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Shortfall of US Citizen Science and Engineering Specialists in Defense Industry

Military Operations Research Society Symposium
United States Military Academy, West Point, NY

21-23 June 2005

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TASC

Northrop Grumman Corporation

Outline

- **Introduction**
- **Survey Description**
- **Survey Data**
- **Appropriate Theoretical Model**
- **The Way Ahead**
- **Discussion**

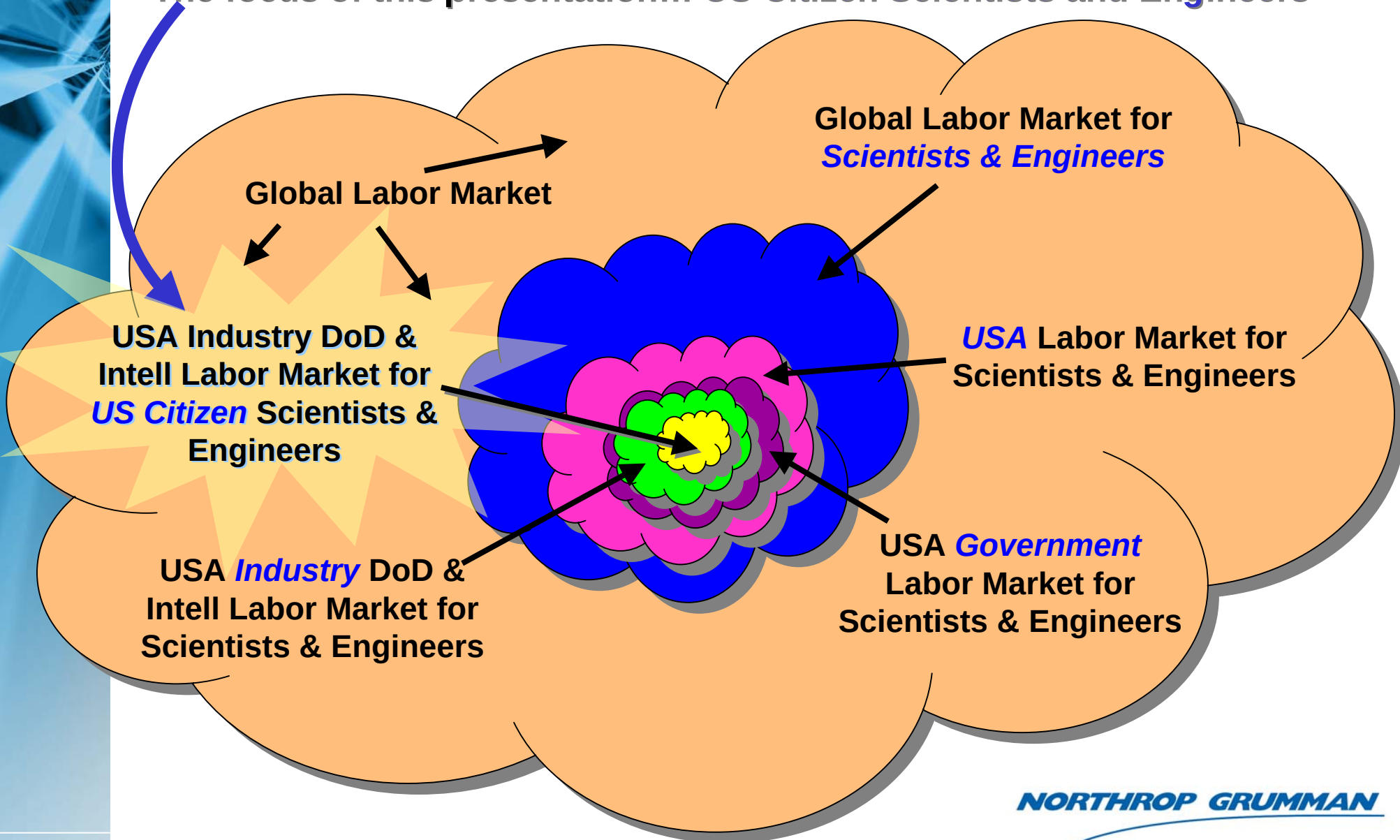
Introduction

Purpose

From the perspective of industry serving the Department of Defense and the Intelligence Community, this presentation enhances the theoretical and empirical rigor focused on the question of *whether there is a shortfall of US citizen scientists and engineers.*

Introduction Perspective

The focus of this presentation... **US Citizen Scientists and Engineers**



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Introduction

Some Perceive a Shortfall

"We now see warnings that America's advantage in defense-related **scientific and engineering intellectual capital is eroding.**" -Testimony of Ron Sega, Director of Defense Research and Engineering, before the House Armed Services Committee, 25 March 2004

"The lack of young engineers in the pipeline to replace those who will retire soon is going to become a big problem... **in the next four years, as many as half of the machinists in the defense side of aerospace, and one-third in the commercial sector of aerospace are expected to retire.**" -March 12, 2004: Aerospace Industry Describes Workforce Decline to House Aerospace Caucus (Aerospace Industries Association Press Release)

"We simply **do not have enough scientists and engineers**, military or civilian, **to meet our requirements,**" Lt. Gen. Stephen Plummer, military director of the Air Force's Scientific Advisory Board, Air Force Print News, November 2002.

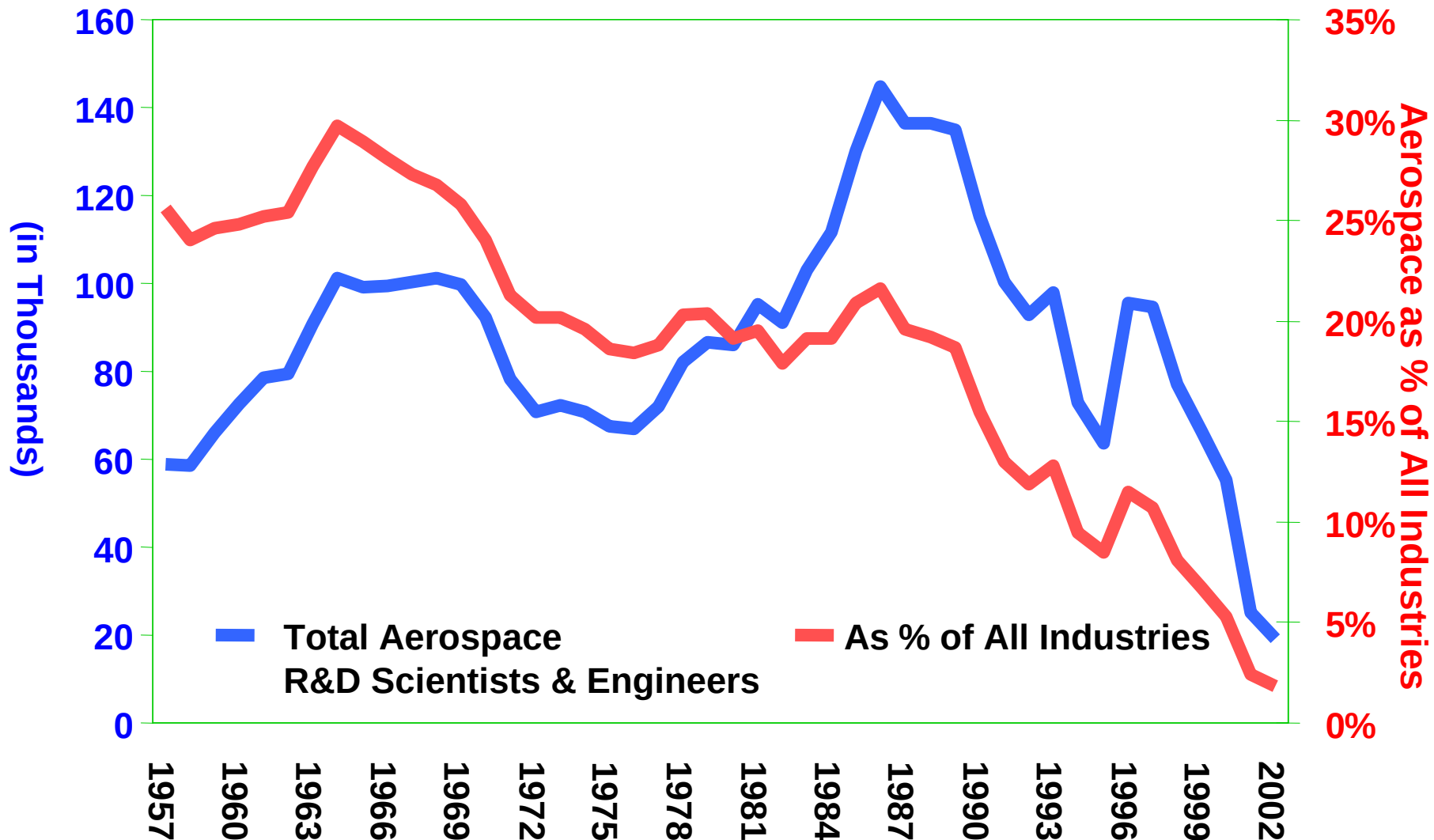
"The Commission recommends... the nation immediately reverse the decline in, and promote the growth of, a scientifically and technologically trained U.S. aerospace workforce" -Commission on the Future of the U.S. Aerospace Industry, Aerospace Industries Association, December 9, 2003

"...**growing deficiency in the right mix of scientists and engineers** to support our national security workforce needs." -SMART Defense Scholarship Pilot Program, (S. Rept. 108-260), June 2004

Introduction

Some Perceive a Shortfall CONT'D

R&D Employment Declining AIA, December 2003



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Introduction

Some Do Not Perceive a Shortfall

“...neither earnings patterns nor unemployment patterns indicate an S&E shortage...”

