Eddy Currents in a Moving Conductor

(NSTX Fields)

M. Ulrickson

Presented at the ALIST/ALPS Meeting
April 11, 2003

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy under contract DE-AC04-94AL85000.

Sandia National Laboratories

Participants

- Richard Nygren
- Tina Tanaka
- Jimmie McDonald
- Tom Lutz
- Fred Bauer
- Ken Troncosa
- Dennis Youchison

Sandia National Laboratories

Recent Modeling Results

- Modeling of electromagnetic flow meter
  - Actual design of flow meter used
  - Predicted voltage agrees well with published data
- PC Opera used to calculate currents induced in flowing lithium in the LIMITS magnet
  - Model assumes rigid motion of the lithium
  - Constant linear velocity assumed

Details of OPERA Solution

- Model size was 1.2 M elements
- Li slab was 20 x 5 mm and the velocity was 10 m/s
- Solution included nonlinear properties of iron and the permanent magnets.
- Solution took 7 iterations and 64750 min. (44.9 days)

Linear Motion of a Conductor in a Magnetic Field

Physical dimensions of the object are small compared to the wavelength of the time varying fields (low frequency limit)

$$\vec{\nabla} \times \vec{H} = \vec{J}$$

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

where

$$\vec{J} = \sigma\left(\vec{E} + \vec{u} \times \vec{B}\right)$$

and

$$\vec{B} = \vec{\nabla} \times \vec{A}$$

Sandia National Laboratories

Linear Motion of a Conductor in a Magnetic Field

For a moving conductor where the cross section does not change (velocity **u**), the current is related to the potentials **A** and V by

$$\vec{J} = \sigma\left(\vec{u} \times \vec{\nabla} \times \vec{A}\right) - \sigma \nabla V$$

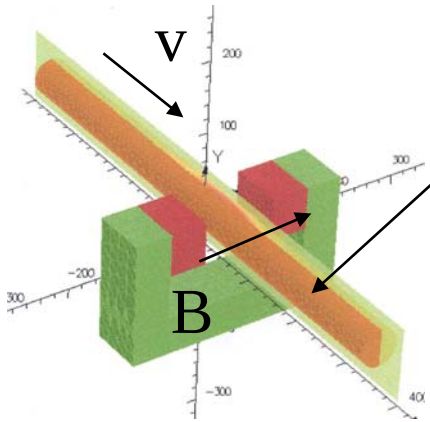
The equation that must be solved is

$$\nabla \times \frac{1}{\mu} \nabla \times \vec{A} - \nabla \frac{1}{\mu} \nabla \bullet \vec{A} = \sigma\left(\vec{u} \times \vec{\nabla} \times \vec{A}\right) - \sigma \nabla V$$

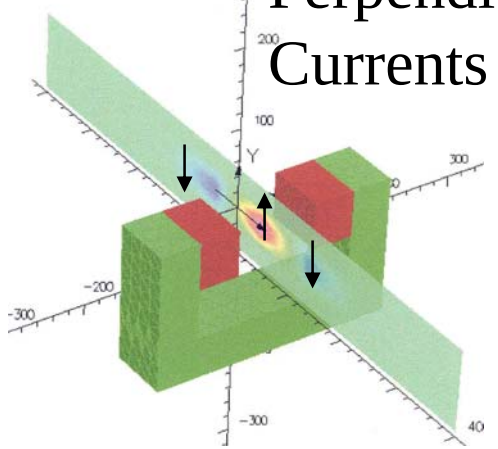
It is also necessary to solve the secondary equation

$$\nabla \bullet \sigma \nabla V - \sigma \nabla \bullet \left(\vec{u} \times \vec{\nabla} \times \vec{A}\right) = 0$$

