Advice for strong NSF research proposals

I gathered the following content from many sources, including National Science Foundation publications and sets of PowerPoint presentations that I inherited from other NSF program officers and then subsequently modified for my own use. Among the many program officers who deserve credit, George Hazelrigg and Anita LaSalle stand out. Any errors are my own responsibility. Also, beware that the NSF revises policy documents periodically, and cultural practices at the NSF may also change.

-- Ted Baker, 2014 (revised 2018)

Outline

1. Advice from the two Georges
2. How to write a strong proposal
3. Managing random factors in the the review process
4. Frequent mistakes in proposals
5. So, your proposal was rejected. What now?
6. How & when to contact a program officer
7. Hurray! But remember if you are funded ...
8. The NSF review process, in more detail
9. The NSF review criteria, and the PAPPG
10. Special considerations for the CAREER program
11. The CPS Program

Classic concise advice on proposal writing from

THE TWO GEORGES

George Heilmeier's Catechism

1. What are you trying to do? Articulate your objectives using absolutely no jargon.
2. How is it done today, and what are the limits of current practice?
3. What's new in your approach and why do you think it will be successful?
4. Who cares?
5. If you're successful, what difference will it make?
6. What are the risks and the payoffs?
7. How much will it cost?
8. How long will it take?
9. What are the midterm and final "exams" to check for success?

The proposal should provide clear answers to all of these.

Read more about George Heilmeier at https://en.wikipedia.org/wiki/George_H._Heilmeier

George Hazelrigg's 12 Steps

1. Know yourself
2. Know the program from which you seek support
3. Read the program announcement
4. Formulate an appropriate research objective
5. Develop a viable research plan
6. State your research objective clearly in your proposal
7. Frame your project around the work of others
8. Grammar and spelling count
9. Format & brevity are important
10. Know the review process
11. Proof read your proposal before it is sent
12. Submit your proposal on time

See full text at www.cs.rpi.edu/~trink/HazelriggWinningResearchProposal.pdf

HOW TO WRITE A STRONG GRANT PROPOSAL

It's simple

1. Start with an innovative idea
2. Present it in a clear, convincing way

- What is the project about? (the research objective)
- How will you do it? (the technical approach)
- Can you do it? (you and your facilities)
- Is it worth doing? (intellectual merit and broader impact)

Remember that you are telling a story.
Make it interesting!

What is an innovative idea?

- Something the reviewers have not seen before
- Ideally, with transformative potential
  - *ideas, discoveries, or tools that radically change our understanding of an important existing concept or lead to a new paradigm*
- and broad impact
  - *the potential to benefit society*
- *Not:*
  - *An incremental advance in a well-studied area*
  - *A routine variation or recombination of old ideas*
  - *Today's hot topic, or a combination of buzz-words*

Match your idea to the right program

- Read the solicitation carefully, with insight.
- Can you make a convincing case that your idea fits this program?
  - If not, look for a different program.
    - Beware the “nearest submission deadline” approach!
  - Don’t waste a good idea, your time, and that of reviewers, by submitting it to a program that does not fit.
- If in doubt, seek guidance from program officers*

*See slides on how and when to contact program officers, below.

Pitch it well

- Understand the review process.
  - Write to make the reviewer's job easy
  - Get experience serving on panels for the program, if possible
- Use title and project summary to direct your proposal to the right panel and reviewers
- Answer all the Heilmeier catechism questions
- Read the solicitation again, and heed it
  - Identify and address all program–specific goals and requirements explicitly
- Formulate an engaging story!

Read & heed the solicitation

- What is the scope of research of interest for the program?
  - Distinguish program goals from examples and broad motivation
- Are there program-specific format and content requirements for the proposal?
  - Identify strong requirements (e.g., “must”) and expectations (e.g., “all proposals are expected to ...”)
- Are there program-specific evaluation criteria?
  - Find the section on solicitation-specific review criteria, hidden in the “boilerplate” near the end of the solicitation

Example:

- *"The goal of the CPS program is to develop the core system science needed to engineer complex cyber-physical systems upon which people can depend with high confidence. …. the CPS program seeks to reveal cross-cutting fundamental scientific and engineering principles that underpin the integration of cyber and physical elements across all application sectors."*
- Pitfall: Ignoring critical words
- Pitfall: Misinterpreting ambiguous phrases.

  The text above says the research results should be broadly applicable, not specific to any application sector.

Write a strong summary

- Start with a statement of your proposed objectives
  - Do not begin with a weather report: “The sky is falling. Tools are breaking. Designs are failing…”
  - Do not begin with a state-of-the-union address: “It is imperative that the nation develop a strong manufacturing base…”
- This not a technical paper, or a murder mystery (where we find out what the objective is on page 15)
- The Intellectual Merit and Broader Impact statements are important

How to structure the summary

- First block
  - The research objective of this proposal is…
  - The approach is…
- Second & third blocks
  - Intellectual Merit
  - Broader Impact

Avoid buzzwords and self-praising adjectives like "transformative", "innovative", "novel", etc.

What the NSF wants to know

- What are your research and educational objectives?
  - This is what directs your proposal to the appropriate program and panel
- What is your approach?
  - Sketch it out, in just a few sentences
- What is the specific research contribution you will make to the knowledge base (the intellectual merit)?
- If successful, what will be the benefit to society (the broader impact)?

Along with the title, program officers will rely heavily on the Project Summary to decide what areas of expertise are needed to review your proposal, and how to “bin” it with other proposals for a panel.

