Investment in High Performance Computing

A Predictor of Research Competitiveness in U.S. Academic Institutions

Really

Amy Apon, Ph.D.
Director, Arkansas High Performance Computing Center
Professor, CSCE, University of Arkansas
Stan Ahalt, Ph.D.
Director RENCI
Professor, Computer Science, UNC-CH

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Collaborators

Amy Apon
University of Arkansas

Stanley Ahalt
RENCI, University of North Carolina

Vijay Dantuluri
RENCI, University of North Carolina

Constantin Gurdgiev
IBM

Moez Limayem
University of Arkansas

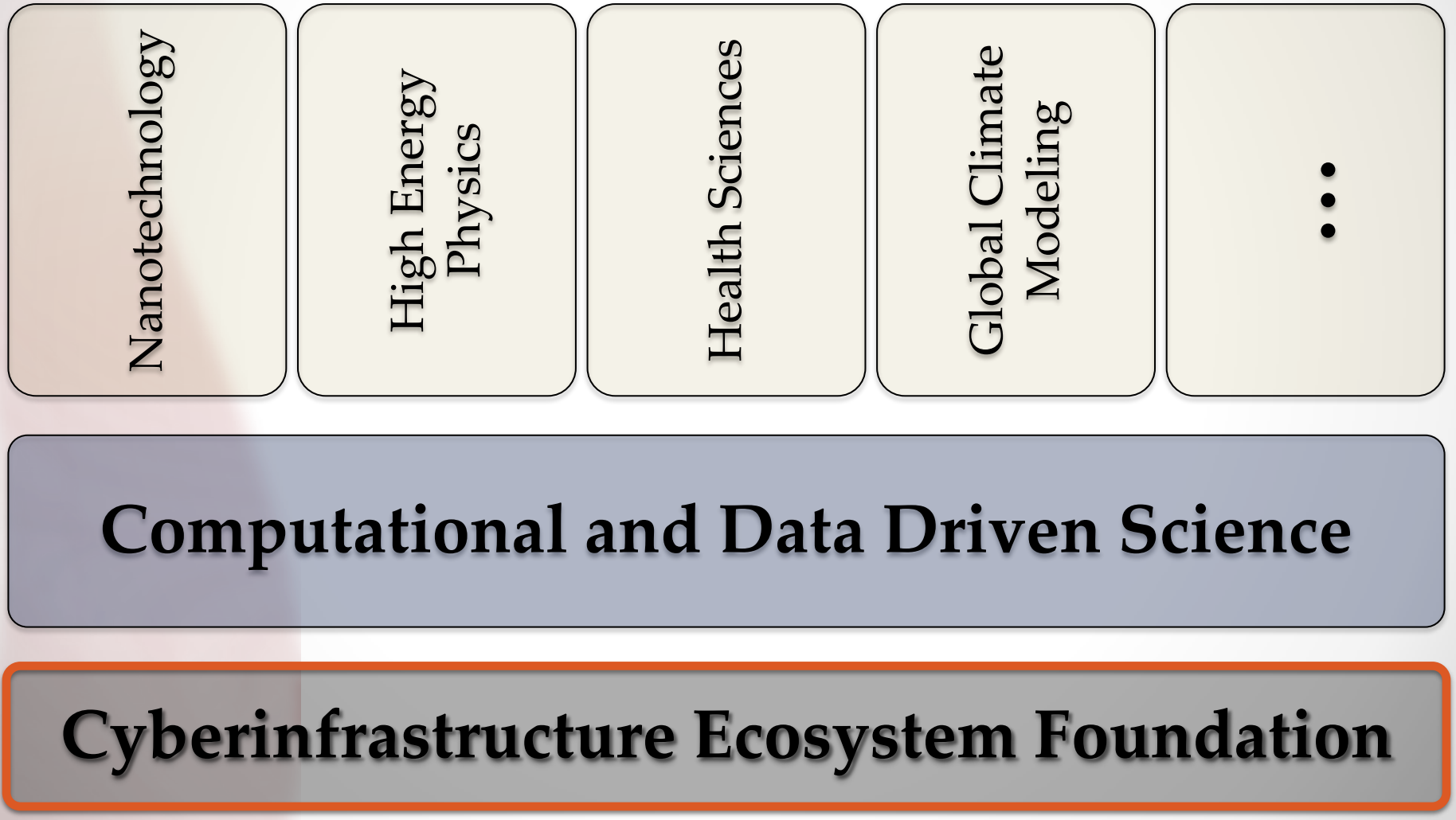
Linh Ngo
University of Arkansas

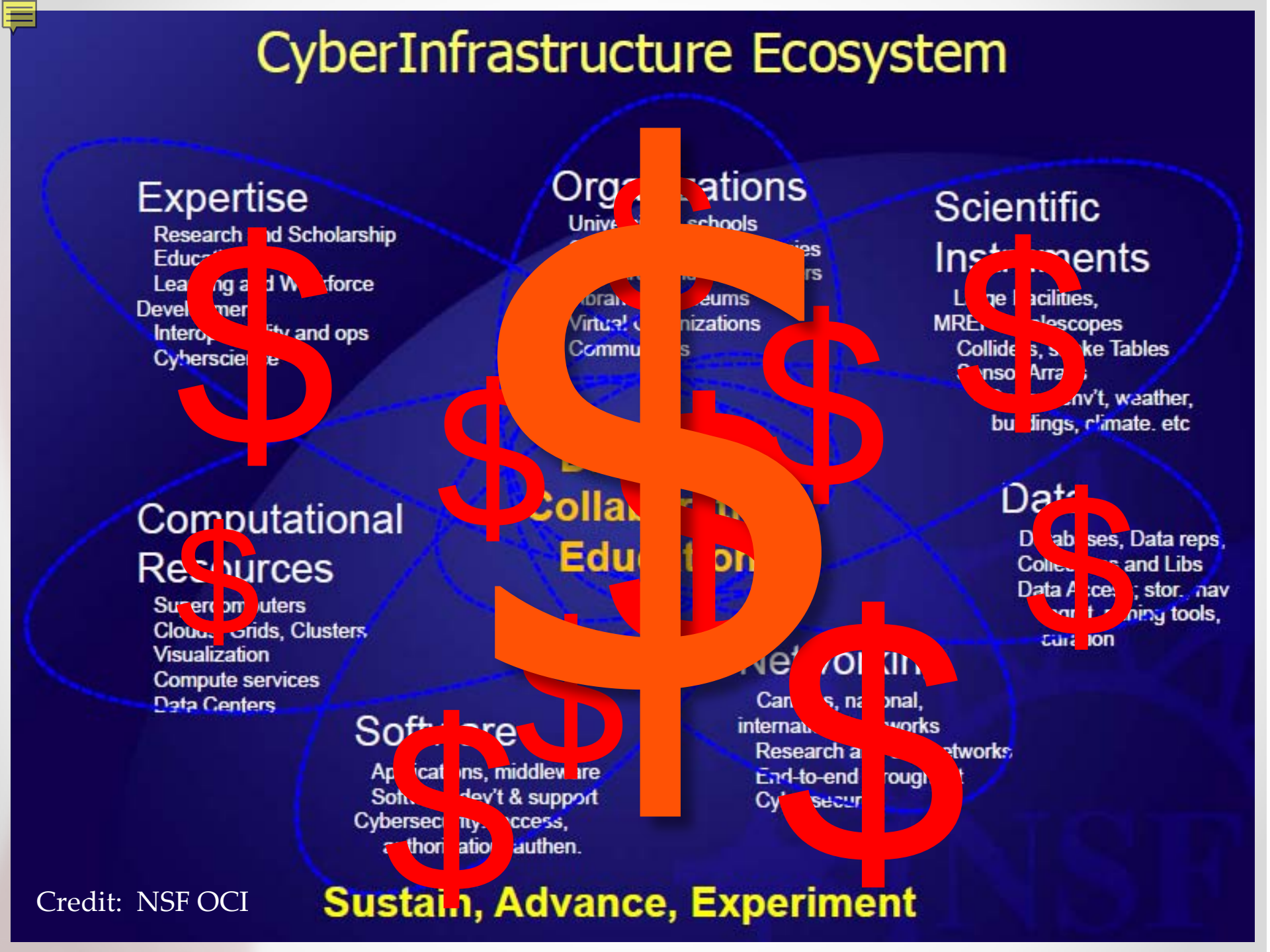
Michael Stealey
RENCI, University of North Carolina

Research Study

- Background and motivation
- Research hypothesis
- Data acquisition
- Analysis and Results
- Discussion

