bris in amateur video images of the breakup of the Space Shuttle Columbia. The purpose of these measurements is to use the brightness values to estimate relative masses of debris objects. In most of the images, the brightness of the main body of Columbia was found to exceed the dynamic ranges of the cameras. A similar problem arose a few years ago in the analysis of video images of Leonid meteors. The present method is a refined version of the calibration method developed to solve the Leonid calibration problem.

In this method, one performs an end-to-end calibration of the entire imaging system, including not only the imaging optics and imaging photodetector array but also analog tape recording and playback equipment (if used) and any frame grabber or other analog-to-digital converter (if used). To automatically incorporate the effects of nonlinearity and any other distortions into the calibration, the calibration images are processed in precisely the same manner as are the images of meteors, space-shuttle debris, or other objects that one seeks to analyze.

The light source used to generate the calibration images is an artificial variable star comprising a Newtonian collimator illuminated by a light source modulated by a rotating variable neutral-density filter. This source acts as a point source, the brightness of which varies at a known rate. A video camera to be calibrated is aimed at this source. Fixed neutral-density filters are inserted in or removed from the light path as needed to make the video image of the source appear to fluctuate between dark and saturated bright. The resulting video-image data are analyzed by use of custom software that determines the integrated signal in each video frame and determines the system response curve (measured output signal versus input brightness). These determinations constitute the calibration, which is thereafter used in automatic, frame-by-frame processing of the data from the video images to be analyzed.

*This work was done by Robert Suggs of Marshall Space Flight Center and Wesley Swift, Jr., of Raytheon Co. Further information is contained in a TSP (see page 1). MFS-32090-1*

# Criterion for Identifying Vortices in High-Pressure Flows

## This criterion could enable appropriate comparisons between experiments and simulations.

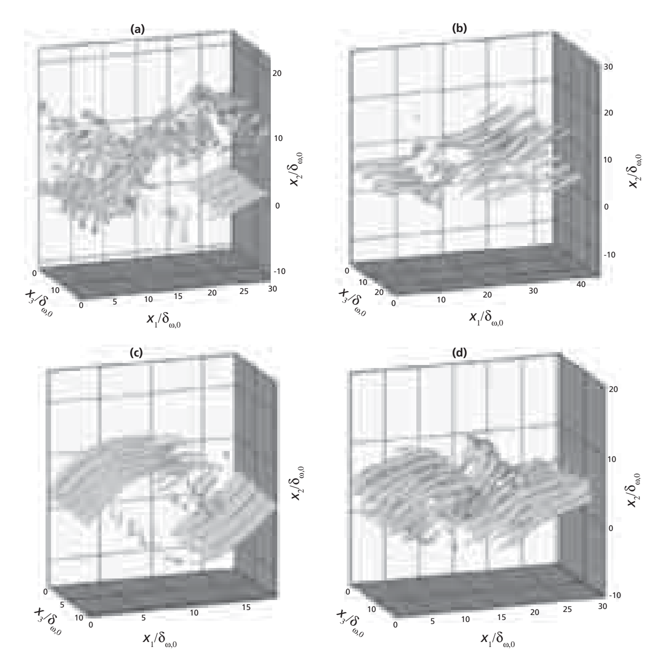
*NASA's Jet Propulsion Laboratory, Pasadena, California*

A study of four previously published computational criteria for identifying vortices in high-pressure flows has led to the selection of one of them as the best. This development can be expected to contribute to understanding of high-pressure flows, which occur in diverse settings, including diesel, gas turbine, and rocket engines and the atmospheres of Jupiter and other large gaseous planets.

Information on the atmospheres of gaseous planets consists mainly of visual and thermal images of the flows over the planets. Also, validation of recently proposed computational models of high-pressure flows entails comparison with measurements, which are mainly of visual nature. Heretofore, the interpretation of images of high-pressure flows to identify vortices has been based on experience with low-pressure flows. However, high-pressure flows have features distinct from those of low-pressure flows, particularly in regions of high pressure gradient magnitude caused by dynamic turbulent effects and by thermodynamic mixing of chemical species. Therefore, interpretations based on low-pressure behavior may lead to misidentification of vortices and other flow structures in high-pressure flows. The study reported here was performed in recognition of the need for one or more quantitative criteria for identifying coherent flow structures — especially vortices — from previously generated flow-field data, to complement or supersede the determination of flow structures by visual inspection of instantaneous fields or flow animations. The focus in the study was on correlating visible images of flow features with various quantities computed from flow-field data.

The quantities involved in the four criteria considered in the study are the following:

- The discriminant of the deformation tensor;
- The second invariant of the deformation tensor;
- The intermediate eigenvalue of the




These **Plots of Isosurfaces** of positive values of the second invariant were generated from numerical simulations of two high-pressure mixing flows of heptane/nitrogen, (a) and (c), and two high-pressure mixing flows of oxygen/hydrogen (b) and (d).

symmetric tensor representing the sum of the square power of the strain-rate tensor and the square power of the rotation tensor; and

- The magnitude of the vorticity vector.

