

tions of the study, at an H₂O₂:NO_x molar ratio of 1.37, the H₂O₂-injection/scrubbing method could be an economically feasible alternative to SCR.

Pilot-scale tests run at Kennedy Space Center demonstrated the feasibility and competitiveness of this new technology. The H₂O₂ to NO molar ratio, at 500 °C

shown to achieve a NO conversion efficiency of > 90 percent was 1:1, which is significantly lower than the required 1.37:1 (See Figure 2).

This work was done by Michelle M. Collins of Kennedy Space Center and C. David Cooper and Christian A. Clausen III of the University of Central Florida.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Commercialization Office, Kennedy Space Center, (321) 867-1463. Refer to KSC-12056.

Subsurface Ice Probe

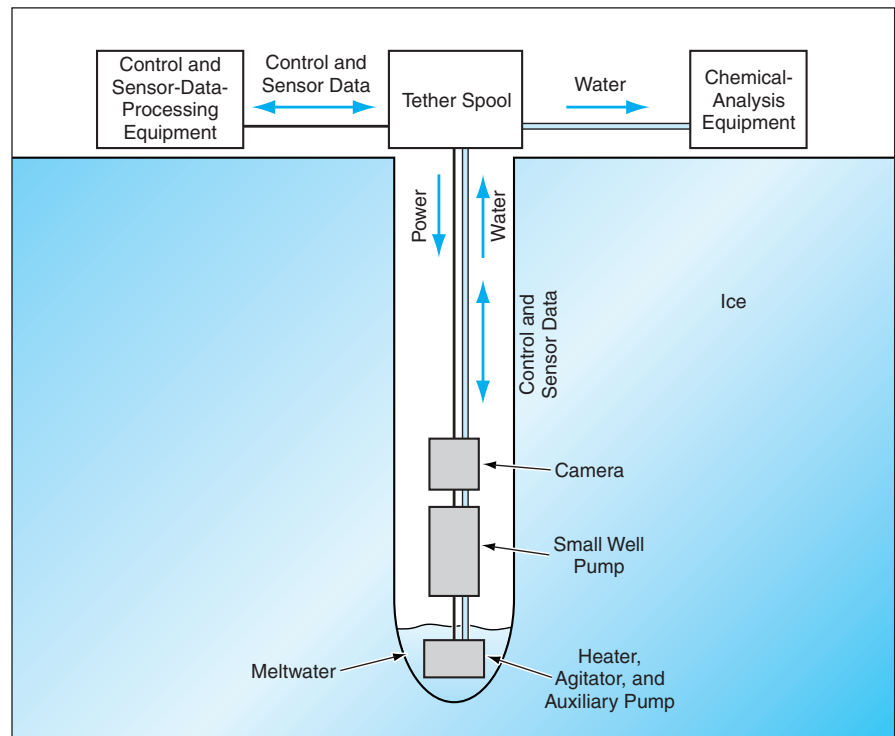
Small samples of ice would be melted and pumped to the surface for analysis.

NASA's Jet Propulsion Laboratory, Pasadena, California

The subsurface ice probe (SIPR) is a proposed apparatus that would bore into ice to depths as great as hundreds of meters by melting the ice and pumping the samples of meltwater to the surface. Originally intended for use in exploration of subsurface ice on Mars and other remote planets, the SIPR could also be used on Earth as an alternative to coring, drilling, and melting apparatuses heretofore used to sample Arctic and Antarctic ice sheets.

The SIPR would include an assembly of instrumentation and electronic control equipment at the surface, connected via a tether to a compact assembly of boring, sampling, and sensor equipment in the borehole (see figure). Placing as much equipment as possible at the surface would help to attain primary objectives of minimizing power consumption, sampling with high depth resolution, and unobstructed imaging of the borehole wall. To the degree to which these requirements would be satisfied, the SIPR would offer advantages over the aforementioned ice-probing systems.

The tether would include wires for power, wires or optical fibers for control and sensor data, and a narrow tube through which meltwater would be pumped to the surface. A unit containing a heater, a cam-driven agitator, and an auxiliary pump (a small peristaltic pump) would be submerged in a small pool of water at the bottom of the borehole. The heater in this unit would melt ice at the bottom of the hole. The agitator would prevent settling of any suspended sediment to the bottom of the hole. The auxiliary pump would quickly transfer the meltwater and any sediment to a small holding tank above the water surface. To minimize unwanted loss of energy through side melting and to optimize the depth resolution of



Scientific Instruments and Control Equipment would reside in an assembly at the surface. Only a small assembly of equipment essential for melting ice, pumping the meltwater, and inspecting the borehole wall would be lowered into the borehole.

meltwater samples, only a small amount of water would be left at the bottom of the hole.

The heart of the down-hole assembly would be a small well pump that would force the water and sediment from the holding tank, up through the tube, to the instrumentation assembly at the surface. The pump must provide sufficient head to lift the water from the greatest anticipated borehole depth. Alternatively, the down-hole assembly could be made smaller by placing a pump on the surface and using a two-way fluid or pneumatic loop to drive the liquid to the surface. The inevitable dissipation of electric energy in the power cables

could be utilized as auxiliary heating to prevent freezing of the water in the tube. Either above or below the pump there could be an electronic camera to acquire images of the borehole wall and/or a nephelometer for acquiring data on sediment particles trapped in the wall.

