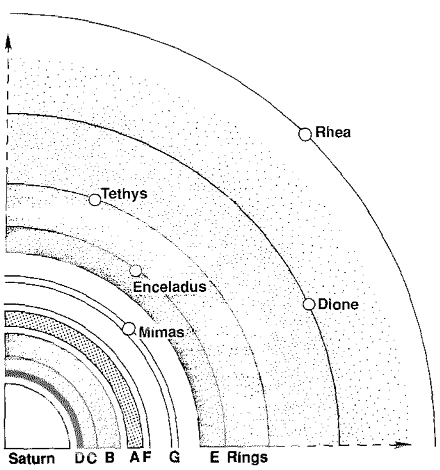
SURFboard

Saturn, its rings, and inner moons. (Not to scale.) *The E ring starts near Mimas's orbit, extends out past Enceladus and Tethys, and trails off somewhere near Rhea or Dione.*



"Enceladus is very bizarre. It's the brightest reflective body in the Solar System. It's ten times brighter than our moon per unit area."

Moonlighting

The Summer Undergraduate Research Fellowship (SURF) program turns ten years old this summer. The program has mushroomed—from 18 students the first year to 176 students this year. SURFing has, in fact, become a prominent feature of undergraduate life. SURF is attracting notice off-campus, too; last year two SURFers won awards at the First Annual National Conference on Undergraduate Research. This issue of E&S *inaugurates SURFboard, a regular feature devoted to undergraduate research.*

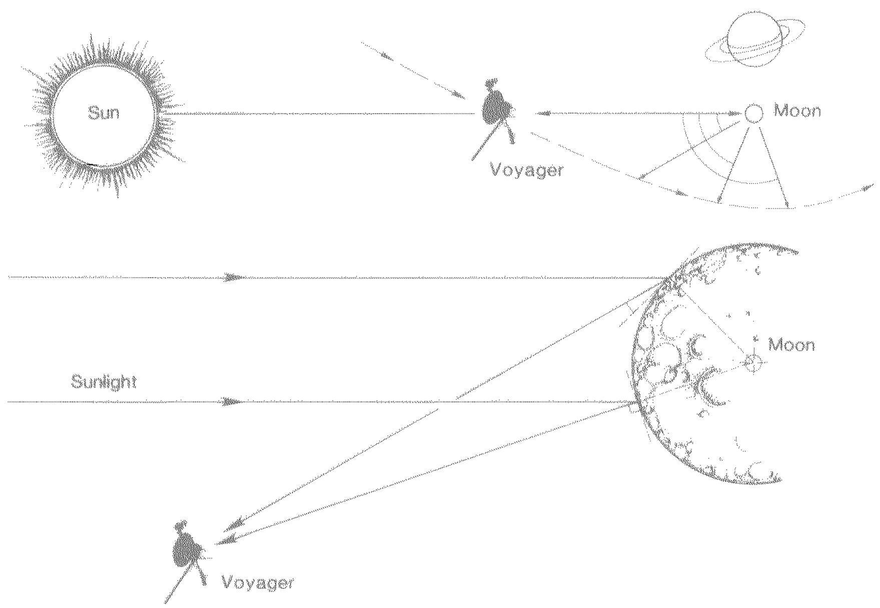
Although Voyager 2 photographed Saturn's moons in late August 1981, and nobody's been back since, there's a lot still to be learned from the images. They show features as small as 50 to 100 km across, in living (or computer-enhanced) color. They can be processed to provide additional information, too. For example, the brightness of each point in the image tells about the albedo, or degree to which light is reflected by the corresponding point on the surface.

Experience with Jupiter's moons had shown that the albedo of an icy surface relates to its age. The relation holds not only for water ice, but for ammonia, methane, and mixed ices (called clathrates) as well. New ice is very bright but gradually loses its luster under the gentle rain of interplanetary dust. Thus, adjoining topographies can have markedly different albedos, depending on their ages. A less gentle rain of meteors provides a more reliable clock: the more densely cratered a surface, the older it is. Again, newer craters tend to be brighter than their surroundings, because the impact exposes bright, fresh ice beneath the discolored surface.

