

Friendly Competition

WACO Trucks of Eugene, Oregon, is out-lifting and out-selling the competition with its new line of telescopic handlers. As Jason Taylor, WACO sales director says "by offering a 7,000-, 9,000-, and 11,000-pound machine, we can offer the end-user a little more capacity and still be price competitive with the 6,000-, 8,000-, and 10,000-pound classes."

From the very start, stress analysis has played an important role in the development of these new trucks. The engineering goals stated by Lee Reinhart of WACO were quite direct: our trucks must be stronger, lighter, and easier-to-manufacture than competing trucks. To kick off this project and to develop a baseline for what might be expected, an analysis of a market leader's lift truck was performed. Interesting enough several high stressed regions were found in their design and, in fact, had been causing problems for this manufacturer. This gave us some confidence that our modeling procedure was on the right track.

The idealization process for a lift truck was not trivial and required the complete tool box of finite elements. The boom sections were modeled with plate elements, while the hydraulic cylinders and axles were idealized as beam elements. The truck frame was a combination of plate and hexahedral solid elements. Then the fun starts. The boom is attached to the truck frame through a large diameter steel pin. The contact interface between the pin / boom / and truck was simulated via gap and rigid link elements. This makes the whole model geometrically nonlinear.

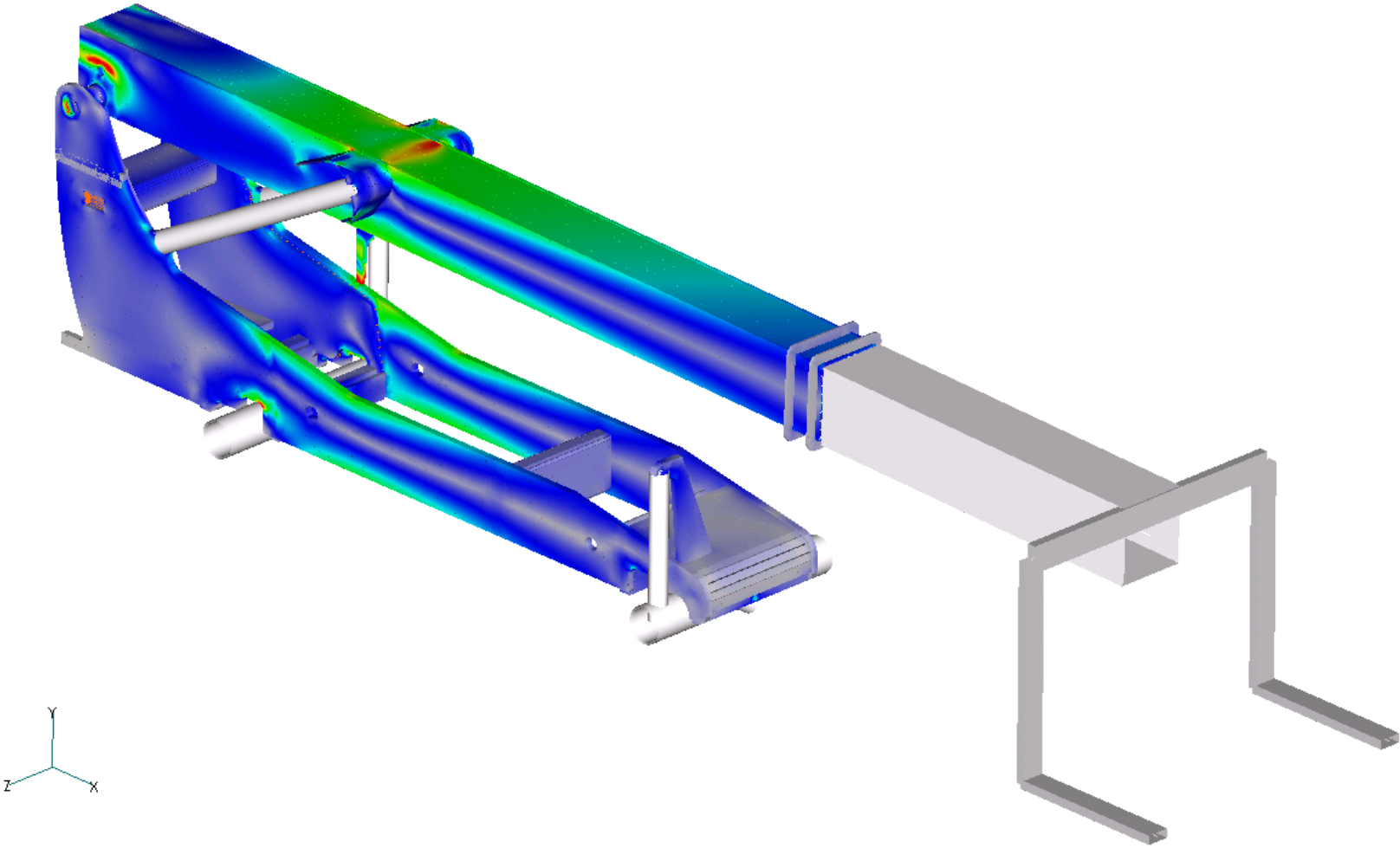
Long analysis story short: with a robust, predictive model several manufacturing scenarios could be quickly simulated. At the end of this process we had a "killer" design that we knew was stronger and tougher than anything on the market. Even better, during this process we uncovered several "mechanics secrets" about the structural behavior of lift trucks. Consequently, as WACO continues to grow their "secret weapons" will be generating revenue and outfoxing the competition.



WACO Lift Trucks & Attachments rough terrain telescopic handler. The truck is rated at 9,000 lb lift capacity.

