UNITED STATES COAST GUARD

INVESTIGATION INTO THE S/V NAHOKU II DISMASTING AND FATALITY

ON 12/01/2006

MISLE ACTIVITY NUMBER: 2833864

U.S. Department of Homeland Security
United States Coast Guard

Commandant
United States Coast Guard

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16732
23 April 2009

INVESTIGATION INTO THE S/V NAHOKU II DISMASTING AND FATALITY ON DECEMBER 1, 2006

ACTION BY THE COMMANDANT

The record and the report of the investigation into the subject casualty have been reviewed. The record, including the findings of fact, analysis, conclusions, and recommendations are approved subject to the following comments.

COMMENTS ON ANALYSIS

Section 2.0 – Rigging report (page 27): As stated in the Vessel History (section 1.2.1), the rigging survey stated that the NAHOKU II's rig was satisfactory. The complete report was as follows:

> I visually inspected the rig on your catamaran on April 26, 2006 at Ala Wai Marine and found no obvious problems. The cable was clean and smooth and the terminals and turnbuckles appeared to be in good shape.

No additional documentation was submitted in support of the report, which the Coast Guard apparently accepted as evidence of the satisfactory condition of the rigging. According to the owner, the ANS rigging manager who performed this survey also designed the modifications to the rig that used a Harken jib furling system as a mainsail furler in 2000. The ANS rigging manager disputed this claim, indicating that the owner gave him the design plans, while also explaining that the use of the jib-furler as a mainsail furler "is done all the time." There is no dispute that the owner initiated the foregoing alterations to the vessel's rig.

Comment: We do not concur with the rigger's comment that jib roller furlers are used on masts all the time. While it may be common in Hawaii, discussions with riggers and experienced designers outside Hawaii indicate otherwise.

ACTION ON RECOMMENDATIONS

Recommendation: National Standards for Standing Rigging
Recommend that Coast Guard Marine Safety Center partner with industry to develop a national minimum standard for masting and rigging of sailing vessels, or to incorporate by reference an existing rigging standard. This can be augmented with guidance via Navigation and Vessel Inspection Circulars and the Marine Safety Manual. In addition, develop a standard time interval for the un-stepping of the mast for inspection and third party surveys.

Action: We do not concur with this recommendation. We do not believe there is justification for the establishment of a national minimum standard for masting and rigging of sail vessels. In this incident, the vessel employed a non-standard sailing rig that had been significantly altered without the required review and approval by the Officer in Charge, Marine Inspection (OCMI) or the optional evaluation by the Marine Safety Center (MSC). We believe existing industry standards and references for rig design and construction, if properly applied, and the current marine inspection requirements for small passenger sail vessels, if properly complied with, would have identified safety concerns associated with this vessel's sail rigging so that they could have been properly addressed.

Recommendation: Sail Plan Review
Recommend that a regulations working group be chartered to investigate and, as appropriate, propose the establishment of uniform design and construction standards for mast and rigging equipment on inspected sail vessels. Pending completion of the project, the Coast Guard should consider requiring the submission to MSC of a naval engineer's or marine architect's report certifying that the proposed sail plan and rigging configuration have been reviewed and that they are appropriate for the proposed service. The report should identify with particularity the methodology used to ascertain the mast and rig's suitability.

Action: We partially concur with this recommendation. We do not believe there is justification for the establishment of uniform design and construction standards for mast and rigging equipment on inspected sail vessels. In this particular incident, the vessel employed a non-standard sailing rig that had been significantly altered without the required review and approval by the Officer in Charge, Marine Inspection (OCMI) or the optional evaluation by the Marine Safety Center (MSC). We believe existing industry standards and references for rig design and construction, if properly applied, and the current marine inspection requirements for small passenger sail vessels, if properly complied with, would have identified safety concerns associated with this vessel's sail rigging so that they could have been properly addressed. We do believe it may be warranted to change the submission of the detailed calculations on the strength of the mast, post, yards, booms, bowsprits, and standing rigging on all sail vessels to the MSC for evaluation under 33 CFR 177.330 from an optional requirement imposed by the cognizant OCMI to a mandatory requirement imposed on all small passenger sail vessels, and will consider seeking this change to the regulations. In the meantime, we will remind all OCMIs that they have this option under 33 CFR 177.330 and that they should use it any time they are concerned with the suitability of the rig design for the vessel's intended service.

Recommendation: Rigging Surveys
Due to the complexity of modern sail boats, the Coast Guard must continue to rely on third party-prepared surveys, furnished at owner expense, to assist in determining the material condition of the mast and rig equipment during periodic inspections. In order for the Coast Guard to perform its oversight function, standards should be developed that will enable the OCMI to critically evaluate the survey against objective criteria. Recommend that the Coast Guard publish uniform minimum standards for rig surveys. An abbreviated example of a qualitative and quantitative rigging survey should include the following parameters"

- Initial review of the rigging system and comparison to the original sail plan;

- Inspection of all fittings and terminals (with magnification where appropriate);
- Inspection of chain plates, clevis pins, toggles, terminals and wires for corrosion and wear;
- Measurement and recording of rigging tension of all stays and shrouds;
- Inspection of mast column and comparison to previous surveys;
- Inspection of spreaders and their alignment;
- Inspection of gooseneck and fittings;
- Inspection of mast step, including Magnaflux dye penetration.

