Writing Successful Grants

(A Twelve Step Program)

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Grant Activity at UTK, 2011:

- About 1/3 of eligible faculty actively involved in proposal development
- Number of proposals submitted: 1,536
- Amount requested: $620,000,000
- Average dollars per request: $403,000
- Awards received: 1,251
- Dollars awarded: $163,000,000
- About 25% of eligible faculty participated in funded projects
"I'm sick of writing grant proposals on spec"

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**Academic writing sample…**

From a study on workplace aggression:

Taken together with the findings from the present study that (a) workplace aggression in the primary job was more closely associated with negative work experiences and (b) both situational and individual characteristics played a role in aggression in the secondary job, future research might benefit from a greater focus on the subjective salience of the job as a moderator of the relationship between workplace experiences and supervisor-targeted aggression. Indeed, despite the differential effects of situational and individual difference factors on aggression, it is notable that the individual difference factors exerted a consistent but relatively low-level effect on aggression across contexts, whereas the more salient situational experiences exerted context-specific effects.

Grant Writing: A Low Probability Game?

- Proposal success rates average 20 to 30 per cent (NSF, NIH, USDA, most private foundations)

- More than half (60%) are rejected on first reading because:
  - Proposal did not match program
  - Applicant did not follow directions

New & Quick, Grantseeker’s Toolkit, 1998
The Critics Weigh In…

(Actual comments made by actual reviewers)

- "The problem statement, such as it is, is too global, showing no relationship to reality with no potential solution being indicated or even possible."
- "This problem has been studied to death. I'm surprised the writer doesn't know this."
- "It is almost impossible to understand what the author wants to study or what the main theme is. The problem is full of jargon and totally unclear as stated."
- "I cannot ascertain what approach the researcher will take in examining the problem as outlined."
- The writer has a flair for the dramatic. The world will not collapse if we do not fund a study of students' daydreams."

So what’s the problem?…

"The problem makes the proposal."

✓ An important need or issue that should be addressed
✓ A gap between where we are now and where we could be
✓ A limitation of current knowledge or way of doing things

It's also an opportunity...

✓ A fresh idea that can advance our understanding or address a societal need
✓ A refinement that improves efficiency or lowers the cost of goods and/or services
✓ A new paradigm that reshapes our thinking or way of doing things
Reviewers are looking for...

- Significance
- Creativity (uniqueness)
- Clearly delineated project
- Research plan (methodology)
- Outcomes (evaluation)
- Clear, concise writing

"Ulrich, that's bad science and you know it."
Consider the Reviewer...

- Many competitive programs utilize review panels (especially federal and state)
- Most private foundations use staff to “screen” proposals for Program Director
- The more competitive, the more reviewer(s) will look for reasons to reject proposals

Success = Good Ideas - Pitfalls

- There is plenty of evidence to show that good ideas are often undermined by missteps in proposal preparation
- The following are some common proposal pitfalls and strategies to avoid them
A Starting Point...

- What are you passionate about?
- What is the problem (and why is it important)?
- How is existing knowledge or practice inadequate?

- Why is your idea better?
- How is it new, unique, different?
- What will it contribute and who will benefit from it?
1. Verify the match

- Develop your funding search skills
- Study program goals and eligibility
- Make contact with program officer before starting proposal!
  - Read program announcement carefully; note questions
  - Research previous awards!
  - Send brief (2-3 short paragraphs) overview of proposed project
  - Inquire about alternative funding sources

2. Structure the Proposal

Always follow the format provided by the sponsor! Where none is provided, build your case in distinct sections:

I. Problem Statement; or Significance of the Research
II. Project Purpose (Overall goal + Specific objectives)
  NB: Cite “fit” with program objectives!
III. Research Design; or Workplan (Activities + Timelines)
IV. Applicant Qualifications and Capabilities
V. Evaluation Plan; or Expected Outcomes
VI. Budget (Summary + Justifications)

Appendix (supplementary materials)
3. Prove the importance of your project

- State your purpose and case for need up front; build a compelling argument
- Think “Op Ed,” not academic journal
- Cite an authoritative source(s)

EX:
"This proposal addresses a priority of the World AIDS Foundation: AIDS prevention in developing countries. Specifically, we propose to conduct a series of five-day AIDS prevention workshops in four cities in Indonesia. The participants will be..."
Start with the Pitch: Sell Your Idea!

I. Set the Stage – Lay Out the Problem (“Who Cares?”)
   A. Get the reviewer interested at the outset
   B. Identify the importance—stress the need
   C. Summarize the state of the art
   D. Describe technical challenges to solving the problem and potential benefits

II. State the Theme – Your Solution
   E. Describe the concept and establish credibility
   F. Describe your project’s fundamental purpose

III. Create a Vision (“So What?”)
   G. Show how your work will advance the field
   H. Envision the world with the problem solved

The “pitch” should be the opening 2-3 paragraphs of the proposal’s very first section (after the abstract), regardless of what that section is called (INTRODUCTION, BACKGROUND, PROBLEM STATEMENT, SIGNIFICANCE OF THE RESEARCH, SPECIFIC AIDS, etc.)

Sample Pitch: USDA Grant

Intravenous Magnesium as a Treatment Modality for Recurrent Airway Obstruction

I. SETTING THE STAGE

(A) Recurrent Airway Obstruction (RAO) is a progressive, debilitating respiratory disease, occurring in 50% of mature horses, (B) with 5% affected severely enough to result in an end to their working careers or to euthanasia. It is a chronic, recurrent condition with clinical characteristics that are well recognized, although its pathogenesis is complex, multifactorial, and currently not well understood. As an indication of industry concern, in June of 2000, 30 of the world’s leading investigators were joined by pharmaceutical companies at a Michigan State University conference devoted entirely to improving RAO prevention and management. (C) Further, current management and therapeutic regimens for horses with chronic or severe disease are either not efficacious or are not able to be implemented. (D) For example, drugs commonly used to manage RAO, such as corticosteroids with anti-inflammatory properties and bronchodilators that open the passageways, also stress the heart, adding additional risk to an already debilitated animal. Strategies to remove environmental precipitators such as dust and mold often fail as many horse owners are unable or unwilling to comply with such husbandry recommendations.

II. PROJECT THEMES

(E) With this study, we propose to administer intravenous magnesium to horses with acute and chronic RAO to determine if this treatment improves respiratory function and/or reduces arterial hypotension, without the deleterious side effects of other commonly administered drugs. Recent case reports show magnesium to be efficacious for acute human asthma attacks who fail to respond to more conventional therapy. (F) As RAO is increasingly seen as an equine analog to asthma in humans (replacing the previous use of the COPD model), and severely affected RAO horses demonstrate many of the same clinical signs as human asthmatics, RAO horses could be equally responsive to this treatment.
III. VISION

(G) Should the research hypothesis be proved, clinicians will have another viable treatment modality at their disposal, one that is inexpensive, and effective in treating a resistant disease without the damaging side effects of other modalities. (H) Additionally, horse owners and breeders could reduce the significant financial losses caused by the malady, currently estimated at more than $800 million annually in the US alone.11
4. Assume an uninformed but intelligent reader

- Use clear, accessible language
- Stick with direct statements and active voice
- Avoid insider jargon and acronyms

"An expanding awareness of the limitations of our training settings, the political fallout of our training mission, the consequence of having therapists work in a particular work setting, and the need to change established institutional structures (e.g., child protective services, Aid to Families with Dependent Children, juvenile court) are examples of the contextualization of training and supervision."