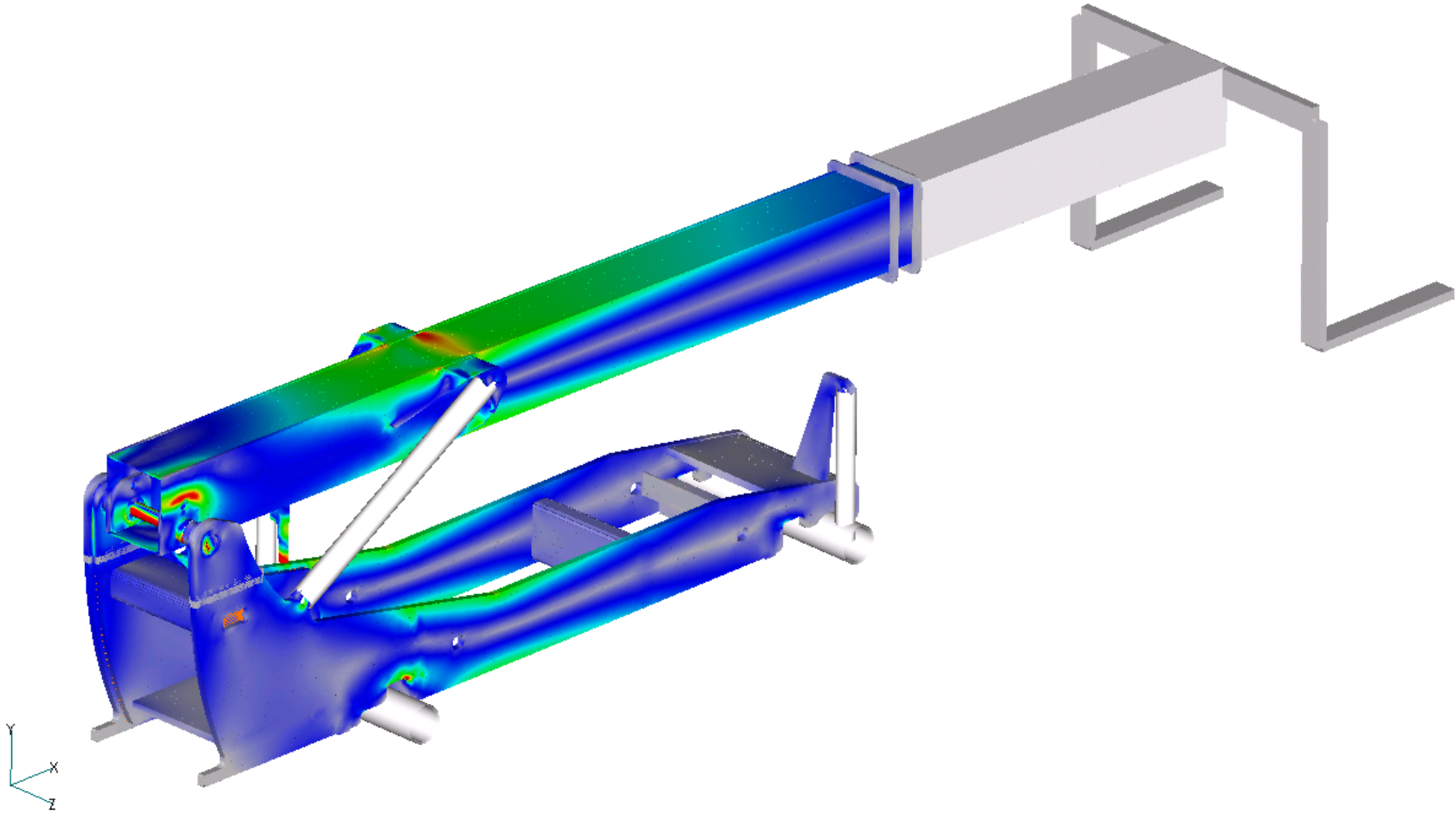


With the boom fully extended, the truck has a reach of 40 ft.



