might have to be apportioned to the government identities. Furthermore, it might be useful to create a semi-government agency such as Americorp to administer the program at the national level. Or a selected university could administer the research and scholarship for which we have funded them.