Physics Careers in Government Contracting: Defense and Energy

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General Atomics
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www.ga.com
www.sci-ed-ga.org
Physics at General Atomics – mostly energy and defense

- Fusion energy science (energy)
- Nuclear reactors (energy)
- Laser fusion target fabrication/evaluation (energy)
- Electromagnetic launch systems (defense)
- Magnetically levitated trains (DOT)
- Advanced energy conversion systems (defense/energy)
- High energy density capacitors (energy/defense)
- Thin film coatings (energy/defense)
- High power laser systems (defense)
- Laser based reconnaissance (defense)
- Unmanned airplanes (defense)
My Brief History

- PhD UCSD Low temperature heat capacity of magnetic superconductors – many publications, 1980
- Disappointing/unproductive post-doc at Exxon Research, 1980-1982
- Hired as solid state physicist at General Atomics (GA) in 1982 to help develop non-nuclear programs. At GA for 27 years – mostly materials R&D.

Every story and perspective of life in industry is unique and changes depending on the stage of one’s career
Neutron transmutation doping of silicon – determining doping/fluence, measuring properties
Studied the electronic properties of graphite fibers—potential lightweight electrical conductors
Invented Photothermophotovoltaic Energy Conversion: a new type of energy conversion system
Developed high temperature electrical insulators for space nuclear power systems
Led high temperature superconducting (HTS) wire development project

- 7 years, papers, patents, presentations
- Effort was commercially unsuccessful
- HTS still not a commercial success
One-Way Imaging Film Development with a small company
Industrial careers are varied – and often unrelated to PhD thesis

- Neutron doping of silicon: ’82-’83 (GA funding)
- Graphite fiber physics and materials science: ’83-’85 (GA funding)
- Thermophotovoltaics: ’86-’87 (Gov. funding)
- High temperature insulators, thermionic energy conversion for space nuclear power: ‘88-91 (Gov. funding)
- High temperature superconductors; ceramic processing; wire fabrication: ‘91-’98 (Japanese Venture Capital funding)
- High temperature insulators for conductors for aircraft: ’98-’00 (Gov. funding)
- Thin film designs and coatings: ‘01-’10 (Gov. funding)
- Program management, government contracting, intellectual property/patents, budgeting, proposal writing, internal and external reports, personnel management: ‘87-’10

*Punctuated Equilibrium Theory of Job Evolution*
Evolution of my job over time

- R&D using knowledge learned in school
- R&D using new knowledge
- Manage technology development
- Manage programs

% of Time Spent on Activity

What do I do all day?

- New ideas/solution to problems
  - Internal R&D proposals to management
    - Sell concept to management, considering technical risk, core competency, existing equipment, schedule, costs, competition
  - Respond to Requests for Proposals (RFP) or Broad Agency Announcements (BAA)
    - Write/manage technical and cost proposal, including schedule, milestones
- Develop/optimize designs/concepts (physics)
- Develop overall experimental approach (manufacturable)
- Initial development
  - Initiate development/analyze data
  - Use analysis to design next experiment
  - Iterate until initial development is complete
What else do I do all day?

- Transition from initial development to pilot scale production
- Assist transition from pilot scale production to full scale production
- Write reports: technical, cost, contractual issues
  - Monthly reports
  - Final report
  - Task/technical reports
- Write and give presentations to internal management and funding agency, neither of whom may be experts in the technology (importance of explaining technology to non-experts!)
- Discuss issues with technicians, engineers, scientists, managers both informally and in formal meetings

*Note: Most of this does not involve solving physics problems!*
Similarity of work in government contracting and university research

- Professor receives funding from government for basic research and manages all aspects of the program
- Program manager in industry receives funding from government for applied R&D and manages all aspects of the program
But major differences between industry and university

Technology Readiness Levels (TRL)

- University Research: TRL 1
- Industry: TRL 1 to 9
Need to understand/consider issues other than technology development

