

*Presentation to National Academy Committee On
Growth of Computer Science Undergraduate Enrollments*

Changing Nature of Computer Science and Its Impact on Undergraduate Education

*For the panel on
Centrality and Dimensions of Computing*

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Outline

Computer Science: The Expanding Sphere

CS + I/T Employment Prospects Diverse and Strong

Implications on Higher Education

Software – Unbounded Opportunities

- **Software is synthetic discipline with ~0 marginal cost of production**
 - Applicable to almost every aspect of human activity
 - But, surrounded by many operational/organizational activities
- **Computing, Storage and Networking:**
 - Enormous capability today: $>10^6$ in *all key* metrics since I was a student
 - Capability will continue to improve geometrically for quite a while
 - Note: lithography limits will not crimp growth even if no major innovation
- **There is virtually no limit on what we can create: the target domain is entirety of human activity**
 - Fewer limits than in most engineering fields
 - Applicability has been hard to predict, but always surprisingly large
 - Backlog, even in traditional spaces, is huge
 - Enormous progress on AI: *When, not, if*
 - Limiting factor, if any, will be security/resilience

Key: Very High Elasticity (Price and Innovation) of Demand

CS: The Expanding Sphere

The core of CS

1. Mathematical Analysis
2. Engineering Methodologies
3. Empiricism (recent, dramatic change in emphasis)

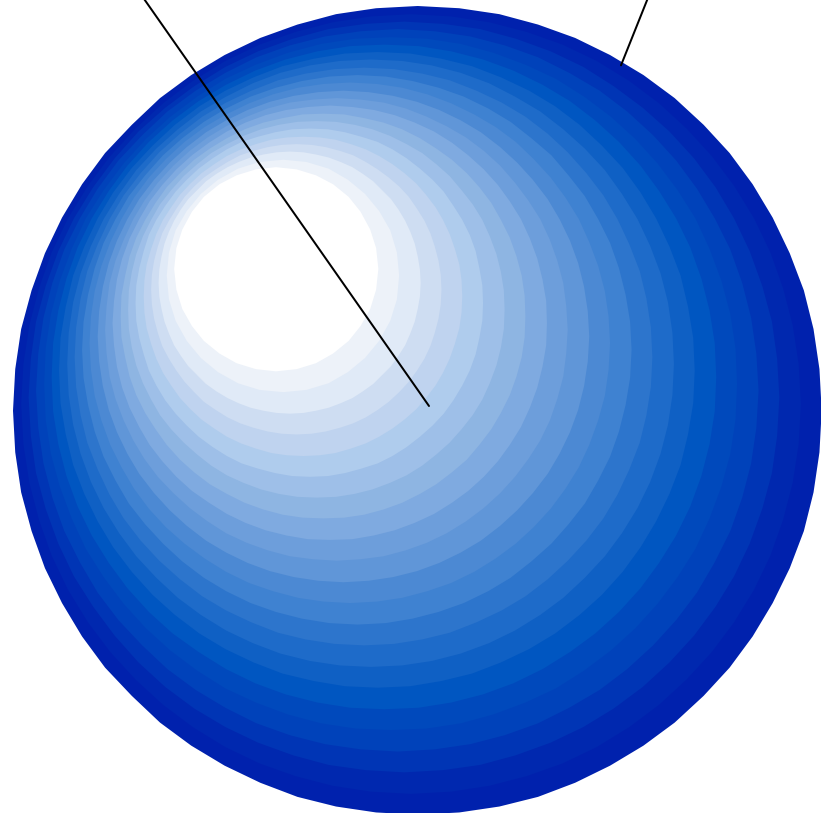
The core is vibrant: opportunities relate to:

1. Massive Parallelism
2. Massive Data
3. New Algorithms and UI's
4. Cloud
5. Software Engineering Tools
6. Security
7. Architecture...

At the edge of the expanding sphere, the field will be at the center of global integration in all disciplines

