CONCEPTS FOR PROJECT GALAXY

A. R. Klumpp[*], M. Smithwick[†] D. E. Eyles[‡], J. F. Jordan[*]

Project Galaxy will build an astronautical and astronomical simulator that will enable simulator pilots to explore all major celestial bodies in the solar system, and an increasing number of objects in the galaxy. Project Galaxy's purposes are (1) to aid in teaching astronomy, astrodynamics, and astrophysics to students in public schools and universities, (2) to aid in planning space missions by enabling participants to view and analyze the consequences of proposed and actual mission designs on the images and other measurements that will be obtained, and (3) to enable space buffs to learn about the solar system and the galaxy from information acquired from space exploration missions and from telescopic, infrared, ultraviolet, and other types of remote sensing.

Using the Galaxy Simulator, anyone with a personal computer can fly along with any existing mission trajectory to destinations in the solar system and, when interstellar missions are flown, to destinations in the galaxy. Simulator pilots can free fly, without the help of existing trajectories, to any modeled planet, satellite, asteroid, comet, solar system, black hole, or quasar in order to see how the modeled object truly appears, moves, and behaves. Users can extend simulator capabilities by replacing modules.

The plan is to develop the Galaxy Simulator in phases spanning many years. In the first phase, capabilities of existing planetarium programs will be extended to enable pilots to fly along on existing missions while controlling the field of view presented on the monitor by means of a joy stick. Free flying will be developed next; the joy stick will control flight path as well as attitude, while the simulation either abides by or disregards the laws of physics, at the option of the pilot. Landing on the moon using Apollo lunar descent guidance, and landing on other celestial bodies will be developed next. Ultimately, all major celestial bodies in our solar system will be accurately rendered, and an increasing number of galactic objects, such as black holes and quasars, will be modeled and displayed.

Each version is expected to be developed using software and human resources at JPL. Contacts with astrodynamics staff of numerous universities suggest that thesis students may also contribute by developing software. Students in local public schools will be recruited for testing each version prior to public release.

Project Galaxy is conceived as a not-for-profit repository of scientific models of the solar system and galaxy in a form that provides easy public access. The project is expected to draw from contributions of many individuals and organizations for as long as knowledge of our celestial environment continues to be acquired.

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[*] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109.

[†] Self-employed software engineer for over six years, as author and producer of the award winning astronomy program Distant Suns.

[‡] C. S. Draper Laboratory, 555 Technology Square Cambridge, Massachusetts 02139.

Objectives

The primary objective is to build a simulator enabling anyone with a personal computer to explore all major celestial bodies in the solar system and all modeled objects in the galaxy. A secondary objective is to provide a repository for scientific models of natural and man-made objects anywhere in the galaxy.

Benefits

The Galaxy Simulator is intended to provide benefits for education, mission planning, and outreach.

For education, the Galaxy Simulator will aid high school students to learn about the planets moons, asteroids, and comets. They can see not only how these celestial bodies look, but also how they move. The simulator will aid college and university students to learn astrodynamics and astrophysics, and how missions are flown.

For mission planning, mission investigators can use the simulator to preview observations and measurements that will result from hypothetical missions, and to feed back these results in changing the missions in ways that improve the results.

For outreach, the project provides a means for enabling the public to share in the results of NASA missions and other scientific investigations in ways that appeal to human needs for adventure and exploration. Using the simulator will be fun as well as a learning experience.

Capabilities

The Galaxy Simulator enables its pilot to view celestial bodies from the vantage point of a spacecraft that can fly anywhere in the galaxy. Celestial bodies are accurately modeled and rendered, so that each image appears to be a photograph taken by a real spacecraft at the same location. Rendering is dynamic, on demand of the simulation, so that there are no limits on the location or field of view of the spacecraft or on the number of images that can be displayed. Dynamic rendering makes it possible for the modeled spacecraft to travel anywhere in three-dimensional space, causing an infinite number of images to be generated. Dynamic rendering contrasts with the much more common static rendering, which is limited to a one-dimensional path that provides a finite set of images.

The pilot selects one of three flight modes:

- In the *mission* mode, the modeled spacecraft is attached to a predefined trajectory such as one already flown or planned. Voyager, Galileo, and Cassini trajectories are examples. The trajectory can also be one generated by the user. In the mission mode, the pilot controls the pace, making it possible to travel from

Earth to Jupiter, for example, in a few seconds, and then move as slowly as desired while viewing Jupiter or one of its moons. For mission planning, the spacecraft can be stopped at any position, while the pilot maneuvers the spacecraft in attitude to find the best pointing direction for a camera or other instrument.

