faults/fault-lines, dykes, and mineral-veins were heavily influenced by the hydraulic boundaries. The hydraulic behavior in wells that receive water from only a few fractures corresponds to a theoretical model of single vertical, horizontal, or inclined fractures in homogeneous, isotropic aquifers.

Descriptions from drilling foremen, geophysical logs in boreholes, and geological profiles showed that water-bearing formations are attached to faults/fault-lines, rock masses extremely strained by tectonic forces, and cracked, sheared rocks (breccia). They are also attached to contact areas between granites, granite dykes, and granite porphyries, and gneisses, on the other hand, as well as to intensively fissured granite dykes within paragneisses, and to old circulation-paths, such as hydrothermally altered or strained areas, mineral-veins, or open fractures filled with minerals. The magnitude of the conductivity of crystalline rocks in the Black Forest is thought to depend on these characteristics. Biotite-rich gneisses, on the other hand, have extremely low conductivity.

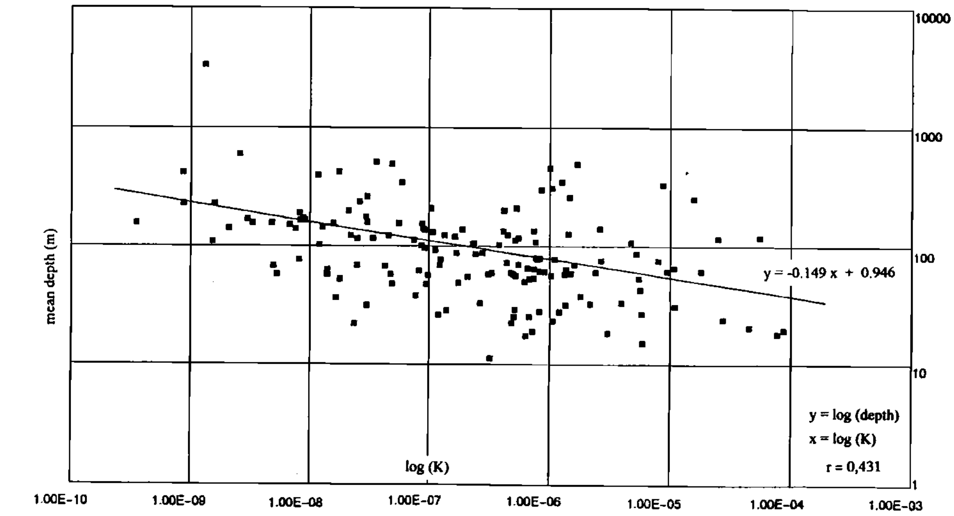

Fig. 2. The logarithm of the K value for bulk rocks independent of log depth.

Geochemistry of Natural Waters in Crystalline Rocks of the Black Forest

Data on the chemical composition of the groundwater will be used to trace the origin of thermal spring-water in the Black Forest. The geochemistry of groundwater in crystalline rocks varies; the concentration of dissolved substances increases as a function of depth. At depths of more than 2000–3000 m below the surface the total dissolved solids show values of more than 5000 mg/kg. In addition, the ionic composition of groundwater changes from Ca-Na-HCO_3-rich near the surface to Na-Ca-SO_4-HCO_3-rich at medium depth to a Na-Cl-dominated groundwater at great depth. High CO_2 concentrations in groundwater tend to promote water-rock-interactions, dissolution, and weathering. The Black Forest study showed that the total concentration of the dissolved substances increases with depth and that the concentrations of Ca and Mg exceed the solubility of the equivalent carbonates.

By using geothermometers and applying chemical analyses of thermal waters, it was possible to determine the temperatures of the deposits from which the thermal waters in the study area originate. The Na-Cl-rich deposits extend some 1000 m below the surface.

Hydraulic and hydrochemical investigations have produced a new picture of the genesis of thermal springs in the Black Forest. The chemical composition of thermal spring water is identical to that of water found at great depth (Na-Cl type), and temperature and chemical characteristics show that these waters must rise from great depths in large quantities, or else they would be cooled down during their journey to the Earth's surface. This may be why thermal springs are found only in granitic rocks, which have a greater capacity for hydraulic conductivity than gneisses. Thermal springs are always situated in valleys at the bottom of steep mountains. The pronounced topographic relief propels rain water to great depths; this rain water then upwells to the lower hydraulic head zones that underlie the valleys.