Example Summary*

My research goal is… In pursuit of this goal, the research objective of this proposal is to test the hypothesis that the propensity of a tree to break is directly proportional to how many monkeys are in the tree. The approach will be to take a sample of ten trees and load them with monkeys until they break…

Intellectual Merit – It is important that we know how many monkeys can climb a tree before it breaks because this affects our perceptions of monkey procreation and… The Snerd Theory holds that tree size limits monkey procreation. This study challenges that theory with the notion that… If the objective hypothesis is correct therefore, it will transform our approach to…

Broader Impact – Monkeys are used in medical research. By knowing how many monkeys can fit in a tree, we will be able to provide more monkeys for such research thereby advancing medical science more quickly and improving the quality of life. Also, by watching the monkeys get hurt when the tree breaks, graduate students will be less likely to climb trees, thereby increasing their probability of graduating.

*From George Hazelrigg.

The next 15 pages

- Back up your summary with details
- Start with a restatement of your goals and objectives, clarify them, and provide a plan to accomplish them
  - Tasks should correspond to objectives, one-to-one
  - Each task description describes what is needed to accomplish one objective
- Restate and provide detail on your intellectual merit and broader impacts, with separate headings

Apply the Goldilocks Principle

- Not too much review of prior work, but enough to show you are not at risk of duplicating work already done, and are informed of relevant foundations.
- Not so much preliminary results that the proposal seems incremental, but enough to show the problem is interesting and your approach is plausible.
- Not too much detail on your approach, but enough to convince reviewers that you have a chance at success.

Intellectual Merit

- What is already known?
- What is new?
- What will your research add?
- Why is your research important for the advancement of your field?
- What will this do to enhance or enable research other fields?

Make a case for novelty

- If there is novelty in the research problem, why is solving it important?
- If there is novelty in your approach, why is success plausible?
- If there is novelty in the application or artifact you will develop, how is what you propose more than development?
  - What are the challenges?

Broader Impacts

Why should the general public care?

Consider:

- Economic/environment/energy
- Education and training
- Providing opportunities for underrepresented groups
- Improving research and education infrastructure

"Broader Impacts"

- How is the project likely to "benefit society or advance desired societal outcomes"
- For most CISE projects, there are specific potential impacts on the economy, society, human well-being, defense, etc.
  - Do not be limited to educational and student outreach activities.
  - Plans for transition to practice and dissemination to industry are important
  - If you propose an activity, describe it as actionable; identify resources, and include impact assessment

"PIs are expected to be accountable for carrying out the activities described in the funded project."

Broader Impact

- The Broader Impact focuses on the benefit to society at large as a result of your research result
- Means to benefit society include:
  - Direct benefits of the new knowledge or technology, e.g. to the economy, quality of human life*
  - Education and training
  - Providing opportunities for underrepresented groups
  - Improving research and education infrastructure

**The key issue is how your research results will be applied. Why would the general public care?*

Summary Template

My research goal is… In pursuit of this goal, the research objective of this CAREER proposal is to test the hypothesis that the propensity of a tree to break is directly proportional to how many monkeys are in the tree. The approach will be to take a sample of ten trees and load them with monkeys until they break…

My educational goal is… In pursuit of this goal, the education objectives of this CAREER proposal are… The approach to accomplishing these objectives will be…

Intellectual Merit – It is important that we know how many monkeys can climb a tree before it breaks because this affects our perceptions of monkey procreation and… The Snerd Theory holds that tree size limits monkey procreation. This study challenges that theory with the notion that… If the objective hypothesis is correct therefore, it will transform our approach to…

Broader Impact – Monkeys are used in medical research. By knowing how many monkeys can fit in a tree, we will be able to provide more monkeys for such research thereby advancing medical science more quickly and improving the quality of life. Also, by watching the monkeys get hurt when the tree breaks, graduate students will be less likely to climb trees, thereby increasing their probability of graduating.

Education

- Undergraduate
  - Curriculum
  - Projects (REUs)
- Graduate
  - Curriculum
  - Conferences
  - Involvement with industry, national labs
- Networks, partnerships
- K-12 outreach (RETs)
- Museum projects
- Should not be a boiler plate, pick and choose

MANAGING RANDOM FACTORS

It's a random process!

- You can't guarantee success
- But you can shift the odds in your favor by writing a strong proposal
- Fallacy:
  - "If a proposal has a funding rate of 10%, I need to submit 10 proposals to succeed."
- Truths:
  - Most of the 90% that are not funded are weak in ways that you can avoid
  - A strong proposal may shift the odds to 50% or better

So, don't waste your time and that of the reviewers.
One great proposal has a better chance than 10 weak ones.

Random Factors in Review

- Who are the reviewers, and what is their expertise?
- What other proposals will the review panel, and later the NSF staff, compare it against?
- Who are the NSF staff making the decision?

You cannot control these things, but you can can improve your odds of a favorable outcome.

Reviewer Effects

- One strongly negative reviewer can kill a proposal, and least one enthusiastic one is needed to make it rise to the top.
- Experts tend to be more critical of details, more demanding of originality, but also more appreciative of a truly excellent proposal and more effective in advocating for it.
- Sometimes, less expert reviewers will fall in love with a proposal because they have not seen the idea before, but it is unwise to base a strategy on this effect.
- So, how to improve your chances of getting expert reviewers?