Research and Computing





Credit: NSF OCI

Conversation with a Chancellor

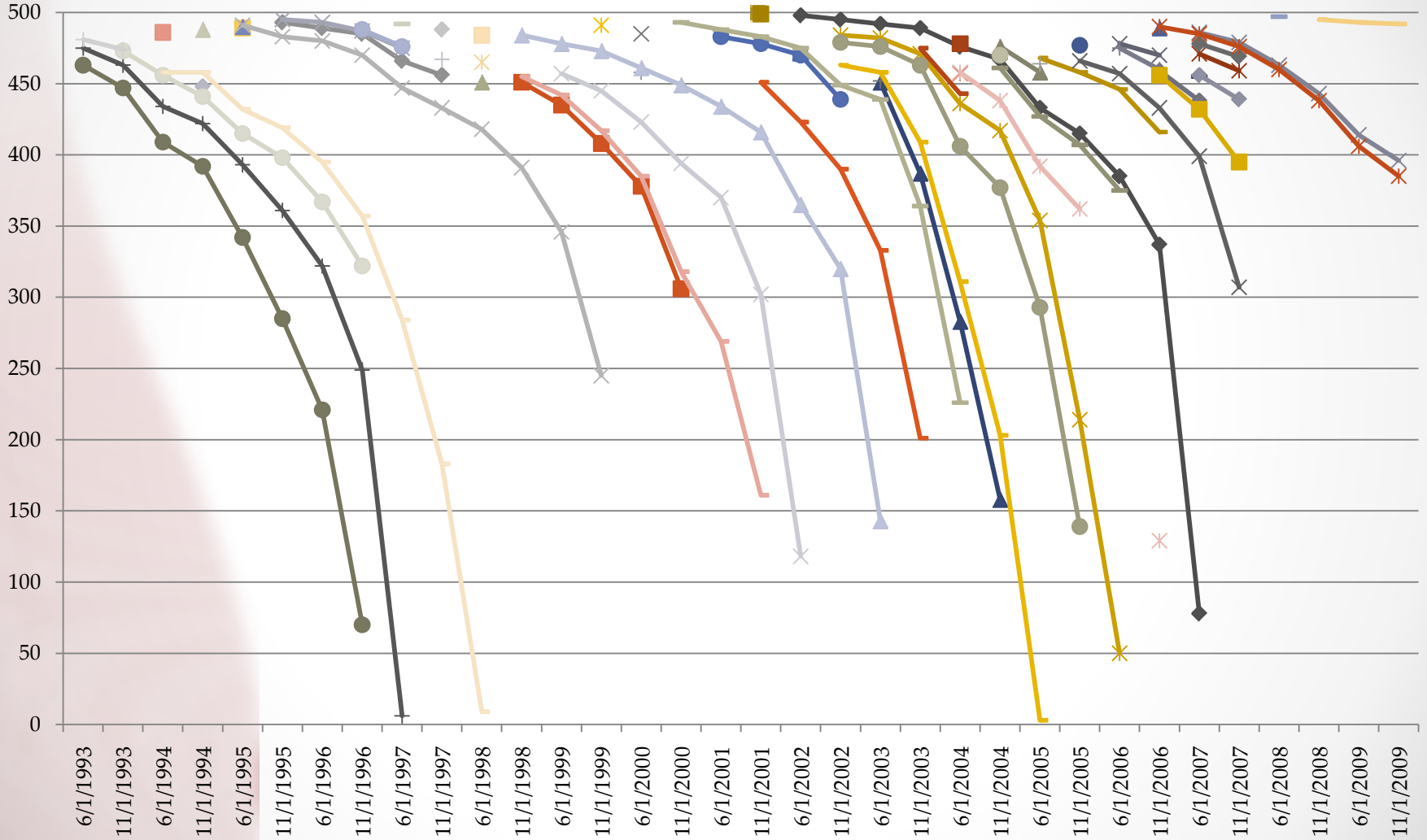
- HPC guys, “This is a great investment! We think we can run the HPC center with only $1M/year in hardware and $1M/year in staffing.”

Chancellor, “Which 20 faculty do you want me to fire?”