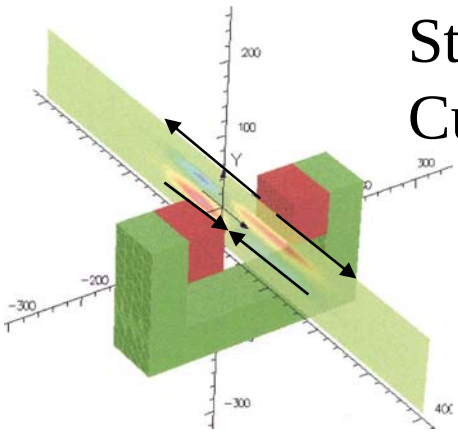
Motion Induced Currents



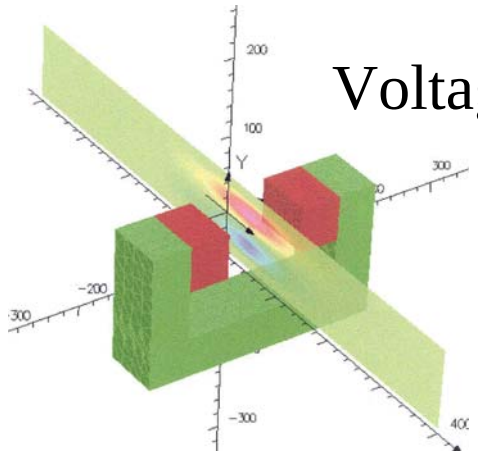
Liquid Metal



Perpendicular Currents



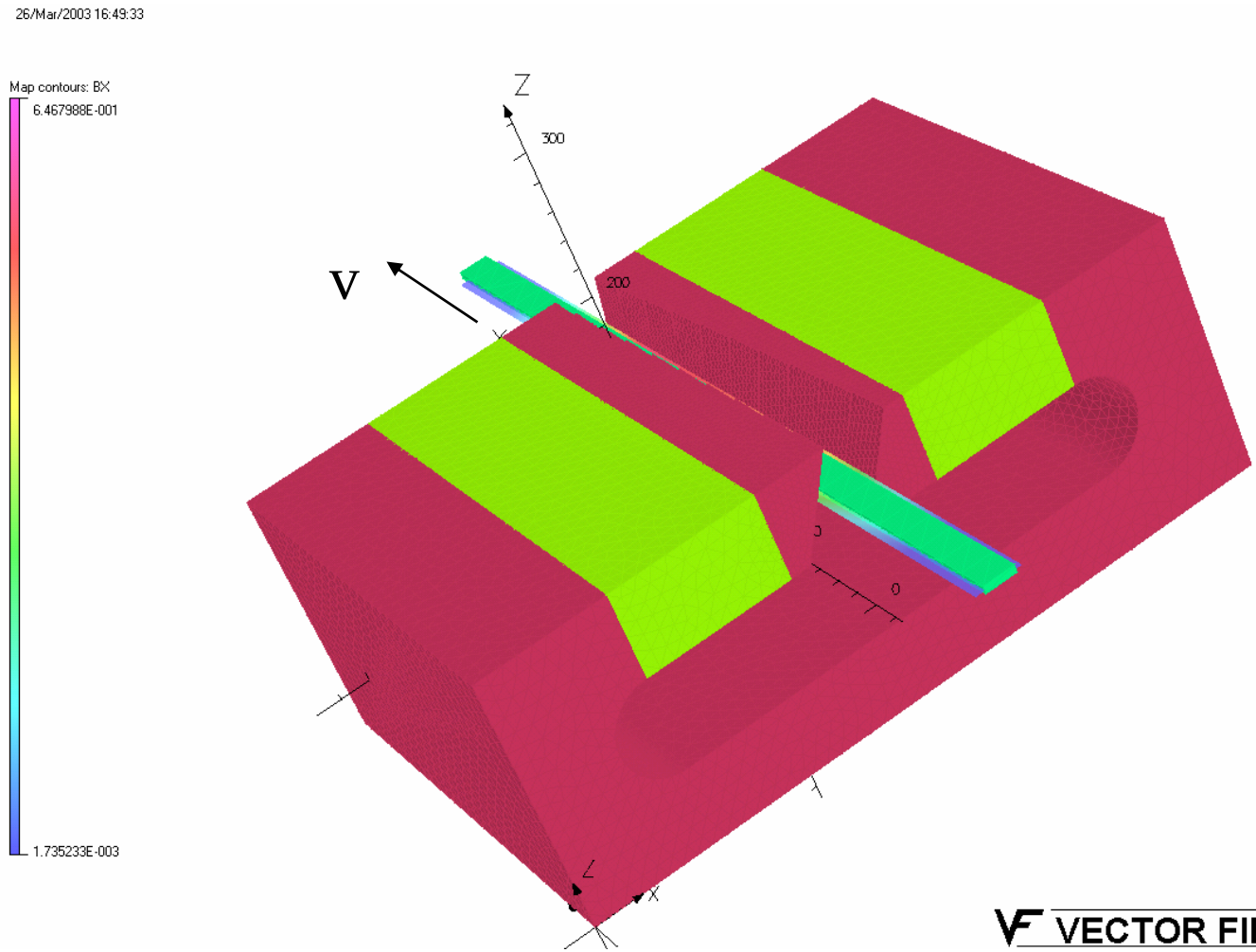
Streamwise Currents



Voltage

Sandia National Laboratories

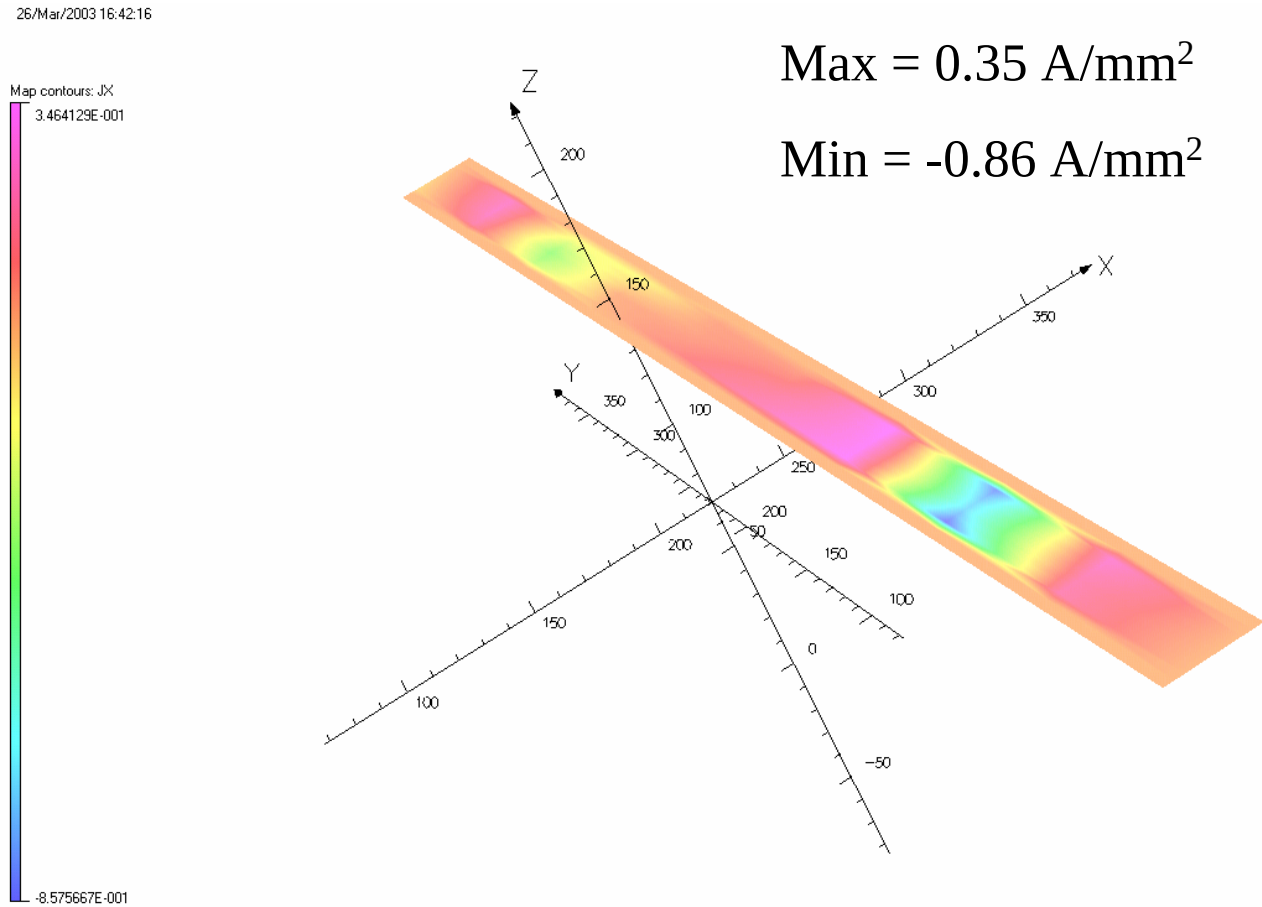
Solution Model



VECTOR FIELDS

Sandia National Laboratories

Induced Current X Direction



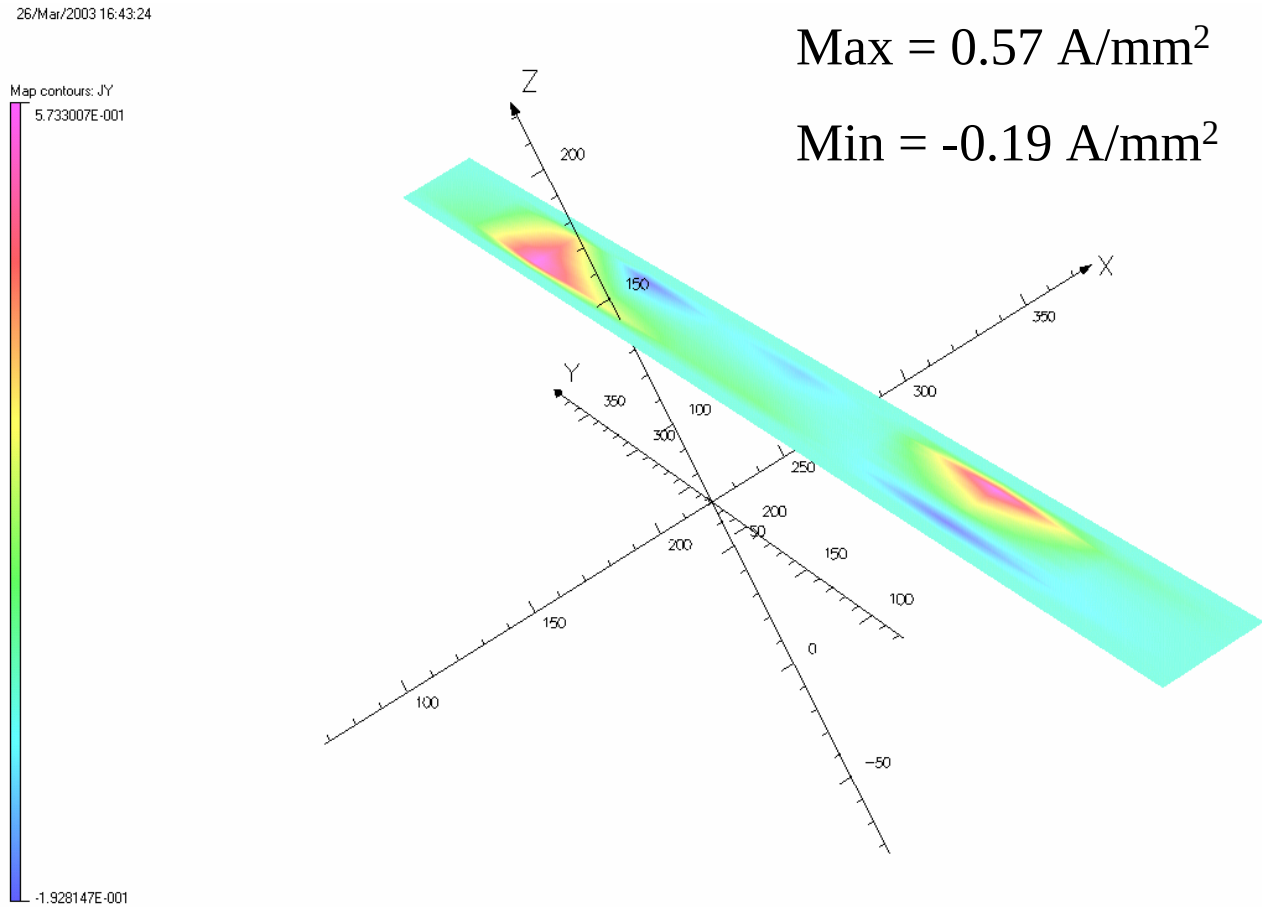