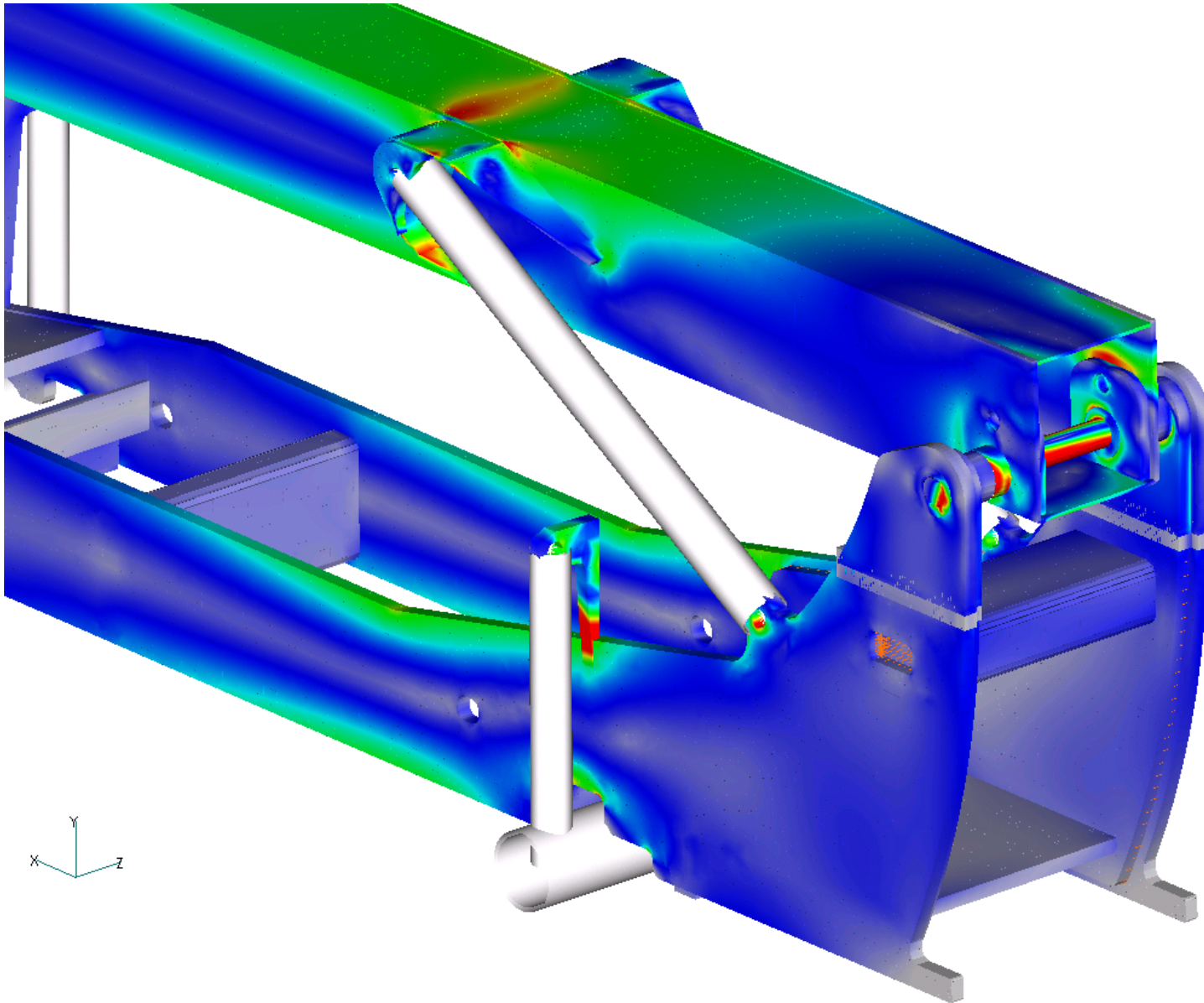
FEA model of the WACO 9045 lift truck.

August 2003

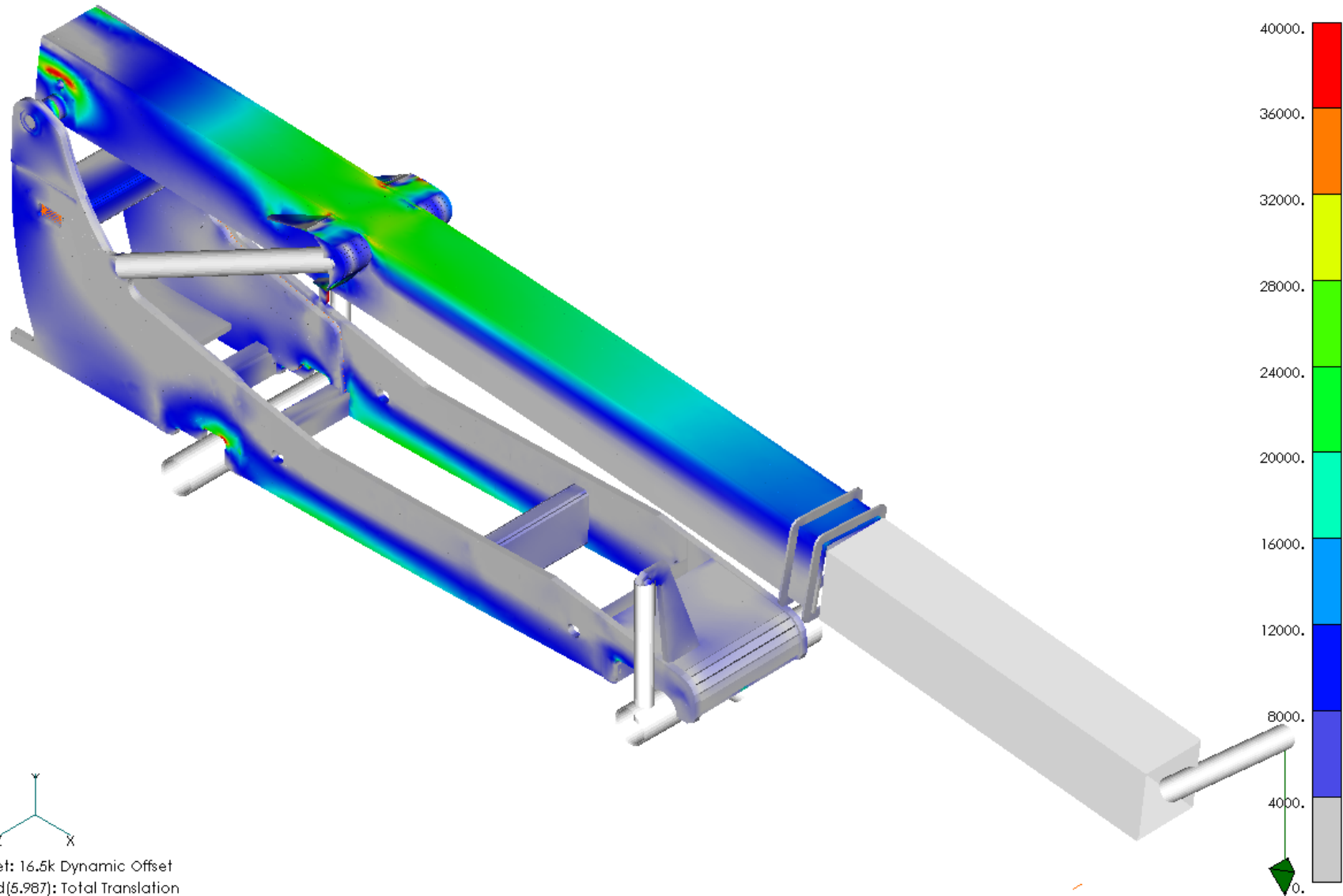


FEA model of the WACO 9045 lift truck.