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Passive vs. Active Voice

- It has been demonstrated by research that...
- The SAP program is being implemented by our department...
- Following administration of the third dosage, measurements will be taken...

- Research shows clearly that...
- Our department launched SAP this year...
- After dosage 3, we will measure...
5. Formulate specific, measurable objectives

**Goal:** General statement of the project’s overall purpose(s)

“Our aim with this innovative curriculum is to improve the supply of graduates with National Registry certification.”

**Objective:** A specific, measurable outcome or milepost

Which is the better objective? Why?

“It is anticipated that completion of the new curriculum will result in enhanced student scores.”

“At least 90 per cent of course graduates will pass the National Registry Examination.”

6. Illustrate: Project concept and the work plan

1) **Overall concept:**
   1) Visualize the overall project with a drawing
   2) Specify major tasks and timelines; use Gantt charts, calendars or flow charts

2) **Work plan:**
7. Follow application instructions exactly!

- Common sins:
  - Late submission
  - Narrative too long
  - Fonts, margins, spacing too small
  - Signatures, certifications missing
  - Budget narrative missing
  - Insufficient number of copies
  - Inappropriate binding
8. Pay attention to all review criteria

- Read evaluation standards carefully; then reference them in the project narrative
- Touch all the bases—not just the ones you’re comfortable with

Reviewers will use the criteria to “score” your proposal

P.S. NSF Means it!

Two key merit review criteria:

1) What is the intellectual merit of the proposed activity?

2) What are the broader impacts of the proposed activity?
   (since 1997)

“(PIs) must address both merit review criteria in separate statements within the one-page Project Summary. This chapter also reiterates that broader impacts resulting from the proposed project must be addressed in the Project Description and described as an integral part of the narrative.”

“Effective October 1, 2002, NSF will return without review proposals that do not separately address both merit review criteria within the Project Summary.”

- Grant Proposal Guide, Ch. III
9. Polish the abstract

- Written last, but read first by reviewers
- Must be an intriguing “first advertisement”
- Should reflect entire scope of project
- Summarizes project purpose and methods
- Must convey:
  - What researcher intends to do
  - Why it’s important
  - Expected outcome(s)
  - How work will be accomplished
- Has to be both CONCISE and COMPLETE!

This may be the only narrative that some reviewers will read
10. Presubmission review

- Ask seasoned colleagues for comments and suggestions
- Should be qualified to critiques proposal content
- Check your ego at the door
- Allow time for rewrites!

*Why bright people make dumb (grant writing) mistakes...*
11. Use proofreaders

- Find an eagle eyed perfectionist
- Proofreaders read for form, not content
- Must be someone who has no stake in the project!
- Learn to love what s/he will do for you
- Zero tolerance--no error is too small to correct
- Root out inconsistencies in format as well as typos, misspellings, grammar, etc.
12. Write, rewrite & rewrite

- Most winning proposals have been polished repeatedly
- Let it rest in between; sleep on every rewrite
- Fight the evil Pride of Authorship
- Must allow time!

(Famous rewriters: Hemingway, Michener)

And Tips for Success...

- Fit research and grant writing into your job
- Find a mentor(s)
- Read successful grants; attend workshops
- Find collaborators; network
- Get on a review panel!
- Get funding alerts; conduct your own searches regularly
- Think big, think small, think different
- Submit, revise & resubmit!
- Treat it like a game (which it is)
Why Academics Have a Hard Time Writing Good Grant Proposals

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Abstract
This paper discusses the contrasting perspectives of academic prose versus grant writing, and lists strategies grant specialists can use to help researchers break old habits and replace them with techniques better suited to the world of competitive grant proposals.

Introduction
When they are new to the grant game, even scholars with fine publishing records can struggle with proposal writing. Many are surprised to find that the writing style that made them successful as academics is not well suited to crafting a winning proposal. To succeed at grant writing, most researchers need to learn a new set of writing skills.

Academic Writing
For purposes of this discussion "academic writing" is defined as that style commonly adopted for scholarly papers, essays, and journal articles. The following is a typical example:

Taken together with the findings from the present study that (a) workplace aggression in the primary job was more closely associated with negative work experiences and (b) both situational and individual characteristics played a role in aggression in the secondary job, future research might benefit from a greater focus on the subjective salience of the job as a moderator of the relationship between workplace experiences and supervisor-targeted aggression. Indeed, despite the differential effects of situational and individual difference factors on aggression, it is notable that the individual difference factors exerted a consistent but relatively low-level effect on aggression across contexts, whereas the more salient situational experiences exerted context-specific effects. (Inness, Barling, and Turner, 2005)

Look at the Difference
To start, glance at the first pages in any sampling of winning grant proposals. The first thing you notice is that they look different from pages in typical academic journals. Sentences are shorter, with key phrases underlined or bolded to make them stand out. Lists are printed bullet style. Graphs, tables and drawings abound. Now read the pages more carefully. The writing is more energetic, direct and concise. The subject matter is easy to understand, as there are fewer highly technical terms.
Each time you learn something about a subject entirely new to you. You are intrigued by exciting new ideas that have a good chance for success. In short, you quickly agree that the review panels made the right choices in funding these proposals.

The lesson here is a hard one for beginners: Success in grant writing is a matter of style and format as much as content. Make no mistake—the best written proposal will not win money for a weak idea. But it is also true that many good ideas are not funded because the proposal is poorly written (New & Quick, 1998; Steiner, 1988). Sometimes the failure is due to a weak or missing component that is key to a good proposal. The research plan may be flawed or incomplete. The evaluation methods might be inadequate. The researchers may not be qualified to carry out the work. But all too often, the core problem in a failed proposal lies in the writing itself, which bears too many characteristics of academic prose. (A baffled professor once came to my office bearing the written critiques he had received from reviewers of a failed proposal. One of them included this killer remark: “Reads like a journal article.”)

**Contrasting Perspectives**

To understand the dimensions of the overall problem, consider the contrasting perspectives of academic writing versus grant writing:

**Table 1**

*Academic Writing versus Grant Writing: Contrasting Perspectives*

<table>
<thead>
<tr>
<th>Academic Writing</th>
<th>Grant Writing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scholarly pursuit:</td>
<td>Sponsor goals:</td>
</tr>
<tr>
<td><em>Individual passion</em></td>
<td><em>Service attitude</em></td>
</tr>
<tr>
<td>Past oriented:</td>
<td><em>Future oriented:</em></td>
</tr>
<tr>
<td><em>Work that has been done</em></td>
<td><em>Work that should be done</em></td>
</tr>
<tr>
<td>Theme-centered:</td>
<td><em>Project-centered:</em></td>
</tr>
<tr>
<td><em>Theory and thesis</em></td>
<td><em>Objectives and activities</em></td>
</tr>
<tr>
<td>Expository rhetoric:</td>
<td><em>Persuasive rhetoric:</em></td>
</tr>
<tr>
<td><em>Explaining to reader</em></td>
<td><em>“Selling” the reader</em></td>
</tr>
<tr>
<td>Impersonal tone:</td>
<td><em>Personal tone:</em></td>
</tr>
<tr>
<td><em>Objective, dispassionate</em></td>
<td><em>Conveys excitement</em></td>
</tr>
<tr>
<td>Individualistic:</td>
<td><em>Team-focused:</em></td>
</tr>
<tr>
<td><em>Primarily a solo activity</em></td>
<td><em>Feedback needed</em></td>
</tr>
<tr>
<td>Few length constraints:</td>
<td><em>Strict length constraints:</em></td>
</tr>
<tr>
<td><em>Verbosity rewarded</em></td>
<td><em>Brevity rewarded</em></td>
</tr>
<tr>
<td>Specialized terminology:</td>
<td><em>Accessible language:</em></td>
</tr>
<tr>
<td><em>“Insider jargon”</em></td>
<td><em>Easily understood</em></td>
</tr>
</tbody>
</table>
Scholarly Pursuit versus Sponsor Goals
Driven to make unique contributions to their chosen fields, scholars habitually pursue their individual interests, often with a good deal of passion. When seeking financial support for these endeavors, however, many find that potential sponsors simply do not share their enthusiasm. "A sound concept, but it does not fit our current funding priorities," or similar phrases, are commonly found in letters that deny funding. With the exception of a few career development programs, funding agencies have little interest in advancing the careers of ambitious academics. Sponsors will, however, fund projects that have a good chance of achieving their goals. This is why seasoned grant writers devote a good deal of time parsing grant program announcements, highlighting passages that express what the sponsors want to accomplish, and what kind of projects they will pay for. Then the writers adopt a service attitude, finding ways to adapt their expertise to match the sponsor's objectives. Finally, they test their ideas with grant program officers before deciding to write a proposal. As one of our university's consistently successful grant writers put it: "My epiphany came when I realized that grant programs do not exist to make me successful, but rather my job is to make those programs successful."

Past versus Future Orientation
In academic writing, the researcher is describing work that has already been done: Literature has been reviewed, an issue examined, a thesis presented, a discovery made, a conclusion drawn. Grant writers, by contrast, describe in detail work that they wish to do. For some disciplines, good grant writing can be viewed as science fiction, i.e., it must be grounded in solid science, but the research design itself is a set of logical yet imagined activities that have yet to take place. This in itself is a major shift in perspective that seasoned scholars find difficult when starting to write proposals.

Theme-Centered versus Project-Centered
Scholarly writers are prone to dwell on theme, thesis and theory. Essays and books can be devoted to the authors' original thinking, contributions of past and present scholars, or the evolution of entire schools of thought. They draw us into the realm of ideas. Grant writers, however, draw us into a world of action. They start by sketching out an important problem, then they move quickly to describing a creative approach to addressing that problem with a set of activities that will accomplish specific goals and objectives. The overall project is designed to make a significant contribution to a discipline or to a society as a whole.

Academic writers often seek funding to "study," "examine," or "explore" some theme or issue. But this can be deadly, as sponsors rarely spend money on intellectual exploration. They will, however, consider funding activities to accomplish goals that are important to them. It is the project that interests them, not just the thinking of the investigator. Finally, academic essays end with their authors' final conclusions, while grant proposals end with their projects' expected outcomes.

Expository versus Persuasive Rhetoric
The academic writer uses language to explain ideas, issues and events to the reader. The aim is to build a logical progression of thought, helping the reader to share the writer's intellectual journey and to agree with the core themes of the piece. But the language in a grant has to be stronger; it must sell a nonexistent project to the reader. The writer has to convince the reviewer that the proposed research is uniquely deserving. The whole effort is geared toward building a winning argument, a compelling case that scarce dollars should be spent on a
truly exceptional idea that has an excellent
chance for success. Grant reviewers are
a notoriously skeptical lot who reject a
majority of proposals, so writers must
use language strong enough to win their
reluctant support. In effect, a good proposal
is an elegant sales pitch.

Impersonal versus Personal Tone
From their undergraduate term papers to
their doctoral dissertations and numerous
papers that followed, scholars have been
conditioned to generate prose in proper
academic style—cautious, objective and
dispassionate, exclusively focused on the
topic, with all evidence of the writer’s
persona hidden from view. Grant writers,
however, seek the reviewers’ enthusiastic
endorsement; they want readers to be
excited about their exemplary projects, so
they strive to convey their own excitement.
They do this by using active voice, strong,
energetic phrasing, and direct references to
themselves in the first person. Here are some
eamples:

Our aim with this innovative curriculum
is to improve the supply of exceptionally
skilled paramedics with National
Registry certification.

This project will provide your grant
program with a powerful combination
of cutting edge nanoscale science
and frontier research in applied
geochemistry.

Though we launched this large and
ambitious program just two years ago,
we are gratified by the regional and
national awards it has garnered.

Sentences like these violate editorial rules of
many scholarly journals.

Solo Scholarship versus Teamwork
With the exception of co-authored work,
academic writing is mostly a solo activity.

Perched at a desk, in the library or at home
in the den, the solitary scholar fills page
after page with stolid academic prose. When
the paper or book chapter is completed, it
may be passed to one or two readers for
final proofing, but the overall endeavor is
highly individualistic. Good grant writing,
however, requires teamwork from the outset.
Because their ultimate success depends upon
nearly unanimous approval from a sizeable
group of reviewers, grant writers place high
value on feedback at every phase of proposal
writing. Before the first draft, a thumbnail
sketch of the basic concept will be sounded
out with colleagues before sending it on to
a grant program officer to test whether the
idea is a good fit. Large multi-investigator
proposals are typically broken into sections
to be written and rewritten by several
researchers, then compiled and edited by
the lead writer. Many large proposals are
submitted to a “red team” for internal review
before sending them out to the funding
agencies. Even single investigator proposals
have been combed over repeatedly as the
documents move from first draft to the final
product. Proposals that bypass this essential
process have a much greater chance of
failure.

Length versus Brevity
Verbosity is rewarded in academe. From
extended lectures to journals without page
limits, academics are encouraged to expound
at great length. A quick scan of any issue of
The Chronicle of Higher Education reveals
the degree to which simple ideas can be
expanded to multiple pages. A common
technique is to stretch sentences and
paragraphs to extreme lengths. Consider
the following example, which won a Bad
Writing Contest sponsored by the journal
Philosophy and Literature:

The move from a structuralist account in
which capital is understood to structure
social relations in relatively homologous
ways to a view of hegemony in which power relations are subject to repetition, convergence, and rearticulation brought the question of temporality into the thinking of structure, and marked a shift from a form of althusserian theory that takes structural totalities as theoretical objects to one in which the insights into the contingent possibility of structure inaugurate a renewed conception of hegemony as bound up with the contingent sites and strategies of the rearticulation of power. (Butler, 1997)

An extreme example perhaps, but its characteristics can be seen in many scholarly essays.