Max = 0.35 A/mm^2

Min = -0.86 A/mm^2

VECTOR FIELDS

Sandia National Laboratories

Induced Current Y Direction



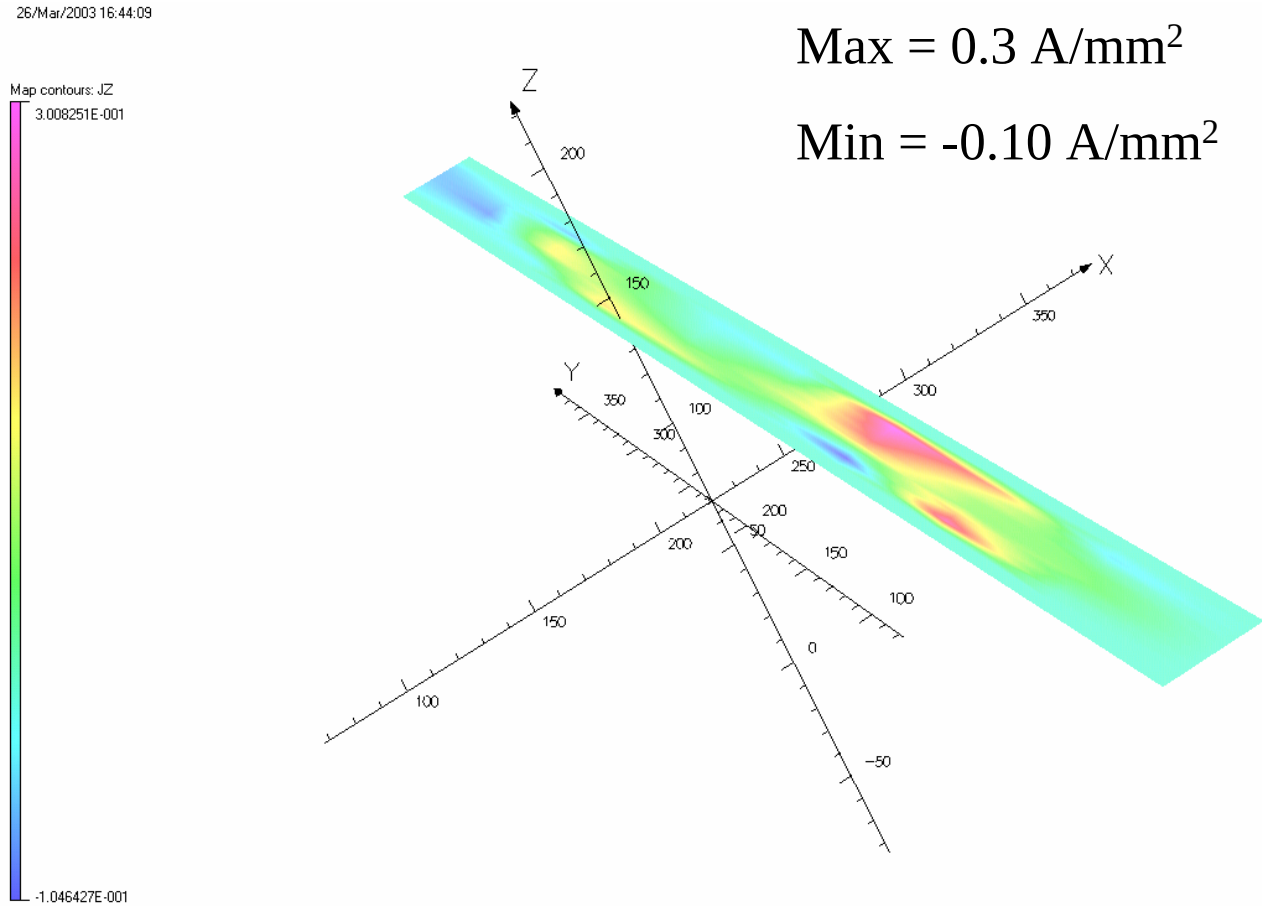
Max = 0.57 A/mm^2

Min = -0.19 A/mm^2

VECTOR FIELDS

Sandia National Laboratories

Induced Current Z Direction



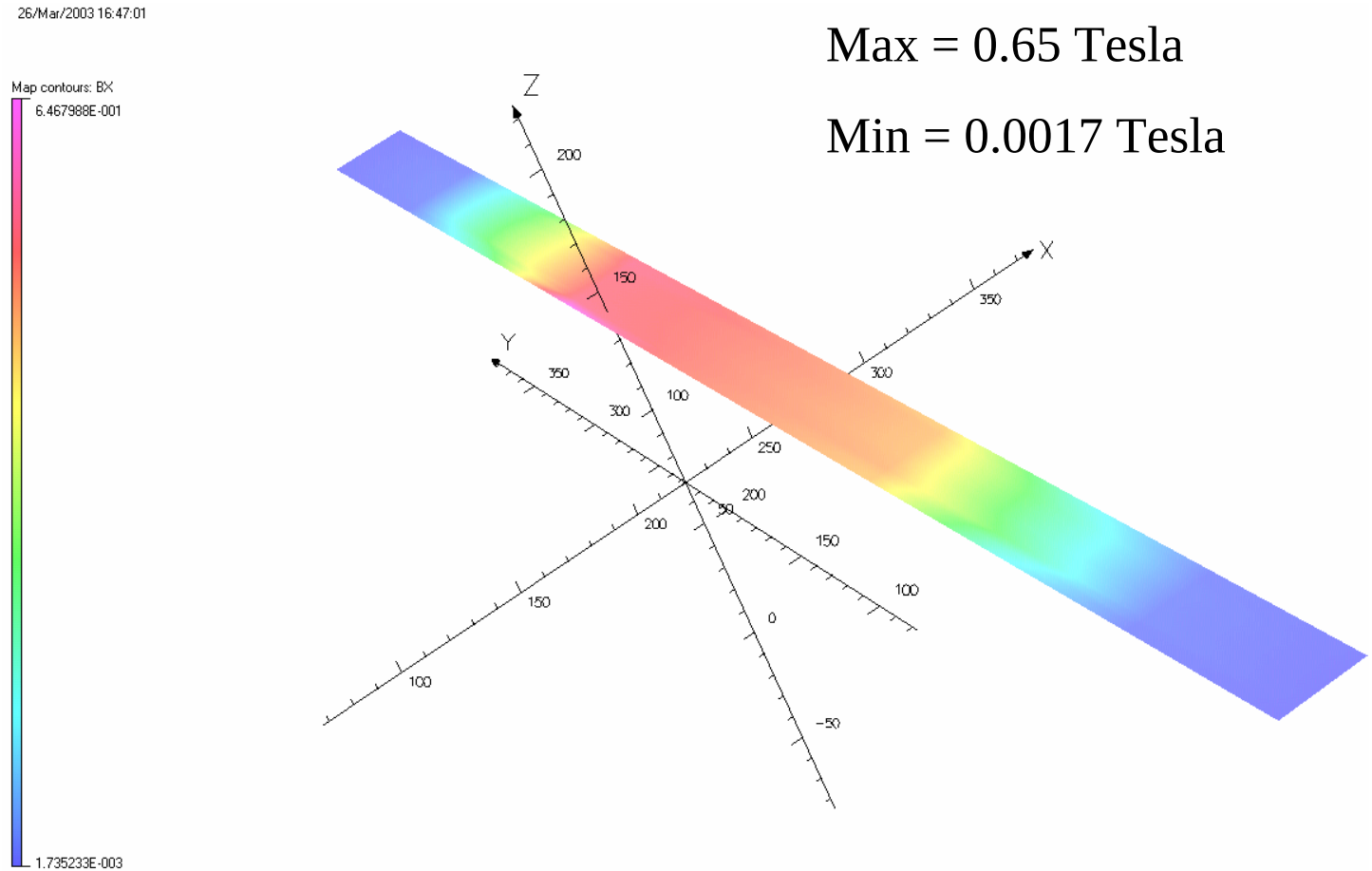
Max = 0.3 A/mm^2

Min = -0.10 A/mm^2

VECTOR FIELDS

Sandia National Laboratories

Magnetic Field (Horizontal)



