S/V Cynthia Woods
Final Investigation Report

Prepared by:
The Office of General Counsel & Internal Audit Dept.,
Texas A&M System
July 17, 2009

S/V Cynthia Woods at the start of the Regatta de Amigos, June 6, 2008
The S/V Cynthia Woods Crew
The *S/V Cynthia Woods* Crew

**Gold Lifesaving Medal** — awarded to someone who rescues, or endeavors to rescue, any other person from drowning, shipwreck, or other peril at the risk to one’s own life and shows extreme heroic and daring.

**Certificate of Valor** — granted to someone who has exhibited courage above and beyond the call of duty in saving a life or attempting to save a life, and/or whose actions put them at extreme personal risk.
Key Technical Definitions

- **Hull** - The main, structural body or shell of the vessel, not including the deck, keel, mast, or cabin.

- **Keel** - An air foil-shaped structure attached to the bottom of a sailboat to create ballast (to keep the boat upright) and prevent side-slipping when sailing towards the wind. The keel on the *S/V Cynthia Woods* was a 2.4 ton bulb keel with a teardrop-shaped, ballast-filled bulb at the bottom.

- **Keel bolt** – The bolt that holds the keel to the hull.

- **Laminate** – To unite layers of material (for example, fiberglass) by an adhesive or other means; or a material constructed by uniting two or more layers of material together.
S/V Cynthia Woods
Keel-to-Hull Connection

Photo of *S/V George Phydias*, the sister vessel to the *S/V Cynthia Woods*, from inside the cabin looking down on the location where the keel connects to the hull with bolts & backing plates.

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Key Technical Definitions

- **Heel** - To lean over to one side, due to wind pressure on the sails or crew on the side. The amount that a vessel is tipped over side-to-side, relative to its normal, horizontal position.

- **Load** – The forces to which a given object is subjected.

- **Shear Force** - External force that acts parallel (same direction) to a plane. In the case of the *S/V Cynthia Woods*, the plane was through the hull laminate where the failure of the keel started; cutting and then tearing through the vessel’s hull laminate.

- **Fatigue** - The tendency of a material to break or fail under repeated stress.

- **Safety Factor** - The ratio of the breaking stress of a structure to the estimated maximum stress in ordinary use.

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Shearing Force
Key Technical Definitions

- **Starboard** - The right side of the vessel when facing forward.
- **Starboard Tack** - A sailboat sailing on a tack with the wind coming from starboard and the boom on the port side.
- **Port** - The left side of the vessel when facing forward.
- **Port Tack** - Sailing with the wind coming from the port side, with the boom on the starboard side.
- **Stern** - The back (aftermost) part of a vessel.
- **Bow** - The forward most or front part of the vessel.
Investigation Approach

- Secured the evidence
- Retained naval architect/engineer expert
- Conducted interviews
- Obtained and reviewed documents
  - TAMUG documents
  - USCG and Diers reports
  - Regulations, guidance and literature
- Conducted scientific analysis
- Evaluated operational procedures
- Findings/Recommendations
Retained Mr. Brendan Dobroth

• B.S.E. in Naval Architecture and Marine Engineering from University of Michigan
• 28 years designing, building, and racing sailboats
• Boats with his keel designs have won Etchells World Championship, Dragon World Championships, and Olympic competitions
• Structural Engineer for Maxi yacht Condor, Cornwall, England
Timeline

• June 6, 2008 – vessel capsizes
• December 18, 2008 – USCG releases report & A&M System submits FOIA requests
• February 21, 2009 – A&M System receives complete USCG report
• July 17, 2009 – A&M System releases report
Step 1 – Normal Keel Position (Port Tack)

Looking from stern (back) to bow (front)

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Step 2 – Shear Failure on Left (Port) Side of Hull
Step 3 – Left (Port) Side of Keel Breaks Away from Hull
Step 4 – Right (Starboard) Side of Keel Tears From Hull
Step 5 – Keel Separates from Hull
Step 6 – Without Keel, Boat Turns on its Side
Step 7 – Boat Completely Capsizes
Before/After View of Keel Connection

Photo of *S/V George Phydias*, the sister vessel to the *S/V Cynthia Woods*, from inside the cabin looking down on the location where the keel connects to the hull.

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Before/After View of Keel Connection

Photo of *S/V Cynthia Woods*, from inside the cabin looking down on the location where the keel was connected to the hull.

