Supplement to *Projecting Science and Engineering Personnel Requirements for the 1990s: How Good Are the Numbers?*, the Record of Rep. Howard Wolpe's Hearing Before the Subcommittee on Investigations and Oversight on April 8, 1992, illuminating obscured graphs, handwritten comments, smeared photocopies used to master the printing, and infelicitously dark highlighting amplified by several generations of photocopying (as opposed to intended redactions).

I have generally **highlighted** discerned text and inserted question marks where doubt appears. Hand-written annotations are additionally indicated by using the **Simpson** or *Mistral* type font. Most — but not all – words enclosed in brackets are my own comments when marked by initials RLM. Please notify me of any corrections. Thanks to Ms. Linda Mitchell of Mt. Vernon, NY, and Mrs. Joan Conner of Memphis, TN, for interpreting the shorthand, though any errors are mine. – Ray L. Marr (512)282-6888

pp. 63-97: "Demographic Trends and the Scientific and Engineering Work Force – A Technical Memorandum" (Dec 1985). US Office of Technology Assessment (Washington, DC: US GPO, OTA-TM-SET-35). Figures 1-1 – 1-12 from Wolpe's hearing record are compared with the Internet pdf copies at http://govinfo.library.unt.edu/ota/OTA 4/DATA/1985/8507.pdf :

1-1 labeling is clearer on Internet but needs work;
1-2 is better on Internet (see "Academia & Other" labels and slices);
1-3 is better on Internet (see "Academia & Other" labels and slices);
1-4 is better on Internet;
1-5 is better in Wolpe hearing record;
1-6 is better on Internet;
1-7 is better on Internet;
1-8 is bad in both; I have readable images of this graph;
1-9 is bad in both sources; I have clear images of the two graphs of Fig. 9;
1-10 is bad in both sources; I have clear images of the two graphs of Fig. 10;
1-11 is bad in both sources; I have clear images of the two graphs of Fig. 11;
1-12 is better on the Internet or in Allan Cartter, *PhD's and the Academic Labor Market* (NY: McGraw-Hill, 1976), p. 129.

p. 102: "Jesse Ausable" [sic] should presumably be "Jesse Ausubel."
p. 166: 3. Dir, OLPA|PAG 3-31-87 JL for KL [Joyce Latham for Karen Lebovich]
* - SRS should OK this too
- check with SD [Shirley Day], OLPA, before any Congressional distribution

reviewed by Marta C[Marta Cehelsky] who's doing a pipeline brochure for more general audience. She notes that there are some typos in this ms., and misuse of principal/principle. See also her comment re p. 18.
Joyce L[Joyce Latham], OLPA 4-3-87

p. 167: Request for Printing , Reproduction, and Distribution of "The Science and Engineering Pipeline" (3/27/87)
8. Carol S. Bochart
9. THE SCIENCE AND ENGINEERING PIPELINE PRA 87-2
14. 28 pages, 1000 copies
20. Light Blue Cover Page, Saddle Stitch Staple,
Disclaimer and TDD on back of front cover, Preface to appear on single page (nothing on back)
25. Please deliver remaining copies to Roger Shull, Room 1233 *How many by bulk mail?*
OLPA J Latham for K Lebovich 4-3-87

p. 168-169: PRA 87-2
2. *Ck w/ [Check with] Shirley Day before sending to Congress – J Latham OLPA*
11. Estimated Costs:
a. for printing: $520.00 (in house)
b. for distribution: $0 (internal distribution) *est. 12.5 cents each*
c. funding source: program funds
organization code: 04010000 087 5733
12. Plans for update or reprint: No reprinting anticipated.
13. Alternatives: Offset printing from camera-ready copy is acceptable.
14. Timetable: For maximum utility, report should be available in early April 1987
Peter W. House

p. 171[handwritten annotations] *MW – add to PRA file*
JL [Joyce Latham]

(orig'l MS. is on my "guest chair" for PRA pickup 4-13
OK – MS. returned to PRA, 4-13. JL [Joyce Latham]

p. 252, Table 1: [consult original in American Association of Engineering Societies Engineering Manpower Bulletin #105, Oct 1990 for more readable copy; I have recovered most of the obscured words; phoned 202-296-2237; archives are in storage and can be accessed only with great difficulty and expense].

THE ORIGINS OF A NEWSPAPER STORY ABOUT FUTURE SHORTAGES OF ENGINEERS: FROM THE NATIONAL SCIENCE FOUNDATION TO THE FREDERICK, MARYLAND *POST*

Source	Statement	Attribution
Unpublished working draft Papers by the Division of Policy Research & Analysis (PRA), National Science Foundation, 1988-1999	Cumulative shortfall of 540,000 people with bachelor's degree in the natural sciences or engineering by the year 2000; shortfall will reach 675,000 by the year 2006	Not Applicable (original source)
Interim report by the Congressionally-chartered Task Force on Women, Minorities, and Physically Handicapped in Science and Technology (1988)	By 2010 we could suffer a shortfall of as many as 560,000 science and engineering professionals	Not stated in the report, but based on one of the early draft papers from PRA/NSF
New[s Item ?], **Chronicle of Higher Education (1989)**	Shortfall of 560,000 scientists and engineers by 2000	Pre-publication announcement of the Task Force Findings
Press release, Women's College Coalition, 1989	Net shortfall of approximately 750,000 scientists and engineers by the year 2000	Not stated, but taken from the *Chronicle*
News story, *Frederick (Maryland) Post, 1990*	Shortage of 750,000 scientists and engineers by the year 2000	Women's College Coalition

Note: see text and accompanying bibliography for formal citation of these materials.

p. 326, handwritten annotation on memo from Peter House to NSF Deputy Dir [Hancock?] (22 Dec 1988):
" => [implies] no purpose in seeking to elevate salaries. That's not a useful policy option. Should focus instead on better preparation.
Caveats:
(1) Have they focussed on the right premium? Sounds pretty comprehensive.
(2) If there were better preparation, the supply might be more elastic. Also the period of analysis was one during which preparation might have been deteriorating. If so, the premium may have operated to offset what otherwise could have been a significant decline."

p. 472, lines 2-3: "MR. WOLPE. Okay, your analysis came under other criticism in the late 1990s [sic-- Wolpe should have said "1980s" -- RLM].

p. 478: Twice Marta Cehelsky typed "shorfall" for "shortfall" on this page -- RLM.