- Technology Readiness Levels (TRLs) leave major transition questions unanswered:
  - Is the technology manufacturable?
  - What will it cost in production?
  - Are key materials and components available?
# Need to consider and increase Manufacturing Readiness Level (MRL)

<table>
<thead>
<tr>
<th>MRL</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Basic Manufacturing Implications Identified</td>
</tr>
<tr>
<td>2</td>
<td>Manufacturing Concepts Identified</td>
</tr>
<tr>
<td>3</td>
<td>Manufacturing Proof of Concept Developed</td>
</tr>
<tr>
<td>4</td>
<td>Capability to produce the technology in a laboratory environment.</td>
</tr>
<tr>
<td>5</td>
<td>Capability to produce prototype components in a production relevant environment.</td>
</tr>
<tr>
<td>6</td>
<td>Capability to produce a prototype system or subsystem in a production relevant environment.</td>
</tr>
<tr>
<td>7</td>
<td>Capability to produce systems, subsystems or components in a production representative environment.</td>
</tr>
<tr>
<td>8</td>
<td>Pilot line capability demonstrated. Ready to begin low rate production.</td>
</tr>
<tr>
<td>9</td>
<td>Low Rate Production demonstrated. Capability in place to begin Full Rate Production.</td>
</tr>
<tr>
<td>10</td>
<td>Full Rate Production demonstrated and lean production practices in place.</td>
</tr>
</tbody>
</table>
Physicists in industry should know something about process and manufacturing engineering

- Process and manufacturing engineers often do not understand the basic physics enough to understand how best to process and manufacture the material/device; physicists need to understand relevant process and manufacturing techniques to efficiently transition basic technology into production
- Perform R&D with final goal informing selection of design, materials, processes
Levels of employment in industry: Level ~$ (physics)
(Aviation Week and Space Technology 2009 Workforce Study)

Level 1. Individual contributor working under direction of technical leadership, beginning to understand internal processes and tools for systems development ($66K)

Level 2. Improved knowledge of product, some self-direction, understands internal processes, and contributes to engineering estimates ($80K)

Level 3. Significant knowledge of products, decisions may have significant impact on costs, schedule, and performance. Mentor to more junior engineers ($99K)

Level 4. Serves as system architect, recommend tools and techniques for continuous improvement, lead preparation of proposals and presentations, estimates and tracks costs and schedules while managing scope ($120K)

Level 5. Develops product and technical roadmaps and competitive assessments, leads or reviews proposals, cross functional teams in a project engineering roles ($138K)

Level 6. Industry expert in knowledge of products and systems, directs sophisticated design, analysis and testing of complex systems, provides direction on strategic technology plans for company ($177K)
1. Be responsive – return phone calls and emails promptly. When asked to do something, do it on time – be sure to ask when it should be done. Document requests and responses in writing.

2. Become the world expert in your particular area.

3. Continually expand the depth and breadth of your knowledge and skills.

4. Utilize all information resources available - books, science magazines, web sites, search engines, search services, colleagues, patents, trade magazines, catalogs, sales reps, conferences.

5. Get involved with or develop projects that have a high probability of contributing to the company’s success.
My 15 Point Guide to Success

6. Understand and be aware of project constraints such as your personnel and company capabilities, competitor’s strengths, and customer needs.

7. Innovate continuously. Always push your envelope as well as the science and technology envelope. Stay uncomfortable with what your skills and knowledge are.

8. Document your work in manner that can be easily understood by a co-worker a year from now. Use spreadsheets, tables and charts to convey your results in a concise, visual, and easy-to-understand manner.

9. Make sure that you learn something useful from any tests or experiments that you perform. These results should form the basis for future tests.

10. Learn from your mistakes. Don’t repeat them.
11. Don’t believe everything you are told, even if it is company lore or told to you by an expert. Be skeptical.

12. Enjoy your work.

13. Treat everyone you work with (above and below you) with respect. Thank them for their work. Acknowledge their contributions whenever possible. Keep them informed as to what you are doing and why you are doing it.