The criteria associated with the first three quantities are those inside a vortex core, the discriminant is positive, the second invariant is positive, and the intermediate eigenvalue is negative, respectively. The fourth criterion — taking magnitude of the vorticity as an indication of vortical activity — might intuitively seem to be a good choice, but it is subjective rather than objective because it entails subjective selection of a threshold magnitude value for isolating flow structures of interest in high-vorticity regions.

These criteria were tested by use of a database generated in direct numerical simulations of high-pressure, binary-species-mixing flows undergoing transitions to turbulence. The quantities involved in the criteria were computed from the database, isosurfaces of these quantities were plotted, and plots were assessed with respect to utility in demarcating flow structures. Of the four criteria, that based on the second invariant was found to yield the most realistic plots of flow structures and to capture structures in all regions of the flow.

The figure presents plots of the second invariant isosurfaces showing vortical features from four of the simulations. The diversity of the features is noticeable and has been interpreted as boding well for the extraction of vortical features from visual data and enabling appropriate comparisons between experimental and computationally simulated flows.

*This work was done by Josette Bellan and Nora Okong'o of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov*
*NPO-41932*

# Amplified Thermionic Cooling Using Arrays of Nanowires

## Cooling devices could be highly miniaturized.

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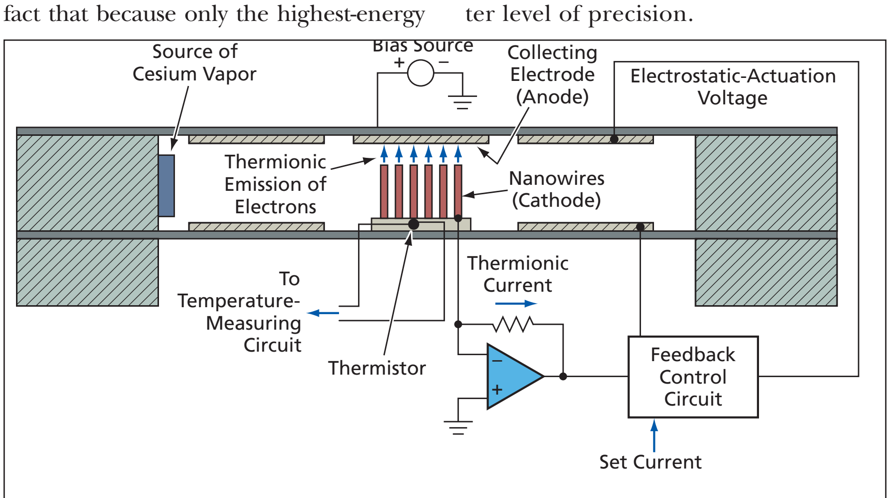
A class of proposed thermionic cooling devices would incorporate precise arrays of metal nanowires as electron emitters. The proposed devices could be highly miniaturized, enabling removal of heat from locations, very close to electronic devices, that have previously been inaccessible for heat-removal purposes. The resulting enhancement of removal of heat would enable operation of the devices at higher power levels and higher clock speeds. Moreover, the mass, complexity, and bulk of electronic circuitry incorporating these highly miniaturized cooling devices could be considerably reduced, relative to otherwise equivalent circuitry cooled by conventional electromechanical, thermoelectric, and fluidic means.

In thermionic cooling, one exploits the fact that because only the highest-energy electrons are thermionically emitted, collecting those electrons to prevent their return to the emitting electrode results in the net removal of heat from that electrode. Collection is effected by applying an appropriate positive bias potential to another electrode placed near the emitting electrode.

The concept underlying the proposal is that the thermionic-emission current and, hence, the cooling effect attainable by use of an array of nanowires could be significantly greater than that attainable by use of a single emitting electrode or other electron-emitting surface. The wires in an array according to the proposal would protrude perpendicularly from a planar surface and their heights would be made uniform to within a sub-nanometer level of precision.




An **Array of Nanowires** would be coated with cesium and tested for effectiveness in thermionic cooling by use of an apparatus shown here in simplified schematic form.

A process of growing metal nanotubes in alumina nanopores has already been demonstrated and would be incorporated into the following process for fabricating an array according to the proposal:

1. An aluminum layer would be deposited on a silicon nitride membrane mesh substrate, the central portion of which would be covered with a silicon island.
2. The aluminum layer would be anodized to grow an alumina nanopore template on the silicon-island portion.
3. Metal nanowires would be grown inside the nanopores of the template by electrodeposition.
4. The exposed surface of the template and nanowires would be subjected to chemical-mechanical polishing.
5. The template would be etched away to expose the array of metal nanowires centered on the silicon island on the nitride membrane mesh substrate.

An experimental prototype array fabricated as described above would be further processed and tested as follows: A thermistor would be embedded in the island. The resulting assembly would be mounted in a vacuum chamber with electrical contacts to the array and the thermistor (see figure). In the vacuum chamber, cesium and/or other alkali metal(s) would be deposited on the nanowires to reduce their work function. The chamber would contain an upper membrane with metal-coated areas that would serve, respectively, as a collecting electrode (anode) and electrostatic-attraction electrodes. By means of electrostatic attraction with feedback