-Rand Corp., *Is There a Shortage of Scientists and Engineers?*, Science and Technology Issue Paper, 2003

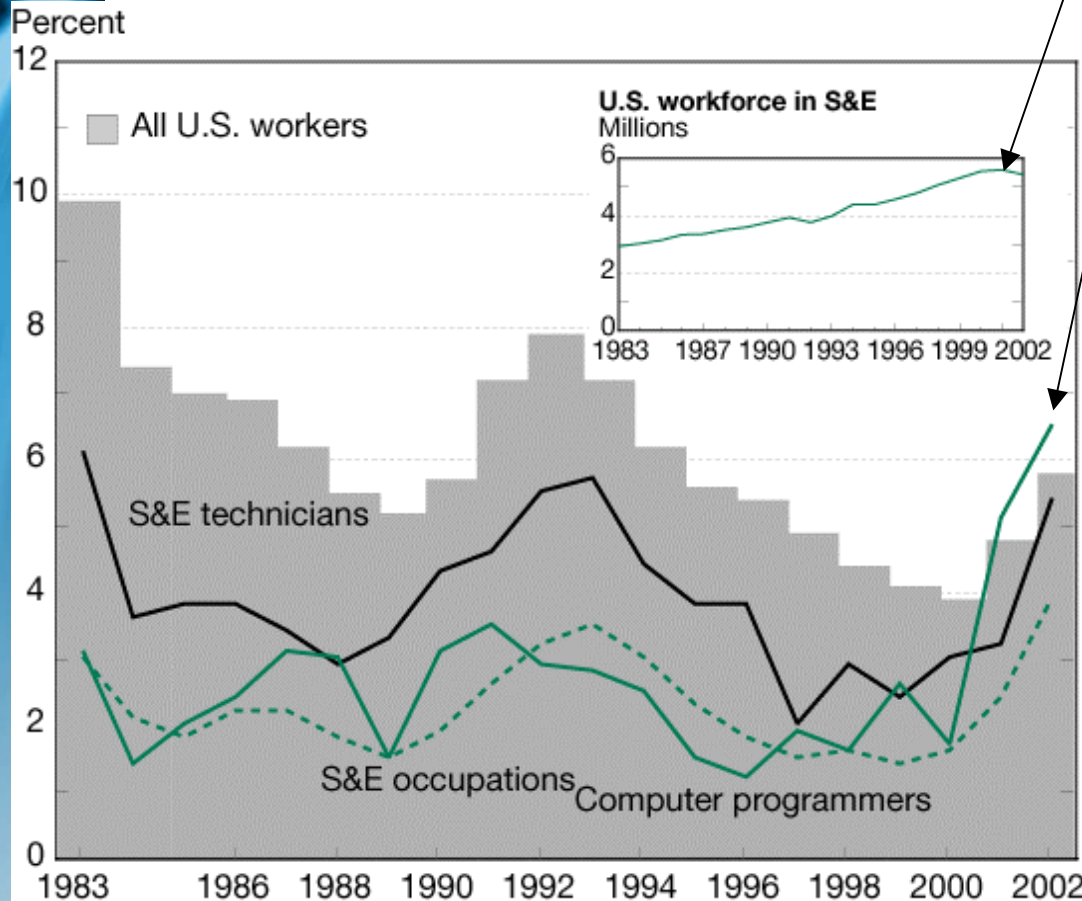
S&E Workforce Leveled Off in 2002

S&E Unemployment rate up in 2002

“...claims of current or future shortages <are> inconsistent with all available quantitative evidence”

-Teitelbaum, “Do we Need More Scientists?”, *The US Scientific and Technical Workforce*, Rand CF-194-OSTP/SF, June 2002

Unemployment rate, by selected occupations: 1983–2002
-National Science Board, *Science and Engineering Indicators*, 2004



Introduction

Main Questions

- **Is there a shortfall in industry, or not?**
 - Collect focused empirical data using a survey
- **If there is a shortfall, why do analysts fail to detect it?**
 - Apply appropriate theoretical model

Survey Description

- **“Snapshot” survey sent to NDIA and AIA member corporate human resource officers**
 - Similar to BLS Job Openings and Labor Turnover Survey (JOLTS)*
- **Quickly address some critical issues**
 - How difficult is it for Defense industry to find US citizen scientists & engineers?
 - What are industry perceptions about future losses and replacements of science & engineering staff?
 - How severe are clearance delays, really?
 - Are the current skillset definitions adequate?
- **Complement other industry surveys**
- **Quantify where possible**
- **Exploit available industry data**

* See www.bls.gov/jlt/home.htm

Survey Description: Methodology

- MS Word survey instrument with attached references for Science & Engineering skill sets
- E-mailed to NDIA and AIA member corporations
- “Snapshot” of hiring situation at the time survey was completed
- One follow-up e-mail reminder
- Automated extraction of data from surveys
- Two Surveys
 - Spring 04
 - Brand new survey instrument created and tested on the fly
 - Very rapid turnaround to match DDRE staff actions
 - No follow-up
 - Sponsored by [National Defense Industry Association \(NDIA\)](#)
 - Fall 04
 - Minor enhancements
 - Follow-up to increase sample size
 - More analysis of results
 - Sponsored by [NDIA](#) and [Aeronautical Industries Association \(AIA\)](#)

Survey Description: Response Rate*

- **Total Potential Responses = 1103 NDIA and AIA corporations**
 - Approximately 700 of 1103 were expected to need US scientists & engineers.
- **Responses received = 146 surveys out of 1103**
 - Response rate = 13 % of 1103
 - Responses needing US security clearances = 78 (varies with Question)
 - 78 represent 54 % of all 146 responses received
 - 78 represent 11 % of 700 expected to need US scientists & engineers
- **Responses more than doubled from last survey**
 - Encouraging sign for further improvement
- **Caution: sample sizes vary in the following charts, mostly in the neighborhood of 70+.**

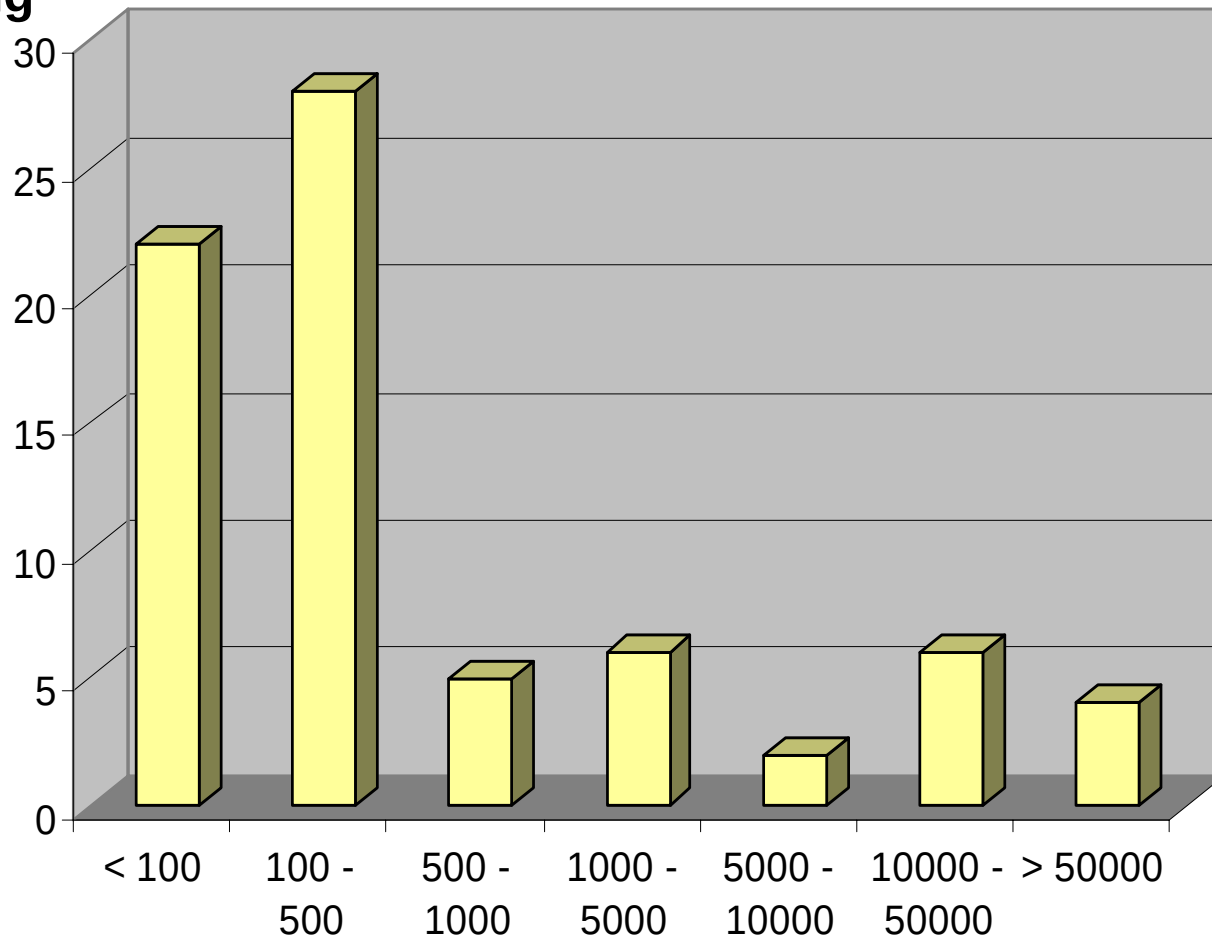
*Data from November survey unless otherwise noted