Getting Good Reviewers

- Proposals are typically “binned” for panel review based first on title, and then on the project summary.
- Each panel ends up being dominated by some theme or aspect that is common to most of the proposals.
- Program Directors, and then panelists, are assigned based on this theme.
- Take care that the title and the Intellectual Merit portion of your project summary convey where the primary research contribution lies, and thereby implicitly identify the peer group that you feel should be evaluating your proposal.

Comparison Effects

- A proposal that is similar to others on the same panel is more likely to have experts on the panel who are qualified to review it.
- However, it must then stand out above those other proposals.
- An outlier may succeed by standing out, or fail dramatically if the panelists don't appreciate it.

See advice above on influencing binning.

NSF Staff Effects

- Staff choose reviewers, may direct panel discussion, and have a strong influence on final decision.
  - A program officer may reverse a panel ranking if a case can be made that the panel got it wrong.
- Before you submit a proposal, contact program officers* to verify program fit, and get their reactions to your idea.
  - You may decide to tailor the proposal, or submit to a different program, based on this information.
- *Never try to lobby for a proposal that has been submitted already, or to reverse a decision a proposal that has been recommended to be declined.*

**See slides on how and when to contact program officers, below.*

FREQUENT MISTAKES

Research Topic Mistakes

- A man with a hammer looking for a nail
  - *A proposal that tries to push a technology, without a compelling application for motivation. e.g., "Have robot, need work."*
- A list of unconnected problems
  - Or whose only connection is your hammer
- Following a herd
  - Jumping on a "hot topic"
- Imitating previously funded projects
- Boring
  - Predictable, incremental work
  - No clear potential for big impact

Strategic Mistakes

- Not heeding the solicitation
- Re-using a proposal originally submitted to another program, without a complete rewrite
- Re-submitting a proposal to the same program, without addressing the reviewer comments
- Cutting and pasting from your research paper(s)
- Resting on your laurels: Proposal is mostly about your prior work: “I’ve done good work before, so give me more money to continue this work.”
- Describing a problem without a plausible path to a solution

Team/Collaboration Mistakes

- Teaming with a collaborator from another discipline who is weak in that discipline (but you don't know it)
- Pasting together contributions from multiple PI's, without integration
  - "omnibus" syndrome
- Including personnel/collaborators whose role in the research is not clear

Writing Mistakes

- Long-winded explanations
- Too many superfluous details
- Poor organization of thoughts into words
- Goals or claims in the project summary that are not borne out by the research plan
- Writing a “defensive” proposal in response to reviewer comments on a prior submission.
- Cramming too many ideas into one proposal

Prior Work Mistakes

- Poor distinction between preliminary results and proposed work
  - e.g., interleaving your descriptions of prior work and new work you propose to do in a way that the distinction is not clear
- Assuming that the reviewers are experts in your research area, and have read or will read the papers that you cite
- Citing only/mostly your own prior work.
- Failure to explain relationship to any grants listed under Current Support that have apparently similar titles.

Lack of Cohesion

- A bunch of separate pieces stapled together
- A laundry list of tasks, with no prioritization or structure
- Nails only united by your hammer

Research Plan Mistakes

- Dependence on a risky initial task, with no back-up plan if that fails
- No plan for assessment of success, no metrics

Broader Impacts Mistakes

- Ignoring direct societal and economic impacts
  - i.e., limiting discussion to education & outreach
- Implausibly long laundry list of activities
  - Where will the PI get the time to do all these things?
- Activities you could do without the grant
  - not in the budget
  - not dependent on the project research
- Activities that depend on resources not supported by collaboration letter
  - e.g., K-12 outreach without school agreement

Education/Outreach Mistakes

- Routine, lackluster
- Re-using text from a prior funded proposal, especially if you have not delivered on those promises
- Vague, non-actionable promises
- Failure to address assessment of these activities

Budget Mistakes

- Padding budget to reach the maximum allowed
- Subcontracts/sub-awards without detailed explanation of the work to be done and why a sub-award is the right way to accomplish it
- Lumps of money in “Other” without explanation and justification
- Asking for more than 2 months of salary for senior personnel, over all NSF grants, without a strong justification

Presentation Mistakes

- Font too small
- Figures illegible
- Figures without explanatory text
- Jargon, acronyms, abbreviations
- Long lists of citations [1,2,3,4,5,6,7,8] without discussion
- Disparaging competitors
- Failure to organize in a way that makes it easy for reviewers to find elements required by the solicitation, and other important questions (see Heilmeier catechism)

Ethical Mistakes

- Plagiarism
- Asking for more than one grant to do the same work
- Asking for money to do work you have already done, especially if you expect to submit a paper to a conference for review before the proposal has been reviewed

Since money is involved, these can constitute fraud against the Federal government, which may be prosecuted as a felony.

If your grad student writes your proposal, you are responsible for the content, and in trouble if there is a breach of ethics.

So, your proposal was rejected. What now?