p. 514, Dir. OLPA/NSF
SHORTFALL:

ROUTING SLIP National Science Foundation
1 *Mrs. Faye [Taye?]* *OBAC* *9*[=For comment]
2 *Mr. McCullough* *OBAC* *9*[=For comment]

Room 425

FROM *R. Bye* DATE *1/18* ROOM NO. *527*
ORGANIZATION *OLPA* TELEPHONE NO. *9838*
REMARKS-
This is a first cut at a statement. Could you please give me comments by C.O.B. Tues. Jan. 22, 1991?
NSF Form 35, August 1988 [OBAC = Office of Budget & Control, a staff office of the NSF Director -- RLM]

p. 642-655: "1992 Employment Outlook" by Bette Hileman and Rebecca L. Rawls, *Chemical & Engineering News*, vol. **50**, 21 Oct 1991, pp. 30-42 & 45. [Get more readable copy – pp. 30-33 & 36-37 have dark smudges]

p. 693: handwritten and shorthand annotations on Erich Bloch's oral statement before Senate Committee on Labor & Public Welfare.

THE PEOPLE PROBLEM

AS THE SOCIETY BECOMES MORE DEPENDENT ON TECHNOLOGY WE WILL NEED ~~A~~ *more of* ~~LARGER FRACTION OF~~ OUR POPULATION EDUCATED IN SCIENCE AND ENGINEERING. A CONSEQUENCE OF UNDERFUNDING BASIC RESEARCH, HOWEVER, IS THAT ~~THIS FRACTION IS DECLINING~~: WE ARE ATTRACTING TOO FEW YOUNG PEOPLE TO THESE AREAS.

CHART 6: TWENTY YEARS AGO THE UNITED STATES HAD FAR MORE SCIENTISTS AND ENGINEERS PER CAPITA THAN ANY OF OUR COMPETITORS. TODAY THIS IS NO LONGER THE CASE.

CHART 7: THE PROPORTION OF OUR YOUNG PEOPLE WHO ARE BEING ATTRACTED TO SCIENTIFIC AND ENGINEERING PROGRAMS IS DECLINING. *as a % of pop.*

CHART 8: EVEN IF WE COULD CONTINUE TO ATTRACT STUDENTS AT THE 1983 RATE, THE DECLINE IN NUMBERS OF 22 YEAR OLDS MEANS THAT WE WOULD PRODUCE NEARLY 700,000 FEWER BACCALAUREATES IN THESE FIELDS IN THE NEXT TWENTY YEARS.
[in shorthand]
If we assume that the same rate of people enter the profession as in '83, [we] might have a shortfall.

CHART 9: INCREASINGLY, WE ARE DEPENDENT ON FOREIGN NATIONALS FOR NEW PHDS IN ENGINEERING, MATH, AND PHYSICS – THE MOST CRITICAL DISCIPLINES OF A TECHNOLOGICAL SOCIETY.
[in shorthand]
Briefly, we benefit from this trade since many people stay and join the workforce several years[?] . It depends on a workforce that is not under our control and would be short of our own men. 9

p. 695: "The projections also show an **overall balance** between supply and demand for engineers for the rest of the 1980s. **The** shortage of engineers that has **received so** much public attention in the past few years has been limited to a few specialists – electronics, computer design, and petroleum engineering – and **certainly** does not justify massive efforts to change basic [curricula].

p. 725, Memo of SRS Div Dir Charles E. Falk to STIA Div Acting Dir on 8/30/1984 Asking PRA Non-Interference with S&E Manpower Reports (BCC Stewart and Charles Dickens), filing annotations [SRS A-22, (Charles Dickens') SRS FILE: STIA/PRA] and one sentence obscured: "**As must be obvious from the title**, **this is [???????] which** ?????????????????????? **SRS since it lies at the core of its** ??????????????????????????????."

p. 727, Letter from Bernard R. Stein to TRP Section Head with Draft Paper (Req. By Erich Bloch) on NSF's View on Means of Coping with Graduate S&E Inadequacies, Annotated by Charles Dickens:

> "The attached draft paper with comments added by Charles Dickens, SRS [Science Resources Studies] was written by and provided by Jim McCullough, OLPA. Requested by the Director, NSF, **the paper purports to reflect his view that goverment intervention may be necessary and** desirable to deal with current and prospective graduate S/E [Science or Engineering] manpower deficiencies. McCullough is of the opinion that the Director, NSF may be considered an 'interventionist' in the sense of contributing through government action to the correction of market imbalances in S/E graduate manpower. Possible policy options mentioned include those in the attached paper. The Director, NSF has not yet gone on the record with any view on this matter, and there is no indication as to when or whether he will."
>
> Attachment should not be circulated further or quoted.

pp. 728-730:

10/18/85

Q: Are there now or will there be significant shortfalls in the production of science and engineering doctorates ?

A: Shortages exist now in some critical fields and, unless Ph.D. production is increased, shortages ~~will~~ be larger and more widespread in five to ten years. (^ may)

Shortage depends on demand as well as supply.

Summary:

Latest information shows current shortfalls in mathematics, computer sciences and some fields of engineering – largely due to increasing industrial demand and a dropoff in the number of graduates in these fields.

Faculty shortages exist in engineering and computer science. Decline in number of new PhD's mainly in mathematics.

Forecasts of future production are notoriously difficult, and existing ones are outdated. But the factors that affect supply and demand are known, and application of these factors in a "common sense" way needs to be stepped up, particularly in certain fields related to future industrial leadership.

Current: (latest data: 1983)

employed science and engineering

- The nation has a total of 370,000 ^ doctorates.

employed S/E

- Life scientists comprise ¼ of ^ Ph.D.'s, ~~all~~ engineers 1/6, physical scientists 1/6, social scientists 1/6, psychologists 1/8, math & computer scientists 1/12.

- The relative distribution among fields is changing, with faster growth in computer sciences, slower in physical and mathematical sciences.

- The total has increased 68% in last ten years, due to a growing industrial demand plus some increases in academia.

Rate is not clear It could mean many things.

number of new doctorates awarded

- but the highest ~~rates of production~~ were ^ in the early 1970's, toward the end of a growth surge in doctoral programs during the 1960's.

between 1972 and 1978

– ~~in fact, each year since 1973~~ the number of S/E doctorates produced has declined, with dramatic declines in several fields. Since 1978 there have been small annual increases in doctorates because of increased participation of women and, in engineering, of foreign citizens.