Survey Data

Corporations Who Need US Security Clearances

Total Employment of Respondents

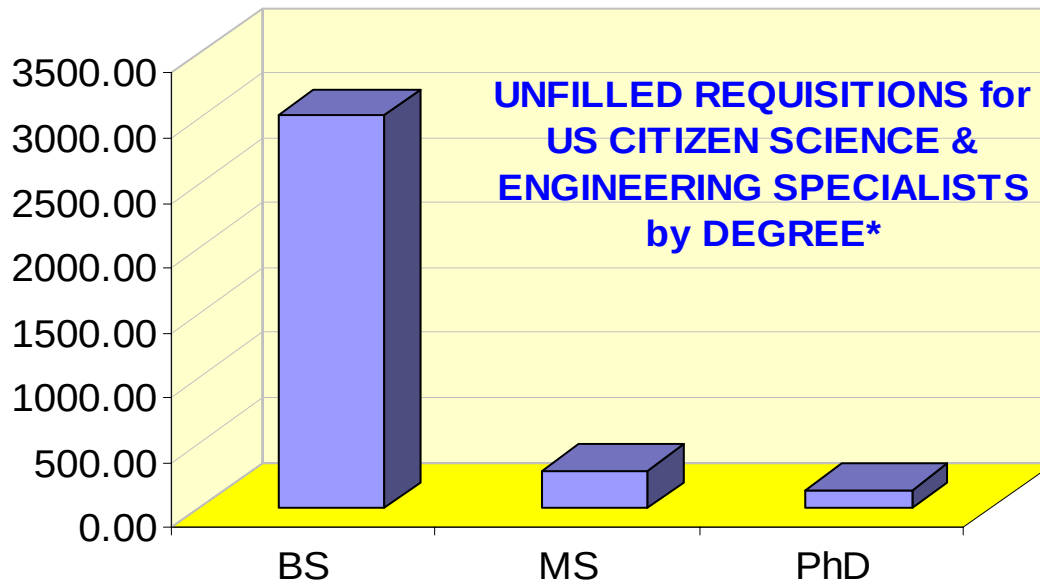
Number of
Corporations
Responding



Total Employment of Survey Respondents

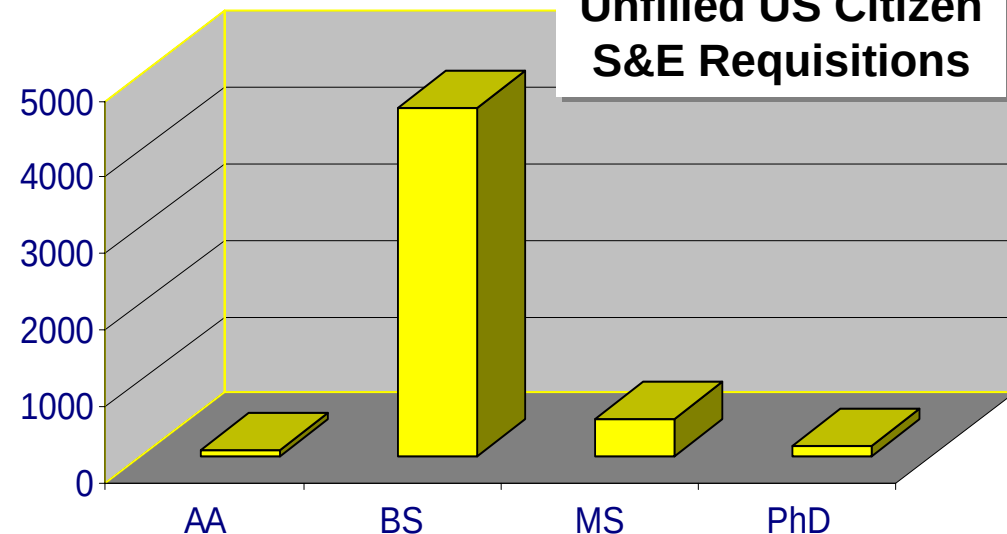
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Previous (Spring '04) Survey Compared to Nov '04 Survey



← **Spring '04**
**Unfilled requisitions
by degree**
Nov '04

↓
**Unfilled US Citizen
S&E Requisitions**

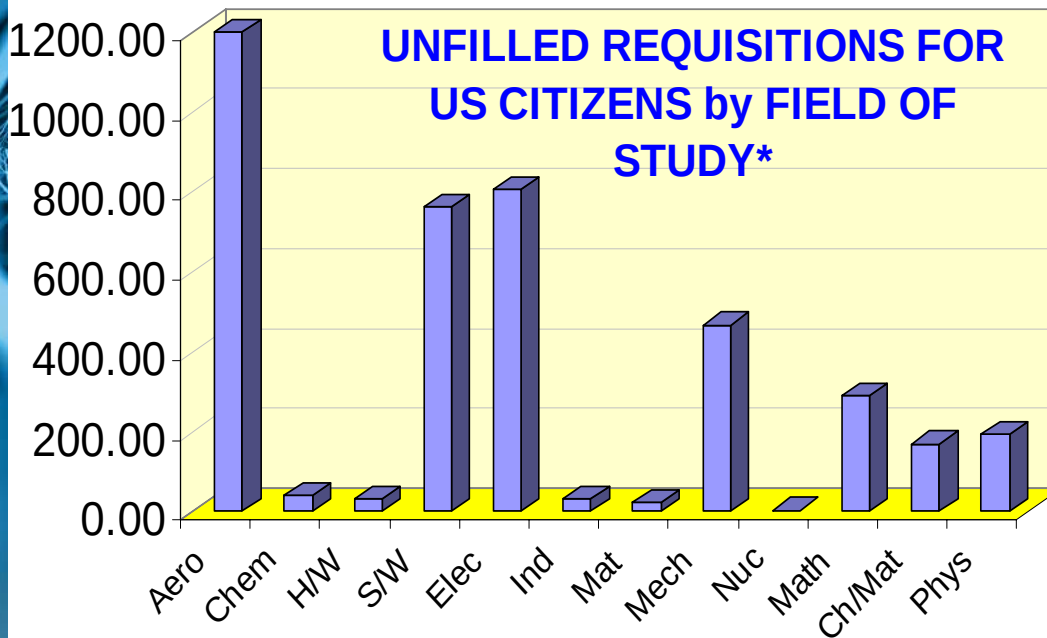


- **Raw data-not normalized**
- **Includes only data from respondents**

Nov '04 included Associate degree

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Previous (Spring '04) Survey Compared to Nov '04 Survey