REJECTED PROPOSALS

Interpreting Reviews

- Understand how reviewers work, and read between the lines.
- Most read a proposal, form an opinion, and then support that opinion with specific comments.
- They may stop writing when they feel they have justified their position, or get hung up on details.
- Some have difficulty writing in English, or may just be lazy about writing comments
- They may never mention some serious problems, or fail to distinguish minor ones from serious ones.
- They will tend to react to what is *in* the proposal, and tend not to comment less on what is *missing* from it.
  - *This is especially true for proposals that are not a good fit to the solicitation.*

Don’t be afraid to ask for information

- Contact a program officer* who sat on the panel, and see if they will help you additional information
  - How to interpret vague reviewer or panel comments
  - Which reviewer comments are most important, especially if they are contradictory
- Some PD’s are more communicative than others, but it is worth asking
- Most are willing to give you more information in a phone call than in writing (e-mail)
- Focus on whether the idea is worth resubmitting, and how to make your next submission better

**See slides on how and when to contact program officers.*

But don't cross the lines

- You can't get the NSF to fund change the decision to decline a proposal by rebutting the reviews* or asking the program officer for mercy.
- And don't ask the program officer to fund your declined proposal as an EAGER grant

*Yes, there is a formal "reconsideration" process, but you would be unwise to use it. As the NSF says: "Because factors such as program budget and priorities factor into the decision on a proposal, NSF cannot ensure proposers that reconsideration will result in an award even if error is established in connection with the initial review." Moreover, while you are waiting for the reconsideration process to complete, you will probably miss the window for the resubmission to the program.

"Competitive" Proposals

- Many proposals end up un-funded, but with generally strong reviews
- They do nothing wrong, but just didn't generate enthusiasm from the reviewers or the NSF staff to rise to the top
- You can roll the dice, by resubmitting (with revisions!)
  - But consider foremost how you can give the proposal more "pizazz"

How and when to make direct personal contact

CONTACTNG A PROGAM OFFICER

EAGER Grants

- These are not consolation prizes.
- Read the description in the GPG:
  - exploratory work in its early stages on untested, but potentially transformative, research ideas or approaches
  - "high risk-high payoff" in the sense that it, for example, involves radically different approaches, applies new expertise, or engages novel disciplinary or interdisciplinary perspectives
  - should not be used for projects that are appropriate for submission as “regular” (i.e., non-EAGER) NSF proposals

Why contact a program officer?

- Please add me to your pool of reviewers
- Does this research idea seems like a good fit for a given program?
  - Send a short (not more than a page) summary
- Can you help me interpret the reviews and panel summary from my declined proposal?
  - Are some comments more important than others?
- I'm considering a departure from the proposed research plan or budget of my funded project

How to contact an NSF program officer

- Start with e-mail
  - explain the question briefly
  - maybe request a telephone discussion
- If no answer, try again
  - program officer may be swamped, or traveling
  - e-mails are also sometimes lost
- Telephone is just about as good as face-to-face
  - easier to schedule
  - cheaper

Should I Meet My Program Officer?

- Why? What do you intend to gain?
- Is your goal to schmooze? (It doesn't help)
  - Don't expect to "pitch" your research
  - Don't even think about taking your program officer to lunch
- If you decide to meet:
  - Be prepared to listen (you don't learn by talking)
  - Be prepared with questions
  - Remember, the program officer is not the panel
  - You can get a free trip to NSF (as a panelist!)

Don’t wear out your welcome

- Program officers have limited time.
- Do not initiate independent parallel and potentially redundant conversations with multiple program officers on the same subject.
- If you are not sure who is the best person to answer your question, send a single e-mail addressed to all those you think might be interested.
- The first one to answer can “cc” the others, so they will not need to respond unless they have something more to add.

Do not ask a program officer to

- Read and comment on a full proposal
- Help you write your proposal
- Give you ideas for research
- Estimate the odds of your idea being funded
- Discuss your proposal currently under review
  - (unless you want to withdraw it)
- Reconsider your declined proposal

How to become an NSF reviewer

- For each program that interests you
- about 1 month before the deadline
- e-mail the program director(s) responsible
  - brief (1 page) bio
  - list of areas of expertise
  - your home page URL
- If you get an e-mail about a web-based form for reviewers, fill it out also.
- *If you are asked to serve, don't say "no"!*

Don't be offended if you are not asked. Some areas of expertise are over-supplied. Other factors, such as panel diversity and mix of experienced and inexperienced panelists, come into play.

Hurray! Your proposal has been funded, but that is not the end of your responsibilities.

AFTER AN AWARD

Annual Reports

- Required for all grants
- Are due 90 days before the anniversary
  (or May 1, whichever is earlier, for continuing grants)
- Are incremental, not cumulative
  - cover what has been done that year
- Relate progress to tasks & milestones
- Include education & outreach activities
- Explain any changes in plan, as well as progress
  - delay recruiting a suitable RA or postdoc, loss of collaborator, a new collaborator, idea for new avenue of research, etc.

Final Reports

- The final report is the last annual report
  - not a cumulative report
- Due 90 days after the grant expiration date
  - That is 90 days later than preceding annual reports
- The grant is over when the final report is filed
  - Too late to ask for a no-cost extension

Don't forget the Project Outcomes Report

- separate from the NSF final report
- for public consumption
- cumulative
- not reviewed or approved by NSF
- also puts an end to no-cost extensions

Overdue Reports

- 90 days after report is due*, NSF will put a hold on all actions affecting PI and co-PIs
- Overdue report =
  - No increments
  - No supplements*
  - No no-cost extensions*
  - No new awards*
- Remember:
  - Hold is not lifted until report is approved
  - Program officer may not be able to read it right away
  - Report may be returned for revision

** Funds may be forfeited*

Don’t raise any red flags in reports!

- Results unrelated to the proposal, without explanation
- Personnel with no explained contribution
- Publications:
  - submitted before the award
  - not accessible to the program officer
  - without acknowledgment of the grant, by number
- No progress on education and outreach activities
- Uncoordinated reports from collaborators
- The program officer can also see expenditures
  - Is spending is far above or below proposal budget? If so, does the report explain why?