– For example, the number of Ph.D.'s awarded in the physical sciences in 1982 was half that of ten years before.

Not correct. No field dropped that much. The largest drop was in mathematics from 1,211 to 699, a decline of 42% between 1974 and 1984. Since the 1974 number included computer science and the 1984 number did not, the 1974 number should be adjusted by (-198, the NCES figure). The comparison for the adjusted figure would be a decline from 1013 to 699, a drop of 31%.

- A lot fewer U.S. citizens are receiving the doctorate. In the last five years, the participation of foreign students in doctoral programs has increased. Both the number and the share of doctorates awarded to foreign students are continuing to go up.

4

– in 198~~3~~ about 20% of the science doctorates and 55% of the engineering doctorates were awarded to non-U.S. citizens

Demand in the Near Future (5-10 years):

- With an expanding economy and more competition from other countries, industrial demand will be up in fields where firms depend heavily on R&D to stay ahead, e.g., electrical engineering, chemical engineering, biology and biotechnology, and computer sciences.

Why biology and biotechnology?

- Higher defense outlays, from both already-approved programs and those being formulated (e.g., SDI), will create even more demand in those fields and some others (e.g., astronautical engineering). Impact of SDI is dubious over next 5-10 years.

  Mechanical engineering may also be affected.

- The largest share of doctorates is employed in academic institutions. Faculty hired in the buildup of the 1960's will need to be replaced in the 1990's due to retirements and deaths.

- In addition, the education level of the general population has risen with each generation. The S/E [science and engineering] doctorates will gradually come to be viewed as a minimum requirement for mere non-research positions in production and management

[three uncertain handwritten bulleted comments on last bullet: -- RLM]

  - no amount
  - study thing
  - forecasting!

Supply in the Near Future:

- The number of U.S. 18-24 year olds is beginning to drop and will continue to do so through the early 1990's.

- The percentage of college entrants who state their intention to major in S/E fields has been constant for 25 years (about 30%).

  More significant may be the fact that about 30 percent of all bachelor's degrees have been in S/E fields for the past 25 years.

- Thus, unless a much higher proportion of college-age youth decide to study for the bachelors in S/E fields, the supply of U.S. citizens qualified to enter doctorate programs will continue to decline.

  Actually, except for Iran, foreign enrollment has grown about 3 percent a year.

- The influx of foreign students, while welcome, is subject to abrupt stops and starts due to political changes over which the universities, and in many cases the Federal government, will have little control.

  - In any event, a large proportion are committed to returning to their countries and will not be available to U.S. industry or academic institutions. But more are staying in the U.S. to work .

What should be done now to boost future production:

Doctorate production involves a long pipeline, from initial pre-college exposure through undergraduate work to completion of requirements. Students make choices all along the way as to whether to proceed or quit. Universities, industry and the Federal Government can take several actions to make careers in S/E, and particularly doctoral work, more attractive.

A larger national research investment in selected fields would:

- Permit expansion of fellowship programs and other direct support to doctoral candidates (the proportion that received v Federal support dropped to 11% in 1984 from 17% in 1978). direct
- Allow more new Ph.D.'s to initiate research careers in academia, including through special efforts such as PYI's.
- Improve conditions for researchers by, for example, providing more up-to-date equipment.
- Create more opportunities to involve undergraduates in research, thus encouraging them to go on to graduate work and research careers.

But to be most effective, this must be supplemented by a much greater effort to develop interest and competency at the pre-college levels and to sustain them at the early undergraduate level.

p. 738-741, "Manpower Modeling: Scientific and Engineering Personnel" Draft (11/2/1085) from Myles Boylan with Comments by Leonard Lederman:

Myles Boylan:
Comments, suggestions, questions, notes on text. Let me know if any require clarifications. Thanks for sharing this with me.
Len Lederman

Manpower Modeling: Scientific and Engineering Personnel

Introduction

Very significant! ! Manpower is one of the most "durable" inputs into the production of goods and services. A typical specialized employee is employed for more than 40 years. This person's skills can be "upgraded" (or modernized) by on-the-job work experience and periodic doses of continuing education. Substitution opportunities among labor force participants with different types of training requirements are very high for occupations in which specialized knowledge and skill requirements are low and for young members of the labor force. They are still moderately high for middle-aged members of the labor force and for occupations with fairly stringent skill requirements.

These special features of labor markets have important consequences for science and engineering manpower modeling. Each year an uncertain number of the stock of (previously trained) scientists and engineers switch from S/E occupations to occupations whose S/E skill requirements are limited or low. Another (unknown) number of labor force participants with some S/E training move from non S/E occupations to S&E occupations. Outflows occur for a variety of reasons (including career advancement) although they probably increase during periods of low growth in demand for scientists and engineers. Backward flows into S/E occupations are probably larger when demand grows more rapidly than the flows of newly trained scientists and engineers. These partly compensating flows, coupled with the flow of new degree-holders, define the supply demand balance at any point in time.

A major modeling problem is that data on flows into and out of S/E occupations by labor force participants with some S/E training is not compiled either systematically or accurately. And, although data describing the annual flow of new degree holders (trained in fields of S/E) into S/E labor markets is systematic and accurate, this flow comprises only a small percentage of the total supply and total employment of scientists and engineers (less than 8 percent in 1982, using the NSF definition of practicing scientists and engineers).

A second major problem is the poor quality of information available from the equilibrium "price" as determined by the supply-demand balance. Whereas prices of raw materials and manufactured products tend to move strongly up and down in response to spot shortages and surpluses, this is clearly less evident in the case of salaries for scientists and engineers. For example,* during the recent demand induced spot shortages of engineers and computer scientists during 1979-1981, a 1981 NSF survey of 255 industrial firms indicate that 43 perent responded with increased recruitment efforts while only 30 percent explained by the fact that relatively low levels of market information are available to "buyers" and "sellers" in labor markets in comparison to product markets, and substitution probabilities are more numerous. It is also important to recognize that "sellers" are not offering identical skills and services, partly due to different levels of training and experience, but also as a consequence of different levels of innate ability for a given level of training and experience. For this reason equilibrium "price" has more operational dimensions in labor markets than in product markets. In addition

? Doubt this

*Reason for this is probably that the higher demand was for engineers & computer scientists <u>with</u> experience, I'll bet.
The salaries of these went up more than starting salaries of others.

