**Failures in Shipping Containers**
(Updated October 2003)

In 2001 WFF constructed for CREAM a rotational GSE, delivered in 2 crates. One held the gear-box, rotation control, and motor ('**Tall Crate**' below), while the other ('**Long Crate**' below) held the construction elements (steel I-beams) with casters, etc. In 2002, WFF delivered to CREAM the upper and lower sections of the Instrument Support Structure (ISS) in another crate ('**Detector Crate**' below). Significant problems appeared with all three crates.

**The Tall Crate**
This crate held a total of approximately 650 lbs. of equipment. The sides were made of 3/8" plywood with 1"x4" wood frame members stapled to the plywood, with no glue used. Upon return from CERN in 2002, the staples holding the frame to the plywood on one corner had pulled out (see Fig. 1), and the plywood had torn (see Fig. 2), making the box unusable.

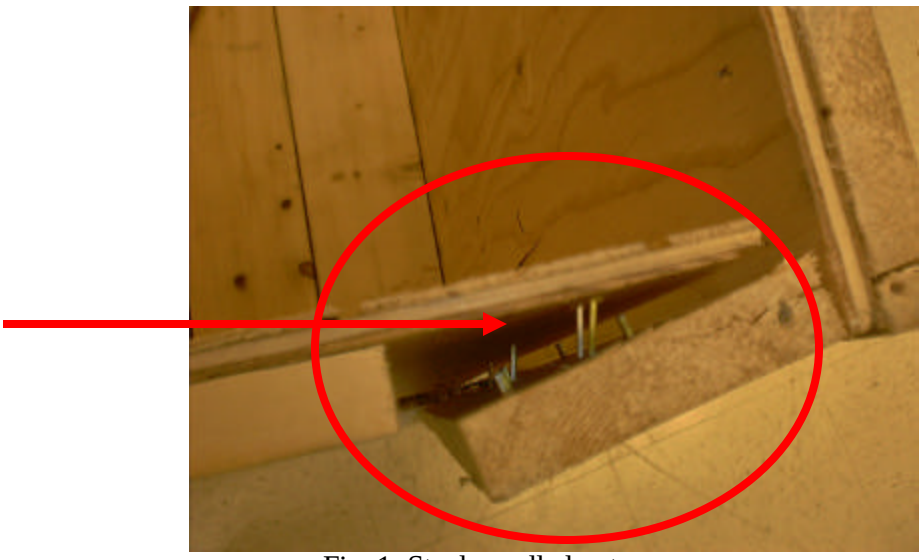
Fig. 1: Staples pulled out on one corner

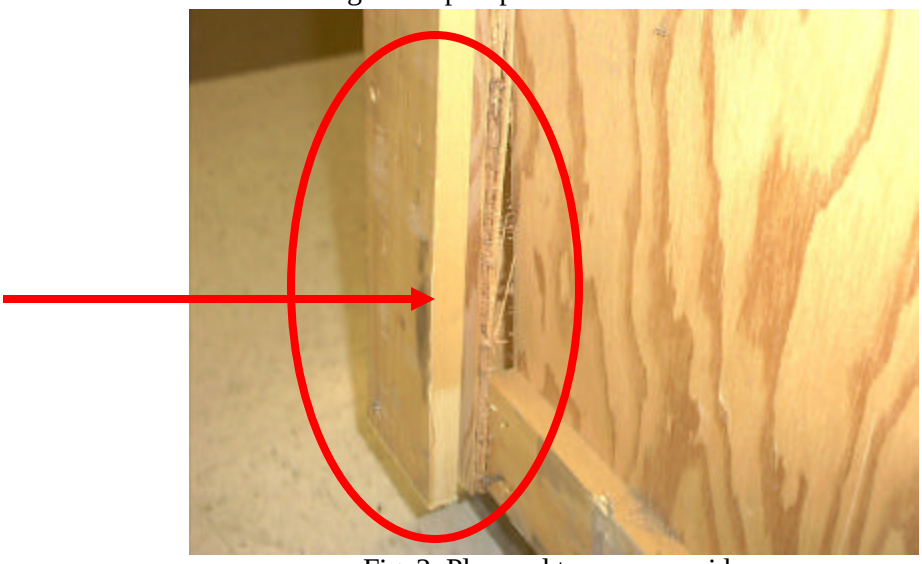
Fig. 2: Plywood torn on one side

**The Long Crate**

This crate held a total of approximately 1300 lbs. of steel elements, held in place by use of 2"x4" wood sections, screwed to the sides of the crate limiting the up-down motion of the I-beams (see Fig. 3). The sides were made of 3/8" plywood sheets with 1"x4" wood frame members (see Fig. 4), nailed together, with no glue used. Motion of the I-beams along the crate's long axis was only limited by the ends of the crate.