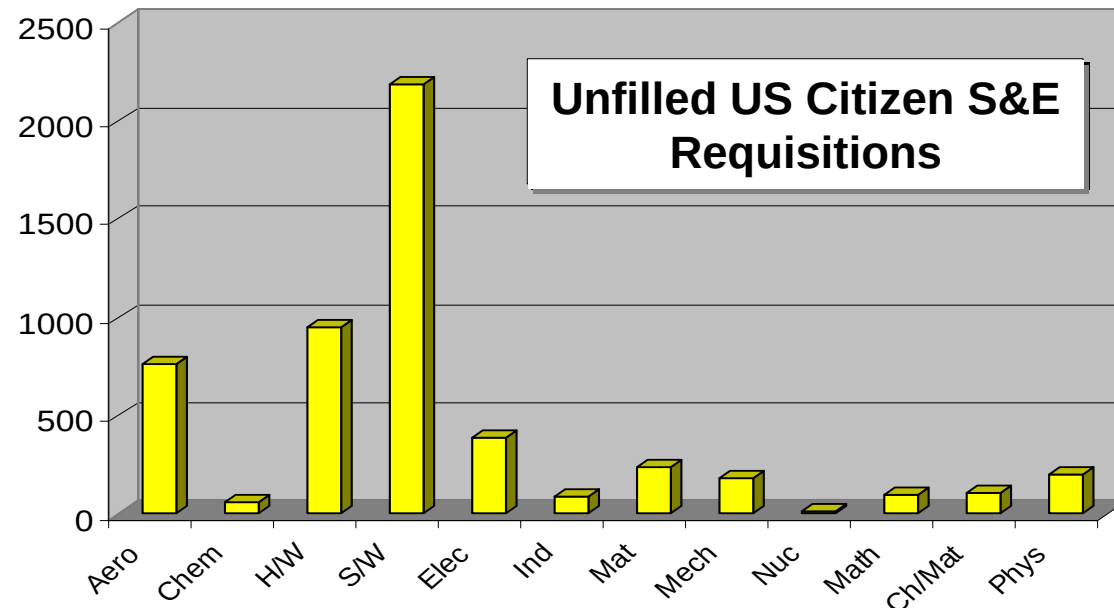


← **Spring '04**
**Unfilled requisitions
by Field of Study**

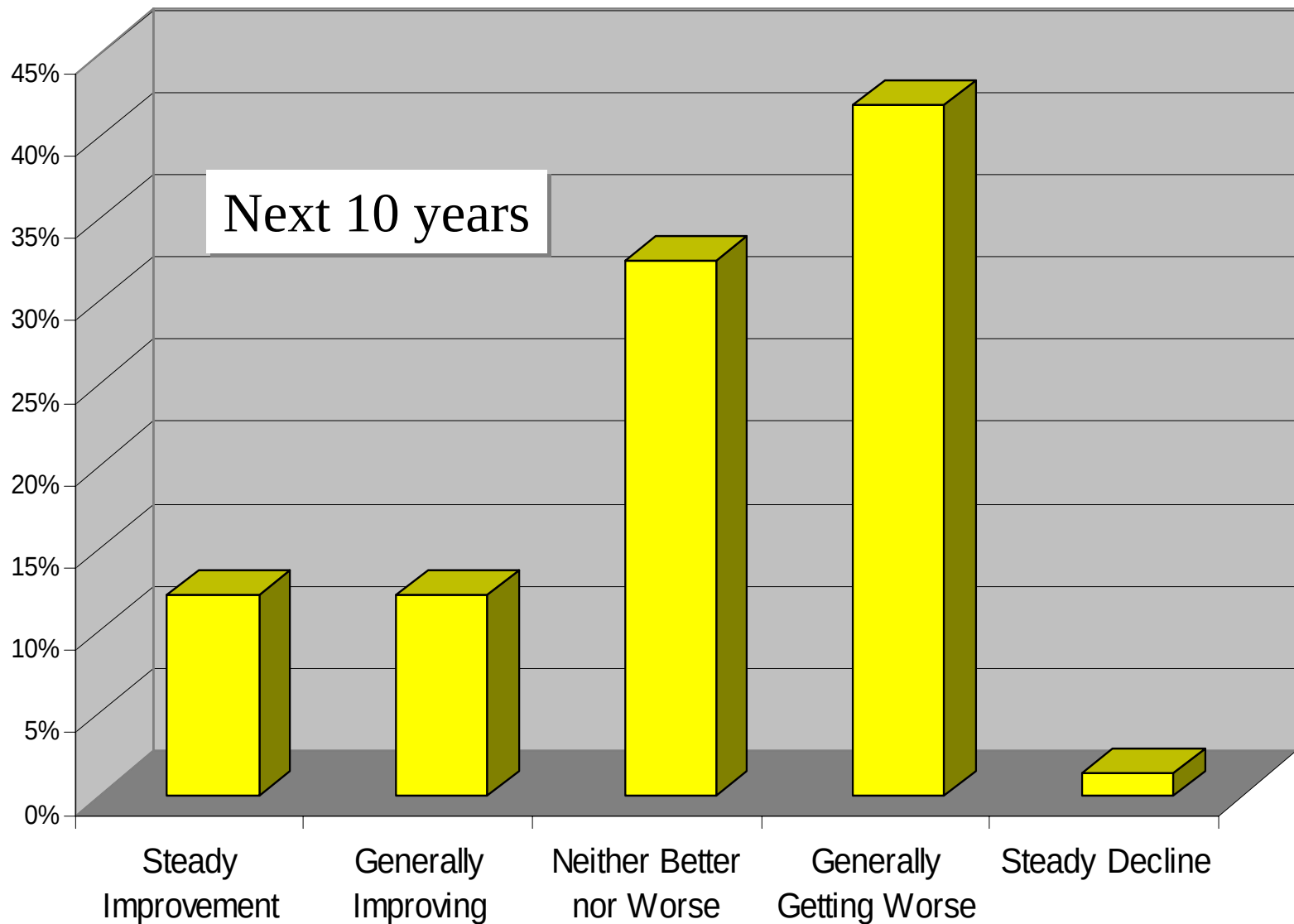
Nov '04



- **Raw data-not
normalized**
- **Includes only data
from respondents**

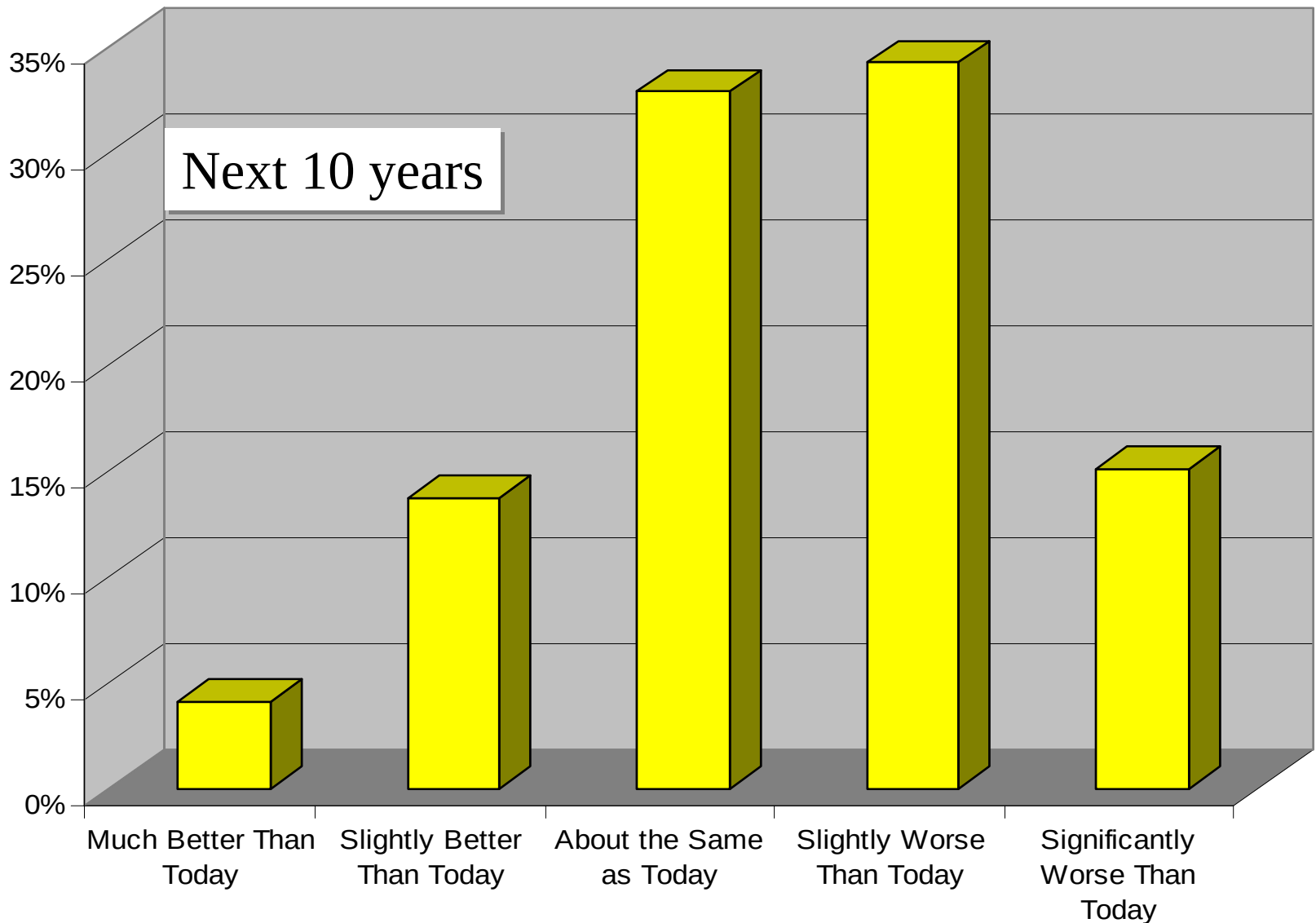


Industry Future Hiring Outlook US Citizen Scientists & Engineers



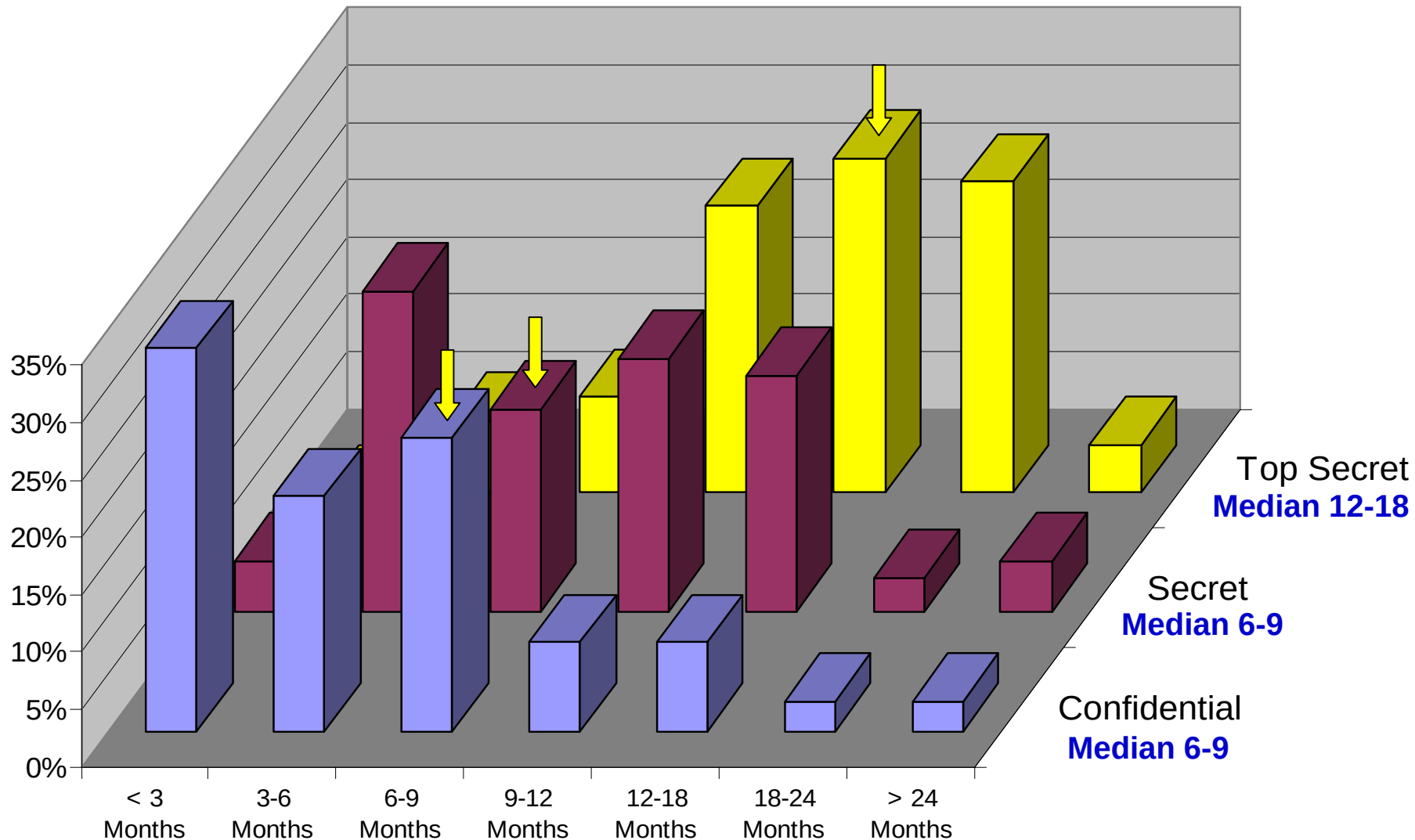
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Industry Future Retirement Outlook US Citizen Scientists & Engineers