HPC: High rePeating Cost

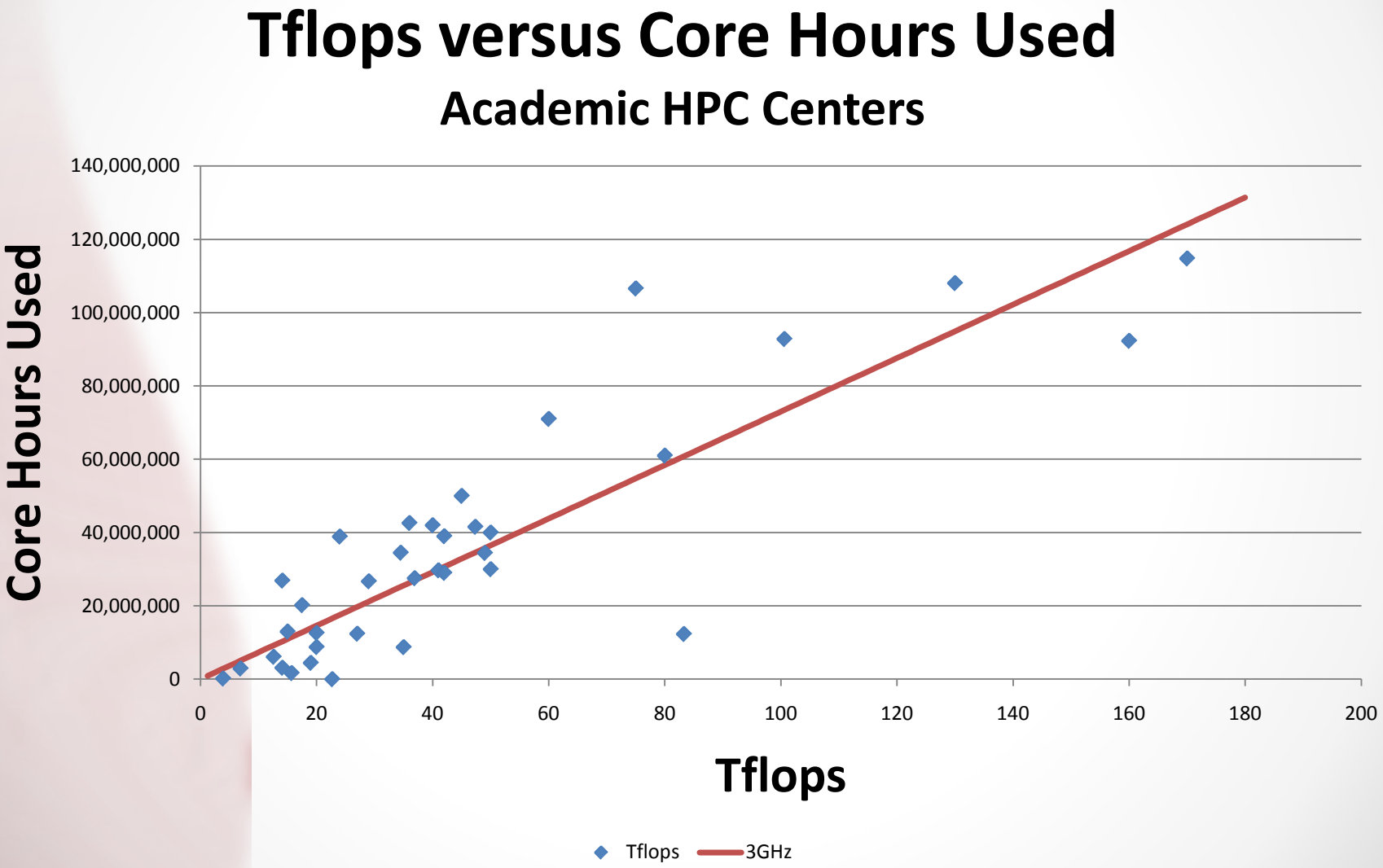
- Computer equipment is usually treated as a capital expense, with costs for substantial clusters in the range of $1M+
- Warranties on these generally last 3 years, or 5 years at most, after which repairs become prohibitive
- Even without that, the pace of technology advances require refreshing every 3-5 years
- Staffing is a long term repeating cost!

HPC: High rePeating Cost



Ranks of Top 500 Computers and Appearances in Succeeding Lists

Some Observations



What is the ROI?

- Can I convince my VPR that the funds invested in HPC add value to the institution and create opportunity?

What if this is not true?

Hypothesis

- Investment in high performance computing, as measured by entries on the Top 500 list, is a predictive factor in the research competitiveness of U.S. academic institutions.

We study Carnegie Foundation institutions with “Very High” and “High” research activity – about 200 institutions