*** I Don't AGREE WITH THIS PRESUMPTION/CONCLUSION. WE HAVE MORE support DATA IN S&E** -2- **SUPPLY DEMAND THAN ANY OTHER OCCUPATIONAL ?GROUP I KNOW. ?Anyhow __PHYSICAL PRODUCTS** [?**not**/?are] **RELEVANT.**

to gradation in quality for labor market entrants (the labor market equivalent, ? Not clear of newly manufactured products) there are salary structures within employing organizations reflecting the value of additional increments of job specific training and experience. Large variations in entry level pay would require adjustments in the entire salary structure in most organizations, and these adjustments tend to be made in the long run rather than in response to spot Yes shortages and surpluses.

The last ?? **is not** ?????????????????????????????????. There are major definitional problems as well. What is a scientist or engineer, and what are S/E occupations? NSF relies strongly but not completely on the judgment of those individuals with college degrees in S&E about their own professional status, and considers all individuals with earned doctorates in S/E to be scientists and engineers. The Bureau of Labor Statistics (BLS) provides surveyed employers with a list of occupations and relies on their judgments about which occupational label to assign to each of their employees. In 1982, the BLS reported a total stock of 1,870,000 S&E's (at all degree levels of training) employed in S/E occupations, only 57 percent of the NSF estimate of the total stock of S&E's (3,253,000). The NSF definition attempts to measure the potential S&E labor force while the BLS definition attempts to describe actual S&E employment. The ratio of BLS to NSF stocks fluctuates from year to year, indicating compensating shifts into and out of S&E employment if the NSF and BLS measures are accurate.

CREDIT OR WHAT? AND ????? ???? potential.

Why is "natural" more predictable than other scientists in terms of "new degree holders"?

Bachelor's Level Scientists and Engineers

The aggregate annual supply of new degree holders in the natural sciences and engineering is the most predictable component of manpower modeling. Disaggregate annual flows of new degree holders are much less predictable, as A consequence of field switching in response to market signals and to periodic exciting breakthroughs in specific fields of science.

?

Aggregate annual flows of new S&E degree holders have proven to be highly predictable as a percentage of the college age population over the last 25 years, irrespective of the percentage of this population actually enrolled in undergraduate programs of all types. **Only the ____dest exception** ????????? ?? ?????? **for computer science** [PhD?] **degree holders.** The stability of this link between the size of the college age population and the annual flow of new degree holders in the natural sciences and engineering can be explained by a number of factors, although these factors have not been carefully studied. Yes

The fraction of the college age population with the necessary ability, pre-college training, and interest in these fields has evidently not changed among males, and is apparently rising at a stable rate among females as sex role employment stereotypes are diminishing. With the exception of engineering and some computer science degree programs, the specific skills learned are not critical to many first employment opportunities available to new undergraduate degree holders, a feature these degree programs have in common withmany other degree programs in the social sciences and humanitites. The acquisition of a bachelor's degree is perhaps at least as significant as the choice of major ?field. ← Not clear what this means.

Doubt this. W????? is nosed out?

We must [?OK a subsidy for student?]
this ??????.

The demand for new undergraduate degree holders in the natural sciences and engineering is much less stable than the aggregate annual flow. There are a number of reasons for this instability. (It is also important to recognize that many undergraduate degree-holders planning to work full-time after graduation do not expect to find employment in science or engineering occupations, and many others plan to enroll in graduate programs or professional programs.) Yes

A major reason for the lack of demand for many new degree holders is the size of the stock of experienced degree holders relative to the supply of new degree holders. When demand for scientists or engineers diminishes, the preferential position of recently unemployed experienced degree holders in filling new openings has a magnified effect on reducing demand for new unexperienced degree holders. The process also works in reverse, with growing substitution of new degree holders in other related fields when growing demand is not satisfied by new supplies in the field experiencing growing demand.

variability as compared to physical, life, and math which have __?__

The ~~instability~~ of demand for new degree holders in S&E has been far more visible in engineering and, recently, in computer science[,] than in the life sciences, physical sciences, or mathematics, for the simple reason that the annual number of new degree-holders in engineering has more closely matched the number of job vacancies. The bachelor's degree has been considered adequate basic training for most entry level positions in engineering, and the likely that most engineering majors would so severely constrain their undergraduate curricula choices unless they expected to find employment in Xengineering after acquiring the BS degree. ← Not the right reason. Reason is few electives allowed in required cur[r]iculum. Yes

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In the other fields **(in the natural sciences), the annual number of bachelor's Level graduates has for decades far exceeded the acquiring employment in their bachelor's fields**, with the result that spot shortages have not been experienced, and large numbers of past graduates no longer consider themselves to be a scientist (unless they acquired advanced degrees). **In these fields, it would appear that future supplies will be adequate to met new demand even if the annual flow of new degree holders diminishes considerably due to the declining size of the college age population.**

PhD Level Scientists and Engineers

Our understanding of the supply and demand for new degree holders at the PhD level is ~~inversely related to our understanding of these forces~~ at the better than bachelor's level occupations, and the majority are associated with training and teaching, or research and development (R&D). Consequently, the demand for new PhD's can be strongly linked statistically to job openings in academe and to R&D expenditures.

The relative importance of faculty vacancies and R&D spending in determining the future demand for PhD scientists and engineers varies considerably by field. He majority of PhD life scientists, mathematicians, and physicists are employed in academe, whereas the majority of PhD computer scientists, engineers, and chemists are employed in business and industry. Yes

The supply of new PhD's is more difficult to predict than the supply of new Bachelor's degree holders, because decisions to acquire PhD's (i.e., decisions To start and finish PhD programs) are driven more strongly by economic factors, primarily the expected future demand for new doctorates. The most | recent models of supply link decisions to enroll in PhD programs to four | factors which jointly are important determinants of demand conditions in the | near future. These factors are (1) the current levels of new PhD awards, (2) recent | trends in R&D spending, (3) the annual niumber of vacant faculty positions in | academe, (4) recent trends in baccalaureate degree conferrals. The number who | remain in PhD programs until completion of degree is linked sequentially (over| Yes time) to the first 3 factors. The fourth factor, recent trends in | baccalaureate degree conferrals, has different effects in different fields. | In engineering, chemistry, and computer science, it represents growing demand | In business and industry for BS level engineers and scientists, and tends to | Have a negative effect on PhD enrollments because of the related increase in | Deferred income resulting from full time graduate study. In physics, the | environmental sciences, mathematics, and the life sciences, it is more likely | to represent growing interest in academic and research careers and tends to | result in increased enrollments in PhD programs.