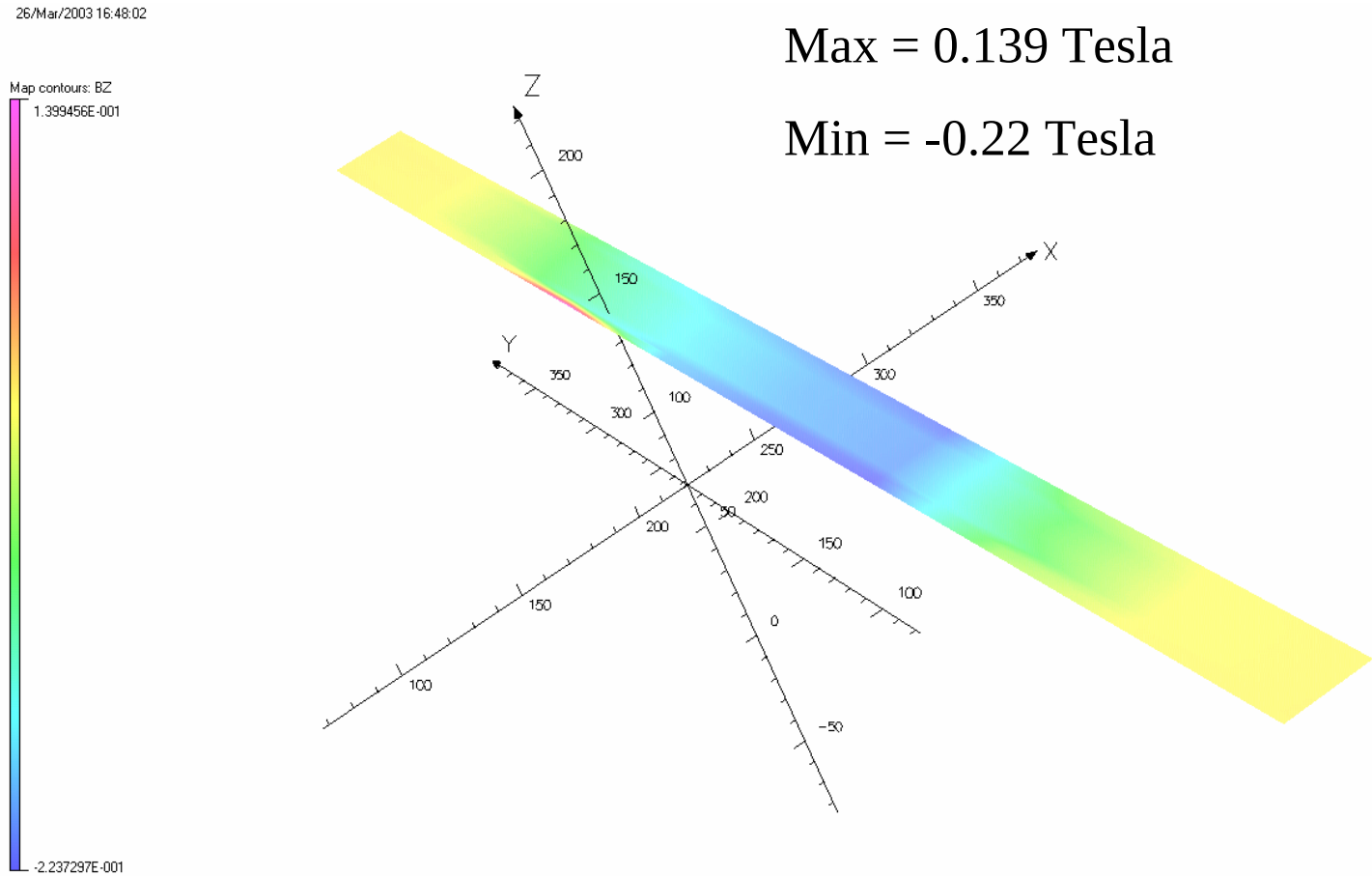
Max = 0.65 Tesla

Min = 0.0017 Tesla

VECTOR FIELDS

Sandia National Laboratories

Magnetic Field (Normal)