Data Acquisition

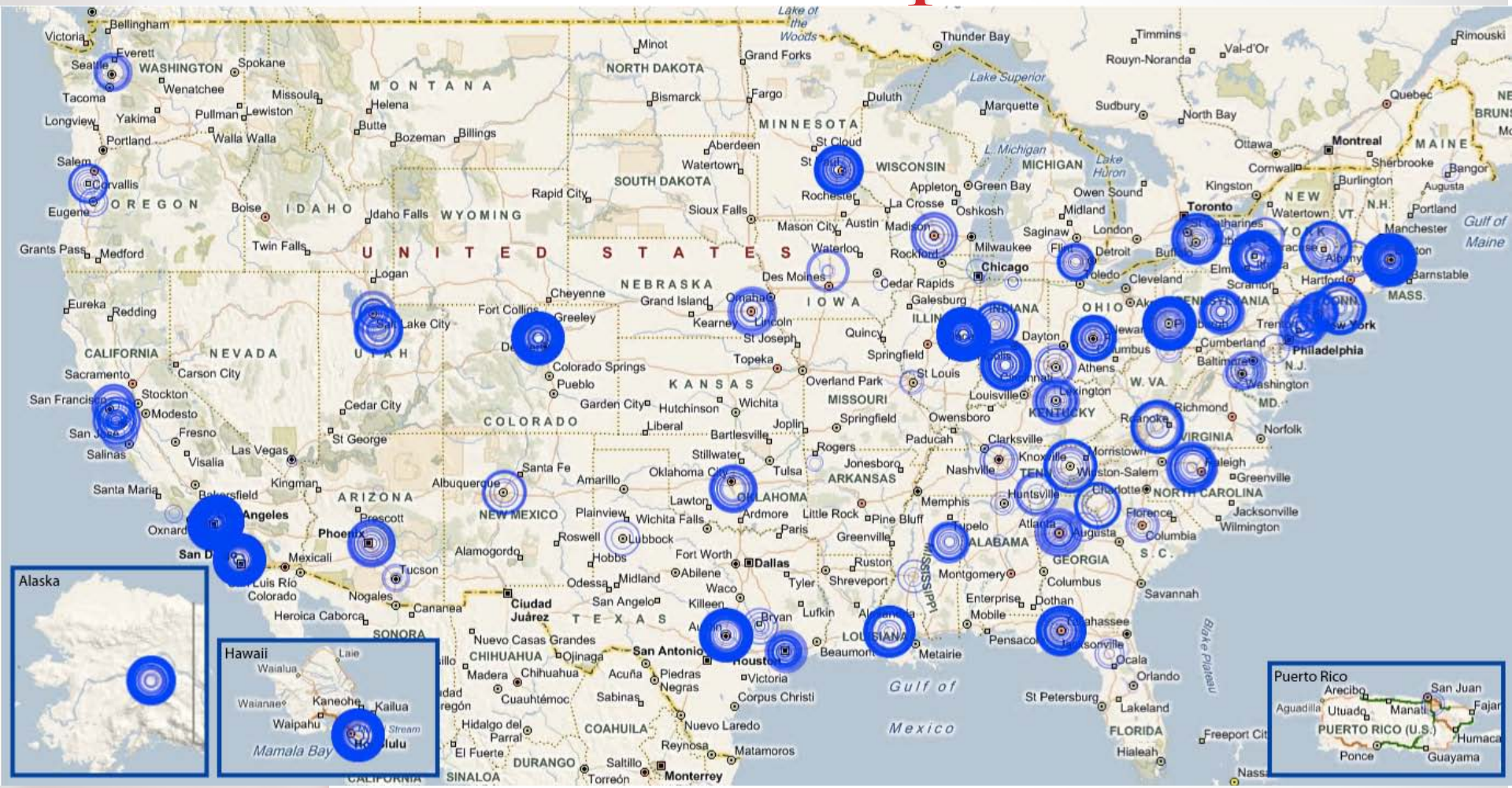
Independent variables

- Top 500 List count and rank of entries
  - Mapped from "supercomputer site" to "institution"
  - We note that entries are voluntary – the absence of an entry