Budget Management

- Don’t view an NSF grant as a savings account
- If you do not spend at the rate in the proposal budget, explain why, in your annual reports
  - e.g., delay hiring research assistant, key personnel on leave
- If you need a no-cost time extension, apply before the annual report is due (not overdue)
  - explain why the work is delayed
  - “We have money left over” is not an acceptable reason
- In any case, NSF funds “change into a pumpkin” after 6 years

Things to avoid

- Never falsify (“fudge”) or fabricate data or results.
- Never charge for work that is already done, or charge multiple grants for the same work
- Never pad travel
- Never commingle funds
  - Don’t mix business and pleasure expenses
  - Don’t mix grant funds and personal business expenses
- Never charge for time not spent on a grant
- Never bill items to your grant that shouldn’t be billed to the grant
- Never bill alcohol or entertainment to a grant
- Never charge give-aways to a grant

THE NSF REVIEW PROCESS

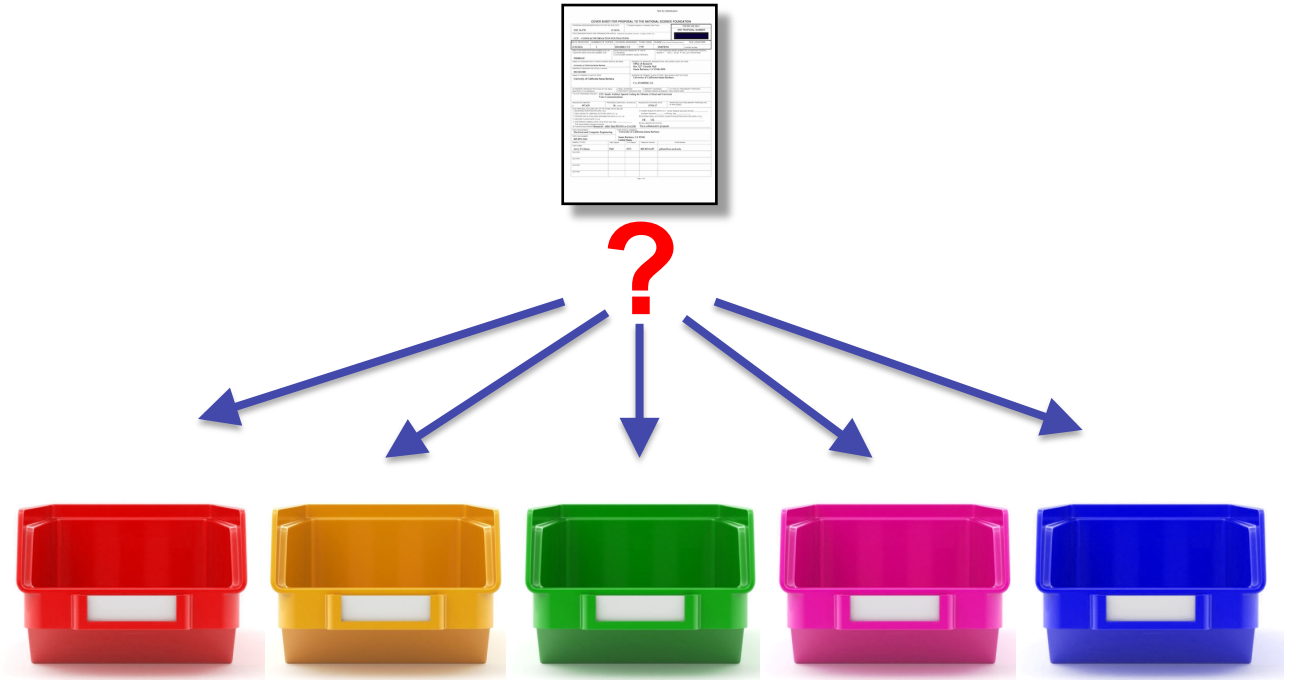
NSF Review Process - Overview

Compliance Checks

- Budget within limits?
- Broader Impact statement within Project Description?
- Collaboration Plan (if two or more PIs)?
- Justification for Small or Medium or Frontier?
- Results from prior NSF support?
- Collaborators and Other Affiliations?
- Other solicitation-specific requirements?
- etc. ...

This process is increasingly automated.
Failure ⇒ Return Without Review

Proposal Binning



Which proposals will be reviewed by the same panel?

Panel Building

- Program officer seeks panelists
  - with appropriate expertise, who agree to serve
- Program officer assigns reviewers to proposals
  - based in part on preferences expressed by reviewers
- Typically 3 or 4 reviews per proposal
  - 8 -11 proposals per reviewer
  - 12 - 36 proposals per panel
  - 6 -18 reviewers per panel

Panel Review

- Typically meets 2 days
  - virtual or face-to-face
- Individual reviews submitted before meeting
  - ratings: E, V, G, F, P
- Panel classifies proposals on a scale, e.g.
  - Highly Competitive, Competitive, Low Competitive, Not Competitive
  - and writes summary of reasons for the classification
- PI receives copies of reviews and panel summary

Clear proposals usually win out over vague or ambiguous ones

Decision Process

- Program Directors make formal fund/decline recommendations
  - based on panel summary, individual reviews
  - taking other factors into account
  - often in consultation with other program officers
- Division Directors review, then concur or send back
- Decline: PI is notified by Division Director
- Award: Division of Grants and Agreements reviews recommendation and notifies Sponsored Research Office of the award

Panelist Instructions and Templates

- The program officer typically provides reviewers with specific instructions, possibly a review template, and generally provides the panel with a panel summary template.
- The content is based on the NSF PAPPG and the solicitation, but may direct attention to specific aspects, and require reviews to answer specific questions.