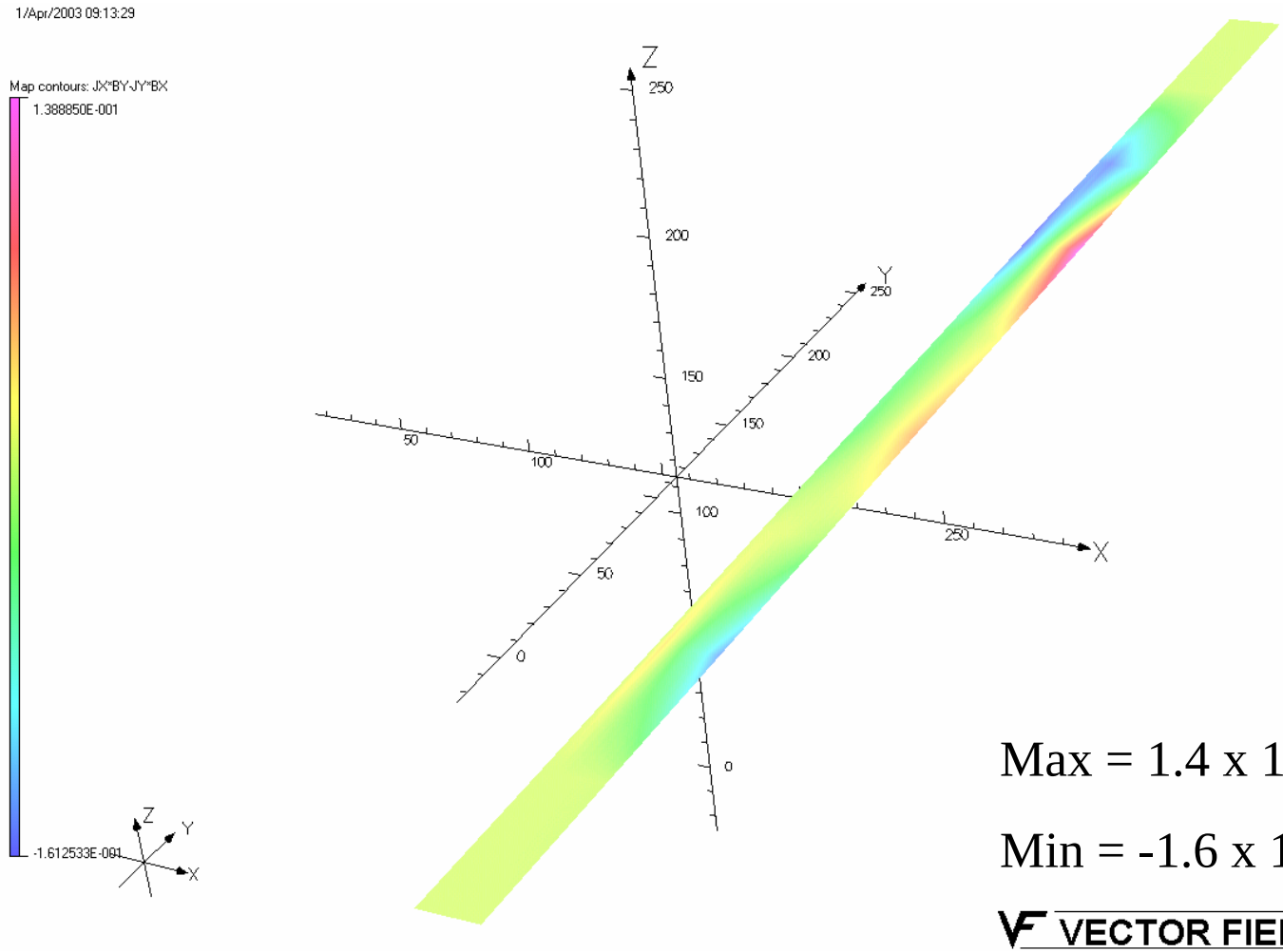
Max = 0.139 Tesla

Min = -0.22 Tesla

VECTOR FIELDS

Sandia National Laboratories

Induced Force (JXB) Fz



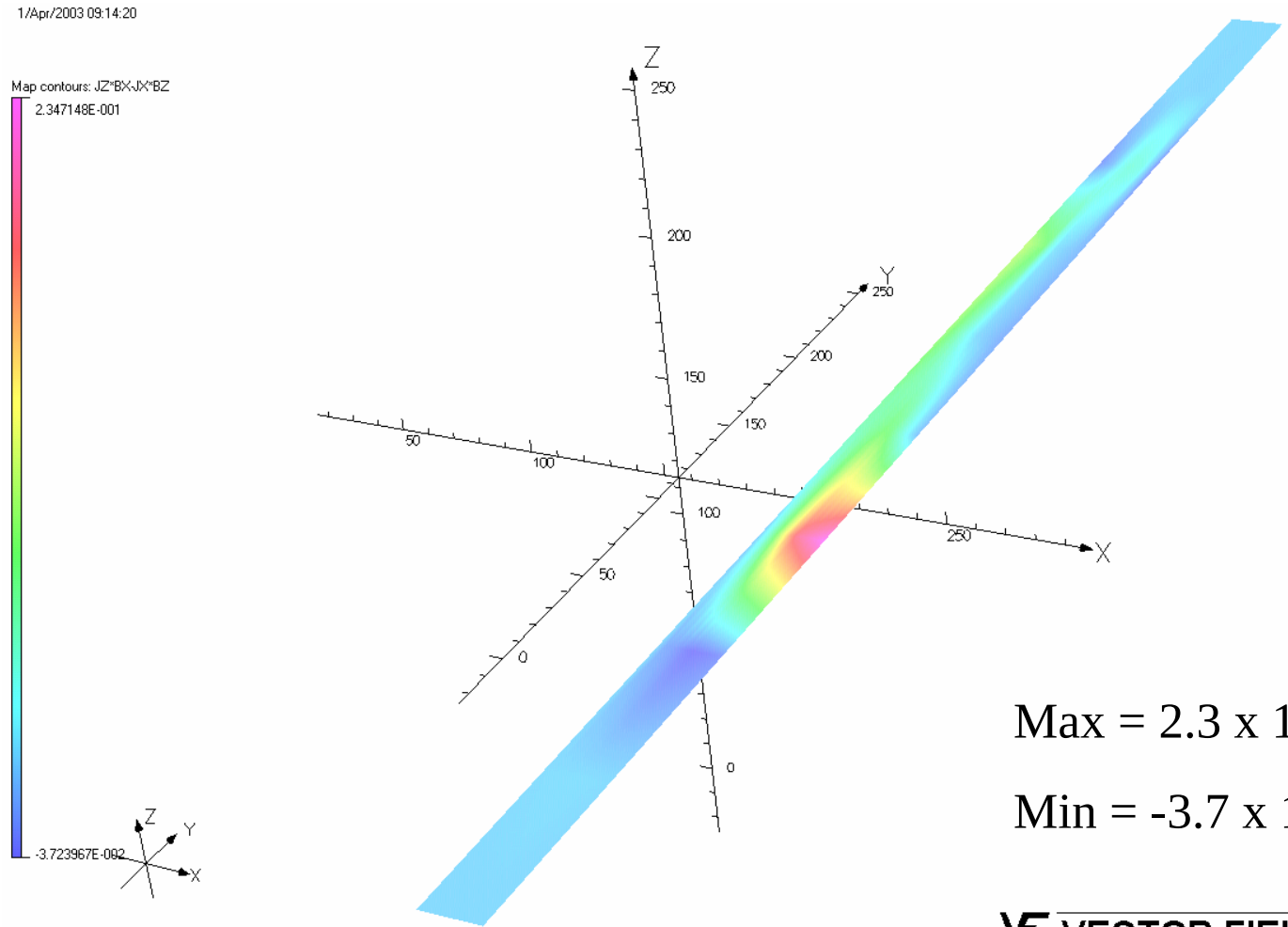
Max = 1.4 x 10^5 N

Min = -1.6 x 10^5 N

VECTOR FIELDS

Sandia National Laboratories

Induced Force Fy



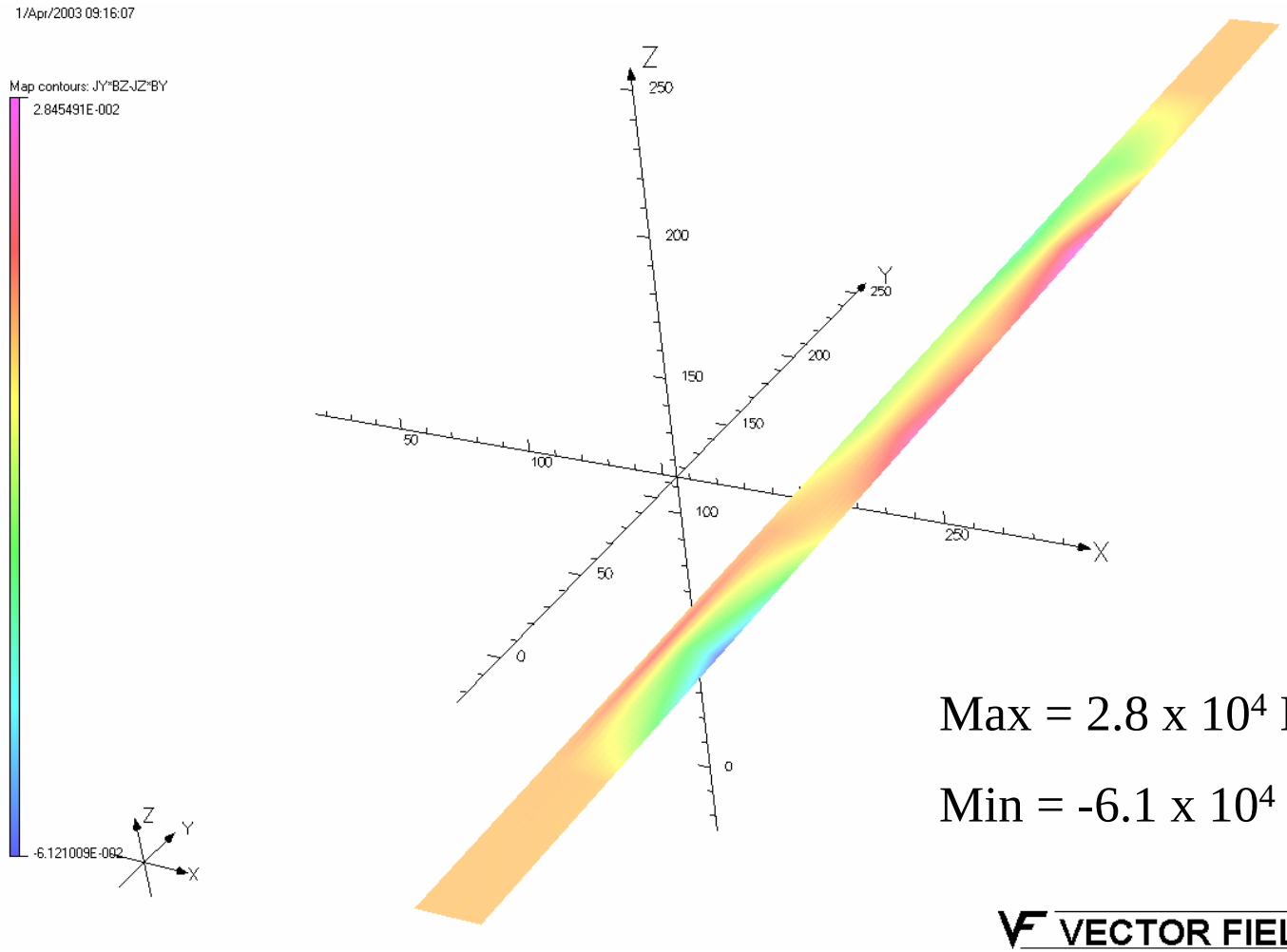
Max = 2.3 x 10^5 N

Min = -3.7 x 10^5 N

VECTOR FIELDS