Action: We partially concur with this recommendation. We note that Sector Honolulu issued Inspection Note #13, "Inspection of Sail Rigging and Masts on Inspected Small Passenger Vessels," on September 11, 2008. This inspection note was developed with the assistance of a Senior Traveling Marine Inspector from Commandant (CG-546), the Marine Safety Center, and the local passenger sailing vessel industry. The note establishes a rigging examination regime with inspection and documentation requirements that is developed for each small passenger sailing vessel operating within Sector Honolulu. We are aware that other Officers in Charge, Marine Inspection (OCMIs), with the assistance of the Traveling Marine Inspection staff, are in the process of developing similar policy guidance tailored to the specific issues associated with small passenger sailing vessels in their areas of responsibility. We will pass Sector Honolulu's inspection note on to other Officers in Charge, Marine Inspection, and provide them with assistance in developing and implementing similar, local regimes for the small passenger sailing vessels in their areas of responsibility. Once local regimes have been established and a knowledge and experience base has been developed, we can revisit this recommendation and evaluate whether a national set of minimum standards for rig surveys are appropriate.

Recommendation: Marine Inspection Training
Existing guidance in the Marine Safety Manual, Volume II, requires marine inspectors to carefully review the vessel's case file, all associated paperwork, surveys, and all pertinent vessel plans and photos for comparison purposes prior to conducting a vessel inspection. In addition, existing guidance instructs marine inspectors to be especially alert for unauthorized alterations that may adversely impact vessel safety. Although faithful attention to these best practices helps to ensure the safety and suitability of the inspected sailing vessel fleet, these practices failed to produce the identification of the serious hazards aboard the NAHOKU II before the mishap, most probably because marine inspectors did not have the specialized training in sail rigging to know what to look for. As indicated above, the ability to identify an improperly configured or mis-tuned rig often turns on the inspector's ability to look beyond the material condition of the vessel and its equipment and to pick up highly subtle warning indicators of a potential hazardous condition. Accordingly, it is recommended that Headquarters review the existing rigging inspection component of the marine inspection training program at RTC Yorktown, and develop an advanced curriculum addressing the unique requirements of sail configuration, rigging design, and rigging maintenance and inspection. Job aids and checklists based on peer-reviewed best practices should also be developed for distribution to marine inspectors in the field. In addition, program managers should consider establishing a sailboat rigging Course of Excellence or a third party training center for marine inspectors assigned to ports with auxiliary sail vessels. Successful completion of an appropriate rigging course should be required for any inspector conducting inspections of sail vessel rigging systems. Any such course should include a case

study of the NAHOKU II mishap, including a technical analysis of the mishap and potential warning indicators for the marine inspector. Sectors with auxiliary sail vessels assigned should periodically review the results of this investigation report and incorporate the lessons learned in their local training program.

Action: We concur with this recommendation. With respect to improving the level of training and knowledge of our marine inspectors, we will work with the Marine Safety School at the Coast Guard's Training Center in Yorktown, Virginia, to incorporate portions of the Small Passenger Plan Review Course's curriculum related to sailing vessels into the Basic Marine Inspector Course. In addition, we will pursue development of a third party advanced training course, similar to the current Wood Boat and Composite training course, addressing the unique requirements of sail configuration, rigging design, maintenance and inspection. We also intend to publish guidance, possibly in the form of a Navigation and Vessel Inspection Circular (NVIC), specifically covering these same issues that can be used by our marine inspectors and members of the maritime industry to work through the marine inspection process for passenger sailing vessels to ensure that sail riggings are safe and suitable for use in passenger service.

//s//
M. P. RAND
By direction

U.S. Department of Homeland Security
United States Coast Guard

Commander (dpi)
Fourteenth Coast Guard District

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APR 2 4 2008

MEMORANDUM

From: [redacted]
Sally Brice-O'Hara, RADM
CGD FOURTEEN

Reply to Attn of: (dpi)
CDR Randall D. Farmer
(808) 535-3421

To: COMDT (CG-54)

Subj: NAHOKU II (D996153) INVESTIGATION (Case No. 329465)

1. Forwarded for your review, recommending approval of the findings, conclusions, and recommendations.

2. In response to the mishaps aboard the Hawaii catamarans NAHOKU II and KIELE V, I directed Sector Honolulu and my district prevention staff to initiate a comprehensive state-wide safety compliance check program of the 59 commercial sailing vessels certificated to carry passengers in Hawaii. The safety compliance check program was undertaken last summer in addition to the existing annual inspection cycle, and included a careful plan and record review followed by an on-site safety examination of rigging, un-reported vessel modifications, and various other safety and structural concerns. Of the 59 vessels visited by Coast Guard inspectors, 30% were found to have safety discrepancies, and 19% (11 vessels) were temporarily taken out of service pending repair of serious safety deficiencies, including excessive corrosion and/or fractures or missing bolts in the masts, spreaders or mast arms. Although this surge effort was largely successful in terms of identifying serious safety hazards aboard the remainder of Hawaii's passenger sailing vessel fleet, it also foreshadowed the critical gaps identified in the NAHOKU II investigation report; namely, the apparent inadequacy of current marine inspector courses in sailing vessel rigging, as well as the lack of objective national standards for evaluating the suitability of mast and rigging equipment.

3. It is essential that Headquarters initiate prompt action to develop and institute national standards for the inspection of mast and rigging aboard inspected passenger sailing vessels, as well as review and reform, as appropriate, the rigging inspection component of the marine inspection training program. I note with approval Headquarters' recent participation in Sector Honolulu's Industry Day, in which a Senior Traveling Marine Inspector, Sector personnel, and members of the inspected sailing vessel community (including operators, riggers, and marine surveyors) met to discuss the development and implementation of appropriate standards and procedures for the inspection and maintenance of masts and rigging equipment. This initiative was a positive initial step and the momentum must be maintained.

