EXPLORATION GRANT APPLICATION FORM 2013

Instructions:
Complete this form in its entirety and email it to Jenna Sadue (2210 Eastman Hall, jscms@rit.edu, 475-2078) no later than February 27, 2013. Please note to save and rename this document substituting your name (in place of “NAME”) in the file name.

Name: Luis Miguel Bazdresch.

Email: mxbiee@rit.edu Phone: 52105

Department/College: ECTET/CAST.

Department head name and e-mail: Michael Eastman, mgeiee@rit.edu

Faculty rank: (full-time lecturer, tenured, and tenure-track faculty only): Tenure-track.

Proposed project name: Platform for hands-on learning of wireless communications.

Total funds requested: (Exploration grants of $3,000-$5,000 will be considered): $4,100.00.

Include these statements under the appropriate heading beginning on page 4.

Statement of utility: (two pages maximum)
1. Provide an overview of the experiment/research you are proposing, including:
   • Its conceptual framework and objectives
   • An explanation of the teaching/learning problem(s) it is designed to address
   • An explanation of the significance of the experiment/research
2. The potential application to other courses, faculty, and/or disciplines. (Please note that special consideration will be given to proposals that have potential for application in more than one discipline.) Provide a brief description of pertinent research already conducted with applicable references.

Statement of creativity: (three paragraphs maximum)
Provide a brief description of how this is a novel approach, or a new application of an existing mode or model of teaching and learning, or represents an entirely new paradigm. (Please note that special consideration will be given to proposals that demonstrate a new use/application of a model, system, or technology already in use at RIT.)

Statement of efficacy: (two pages maximum)
Provide a brief description of the experiment/research design, methodology, and methods of data collection you will use to gauge efficacy.
EXPLORATION GRANT APPLICATION FORM 2013

Dissemination plan (Optional):
If applicable, provide details about the journal, conference, show, other external vehicle with strong potential for dissemination of your results. Include supporting documentation such as preliminary interest or acceptance with your application, if available. (Please note that special consideration will be given to proposals that have a defined opportunity for external dissemination, such as an academic journal or professional conference.)

Budget:
Provide information on how the funds will be used, modifying the following categories as needed to match your project. (Please note that the budget total must match the “Total funds requested” amount on page one of the application.)

<table>
<thead>
<tr>
<th>Budget item</th>
<th>Amount requested</th>
<th>Amount committed from other sources</th>
<th>Brief statement of explanation/justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel (including course release, consulting support, etc.)</td>
<td>$800.00</td>
<td></td>
<td>40 hours of student work at $20.00/hour. Students will validate and improve the material before it is put to wider use.</td>
</tr>
<tr>
<td>Equipment</td>
<td>$1,800.00</td>
<td>$1,500.00</td>
<td>Two complete radio sets. Two development computers.</td>
</tr>
<tr>
<td>Licenses (i.e., software)</td>
<td></td>
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<td>Travel</td>
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<td>Other Resources (specify)</td>
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<td><strong>Total</strong></td>
<td><strong>$4,100.00</strong></td>
<td><strong>$</strong></td>
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</tbody>
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Proposed timeline:
Provide a high-level timeline for your investigation. (see the Dissemination Agreement section of this application for more details)

<table>
<thead>
<tr>
<th>Task</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment/study design complete</td>
<td>May 30th, 2013</td>
</tr>
<tr>
<td>Preliminary findings complete</td>
<td>December 20th, 2013</td>
</tr>
<tr>
<td>Summary of final findings complete</td>
<td>Week 1, Spring semester, 2014</td>
</tr>
<tr>
<td>Final budget accounting complete</td>
<td>Week 1, Spring semester, 2014</td>
</tr>
<tr>
<td>Faculty Teaching &amp; Learning Commons entry complete (development facilitated by the ILI Teaching &amp; Learning Studio)</td>
<td>End of Spring semester, 2014</td>
</tr>
<tr>
<td>Participation in faculty panel event complete (event to be planned and facilitated by the ILI Teaching &amp; Learning Studio)</td>
<td>By the end of the Spring Semester, 2014</td>
</tr>
</tbody>
</table>

Please note that the timeframe for milestone completion must align with the PLIG timeline.
EXPLORATION GRANT APPLICATION FORM 2013

Dissemination agreement:

By completing this grant application, I agree to provide the materials described here, in support of disseminating what is learned from this project to other faculty at RIT.

I also agree to return all/a portion of the funds that I receive for this project to RIT if I fail to complete or provide the materials described here.