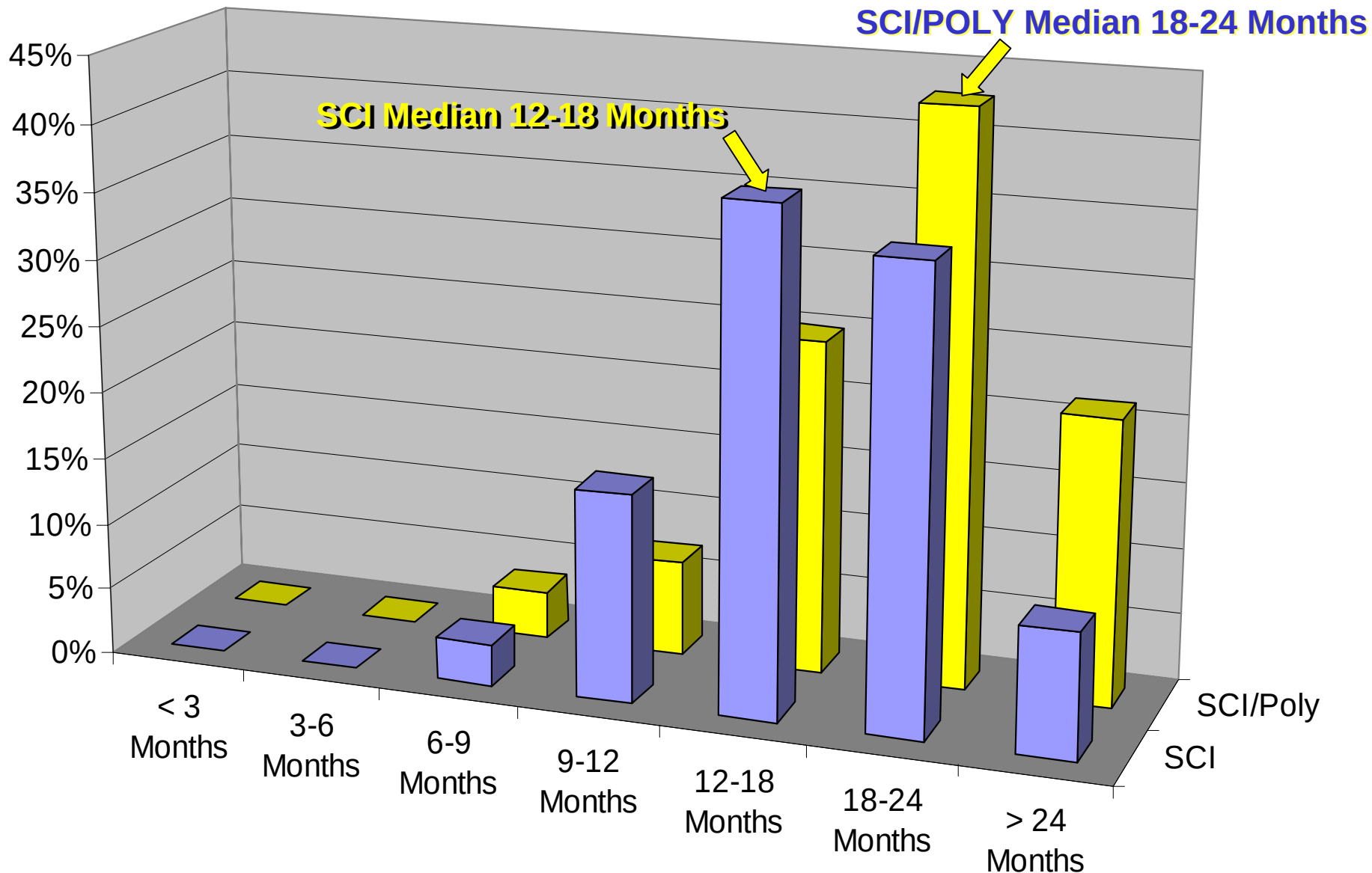


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Time to Obtain Collateral Clearance



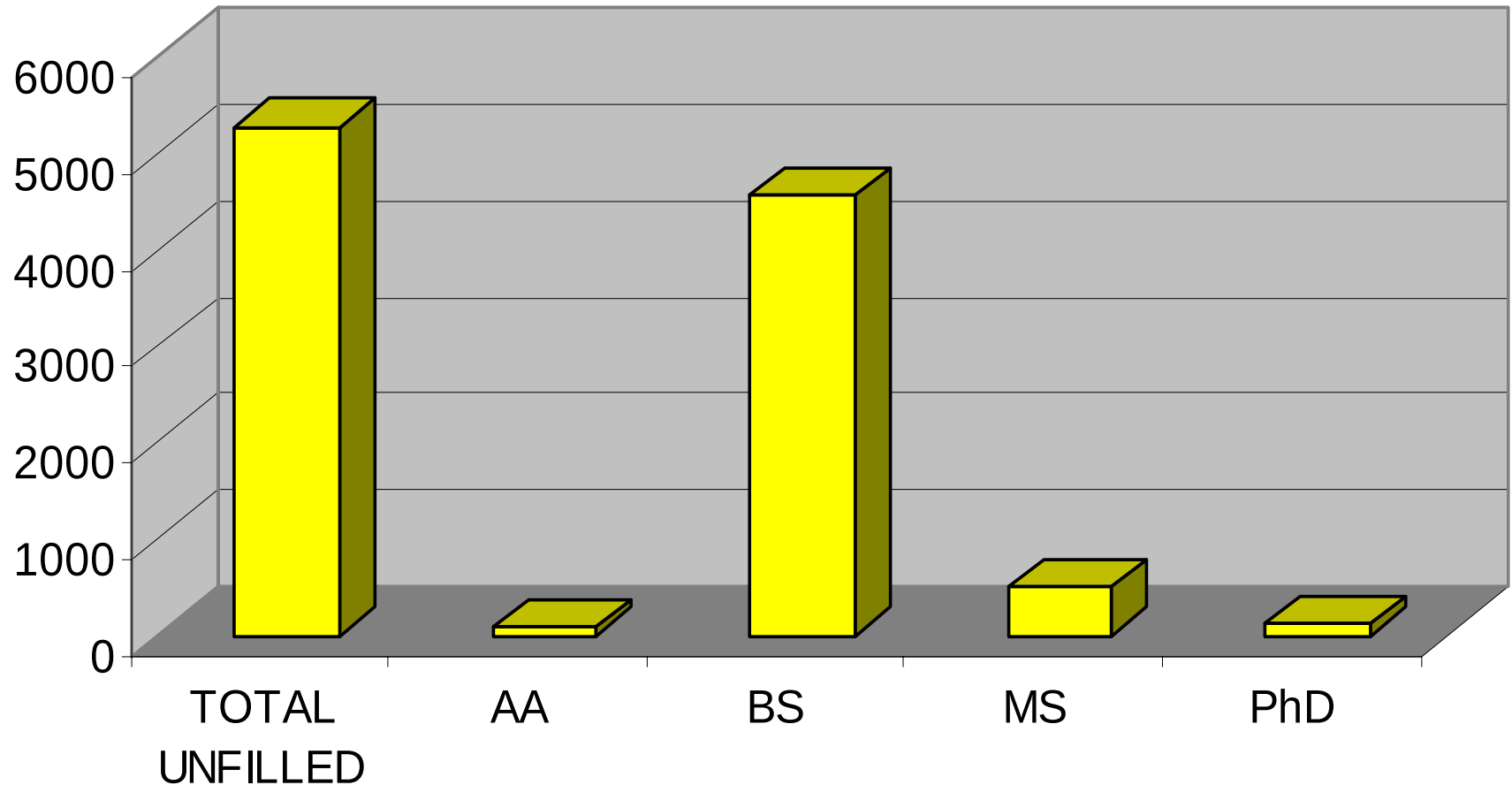
Time to Obtain SCI Clearance



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Unfilled S&E Requisitions Snapshot

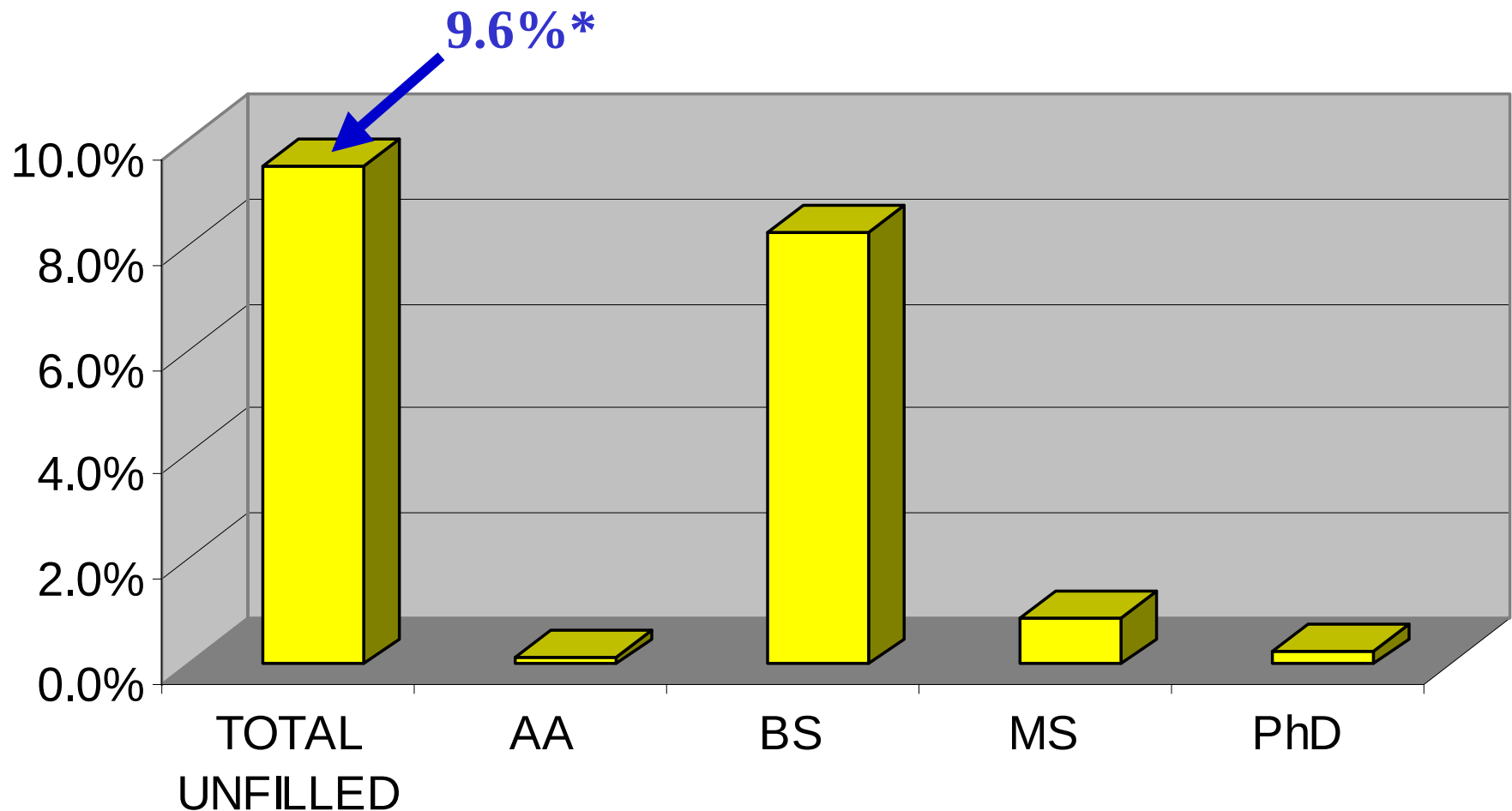
November 04



All US Citizen Science & Engineering Specialties

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Unfilled Requisitions as a Percentage Of Total Employment

