folded beams allow a much smaller foot-
print to achieve the same flexibility as
the conventional configuration.

The breadboard sensor was tested in
a water tank testbed. The testbed in-
cludes a “false bottom” plate and a run-
ing conveyor belt. The false bottom
plate simulates the riverbed, and pro-
vides an opening for attaching the sen-
or mounting plate and an air pocket
for separating the encoder from the
water. The running belt is placed paral-
lel to the direction of measurement,
and is placed on a structure different
than the false bottom for vibration iso-
lolation. The belt was running at controlled
speed of up to 2 m/s in both forward
and opposite directions, about 38 mm
above the false bottom plate where the
sensor was mounted. An average posi-
tion change is about 620 nm, corre-
doping to a change in direction of the
boundary shear stress. The fluctuation
is believed to be caused by the turbu-
lenence of the flow.

Another flexure with a 3D configura-
tion was proposed as well. The 3D version
was designed to allow for a plate to rotate
about an axis defined by three sets of flex-
ures. The plate is mounted on a beam
that passes through this axis and extends
on the other side of the axis where it has
a free end. An optical or capacitive sensor
would read the displacement of the free
end of the beam, which would be used
with the flexure’s stiffness to calculate the
shear force on the sensor plate. This con-
figuration could use the horizontal blade
to separate the test media, such as water,
from the optical or capacitive sensor, but
would present more manufacturing and
packaging challenges.

This work was done by Xiaoqi Bao, Mircea
Badescu, Stewart Sherrit, Yoseph Bar-Cohen,
Shyh-Shiuh Lih, Zensheu Chang, and Brian
P. Trease of Caltech; Kornel Kerenyi of the
Federal Highway Administration; and Scott
E. Widholm and Patrick N. Ostlund of Cal
Poly Pomona for NASA’s Jet Propulsion Lab-
oratory. Further information is contained in
a TSP (see page 1). NPO-47812

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Model-Based Method for Sensor Validation

Fault detection, diagnosis, and prog-
nosis are essential tasks in the opera-
tion of autonomous spacecraft, instru-
ments, and in situ platforms. One of
NASA’s key mission requirements is ro-
bust state estimation. Sensing, using a
wide range of sensors and sensor fu-
sion approaches, plays a central role in
robust state estimation, and there is a
need to diagnose sensor failure as well
as component failure. Sensor valida-
tion can be considered to be part of
the larger effort of improving reliabil-
ity and safety.

The standard methods for solving the
sensor validation problem are based on
probabilistic analysis of the system, from
which the method based on Bayesian
networks is most popular. Therefore,
these methods can only predict the most
probable faulty sensors, which are sub-
ject to the initial probabilities defined
for the failures.

The method developed in this work
is based on a model-based approach
and provides the faulty sensors (if
any), which can be logically inferred
from the model of the system and the
sensor readings (observations). The
method is also more suitable for the
systems when it is hard, or even impos-
bile, to find the probability functions
of the system. The method starts by a
new mathematical description of the
problem and develops a very efficient
and systematic algorithm for its solu-
tion. The method builds on the con-
cepts of analytical redundant relations
(ARRs).

This work was done by Farrokh Vatan of
Caltech for NASA’s Jet Propulsion Laboratory.
Further information is contained in a TSP
(see page 1).

The software used in this innovation is
available for commercial licensing. Please con-
tact Daniel Broderick of the California Insti-
tute of Technology at danielb@caltech.edu.
Refer to NPO-47574.