- Project plan (including roles and responsibilities, milestone dates, and pertinent project details)
- Overview of preliminary findings (may include experiment/study design, lessons learned, initial data collection, and/or literature review summary)
- Research findings summary (including data collection, lessons learned, implications for further study, and which may be in the form of an article abstract, conference presentation outline, or short report)
- Faculty Teaching & Learning Commons entry (excerpts from research findings summary, the development of which is facilitated by the ILI Teaching & Learning Studio)
- Participation in faculty panel event (presentation of a brief summary of project and lessons learned and response to faculty questions. Event is planned and facilitated by the ILI Teaching & Learning Studio)
- Final budget accounting (reconciliation of budget provided with your application and the actual project expenses)

By submitting this application through my RIT email account, I accept this agreement.
Statement of utility: (two pages maximum)

1. Provide an overview of the experiment/research you are proposing, including:
   - Its conceptual framework and objectives
   - An explanation of the teaching/learning problem(s) it is designed to address
   - An explanation of the significance of the experiment/research

2. The potential application to other courses, faculty, and/or disciplines. (Please note that special consideration will be given to proposals that have potential for application in more than one discipline.)

Provide a brief description of pertinent research already conducted with applicable references.

I present a proposal for teaching digital and wireless communications, in engineering technology, at undergraduate and graduate levels.

Teaching digital and wireless communications has traditionally been a hard problem. The reasons can be classified as follows: theoretical complexity, large problem space, and difficulty in setting up experiments.

Before one is able to glean some understanding of the techniques involved in the digital, wireless transmission of information, at least some basic knowledge of a large number of fields is required: calculus, signals and linear systems, linear algebra and probability as a minimum. This means the student has to slowly and with difficulty build a body of knowledge before seeing a practical application.

There are a large number of problems to be solved in a communications system: formal, information-theoretic analysis; radio-frequency electronic design; electromagnetic wave propagation; digital signal processing and algorithm design; networking protocols, among others. Which to include in the curriculum, and how to teach them, is a difficult problem for curriculum designers.

Finally, similar problems arise for the experimentalist or the hands-on student: even with all the background in place, before actual communication takes place one must set up an information source, generate band-pass and high-frequency signals, and convert them to electromagnetic waves. The process repeats, in reverse, at the receiver. Setting this up is not a trivial matter and often requires complex procedures.

How, then, to teach (and learn) this subject? Several approaches have been adopted in the past. Three common ones are:

- The theoretical approach. Just forgo experimentation and focus on the theory. Most textbooks on this subject take this approach.
- The simulation approach. Simulate the communications systems using a computer and a numerical computation tool (often Matlab).
- The experimental black-box approach. Acquire equipment that solves a part (often large) of the problem; the student solves the remaining part.

These approaches, while valuable and serviceable so far, are not satisfactory. In an engineering technology program such as RIT's, the purely theoretical approach does not serve our students' best interests. Numerical simulation, while a definite step forward, remains frustrating because no actual communication is produced, and problems that arise in practice are ignored. The black-box approach teaches valuable skills (students need to know how to design products using off-the-shelf devices), but doesn't provide much insight into the actual communications problems that the devices are solving or, indeed, what techniques they use to solve them and what engineering decisions they make.
**EXPLORATION GRANT APPLICATION FORM 2013**

Statement of utility continued:

My proposal intends to address the shortcomings of the existing learning methods as described above. The key piece in the proposed method is a device known as a software-defined radio. A software defined radio (SDR) takes advantage of the capabilities of current digital hardware (CPUs and DSPs) to reduce the radio-frequency and analog portions of a radio to the minimum. Essentially, in a SDR, signals are defined and processed in the digital domain. The analog and RF portions of the device are reduced to the bare essentials, namely, to convert signals to and from the digital domain to the radio-frequency domain. Together with open interfaces, open hardware, and robust libraries, this has tremendous potential advantages for learning. Some of the main ones are:

- Since they are software-defined, a single piece of hardware can play the role of any radio: from a simple AM radio, to sophisticated multimedia communications systems. All one has to do is to program the appropriate digital processing algorithms.
- They can assume any role from white-box to black-box. A student can use powerful open-source libraries to design a complete system, or she can design it from scratch, or take some functions from the libraries and design or modify others.
- They can be used for education at any level of the communications stack, from the physical layer to the MAC and data link layers, and above. This means students can use an SDR to implement and test new protocols, even atop of existing ones (such as TCP/IP).
- The development tools may also operate in simulation mode, where no actual signals are transmitted. Students may hone their design skills in this mode, and jump to actual signal transmission when they’re ready, without having to change tools or development environments.
- Since their operation crosses many disciplinary boundaries, SDRs can be used in a number of courses. In some of them they can be core to the learning experience, while in others they may provide motivating examples and case studies.
  - Digital design, where students can learn from and modify the hardware base-band processors.
  - Signals and Systems, where students can use them as universal signal generators and signal acquisition systems.
  - Digital Signal Processing, which is the theory behind most communications algorithms.
  - Any telecommunications course with a laboratory or experimental component.
  - Programming, where different algorithms (and even languages) may be tested and evaluated on real-world situations.