14. Have a sense of humor.

15. Develop a unique and necessary skill and knowledge set that complements those of your co-workers and greatly increases the value of your project/team. Be indispensible.
Expanding on these points …

- “… you need to be very good at whatever you are hired to do. One aspect of communication is to let your colleagues know that you are being productive.”
- “Being good at what you are hired to do will help you keep your job today. Constantly learning and growing in your abilities will help you remain competent tomorrow. Taking on project management responsibilities will broaden your experience and build your reputation and network of contacts. What you learn in the process will keep you employable, not to mention being more valuable to your company.”

Advantages of Careers in Industry

- Goal is development of a product
- Satisfaction of seeing your efforts make a difference to people
- Opportunities for patents, business development
- Challenge of not just doing science, but applying science to technology, then figuring out how to commercialize it. Challenges include science, technology, manufacturing, costs, schedule, competition, a dynamic marketplace.
- Challenge of learning how to perform R&D and scale-up under time, cost, equipment, personnel, facilities constraints
- Varied career opportunities: science, technology, manufacturing, program management, group management
- Many different projects; constant learning needed
- Pay, bonus pool
Disadvantages of Careers in Industry

- Often minimal publications or presentations due to proprietary or security issues
- Focus on a defined goal
- Limited freedom to pursue your personal interests
- Reduced likelihood of being recognized for your achievements from an academic perspective, e.g. awards, fellowships, etc
- No sabbaticals, no tenure
- Reduced interactions with peers due to proprietary or security issues
- Need to rapidly reinvent yourself as technologies and business areas change
Recommendations to enhance preparedness for physics related careers in industry

- Have grad students participate in proposal writing and in determining the direction of future research – similar to determining the strategic direction of a business unit
  - Evaluate core competencies vs. competitors
  - Evaluate opportunities for major discoveries (academic) or businesses (industry)
- Have grad students locate, discuss and evaluate proposal opportunities from RFPs and BAAs
- Have grad students schedule and track contractual and financial progress
Recommendations to enhance preparedness for physics related careers in industry

- Have learning goals in classes more closely mirror industry needs
  - Short term memorization and rapid problem solving are not important, yet form the basis for most tests – major disconnect
  - Need to be able to develop solutions to new problems based on deep conceptual and quantitative understanding across multiple fields
  - Often a focus on mathematical derivations to the exclusion of deep conceptual understanding, especially in graduate classes – isn’t this a form of rote learning?
Recommendations to enhance preparedness for physics related careers in industry

- Have grad students evaluate eventual commercialization of their research
  - How could it be mass produced
  - What are advantages vs. competition
  - Work with grad students in process engineering and manufacturing engineering and learn about these topics
  - Evaluate potential material and production costs

Could this meet, in part, the NSF broader impacts requirement?
Recommendations to enhance preparedness for physics related careers in industry

- Include more engineering in physics courses
  - real-world problems
  - Industrially relevant advanced labs
- Bring in industrial physicists for colloquia to talk about their work
  - Near exclusion of information for undergrads and grads to understand what life is like in industry
- Survey your graduates in industry and ask them how their education could have been improved to increase their success at work – see next slide
Survey of MIT ME Grads ‘92-’96

Source of Learning

- did not elsewhere job grad school
- MIT ungd

ME Core
Professional skills
How & Why

From MIT S.B. June 2004 Thesis of Kristen Wolfe, under Prof. Seering via Prof. Woodie Flowers
Overall: need to educate for innovation

- “The inability of graduating students to integrate all they have learned in the solution of a real-world problem, at any level, is a failure.”
- “Innovation, the process of inventing something new, desirable, useful, and sustainable, happens at the intersection of technology (is it feasible?), business (is it viable and sustainable), human factors (is it desirable?), and complexity (is it usable?)”
- “[students] must be able to identify the needs of people and society, critically think and solve problems, generate human centered ideas and rapidly prototype concepts, integrate human values and business into concepts, manage complexity, work in multidisciplinary teams, and effectively communicate results”