4. Pending Headquarters action on the above, I am directing my prevention staff and Sectors to continue this engagement with industry, and to develop uniform standards and procedures for the inspection and maintenance of mast and rigging systems aboard all inspected sailing vessels in the Fourteenth Coast Guard District . I am also directing my prevention staff and Sectors to identify and recommend appropriate minimum training standards for marine inspectors who conduct inspections of passenger sailing vessels. It is my intention that the Fourteenth District shall serve as the Center of Expertise for the inspection of passenger sailing vessels in the Coast Guard.

5. My point of contact is Commander Randall Farmer at (808)535-3421.

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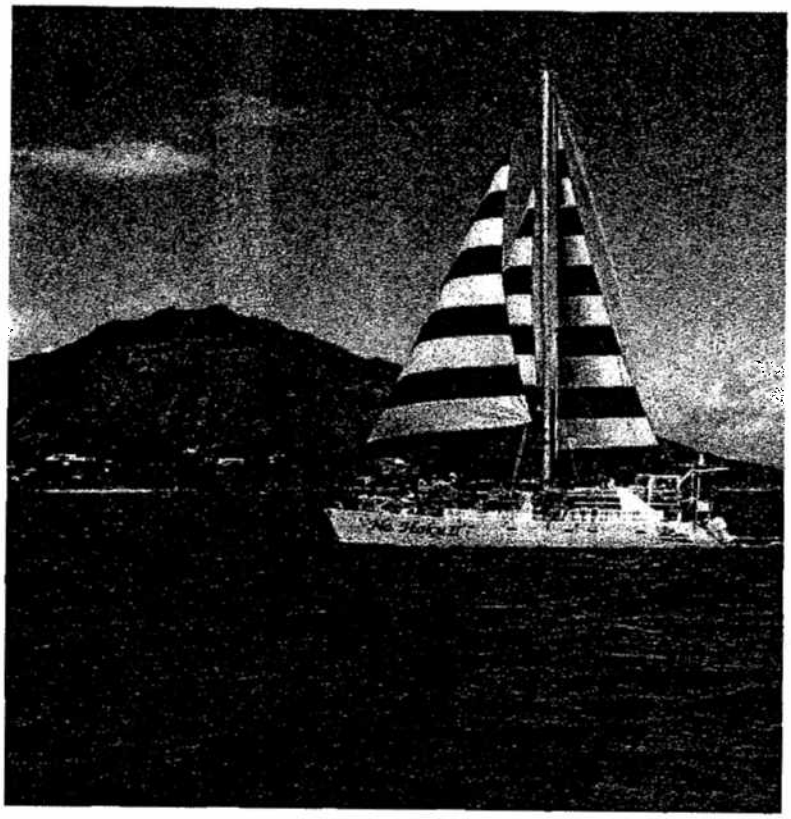
Enclosure

Copy: CG PACAREA (Pp)
Sector Honolulu
Sector Guam

Coast Guard Summary of Investigation:

S/V NAHOKU II (O.N. 996153) Dismasting and Fatality

December 1, 2006

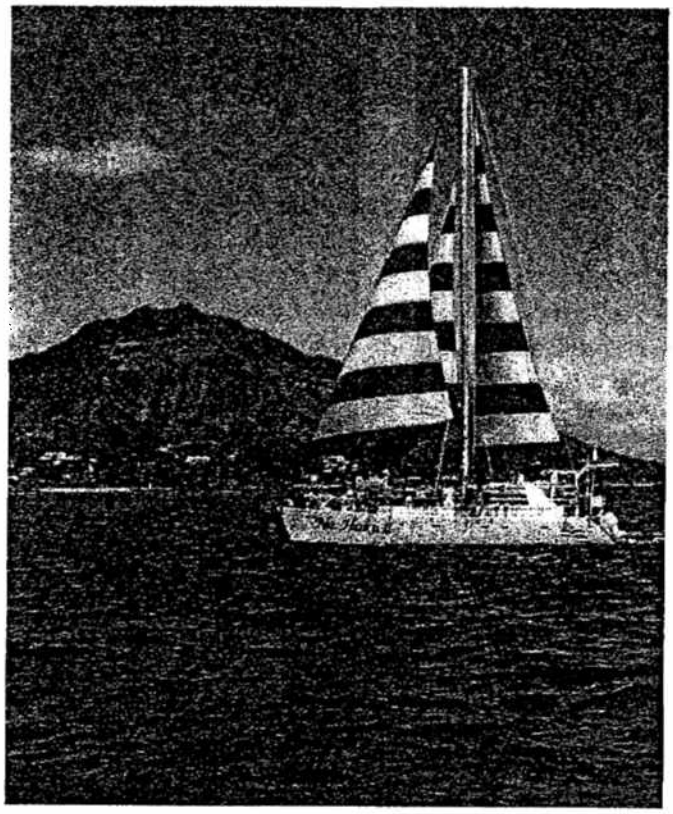


Prevention Division
Fourteenth Coast Guard District, Honolulu, Hawaii

Coast Guard Summary of Investigation:

S/V NAHOKU II (O.N. 996153) Dismasting and Fatality

December 1, 2006



Prevention Division
Fourteenth Coast Guard District, Honolulu, Hawaii

Summary

On December 1, 2006 at approximately 1600 (all times are Hawaiian Standard Time unless noted), the sailing vessel NAHOKU II, a small passenger vessel inspected and certificated by the Coast Guard to carry passengers for hire, was on its third round-trip sightseeing tour of the day from Waikiki Beach to Diamond Head, Oahu, Hawaii. On the return leg of this trip, while the vessel was proceeding in a northwesterly direction on a starboard tack, the mast buckled and collapsed on the cabin top, trapping and fatally injuring a [redacted] male passenger, and injuring three others. At the time of the casualty the NAHOKU II was less than one mile from shore and ¼ nautical miles northwest of Diamond Head Reef Lighted Buoy 2 (LLNR 29065). The on-scene weather observed by the master was winds of approximately 15 to 25 knots from the northeast with three to five foot seas.

