water from a urine container into the concentrated fortified drink as part of a recycling stage. An activated carbon pre-treatment removes most organic molecules. Salinity of the initial liquid mix (urine plus other) is synergistically used to enhance the precipitation of organic molecules so that activated carbon can remove most of the organics. A functional osmotic bag is then used to remove inorganic contaminants. If a contaminant is processed for which the saline content is different than optimal for precipitating organic molecules, the saline content of the liquid should be adjusted toward the optimal value for that contaminant.

A first urine treatment method converts urine into a fortified sports drink, resembling Gatorade, using a first urine cell. A membrane filter that is hydrophilic allows water to diffuse through the filter but blocks most contaminants using a micropore construction. Water is drawn through the membrane by a forward osmotic pressure differential, generated by the liquid feed, sugars, and electrolytes contained in a concentrated sports drink, which is positioned on the product (output) side of the membrane. Water, initially contained in urine, diffuses through the membrane to approximately balance the concentration gradient. As a result, the sports drink will become diluted and the urine will become concentrated. The maximum number of urine recycling sessions is about ten. The process is a modification of a process used in a water treatment cell from Hydration Technologies X-Pack.

A second urine treatment method uses osmotic distillation and a hydrophobic, microporous membrane filter, with a product (output) side exposed to a second liquid phase that is capable of absorbing wastewater that is presented on the input side of the filter. The method is sometimes referred to as isothermal membrane distillation and is driven by a vapor pressure gradient rather than by a temperature gradient.

This work was done by Michael T. Flynn of Ames Research Center and Sherwin J. Gormly of the National Space Grant Foundation. Further information is contained in a TSP (see page 1). ARC-15890-1

Microchip Non-Aqueous Capillary Electrophoresis (μNACE) Method to Analyze Long-Chain Primary Amines

NASA's Jet Propulsion Laboratory, Pasadena, California

A protocol was developed as a first step in analyzing the complex organic aerosols present on Saturn's moon Titan, as well as the analogues of these aerosols (tholins) made on Earth. Labeling of primary amines using Pacific Blue™ succinimidyl ester is effected in ethanol with 25 mM triethylamine to maintain basic conditions. This reaction is allowed to equilibrate for at least one hour. Separation of the labeled primary amines is performed in ethanol with 1.05 M acetic acid, and 50 mM ammonium acetate in a commercial two-layer glass device with a standard cross-microchannel measuring 50 microns wide by 20 microns deep. Injection potentials are optimized at 2 kV from the sample (negative) to the waste well (positive), with slight bias applied to the other two wells (–0.4 and –0.8 V) to pinch the injection plug for the 30-s injection. Separation is performed at a potential of 5 kV along the channel, which has an effective separation distance of 7 cm.

The use of ethanol in this method means that long-chain primary amines can be dissolved. Due to the low pH of the separation buffer, electro-osmotic flow (EOF) is minimized to allow for separation of both short-chain and long-chain amines. As the freezing point of ethanol is much lower than water, this protocol can perform separations at temperatures lower than 0 °C, which would not be possible in aqueous phase. This is of particular importance when considering *in situ* sampling of Titan aerosols, where unnecessary heating of the sample (even to room temperature) would lead to decomposition or unpredictable side reactions, which would make it difficult to characterize the sample appropriately.

This work was done by Peter A. Willis and Maria Mora of Caltech, and Morgan L. Cable and Amanda M. Stockton of ORAU for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-48615

Low-Cost Phased Array Antenna for Sounding Rockets, Missiles, and Expendable Launch Vehicles

Commercial applications include conformal satellite antennas for recreational vehicles, cars, and residences.

Goddard Space Flight Center, Greenbelt, Maryland

A low-cost beamformer phased array antenna has been developed for expendable launch vehicles, rockets, and missiles. It utilizes a conformal array antenna of ring or individual radiators (design varies depending on application) that is designed to be fed by the recently developed hybrid electrical/mechanical (vendor-supplied) phased array beamformer. The combination of these new array antennas and the hybrid beamformer results in a conformal phased array antenna that has significantly higher gain than traditional "omni" antennas, and costs an order of magnitude or more less than traditional phased array designs.

