

## A proposal to the ACS Technology Fellows Program.

This proposal outlines a plan to implement VPython illustrations in introductory astronomy.

### 1. Background: Rationale for the Overall Project.

Astronomy students are typically liberal arts majors with minimal background in math and science. They need powerful tools to visualize the complex systems and interactions that are routinely discussed in an introductory astronomy course. Computer simulations provide the visualization opportunities students need to fully comprehend the course material. Simulations also provide a means for students to interact with complex systems and perform simple but instructive experiments. As a result, students develop a much deeper understanding of complex phenomena than they would if taught with traditional techniques.

A central aspect of modern science is the use of models to analyze nature. Models allow scientists to explore the complex relationships between a variety of physical parameters. Since the primary goal of our introductory astronomy course at Birmingham-Southern is to teach students science as method—as opposed to a mere collection of facts—it is imperative that we provide them with a good understanding of how models are developed and used in modern astronomy. Computer animations give students the opportunity to make mental connections that are not possible with static figures from the textbook or the classroom blackboard. Since the animation is the model, animations provide faculty with an opportunity to teach students how a model functions in a scientific program.

Python is a fully object-oriented computer language. VPython is a set of library routines written in the Python programming language that allow one to create real-time 3D animations. The animations are simple, powerful, and portable. They are easy to create and modify for both students and professors. Little or no programming experience is necessary. VPython animations are currently in use in several introductory physics courses across the nation, and are a main part of the new physics textbook by Chabay and Sherwood. VPython simulations are run locally on any Windows-based PC. Once downloaded, you do not need network access to run the simulations.

### 2. Description: Part of the Project to be Done Under ACS Funding.

ACS funding will support six steps to bring this project to completion:

1. Outline of curricular materials—what simulations are needed for an introductory astronomy course? There are several excellent introductory astronomy textbooks on the market. Of particular note are the texts by Zeilik; Chaisson and McMillan; Arny, Bennet, Donahue, Schneider, and Voit; Comins and Kaufmann; and Fix. We currently use Zeilik at BSC. There is strong overlap of material among the different texts, but each has its unique approach. The outline of curricular materials would involve a thorough survey of these texts to determine which figures, concepts, and models could be best explained through a 3-D computer animation. This list will constitute the group of individual programs needed to code each animation.
2. Development of the VPython source code. Each individual animation will be coded in a separate, well-documented file to allow for easy analysis and modification by students and professors. Commonly used subroutines will be coded in general-purpose library files that are shared by the individual animations.
3. Debugging the VPython source code. Of course, not every animation will run as expected on the first try. Debugging code is an unfortunate but absolutely necessary part of any development project, and we must allow for it when constructing the time-budget for this project.
4. Development of support documentation. Two documents will accompany the source code.
  - The first is a Programmer's Guide for faculty and students who wish to create new simulations or modify existing ones. It will provide a description of each animation and the programming logic that underlies it, including pseudo code and any numerical accuracy issues one must consider when attempting to modify or improve a given program. It will also explain the naming convention for variables, list the subroutines available in the general-purpose libraries and the number and type of arguments expected by each subroutine. I will make the explicit assumption that users of the Programmer's Guide are already familiar with the basic astronomical and physical principles that underlie a given animation—this is likely to be the case—in order to reduce the amount of text.
  - The second document will be a User's Guide primarily for students. This document will explain each animation in detail with emphasis on the astronomical and physical principles that underlie it. In particular, it will focus on any special instructions the user must be aware of to get the animation to run correctly, such as necessary input data. It will also provide a list of suggested exercises or experiments for each animation. (Faculty will find these useful for constructing homework assignments, laboratory exercises, and pre-class reading quizzes.)
5. Field-testing of selected simulations and documentation with volunteer students and faculty. To make certain each animation is running correctly,

and especially to make sure each animation and its supporting documentation in the Users' Guide achieve the appropriate level of efficacy, it will be necessary to field test the animations with volunteer faculty and students. I interview each volunteer before and after exposure to a set of animations to gauge how effective the animations were at providing instruction and/or enhancing student knowledge. I will also prepare a survey for volunteers to fill out after they have been exposed to the animations. The results of this survey will help me determine if the animations and supporting documentation are easy to use and effective at teaching basic astronomical concepts.

6. Bundle materials for online distribution. The final product of this project will be made available free of charge on the Internet. Users who download the source code will be prohibited from deleting any comment statements from the source code that identify me as the original author and the ACS as the source for the grant money that supported the project. Otherwise, users will be free to modify and redistribute the code as they wish. The individual animations and library files will be bundled as plain-text documents so that users can edit them with any text-editor. Supporting documentation will be made available in PDF format.