Long term projections of new supplies of PhD's are very imprecise because none of these four factors that determine PhD enrollments and degrees are themselves ?not [Len seems not to have noticed the prior negative "none" when he wrote "?not" – RLM] predictable with much accuracy. R&D spending, for example, has exhibited periods of rapid growth and periods of slow growth, and the composition of R&D spending has changed considerably (particularly the composition of Federal R&D spending) in ways that would have been very difficult to anticipate 5 or 10 years earlier. The annual number of vacant positions in academic departments of science and schools of engineering is possible to forecast more precisely in the aggregate, because of the stable link between BS degree conferrals and the college age population. However, even aggregate forecasts are forced to depend on assumptions about the future that may be inaccurate (e.g., constant student-faculty ratios, constant proportions of teaching and research faculty, and an unchanging retirement age distribution). More importantly, what really matters in forecasting faculty vacancies are accurate forecasts of baccalaureate degree conferrals by field levels of aggregation that correspond to academic departmental units. These cannot be forecast within useful bounds of accuracy beyond four years in advance.

How accurate have been past forecasts of future PhD conferrals? A carefully prepared forecast of the 1982 level of PhD conferrals, using state-of-the-art models and based on data through 1978, predicted 20,600 conferrals in the natural sciences, social & behavioral sciences, and engineering. The actual number of conferrals in these fields was 16,237, 21 percent below the forecast level.

```
Should say something about:
(1)       Faculty agedistribution & likelihood of significant increase
       in retirement - soon
(2)       The effects of the defense R&D buildup (recent SGS [?] publication).
(3)       Given the state-of-the-art, what kind of questions/issues we can
   deal with reasonably & what kind we can't.
(4)       The comparison of previous shortage statements (chicken-little) vs.
        actual data for past years.
Overall: I think this is too pessimistic about the state-of-the-art & what
        Is realistic to use it for.
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p. 779, smeared text but readable:

p. 791 and 795 also have smeared but readable text.

p. 814, handwritten correction of erroneous date in forwarded e-mail:

? Dec 90

Date: 23 Aug 91 09:39
To: mcehelsk@nsf.gov
From: ~~jcrawfor~~@nsf.gov Mcehelsk[y]

p. 817, handwritten annotations and editing:

90-12-28

SCIENCE, ENGINEERING, AND MATHEMATICS
HUMAN RESOURCES FORECASTING

There is a need for more adequate understanding of science, engineering, and mathematics (SEM) human resources demand and supply in the United States. The principal clients for this information are employers, educators, guidance counsellors, students and the Government.

The process for doing this work is based on several assumptions:

(1) It is impossible to generate a widely credible single numerical estimate of the field by field surplus or shortage of SEM talent. The presentation of a series of closely reasoned scenarios is more credible and useful to the clients of this work.

(2) It is impossible for key operators within social systems to agree on specific numbers that characterize future developments in those systems, but ~~is~~ it may be possible them to agree on a series of scenarios.
^ for

(3) The issue in the SEM human resources forecasts to date, including ~~particularly the~~ PRA's one reflecting a 675,000 short~~age~~fall during the last years of this millennium, ~~is not~~ can relate to the Nation's strength in [human resources.] ~~whether or not there will be an~~ overall human resources ~~shortage in these fields, but~~ so cannot ~~substitute for~~ predict the field by field dynamic interaction of supply and demand and likely results.

(4) An important side issue is the so-called "fungibility" question, the degree of difficulty or ease experienced by persons in one SEM field to move to new employment in intellectually adjacent fields.
. . .

p. 818, item (3): "A group of analysts in STIA's SRS Division will then take these questions and scenarios and provide indications of the consequences of each of the scenarios [and? according to? for?] the needs of each major client group, based on the questions they have articulated."

pp. 866-867 [source: *obscured lines are contained in the e-mail on pp. 530-531*]

SUBJECT: Comments on Draft Statement on the Future Supply and Demand for Scientists and Engineers
"Thank you for the opportunity to comment on this draft document. It was very interesting, and the ideas are very well expressed. However, the document was disconcerting—perhaps because its title **implies development of an official position on future supply and demand, a step that seems to me inadviseable** [sic] **as well as unnecessary.**

"The draft seems to tie NSF programs in mathematics and science (for which there is a clear need) **to a set of analytical techniques that are at best disappointing and have demonstrated limited success, as the paper itself points out.** The NSF programs could suffer from this link."
. . .
"Projections will always draw criticism. **The discussion in this draft of the differences in the needs and demand is one example. The PRA exercises have been questioned (and, I would agree, for good cause) on other methodological and statistical grounds as well. Given this situation, the paper could more explicitly raise the issue, Should NSF be making projections, of either need or supply, and if so, who should be doing them and what should be done with the results?**

“At minimum, there is danger (as we are seeing now) in having a single group both making the projections (or forecasts) <u>and</u> using them in a policy-advocacy sense, without providing the customary detailed discussion of methodology that is standard practice for f ” [remainder edited and/or abruptly truncated by Mary Golladay or somone above her whether because it was irrelevant to the point at issue or because it was to be deleted altogether. It is likewise unclear who highlighted the obscured passages or whether the highlighting was intended to be an intended editorial deletion by a boss or by someone at NSF or on Wolpe’s staff; see p. 531 for deleted portion. -- RLM]

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p. 870, handwritten transmittal note of Carlos E. Kruytenbosch to Karl Willenbrock accompanying his draft “NSF S&T Data and Analysis Activities” of 2/4/1991 :

<u>show as is</u>

<u>Karl W[illenbrock]</u> 2/4/91

(1) My draft on NSF-wide policy and data functions – including some detail on SRS. (as requested by Committee)

(2) Additional copy of Committee Minutes of Jan 9 meeting – for Judith’s signature

(3) 20 Copies of the OTA study on Statistical Needs for the U,S. Economy are on their way

(4) Michael Teitelbaum of the Sloan Foundation – referred to by Jesse Ausubel – has been looking at