Existing omnidirectional antennas for sounding rockets, missiles, and expendable launch vehicles (ELVs) do not have sufficient gain to support the required

communication data rates via the space network. Missiles and smaller ELVs are often stabilized in flight by a fast (i.e. 4 Hz) roll rate. This fast roll rate, combined with vehicle attitude changes, greatly increases the complexity of the high-gain antenna beam-tracking problem. Phased arrays for larger ELVs with roll control are prohibitively expensive. Prior techniques involved a traditional fully electronic phased array solution, combined with highly complex and very fast inertial measurement unit phased array beamformers.

The functional operation of this phased array is substantially different from traditional phased arrays in that it uses a hybrid electrical/mechanical beamformer that creates the relative time delays for steering the antenna beam via a small physical movement of variable delay lines. This movement is controlled via an innovative antenna control unit that accesses an internal measurement unit for vehicle attitude information, computes a beam-pointing angle to the target, then points the beam via a stepper motor controller. The stepper motor on the beamformer controls the beamformer variable delay lines that apply the appropriate time delays to the individual array elements to properly steer the beam.

The array of phased ring radiators is unique in that it provides improved gain for a small rocket or missile that uses spin stabilization for stability. The antenna pattern created is symmetric about the roll axis (like an omnidirectional wraparound), and is thus capable of providing continuous coverage that is compatible with very fast spinning rockets. For larger ELVs with roll control, a linear array of elements can be used for the 1D scanned beamformer and phased array, or a 2D scanned beamformer can be used with an N×N element array.

This work was done by Daniel Mullinix, Kenneth Hall, Bruce Smith, and Brian Corbin of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15805-1

Mars Science Laboratory Engineering Cameras

NASA's Jet Propulsion Laboratory, Pasadena, California

NASA's Mars Science Laboratory (MSL) Rover, which launched to Mars in 2011, is equipped with a set of 12 engineering cameras. These cameras are build-to-print copies of the Mars Exploration Rover (MER) cameras, which were sent to Mars in 2003. The engineering cameras weigh <300 grams each and use <3 W of power. Images returned from the engineering cameras are used to navigate the rover on the Martian surface, deploy the rover robotic arm, and ingest samples into the rover sample processing system. The navigation cameras (Navcams) are mounted to a pan/tilt mast and have a 45-degree square field of view (FOV) with a pixel scale of 0.82 mrad/pixel.

The hazard avoidance cameras (Hazcams) are body-mounted to the rover chassis in the front and rear of the vehicle and have a 124-degree square FOV with a pixel scale of 2.1 mrad/pixel. All of the cameras utilize a frame-transfer CCD (charge-coupled device) with a 1024×1024 imaging region and red/near IR bandpass filters centered at 650 nm. The MSL engineering cameras are grouped into two sets of six: one set of cameras is connected to rover computer "A" and the other set is connected to rover computer "B". The MSL rover carries 8 Hazcams and 4 Navcams.

This work was done by Justin N. Maki, David L. Thiessen, Ali M. Pourangi, Peter A. Kobzeff, Steven W. Lee, Arsham Dingizian, and Mark A. Schwochert of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-48550

Seismic Imager Space Telescope

The imager will offer alternative ways of studying earthquakes and improve early warning systems.

NASA's Jet Propulsion Laboratory, Pasadena, California

A concept has been developed for a geostationary seismic imager (GSI), a space telescope in geostationary orbit above the Pacific coast of the Americas that would provide movies of many large earthquakes occurring in the area from Southern Chile to Southern Alaska. The GSI movies would cover a field of view as long as 300 km, at a spatial resolution of 3 to 15 m and a temporal resolution of 1 to 2 Hz, which is sufficient for accurate measurement of surface displacements and photometric changes induced by seismic waves. Computer processing of the movie images would exploit these dynamic changes to accurately measure the rapidly evolving surface waves and surface ruptures as they happen. These measurements would provide key information to advance the understanding of the mechanisms governing earthquake ruptures, and the propagation and arrest of damaging seismic waves.

GSI operational strategy is to react to earthquakes detected by ground seismometers, slewing the satellite to point at the epicenters of earthquakes above a certain magnitude. Some of these earthquakes will be foreshocks of larger earthquakes; these will be observed, as the spacecraft would have been pointed in the right direction. This strategy was tested against the historical record for the Pacific coast of the Americas, from 1973 until the present. Based on the seismicity recorded during this time period, a GSI mission with a lifetime of 10 years could have been in position to observe at least 13 (22 on average) earthquakes of magnitude larger than 6, and at least one (2 on average) earthquake of magnitude larger than 7.

A GSI would provide data unprecedented in its extent and temporal and