### 3. Timeline: Deliverables/Milestones for ACS Funded Part of the Project.

Work on the project begins on 1 June 2005. The project will be finished on 30 August 2005. Target dates:

1. Outline of curricular materials completed on 7 June 2005.
2. Source code and User's Guide developed in parallel. Finished by 15 July 2005.
3. Field testing begins 16 July 2005 and finishes 30 July 2005.
4. Debugging and refinement from 1 August 2005 to 15 August 2005.
5. Develop Programmer's Guide from 15 August 2005 to 25 August 2005.
6. Bundle materials for online delivery. Finished by 30 August 2005.

### 4. Technology: Technical Requirements for the Project.

VPython animations are developed and run on Windows-based PCs. To create the animations, I need the following:

- A Windows-based PC.
- Python compiler, VPython library files, and an IDLE. (All of these are available on the Internet and are free.)
- MS-Word and Adobe Acrobat Professional.

- Internet access.

I already have all of these. No additional technology is needed to create the animations. To run the animations in class, one needs a classroom equipment with a Windows-PC and a video projector.

5. Other Support: Institutional and/or Outside Support for the Project.

No funding beyond that provided by the ACS is needed. The work will proceed on machines and software owned by Birmingham-Southern College.

6. Learning Outcomes: How the Project Will Enhance Teaching/Learning.

VPython animations enhance student learning in three important ways:

0. They provide visualization opportunities of complex systems and interactions in a way that cannot be achieved either with static textbook figures or two-dimensional animations such as Physlets.
1. They provide opportunities for “hands on” access to complex phenomena. Students can view systems from different angles or zoom in and out. They can modify parameters and perform simple experiments to explore physical relationships.
2. The process of coding new animations leads to a deeper understanding of the source material for both students and faculty. This project will encourage users to modify source as needed or to develop new animations.

VPython animations enhance teaching in the following ways:

3. VPython animations shift attention from the teacher and material to the student. With static images projected onto a screen or drawn on a blackboard, the professor must expend considerable effort “animating” the figure by explaining how different parts of the figure would move if the figure were animated. Most students become disconnected because they find it impossible to visualize motion in a static figure. With animations, students remained intellectually engaged. The professor can move among the students and focus on how the students are responding to the animation. With appropriate feedback, for example through ConcepTests, the professor can correct misconceptions related to the topic under discussion. This has a profoundly positive impact on classroom instruction.
4. In addition to serving as a basis for Peer Instruction questions such as ConcepTests, VPython animations can be used in several other active-learning strategies. For example, an animation can form the basis of a pre-class reading quiz, or an in-class group-work exercise. They can reference

in homework problems or in computer-based laboratory exercises. In the latter case animations can be easily designed that allow students to modify various parameters and conduct desktop experiments. This greatly enhances student learning.

5. As mentioned above, the very process of coding the animations leads to a deeper understanding of the source material for both students and faculty. It is not unreasonable to develop laboratory or homework exercises that require the creation of new animations.

## 7. Curriculum: How the Project Will be Integrated into the Curriculum.

There are several options for integrating this material into an existing course plan. They are not mutually exclusive, and all have been touched upon in the above discussion.

0. In-class group-work activities. This will work best if student groups have access to a personal computer or laptop.
1. In-class teacher-led demonstrations. The teacher can engage the class in questions about how different parameters affect the overall system. Parameters can be changed on the fly in response to student input. Students can see the effect of changing a given parameter on the behavior of the system.
2. Computer-based labs. Here, students can be given direct access to the animations. Students can conduct desktop experiments by modifying input parameters and examining the results.
3. Homework problems.
4. Pre-class reading quizzes.
5. Peer-instruction questions such as ConcepTests.

Note that (4) and (5) require reliable internet distribution and student access to networked computers.

## 8. Assessment: How the Project Will Be Evaluated.

Animations will be field tested with volunteer students and faculty. Each volunteer will be asked to participate in a brief interview that centers on a particular topic in introductory astronomy. They will then be exposed to animation related to that topic. After completing several exercises, they will be interviewed again to determine if the animation was successful in clearing up misconceptions and/or establishing a good conceptual understanding of the topic. A survey will be developed that will allow volunteers to comment on the ease of use of the animations.

9. Collaboration and Dissemination: How the Project Will Be Shared with ACS Colleagues.

Python and VPython software is available on the Internet for free. The animations and supporting documentation will be bundled for download either from my personal web page from the college web site.

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