Be Bold: Scaffolding Science Opportunities and NSF’s 10 Big Ideas

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WHO THE HECK IS JIM POWELL?

(and why is he talking at the College of Science Retreat?)
Jim’s Biographical Sketch

- PhD in Interdisciplinary Applied Math, U of AZ
  - Propagation of Phase Transitions and ‘Wimpy’ Turbulence
- AFOSR Postdoc
  - Anomalous Eye Damage from Ultra-Short Lasers
- Asst. Professor, Math & Stat, USU, 1991
  - Bugs and Trees with Logan Forestry Sciences Lab, 1995
- Assoc. Professor, 1998; Professor, 2003
  - Associate of the USU Ecology Center, 2008
  - Asst. Dept Head and 2x Director of Graduate Studies
- Visiting NSF Program Director for MathBio, 2017-19
- Professor and Interim Head, Math & Stat, 2019
NSF Visiting Program Officers

• About half of NSF program directors are rotators
• POs selected for:
  – Academic credibility/connectivity
  – Experience in managing grants/administration
  – Involvement with NSF vision and priorities
  – Soft skills is writing and program management
• Rotators are responsible for maintaining ongoing relevance, scientific currency, disciplinary connection
• I spent ten years building a portfolio and applying to serve as a visiting program officer
What I will talk about

• Goals and Mission of the National Science Foundation
• The broader purpose of the 10 Big Ideas (and similar NSF calls)
• Being Bold: Opportunities for USU and the College of Science
• Tips and Lessons from my NSF rotation
Scope of the National Science Foundation

- Budget $7.8 \times 10^9$ (2018 appropriation)
  - About $\frac{1}{4}$ size of NIH extramural research budget
- Made $\sim11,000$ awards in 2018
  - out of $\sim50,000$ proposals submitted
- Supports fundamental research in all fields of science except medical science
- About 24% of federally-funded basic research and science education at academic institutions
Formative NSF History

• At the end of WWII, when VP Truman -> President, he had no clue about the Manhattan Project
  – Fundamental science had obvious (err – nuclear) impact on national issues
  – How to organize and manage science?
• Vannevar Bush, Director of Office of Strategic Research and Development during WWII, was asked to do a study
  – *Science, The Endless Frontier* became the framing document for the National Science Foundation
  – “New products and new processes do not appear full-grown," Bush wrote. "They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science!”
Mission of the National Science Foundation

• Created by an act of Congress in 1950
  – “to promote the progress of science; to advance the national health, prosperity and welfare; to secure the national defense.”
  – When all else is equal, consider geographic diversity

• Ensure that the US retains leadership in scientific research, innovation and development of new technologies

• Support Discovery, Learning & Workforce Development, Research Infrastructure and Stewardship of Knowledge

• Maintain a list of US research scientists and engineers
  – Which, fair enough, no more secret organizations of scientists building WMDs
The most competitive National Science Foundation proposals serve NSF’s goals

- Transformative science, engineering and education research which promotes scientific progress
- Integration of research and STEM education to prepare and engage a diverse, competitive workforce
- Enhance research infrastructure and data access to drive scientific innovation
- Advance the national health, prosperity and welfare and secure the national defense
National and International `Gold Standard’ for scientific review

NSF MERIT REVIEW PROCESS
NSF Review Criteria

• **Intellectual Merit**
  - The potential for a project to advance knowledge and understanding within its own field or across different fields
    • Quality of project as a purely scientific endeavor

• **Broader Impacts**
  - The potential for a project to benefit society and contribute to the achievement of specific, desired societal outcomes
    • Utility of project with respect to broad NSF goals
Five Review Elements (for both IM and BI)

1. What is the potential to advance knowledge/benefit society?
2. Does project suggest/explore creative, original or potentially transformative concepts?
3. Well-reasoned, well-organized plan based on sound rationale? Mechanisms to assess success?
4. Is team/organization well-qualified to conduct the activities?
5. Are adequate resources envisioned for the activities?
NSF Review Process – Six Months

• At least three (anonymous) reviewers assess proposals
  – Independent disciplinary experts, written reviews
  – Grades: Excellent, Very Good, Good, Fair, Poor

• Panels of reviewers discuss proposals in groups
  – Panel as a whole categorizes proposal competitively, e.g.
    • Highly Competitive (top 5-10%)
    • Competitive (next 25%)
    • Not Competitive (the rest)
  – Program Directors manage panels, read reviews and panel summaries, then make funding recommendations
    • Panel’s output is advisory
    • POs also consider portfolio of funding, NSF mission
Broader Impacts - the tail wags the dog

• “Experience shows that while most proposers have little difficulty responding to the criterion relating to intellectual merit, many proposers have difficulty understanding how to frame the broader impacts of the activities they propose to undertake.”