August 2003



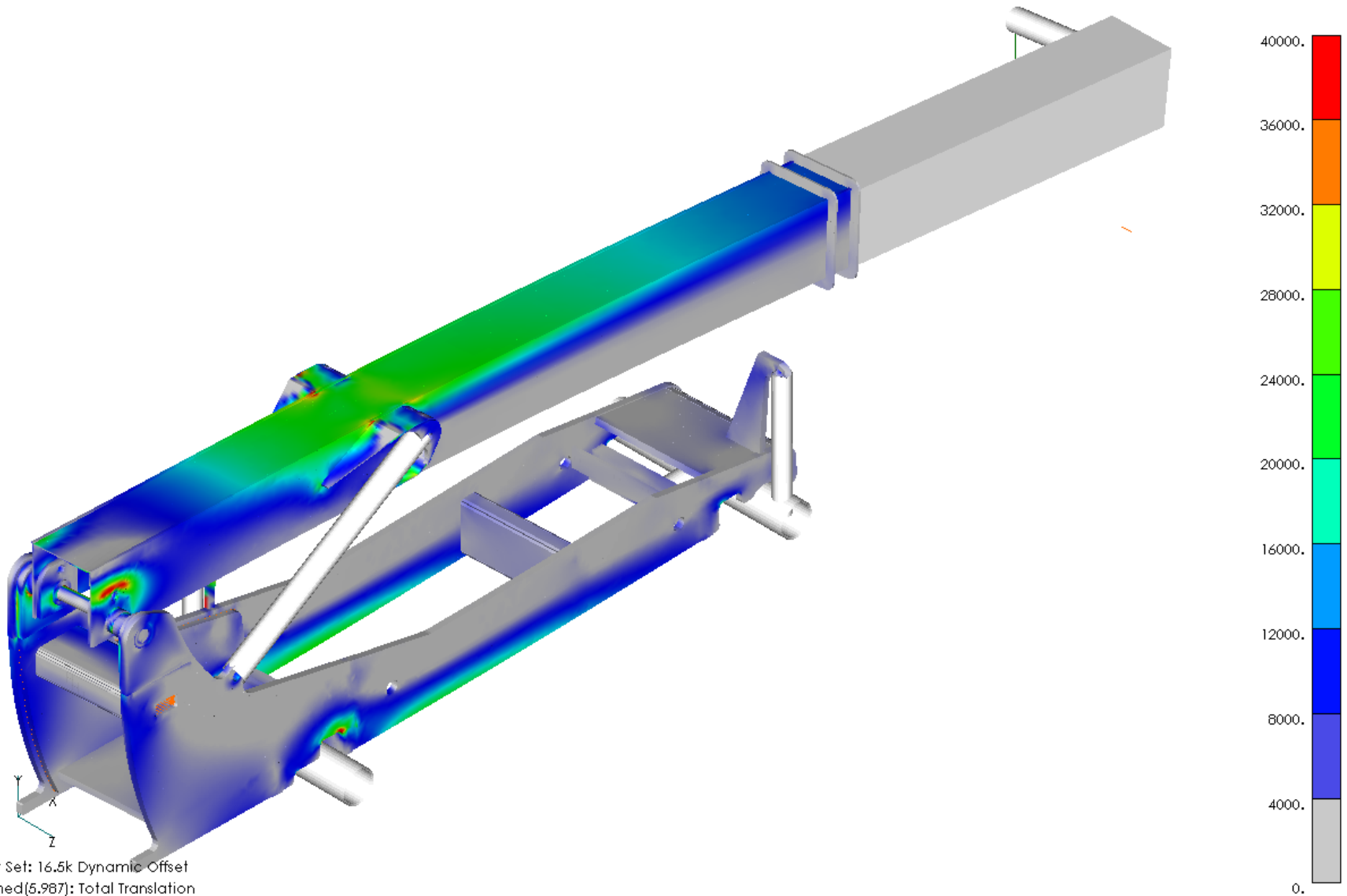
The truck FEA model required the use of a wide range of element types. For example, the hydraulic cylinders were modeled with beam elements, the boom with plates, and the truck body with hex and plate elements. Gap and rigid link elements were used to simulate the interaction between the boom pin / boom / and truck body.



August 2003

Output Set: 16.5k Dynamic Offset
Deformed(5.987): Total Translation
Contour: Plate Bot Major Stress, Plate Top Major Stress, Solid Max Prin Stress