Example CISE Panel Charge

- The panel's recommendations are advisory to the NSF – final recommendations for awards by the CPS team must also consider a variety of other issues
- The panel is charged with using its individual and collective expertise and judgment to evaluate and recommend appropriate proposals
  - Reserve the Highly Competitive (HC) ranking for only a small number of the very strongest proposals with respect to intellectual merit, broader impacts, and the additional solicitation-specific review criteria
  - Competitive (C) proposals are strong with respect to intellectual merit, broader impacts, and the solicitation-specific review criteria

Triage

For some programs, the review panel may agree not to discuss proposals that received uniformly unenthusiastic reviews. The triage decision will be based on unanimous consent by the panel. **Any panelist may request that a proposal be discussed.**

In these cases the individual reviews may be quite contradictory, since the reviewers never got a chance to resolve their differences.

Some Questions Asked of Panelists

- If there is unfunded collaboration, e.g. from industry, are there letters of commitment?
- Do the backgrounds of the proposing team cover the set of skills needed to realize the project goals? Are their planned interactions likely to achieve integration across disciplinary areas?
- Does the project include a plan for validation of the research?
- Are human or vertebrate animal subjects involved? If so, is there IRB approval?
- If the proposal involves more than one PI, how is it more than just an aggregation, and how will effective continual collaboration be assured?
- If more than one institution, is there a compelling rationale for this structure?

Panelists are asked to think like investors

- They are not reviewing for a journal or conference, or awarding a prize for best- written proposal.
- They are advising the NSF on how to invest taxp $$.
- So, they should balance risk against potential pa and allow that game-changing proposals are unl... to have all the details worked out.
- *But they do not always follow these instructions.*

Compared to Heilmeier's questions

THE NSF REVIEW CRITERIA

Relation to NSF Review Criteria

- *What are you trying to do? Articulate your objectives using absolutely no jargon.*
- "…reviewers will be asked to consider what the proposers want to do…"
- "…projects should include clearly stated goals..."

Relation to NSF Review Criteria

- *How is it done today, and what are the limits of current practice?*
- "The Project Description .. must include ... relation to the present state of knowledge in the field, to work in progress by the PI under other support and to work in progress elsewhere."

Relation to NSF Review Criteria

- *What's new in your approach and why do you think it will be successful?*
- "…reviewers will be asked to consider … how they [the proposers] plan to do it …
- "…projects should include …specific descriptions of the activities that the PI intends to do, and a plan in place to document the outputs of those activities…"
- "To what extent do the proposed activities suggest and explore creative, original, or potentially transformative concepts?"
- "Is the plan for carrying out the proposed activities well-reasoned, well-organized, and based on a sound rationale?"
- "How well qualified is the individual, team, or organization to conduct the proposed activities?"

Relation to NSF Review Criteria

- *Who cares? If you are successful, what difference will it make?*
- "…reviewers will be asked to consider … why they [the proposers] want to do it … "
- "… reviewers will be asked to consider … what benefits will accrue if the project is successful … "
- "What is the potential for the proposed activity to:
- a. Advance knowledge and understanding within its own field or across different fields (Intellectual Merit); and
- b. Benefit society or advance desired societal outcomes (Broader Impacts)?"

"Broader Impacts"

- How is the project likely to "benefit society or advance desired societal outcomes"?
- Ideally, identify specific potential impacts on the economy, society, human well-being, defense, etc.
  - Do not be limited to educational and student outreach activities.
  - Plans for transition to practice and dissemination to industry are important
  - If you propose an activity, describe it as actionable; identify resources, and include impact assessment

"PIs are expected to be accountable for carrying out the activities described in the funded project."

Relation to NSF Review Criteria

- *What are the risks and the payoffs?*
- For payoffs, see question 4 above.
- Technical risks should be covered in the Research Plan, with appropriate fallback plans if risky aspects of the initial approach should fail.
- There are also management risks. One of the biggest risks in a collaborative project is that the collaboration will degenerate into a collection of independent activities, with no synergistic effect. A strong collaborative proposal needs to explain how every component will contribute, and how they will be coordinated and integrated throughout the project. Some solicitations emphasize this by calling for an explicit “management plan”, “coordination plan”, or “collaboration plan”.

Relation to NSF Review Criteria

- *How much will it cost? How long will it take?*
- "Are there adequate resources available to the PI (either at the home organization or through collaborations) to carry out the proposed activities?"
- Include a project time-line
- Justify your budget

Relation to NSF Review Criteria

- *What are the midterm and final "exams" to check for success?*
- "… reviewers will be asked to consider … how they [the proposers] will know if they succeed … "
- "Does the plan incorporate a mechanism to assess success?"
- "Meaningful assessment and evaluation of NSF funded projects should be based on appropriate metrics."
- Some solicitations emphasize this requirement by calling for an "evaluation plan" or "validation plan".

Criteria apply to all of the proposal

- All the review criteria, including the need for assessment of success, "*apply both to the technical aspects of the proposal and the way in which the project may make broader contributions*", including proposed educational and outreach activities.

Special considerations for

CAREER PROPOSALS

CAREER Program

“The intent of the program is to provide stable support at a sufficient level and duration to enable awardees to develop careers not only as outstanding researchers but also as educators demonstrating commitment to teaching, learning, and dissemination of knowledge.”