Grant reviewers are impatient readers. Busy people with limited time, they look for any excuse to stop reading. They are quickly annoyed if they must struggle to understand the writer or learn what the project is all about. Worse, if the proposal does not intrigue them by the very first page, they will not read any further (unless they must submit a written critique, in which case they immediately start looking for reasons to justify why the proposal should not be funded). When asked to describe the characteristics of good grant writing, senior reviewers put qualities such as “clear” and “concise” at the top of the list (Porter, 2005). Brevity is not only the soul of wit; it is the essence of grantsmanship. Or, to cite Mies van der Rohe’s famous dictum about modern architecture: “Less is more.”

Specialized Terminology versus Accessible Language
Every discipline uses specialized terminology, much of it dictated by the need to convey precise meaning. But there reaches a point where specialized words become needlessly complex and the reader becomes lost in a tangle of dense verbiage. As Henson (2004) points out, a spell comes over us when we know our writing will be evaluated, either by editors or by grant reviewers: We want our work to appear scholarly, so we habitually inflate our prose with large words and complicated sentences to achieve the effect of serious thinking. Unfortunately, such tactics have the opposite effect on readers. Alley (1996) shows how too many big words and convoluted expressions can result in muddled jargon:

The objective of this study is to develop an effective commercialization strategy for solar energy systems by analyzing the factors that are impeding commercial projects and by prioritizing the potential government and industry actions that can facilitate the viability of the projects.

A sentence like this could kill a grant proposal on the first page. Grant writers cannot afford to lose even one reviewer in a barrage of obtuse phrasing. They must use language that can be understood by a diverse group of readers, some of whom may be as highly specialized as the writer, but most will be generalists. Reworking the cumbersome structure above, Alley comes up with simpler, more accessible language:

This study will consider why current solar energy systems have not yet reached the commercial stage and will evaluate the steps that industry and government can take to make these systems commercial.

Fewer words with greater clarity—a tradeoff that will improve the score of any grant proposal. But how can one consistently strike a balance between scholarly precision and meaning that is clear to a mixed audience? One NIH web site on grant writing advises writers to study articles published in Scientific American (National Institute of Allergy and Infectious Diseases [NIAID], 2006). Here world class scientists use accessible language to teach a general
readership about complex subjects while simultaneously informing them of cutting edge developments. Good proposals do the same. The following excerpt is from a recent Scientific American article on stem cells and cancer research:

Conventional wisdom has long held that any tumor cell remaining in the body could potentially reignite the disease. Current treatments therefore, focus on killing the greatest number of cancer cells. Successes with this approach are still very much hit-or-miss, however, and for patients with advanced cases of the most common solid tumor malignancies, the prognosis remains poor. (Clarke & Becker, 2006)

Clinically accurate yet easily understandable, this would be a fine introduction to a grant proposal.

Remedial strategies
Given the contrasting perspectives listed above, what can the university research office do to help academics adapt to the unfamiliar standards of grant writing? First, recognize that no one likes to be told they do not write well, especially highly educated folk who are justly proud of their intellectual achievements. Nevertheless, proactive and tactful research administrators can do much to help instill good proposal writing habits. Here are five remedial strategies that instruct without offending.

1. Home-Grown Workshops
For young investigators, grant writing workshops are an effective way to learn good writing techniques. Home-grown workshops, taught by any combination of research office personnel and grant-savvy faculty, can yield positive returns at a very low cost. Beginning workshops on basic grant writing skills should be offered on a regular basis, supplemented periodically by those focusing on specific funding agencies. Especially popular are presentations by successful grant writers and copies of winning proposals (Porter, 2004).

2. Reading Successful Proposals
Winning grants teach by example. By perusing several, the new grant writer will note some common differences from accepted academic style, and can be encouraged to mimic them. Successful proposals from one's own institution can be put online, with access limited to internal researchers. Copies of winning proposals can also be purchased from The Grant Center at reasonable rates: www.tgcigrantproposals.com. Finally, successful proposals can be obtained directly from federal agencies under the Freedom of Information Act, but be prepared to wait several months for the documents to arrive, with sensitive information deleted.

3. Editing by a Grants Specialist
While no amount of editorial polishing can save a weak idea, a seasoned grant writer can add value to a sound concept by judicious editing. This is labor intensive at first but once the writer catches on to the simpler, livelier style of grant writing, the need for personal attention drops off rapidly.

4. Red Team Reviews
Writing a strong proposal for a major multidisciplinary grant is a challenging project all by itself, one that can overwhelm the researchers, for whom grant writing is often an additional chore on top of full workloads. One effective tool is to form an internal review team consisting of experienced senior colleagues. If carefully selected for their expertise and reputations, their written comments can have great impact. Be warned, however: A considerable degree of gentle but persistent nagging is required for the writers to have the
document ready for internal review with sufficient lead time before the sponsor’s deadline.

5. Writing Tips
Finally, the research office should post a set of simple writing tips on its web site. These are most helpful if examples of bad writing are contrasted with effective revisions. Seeing them side by side, readers will quickly spot which bad characteristics are their own, and will note how they can craft better versions. Alley’s work, in particular, is peppered with numerous examples of weak composition contrasted with more effective phrasing. A truly time tested source is Strunk and White’s familiar Elements of Style (2000). Versions of this concise, lively handbook have been popular for nearly half a century, and its instructions for crisp and vigorous writing will give heart to academics who are trying to break old habits.

Conclusions
As competition intensifies for limited research dollars, proposal success rates for most agencies are declining. To be successful in this environment, proposals must be written in a strong, persuasive style, and academic writers accustomed to a different style need help to develop more effective writing habits. Such leadership can be provided by a proactive research office that is sensitive to this pervasive need.

References
BUILDING THE RESEARCH GRANT PROPOSAL
Writing Exercises

A. A Starting Point. The following questions are a necessary starting point for any grant proposal: You need a brief, convincing answer to each of them as a way of testing your readiness to start writing. Answer each of the following in 25 words or less:

1. What are you passionate about? (In terms of research, that is)

2. What is the problem (or need) and why is it important?

2a. What sources or kinds of data can you use to validate the importance of your proposed project?

3. How is existing knowledge or practice inadequate?

4. Why is your idea better?

5. How is it new, unique, different?

6. What will it contribute and who will benefit from it?
B. Writing Style: Simplicity. Substitute a single word for each of the following phrases:

at this point in time ________ in the event that ________
at that point in time ________ in the vicinity of ________
has the ability to ________ owing to the fact that ________
has the potential to ________ in the course of ________
in light of the fact that ________ in the near future ________

C. Writing Style: Jargon, Passive vs. Active Voice. 1. Reduce the following sentence to a simpler form with fewer words and active voice that conveys the same meaning:

It has been determined that this study will develop an effective commercialization strategy for solar energy systems by analyzing the factors that are impeding commercial projects and by prioritizing the potential government and industry actions that can facilitate the viability of the projects.

2. Rewrite the following as a single sentence with active voice:

Today it was determined that a recent ruling by the Illinois Supreme Court would be allowed to stand. The case involved whether the court should or should not grant custody of a baby boy to his biological father, even though that father has never seen his son. The original Illinois ruling which granted custody to the father was appealed to the US Supreme Court, and today, in an order written by Justice John Paul Stevens, the US Supreme Court refused to delay the Illinois ruling. (3 sentences; 83 words)

D. Writing Style: Tentative phrasing. Rewrite the following sentences in a more positive tone:

A general review of the literature indicates that this topic has likely not been previously investigated.