Prior to the incident, on April 28, 2006, the vessel was inspected by Coast Guard inspectors from Sector Honolulu and issued a Temporary Certificate of Inspection (COI), valid for one year.[1] As part of this inspection, and prior to the issuance of the Temporary COI, Coast Guard inspectors required the owner to submit a survey attesting to the satisfactory condition of the mast, rigging, and related equipment. The owner contracted a private marine surveyor, Art Nelson Sailmaker Inc., to complete an inspection of NAHOKU II's mast and rigging. According to the surveyor's written report, the mast and rigging were found to be satisfactory.

Investigation revealed that in about 2000, the owner significantly modified the vessel's rig. The owner altered the rig configuration by replacing the mainsail with a modified jib, and replaced the boom and associated hardware with a modified jibsail furling system.[2] This furling system was designed for use as a jib furler and was attached to the mast and the deck.

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[1] Issuance of a temporary Certificate of Inspection (COI) is authorized by 46 U.S.C. 3309 and the Marine Safety Manual, Volume II. A temporary COI provides evidence that a vessel has satisfactorily completed an inspection for certification and normally is issued when immediate issuance of a permanent COI is not possible. A temporary COI has the force and legal effect of a permanent certificate.

[2] The owner recalled that the boom was removed and a jib roller furling system for the mainsail was installed during 2000. The owner's recollection is supported by the vessel file, which shows receipts for a H1036 #3 RF Harken Roller Furling system that was purchased on 17 March 2000 for $5408.00, and three winches that were purchased on 20 March 2000 for $2184.00. These were two of the significant parts of the modification.

The owner also installed eight new shrouds to help support the mast. In addition, holes were drilled in the lower section of the mast to support the installation of additional gear, including an EPIRB. Unused holes were either filled with a fastener, body filler like Bondo, or were not filled at all. None of these modifications was submitted to the U.S. Coast Guard for review and/or approval as required by 46 CFR § 176.700. In addition, at the time of the mishap the vessel's original sail plan had not been updated to reflect any of these modifications, nor was a revised sail plan submitted for a new stability review.

Post-casualty analysis determined that the aluminum mast of the NAHOKU II buckled in three places. Investigation also revealed that not a single stay, shroud or chain plate broke or separated. As part of the Coast Guard's investigation, the NAHOKU II's mast was submitted to a metallurgical forensics specialist from the National Transportation Board (NTSB). The NTSB analysis revealed that the aluminum mast was in a satisfactory condition despite the slight corrosion around the numerous holes in the mast.

Coast Guard investigators also submitted photos from NAHOKU II's setup, descriptions of the manner in which it was rigged, and the original sail-plan, to the Coast Guard Marine Safety Center (MSC) for post-casualty analysis. The MSC concluded that the unauthorized modifications to the mast, rigging, and sail configuration led to increased mast compression which, in conjunction with an undersized mast with multiple holes drilled in the unsupported span, increased the likelihood of a buckling failure.

Jurisdiction & Authority

NAHOKU II is an inspected U.S. flagged vessel inspected under 46 Code of Federal Regulations (CFR) Part 176. The marine casualty occurred in Mamala Bay, a navigable waterway of the United States.

46 USC 6301 and 46 CFR Part 4 provide the authority to conduct marine casualty investigations, and set forth the scope of the investigation.

Level of Investigation.

In accordance with Chapter 5, Marine Safety Manual (MSM) Volume V, the investigation was conducted at the informal level.

1. Finding of Facts

1.1 Vessel Description

The NAHOKU II is an auxiliary sail catamaran that is owned and operated by Anela Kai Catamaran, Inc. It was purpose-built in 1989 by the Knight and Carver Boat Yard in San Diego to operate as a small passenger vessel, and was designed to have one extruded aluminum mast and boom, a mainsail, and two head sails. Enclosure (1). The vessel originally was constructed at 46.5-feet in length, but was later shortened to a 45-foot length to comply with Hawaii State requirements. Enclosure (2). The vessel is homeported for passenger service in Honolulu, Hawaii.

1.2 Vessel Particulars.

The vessel's typical operating route takes passengers from Waikiki Beach in the vicinity of Duke's Restaurant to Diamond Head Reef Lighted Buoy 2 and back again. The vessel ordinarily embarks and disembarks passengers by placing the bow aground on sand at Waikiki Beach. The trip typically takes about 45 minutes to one hour.

The vessel's particulars are as follows:

Name: NAHOKU II

Flag: United States

Type: Auxiliary Sail Catamaran

Route: Limited Coastwise

Gross Tons: 14

Homeport: Honolulu, Hawaii

Date Keel Laid: 01 January 1989

Operator: Anela Kai Catamaran, Inc.

Owner: Anela Kai Catamaran, Inc.

Service: Passenger (Inspected)

Passenger Count: Max 49

Length: 45 ft.

Required manning: 1 master, 1 unlicensed crew

Date Delivered: 30 June 1989

1.2.1 Catamarans.[3]

Catamarans are boats (either motor or sail) consisting of two hulls joined together by a frame, deck, and/or superstructure. The purpose of the additional hull is to provide stability. In a sailing catamaran the additional hull resists the lateral force of the wind on the sails. On a monohull (i.e. a boat with only one hull) this lateral force is countered by a ballasted keel. For example, the ballasted keel of a 45-foot monohull – the same length as the NAHOKU II – weighs several thousand pounds.