[2018 CAREER solicitation]

CAREER Proposal Overview

- Funds the academic career development of new faculty (It is not a research award.)
- Is based on a development plan, “a well-argued and specific proposal for activities that will, over a 5-year period, build a firm foundation for a lifetime of contributions to research and education in the context of the PI’s organization”
- The proposed project should aim to advance the employee's career goals and job responsibilities as well as the mission of the department or organization.
- Duration: 5 years
- Min (in most programs also a max.) amount: $400,000
  - Contact your program area for actual maximum

Distinguishing Features

- Is not a research award
- Is a career development award

The proposal must reflect this focus.

What does this mean?

- A conventional research proposal tells a story about a research problem, including why it is important, and how you will attack it.
  - If the research story is strong enough you might get away with a weak story about education.
- A CAREER proposal a story about a person (you), and your plans for career development.
  - Yes, you also need to have a sub-story about the research you plan, but presented in the above context.
  - And, the quality of your plans for development as an educator is likely to be given equal weight.

CAREER-specific criteria

- Proposal should include, besides a description of the research activities:
  - a description of the proposed educational activities, including plans to evaluate their impact on students and other participants
  - a description of how the research and educational activities are integrated with one another

"Successful applicants will propose creative, effective research and education plans, along with strategies for assessing these components."

"All CAREER proposals should describe an integrated path that will lead to a successful career as an outstanding researcher and educator."

[2018 CAREER solicitation]

Tell your story

- Your expertise and interests
- Your career and life goals
- Your position and resources
- For what do you hope people will eventually recognize your unique achievements in education & research?
  - e.g., the foremost expert in ...
- How do your plans fit into the context of your institution and department?
  - What specific research and educational roles does the department expect of you?
  - What are the specific opportunities, challenges, and resources in your department, institution, and community?

What is your strategic plan?

- Three elements:
  - Where are you today?
  - Where do you want to be in the future (5, 10, 20 years from now)?
  - How do you get from here to there?
- In other words, a projected roadmap for your life.
- Of course, your plans will need to evolve, but this is the basis for your proposal.

Your Proposal

- Should advance you toward your life goals
  - A stepping stone to the next thing
- Should be compatible with your institution's goals
  - Supported in that by your Departmental letter
- Should represent a contribution to society at large
- Test: If you accomplish your objectives, are you better off for the effort?

Scope of Research for this Project

- Your career involves a research *path*, not a research project
- Determine and describe your long-term research goals, and then identify *milestones* toward your goals.
- Detail the first one or two as the research objectives for your CAREER proposal project
  - Fit the time scale and budget limitations
  - Provide enough detail, and preliminary results, to make the case those milestones are achievable
  - Provide less detail on milestones further out
  - Consider risk-mitigating alternatives in plans for longer-term higher-risk goals
- Clearly separate what this grant will fund from has been done, and what you hope to do after.

Scope of CAREER Project

A road that leads to other roads.
The trunk of a seedling tree, that will develop many branches.

Your CAREER Research Path

- Lifelong research goals
  - Don’t end with a single project
  - May never end
  - Have broad application
- Examples:
  - To improve our ability to make engineering decisions under uncertainty and risk
  - To perform large-scale modeling of engineering systems thereby enabling better system optimization
  - To improve our understanding of metal cutting operations enabling improvements in machining

Education Elements to Consider

- Undergraduate
  - Curriculum
  - Projects (REUs)
- Graduate
  - Curriculum
  - Conferences
  - Involvement with industry, national labs
- Networks, partnerships
- K-12 outreach (RETs)
- Museum projects

But don't try to "check all the boxes" and claim to do more than you believe you will actually do.

Limit yourself to things for which you are ready to be held accountable in your annual reports!

Do's for Education Plan

- Don't just give a laundry list
- Focus on actionable plans
  - Be specific; give enough detail to be plausible
  - State what you hope the impacts will be
  - Explain what resources and/or commitment will be required from your department for success
  - Include plans for assessment
- Try to identify an unmet educational need and tell a story about how you hope to meet it.
- Relate it to your research plans.

DOs

- Have a strategic plan
- Build on your strengths, and the context of your department
- Differentiate this proposal from your Ph.D. thesis work and other sponsored work
- Perform thorough literature search and exploratory research before writing the proposal
  - Journal articles (update with personal contacts to authors)
  - Read the NSF Proposal & Award Policies & Procedures Guide (PAPPG)
- Establish and keep your contacts

DON'Ts

- Rush
- Wait until last minute (1 month) to contact program directors or ask for advice from colleagues
- Make the proposed work (research and education) too broad
- Make the proposed work too narrow
- Ask for too much (or too little) money
- Ignore specific requirements of the PAPPG or CAREER solicitation

Important Questions for Program Officers

- Does my research objective fit well with your program?
- What is your funding policy for CAREER awards? What is the maximum size of your CAREER awards? (Remember, the minimum is $400,000)
- How are CAREER proposals submitted to your program reviewed?

Multidisciplinary Research

- My research doesn't fit in any single NSF program, how about joint submission/review?
  - Did you formulate a clear research objective?
  - Is your research objective too broad?
  - Do you want to consider focusing your scope?
- Suppose my research really does span multiple programs?
  - Contact all potentially relevant program directors
  - There are a few cross-cutting programs at the NSF that

Collaborators?