By investigating the characteristics of chalogenic glass, we hope to determine new future roles for it in the field of microphotonics.
While it is true that Dr. Schmidt has never worked on a kinesiology project, his extensive research in biology will contribute to our work.

E. Funding sources. Using the NSF Awards database, identify at least two grant programs that might fund your research. Read the mission statements for those programs, note the terminology used to describe program purpose, goals and objectives, and identify the program officers.

1. 

2. 

F. Goals and Objectives. Write a goal statement for your proposal:

Write three specific, measurable objectives for your proposal:

1. 

2. 

3. 

G. Project Summary: The Pitch. Read carefully the attached Project Summary from a successful NSF proposal: “WITS: A Wireless Interactive Teaching System.” What features of this writing made it successful? (It was funded twice). Identify the specific writing strategies that “sold” this concept to two separate NSF review panels. Points to consider:

Title: What makes this title “strategic”?

Tone: What is the overall feeling you get from this document? What words are used to communicate feeling?

Bullets: Why use them? What do they do? How are they structured?

Significance: How does the writer convey the importance of the issue to be addressed?

Success: Why is this project likely to succeed?

Final argument: What is the purpose of the last paragraph?
H. Preabstract. Write a preabstract for your proposal that you will use to initiate contact with an NSF program officer. Summarize the nature of your research, specify your goal and objectives, and indicate why you think it could be suitable for funding by that program. Close by asking if the concept is an appropriate fit.
ACTIVE VERBS FOR GRANT WRITING

accelerate  accomplish  achieve*  acquire*  act  adapt*  add  address*  adjust  administer  advance*  aim  allocate  analyze*  answer  anticipate  appropriate  arrange  arrest  ascertain*  assemble  assess*  attain*  calculate*  characterize*  classify*  collect  compile*  complete  compose  compute*  conduct*  conserve  consolidate  construct*  consult  control*  coordinate*  counsel  count  create*  cut  decide  deduct  define*  delegate  delineate*  deliver  describe*  design*  detect*  determine*  develop*  devise*  diagnose  dictate  direct  discover  display  dissect  distribute*  divert  devise*  draft*  drag  drain  dramatize  edit  elevate  engage*  enjoin  enter  establish*  estimate  evaluate*  examine*  exert  expand*  expedite  explain  explore*  expose  extend  extract  extricate*  feed  feel  fend  file  fill  find*  force  formulate*  furnish  generate*  get  give  grow  growl  guide  hypothesize*  identify*  illustrate*  imitate  implement*  improve*  increase*  induce  influence  inform  inject  insert  inspect  inspire  install  instigate  institute*  interchange  interpret*  interview  invent  inventory  investigate*  isolate*  launch*  lead  level  log  maintain*  make  manage*  mark  measure*  mediate  mentor  mobilize*  model*  monitor*  motivate  move  negotiate*  observe  obtain*  occupy  offer  officiate  operate  order*  organize*  oversee  penetrate  perceive  perform*  persuade  photograph  pick  plan*  polish  pore  predict*  prepare*  prescribe*  present  preside  produce*  program  project*  promote*  prompt  propel  protect  provide  pump  punch  purchase  pursue  question  raise  rally  realize  receive  recommend*  record*  recoup  recruit*  redeem  reduce*  refer  regain  rejoin  relate*  render  repair  report  represent  repulse  research  resign  resolve*  respond  restore*  retrieve*  reveal  review*  save  scan  schedule*  score  seal  search  select*  set  shape*  stop  strike  strip  study*  submit*  summarize*  summon  supervise  supply*  support  survey*  suspend  swerve  systematize*  target*  teach*  test*  track*  train*  transcribe  transfer  translate*  treat  turn  undertake*  unify  unite*  update*  utilize*  write

* most commonly used
Goals, Hypotheses, Research Questions, and Project Objectives

A. Three ways to begin an academic research project:

1. A goal statement or statements
2. An hypothesis or hypotheses
3. Research questions

1. Goal: A general statement of a project’s ultimate purpose. It can be open-ended, idealistic, even visionary.

- Our goal with this project is to improve the teaching of STEM subjects (science, technology, engineering, mathematics) to undergraduates.
- This project will deepen our understanding of the effects of global climate change on populations of saltwater plankton.
- This study will result in the first complete database for the assessment of the effects of toxic metals on human reproduction
- We seek to understand how cell division and differentiation are regulated by a myriad of extracellular and intracellular signals.
- The research team will develop an analytical framework for classifying brain potential analysis of motor functions and decision making.

2. Hypothesis: A specific, testable assumption or conjecture that the research data are expected to support. (Note: Whether the data do or do not support the hypothesis is of equal scientific importance)

- We will test the hypothesis that large neurons are selectively destroyed in Alzheimer's Disease by measuring the sizes of ganglion cells in retinas of AD patients compared with those in age-matched control groups.
- Magnesium deficiency caused by glucose intolerance, insulin resistance, or other factors in hypertensive patients leads to increased vasomotor tone via altered release of vasoactive cyclooxygenase and lipoxygenase products.
- For infection to occur, the capsids of parvoviruses undergo structural variation through the binding or release of divalent ions, by site-specific proteolysis, or by variation in specific intra- or inter-chain bonds.
- We hypothesize that moderate consumption of fruits grown in Oman over the routine baseline intake would reduce the progression of cognitive impairment inpatients diagnosed with Alzheimer's Disease (AD) and mild cognitive impairment (MCI).
3. Research Questions: Inquiries related to lack of knowledge in an important area of research, answers to which are sought through the research design.

- Are there common lifestyle traits among those suffering from diabetes in this region?
- Do local physicians address these traits in prescribing treatment and follow up regimens?
- Are there significant variations in standards of practice among physicians?
- If so, is there a rational basis for these variations?

B. Project objective: A specific, measurable, benchmark, milepost, or outcome achieved in moving toward the goal.

- Whether starting with a goal, an hypothesis, or research questions, the next step is to formulate the project’s objectives
- Most successful research designs are driven by 2 – 4 objectives
- Active verbs are key to writing strong objectives
- Upon completion of the final objective, the goal should be obtained (or at least major progress should be achieved)
- In health-related research, objectives are often referred to as “Specific Aims” (US National Institutes of Health)
- Examples:
  - We will design and test ten new modules for teaching cardiopulmonary resuscitation to first year nursing students
  - Utilize a modeling approach to characterize pharmacokinetic data and factors influencing tacrolimus dosage among the target population
  - Determine the potential involvement of the calcium-sensitive process in the development of myogenic tone in both young and aged coronary arteries
  - To identify the primary means parents use to discipline their children, and rank them by level of violence
The Project Description
Master Proposal
Developing the Proposal
to assess the results of the project. The project’s sustainability flows directly from its success, hence its ability to attract other support. The five subsections present an interlocking picture of the total project.

Objectives

Objectives are the measurable outcomes of the program. They help delineate your methods. Your objectives must be tangible, specific, concrete, measurable, and achievable in a specified time period. Grantseekers often confuse objectives with goals, which are conceptual and more abstract. For the purpose of illustration, here is the goal of a project with a subsidiary objective:

<table>
<thead>
<tr>
<th>Goal:</th>
<th>Our afterschool program will help children read better.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective:</td>
<td>Our afterschool remedial education program will assist 50 children in improving their reading scores by one grade level as demonstrated on standardized reading tests administered after participating in the program for six months.</td>
</tr>
</tbody>
</table>

The goal in this case is abstract: improving reading, while the objective is much more specific. It is achievable in the short term (six months) and measurable (improving 50 children’s reading scores by one grade level).