Sandia National Laboratories

Induced Force Fx



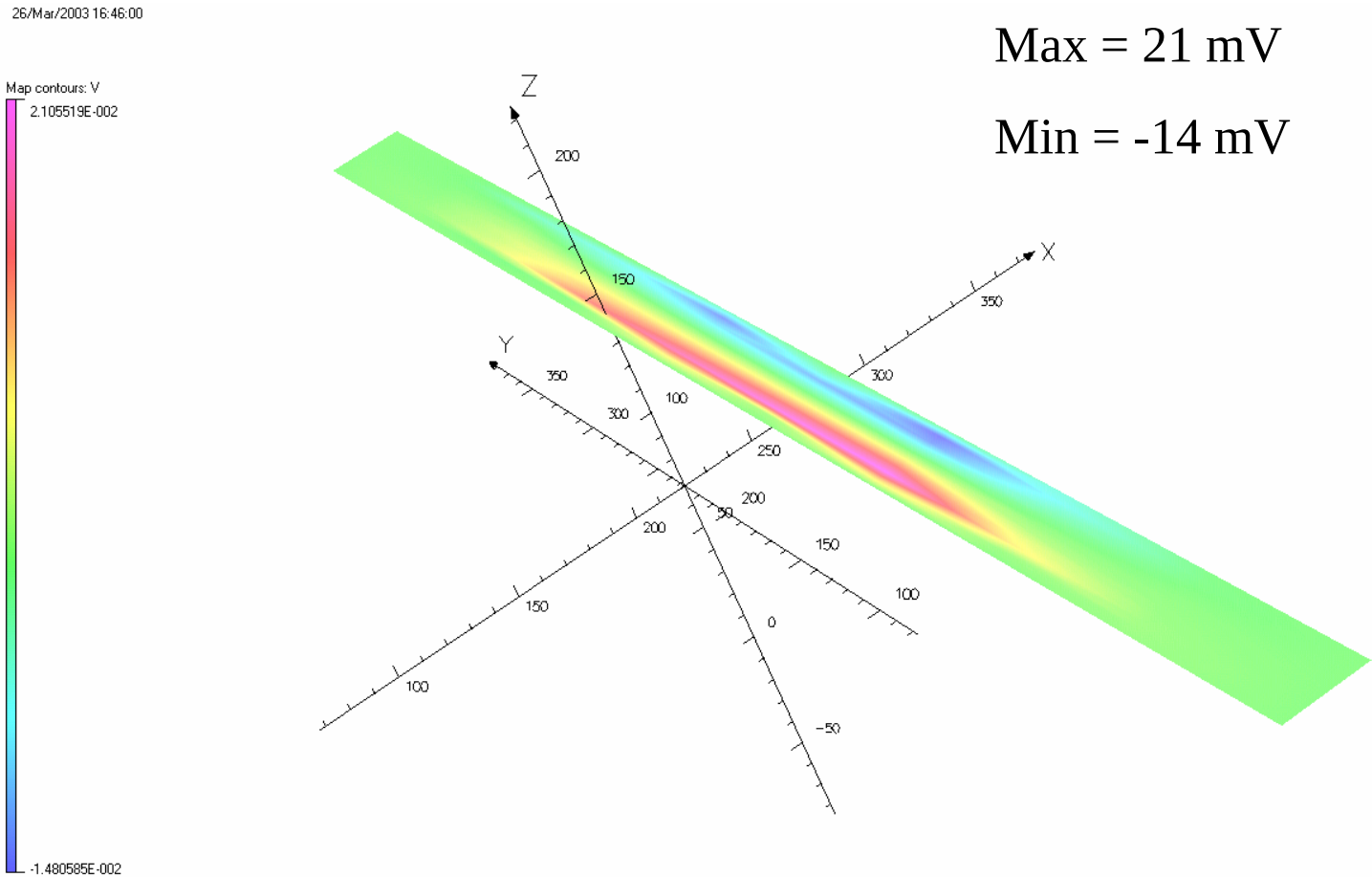
Max = 2.8 x 10^4 N

Min = -6.1 x 10^4 N

VECTOR FIELDS

Sandia National Laboratories

Induced Electric Potential



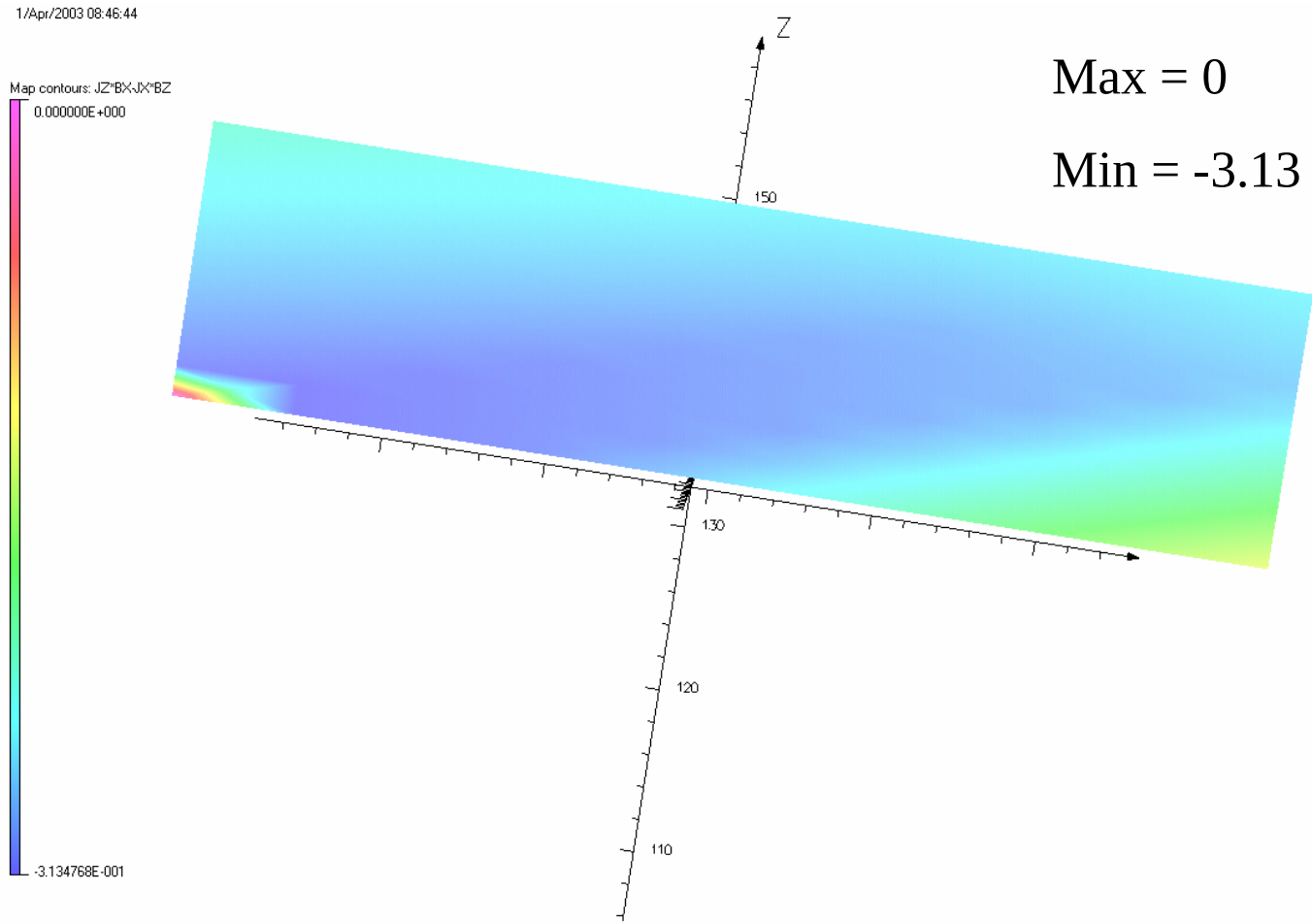
Max = 21 mV

Min = -14 mV

VECTOR FIELDS

Sandia National Laboratories

Cross Section Fy Force at Entrance



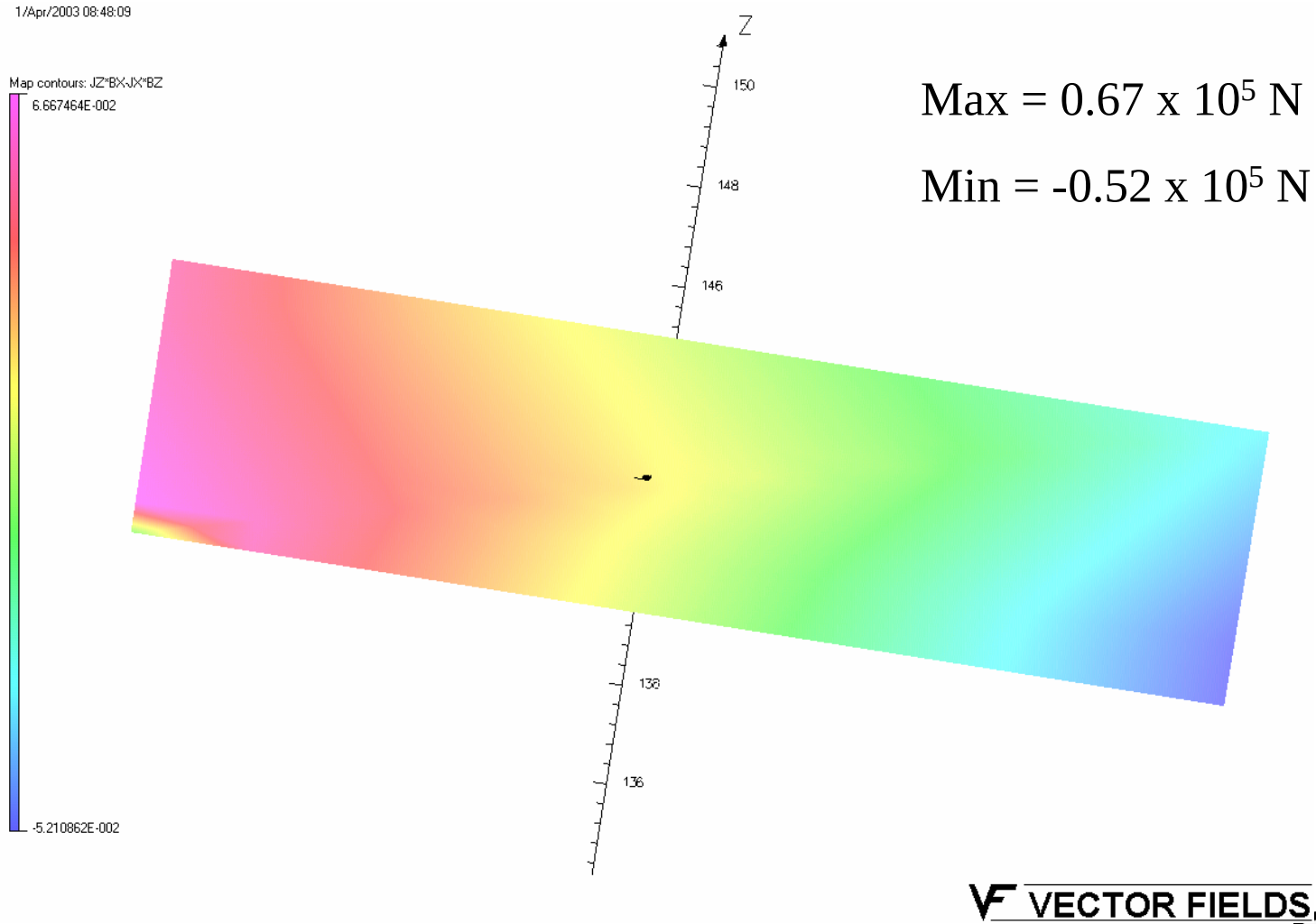
Max = 0

Min = -3.13×10^5 N