On a monohull the mast is typically stepped (mounted) on the keel. Since the keel is very heavy and often made of lead, it provides a very firm foundation for a mast. However, on a catamaran, the mast is stepped on the frame or deck connecting the two hulls. The deck between the two hulls of a catamaran flexes considerably when underway. The amount of this flexing depends on the sea state, wind speed, and weight of the vessel, which changes with the number of people onboard. The standing rigging (shrouds and stays) ordinarily is adjusted to account for this flexing. Adjusting the rigging to support the mast on a catamaran potentially subjects the mast to increased compressive loads when the boat is underway, due to the hull flexing and other dynamic forces that result from wind force and sea state.

A review of Coast Guard records revealed that the original and approved sail plan for the NAHOKU II consisted of a mainsail and two head sails (jibs). The approved mainsail was a standard Bermudan sail which consists of a triangular-shaped mainsail attached to and aft of the mast.

The *head* of the sail is hauled to the top of the mast, and the *luff* is attached to the mast with *slides* or *slugs* which fit into the *mast track* (see Figure 1).

[3] Source: Figures 1,2,3, and 4; [redacted], *Chapman Piloting & Seamanship*, 64th Ed. (Hearst Corporation 2003); Figure 5, Schaefer Marine Inc., at www.furling.com.

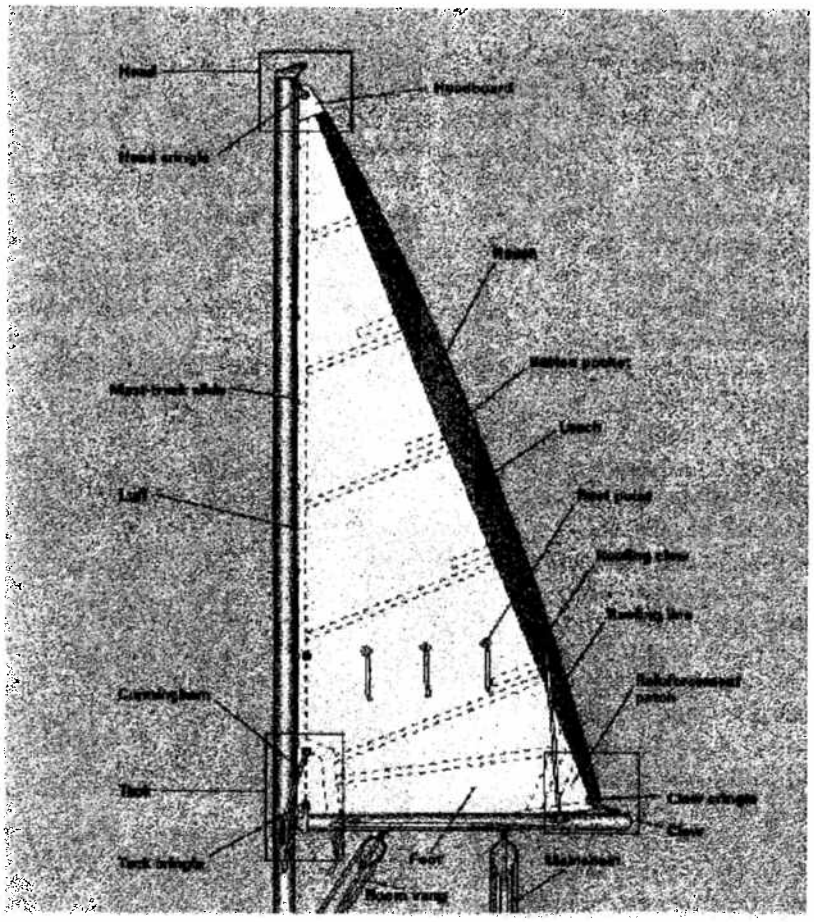

Figure 1 – mainsail and mast terms

The *foot* of the sail is attached to the boom, and one end of the *boom* is secured to the mast via a coupling commonly known as the *gooseneck*. A *sheet* (line) is attached to the other end of the boom. Pulling in on the sheet or releasing tension allows control of the angle of the sail to the wind on each point of sail, i.e. the boom allows control of the shape of the sail relative to the wind. The boom will need to be adjusted if the wind or the boat changes direction. It is possible for the boom to whip from one side to the other with considerable force. To reduce the potential of injuries the boom is often placed high enough so a person standing in the cockpit will not get injured when the boom swings when changing tack.

The jib, or head sail, is also a triangular sail but without a boom. It is typically *hanked on* (attached) to the forestay (see Figure 3).