effectiveness of projections of S/E labor force. He’s willing to come & talk on M[ar]ch 7 if we want!
Note also, SRS sponsored a review of projections by 2 economists of U. Arizona. I now just got a
copy of this and will give you my thoughts as to whether the Committee should see it.

Carlos

[Note: Jesse H. Ausubel then of Rockefeller University was on the STIA Advisory Committee – RLM]

p. 871, handwritten annotation on draft of “NSF S&T Data and Analysis Activities” by Carlos E. Kruytbosch on 2/4/91.

Karl [Willenbrock] from Carlos **Kruytbosch**
NOTE: The Data tables need work!! I’ll fix them next week.

p. 886: (b) “. . . **clearly indicating**. . .”
(c) “. . .clearly and objectively display **actual data** and results of analysis. . .” [careful reading of spacing & letter forms]
p. 902, bottom right annotation: “**This statement refer[r]ed to 30 yr forecast**”

p. 903, annotations to the right of Paragraphs 1, 3, 4:
P1: **Another idea**
P3: Never mentioned a shortage [and to the right of the last sentence of P3:] No
P4: [to the right of the second and third sentences of P4] No
[also editorial suggestion to replace “Dr. Norwood” by “Dr. P. Norwood” and
“the lack of knowledge” by “her lack of knowledge”]
[presumably to distinguish Dr. Paula Norwood from Dr. Janet Norwood. – RLM]

p. 966, illegible portions: “**NSF/STIA/** [??] **should be based upon the declining demographics** of the relevant age group and the declining percent of all students interested.”

- “**PRA does not**. . . [?????????????????????????????] **at least ?repair/[?remain] the** [????] . Most forecasters say demand is likely to continue to grow but at slower pace than over the last decade or two. **As a result the** [????????????????????????????????????], **which requires a projection of demand.”**
- **“NSF/STIA** [?????????????][instant?] **surveys for S&E’s in the** [???y ?????????].”

p. 967, illegible portions: “PRA staff analysts have reviewed **the report and** recommend that it be more fully vetted before it is disseminated to a broad **audience.”** [source: discerned from ascenders and descenders]

"PRA analysts find that the report rests on a **partial and flawed** analysis, which does not reflect a full understanding of relevant reported research; **that the narrative** does not constitute a cohesive analysis; and that the conclusions presented are not **adequately** reported." [source for lacunae: passage is quoted inline at http://perimeterprimate.blogspot.com from 6 July 2009 at least through 21 May 2010]

p. 978, obscured words: "In my view this treatment of the projections is **careful to** moderate."

p. 979, obscured words: ". . . [illegible words] **sent**???? **is subject to** [illegible words] **[f?t?y] [increasing?] our** [**work**?]."

p. 981: see Figures 3-15 & 3-16 on p. 369 of Wolpe hearing, or Appendix Tables 3-12 & 3-13, *Science & Engineering Indicators – 1991*.

p. 982-985: see pp. 370-373 of Wolpe hearings for clear images of graphics and sidebars.

p. 1074: ". . . shortfall of bachelors to the year 2006 would be about **675,000, with 275,000 being** in engineering degrees (Figure 4)."

p. 1135-1138: "**The projections are quite clear**," says the NSF's **Shakshiri. "We are** going to have a tremendous shortfall."

> "**Some experts say the effects of demographics and slipping freshman interest will likely be felt sometime in the 1990s. In other words, demand will outstrip supply**."
>
> "Figures from the NSF predict a cumulative shortfall of 103,000 between now [1989] and 2006."
>
> ` " 'OTA concludes that the shortages of scientists and engineers are not inevitable; the labor market will continue to adjust, albeit with transitory and **perhaps** costly shortages and surpluses.' "

> "**There will be shortages**."
>
> "But Morris H. Shamos, a **former** president of the science teachers' group, says, 'I'm not convinced.' "
>
> "Shamos wrote a piece in Science Education for the magazine *Issues in Science and Technology*."
>
> "Congress **appropriated $171 million in fiscal 1989 for NSF's education directorate; the agency has requested $190 million for 1990.** The House-passed HUD-VA-Independent Agencies appropriations bill (HR 2916 – HR Rpt 101-150) which includes NSF funding, would provide $210 million."
>
> **"Those levels, while close to what Congress has authorized, are considerably below what was being spent in the 1960s, when appropriations peaked at $446 million in 1968 (in 1998 dollars)."**
>
> p. 1138, obscured portions**: "Sherwood Bohlert, R-NY. His proposal (originally HR 1293) would offer 500 scholarships a year to undergraduate students willing to commit themselves to teaching elementary or secondary education science and math classes.**"
>
> Graph legend for triangular plotpoints: "**Projected Demand**";
>
> Graph description below graphs: "Cumulative shortfall (1987-2006) = **765,000**"
>
> [source: *Congressional Quarterly*, 19 August 1989, pp. 2179-2183, which contains 4 clear printings of NSF graphs used in PRA shortage literature -- RLM].
>
> p. 1139-1140: "People Needs: Work Trends and Shortages," TRW Advertising Supplement to *Aviation Week & Space Technology*, 20 Nov 1989, S5 - S6. [seek original!]
>
> p. 1142, parts of paragraphs 1, 4, and 5 obscured by highlighting:
>
> P1: "**If demographers' warnings go unheeded, there could be a shortfall of 275 000 engineers and 400 000 Scientists by the year 2006, according [to] a report issued this fall by the National Science Foundation (NSF), Washington, D.C."**
>
> P4: "**Even market forces may not help because similar shortages are expected in all academic fields and little correlation exists between the higher starting salaries in engineering and the natural sciences** and the number of bachelor of science degrees produced in these fields."
>
> P5: "**To address possible shortages, educators should attempt to get students interested in the sciences even**

before they reach high school, to involve more minorities and women in similar pursuits, and to retain students through scholarship programs, the report advises.

[source: *IEEE Spectrum* (Jan 1990), p. 23, "Demand to Exceed Supply for Engineers"]

p. 1143, *The Washington Post*, Tuesday, Jan 9, 1990, p. A17: Paragraph 4 and the table are obscured.

P4: "**In its final report last month, the panel recommended that the research agencies take action to ease the nation's projected shortfall of 560,000 scientists and engineers by the year 2010. The recommendations focus on minorities, white women and the handicapped because they are expected to constitute 85 percent of new workers in the year 2000."**

pp. 1149-1150, 1154, "Supply and Demand for Scientists and Engineers: A National Crisis in the Making" by Richard C. Atkinson, *Science* **248**:425-432, 27 Apr 1990 (incl. 7 PRA graphs) :

p. 1149, 2nd paragraph in 1st column:

"In addition to financial constraints, we may also have to learn to live with severe shortfalls between the supply and demand for scientists and engineers. **Prudent assumptions, based on demographic data and historic trends, indicate that there may be a cumulative shortfall of several hundred thousand scientists and engineers at the baccalaureate level by the turn of the century.** That shortfall. . ."