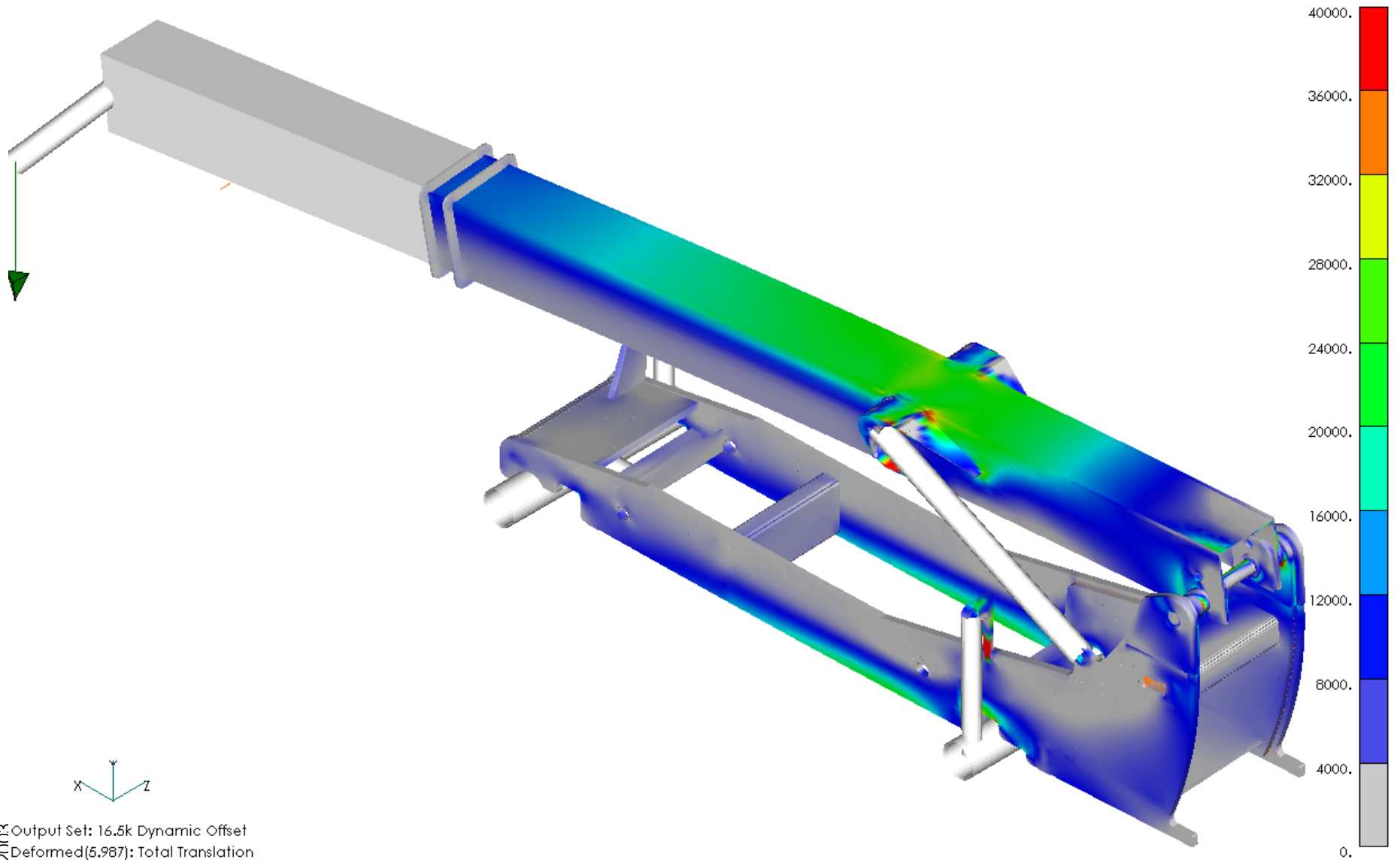
Waco truck 1145 model. The 16,500 lbf is hanging off of one fork in the front. The stress legend is capped or limited to 40,000 psi to better display the stresses on the boom and the side plates. Individual peak stresses within specific components will be discussed in subsequent slides.



Output Set: 16.5k Dynamic Offset
Deformed[5.987]: Total Translation
Contour: Plate Bot Major Stress, Plate Top Major Stress, Solid Max Prin Stress