The design of the tube is anticipated to demand a major part of the overall design effort. The bore of the tube must be narrow enough that the mixing length within the tube corresponds to a short column of water in the hole: this length defines the depth resolution of the system (intended to be of the order of centimeters). At the same time, the

bore must not be so narrow that the consequent resistance to flow exceeds the capability of the well pump, and the bore must be wide enough to accommodate suspended particles. The tube

must not kink or fracture at low temperatures. It should be sufficiently insulated to prevent freezing during normal operation and it should tolerate inadvertent freezing.

This work was done by Michael Hecht and Frank Carsey of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-40031

Real-Time Simulation of Aeroheating of the Hyper-X Airplane

Computational simulations are expected to provide guidance for initial design choices.

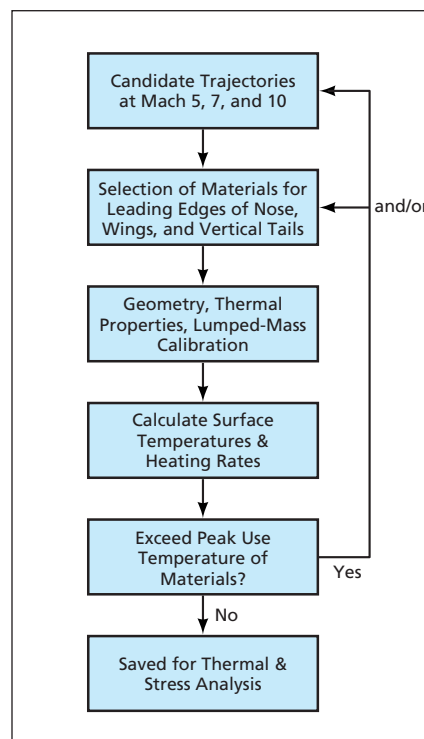
Dryden Flight Research Center, Edwards, California

A capability for real-time computational simulation of aeroheating has been developed in support of the Hyper-X program, which is directed toward demonstrating the feasibility of operating an air-breathing ramjet/scramjet engine at mach 5, mach 7, and mach 10. The simulation software will serve as a valuable design tool for initial trajectory studies in which aerodynamic heating is expected to exert a major influence in the design of the Hyper-X airplane; this tool will aid in the selection of materials, sizing of structural skin thicknesses, and selection of components of a thermal-protection system (TPS) for structures that must be insulated against aeroheating.

The Hyper-X airplane will include an inlet/combustor/nozzle assembly attached to an airframe. The forebody of the inlet will consist of a leading edge and a tungsten ballast. Movable wings and vertical tail rudders will give the autonomous airplane controllability. Mounted inside the airframe will be all the active systems needed to fly and to demonstrate the ramjet/scramjet engine. The fuel-burning and flight hardware will be instrumented to collect and telemeter flight data.

Because of the short duration of flight, critical areas on the airframe TPS will be limited to the leading edges on the nose, cowl, and side walls of the inlet and the horizontal wings and vertical

tails. In addition to other aeroheating effects, gap heating is expected to occur at horizontal wing roots, and at vertical rudder roots by amounts that will vary with movement of the rudders.



The **Computational Simulation of Aeroheating** is one of several real-time simulations used in initial design studies. This simulation can be used to eliminate flight trajectories that would give rise to local temperatures in excess of structural-design temperature limits.

The present capability for real-time computational simulation of aeroheating makes it possible to predict temperature as a function of time at critical heating locations on the Hyper-X airplane. Simulations of this type are used extensively to select acceptable flight trajectories by eliminating ones for which structural-design temperature limits would be exceeded (see figure). Other real-time simulations can be performed, using software modules that enable evaluation of other aspects of operation and design, including aerodynamics, reaction control system, flight guidance, and airplane structures. At speeds in excess of mach 2, aeroheating is considered important enough to affect design parameters, so that it becomes necessary to include a software module for simulation of aeroheating.

Thus far, a mathematical submodel of a nose with a solid carbon/carbon leading edge has been incorporated into the mathematical model used in the simulation of aeroheating. This submodel includes 14 temperature nodes. Other submodels of aeroheating of the tail rudder and the leading edges of the horizontal and vertical tails were undergoing development at the time of reporting the information for this article.

This work was done by Les Gong of Dryden Flight Research Center. For further information, contact the Dryden Commercial Technology Office at (661) 276-3143. DRC-98-76

Using Laser-Induced Incandescence To Measure Soot in Exhaust

This system incorporates several improvements over prior LII soot-measuring systems.

John H. Glenn Research Center, Cleveland, Ohio

An instrumentation system exploits laser-induced incandescence (LII) to measure the concentration of soot particles in an exhaust stream from an en-

gine, furnace, or industrial process that burns hydrocarbon fuel. In comparison with LII soot-concentration-measuring systems that have been described in

prior *NASA Tech Briefs* articles, this system is more complex and more capable.

Like the other systems, this system includes a pulsed laser and associated op-