does not mean that an institution does not have HPC

Dependent variables

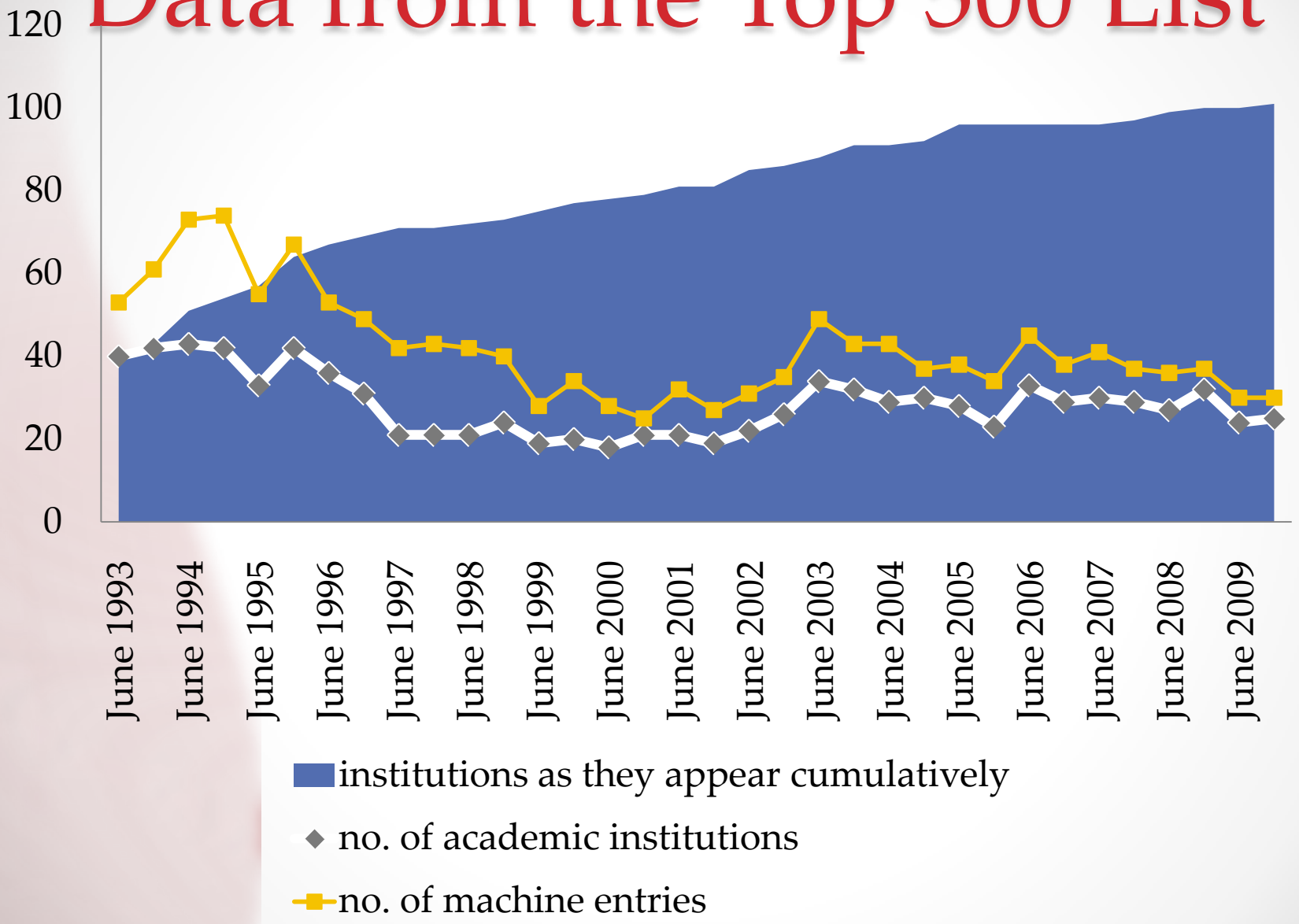
- NSF and other federal funding summary and award information
- Publication counts
- U.S. News and World Report rankings