- In the *free-flight-abide* mode, the pilot flies the spacecraft using a joy stick and the keyboard to control attitude and thrust while abiding by the laws of physics. This mode is useful for simulating landings on foreign bodies, while training the pilot and acquiring statistics on fuel consumption. The mode can also be used for playing games in which the competitors compare their abilities to fly from an Apollo lunar orbit to touchdown, for example, without running out of fuel or crashing. Apollo astronauts were typically unable to do this, making an automatic landing system essential. The mode can also be used for flying the Apollo lunar descent guidance, or guidance algorithms devised by the user.

- In the *free-flight-disregard* mode, the pilot flies the spacecraft using a joy stick and the keyboard while selectively disregarding the laws of physics. In this mode, the pilot can set the destination to be a distant sun, and travel thru the galaxy at many times the light speed. In this mode, relativistic foreshortening can be turned on, in order to observe the effects of relativistic speeds on the shape of constellations.

USER-SUPPLIED EXTENSIONS

The Galaxy Simulator consists of numerous modules with clearly defined interfaces so that any module can be replaced by a later version or a version more suited to the individual needs of the user.

By replacing modules, the user can:

- Supplement the ensemble of mission trajectories with any number of custom trajectories to any location or celestial body supplied with the simulator or by the user.

- Supplement the ensemble of celestial body models with custom bodies, including their ephemerides and surface, and atmospheric models.

- Replace hardware models with models of advanced or custom hardware. Hardware models included and subject to replacement are spacecraft translational and rotational dynamics, thrusters for translation and attitude control, reaction wheels, and others.

- Replace navigation, guidance, and control algorithms with advanced or custom algorithms. Algorithms included and subject to replacement are Apollo lunar descent guidance, Viking landing guidance, and others.

Model Fidelity Goals

Models will be developed by numerous organizations and individuals over many years. Mission trajectories and celestial-body orbits are already modeled to high accuracy, enabling models of such accuracy to be incorporated in the Galaxy Simulator at an early date, possibly in a year. Other models, such as celestial-body surfaces, need to be developed. Dynamic rendering of these surfaces at speeds that are satisfactory for viewing on home computers is a difficult problem that remains to be solved. Long term goals for model fidelity are:

- Trajectories are to be modeled to the accuracy of those supplied by JPL and other mission providers.
- Planetary motions are to be modeled to the accuracy of JPL ephemerides.
- Satellite motions are be modeled to the accuracy of JPL ephemerides, or, to the accuracy with which JPL ephemerides can be extended by numerical integration.
- Celestial-body surfaces are to be modeled to the accuracy known at the time the models are written. For landings, surface models will be extrapolated by fractal techniques to the resolution required for realistic, though artificial, rendering.

Project Evolution

The project is expected to evolve over the course of decades. In the long term, software will comprise tens of gigabytes of ephemerides; trajectories; physical models of celestial bodies and their surfaces; readers for ephemerides, trajectories, and models; navigation, guidance, and control algorithms; and rendering and display drivers. Long-term human resources may be hundreds of work years or more, depending on the initiative of contributors and on concepts for the simulator that are adopted as it evolves.

In the Short term, the goal is to define a modular structure for the simulator that enables long-term evolutionary growth while introducing basic capabilities within the first year. Several work years are foreseen.

Resources Management

Development of the Galaxy Simulator is being initiated by a small number of individuals, who are either staff members of the Jet Propulsion Laboratory or prospective outside collaborators. In order for the simulator to achieve its long-term goals, it will be necessary to increase JPL involvement, and to recruit other organizations and individuals who will contribute time and software models. The simulator has been discussed with astrodynamics specialists from numerous universities and technical institutes, and the possibility of engaging thesis students to contribute the simulator has been enthusiastically received. In the long term, the simulator is planned to be a repository of scientifically accurate models from many sources around the globe.

We intend to make a portion of the simulator freely available on a publicly accessible site, such at the JPL web site. The portion available via the web is limited by the web's data-handling capabilities: It is currently infeasible to transmit tens of gigabytes of data.

We intend to make the entire simulator available to the public via CDs and DVDs, following the model already established by other NASA projects.