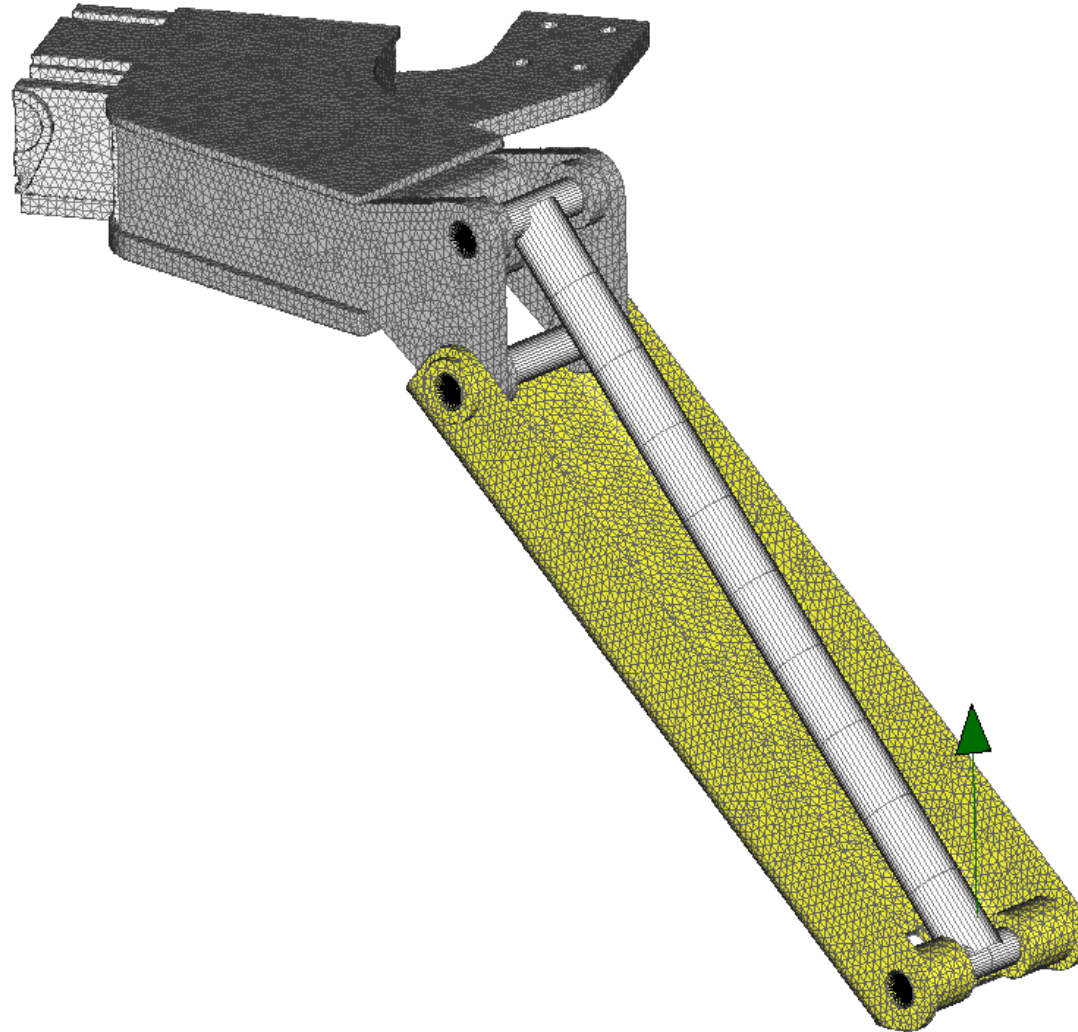
August 2003

Another view of the WACO 1145 boom truck.



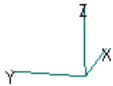
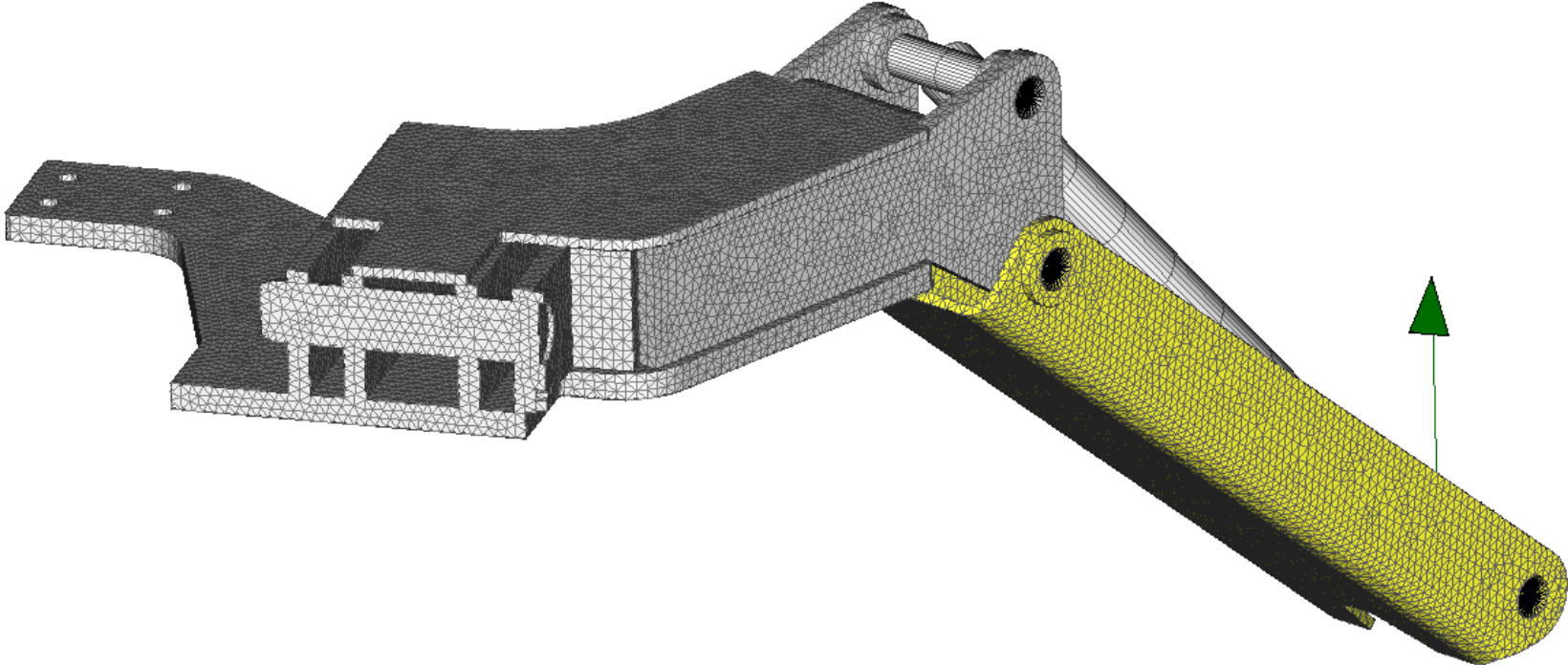
August 2003
Output Set: 16.5k Dynamic Offset
Deformed(5.987): Total Translation
Contour: Plate Bot Major Stress, Plate Top Major Stress, Solid Max Prin Stress

Another view of the truck model.