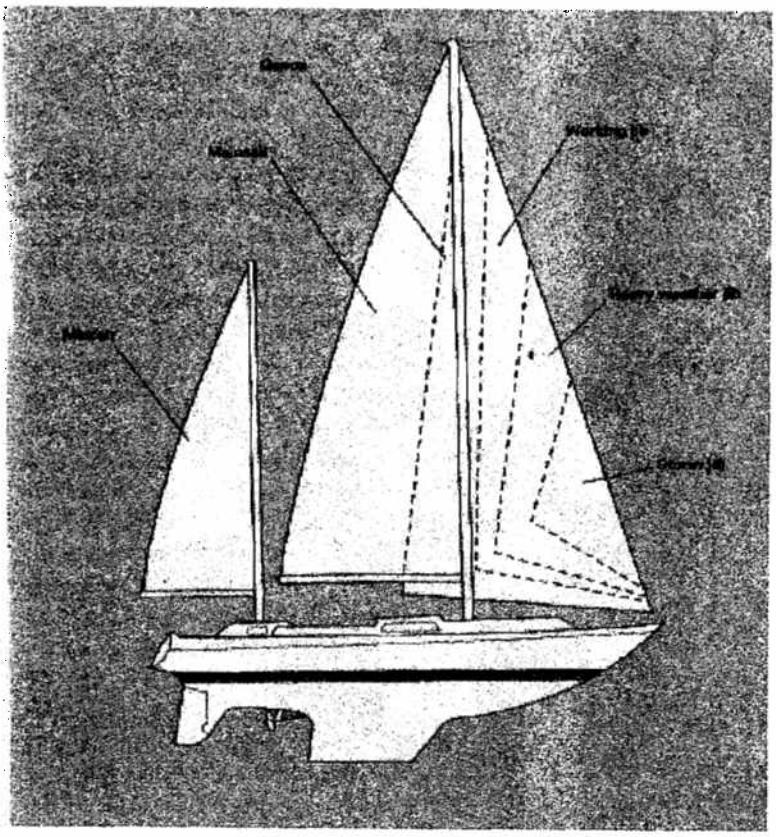

Figure 2 – sail terms

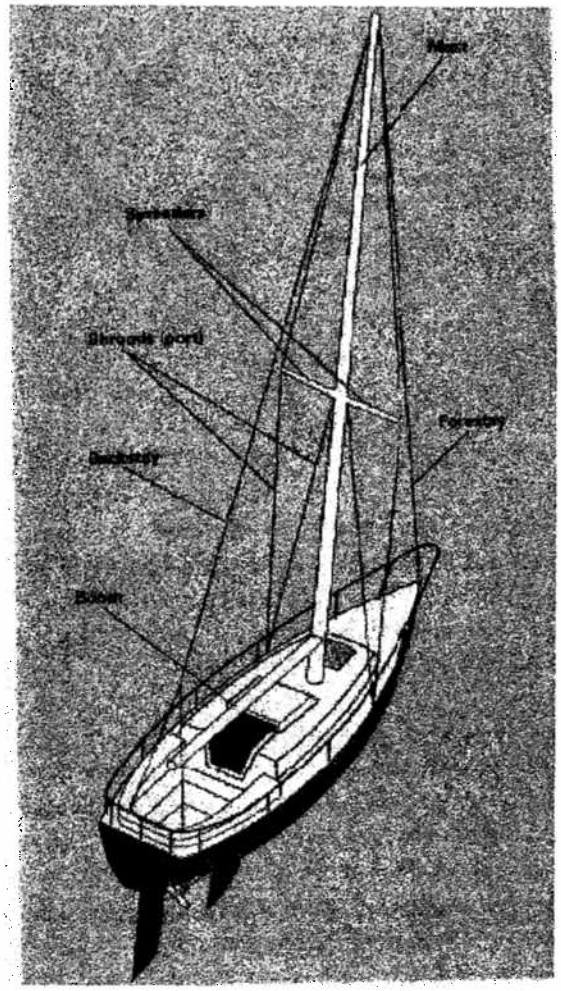

Figure 3 – standing rigging terms

1.2.2. Furling overview.

Depending on the force of the wind it is desirable to change the amount of exposed sail area. For jibs this is typically achieved by dousing the presently flown jib and hanking on a different size jib. For example, should the wind speed exceed, say, 25 knots, the working jib (see Figure 2) might be replaced with the heavy weather jib.

Another method to change the amount of exposed sail area is to roll up (or let out) the sail. This is commonly referred to as furling or unfurling the sail. In a jib furling system the luff of the jib is attached to a sleeve (tube) around the *forestay* (see Figure 3). The furling sheet is rolled up on a drum at the bottom of the system and led back toward the helm of the boat.

Note that the drum is full when the sail is completely unfurled. For example, pulling on the furling sheet will roll up the jib, thus making it easy to adjust the amount of sail area.

Furling a mainsail is similar in concept. There are two types of mainsail furling systems: In-boom furlers, and In-mast furlers. As the names imply, the In-boom furlers wrap the mainsail around a tube inside the boom, whereas In-mast furlers wrap the mainsail around a tube inside the mast. In either case the sail plan corresponds very closely to its non-furling counterpart. There is some additional weight and windage associated with a furling system but generally this does not significantly alter the static or dynamic characteristics of the rig.

The above describes a typical set up. In NAHOKU II's case the boom was at a height just above the cabin top. While that is an ideal location to prevent the boom from hitting people, the location also precluded anybody from using the cabin top as a seating area. The owner advised investigators that he decided to remove the boom in order to gain additional seating area for passengers.

Figure 4 - View of an installed jib furler

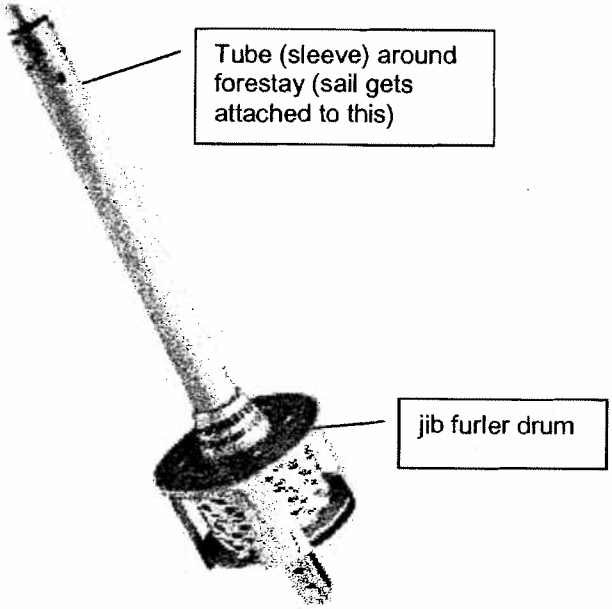

Figure 5 – jib furling system

Since commercially available furling systems for mainsails do not eliminate the boom, the NAHOKU II owner decided to use a Harken, Inc. jib furling system that was awkwardly attached to the mast and used improperly as a mainsail furler. Enclosure (3).