Data from the Top 500 List



An historical record without comparison of supercomputers

Data from the Top 500 List



About 100 U.S. institutions have appeared on a Top 500 List

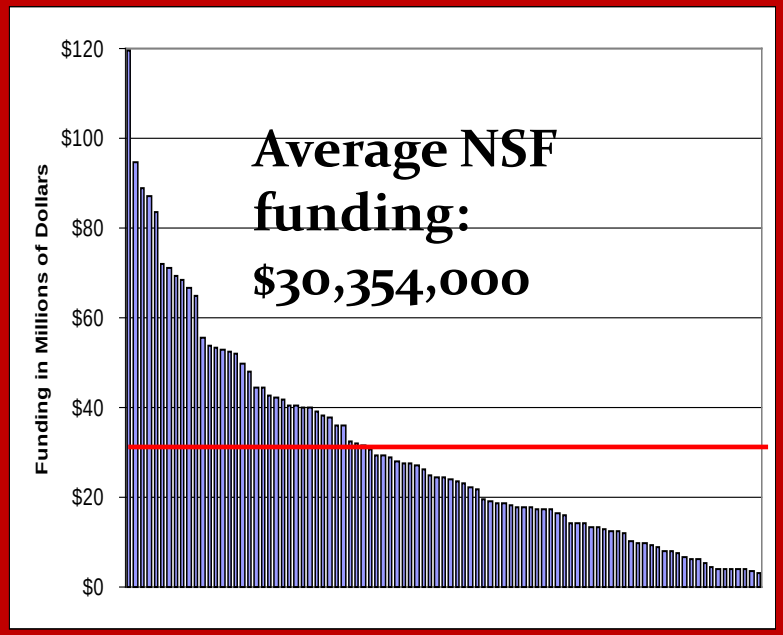
Analysis

- Examples
- Correlation analysis
- Regression analysis

Simple Example of ROI

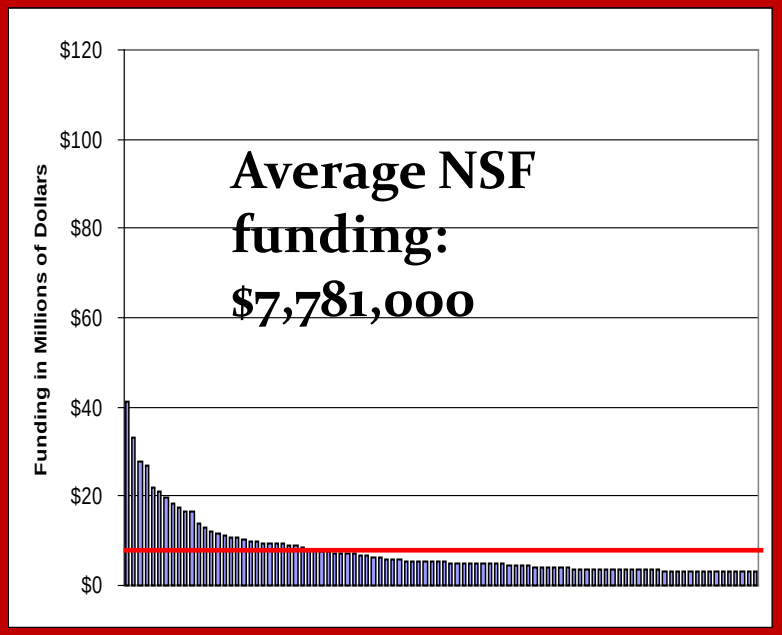
- Evidence based on 2006 NSF funding

With HPC



95 of Top NSF-funded Universities with HPC

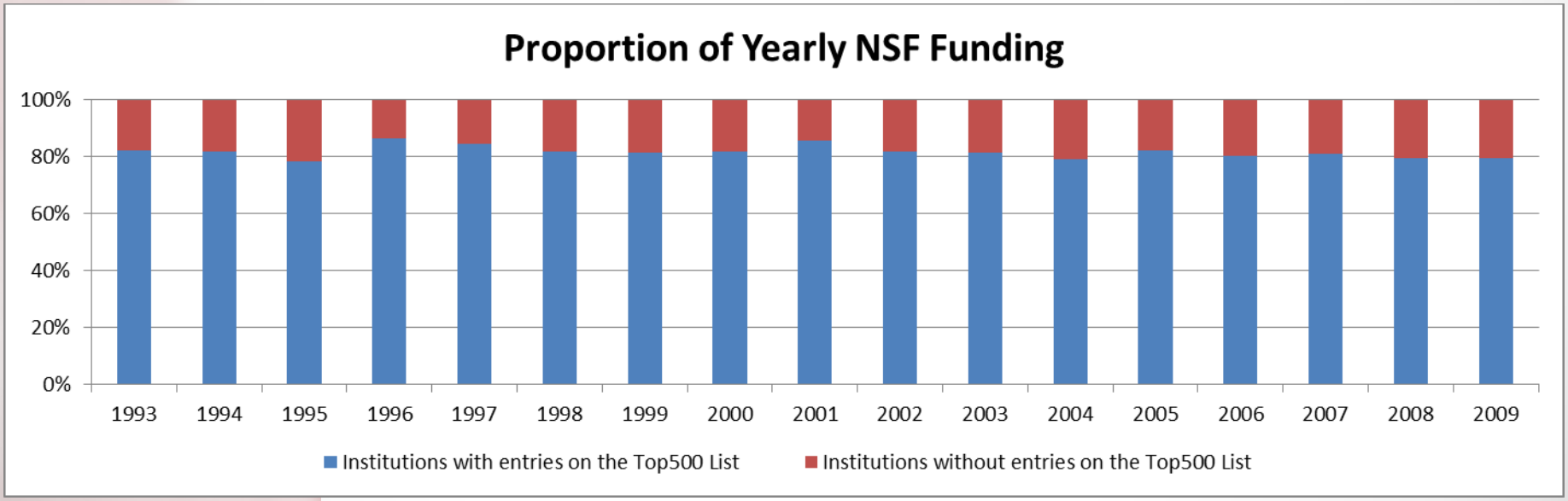
Without HPC



98 of Top NSF-funded Universities w/out HPC

Longer Example of ROI

- More evidence, 1993-2009 NSF funding



Correlation Analysis

	Counts	NSF	Pubs	All Fed	DOE	DOD	NIH	USNews
dRankSum	0.8198	**0.6545**	0.2643	0.2566	0.2339	0.1418	0.1194	-0.243
Counts		**0.6746**	**0.4088**	0.3601	0.3486	0.1931	0.2022	-0.339
NSF			0.7123	0.6542	0.5439	0.2685	0.4830	-0.540
Pubs				0.8665	0.4846	0.3960	0.8218	-0.588
All Fed					0.4695	0.6836	0.9149	-0.543
DOE						0.1959	0.3763	-0.384
DOD							0.4691	-0.252
NIH								-0.500

Regression Analysis

- Two Stage Least Squares (2SLS) regression is used to analyze the research-related returns to investment in HPC
- We model two relationships
  - **Model 1**: NSF Funding as a function of contemporaneous and lagged Appearance (APP) on the Top 500 List Count and Publication Count (PuC), and
  - **Model 2**: Publication Count (PuC) as a function of contemporaneous and lagged Appearance on the Top 500 List Count (APP) and NSF Funding

Endogeneity

- Funding allows an institution to acquire resources
- Resources are used to perform research, which leads to more funding
- Resources are also cited in the argument for research funding
- NSF funding begats HPC resources which begats NSF funding …

Regression Analysis

- Original tests revealed significant problems with endogeneity of Publication Counts (PuC) and NSF Funding.
- To correct for this, we deployed a 2SLS estimation method, with number of undergraduate Student Enrollments (SN) acting as an instrumental variable in the first stage regression for PuC (Model 1) and NSF (Model 2).
- In both cases, SN was found to be a suitable instrument for endogenous regressors.