VECTOR FIELDS

Sandia National Laboratories

Cross Section Force Fy at Y=150 mm



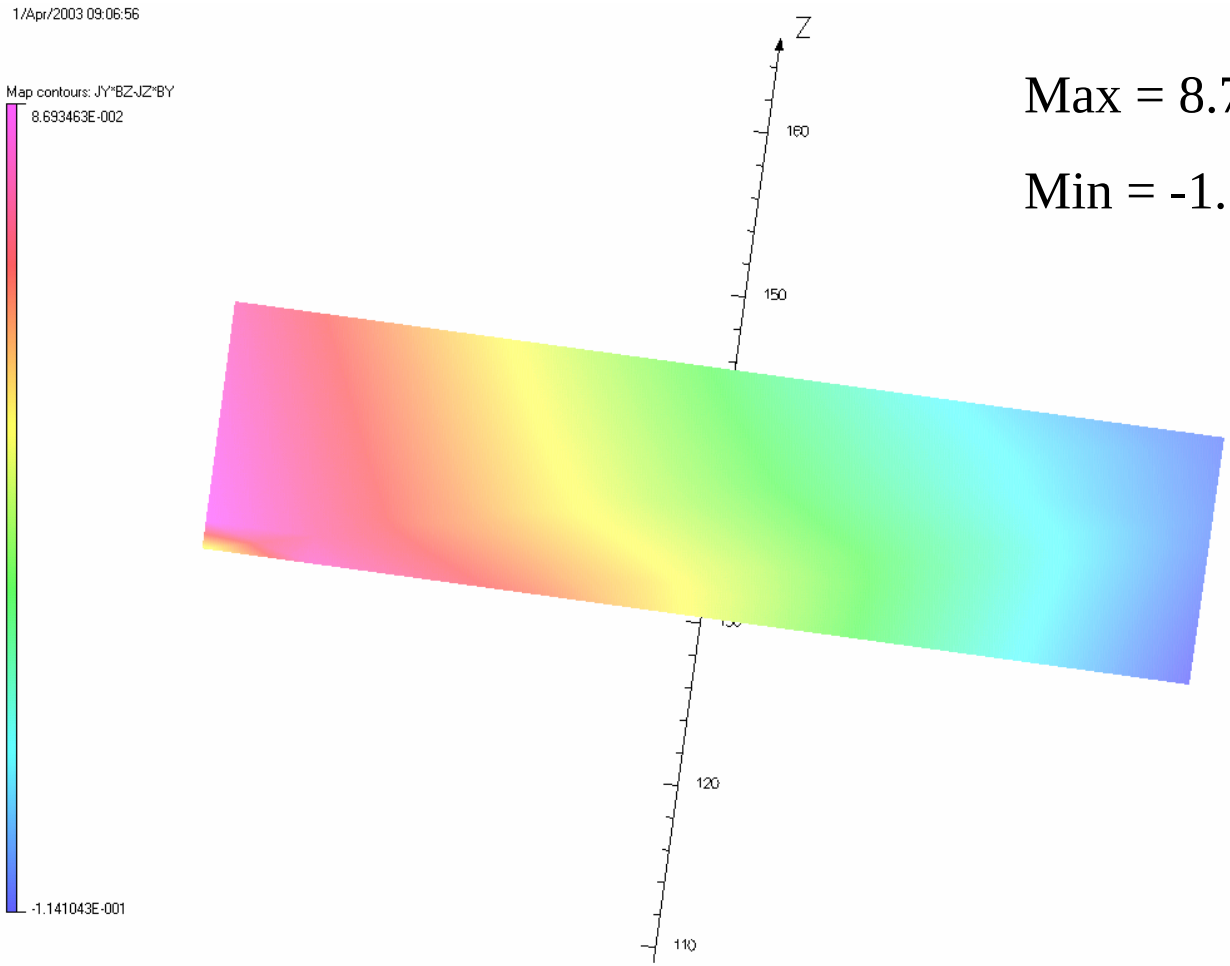
Max = 0.67 x 10^5 N

Min = -0.52 x 10^5 N

VECTOR FIELDS

Sandia National Laboratories

Cross Section Fx at Entrance



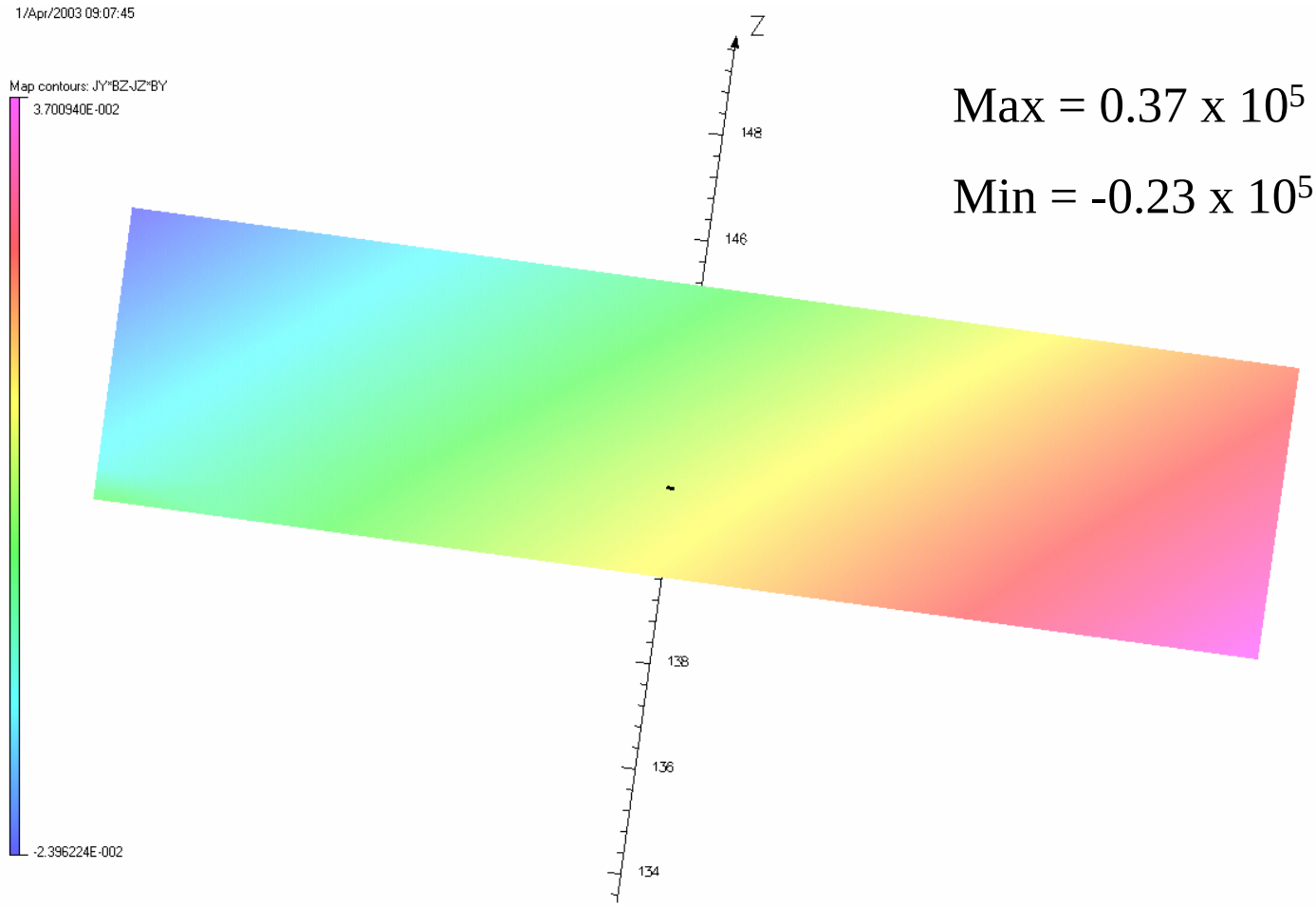
Max = 8.7×10^4 N

Min = -1.14×10^5 N

VECTOR FIELDS

Sandia National Laboratories

Cross Section Fx at y=150 mm