p. 1150: Source legend under Fig. 4, **"[Source: National Science Foundation]**"

p. 1150, top paragraph on left:

". . . values in a baseline year. **Bowen and Sosa's projections yield a cumulative decline of nearly 70,000 baccalaureate recipients in the mathematical, physical, and biological sciences between 1987 and 1997 and more than 100,000 by the turn of the century (7). NSF projections, based on somewhat less conservative assumptions, project a decline of almost 400,000 in the natural sciences and engineering by the turn of the century (8)."**

p. 1154: "References and Notes:

. . .

9. Division of Policy Research and Analysis, National Science Foundation, "The State of Academic Science and Engineering" (National Science Foundation, Washington, DC, in press)

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p. 1159, "They're Not Dumb, They're Different: Stalking the Second Tier" by Sheila Tobias, published by Research Corporation, Tucson, AZ (5/1/1990) , p. 8, footnote 3, which is highlighted out:

"**Shortfall," not "shortage," is the preferred term for the anticipated difference between supply and demand for science practitioners in the past several decades. The term is generally credited to Erich Bloch, director of the National Science Foundation. Estimates of the shortfall vary from 250,000 to 700,000 B.S. (B.A.) recipients in science and engineering by 2005 and 7,500 Ph.D.'s annually by that year. See Atkinson (note 14) and *The Ph.D. Shortage: The Federal Role*, report by the Association of American Universities, Jan. 11, 1990.**

pp. 1161-1162, highlight-obscured portions: "Who Will Do Science in the 1990s?" by Robert Pool, *Science* (4/27/1990), pp. 433-435, News & Comment

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p. 1161, paragraph 2: **Dauffenbach's difficulties show just how hard it is to predict the future of the scientific job market. Yet he and other prognosticators provide a vital service to anyone making plans related to science:** college students thinking about careers, managers at research labs or universities, and government planners. Furthermore, in spite of some uncertainties, forecasters agree surprisingly well on what the major trends of the 1990s are going to be. Perhaps the most striking will be a sharply increasing demand for scientists and engineers as the decade wears on. **Indeed, if more U.S. citizens do not start going into science careers, the nation could face a serious shortage by the early part of the next century.**

p. 1161, paragraph 5: But within engineering, there will be some sharp variation in job opportunities. **Electrical and electronic engineers will be hot; chemical engineers will not.** And then there are some fields where the predictions depend mostly on who is making them. **The NSF thinks aeronautical and astronautical engineers will be the most popular folks around, with a 48%**

job growth from 1988 to 2000; the Labor Department sees them as wallflowers, with a measly 13% rise. Although economic forecasters at the NSF and BLS could not pinpoint the reason for the inconsistency between projections, it may have been caused by different assumptions concerning how much defense funding will be cut in the 1990s.

p. 1161, paragraph 7: A college student who wants to go into science instead of engineering will have to be a little pickier about choosing a specialty. **In general, the physical sciences--physics, chemistry, and earth science--won't grow any faster than the rest of the economy. One exception: materials science.** New technologies will require new materials, and salaries for trained materials scientists --now in short supply--can only go up. Within this field, the hottest topics are likely to be electronic and optical materials, superconductivity, composites, and materials analysis using such tools as synchrotron radiation, lasers, or scanning microscopes.

p. 1162, 2nd sentence: And the biggest growth industry of the last decade should be big for the 1990s, too. According to the NSF, 260,000 new positions will open up for computer specialists by 2000, a 52% jump.

p. 1162, paragraph 2:

> This increasing demand is the good news. The bad news is that the crystal ball doesn't say where all these scientists and engineers are going to come from. According to Richard Atkinson, chancellor of the University of California at San Diego, **the United States could experience a shortage of as many as 150,000 Ph.D.'s from 1995 to 2010 (see also p. 425). Estimates of the deficit in science and engineering baccalaureates range as high as 650,000.** Although supply is much harder to predict than demand, there seems to be good reason to worry about not having enough trained workers in the late 1990s and beyond.

p. 1162, paragraph 4:

> **Adding to the problem is the fact that the number of U.S. citizens getting science and engineering doctorates has been declining since 1970.** Foreign students have taken up the slack.

p. 1161, Table illegible as is NSF graph of % of aging science and of aging engineering faculty 1979-1987.

p. 1162, Bureau of Census graph of college-age population, 1985-2010.

pp. 1164-1165 (all obscured text can be discerned) “Outreach Matters” by Allison Good in *Cementing the Future*, NSF Center for Science and Technology of Advanced Cement-Based Matls (ACBM), Vol. 2, Summer, pp. 1-2 [S&E Pipeline and Coming Shortage]

ACBM Cementing the future Summer 1991?, Vol. 2 No. 2?
National Science Foundation Center for Science and
Technology of Advanced Cement-Based Materials

Outreach Matters by Allison Good, ACBM Outreach Coordinator

This article is the first in a continuing series about ACBM educational outreach

As the most recent addition to the staff of the Center for Advanced Cement-Based Materials, I welcome the Opportunity to communicate with you and other interested menbers of our growing audience. I have chosen to name this column *Outreach Matters* to address both the goals and value of outreach in terms of philosophy and programming.

The main goal of outreach has always been to ensure that the results of research find their way into the country’s Knowledge and technology base. Traditionally this has been accomplished by publishing and presenting. In 1989 the National Science Foundation (NSF) instituted Science and Technology Centers (STC) to improve the mechanism for Increasing the transfer of knowledge among sectors of society and ensure a solid foundation for attracting undergraduate Students into science and engineering careers, with special emphasis on minorities and women. (continued on p. 2)

Recent statistical findings by the U.S. Department of Labor and the NSF have shed light on the scope and scale of potential human resource problems which may broadly influence future U.S. knowledge and technology bases in science and engineering:

1. By the year 2000, it is estimated that 85 percent of the incoming labor force will be women, minorities, and immigrants.
2. Too few American students are pursuing science and engineering degrees (see The Pipeline graph).