Education activities are possible in industry

- Outreach program started at GA in 1992
- Many companies have education outreach programs
- Details and funding are highly dependent on the company and the initiative and desire of the individual scientist
- Use your unique knowledge and insight to develop an education activity of use to K-12 (or others)
Developed education modules and posters,
Curriculum designer and content reviewer for middle and high school science program
Extensive education activities are possible in industry – although not necessarily common

- Developed 3 Posters
- Developed educational modules and materials
- 2 papers in The Physics Teacher (and a cover!)
- >100 presentations/workshops
- NSF education proposal review panels
- Reviewed NSF programs
- Curriculum reviewer for 2 middle school modules and a 3-year interdisciplinary high school program
- APS Forum on Education Chair
- APS Forum on Education newsletter editor/session org.
- APS Committee on Education
- Future of Materials Education Workshop
- Many activities related to CA standards, framework, and instructional materials
Conclusion

- **Physics careers in industry**
  - Varied
  - Rewarding
  - Dynamic
  - Challenging
  - Many aspects not included in curriculum

- **Education opportunities in industry**
  - Outreach
  - May be more extensive depending on personal motivation and corporate culture
“ I never varied from the managerial rule that the worst possible thing we could do would be to lie dead in the water with any problem. Solve it. Solve it quickly, solve it right or wrong. If you solve it wrong, it will come back and slap you in the face, and then you can solve it right. Lying dead in the water and doing nothing is a comfortable alternative because it is without risk, but it is an absolutely fatal way to manage a business.”

Thomas J. Watson, Founder of IBM
Importance of good health

- Balanced and varied diet
- Daily exercise
- Outdoor activities
- Sufficient sleep
  - Sleep apnea resulted in ~10 years of subpar performance compared to 100% awake (fuzzy brain for 80% of day, fighting to stay awake, particularly when driving – lethal danger)
Aim is to transform engineering undergraduates into tomorrow’s engineering leaders via project-based learning, extensive interaction with industry leaders, hands-on product development, engineering leadership labs, and authentic leadership challenges and exercises.

“What’s important in engineering education? Making universities and engineering schools exciting, creative, adventurous, rigorous, demanding, and empowering environments is more important than specifying curricular details” Charles Vest, NAE President and former President of MIT

http://web.mit.edu/gordonelp
Goal: High quality as defined by ISO 9001

Quality Management

An organization [needs to] enhance customer satisfaction through the effective application of the system, including processes for continual improvement of the system and the assurance of conformity to customer and applicable statutory and regulatory requirements.

- Well defined requirements
- Well defined specifications and procedures for materials/inputs, processes, and products/outputs
- Procedures for determining customer satisfaction and for continual improvement
The Critical Need for Closer Ties Between Physics and Industry

“Many [physicists] are spending much of their time in dead-end ‘Waiting for Godot’ post-doctoral positions when they might better be directing their efforts to the Nation’s critical industrial needs...We must redirect, somehow, our physics resources to the refinement and expansion of the Nation’s manufacturing infrastructure.”

Philip Wyatt in APS News, Dec 2009 (See also letters to the editor in Feb 2010 APS news in response)
70% of physics PhDs are in non-academic positions

Table 3. Initial employment sectors of physics PhDs by type of position accepted, classes of 2005 & 2006.

<table>
<thead>
<tr>
<th>Type of Position</th>
<th>Potentially Permanent</th>
<th>Postdoc</th>
<th>Other Temporary</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic*</td>
<td>29%</td>
<td>75%</td>
<td>68%</td>
<td>61%</td>
</tr>
<tr>
<td>Private Sector</td>
<td>60%</td>
<td>1%</td>
<td>13%</td>
<td>19%</td>
</tr>
<tr>
<td>Government</td>
<td>10%</td>
<td>22%</td>
<td>12%</td>
<td>17%</td>
</tr>
<tr>
<td>Nonprofit</td>
<td>1%</td>
<td>2%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>-</td>
<td>2%</td>
<td>1%</td>
</tr>
</tbody>
</table>