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NASA Works to Find Gains From Lost Satellite

PAGES 93, 96

NASA astronauts and scientists proved two concepts with the recent reflight of the Tethered Satellite System (TSS-1R). Unfortunately, they were only trying to prove one.

"We have demonstrated that you can generate a lot of electricity with a tether," said mission specialist Jeff Hoffman in a February 26 news briefing from the space shuttle *Columbia*. "Unfortunately, we've also demonstrated that you can use tethers to launch a satellite into a much higher orbit."

Though the TSS-1R mission was cut short by the breaking of the tether that kept the satellite leashed to the space shuttle, the experiment demonstrated that a tether system can be a viable mechanism for generating electrical energy and can be a valuable tool for studying the electrodynamics of the Earth's ionosphere. In nearly 5 hours of experiments, the tethered satellite system (see Figure 1) generated electrical currents as strong as 3.7 kV and 440 milliamps, while collecting data on ionospheric plasma over 19.7 km of the planned 20.7 km range of the tether.

The unintended launch into a higher orbit came at roughly 7:30 p.m. CST on February 25, 4.75 hours after astronauts began deploying the satellite. Without warning (astronauts reported no high tension or unusual oscillations of the tether), the satellite and tether broke free from the boom attaching it to *Columbia*, lurching away from the shuttle at 24 m/s and dangling more than 19 km of tether behind it. No attempt was made to retrieve the satellite because the flight team was concerned that the tether would wrap around the shuttle and disable it.

Preliminary television and telephoto images gathered by the crew of *Columbia* showed the ends of the tether to be frayed and charred (see Figure 2), though mission specialists were unwilling to speculate about whether that was a cause or effect of the break. The 0.24 cm-thick tether, which was manufactured by the Cortland Cable Company for Martin Marietta Astronautics, was designed to withstand 3 amps and 10 kV of electrical power, as well as 1800 Newtons of force. During the 5 hours that TSS-1R was be-

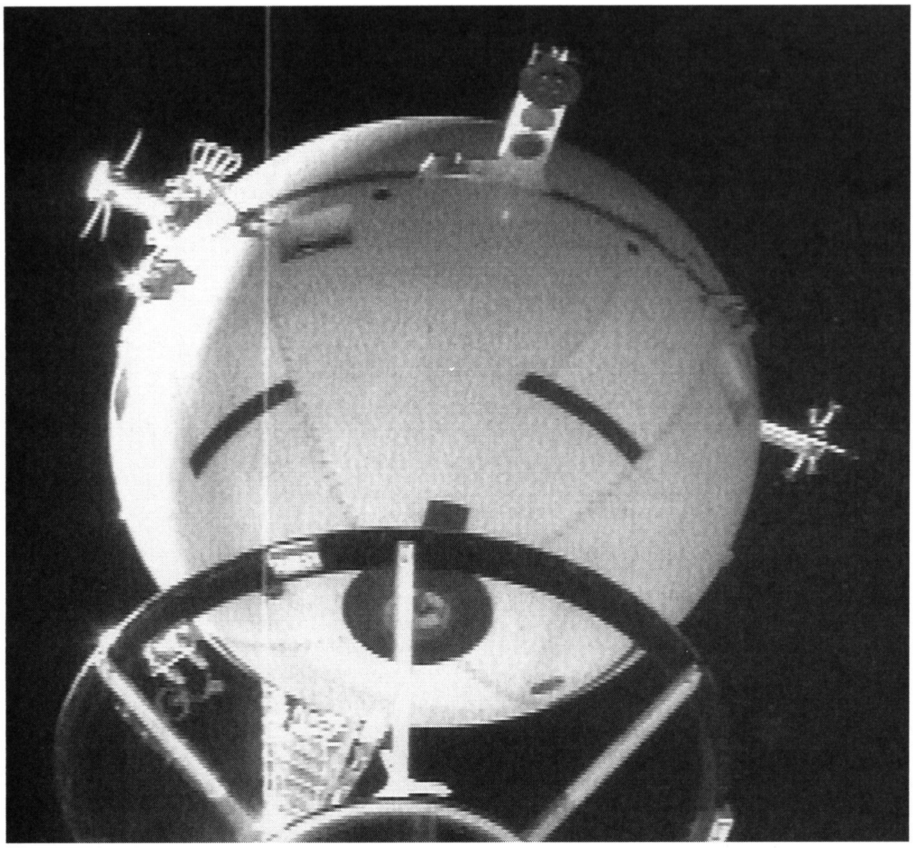

Fig. 1. The round Tethered Satellite is released from the boom as unreeling begins. Photo courtesy of NASA-Johnson Space Center

ing unreeled, the copper, nylon, and Teflon tether endured a maximum current of just 440 milliamps of current, voltages of 3.7 kV, and 67 Newtons of force. The amount of friction was even below predictions.