3. By the year 2010, the U.S. will face shortages of 300,000 to 700,000 scientists and engineers.

There is evidence to suggest that outreach efforts must be expanded and strategically targeted if we are to improce the general understanding of science and technology for our citizenry, increase the number of Americans preparing for scientific and engineering professions, particularly minorities and women, and keep our economy growing in an internationally competitive world.

This is the challenge that ACBM outreach must meet: It must encourage collaborations which leverage Center faculties, students, facilities, and equipment. In addition to the traditional transfer of knowledge and technology, which the Center Generates to other related scientific and technical communities and institutions, outreach will also need to promote communication with and educational opportunities for people in education, industry and commerce, government and society at large.

Our ACBM outreach philosophy is being shaped by: 1) the nature of our research; 2) the structure of the ACBM Center as an NSF Science and Technology Center; and 3) the national focus on human resources and science education. Lack of scientists trained in the multidisciplinary aspects of cement-based materials and neglect of the subject in university curricula have contributed to the current gap in cement technology. The establishment at NSF of a Science and Technology Center for Advanced Cement-Based Materials consolidates the renaissance that appears to be occurring in cement research. To this end, the Center will develop broad outreach strategies to address three areas – student recruitment, faculty enhancement, and communication with commerce and industry.

The Pipeline

[original displays this as a sort of graph of a narrowing pipeline with the following annotations]

4,000,000 high school sophomores in 1977

High school sophomores with science and engineering interests	750,000 in 1977
High school seniors with science and engineering interests	590,000 in 1979
College freshman with science and engineering interests	340,000 in 1980
College degrees in science and engineering	208,000 in 1984
Graduate students in science and engineering	61,000 in 1984
Masters degrees in science and engineering	46,000 in 1988
PhD degrees in science and engineering	9,700 in 1992

Source: Directorate for Science and Engineering Education, National Science Foundation

Student Recruitment

Addressing a growing shortage of scientists and engineers, the Center will have and additionally may additionally seek resources to 1) increase undergraduate research opportunities, especially for minorities and women; 2) train a significant number of scientists in multidisciplinary aspects of cement-based materials; 3) participate in programs which enrich learning experiences for high school teachers and students; 4) explore possible collaboration with junior high school teachers in school districts serving minority students.

continued on page ? [page number clipped]

p. 1166, paragraphs 3 and 4 obscured, "Understanding the Engineering Shortage" by Theodore A. Bickart, Michigan State University (College of Engineering) *Currents*, Fall 1990, p. 2 .

P3: "A recent model released by the National Science Foundation of human resource needs in science and engineering suggests the country will experience a shortfall of about 165,000 engineers by the turn of the century."

P4: "If, in fact, these estimates are correct, we would have to increase the graduation rates of the next five senior classes – the Class of 1996 through the Class of 2000 – by fifty percent in order to gain an additional 165,000 engineers."

p. 1172, smudged portions, "Heading off a Ph.D. Shortage," *Issues in Science & Technology*, Winter 1990-91, pp. 66-73:

Unless prompt action is taken, a sharply increased demand for Ph.D.s in the United States will outstrip a comparatively level supply before the turn of the century. Industry, government, and universities will be pitted against each other in a battle for this critical human resource, and the entire nation will pay the price – diminished leadership and competitive strength.

. . .

- Increases in "replacement demand" resulting from the well-documented aging of the U.S. academic, industrial, and government scientists and engineers, a consequence in part of the surge in hiring during the post-Sputnik period of growth in American science.

p. 1184, righthand margin: "I'm rather bewildered. I believe that I'm one of the best young theorists in the country. Without a doubt, I've led by far the most successful group of graduate students in my field. [Yet any] NSF Single-investigator funding is being cut from four students to none. In the past two years my efforts to avert this disaster have been fruitless. For obvious reasons, I'm forced to change my style of research. In the next two years I'm shifting a large part of my efforts to workstation software development, for which there is support from private industry.—Associate Professor of Physics, Cornell"

p. 1186, smudged portion: "A recent National Science Foundation report commissioned by Congress warned that, by the year 2010, this nation may be short 560,000 scientists and engineers."

p. 1191, scan and lighten inset figure to try to better display, "Amid 'Shortage,' Young Physicists See Few Jobs" by Malcolm W. Browne, *NY Times*, (ca. 1990), p. C1

p. 1218 (p. 1287 has a clean copy):

p. 1309: [smudged but readable; retype from Wolpe hearing record]

p. 1317 (completely discernible with difficulty except for the first sentence) "WEPAN: Count on Women to Fill Engineer. . ." by Margaret Ryan, The Profession, *Electronic Engineering Times* (6/18/1990) [WEPAN is Women in Engineering Program Administrators Network]

p. 1320, 1991 Keynote Address by IEEE Pres-Elect Merrill W. Buckley, Jr, to USAB and PACE:
"We also have to be honest with potential engineering students. I'm against trying to hold back students who really want to be engineers. [Illegible short sentence]. We have to search for them.

p. 1321, highlighter-obscured sentence at end of second paragraph: "We have to make sure that this doesn't [about 36 spaces unreadable].

p. 1321, paragraph 3: The *Forbes* magazine article to which Merrill W. Buckley, Jr, was referring is "Train 'em Here, Keep 'em Here" in the Forbes magazine issue of May 27, 1991 (pp. 110ff.) in which Forbes staffer Susan Lee quotes lifelong immigration lobbyist Harris Miller (then of the Business Immigration Coalition) boasting after successful passage of the H-1B visa: "We were successful because we refashioned the debate from the jobs displacement issue, where we always lost, to the competitive issue."

p. 1331, "Where Will We Get Them?" by Robert L. Schwed, Editor, *Engineered Systems* **8**(1):8, Jan-Feb, 1991.
[handwritten comments by person unknown]:
"Where will we get them?" `From the 47000 engineer lay-offs per year!`
"Whatever the reason, the demand for engineers is growing. And the supply is shrinking." `What is your source?`

`BoB -- See my enclo[s]ures` ["Bob" more likely Robert Bellinger than Robert Schwed – RLM]