• Broader Impacts comprise responsiveness to the more general NSF mission and strategy.

• Broader Impacts often separate the wheat from the chaff
  – Highly competitive (top 5-10%) will usually get funded
  – 20% funding rate only stretches halfway down the Competitive category
  – Relative placement in Competitive often due to BI
Broader Impact activities are convincing...

- if you are already doing them
- if you have experience doing them or work with experienced collaborators
- if they are integrated into your research
- if you have a plan to measure their effects and report them to an audience
- if the people involved appear in your budget
- if the activities appear in your timeline
- if contributors are identified specifically and provide biosketches and/or supporting letters

• Successful programs have a Broader Impacts `infrastructure’
A rotator’s perspective....

NSF INNOVATION STRATEGY

August 2019
Basic Strategic Tensions

• The NSF budget usually only funds ~20% of proposals
• Programmatic research within divisions tends to get stovepiped:
  – Inevitable reliance on expert/panel recommendations
  – Need to transparently document fairness and accountability to internal and external review
• Foundation goals explicitly include (and Congressional support depends on) encouraging competitive scientific/technological advances
• Longer-term NSF strategy is keenly aware of balance between supporting disciplinary science and promoting transformative innovation
To promote next-gen innovation

- NSF likes to roll out broad, compelling, multidisciplinary challenges
  - Funded separately (not at the cost of) disciplinary programs
  - Often motivated by need to get ahead of perceived challenges
  - Frequently with novel scaffolding requirements
    - Multi-disciplinary participation
    - Capacity-building and/or workforce development
    - Educational, translational or outreach requirements
  - Turns over the scientific compost pile, allows new stuff to ferment
NSF Strategic Requisites (2018-2022)

• Emphasis on “Dynamic Planning,” recognizing:
  • Need to compete globally
    – STEM education, workforce development, broadening participation
    – national investment in fundamental research portfolio
  • Impacts of new enabling technologies
  • The role of complex systems
  • Potentials in data-intensive science
  • Benefits of convergence science
    – diverse perspectives and expertise from different fields of science and engineering

NSF’s 10 Big Ideas (2017-2022)

• Quantum Leap: Leading the Next Quantum Revolution
  – Exploiting quantum mechanics to observe, manipulate, and control the behavior of particles and energy at atomic and subatomic scales, resulting in next-generation quantum-enabled science and technology
NSF’s 10 Big Ideas (2017-2022)

- Quantum Leap: Leading the Next Quantum Revolution
- Future of Work at the Human-Technology Frontier
  - Catalyzing interdisciplinary science and engineering research to understand and build the human-technology relationship
NSF’s 10 Big Ideas (2017-2022)

• Quantum Leap: Leading the Next Quantum Revolution
• Future of Work at the Human-Technology Frontier
• Understanding the Rules of Life: Predicting Phenotype
  – Elucidating and harnessing the sets of rules that predict an organism's observable characteristics, its phenotype
NSF’s 10 Big Ideas (2017-2022)

- Quantum Leap: Leading the Next Quantum Revolution
- Future of Work at the Human-Technology Frontier
- Understanding the Rules of Life: Predicting Phenotype
- Windows on the Universe: Multi-Messenger Astrophysics
  - Using powerful new syntheses of observational approaches to provide unique insights into the nature and behavior of matter and energy
NSF’s 10 Big Ideas (2017-2022)

• Quantum Leap: Leading the Next Quantum Revolution
• Future of Work at the Human-Technology Frontier
• Understanding the Rules of Life: Predicting Phenotype
• Windows on the Universe: Multi-Messenger Astrophysics
• Navigating the New Arctic -- document and understand the Arctic's rapid biological, physical, chemical, and social changes
NSF’s 10 Big Ideas (2017-2022)

- Quantum Leap: Leading the Next Quantum Revolution
- Future of Work at the Human-Technology Frontier
- Understanding the Rules of Life: Predicting Phenotype
- Windows on the Universe: Multi-Messenger Astrophysics
- Navigating the New Arctic
- Harnessing the Data Revolution
  - Fundamental data science and engineering
  - Cohesive approach to research data infrastructure
  - Workforce development
NSF’s 10 Big Ideas (2017-2022)