The accident came nearly four years after the TSS-1 system failed in its maiden voyage. On an August 1992 shuttle mission, the tether unwound just 260 m before snagging on a bolt and halting the experiment. Since that time, NASA and Agenzia Spaziale Italiana made $60 million in repairs and improvements to the TSS-1R, bringing the total price tag to $440 million. ASI developed the 518-kg white satellite; NASA developed the tether and deploying system.

"Tethers have the potential to revolutionize a lot of the ways we operate in space," said Hoffman. "I would have hoped that after two flights we would have gotten a little further than we got this time. And I don't want to try to pretend we're not pretty bitterly disappointed."

"We have mixed emotions," said Dennis Papadopoulos, a modeler and theorist for the TSS-1R mission from the University of Maryland. "While we are very disappointed, the quality of the data we have is excellent and much cleaner and reproducible than we expected. But then we look at what was lost," he added. "We have glimpsed the future, and it escaped us."

One of the principal goals of the mission was to prove that the Earth's ionosphere could be used as part of an unorthodox electric motor. By pulling an electrical conductor across the Earth's magnetic fields at 8 km/s, the investigators were hoping to generate power up to 5 kV and 500 milliamps. Creating the equivalent of a DC generator, the TSS-1R system was supposed to collect electrons from ionospheric plasma to create current that would flow down to the shuttle. At the shuttle, the current would be ejected back into the ionosphere by electron guns, completing the circuit.

"We went beyond proof of concept," said Nobie Stone, mission scientist for TSS-1R. He noted that investigators were able to gather enough data in just five hours to study the electrodynamics of a long tether, and "we got some very interesting results." In particular, Stone noted that preliminary data revealed currents higher than the models predicted and "some interesting wave particle physics," such as 10-kV electrons gathering in the sheath around the satellite. The shortcoming of the experiment, however, is that "we did not get to look systematically at the various points," Stone said. "The data will be more random than the systematic data taking we planned."

Brian Gilchrist, a principal investigator from the University of Michigan, added that "we pushed the envelope, but we just wish we had more data. What we're missing is detailed measurements to fill in between sparse data points." But even the sparse results of the collected current-voltage observations were "30–40% higher" than the theoretical limits predicted by earlier models.

"The discovery that currents as high as 1.0 Ampere can easily be collected from the ionosphere with modest potentials establishes the viability of electrodynamic tether technology," said Papadopoulos.

The objectives of the mission were to characterize the current-voltage response; to characterize the sheath structure and current collection process; to verify tether control laws and basic tether dynamics; to demonstrate the effects of neutral gas on the plasma

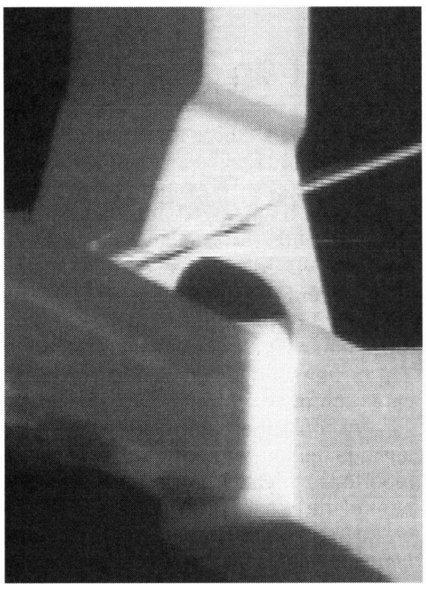

Fig. 2. The tether was frayed and charred at both (a) the boom end attached to the shuttle and (b) the satellite end.

sheath and on current collection; to characterize TSS-1R radio frequency and plasma wave emissions; and to characterize the dynamic-electrodynamic coupling (*Eos*, Vol. 73, No. 30, July 28, 1992).

According to Stone, some of those objectives can still be met, and "we will be able to learn some things, although we will probably be unable to understand them completely." Serendipity may lead scientists to gain information for some objectives, even though the satellite was not attached long enough to allow them to conduct formal experiments. For instance, the effects of gas release may be derived from matching the data with moments during which the shuttle fired its thrusters. Also, perturbances during the deployment—including the tether break itself—may provide a bit of information about dynamic noise.