1.2.3 Sail Plan and Vessel Stability.

Small passenger sailing vessels are required to operate in accordance with an owner-submitted sail plan that has been reviewed by the Coast Guard Marine Safety Center or the cognizant Officer in Charge of Marine Inspection in accordance with 46 CFR §§ 170.075, 170.170, and 171.055; and the Marine Safety Manual, Vol. IV, Section E.3. The purpose of this review is to help determine the vessel's stability under stationary and operating conditions, including when the vessel is operating under the maximum authorized area of sail. To this end, MSC considers the total sail area and the center of the sail area as described in the owner submitted plan.

Importantly, the sail plan is not used to determine the mast and rig's structural integrity or their suitability for the intended service. Although 46 C.F.R. § 177.330, authorizes the OCMI to require the owner to submit calculations on the strength of the mast, post, yards, booms, bowsprits, and standing rigging to MSC for evaluation, the regulatory history emphasizes that suitable standards for modern rigging do not currently exist. Specifically, 59 Federal Register 2022, dated 13 January 1994, states that § 177.330 "is intended to ensure that appropriate consideration is given by designer to the adequacy of the rigging, and does not require that a particular standard be met." Furthermore, "[r]outine plan review [by the Coast Guard] is not expected, partly due to the lack of suitable design standards."

The results of the Coast Guard's stability analysis (which includes evaluation of the owner submitted sail plan) are published, along with any applicable restrictions, in the vessel's Permanent Stability Letter. In this case, the vessel history indicates that on August 12, 1988 the owner originally submitted an application for vessel inspection and plan review to MSC. Enclosure (4). Correspondence from MSC dated November 30, 1989 indicates that the proposed sail plan was returned to the owner for revisions. Enclosure (5). A MSC letter to the owner dated 7 January 1994 references, among other documents, an owner submitted sail

plan for NAHOKU I (apparently a sister vessel) and notifies the owner that "the stability of the subject vessel may be handled locally or at our office depending (*sic.*) the OCMI's determination on the type of stability review required for this vessel." Enclosure (6). A follow-up MSC letter dated February 3, 1994 refers to the same owner submission, and states that MSC would hold copies of the owner's proposed sail plan on file without action pending receipt of stability calculations. Enclosure (7). On September 26, 1994, the owner submitted a naval architect's stability calculations and sail plan for "NAHOKU II" directly to OCMI, Honolulu. Enclosure (8). On September 30, 1994, the OCMI reviewed and approved NAHOKU II's sail plan consisting of two head sails (jibs) and one mainsail, and issued a Permanent Stability Letter authorizing a maximum permissible sail area of 1,370 ft^2. Enclosure (9). The Permanent Stability Letter included, among other requirements, authorization to carry "49 passengers on exposed waters, with a minimum of 36 passengers required to be on board for this route." However, with less than 36 passengers onboard, the letter also required, "the stability with full sail area is sufficient for protected waters only," and "with a reduced sail area of 1064 square feet (Main Sail and Jib) any amount of passengers up to 49 may be carried on exposed waters."

At the time of the mishap, the NAHOKU II was under sail with a configuration consisting of a jib, a second jib (a genoa) and a modified jib that was used in place of the mainsail. As previously indicated, this modified sail configuration, and the modifications to the boom, jib furling system, and shrouds, had not been submitted as a proposed alteration to the OCMI or MSC, as required by 46 C.F.R. §176.700. In addition, the owner did not submit an updated sail plan for stability review. At the time of the mishap, all three sails were flown and reefed. The sail area in use was approximately 1,165 ft^2. With only 23 passengers onboard, the vessel's existing stability requirements authorized operation with up to the maximum sail area of 1,370 ft^2 on protected waters, but only under 1064 ft^2 of sail area on exposed waters.[4] At the time of the mishap, the vessel was operating on partially protected waters which were not specifically identified in the Permanent Stability Letter.

[4] Exposed waters are waters more than 20 nautical miles form the mouth of a harbor of safe refuge and other waters which the OCMI determines to present special hazards due to weather or other circumstances. Partially protected waters are waters within 20 nautical miles of the mouth of a harbor of safe refuge, unless determined by the OCMI to be exposed waters. Protected waters means sheltered waters presenting no special hazards such as most river, harbors, lakes, etc. 46 CFR § 170.050(c).