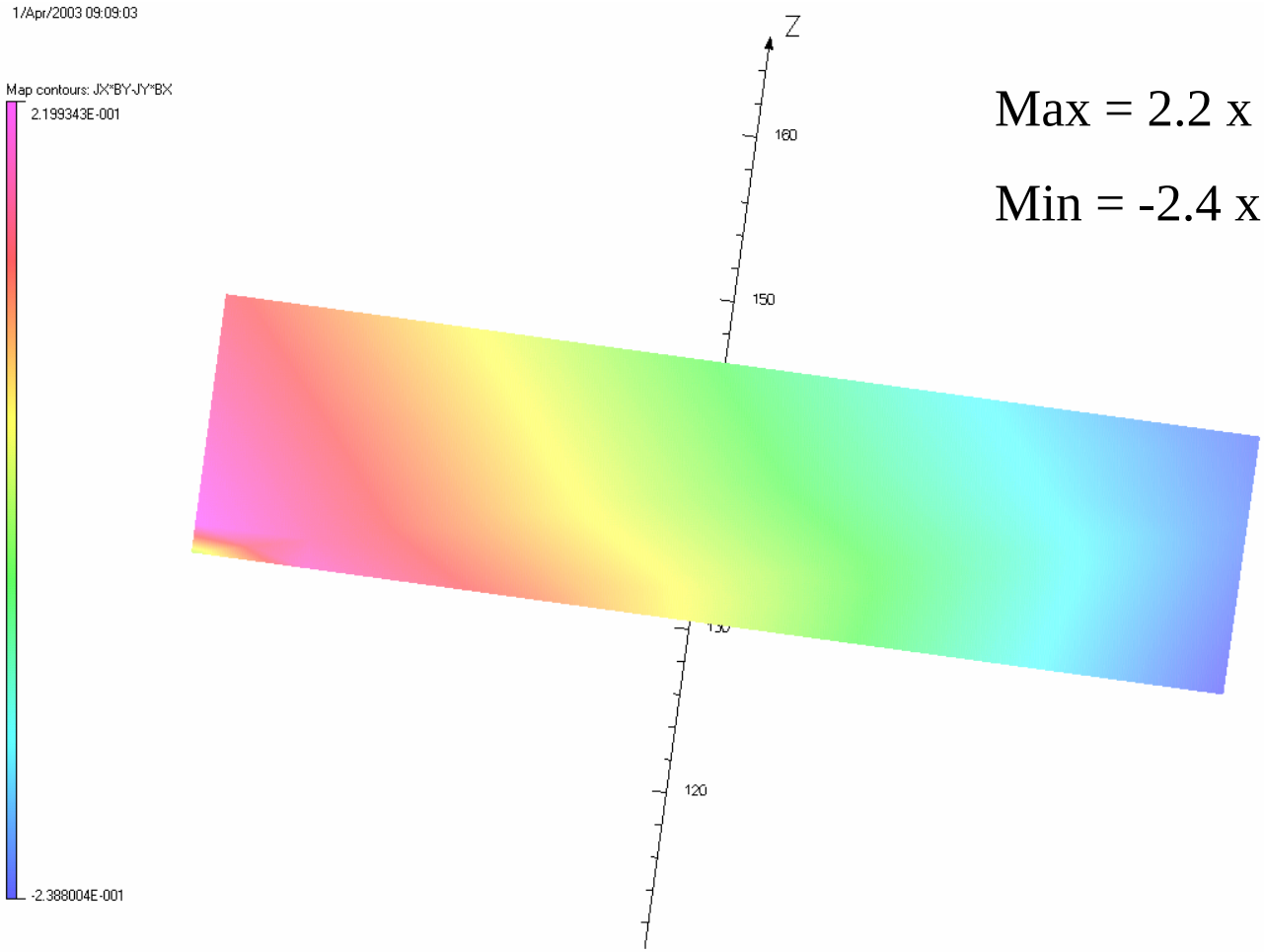
Max = 0.37 x 10^5 N

Min = -0.23 x 10^5 N

VECTOR FIELDS

Sandia National Laboratories

Cross Section Fz at Entrance



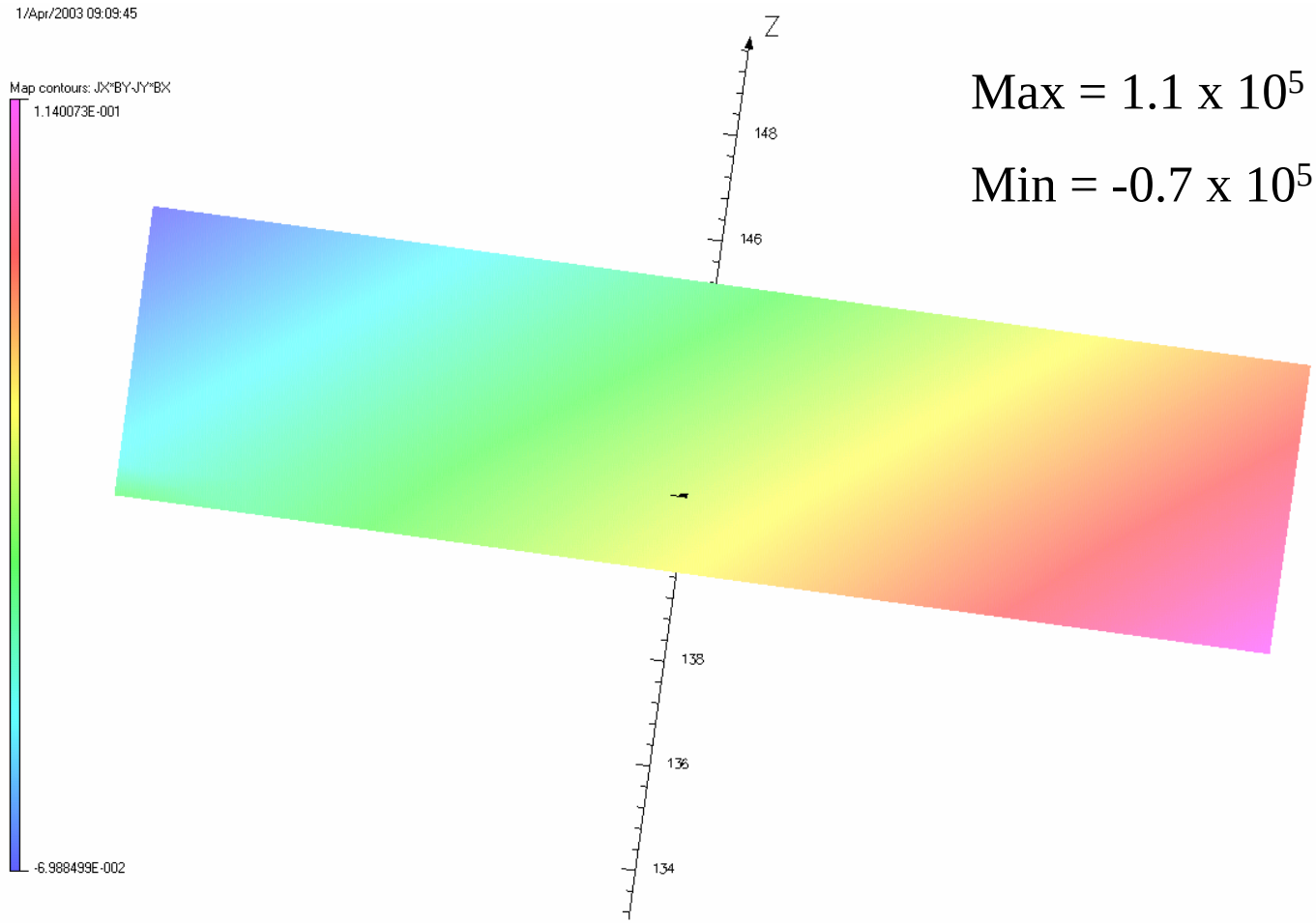
Max = 2.2 x 10^5 N

Min = -2.4 x 10^5 N

VECTOR FIELDS

Sandia National Laboratories

Cross Section Fz at y=150 mm



Max = 1.1 x 10^5 N

Min = -0.7 x 10^5 N

VECTOR FIELDS

Sandia National Laboratories