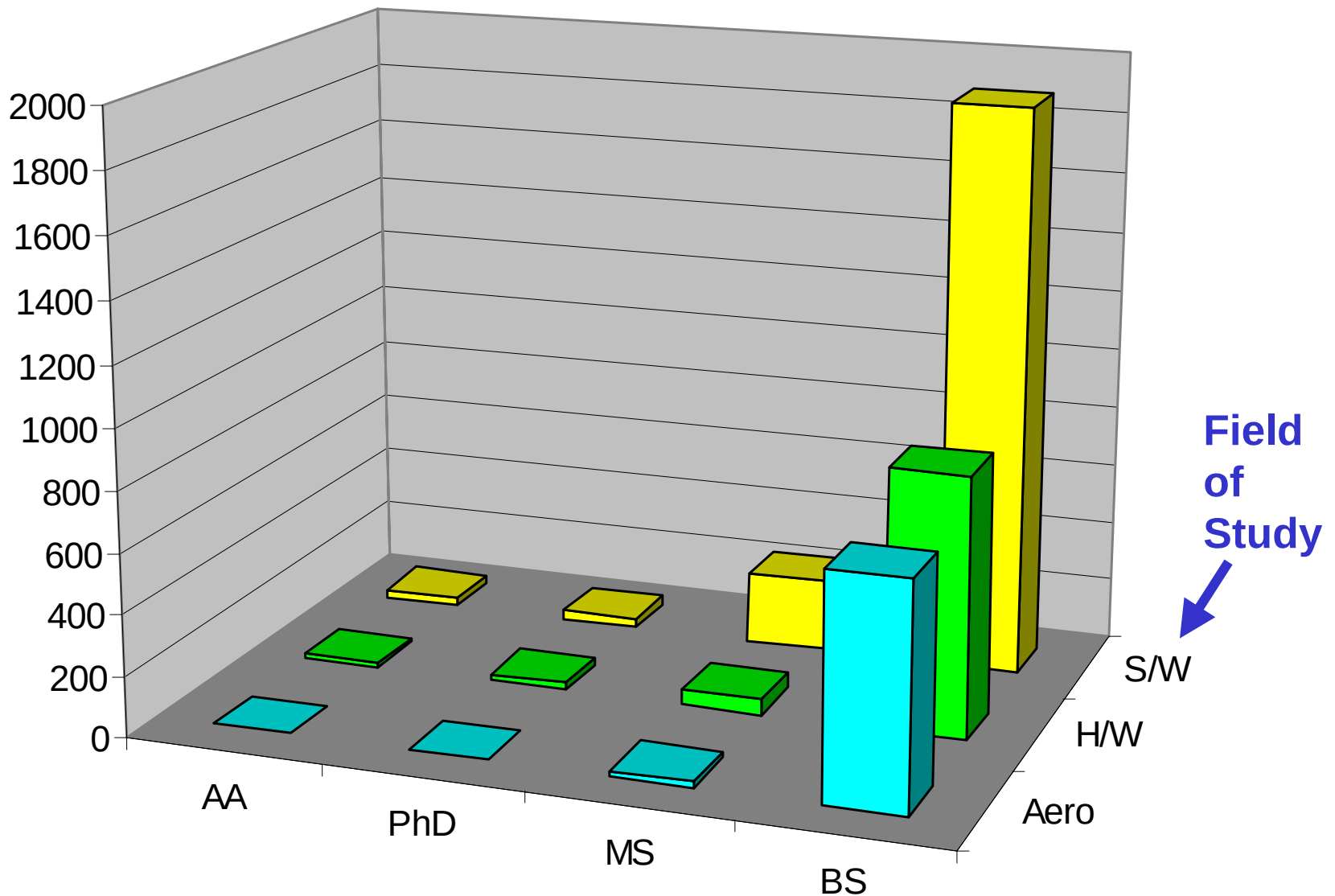


*As a percentage of respondents' total of 55,322 employees of all types, representing the total employment of corporations that responded to the survey and needed US citizen scientists and engineers .

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Unfilled Requisitions by Field of Study

Industry Snapshot November 2004



Aero-Aeronautical Engineering
H/W-Computer Hardware Engineering
S/W-Computer Software Engineering

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Hardest Positions to Fill*

1. Software Engineer
2. Systems Engineer
3. RF Engineer
4. Electrical Engineer
5. Physicist
6. Mechanical Engineer
7. Chemical Engineer
8. Operations Research
9. Program Manager
10. Network Engineer
11. Reliability Engineer
12. Many singles, eg, Focal Plane Gate Array, PCB Design

*Note: 50 responses from HR experts in rough order of number of responses; does not necessarily indicate qualitative scarcity.

Selected Anecdotal Comments

...Our customers, including the U.S. Government, are losing skills in the technical areas of < > and < > design/analysis as well as < >. There are **very few people in the US who can perform the technical tasks required**, and fewer who have incorporated lessons learned from the past 50 years of test and analysis.

...We are having difficulty hiring new employees for the roles ... that have existing security clearances. There is a **real war for talent for individuals with the technical skills AND clearances...**

...any government specific technology that has been contracted out will continue to be a hard to find and a stretch for all companies.

...The safety critical nature of < > is an area that **takes engineers a few years to fully understand** so the transition from the "old-timers" needs to begin within the next few years. In addition, given the nature of the defense business, it is difficult to forecast to a young college graduate engineer, what a challenging 3 to 5 year career path might look like. While it might seem appropriate for companies in our business to "invest" in the development of these young engineers, our margins are being squeezed by the Gov't and the primes and the ability to establish a "pool" of funds dedicated to this area has greatly diminished.

...The primary technical capabilities we look for are < > engineering, and we've had no difficulties hiring these individuals. In 1997, we hired a <foreign> national for a < > engineering position, and then got into some highly classified contracts, which caused some hissy fits on the part of DoD types, and we ended up creating a Technology Control Plan to keep everyone happy. Since that time, **we have purposely avoided hiring foreign nationals.**

...Interim clearance can take just a few days, but **we can't use the interim clearance for most of our work.**

Conclusions from Survey Data

- **Median clearance delays are 1 to 2 years for Top Secret and above**
 - Impacts Government program schedules and industry profits
- **Unfilled requisitions comprise 9.6 % of total employment**
 - Reflects significant shortfall in supply
 - Shortfalls in many science & engineering disciplines
 - Impacts Government program schedules and industry profits
 - Persistent results in Spring '04 and Fall '04 surveys
- **Results among fields of study (FOS) are highly varied**
 - Distribution of unfilled requisitions for each FOS varies significantly across technicians, BS, MS, PhD
 - Dynamic, large changes from Spring to Fall survey
- **Need more insight into shortfalls**
 - Qualitative aspects of demand and supply not captured in first tier definitions
- **Interesting empirical issues**
 - **Fluctuations** in unfilled requisitions may have periodic (seasonal) component
 - Large contract awards and losses may be reflected in fluctuation
 - Could use survey data to estimate total shortfalls, including non-respondents

Survey Methodology Conclusions

- **Snapshot Methodology**
 - Unique information
 - Unfilled requisition data provide dynamic demand/supply insight
 - Collected by neither government nor industry
 - Tracking over time would yield trend data for planning forecasts
 - Skillset shortage data could provide targets for focused short and long term remediation (fix the right problem)
 - Efficient
 - Internet administration
 - Simple survey form
 - Automated collation
 - Low corporate burden
 - Survey uses information generally at hand in corporate HR
 - No paper
 - Protects proprietary information

Appropriate Theoretical Model

Why This Shortfall Was not Detected

- **Neoclassical theoretical model of labor market**
 - Foundation for most Government job and employment data
 - Analysts gravitate toward readily available data
 - Typical model used in undergraduate economics
 - More readers will understand the analysis
 - Unfortunately
 - Actual market forces violate essential assumptions
- **Shortfalls are highly dynamic and detailed**
 - Typical Government data updated through biennial paper surveys*
 - Biennial data do not shed light on this dynamic activity
 - Analyses which use biennial data thus have not shed light on this issue
 - Most government data do not distinguish US citizen scientists and engineers from non-citizens

* BLS JOLTS is an exception

Appropriate Theoretical Model

Neoclassical Shortfall Indicators

From Neoclassical Economic Equilibrium Analysis:*

If the Demand for and Supply of scientists and engineers are not equal, then their wages will tend to rise and their unemployment rates will tend to be lower until equilibrium is restored.

Neoclassical Indicators:

- Increased average salaries
- Reduced unemployment rates
- Increased churning (quit rates) as firms compete for scarce labor
- Increased vacancy rates when firms cannot find workers
- Increased entry level salaries
- Increased immigrant hiring (H-1 visas)

*e.g., see Ch 1 & 4, Labor Economics, Cahuc & Zylberberg, MIT Press, 2004

Appropriate Theoretical Model

Neoclassical Limitations

Neoclassical Competitive model sheds no light on this problem due to:

- **Imperfect job market information**

- Secondary and post secondary school career guidance centers may have limited understanding of the nature of S&E jobs in DOD and IC
- Clearance requirements severely limit information for potential new entrants
- Worker information accessible by industry only if worker is searching
- Many other limitations on job market information transfer

- **Job mobility costs**

- Clearances are expensive for industry
- Waiting for clearances creates monetary and opportunity costs for new hires
- Potential pension benefit losses
- Loss of vacation and sick leave rights
- Moving
- Interviews
- Retraining

- **Inflexible labor supply pipe**

- Long production time, FOS freedom of choice, education expense

- **Inflexible wages**

- Government imposed restrictions on contractor wage changes
- Worker perception/reservation wages tend to make wages 'sticky'
- Industry wage changes respond to profitability, but the defense industry has limited competitive forces, with 'lumpy' production runs that generate large employment changes

Appropriate Theoretical Model

Analysis Conclusions

- **US Defense industry had significant difficulty finding and hiring US citizen scientists and engineers in Spring and Fall 04**
 - **9.6% unfilled S&E requisitions seems too large** to be explained by typical firing, quitting, retiring, and hiring rates
 - Every unfilled day is Government Defense work not performed
 - Every unfilled day is a missed day of current profit
- **Reject the hypothesis that there is no shortage**
- **Labor market for US citizen S&E specialists appears to be distinct from more general labor market**
 - Size of shortages varies significantly among skillsets
 - Degree vacancies vary significantly among skillsets
 - Skillset shortages vary significantly within a year
- **Large delays in security clearance processing**
 - Inhibits workforce mobility into jobs requiring clearance
 - Slows industry response to Government needs
 - Imposes real dollar costs and opportunity costs on job seeking new scientists and engineers, and on industry