Fig. 3: 2"x4" sections preventing up-down motion of I-beams

Fig. 4: 3/8" plywood sides with 1"x4" frame members

When the Long Crate arrived at CERN in 2001, the ends of the crate were damaged, apparently by the I-beams breaking through the ends during transit. To make the return trip, UMD personnel had to reinforce these sides using ¾" wood sheets inside the crate. In addition, where the nails holding the crate walls to each other had started pulling out, UMD personnel had to use screws to reinforce the crate. These repairs worked and the crate survived the return trip. However, when the crate was shipped again to CERN in 2002, upon arrival it was found that the nails connecting the crate walls to its bottom had pulled out around most of the crate, and especially at one end. This allowed the crate walls to separate from the bottom of the crate, rendering the crate unusable (see Fig. 5). .

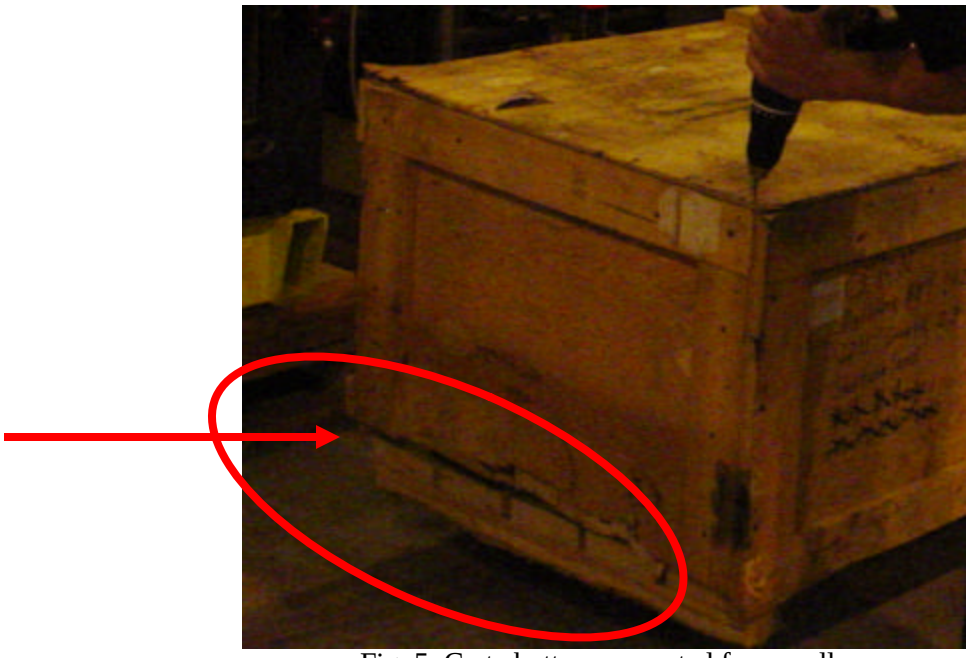

Fig. 5: Crate bottom separated from walls

It is clear from the above that the technique and materials used were inadequate to the stated requirements the crate needed to meet. The crate should have been constructed of ¾" plywood, with more frame-members than used, with all sides attached using glue and screws rather than nails. While this would have resulted in a more expensive and heavier crate, it would have survived the repeated trans-Atlantic transits.

**The Detector Crate**

The Detector Crate was made with a 0.030" aluminum bottom cover under an aluminum beam structure, and steel C-channels for fork-lift operations. The C-channels were placed at the correct distance from each other for standard fork-lifts. This did not take into account the fact that the crate would need to be sent to CERN and to McMurdo Station, where along the way it would encounter people who may not know to use the proper size fork-lift. Indeed, at the University of Chicago an attempt was made to lift the crate with a smaller fork-lift, resulting in the aluminum bottom being damaged (see Fig. 6). Luckily, the flight honeycomb pallet was not in the crate at the time, so the only expense and delay were to repair the crate (see Fig. 7). Once the crate arrived at UMD after repairs were completed, UMD added a 1" plywood sheet, reinforced by sections of 4"x4" wood between the two C-channels to prevent similar damage in the future (see Fig. 8). While at CERN, had UMD personnel not intervened, the CERN Shipping Dept. personnel would have used a similar small fork-lift to assist in off-loading the detector crate from a truck. Following this intervention the CERN Shipping personnel arranged for the correct size fork-lift to be brought in and used.