On the other hand, the data from the experiment will suffer from the lack of multipoint measurements, no real observations on sheath physics, and the inability to systematically study the current collection process. Also, experiments related to the satellite's boom and to the release of gases were not even begun when the tether snapped.

"Nobody is happy with the situation, but we are making the most of it," Stone said. "Clearly, we can't declare a success. But we did nearly arrive at our first station, and we do have quite a bit of data. I wouldn't declare the mission a failure. We will just have more of a challenge to extract information [from those five hours]."

In addition to creating a power generator, space physicists and engineers believe they eventually can use tether systems to lower satellites and probes into hard-to-reach altitudes of the Earth's atmosphere—primarily the ionosphere, which is too high toreach by balloon or plane, but too low for flying a traditional satellite. Other potential applications of tether technology include use as elevators to raise and lower science platforms and packages from orbiting craft; as artificial gravity producers; as wind-tunnel-like flight testers; and as the world's longest, lowest-frequency antennas. And, as this foundering mission proved, the tensile force in tethers can be used to boost satellites and space stations into higher orbits.

The free-floating satellite is now drifting in a decaying, elliptical orbit of 433 by 319 km, and it should fall back into the Earth's lower atmosphere and burn up by mid-March. At press time, NASA had made radio contact with the satellite from various ground stations around the world. Controllers found TSS-1R's radio antenna was still working and its batteries had two days of working life left, although one primary computer and one gyroscope had gone dead. NASA also found that the valves on the satellite's nitrogen gas thrusters were open and its fuel tanks were empty.

According to Stone, ground controllers had turned the satellite back on and extended its instrument sensor booms by February 27 in order to retrieve data remotely. All instruments on the satellite were functioning as planned, Stone said, and the satellite was "spinning with a 109-second period, very close to what the mission plan called for." He noted that, in the three days after the satellite broke free, engineers and principal investigators at Marshall Space Flight Center improvised plans to monitor the effect of the drag of the tether on the electrodynamics of the satellite. They also planned to use the electron guns on the space shuttle to create disturbances in the magnetic field whenever the shuttle and satellite passed each other in orbit, about once every few hours.

Within a day after the accident, NASA announced that it had already begun forming an independent panel to review the loss of the satellite. The panel will be chaired by Kenneth Szalai, director of the Dryden Flight Research Center in Edwards, California. A preliminary report is due by mid-May, although Gilchrist noted that the crew would probably be able to tell what caused the tether break once they can see the frayed remains. "We don't know if it was a mechanical problem or a problem of the high voltage circuit [that was created by the system]," Gilchrist said.

"Given the public investment in the tethered satellite, it is important that we find out what went wrong," Wil Trafton, acting associate administrator for NASA's Office of Space Flight, said in a statement. "To do any less would be a disservice to the American and Italian people."
—Michael Carlowicz

FORUM

Comment on Uses and Abuses of House Journals

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In "Uses and Abuses of House Journals" [*Eos*, October 3, 1995, p. 395] Raymond Hide lamented that "Meeting abstracts reputedly enjoy a much wider readership and are generally more influential with funding agencies and other bodies than are detailed accounts of scientific work published in fully refereed journals." His linkage of this perceived reality to a call for the institution of "safeguards against the publication of such potentially damaging material" deserves rebuttal.

Scientists working in funding agencies are supposed to perform different functions from those who review articles submitted for publication in peer-reviewed journals, despite their overlapping spheres of influence. Peer review for discipline-specific journals performs many valuable functions. An important purpose of peer review is to apply those criteria through which the various disciplines of science establish and maintain a sense of "self-identity." In addition, the review process ensures that papers published represent progress in their respective fields. By virtue of definition, the review of a work by an author's peers is a "backward-looking" process that defines for a discipline's other members and a specific journal's readers "that which is known" by that group.

While I seriously doubt that scientists working within funding agencies give more weight to abstracts than they do to formal publications in comprehensively reviewed journals, their consideration of ideas presented in abstracts is entirely consistent with their personal responsibility to fund forward-looking research where work remains incomplete. Entirely speculative notions are frequently presented for the first time in printed abstracts, while this same class of preliminary presentation is consistently removed from the refereed publications by the peer-review process.

Beyond this is a more important matter. The study of the history of scientific progress has repeatedly shown that the great majority of truly revolutionary advances in specific subdisciplines have not come about through insights arising from within a given subdiscipline but, rather, through discoveries found buried between disciplines. This reflects the fact that universal truths display their utilitarian character by building bridges between