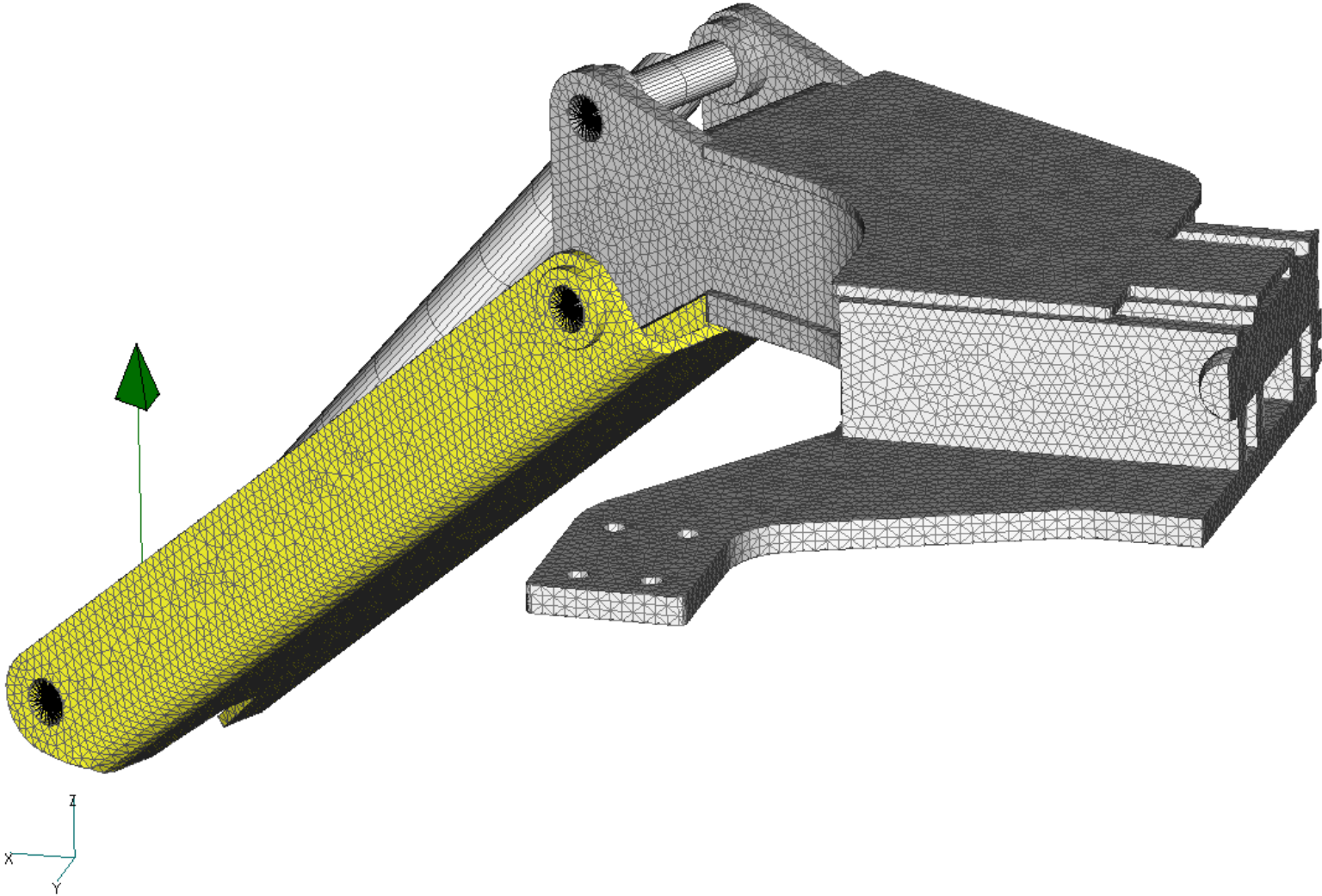
August 2003

Under worst case conditions, one outrigger arm would support the total load carried by the front axle. Under full design load (11,000 lbf load X 1.5 dynamic bounce factor = 16,500 lbf) of 16.5klbf, one outrigger carries a load of 35,000 lbf. The pins and hydraulic cylinder were modeled as simple beams to facilitate load transfer between the parts.