- Success of your career really should not depend critically on someone else. They can die, move, change plans, etc.
- “Because the CAREER program is designed to foster individual career development, partners or collaborators may not be listed as co-principal investigators on the cover page. If critical for a given project, support for collaborators may be requested in the senior personnel or consultant services budget line items of the proposal, or in subawards to another institution.” [2018 CAREER solicitation]
- Don’t forget to include letters from any collaborators.

CAREER Summary Example

My research goal is… In pursuit of this goal, the research objective of this CAREER proposal is to test the hypothesis that the propensity of a tree to break is directly proportional to how many monkeys are in the tree. The approach will be to take a sample of ten trees and load them with monkeys until they break…

My educational goal is… In pursuit of this goal, the education objectives of this CAREER proposal are… The approach to accomplishing these objectives will be…

Intellectual Merit – It is important that we know how many monkeys can climb a tree before it breaks because this affects our perceptions of monkey procreation and… The Snerd Theory holds that tree size limits monkey procreation. This study challenges that theory with the notion that… If the objective hypothesis is correct therefore, it will transform our approach to…

Broader Impact – Monkeys are used in medical research. By knowing how many monkeys can fit in a tree, we will be able to provide more monkeys for such research thereby advancing medical science more quickly and improving the quality of life. Also, by watching the monkeys get hurt when the tree breaks, graduate students will be less likely to climb trees, thereby increasing their probability of graduating.

Departmental Letter

- Must commit to support of your plans
- What niche does the department see you as filling?
- Is there a commitment to teaching assignments consistent with the educational development plans in your proposal?
  - Will you be assigned to teach that course you plan to develop?
  - Will you have a chance to teach graduate courses from which you can train and recruit suitable research assistants?
- Are the research and educational plans consistent with the department's expectations for tenure?

Special considerations for

CYBER-PHYSICAL SYSTEMS PROPOSALS

CPS-Specific Challenges

- Writing for interdisciplinary reviewers
- Integrating a proposal, and team, across disciplines
- *"abstracting from the particulars of specific systems and application domains ... to reveal cross-cutting fundamental scientific and engineering principles that underpin the integration of cyber and physical elements across all application sectors"*

CPS-Specific Mistakes

- Focusing on an artifact:
  - *"The goal of this project is to design/develop/build a ...."*
- Failure to explicitly address all the items under *"All proposals are expected to:"*
  - Especially:
    "Explain how research outcomes can be generalized to other areas of application; "

All proposals are expected to ..

- *"Describe how the project goals and research and education outcomes will contribute to the realization of the CPS program goal and vision;*
- *Clearly explain the research component(s) of the project and their specific contribution to CPS science and technology;*
- *Explain how research outcomes can be generalized to other areas of application;*
- *Explain how the project research fits the Program Description for the class of proposal (Small, Medium, or Frontier);*
- *Present a plan to integrate research outcomes into education and more broadly advance education in CPS; ...*
- *Provide plans for disseminating the research and education outcomes in a manner that enables the CPS research community and helps scientists and engineers to use the results in ways that go beyond traditional academic publication;*"

Don’t forget the elephant!

- The CPS solicitation starts with a specific desired goal that will benefit society:

  “to realize cyber-physical systems with capability and dependability far beyond what we are able to achieve today”

- What will your project do towards achieving this goal?

This should be your first point under Broader Impacts

Don't miss the "must"!

".... a proposal must address at least one of the following three "research target areas" as described below"

- Read the full paragraphs, which define the areas.
- *Don't just say*:
  "This proposal addresses the Science of CPS."
- *Do say what*, specifically, the proposal contributes to the Science of CPS, and how.
  "This project seeks to bridge the computational versus physical notions of time by ... "

What is the Solicitation looking for in Science of CPS?

- “CPS must move beyond the classical fundamental models of computation and physics.
- CPS require new models and theories that unify perspectives, capable of expressing the interacting dynamics and integration of the computational and physical components of a system in a dynamic environment.
- A unified science would support composition, bridge the computational versus physical notions of time and space, cope with uncertainty, and enable cyber-physical systems to interoperate and evolve.”

What is the Solicitation looking for in Technology for CPS?

- “New design, analysis, and verification tools that embody the scientific principles of CPS and incorporate measurement, dynamics, and control are needed
- These tools should offer important perspectives into behaviors and interactions of CPS. New building blocks are also needed, including hardware computing platforms, operating systems, and middleware.
- The chain of tools and building blocks must integrate to support end-to-end assurances, and cover the full lifecycle of systems.
- Particular attention should be given to interfaces, interface management, extensibility, interoperability, and the controlled visibility of explicit and implicit assumptions.
- A particular goal is to enable evidence-based certification, and to maintain certification as a system evolves.

What is the Solicitation looking for in Engineering of CPS?

- CPS open a new opportunity to rethink the principles and methods of systems engineering that are built on the foundations of CPS science and technology.
- Attention should be given to system architectures, designs, and integrations as well as the exploration of design spaces that may have requirements for certifiably safe or dependable systems behavior.
- New engineering principles are needed to systematize design for the growing numbers of CPS that involve adaptation and autonomy.
- All advances should be assessed by appropriate benchmarks.
- The engineering processes must also support certification and maintenance of certification over system lifecycles.

Other CPS-Specific Issues

- “Separate but equal” cyber and physical research components won’t do
- Do show how cyber and physical domain knowledge combine to produce new insights, new solutions
- Don’t let an application domain expert dominate the proposal writing