With competition for dollars so great, well-articulated objectives are increasingly critical to a proposal’s success.

Calling upon a different example, there are at least four types of objectives:

1. Behavioral—A human action is anticipated.  
   Example: Fifty of the 70 children participating will learn to swim.

2. Performance—A specific time frame within which a behavior will occur, at an expected proficiency level, is anticipated.  
   Example: Fifty of the 70 children will learn to swim within six months and will pass a basic swimming proficiency test administered by a Red Cross–certified lifeguard.

3. Process—The manner in which something occurs is an end in itself.  
   Example: We will document the teaching methods utilized, identifying those with the greatest success.

4. Product—A tangible item will result.  
   Example: A manual will be created to be used in teaching swimming to this age and proficiency group in the future.

In any given proposal, you will find yourself setting forth one or more of these types of objectives, depending on the nature of your project. Be certain to present the objectives very clearly. Make sure that they do not become lost in verbiage and that they stand out on the page. You might, for example, use numbers, bullets, or indentations to denote the objectives in the text. Above all, be realistic in setting objectives. Don’t promise what you can’t deliver. Remember, the funder will want to be told in the final report that the project actually accomplished these objectives.

The example that follows is from a proposal to the Henry Luce Foundation from the San Francisco Theological Seminary. It is a brief statement of the proposed project’s objectives, presented in outline form.

<table>
<thead>
<tr>
<th>Expected Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>With partnership support from The Henry Luce Foundation, San Francisco Theological Seminary looks forward to the following:</td>
</tr>
<tr>
<td>A. An established network for recruiting students, financial contributions, and other forms of support for the Seminary in Southern California from among its diverse constituencies.</td>
</tr>
<tr>
<td>B. An increase in SFTS/SC student enrollment by 100 percent by academic year 2004, reflecting the breadth of racial/ethnic and cultural constituencies in the region.</td>
</tr>
</tbody>
</table>
Like helping the parents learn to enjoy swimming with their children, learning to operate a swimming pool will be a major step in their development of confidence and skill. Our pool will be an effective tool for teaching children how to swim, and it will also provide a place for parents to practice their own swimming skills. The pool will be open to the public, and parents will be encouraged to bring their children to swim. The pool will be staffed by lifeguards who will be trained to the highest standard.

The project is divided into three main phases:

1. **Community Engagement:**
   - Engage the community in the planning and implementation of the project.
   - Provide education and training to the community on the benefits of swimming.

2. **Construction and Design:**
   - Design and construct the pool and associated facilities.
   - Ensure that the pool meets the highest safety and accessibility standards.

3. **Operation and Maintenance:**
   - Manage the pool and facilities according to the highest standards.
   - Provide ongoing education and training to pool staff.

The purpose of this project is to increase community participation in outdoor activities and to provide a safe and accessible space for all members of the community to enjoy.

**Goals and Objectives:**

- Improve community health and fitness through swimming.
- Reduce drowning incidents and improve water safety awareness.
- Create a center of community activity and social interaction.

**Purpose and Goals:**

Our project aims to promote the following goals:

- Increase community participation in swimming and other water activities.
- Improve water safety and drowning prevention.
- Create a hub for community events and social gatherings.

To address these needs, we will develop a comprehensive project plan that will include the following components:

- Community engagement and outreach.
- Design and construction of the pool and facilities.
- Ongoing operation and maintenance.

**Conclusion:**

We believe that this project will have a positive impact on the community, improving health and fitness, reducing drowning incidents, and providing a space for community and social interaction. This project aligns with the goals of our community and will be a valuable asset for many years to come.
because using swimming to bring the family together in wholesome
exercise is not a stated objective of the project.

The Community Projects Foundation proposal to the John S. and
James L. Knight Foundation briefly describes an audience develop-
ment project.

The CPF requests funding to conduct and implement a collabo-
rate audience research and development effort among the
organizations involved in the Challenge that can also act as a
model for similar organizations in small- to mid-sized cities. In
addition to the CPF, the nine organizations involved are: the
Coca-Cola Space Science Center, the Columbus Museum, the
Columbus Symphony Orchestra, the Historic Columbus Foun-
dation, the Liberty Theatre Cultural Center, Port Columbus
Civil War Naval Center, the RiverCenter for the Performing
Arts, the Schwob Department of Music of Columbus State
University, and the Springer Opera House. This project is not unlike
the efforts being taken by the collaborative efforts in Long
Beach and San Jose, California, and we will share information
with these communities.

This project involves three phases: audience research, mar-
ket planning, and plan implementation. Knight
funds are being requested to make possible the first and second
phases, which will be carried out by a market research firm specializing in research and marketing counseling for arts, culture,
and history organizations.

Phase One consists of a thorough analysis of the existing and
potential arts, culture, and history audiences in our area and,
for organizations whose audience might be primarily tourist
visitors, outside our area. The analysis will involve both general
research and research specific to each organization. Phase Two
consists of the development of marketing plans for each organiza-
tion, identifying every possible avenue for collaborative
efforts among one or more of the other participating organiza-
tions. Phase Three, the implementation phase, will implement,
for purposes of this project, only the collaborative efforts identi-
fied in Phase Two. Components of each group's plan that are
specific only to that group will be carried out on a funds-
available basis at the discretion of the group, outside of this
project.

Implementation of the project will probably take 24 months,
broken down as follows: three months to identify and hire the
consulting firm, six months for them to design and conduct their research, two months for them to design and present their
marketing plans, and 12 months for the organizations to imple-
ment the resulting collaborative marketing efforts. In addition
to regular evaluation meetings among the organization prin-
cipals during the project period, at the conclusion of the project,
one month of follow-up evaluation will be conducted, and a
case study will be written and submitted to Knight Foundation.

In addition to the case study prepared for Knight Foundation,
results and conclusions of the project will be shared with
other arts, culture, and history groups in our area, involving
each of them in efforts to offer services to a maximum number of
people as well as other Knight communities.

Another application to the Knight Foundation from the Museum
of Science in Boston, Massachusetts, lays out detailed plans for a
touring exhibit. For the sake of brevity, we have shortened it here.

The Museum of Science is planning, developing, and imple-
menting a major new interdisciplinary traveling exhibition enti-
tled The Secrets of Aging, which examines the processes and
effects of human aging from scientific, social, humanistic, and
cultural perspectives. The Secrets of Aging is scheduled to open
at the Museum of Science in April 2000, and it will tour nation-
ally (the tour will include the Journey with Me component) dur-
ing the following three years to the other five museums making
up the Science Museum Exhibit Collaborative. After that time,
the exhibition will be available to travel to additional sites. Two
of the six SMEC museums to which the exhibition will travel are
located in Knight communities of interest: The Franklin Insti-
tute in Philadelphia and the Science Museum of Minnesota in
St. Paul; a third museum directly serves a Knight community of
interest: the California Science Center in Los Angeles, which
serves Long Beach; and a fourth museum, the Center of Science
and Industry, is within 125 miles of the Knight community of
interest of Akron, Ohio.
Developing the Master Proposal: The Project Description

Guide to Proposal Writing
1. Overview and Objectives

This proposal presents the enabling technology for wireless networks consisting of intelligent nodes sharing a distributed knowledge base and capable of both individual and collective reasoning and learning. The nodes are cognitive radios (CRs): intelligent machines that can determine the best way to operate in a given situation and configure themselves accordingly. Like living creatures, they are aware of their surroundings, their own and their peers’ capabilities, and the governing social constraints. Their actions arise from a rational process that predicts probable consequences and remembers past successes and failures.