In September 2003, on the way back from CERN the top of the detector crate was damaged in a manner consistent with someone having placed another crate on top, which started breaking through the plywood top and 1"x2" frame member (see Figs. 9 and 10 for views from outside the box and from inside the box).

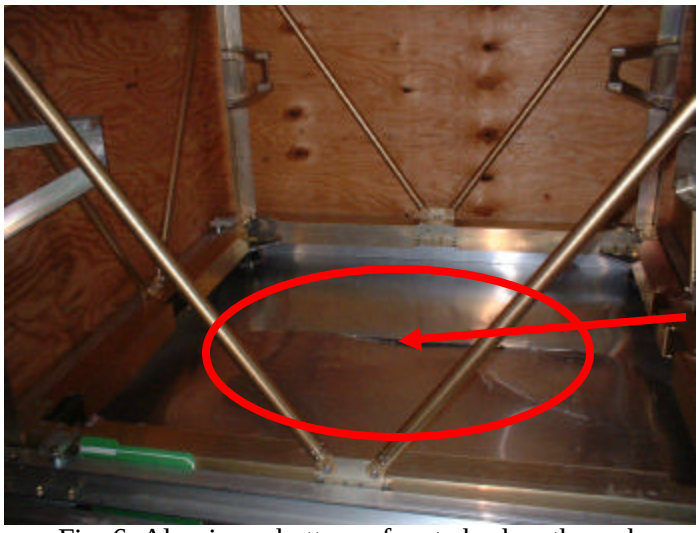

Fig. 6: Aluminum bottom of crate broken through

Fig. 7: Repair of aluminum bottom

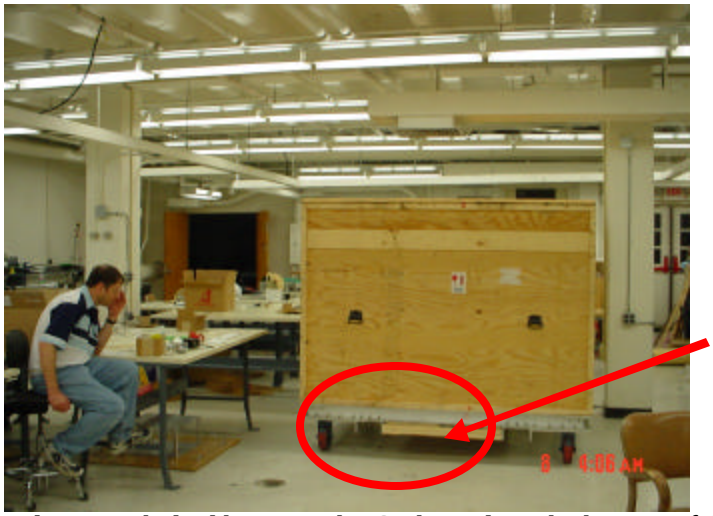

Fig. 8: Wood support bolted between the C-channels at the bottom of the crate

Fig. 9: Top of detector crate damaged (outside view)

Fig. 10: Top of detector crate damaged (inside view)

**Summary**

The following table summarizes what damage occurred when.

| Crate | Damage Description | Time of Damage | Repair Location |
|---|---|---|---|
| Long Crate | I-beams broke through end | August 2001 | CERN |
| Detector Crate | Aluminum bottom damaged by forklift | June 2002 | Univ. of Chicago |
| Long Crate | Walls separated from bottom | July 2002 | CERN |
| Tall Crate | Frame pulled out at one corner | August 2002 | UMD |
| Detector Crate | Top of cover broken | September 2003 | UMD |

It seems that when constructing these crates, too much emphasis was put on minimizing cost, rather than on verifying that the crates would last through many transits, while being handled by people who may or may not be sufficiently trained or motivated to handle them with great care. In the case of the detector crate, it was a stroke of fortune that prevented damage to the $200,000 honeycomb pallet when the forklift buckled the thin aluminum bottom, and another stroke of fortune that when the top of the cover of that crate was broken, the only detector inside was the calorimeter module which sits about 3' under the cover.

It is our recommendation that future shipping crates provided to the CREAM project (as well as other projects) be constructed of thicker plywood, with more frame members, and using glue and screws rather than staples and/or nails. In general, such crates should be constructed to be robust enough for multiple trips, taking into account a fair amount of mis-handling by shippers.