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Summary of Findings

- Loss of keel was result of improper design and construction (failed ABS Guide criteria)
  - Fiberglass laminate hull too thin
  - Insufficient shear load capacity when heeling due to deficient safety factor
- Groundings and the repairs made by students and ship repair yard did not contribute to keel failure
Detailed Investigative Findings
Hull Thickness

• The hull’s fiberglass laminate was too thin to support the bulb keel.
• The hull was 1/2” to 9/16” thick (0.50 – 0.56)
• The *minimum* ABS thickness (Rule 7.3.1) is 1 1/2”
• The hull was one-third of the minimum fiberglass laminate specified by ABS.
\textit{S/V Cynthia Woods} (left) - at the forward keel bolt, 1 \(\frac{1}{2}\) inch bolt through a thin (1/2" to 9/16") fiberglass hull laminate.

ABS design requirement (right) – a 1 \(\frac{1}{2}\) inch bolt requires reinforcement of a \textit{minimum} of 1 \(\frac{1}{2}\) inches of fiberglass hull laminate.

Shear Load Capacity

• The *second major cause of the keel* failure was the insufficient shear load capacity when the boat is heeling.

• The required ABS safety factor (to account for fatigue) is **2.0**

• The "as-built" safety factor was **.32**

• Following ABS, the hull must be 3.11” thick

• The hull could have been thinner if the backing plates were 3 to 4 times wider
Shear Load When Heeling

This diagram is drawn as if you are looking from stern (back) to bow (front)—the boat is sailing on a port tack. At the time of the accident, the S/V Cynthia Woods was on a port tack.
**Compression Side** – Stress or load is distributed over the entire length of the top of the keel, which measures 42 inches in length.

**STARBOARD (RIGHT)**

**PORT (LEFT)**

**Tension Side** – Stress or load is distributed only to the keel backing plates, which total 22 inches in length. The load is double on the port side because it is distributed along a smaller length. The initial failure point was located on this side on the front-left corner of Plate 2 at bolt 2.
Finite Element Analysis – Report Fig. 5

Shear force on the hull. This diagram shows the failure mode for the vessel. The failure started on the middle backing plate’s front left corner (bottom left corner in this diagram.)
Shear Load Capacity (cont.)

- Narrow backing plates (only as wide as the top footprint of the keel) exacerbated the effect of the low safety factor used by the builder. See following picture.

- For the backing plates to be effective, they should be much wider than the keel. Backing plates the same width as the keel produce high stress concentrations at the connection point. Wider backing plates would have decreased the required thickness of the hull.

- The configuration turned the keel plate into a can opener.
Shear Load Capacity (cont.)
Dobroth Opinion – Repairs

- The frame repairs completed by the students did not contribute to the failure of the keel-to-hull joint.
  - After the March 2007 grounding, some cracks at the junction of the frame face and hull were repaired by students. These repairs were made with a yellowish epoxy resin which is stronger than the red vinylester resin used for the hull. These repairs were done to industry standard.
  - The inspection photos indicate that all of these repairs were still intact, even after the significant trauma of the recovery operation. Photo on next slide shows failure didn’t occur at repair site.
Point of Initial Shear

Port/Left

Bow/Front

Starboard/Right

Stern/Back
Marine Surveyor’s Opinion

• *Same as Dobroth’s opinion*

• K.W. Diers & Associates, Inc. - marine surveyor retained by the university’s property insurer

• In a report issued June 16, 2008, they concluded that the damages sighted were the result of a sudden and catastrophic loss of the keel which was due to an *inadequate and unacceptable keel-to-vessel mounting system.*
USCG Released its Investigation Report on Dec. 18, 2008
(report did not include Tiger Team Report, Ancon Marine Exhibit, or Structural Composites Report)
USCG Report - Summary

• The hull failed due to multiple groundings and the storage of the vessel in shallow water. Subsequent damage assessments and repairs were inadequate.

• An unqualified employee determined the safety and integrity of the repairs made by students.

• Payco Marine’s minimal role did not contribute to the keel failing.
Conflicting Opinions

The conflicting opinions of the reports issued by the USCG, Diers & Dobroth were not reconciled as part of the TAMUS investigation.

– Diers & Dobroth both state that the incident occurred as a result of design and construction flaws.
– USCG states that the incident occurred as a result of inadequate operation, maintenance and repairs.
TAMUG Operational Issues

• We also identified some organizational & procedural issues that need to be addressed to strengthen the control systems related to the future of the sailing program.

• Immediately following the incident, the university began taking steps to correct deficiencies noted during the initial phase of the TAMUS investigation.
Actions Taken

• The university had all boats inspected by a marine surveyor.
• A Waterfront Committee was formed to review & manage waterfront operations.
• A Total Vessel Operations Program is being developed.
• A Waterfront Director position & a Safety Advisor position have been created.
Questions & Answers

NOTE: The full report and all appendices can be viewed at:
www.tamus.edu/offices/communications/cynthiawoods/index.html