a distribution network connecting the elements can be created from conventional technologies such as lightweight, flexible coaxial cable and a surface mount power divider, or preferably, from elements formed from conductive fabrics. Conventional technologies may be stitched onto a supporting flexible membrane or contained within pockets that are stitched onto a flexible membrane. Components created from conductive fabrics may be attached by stitching conductive strips to a nonconductive membrane, embroidering conductive threads into a nonconductive membrane, or weaving predetermined patterns directly into the membrane.

The deployable antenna may comprise multiple types of antenna elements. For example, thin profile antenna elements above a ground plane, both attached to the supporting flexible membrane, can be used to create a unidirectional boresight radiation pattern. Or, antenna elements without a ground plane, such as bow-tie dipoles, can be attached to the membrane to create a bidirectional array such as that shown in the figure. For either type of antenna element, the dual configuration, i.e., elements formed of slots in a conductive membrane, can also be used. Finally, wide bandwidth antennas or arrays can be formed in which the principal direction of radiation is in the plane of the membrane. For this embodiment, the set of elements on the membrane is arranged to form one or more traveling wave antennas. In this case, a nonconductive form of the perimeter springlike material is required to provide the deploying force.

# Faster Evolution of More Multifunctional Logic Circuits

Evolution is driven to find circuits that perform larger numbers of logic functions.

NASA's Jet Propulsion Laboratory, Pasadena, California

A modification in a method of automated evolutionary synthesis of voltage-controlled multifunctional logic circuits makes it possible to synthesize more circuits in less time. Prior to the modification, the computations for synthesizing a four-function logic circuit by this method took about 10 hours. Using the method as modified, it is possible to synthesize a six-function circuit in less than half an hour.

The concepts of automated evolutionary synthesis and voltage-controlled multifunctional logic circuits were described in a number of prior *NASA Tech Briefs* articles. To recapitulate: A circuit is designed to perform one of several different logic functions, depending on the value of an applied control voltage. The circuit design is synthesized following an automated evolutionary approach that is so named because it is modeled partly after the repetitive trial-and-error process of biological evolution. In this process, random populations of integer strings that encode electronic circuits play a role analogous to that of chromosomes. An evolved circuit is tested by computational simulation (prior to testing in real hardware to verify a final design). Then, in a fitness-evaluation step, responses of the circuit are compared with specifications of target responses and circuits are ranked according to how close they come to satisfying specifications. The results of the evaluation provide guidance for refining designs through further iteration.

As described in more detail in the prior
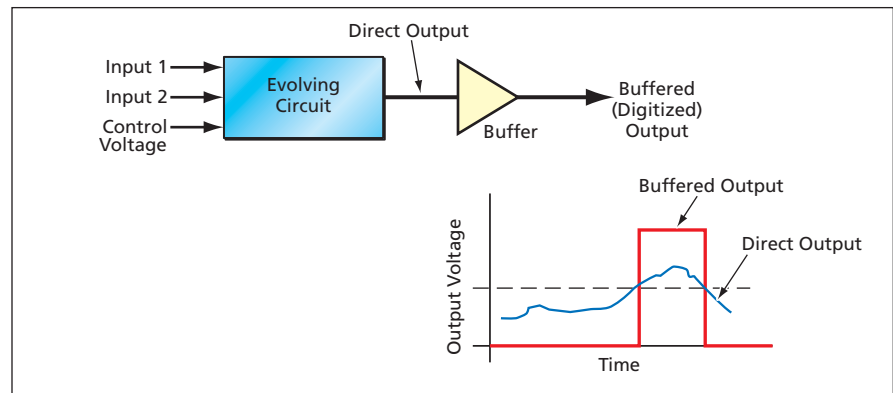
A **Buffer Must Be Added** to an evolving circuit to obtain a digital output because the direct output of a typical evolving circuit is an analog voltage.

NASA Tech Briefs articles on multifunctional logic circuits, the multiple functionality of these circuits, the use of a single control voltage to select the function, and the automated evolutionary approach to synthesis, offer potential advantages for the further development of field-programmable gate arrays (FPGAs):
• Typical circuitry can be less complex and can occupy smaller areas; because only a single analog control line is needed to select different functions.
• If voltage-controlled multifunctional gates were used in the place of the configurable logic blocks of present commercial FPGAs, it would be possible to change the functions of the resulting digital systems in much shorter times;
• Relative to conventional circuits designed to perform single functions, multifunctional circuits can be synthe-

sized to be more tolerant of radiation-induced faults.

In the unmodified method of automated evolutionary synthesis, the target responses of a multifunctional logic circuit are fixed: that is, the user specifies in advance which logic function the circuit is to perform at each of several discrete values of control voltage (for example, AND at 0 V, NOR at 0.9 V, and NAND at 1.8 V). In the modified method, the user no longer specifies which logic function occurs at which control voltage: Instead, the evolutionary algorithm is allowed to find the control-voltage levels at which various logic functions appear, and the fitness-evaluation function is modified to assign a higher fitness score to a circuit that exhibits a greater number of logic functions over the full range of the control voltage. Thus, evolution is driven to

find circuits that perform a larger number of logic functions.

In order to be able to score fitness in this way, one must ensure that circuit output is a digital waveform at every value of the control voltage, so that the output can be classified as a particular logic function. Nevertheless, it has been observed that the circuits generated during evolutionary search typically generate analog outputs, taking values between zero volts and the power-supply voltage. In order to solve this problem, the output of an evolving circuit is digitized by use of a buffer, as illustrated in the figure. Whereas the direct output of the evolving circuit is evaluated in the unmodified method, the buffered output is evaluated in the modi-fied method. In effect, for the purpose of evaluation, the buffer becomes part of any such evolved circuit.