A CR is a software defined radio with a “cognitive engine” brain. Conceptually, the cognitive engine responds to the operator’s commands by configuring the radio for whatever combinations of waveform, protocol, operating frequency, and networking are required. It monitors its own performance continuously, reading the radio’s outputs to determine the RF environment, channel conditions, link performance, etc., and adjusting the radio’s settings to deliver the needed quality of service subject to an appropriate combination of user requirements, operational limitations, and regulatory constraints. We call these processes “turning the radio’s knobs” and “reading the radio’s meters” for short.

Our group is developing a distributed cognitive engine that can make any radio with electronically accessible inputs and outputs truly cognitive. A first proof of concept prototype is now operational. In this proposal we seek to apply our technology at the network level, using cognitive GNU Radios as intelligent nodes, and to build and test cognitive networks using the Rutgers University’s ORBIT facility [ORBIT] and the University of Utah’s Emulab [Emulab] facility. With these tests we will explore the general behavior of cognitive networks and investigate cognitive techniques for spectrum access and sharing and quality of service (QoS) provisioning. Figure 1 presents the planned timeline for the project.

This work takes programmable wireless networking to new levels (literally) by extending intelligence that, in the past, has at best resided at the application layer, down to the medium access control (MAC) and physical (PHY) layers. It allows nodes cooperatively to set their own data rates, transmitter power levels, modulation formats, etc., rather than limiting these quantities to constant values or to settings dictated by a central authority.

2. Relationship to Current State of Knowledge and Work in Progress

2.1 The Virginia Tech Cognitive Engine in Context

Joseph Mitola invented the basic cognitive radio concept in the late 1990s when he envisioned a CR as a universal and highly intelligent wireless personal digital assistant, operating primarily at the application level. More recently the DARPA XG program extended the concept to allow the CR to operate as an intelligent agent. Our work, based on learning algorithms, extended cognition to the MAC (medium access control) and PHY (physical) layers. This allows the cognitive process to monitor and control
processes (e.g., modulation) and settings (e.g., transmitter power) that are inaccessible from the higher layers. Fig. 2 provides a historical context for our work.

Figure 2. The VT Cognitive Engine in Historical Context

2.2 Brief Description of the VT Cognitive Engine and Its Operation

Our cognitive network research uses a distributed cognitive engine that can make any radio with electronically accessible inputs and outputs truly cognitive. Sketched in Fig. 3, it consists of three software subsystems that (1) model the environment, (2) develop, update, and maintain knowledge, and (3) develop new radio configurations through evolutionary techniques. The CSM (Cognitive System Module) is responsible for learning and the WSGA (Wireless System Genetic Algorithm) adapts the radio behavior based on what the CSM tells the WSGA to do. The CSM contains two main learning blocks: (1) the Evolver and (2) the Decision Maker. The latter takes feedback from the radio and allows the Evolver to update the knowledge base and then respond to and direct the system behavior. The third block in the diagram is the Resource Monitor, which is closely tied to the CSM and provides radio system information like available battery life, computational power, and memory resources. The final subsystem is the Modeling System, which is responsible for taking in external data such as the radio environment, user domain, security restrictions, and the regulatory policy domain and processing and modeling this information.

2.3 Relationship to Prior Results of Principal Investigator’s Work

The VT cognitive engine and our work in CR grew directly from NSF award 9987586, Testbed for High-Speed ‘End-to-End’ Communications in Support of Comprehensive Emergency Management, C.W. Bostian PI and S.F. Midkiff Co-PI. In that project we researched communications networks for disaster response applications. A key problem was to develop radios that can find short-lived paths of opportunity and compensate for shortcomings of these paths to deliver optimum performance. An important characteristic of these paths is a phenomenon called rough-surface scattering that takes short (nanosecond) radio pulses and smears them out in time, introducing “pulse stretching” and serious distortion. This had not previously been observed at the frequencies and time scales we use. To investigate these paths we subsequently built a new type of impulse channel sounder. Inspired by the needs of the public safety community and building upon the developments of the disaster response project, we conceived a CR that would make intelligent decisions based on the sounder output, and developed a cognitive engine that will indeed allow a radio to adapt intelligently to unanticipated situations. That cognitive engine is the basis of this proposal. Subsequently we built a proof-of-concept prototype that allows legacy Proxim Tsunami® 5 GHz radios to adapt to changing propagation and
interference conditions. This prototype is installed at SAIC’s Public Safety Integration Center near Washington, DC, and is available for demonstrations there.

This work under NSF award 9987586 is described in a U.S. patent application for cognitive radio in a network [Patent, 2004], a Ph.D. dissertation, [Rieser, 2004a], and several recent conference presentations and publications [Rondeau, 2004a], [Rieser, 2004b], [Rondeau, 2004b], [Bostian, 2004], [Bostian, 2002].

![Diagram of the Cognitive Engine](image)

**Figure 3 Structure of the Cognitive Engine**

### 2.4 Work in Progress

Currently we are building the complete software for full scale network tests of the cognitive engine with software defined radios, and this proposal is part of that effort. Research topics include (1) monitoring and modeling the user requirements with as little overhead as possible, (2) distinguishing co-channel interferers from ambient noise and propagation impairments, (3) securing proper adaptation by all members of a cognitive network, and (4) improving learning and adaptation to make maximum use of the intelligence available in a network of cognitive radios. We are also considering the related issues of software verification and FCC certification – how do you insure yourself and convince the FCC that a software defined cognitive radio cannot transmit illegally (i.e., with too much power, on the wrong frequency, etc.), even when hacked, damaged, or given an incorrect or illegal command by its operator? We have proposed to investigate these issues for public safety radios in a submission to the National Institutes of Justice (NIJ) and will coordinate that work with the project described in this proposal.

### 3. Research Tasks, Methods, and Procedures

#### 3.1 Completing the Cognitive Engine

##### 3.1.1 Overview of Major Tasks

Our cognitive engine is already well on the way to completion, and the WSGA block is up and running as part of the disaster response project described in Section 2.3. However, much still remains to be done, and a fully functional cognitive engine is an important outcome of this project. As shown in Figure 1, making the cognitive engine ready for the proposed experiments is our first goal, but we will update and enhance it throughout the life of the project. In this section we provide a broad overview; later sections discuss implementation details and research issues in more depth.
The set of tasks listed below describe the modules we must complete before realizing the full potential of the cognitive engine. Tasks A, B, and C will be done concurrently; subtasks are listed in chronological order as determined by relative importance to the overall project timeline.