Appropriate Theoretical Model

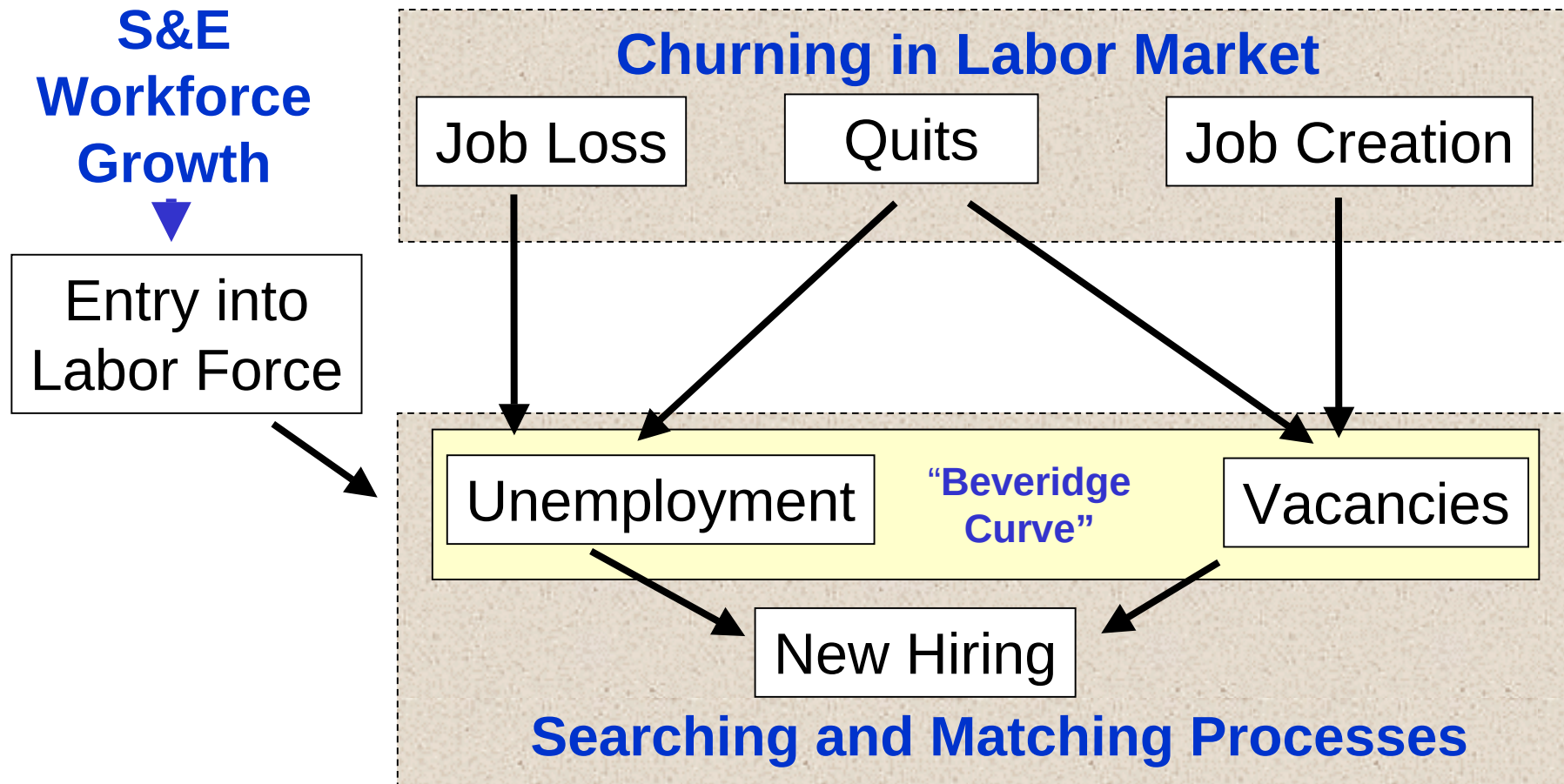
A Better Approach

- **Matching Model***
 - Number of hires and vacancies depends on matching job seekers with vacant jobs
 - Skills
 - Location
 - Clearances
 - Wages
 - Benefits
 - Jobs and workers are heterogeneous
 - Imperfect information leads to persistent vacancy rates
 - Example functional forms
 - Probabilistic- matching urns and balls concept
 - Cobb-Douglas – hires as a function of job seekers and vacancies.

*e.g., see Ch 9, Labor Economics, Cahuc & Zylberberg, MIT Press, 2004

Appropriate Theoretical Model

Matching Model Indicators *



*see "Shifts in the Beveridge Curve, Job Matching, and Labor Market Dynamics," Bleakley & Fuhrer, New England Economic Review, Sep/Oct 1997.

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Appropriate Theoretical Model

Beveridge Curve*

Proxy for
unfilled
requisitions

Vacancy
Rate

Empirical data
suggest that the
**average
vacancy rate is
less than 4%** for
professional
services*

More Efficient Matching Processes
Shift Curve Toward Origin

Empirical data: this curve shifted
out in the 70's and 80's, now has
shifted back.*

5.2% Jan 2005

<http://www.whitehouse.gov/fsbr/employment.html>

Unemployment
Rate

*see Figure 3, "Shifts in the Beveridge Curve, Job Matching, and Labor Market Dynamics," Bleakley & Fuhrer, New England Economic Review, Sep/Oct 1997, also "Job Openings and Labor Turnover, December 2004," NEWS, Bureau of Labor Statistics, USDL 05-206, Feb 9 2005.

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Appropriate Theoretical Model

Evidence of a Shortfall

- To the extent that unfilled requisitions are not planned retirements, unfilled requisitions are a reasonable proxy for vacancies
- **9.6 % is more than twice the 4 % implied by Beveridge Curve**
 - Empirical evidence of a shortfall in supply of S&E workforce in 2004.
- **Emphasizes the critical need for continued data collection**
 - Foundation for Government to anticipate demand – supply mismatches for long term policy changes
 - Track US citizen S&E shortfalls
 - **Surpluses and shortages by discipline**
 - Current trend analysis
 - Nuances of **skillset mix** in demand
 - **Feedback** for US post-secondary education
 - **Scope** of diminishing experience base
 - Basis for more thorough modeling and forecasting in this labor sub-market
 - **Current lack of dynamic S&E data prevents valid forecasts**

The Way Ahead

Addressing the Issues

- Analysis
- Supply Side Flows
- Demand Side Vacancies
- Demand Side Specialty Feedback
- Supply Side Specialty Response
- Forecasting

The Way Ahead

Issues

- Government education and clearance processing **initiatives need feedback** to properly shape and adapt policies to results
 - Industry is significant part of feedback
- US citizen science and engineering is a **National Security issue**
 - Industry is a significant part of the workforce
- US citizen science and engineering supply is a slow, ponderous process
 - Long lead time for policy impact requires long lead forecasting
 - Need good projections to shape supply policy to meet demand
 - Industry represents a significant part of demand
- **Supply issues do not stand alone**
 - Importance is relative to demand
 - Supply-demand mismatch
 - Dynamic changes in demand for emerging sub-specialties
 - US private sector competition for S&E specialists
 - Global competition for S&E specialists
- **Use the Matching Model of Labor Market**

The Way Ahead Analysis

- **Compelling National Defense need** to understand and quantify this labor market
 - 'Steady state' rates
 - Quit rates
 - Retirement rates
 - Vacancy rates
 - Seasonal effects
 - Large contract impacts
 - Security clearance effects
 - Global competition for scientists and engineers
 - Trends
- **Analysis is the prerequisite for anticipating supply and demand mismatches**
- **Data is the prerequisite** for analysis

The Way Ahead

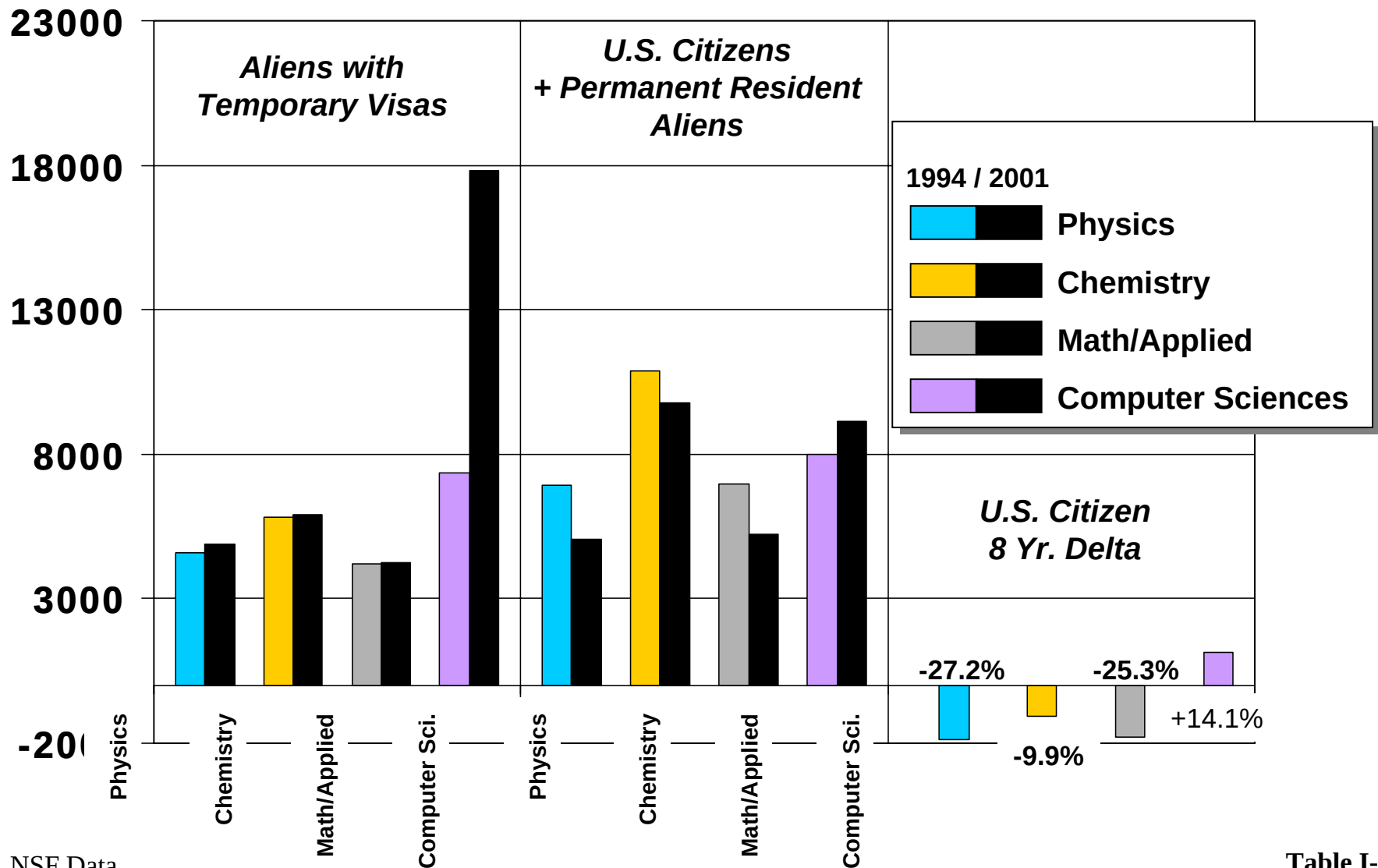
Supply Side Flows

- **Relatively easy to model the annual supply processes**
 - US **academic infrastructure is somewhat static**
 - Data are available on US citizen demographics
 - Few decision points for citizens
 - Early math & science interest
 - Continued interest through secondary school
 - Initial Undergraduate S&E major
 - Continued S&E major to BS
 - Grad school programs
 - Internships
 - Employment
 - **Commercial software well suited to task**
- **Feedback for Government initiatives**
 - **Measure effects of government policies at decision points**
 - Adapt policies to projected changing conditions
- **Industry participation**
 - Support education initiatives
 - Foster deeper relationships with US S&E sources