Even then, software-defined radios are complex systems that require a certain degree of knowledge and skill from their users. In any particular course, the instructor must be careful to expose students to the software and hardware tools in a way that is conducive to learning. If the student gets frustrated because of the tool’s complexity, then the learning objectives are in peril.

The main objective of this proposal is to develop learning materials using software-defined radios in a specific course, Advanced Wireless Communications, which is currently being developed for the Master’s program in Telecommunications Engineering Technology. I propose to acquire two radios, develop the material, and hire two students to use the material as if in a course, in order to obtain feedback and make all necessary adjustments and corrections. At the end, students will be evaluated to verify what they learned. If the project is successful at this stage, I will start looking for funding to continue the project in its implementation phase.

I have already done some efforts in the area of hands-on teaching of communications system. The paper cited below is available upon request. The proposal presented here is a continuation of this work.

In a way, this proposal is not really novel. Hands-on learning is a well-known technique used to complement traditional lectures, and it is practiced every day at RIT’s laboratories. What is new in the use of software-defined radios as a learning tool is:

- The radios’ flexibility and modularity offer a solution to the complexity involved in teaching this subject, at both undergraduate and graduate levels.
- The use of these radios allows students to put into practice skills acquired in digital design, signals and systems, networking, analog electronics, and programming courses.
- Because of their open nature, students and instructors have full visibility into, and control of, every aspect of the radio’s operation.
- Students can use these radios to explore almost every conceivable digital and wireless communications application, including those of their own design.

These opportunities (and challenges) open entire new fields of research and innovation in telecommunications teaching and learning. As far as I know, this has not been attempted at RIT before.

We wouldn’t be the first to try this approach, though. A few other universities have already taken steps in this direction. For example, the Wireless@VirginiaTech center, one of the largest university research groups in wireless in the US, makes extensive use of software-defined radios (see [http://wireless.vt.edu](http://wireless.vt.edu)) for research and teaching. Another example is Notre Dame’s Radioware project ([http://radioware.nd.edu](http://radioware.nd.edu)). I consider this previous work an indication that my proposal is feasible and with high probability of success.

With adequate material and proper planning, a laboratory-based course with software-defined radio is an excellent opportunity to put into practice a flipped classroom approach. Students would take a first look at the theory by reading, watching videos, and/or doing practice problems. Then, in the lab, they would use the radios and associated software to put theory into practice. In fact, by choosing problems carefully, students would be motivated to go back to the theory in order better to understand the practical problems they will face. This iterative back-and-forth promotes deeper and more meaningful learning.
The efficacy of this proposal hinges on the students being exposed to precisely the right amount of system complexity, in order to maximize their learning and minimize unnecessary frustration. The students’ experimental work with software-defined radios needs to be carefully tailored to a specific course’s intended learning outcomes, while also excercising and reinforcing pre-requisite skills in areas such as programming and linear systems.

We propose to focus first on one course, Advanced Wireless Communications, at the Masters in Telecommunications Engineering Technology program, which is in development at the time. This is the most advanced course on the subject taught at the ECTET department. In a way, this makes our task easier, since students can be expected to be more knowledgeable and resourceful.

In this first, exploration phase, the main objective is to develop learning material, including tutorials and lab assignments. These will be reviewed and put in practice by two students. Their feedback will serve to adjust the materials’ clarity and efficacy. Likewise, the students themselves will be evaluated to insure that, in performing the planned activities, they learned what was intended.

More precisely, I will set up the radios and have preliminary tutorials and lab assignments, tested by me, on May 30th. This material will have specific learning objectives. During the Fall semester, two hired student assistants from the Masters program will use the material, evaluate it and provide feedback. With help from the students, I will make the necessary adjustments to the material. At the end of the semester, I will evaluate the students’ learning to determine whether the objectives were met.
EXPLORATION GRANT APPLICATION FORM 2013

Statement of efficacy continued:
**EXPLORATION GRANT APPLICATION FORM 2013**

**Dissemination plan (Optional):**

If applicable, provide details about the journal, conference, show, other external vehicle with strong potential for dissemination of your results. Include supporting documentation such as preliminary interest or acceptance with your application, if available. *(Please note that special consideration will be given to proposals that have a defined opportunity for external dissemination, such as an academic journal or professional conference.)*

One natural outlet for publishing the results of this project is the IEEE Signal Processing Education Workshop (where I have published before). This workshop includes topics such as novel laboratory, computer-based, and distance teaching methods, and signal processing across the engineering curriculum. A similar venue is the GNU Radio Conference. The IEEE Frontiers in Education Conference has published papers on this subject before (for example, “Software defined radio in the electrical and computer engineering curriculum”, by Nagurney et al, FIE 2009).