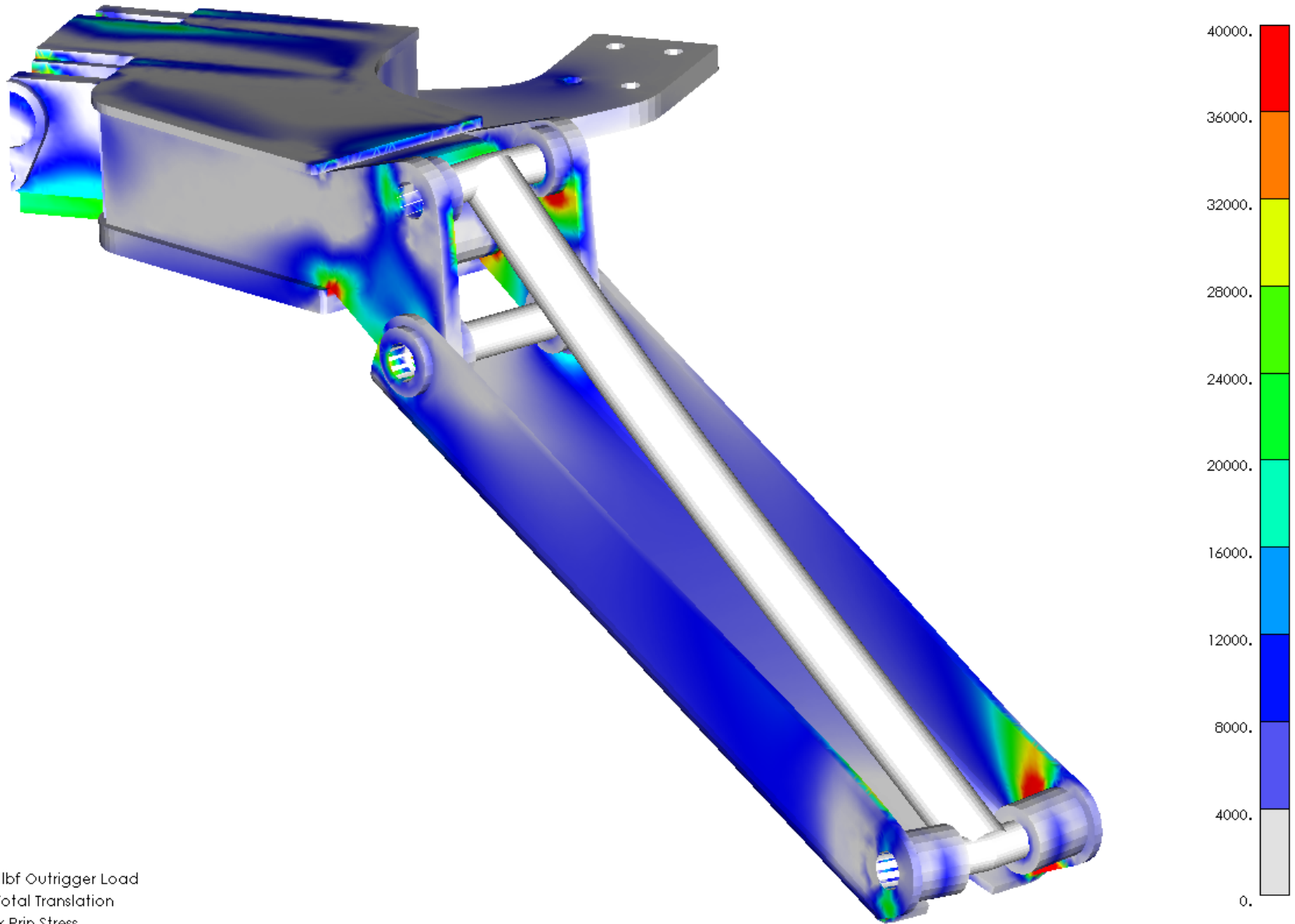
August 2003

Another view of modeling structure.



Another view of modeling structure.

August 2003

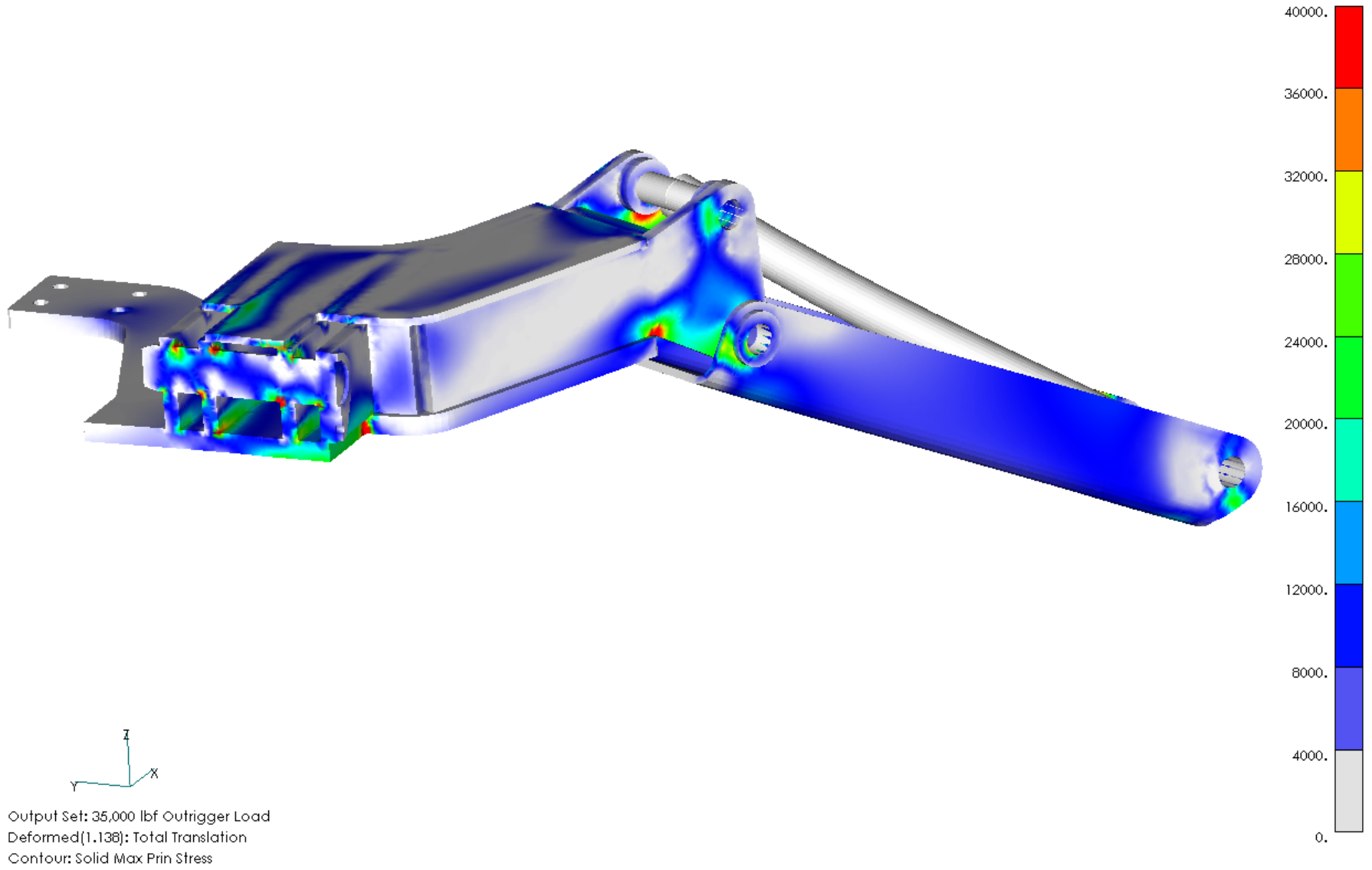


August 2003



Output Set: 35,000 lbf Outrigger Load
Deformed(1.138): Total Translation
Contour: Solid Max Prin Stress

The maximum principle stress is contoured over the structure. This stress vector is dominantly tensile and correlates extremely well with fracture initiation under single occurrence peak loads. The legend is capped at 40,000 psi. The deflection of the part is magnified by a factor of 5x.



Another view of the structure under the 35,000 lbf outrigger load.

August 2003