The Way Ahead

Supply Side Flows - Science Disciplines

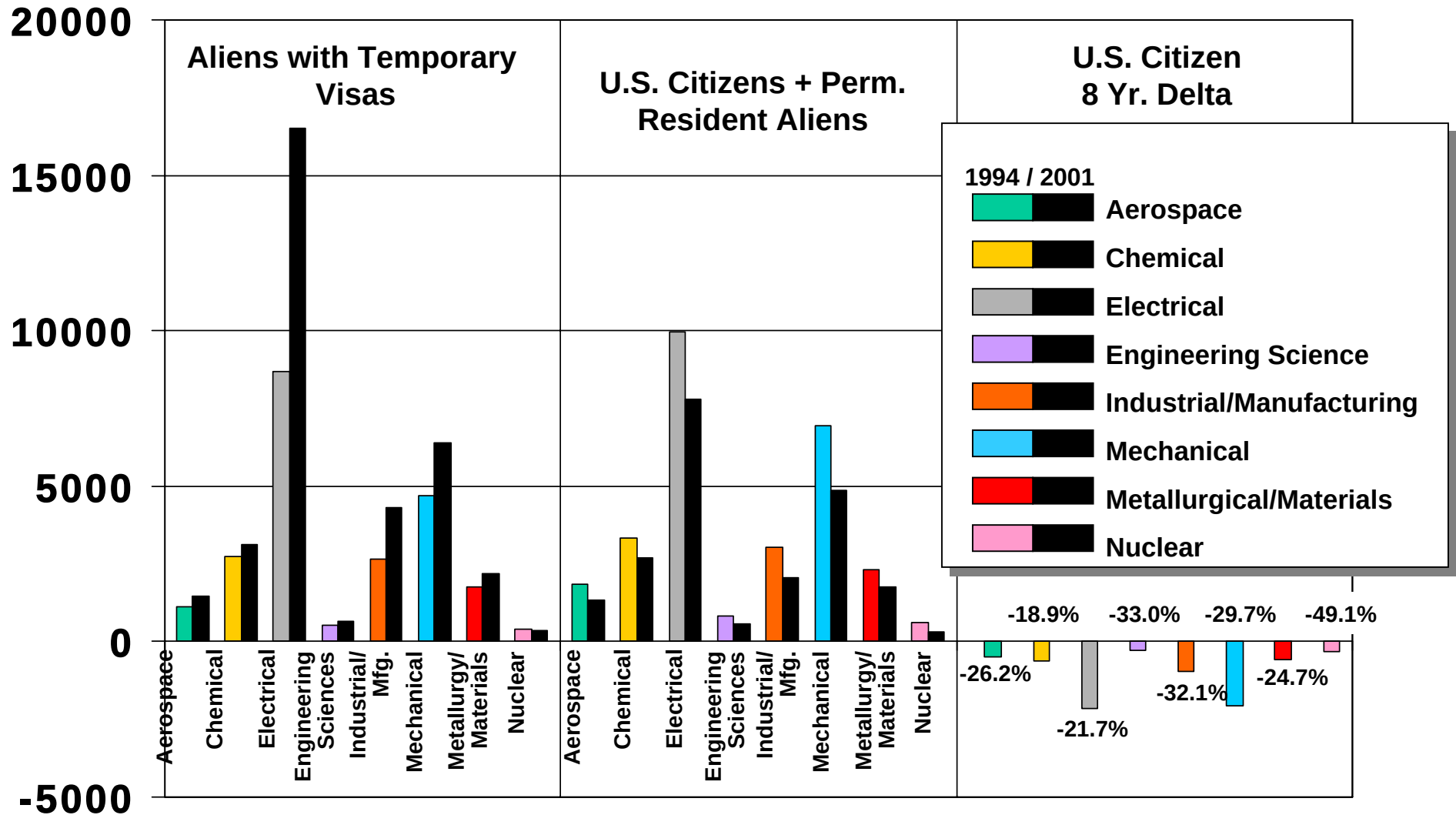
U.S. University Trends in Defense-Related
S&E Graduate Student Enrollment (1994-2001)



The Way Ahead

Supply Side Flows - Engineering Disciplines

U.S. University Trends in Defense-Related
S&E Graduate Student Enrollment (1994-2001)



The Way Ahead

Demand Side Vacancies

- **Survey Approach**
 - Efficient to administer
 - Efficient to complete
 - Proprietary information was easy to protect
- **Publish Results**
 - Web site accessible by subscribers
 - NDIA, AIA, Government, Academia
 - Push monthly results to subscribers
 - 1 week turnaround of new monthly and trend data
- **Establish historical database for analysis**
 - Collaborate with BLS, NSF, DOE, Dept of Education
- **Survey enhancements**
 - Additional automation of data compilation
 - Small macro coding task
 - Employ survey text analysis tools
 - Efficiently exploit free text responses
 - Commercial software well suited for this task

The Way Ahead

Demand Side Specialty Feedback

- **Follow-up with respondents to refine understanding of emerging skills demanded by industry**
 - **Collaborate** with BLS, NSF, DOE, Dept of Education
- **Employ a survey text analysis tool**
 - Open-ended questions can provide new insights
 - Commercial off the shelf software
- **Identify sub-specialties**
 - **Timely data on changing demand**
 - New specialties
 - Shortfalls
- **Publish information annually**
- **Respond to data requests from subscribers**
 - Create open-ended survey questions in free text form

The Way Ahead

Supply Side Specialty Response

- **US industry has limited impact on entry-level supply**
- **Academic institutions have limited insight into this labor market**
 - Changing trends in demand
 - Specialty skill shortfalls
 - Emerging demand for new skills
 - Specific demand for US citizens
 - Classified information on workforce tasks
- **Government is impacted by supply shortfalls**
 - Contract performance (cost, schedule, risk)
 - Product quality

The Way Ahead Forecasting

■ Supply forecasting

- Academia, Gov't Labs, and industry intern programs provide entry level flow
 - Relatively static flows-conceptually simple models
- Could be performed by industry or government
- Required technology is in hand
 - Process modeling software
 - Drag & drop icons
 - Explicit flows through nodes
 - Probabilistic choices at decision points
 - Influenced by policies and outreach
- Main effort is collecting the data
- Model IOC in 12 months, FOC in 18 months

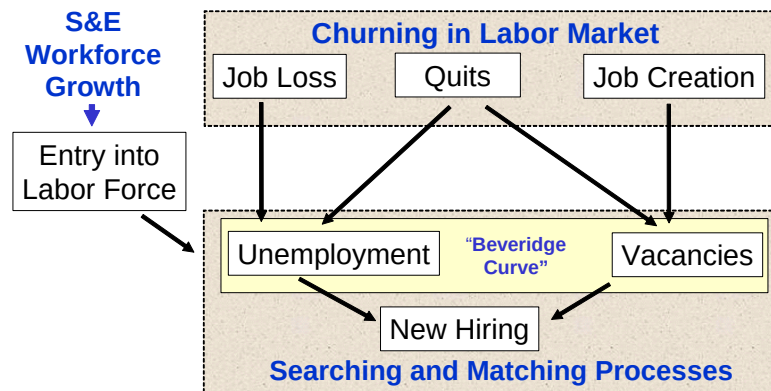
The Way Ahead Forecasting

- **Demand forecasting**

- Government demand closely tied to R&D funding
 - Relatively simple econometric model
- Industry demand model depends on continued industry survey data collection and analysis
 - Start with simple monthly model
 - Evolve complexity to include impact of contracts, annual hiatus due to Congressional appropriations politics, vacancies due to global competition, etc.
- Integrated with other forecasts
 - Government R&D budgets
 - US S&E labor market and economy
 - “Rest of World” S&E labor market and economy

The Way Ahead Forecasting

- **Anticipating supply-demand mismatches**
 - Inform government policy decisions
 - Influence supply chain resource allocation
 - Scholarships
 - Fellowships
 - Internships
 - Community outreach for S&E careers
- Final total supply-demand model requires several skills
 - Labor Market Economics
 - Time series analysis
 - Econometrics
 - Understanding of US DOD and Intell industry



The Way Ahead

Bottom Line

- **This is a tractable problem**
- **Analytic methodology is in hand**
- **Data collection is critical**
 - Shown to be relatively easy and inexpensive
 - Understand the nature of this specialized labor market
 - Enable analysis
 - Anticipate demand and supply mismatches
 - Inform supply side
 - Academia
 - Labs
 - Measure the effects of government and industry initiatives

The Way Ahead

Bottom Line

■ Recommendations

- Immediately begin monthly data collection using existing survey instrument
- Immediately begin modeling supply side flow using commercial tool
- Immediately establish web site for collaboration
 - DoD
 - Industry
 - BLS, NSF, DOE, DOEEd
- Develop plan for implementation in 12 months
 - Feedback for government initiatives
 - Demand forecasting
 - Anticipating supply-demand mismatch

Open Discussion

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Defining the Future

NORTHROP GRUMMAN