First Result

- A single HPC investment yields statistically significant immediate returns in terms of new NSF funding
- An entry on a list results in an increase of yearly NSF funding of $2.4M
  - Confidence level 95%
  - Confidence interval $769K-$4M

Second Result

- A single HPC investment yields statistically significant immediate returns in terms of increased academic publications
- An entry results in an increase in yearly publications of 60
  - Confidence level 95%
  - Confidence interval 19-100

Third Result

- Analysis on the rank of the system shows that rank has a positive impact to competiveness, but with reduced confidence.
- We have not studied returns to *other* institutions of investments by resource providers, or returns to overall U.S. competitiveness.

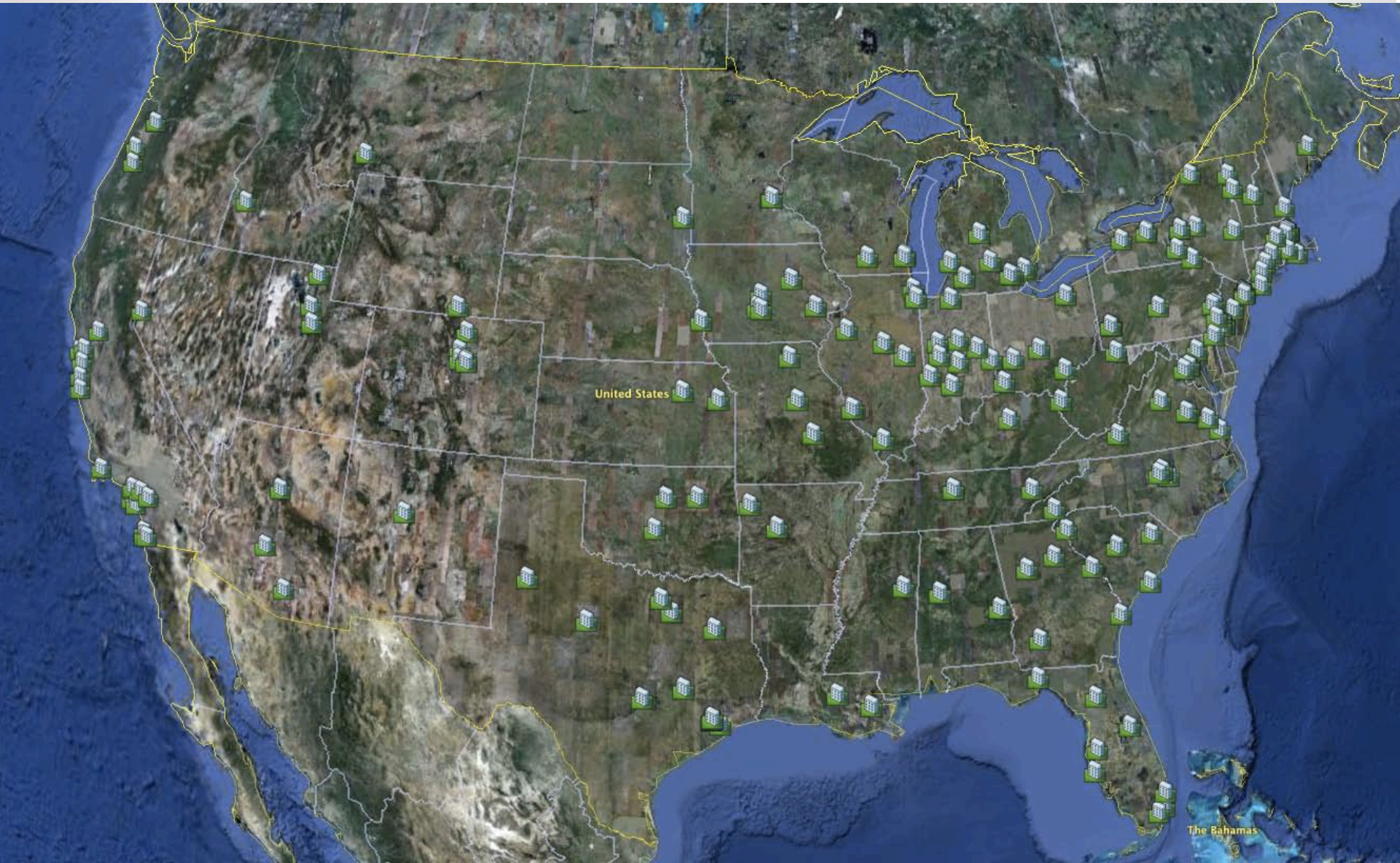
Fourth Result

- HPC investments suffer from fast depreciation over a 2 year horizon
- Consistent investments in HPC, even at modest levels, are strongly correlated to research competitiveness.
- Inconsistent investments have a significantly less positive ROI

Discussion

- More study is needed to precisely determine the rate of depreciation of HPC investments
- The publication counts include all publications, not just those related to HPC
- More study is needed regarding how use of national systems, such as Teragrid, may impact research competitiveness

Data from Teragrid Usage



Questions?