A Vibrant CS Core

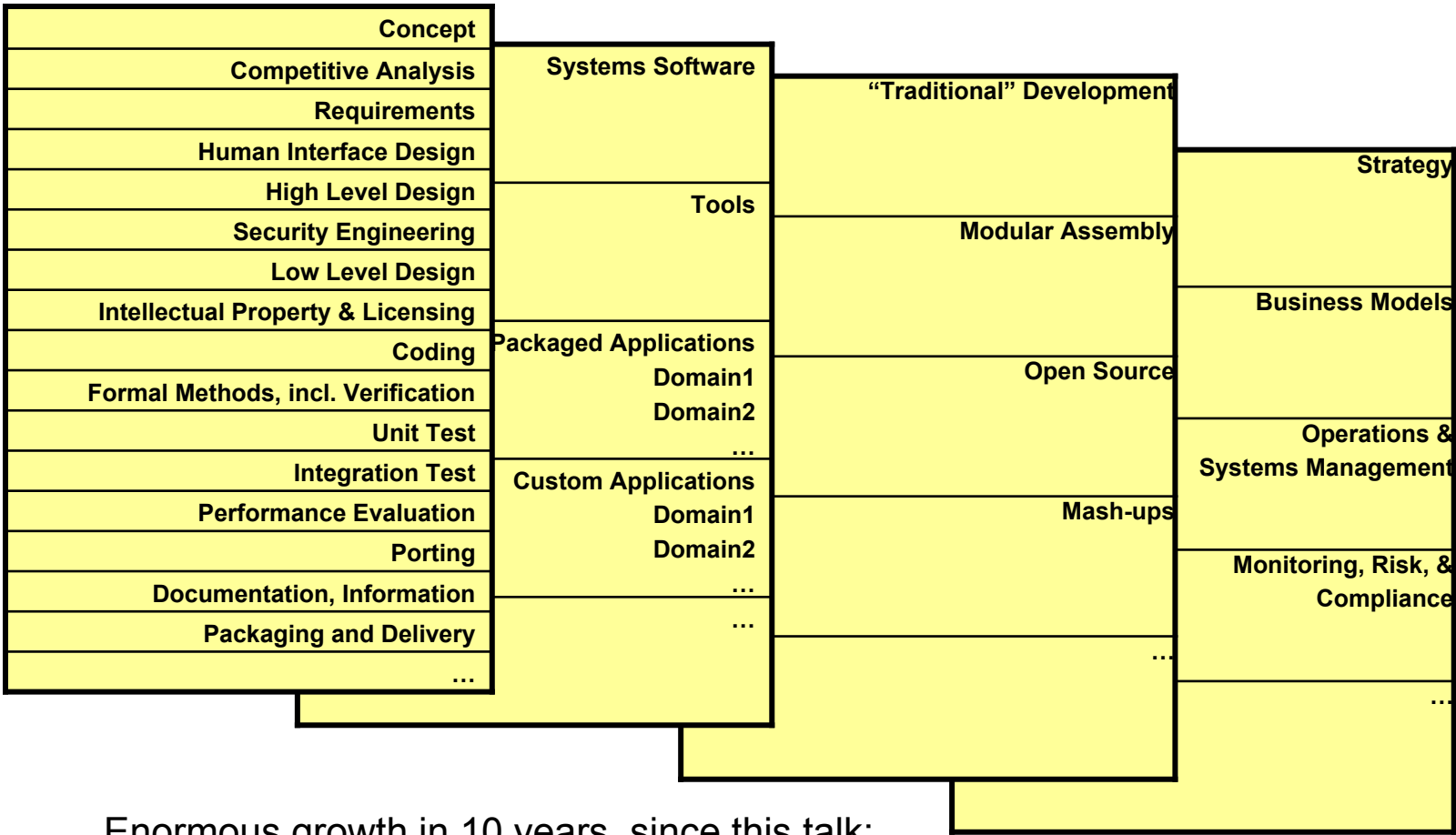
Vast opportunity at the edge as the sphere expands into $\forall \text{CS} + X_i$ (for all X_i)¹



Expanding Sphere of Computer Science

¹from AZS Presentation to Harvard in 11/2004

Software: A Very Diverse Field of Endeavor¹



Enormous growth in 10 years, since this talk:

Cloud computing, smartphones, machine learning and AI, social networking, data science, security, robotics, computational photography, computational finance, resource sharing, computational social science, digital humanities, EHRs, X-omics, ...

¹From 2006 NAE Talk on Software Offsourcing

Corroborating Experience from my Time at Google & Two Sigma

- **Both of my recent companies, Alphabet and Two Sigma**
 - Believe immense opportunity, that is somewhat talent-limited
 - Have been growing at 20+% CAG in CS Hiring
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- **Talent acquisition and retention are key to firms**
 - Starting salaries for good CS graduates typically >> \$100K
 - Grace Hopper: 8,700 attendees recruiting 3,000 female students
 - Even my relatively modest-sized company decided to create a large, education-focused onboarding (NewTS) program
 - Employee perks abound

Summary re: Field and Employment

1. Fundamental, technical reasons to believe in CS Exceptionalism
2. Enormous diversity of computing growth
 - Within sphere and at the periphery
 - Great variability in objectives, job types, and practices
3. Demonstrably high employment demand today
4. Long term growth trends, not likely to be derailed
 - Backlog, unpredictable applications, AI, security, ...
 - Perhaps, compensation is frothy in some pockets
 - High elasticity of demand

Implications on University Computer Science Education

- CS, as a field, has broadened very rapidly - in 40 years:
 - Vastly many more sub-disciplines
 - Whether CS+X, Computational Thinking, or Big Data, every department needs CS infusion
 - Vastly more applications and economic activity
- Challenges
 - Compensation challenges
 - Faculty capability, size, and workload
 - Departmental and School organization
 - Efficiency and quality matter: **no** field has greater opportunity for immersive, social, adaptive **EdTech**
 - Vast amounts of educational material on the web
 - Significant progress in underlying technology
 - Computer scientists are at the forefront



Overall Summary/Conclusions

- CS has surprisingly, unlimited potential
- There is high elasticity of demand
- We need to teach CS core students and those at the periphery
 - CS Major, Masters, Ph.D.'s important
 - Hybridization is very important with every discipline
 - $\forall X_i$ (CS + X_i) benefits all departments
 - Each hybrid program requires crafting - curricula vary
 - Universities should recognize CS exceptionalism
 - EdTech should grow rapidly everywhere but faster in CS
- Leadership in CS and I/T are important for the broader economy; and we cannot take our leadership for granted