- Quantum Leap: Leading the Next Quantum Revolution
- Future of Work at the Human-Technology Frontier
- Understanding the Rules of Life: Predicting Phenotype
- Windows on the Universe: Multi-Messenger Astrophysics
- Navigating the New Arctic
- Harnessing the Data Revolution
- Growing Convergence Research
  - Merging ideas, approaches, tools, and technologies from widely diverse fields of STEM to stimulate discovery and innovation
NSF’s 10 Big Ideas (2017-2022)

- Quantum Leap: Leading the Next Quantum Revolution
- Future of Work at the Human-Technology Frontier
- Understanding the Rules of Life: Predicting Phenotype
- Windows on the Universe: Multi-Messenger Astrophysics
- Navigating the New Arctic
- Harnessing the Data Revolution
- Growing Convergence Research
- Mid-scale Research Infrastructure ($6-70M scale gap)
- NSF INCLUDES (broadening STEM participation)
- NSF 2026 (long term program development)

NSF’S 10 BIG IDEAS

- Line items in the congressional appropriation
- $30 Million/Big Idea/Year
Beyond the Big Ideas

• NSF is consistently looking for ways to turn the compost
  – Lots of other innovative and cross-cutting programs
  – There will be other Big Ideas, for which we should be poised (more on this later)

• Broader than NSF (but guided by NSF’s example), other federal agencies recognize the need to invest in translational science and science education
  – NSF Research Traineeship clones (and of course NRTs)
  – New models for multi-disciplinary grad/undergrad education addressing critical national needs
    • E.g. data-science training for *disciplinary* practitioners (biomedical researchers, land managers, ….)
Beyond NSF

- This may seem very specific to NSF
  - I was an NSF PO until August 1
  - And yes, I drank the Kool-Aid

- BUT, at the federal/international level
  the NSF review process is the recognized gold standard for promoting innovation in science and education
  - Other agencies start with the NSF model when they need to do something novel (particularly w.r.t. education, workforce development, or capacity-building)
  - I co-managed NSF programs and contributed to workshops involving several other funding agencies
  - (and I was not particularly precocious, Kool-Aid notwithstanding)
A newbie department head’s perspective

WHY WE SHOULD BE BOLD
Big Ideas are NSF’s cry for something new

• Each big interdisciplinary call starts from scratch
  – Establish novel connections within NSF
  – Create formative collaborations in science
  – Bring new players to the table
• Avoid trap of being proscriptive
  – Telling community too much what you want is limiting
  – Identify challenges, let funding seed creative responses
  – Reconnaissance by fire: NSF learns how to proceed by inciting a community response
• Fortune favors the bold
  – Projects get funded which would never come out of a disciplinary review panel
Absence of program history is opportunity

• For Big Idea style calls there are not
  – Established networks of panels, program officers, awardees, and experts
  – Management precedents which stovepipe decision-making

• There are
  – New groupings of personnel, trying to figure it out
  – Big, dedicated budgets, needing to be spent
  – Internal opportunities to rediscover and reinvigorate NSF’s core mission

• USU, with unique identity and strengths, is well-suited to set new trends
Our disciplinary barriers are low

- The 10 Big Ideas (and many similar federal RFPs) require interdisciplinary efforts
Our disciplinary barriers are low

• The 10 Big Ideas (and many similar federal RFPs) require interdisciplinary efforts
  – USU science is distinguished by facile collaboration
  – Relative ease of grant administration across departmental boundaries
  – Openness of PnT process to multi-disciplinary publication

• Most Big Idea calls ask for capacity-building and workforce development
  – USU students can easily be trained in multiple fields
  – Formal degree requirements are discipline-agnostic
  – Faculty much more educationally-oriented and free to teach across boundaries
Our education mission is a strength

Early math outreach at USU....
Our education mission is a strength

• The STEM component of Gen Ed aligns perfectly with NSF’s vision of a scientifically engaged population
  – Any research/education activities translated into Gen Ed classes become perfect Broader Impacts
    • Complete with institutionally-supported assessment!
• USU vision incorporating high-impact practices is a fertile field for growing compelling Broader Impacts
• Statewide Campuses and Distance Education provide natural venues for reaching
  – Underrepresented and non-traditional students
  – Pre- and in-service teachers
Some of our other advantages

• Geographic disadvantage is advantageous
  – Broad distribution of funding is explicit in NSF mission
  – NSF very conscious of Congressional oversight