* Includes University Affiliated Research Institutes

*Statistical Research Center, Initial Employment Report*
Employers that recently hired BS Physics

- 3M
- Aerotek
- American Museum of Natural History
- BAE Systems
- Boeing
- Booz Allen Hamilton
- Corning, Inc.
- DuPont
- Epic Systems Corporation
- General Electric
- Gunderson Dettmer
- Honeywell
- Intel Corporation
- Kaplan
- Lockheed Martin
- Microsoft
- NASA
- Northrop Grumman
- Raytheon
- Schlumberger
- Sonoscan, Inc.
- Sylvan Learning Center
- United Space Alliance
- US Patent & Trademark Office
- ViaSat, Inc.
Goal is:
- Mature technologies
- Stable designs
- Production processes in control

Products made by immature manufacturing processes generally:
- Cost more
- Are prone to quality problems
- May not all perform the same
- Have a hard time delivering on schedule
Understand Manufacturing Readiness

- Manufacturing risk identification and management must begin at the earliest stages of technology development, and continue vigorously throughout each stage of a program’s life-cycle.
- Matters of manufacturing readiness and producibility are as important to the successful development of a system as those of readiness and capabilities of the technologies intended for the system.
Science research needs to be responsive to society’s needs and contribute to the economy

WHAT’s NEW  Robert L. Park  Friday, 5 Feb 2010  Washington, DC

2. LOCAL WARMING: SCIENCE IS SPARED FROM DOMESTIC SPENDING FREEZE

The administration believes research will increase the long term prospects for employment, which is almost certainly true. Science was therefore exempted from the domestic spending freeze. NSF would receive a boost of more than 7% and global climate research would increase by 21% across eight agencies. The scientific community must now demonstrate that the President’s trust is not misplaced.
Solving problems: my general approach

- Define the problem: what am I trying to solve?
- Learn relevant background information
- Develop multiple approaches to solve the problem
- Summarize data into tables and charts that can be understood by someone else a year from now
- Analyze and summarize data and results in report
- Use these results as the basis for further work (and be persistent and don’t get discouraged)
## Differences Between School and Work

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>SCHOOL</th>
<th>WORK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning</td>
<td>Curriculum-based learning</td>
<td>Needs-based learning</td>
</tr>
<tr>
<td>Memorization</td>
<td>Often</td>
<td>Never</td>
</tr>
<tr>
<td>Importance of solving timed problems</td>
<td>Very</td>
<td>Not</td>
</tr>
<tr>
<td>Learning resources</td>
<td>Mainly textbook</td>
<td>Co-workers, books, suppliers,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>technical papers, web, trade</td>
</tr>
<tr>
<td></td>
<td></td>
<td>magazines, etc.</td>
</tr>
<tr>
<td>Nature of problems</td>
<td>Well-defined</td>
<td>Often ill-defined, e.g.</td>
</tr>
<tr>
<td></td>
<td>Single subject area</td>
<td>What is the best way to ... ?</td>
</tr>
<tr>
<td></td>
<td>Work alone</td>
<td>Multidisciplinary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Work as part of team</td>
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</table>
“In place in America’s schools and colleges is a curriculum adopted in the 19th century, a curriculum that ignores the fundamental, systemically integrated, mutually supportive nature of knowledge, that has no agreed-upon aim, that lacks criteria establishing what new knowledge is important and what old knowledge to discard… The curriculum has no built in mechanism forcing it to adapt to change.”

From: “National Subject Matter Standards? Be Careful What You Wish For, Marion Brady, Education Week, September 22, 2009
Some Useful Resources

New York Times “Corner Office” articles about how to manage and lead
  • www.nytimes.com/corneroffice

Undergraduate careers
  • http://www.physics.cornell.edu/undergraduate/careers/

The engineer of 2020
  • http://www.nae.edu/nae/naepcms.nsf/weblinks/MKEZ-5Z5PKL?OpenDocument