This work was done by Adrian Stoica and Ricardo Zebulum of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).* NPO-40934

Video-Camera-Based Position-Measuring System

Coordinates of nearby targeted objects are measured quickly, easily, and safely.

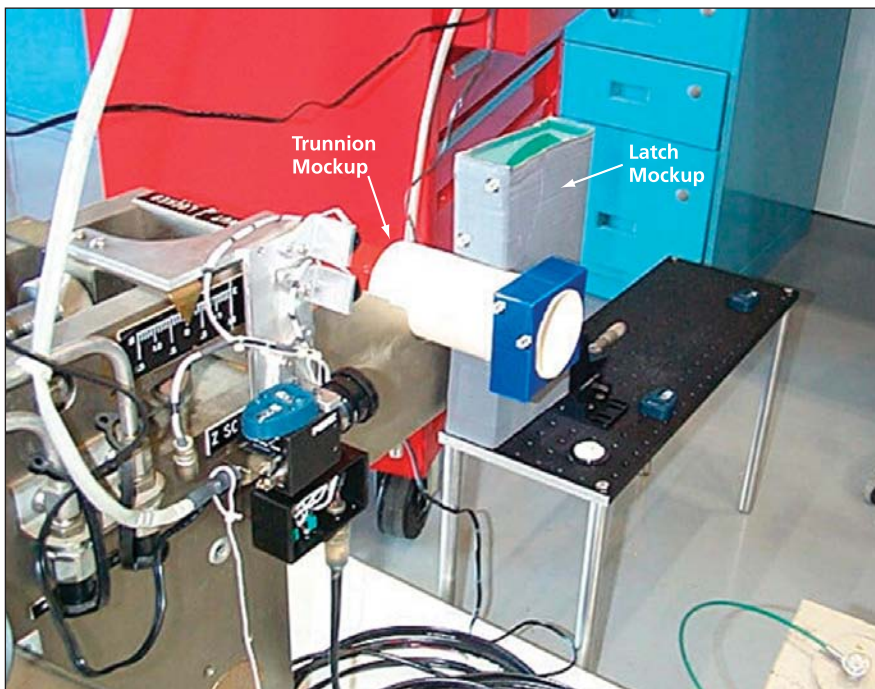*John F. Kennedy Space Center, Florida*

Figure 1. In this **Laboratory Setup,** the camera of the prototype system is aimed at a mockup of a latch mating with a trunnion to demonstrate the use of the system to measure the three-dimensional coordinates of the latch relative of the trunnion.

A prototype optoelectronic system measures the three-dimensional relative coordinates of objects of interest or of targets affixed to objects of interest in a workspace. The system includes a charge-coupled-device video camera mounted in a known position and orientation in the workspace, a frame grabber, and a personal computer running image-data-processing software. Relative to conventional optical surveying equipment, this system can be built and operated at much lower cost; however, it is less accurate. It is also much easier to operate than are conventional instrumentation systems. In addition, there is no need to establish a coordinate system through cooperative action by a team of surveyors.

The system operates in real time at around 30 frames per second (limited mostly by the frame rate of the camera). It continuously tracks targets as long as they remain in the field of the camera. In this respect, it emulates more expensive, elaborate laser tracking equipment that costs of the order of 100 times as much. Unlike laser tracking equipment, this system does not pose a hazard of laser exposure.

Images acquired by the camera are digitized and processed to extract all valid targets in the field of view. The three-dimensional coordinates (x, y, and z) of each target are computed from the pixel coordinates of the targets in the images to accuracy of the order of mil-
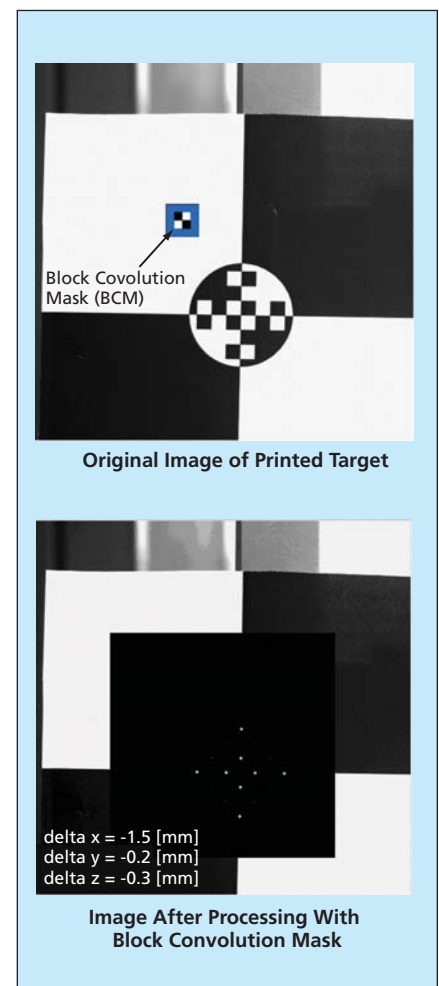

Figure 2. A **Target Pattern of Light and Dark Squares** is processed by a block convolution mask to obtain a pattern of bright dots on a dark background. The three-dimensional positions of the target can be determined from the pixel coordinates of the dots.

limeters over distances of the orders of meters. The system was originally intended specifically for real-time position measurement of payload transfers from payload canisters into the payload bay of