• Relative lack of diversity in northern Utah means that new activities can have disproportionate impact
  – New networking approaches targeting underrepresented groups can scaffold development (stay tuned)
  – Outreach through STEAM Expo on Blanding Campus
  – Science Unwrapped and Utah Public Radio
  – Latinx Cultural Center at USU
BUT we must prepare to make our case

- Keep disciplinary boundaries low and take mindful advantage of interdisciplinary science freedom
- Make sure real science interests are projected in USU’s potential educational strengths
  - General education
  - Statewide outreach
  - High-impact undergraduate practices
- Invest in building an infrastructure for successful Broader Impacts
  - Integrated with science research
  - Leveraging USU and CoS priorities
Fortune cookies from my time as a program officer

NSF TIPS AND LESSONS

August 2019
Jim’s NSF Take-Homes

• Read the Program Solicitation, Dummy!
  – Panels are looking for ways to stick you in the bottom 65%
  – Understand direct goals and specific requirements
  – See through to the NSF mission
  – Make sure you are aligned and take advantage of CoS and NSF resources!
Jim’s NSF Take-Homes

- Read the Program Solicitation, Dummy!
- Construct a Compliance Matrix

<table>
<thead>
<tr>
<th>Solicitation Requirement</th>
<th>Addressed How</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 3 pg Multi-PI Management Plan</td>
<td>MPI MP uploaded as a Supplementary Doc</td>
</tr>
</tbody>
</table>
Jim’s NSF Take-Homes

• Read the Program Solicitation, Dummy!
• Construct a Compliance Matrix
• Develop a Logic Model
Build a logic model

Inputs
- Materials
- Personnel
- Equipment
- Money

Activities
- Experiments to be performed

Outputs
- Expected Observations

Outcomes
- Relationship to hypotheses tested

Strategic Impacts
- What this does for Science

Significance of the products

Relevance to NSF goals and mission

One Specific Aim

Who and What are necessary

What will actually be done

Measurable products expected

August 2019
Build a logic model (TUES example)

**Inputs**
- NSF Funding
- PIs at CC and USU
- Graduate RAs

**Activities**
- Develop Bio-Labs for use in Calculus
- Teach project-based calculus using bio-labs
- Think-aloud observation of calc students

**Outputs**
- Bio-labs that math profs can use
- Calc students learn math as investigative tool
- Calc students display quant. approach to bio.
- Vignettes of typifying examples

**Outcomes**
- Real-world projects used in calculus classes
- USU and CC students comfie w/ applying calc
- Evidence that project-based bio-teaching improves education
- Increase understanding project-based learning
- PIs can describe how students learn in a project-based class

**Strategic Impacts**
- Increase interest of students in math
- Increase use of quantitative techniques in bio
- Produce pubs/workshops broadening palette of math teaching techniques

**August 2019**
Jim’s NSF Take-Homes

- Read the Program Solicitation, Dummy!
- Construct a Compliance Matrix
- Develop a Logic Model
- Start having a Broader Impact Now
Jim’s NSF Take-Homes

- Read the Program Solicitation, Dummy!
- Construct a Compliance Matrix
- Develop a Logic Model
- Start having a Broader Impact
- Invest in Interdisciplinarity

August 2019
Jim’s NSF Take-Homes

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Scientific Papers are Terrible

Templates for Proposals
- Wrong audience
- Wrong style and purpose
- A concave spoon in a convex world
Jim’s NSF Take-Homes

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- Construct a Compliance Matrix
- Develop a Logic Model
- Start having a Broader Impact
- Invest in Interdisciplinarity
- Scientific Papers are Terrible
- Templates for Proposals
- It’s About Making a Case
Jim’s NSF Take-Homes

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• Construct a Compliance Matrix
• Develop a Logic Model
• Start having a Broader Impact Now
• Invest in Interdisciplinarity
• Scientific Papers are Terrible

Templates for Proposals

• It’s About Making a Case
  – Write (and test!) a compelling project summary early
  – Summary should make most concise case addressing innovation and significance in Intellectual Merit and Broader Impacts
Jim’s NSF Take-Homes

- Read the Program Solicitation, Dummy!
- Construct a Compliance Matrix
- Develop a Logic Model
- Start having a Broader Impact Now
- Invest in Interdisciplinarity
- Scientific Papers are Terrible
- Templates for Proposals
- It’s About Making a Case
- This all takes time and effort….
(the end)

QUESTIONS AND DISCUSSION?