But Saturn's icy moons didn't seem to work the same way. Although each moon had a different average albedo, local variations were less dramatic. Perhaps if a moon's albedo map could be superimposed on its topographic map, subtle correlations between surface features and local albedo would emerge.

Making an albedo map is not quite that simple, however. The amount of light reflected to Voyager depends not only on a region's intrinsic albedo, but on the angles between Voyager, the sun, and the reflecting surface. Reflectivity peaks when the sun, Voyager, and the planetary moon are all in a line, with the sun shining over Voyager's shoulder, as it were. As Voyager flies by, the angles keep changing, causing the apparent albedo to change as well. Furthermore, for any given arrangement of sun, Voyager, and moon, a point directly "below" Voyager, where the moon's surface is perpendicular to the camera, will appear brighter than an equally reflective point at the limb where the surface is almost parallel with Voyager's camera, and hence reflects less light back to it.

Bruce Rossiter, now a senior in Engineering and Applied Science, tackled the problem as a SURF (Summer Undergraduate Research



Top: Reflectivity peaks when the sun, Voyager, and Saturn's moon are all in line. As Voyager flies by, the angles change. Bottom: A point directly "below" Voyager, where the surface is perpendicular to the camera, seems brighter than a point on the limb, where the surface is almost parallel to the camera.

Fellowship) project last summer, working with Bonnie Buratti, a Member of the Technical Staff at the Jet Propulsion Laboratory. Armed with the laws of trigonometry and IDL—a high-level graphics programming language—he wrote a set of programs to transform observed brightness into intrinsic albedo.

Each Voyager image is a matrix of 160,000 picture elements, or pixels, laid out in an 800 × 800 square. The program adjusts each pixel's brightness to what it would be if the corresponding surface point were in the position of maximum reflectivity, using data from Voyager's navigational records to determine the three objects' relative positions, and using information about each moon's size and shape to determine surface orientations. The computer then converts brightness to albedo by calculating the amount of light reflected as a percentage of the solar flux—the amount of sunlight falling on that point. Finally, the system plots the albedos, either as contour maps or as histograms.

"People have written similar programs before," says Buratti, "but Bruce's is much easier to use, and it didn't cost millions of dollars or take years to develop, either."

Work has continued over the past year, and Buratti and her colleagues have produced albedo maps for five of Saturn's icy moons: Mimas, Enceladus, Tethys, Dione, and Rhea.

"Enceladus is very bizarre," Buratti says. "It's the brightest reflective body in the Solar System. It's so bright that it basically reflects everything. Earth's full moon reflects about ten percent of the visible light that hits it, so Enceladus is ten times brighter than our moon per unit area." One might think that Enceladus's whole surface is very new, but it isn't: some areas are quite smooth, and probably new, but other areas are as cratered as the highlands of our moon, and presumably as old. Yet they have the same albedo. "It's like something was painted on," Buratti says.

That's a pretty good indication that the shiny stuff was deposited from an external source—an exogenic process. If it came from within (an endogenic process), it would tend to vary with the terrain: pooling in lowlands if it had oozed out like flowing lava, or leaving streaks pointing back to its source if it had been blown out by a geyser or volcano.

Saturn's E ring, a tenuous ring of unknown composition, seems to be the most likely source. The E ring starts near Mimas's orbit, extends out past Enceladus and Tethys, and trails off into nothingness somewhere near Rhea or Dione. When Rossiter and Buratti compared albedo variations with position, they found the interior satellites—Mimas, Enceladus, and Tethys—to be very bland, with little albedo variation and no correlations to surface features. Farther out, Dione and Rhea have increasingly variable albedos with better correlation to surface features. "There are different levels of things we'd like to show," according to Buratti. "And the first is that there's no correlation. So Bruce got the contour plots up and running, and quantified the albedo changes. Now we're ready to show that the albedo variation is exogenic, simply because it doesn't correlate with the geologic units. It looks like a coating."□—*DS*