Task A: Cognitive System Monitor (CSM) Completion

Subtask A.1 Knowledge Base: The Knowledge Base is a data base representing the models, system performance, and behavior; it is the most important piece of the CSM since everything else relies on it. Many input parameters from the radio hardware, regulatory requirements, and user domains and the WSGA output parameters require access to the Knowledge Base.

Subtask A.2 Decision Maker: The Decision Maker interacts with the Knowledge Base and decides how the WSGA should act and what data it should act upon.

Subtask A.3 Resource Monitor: The Resource Monitor takes information from the radio to determine the impact of the system settings. Resources are system parameters like computational power, memory, and battery life.

Subtask A.4 Evolver: The Evolver monitors both the output of the radio and the WSGA to compare the actual performance to the simulated performance. The Evolver rewards good performance, penalizes poor performance, and uses machine learning techniques to update and evolve the Knowledge Base.

Subtask A.5: Distributed Cognition: The final cognitive engine can be distributed among all radios on the network to provide enhanced learning and faster adaptation. A shared Knowledge Base can provide all radios with knowledge learned by any one machine, thereby reducing the need to redevelop this knowledge within each node. Other benefits come with distributing the computational responsibilities between the nodes or sharing capabilities some radios may not have (like modeling systems).

Task B: Radio Hardware and Interface

Subtask B.1: Radio environment modeling: The radio environment information includes both node data (channel frequency, transmitter power, modulation, etc.) and network data (spectrum occupancy, protocols, capacity, etc.), which is important for the CR to learn and adapt intelligently. Properly representing such knowledge requires a balance between speed and fidelity.

Subtask B.2: Hardware capability knowledge: The cognitive engine needs to be aware of the functional capabilities of the hardware radio platform (including both RF functions and DSP functions) to control its operation. We are developing a universal Application Programmable Interface (API) to serve as middleware between cognitive engine and various radio platforms.

Subtask B.3: Genetic Algorithm enhancements: The cognitive engine should analyze the overall environment information (including physical link constraints, user service demands, and security/policy regulations) and make a performance optimization decision that balances these (multiple) objectives and constraints. Although a regular multi-objective genetic algorithm (MOGA) is capable of solving this problem, it must be designed in both algorithm core and interface for robustness and convergence speed under various situations. Genetic algorithms can be distributed over multiple network nodes for a global system optimization.

Subtask B.4: User interface for CR function control and feedback
The cognitive engine provides different types of user interfaces between system operators and consumers (end users).
This project consists of the following three layers: the bioassay layer, the imaging layer, and the treatment layer. In the bioassay layer, a biopsy sample of a patient's cancer will be implanted into the mouse, while the leukocytes from a donor(s) will be labeled with fluorescent probes and transferred to the mouse. The bioassay layer serves as a test bench for the leukocytes infiltrating and cancer-killing activities. In the imaging layer, optical molecular imaging will be performed in vivo to select the most effective leukocytes to be used in the treatment layer. In the treatment layer, the selected leukocytes will be infused to the patient, and the therapeutic process will be monitored using the same imaging approach. Our overall idea on development of optical molecular imaging for application in the GIFT is illustrated in Figure D.1. This project is only the initial step in a larger research project, and provided that this step is successful, we envision a much more magnificent future for cancer treatment. This project will address several important clinical concerns in the GIFT and also exemplifies the transition of the optical molecular imaging technology from the bench top to the bedside.

Fig. D.1. Optical molecular imaging for granulocyte infusion therapy (GIFT). Since 2002, Dr. Ge Wang's group has been devoted to optical molecular imaging research based on bioluminescence and fluorescence. In 2007, Dr. Zheng Cui's group discovered the cancer-killing effect of the human granulocytes and proposed to transfuse granulocytes from cancer-resistant donors to cancer patients. Our primary synergic idea is to label the donor's leukocytes with fluorescent molecular probes, transfer the labeled cells into a mouse, and monitor the migration pattern of these cells to identify the best donor-recipient pair as well as image the patient similarly for GIFT optimization (Wang G, Cong WX, Shen HO, Cong A, Stiehl, J, Cui Z: Optical Leukocytes Imaging. Provisional Patent Application, 01/07/08).
SAMPLE PROJECT SUMMARY
Sheryl Ball, “WITS: A Wireless Interactive Teaching System”

The Wireless Interactive Teaching System (WITS) represents an exciting new approach to improving the quality of STEM (science, technology, engineering, and math) education for undergraduate students. WITS is an inexpensive, portable wireless system of handheld computers designed to enable and enhance active learning in economics classes using interactive exercises—classroom “experiments”. These experiments can be used to illustrate vividly many different concepts in economics. Decision and outcome data from the exercises are projected on a screen as needed during class and can be posted on a website for use in answering a related homework assignment. Based on our assessment data collected to date in economic principles we can provide potential adopters with evidence of its positive and meaningful impact on learning (Ball, Eckel, and Rojas, 2006).

We request funding to extend and apply the WITS system in three ways:

- New exercises and materials: we plan to create and test ten new modules for use in microeconomic theory and economics elective courses, as well as courses in related disciplines such as political science and public policy. We also plan to create student and instructor manuals for our previously developed principles exercises as well as for new exercises.
- New users: we plan to conduct training sessions for senior graduate students and targeted faculty at the PfA’s two very different universities, and assist them in developing and implementing interactive exercises in their classes. This training will also help us to prepare for future broad dissemination.
- New audiences: we plan two new sets of tests to see whether the learning gains we have seen with WITS generalize across other educational settings. The first is with students in microeconomic theory. The second is with minority and community college students.

Intellectual Merit: Many students have difficulty learning economics. Earlier research with the WITS system successfully demonstrated that allowing students to experience economic theory through economics experiments improved student performance, especially for groups that currently struggle most with the material—women and freshmen. The current proposal would allow us to extend WITS to microeconomic theory and courses that apply theory to real world problems. Success in intermediate micro course is an essential element of an undergraduate economics degree; applied courses teach students how to think about difficult problems using economics. The flexibility of the WITS system enhances the instructor’s ability to help students develop and test their own hypotheses, so that students learn economics by “doing science”.

Broader Impacts: We plan to conduct evaluations of the system in two new student populations: community college students and minority students (both at UTD and at an HBC.) These new pilot venues allow us to evaluate the potential uses of the system and its flexibility in meeting alternative educational needs and goals. Given the results of our initial pilot program, it is particularly important to test the system in environments where students have varying ethnicities, ability levels and learning styles.

Broader impacts of the research also include its impact on the recruitment of women students into economics, and building interdisciplinary and cross-institution bridges. A concern expressed at NSF and elsewhere is the low rate of participation of women and minorities in STEM disciplines, including economics. Our previous evaluations indicate that women and younger students benefit most from learning with the WITS system. If this mode of teaching helps women to succeed in undergraduate economics, then more of them may choose to attend graduate school, eventually increasing participation in the field. Furthermore, the WITS system can be adapted for teaching in other STEM disciplines, thus extending the learning gains beyond economics. Additional broader impacts involve building intellectual bridges between economics and other social sciences, as we implement the use of the system in other fields, and between two major research universities, an HBCU and community colleges. Finally, since both undergraduate and graduate students have been and will continue to be involved in the WITS project we are helping to achieve the NSF’s goal of integrating research and education.