1.2.4 Vessel Inspection History From 2000

At the time of the mishap, the NAHOKU II was operating as an inspected small passenger vessel with a valid temporary COI. The approved COI route was limited to "southern and western coasts of the Island of Oahu between Koko Head and Kaena Point." Enclosure (10). Review of the vessel's Coast Guard inspection history from 2000 revealed the following pertinent details:

a. On 1 June 2000, Coast Guard inspectors completed a hull inspection in drydock. The CG 840 workbook also contains a receipt for "Shorten Rigging" on 1 June 2000 and an entry stating "Replaced sails this drydock," but otherwise contains no comments concerning the vessel's rig. A separate Marine Safety Information System (MSIS) entry indicates that during the drydock "rudders, outboard motors, steering system and winches were replaced in kind and new sails were purchased." Coast Guard records contain no other references to the masting or rigging equipment.

b. On 28 August 2000, Coast Guard inspectors completed a COI inspection identifying seven outstanding requirements, none related to the rigging or the structural integrity of the vessel. There was no reference to rigging in either MSIS or in the CG 840 work book.

c. Investigation revealed that the Coast Guard inspector who had conducted the June 2000 drydock inspection and the August 2000 COI inspection had attended a course in sail vessel rigging in Port Townsend, Washington around the same time frame, but the exact date could not be established. The inspector recalled specific areas of concern involving chain plates and hull repair but could not recall any changes to the rigging. The inspector did state that it was normal practice to conduct a sail plan review prior to going out on an inspection. The inspector indicated that it was likely that the sails had been removed from the vessel because the vessel was in drydock. Based on the owner's recollection and the receipts from March 2000 for the roller furler system and related equipment, the

unauthorized modifications to the rig likely were made during this period. Enclosure (3)

d. On 11 June 2001, a Coast Guard inspector performing an unrelated inspection at Kewalo Shipyard discovered that the NAHOKU II was undergoing modifications to replace the forward deck area with a trampoline. The owner was issued a requirement to submit plans for the alterations to the Coast Guard. In addition, the owner was prohibited from carrying passengers for hire until modifications were approved and examined by an inspector. The alterations were completed and approved by the Coast Guard on 14 June 2001.

e. The Coast Guard conducted annual reinspections of the NAHOKU II on 30 November 2001, 28 October 2002, 26 April 2004, and 15 November 2004. In addition, credit drydock inspections were completed on 16 May 2002, 4 June 2004, and 31 May 2005, and a damage inspection was completed on 20 November 2002 as a result of a collision with another vessel that did not involve the rigging. As a result of the 16 May 2002 drydock inspection, inspectors issued a worklist item for the vessel to "have sail rigging inspected, especially the starboard backstay." The vessel file indicates that the requirement was issued on 7 May 2002 and resolved on 14 May 2002, although how the item was resolved is not documented. In addition, records of the 4 June 2004 drydock inspection include a requirement to "Survey all rigging and replace forestay." There is no record of an annual inspection of the vessel in 2003 or a COI inspection in 2005.

f. In August 2005, the vessel's COI expired and there is no record in the vessel file indicating that the owner contacted the Coast Guard to request or schedule a new COI inspection.[5] The owner continued to operate the vessel as a small passenger vessel without a valid COI for a period of eight months, in violation of 46 U.S.C. § 3311 and Coast Guard regulations. However, Coast Guard marine inspectors conducting a pre-inspection file review on 28 April 2006 discovered that the

[5] Under regulations set forth in 46 CFR Part 176, Subpart D, the vessel owner is responsible for notifying the Coast Guard that a vessel inspection is due and for scheduling a time and date to have a marine inspector visit the vessel.

NAHOKU II had been operating without a valid COI, and issued a Notice of Violation (NOV) to the owner. This violation resulted in a civil penalty assessment against the owner in the amount of $1300.00. Enclosure (11).

g. As part of the COI inspection in April 2006, the Coast Guard inspectors required the vessel's owner to submit evidence of a survey attesting to the satisfactory condition of the mast, rigging, and related equipment aboard the NAHOKU II.[6] The individual conducting this survey was the Rigging Manager for Art Nelson Sailmaker, Inc. (ANS). He informed the investigator that he had worked as a rigger for ANS for the past 35 years, and that in 2000 he had installed the modified furling system on the NAHOKU II. The surveyor's complete rigging report dated April 28, 2006, consisted of the following statement:

> I visually inspected the rig on your catamaran on April 26, 2006 at Ala Wai Marine and found no obvious problems. The cable was clean and smooth and the terminals and turnbuckles appeared to be in good shape.

The report contained no additional details or description concerning how the survey was conducted, or how the surveyor came to his conclusions. Enclosure (12). The Coast Guard accepted the survey report as evidence of the rig's satisfactory condition.

h. The April 2006 COI inspection revealed several deficiencies in the owner's implementation of the vessel's mandatory Drug and Alcohol Program, as well as eighteen other deficiencies that were not directly related to the mishap. Each of

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[6] The Marine Safety Manual, Vol. II, Section B, Chapter 1, authorizes Coast Guard inspectors to consider surveys when evaluating the safety and overall condition of the vessel:

> In appraising the condition of a vessel and its equipment, the inspector shall use all available evidence, including the latest inspection findings, records of previous Coast Guard inspections, the opinions or records of other interested surveyors or inspectors, information furnished by the officers and crew, facts concerning the vessel's classification, and previous certification.

The MSM also states that after considering the results of surveys and other information, "the inspector shall reach an independent conclusion as to vessel and equipment conditions and shall act accordingly."

these deficiencies was corrected by the owner and cleared on 23 May 2006 during a follow-up inspection. The vessel was issued a temporary COI on 24 May 2006 which was valid for one year. The vessel was operating under the Temporary COI at the time of the mishap. Enclosure (10).

1.2.5 Prior Vessel Modifications Accepted by the CG.

Review of the vessel history revealed the following accepted modifications to the NAHOKU II:

a. On August 24, 1994, the owner submitted a letter to MSO Honolulu stating that the fuel tanks located in the stern of the cabin area would be moved to the forward seating area.

b. On March 27, 1995, the owner requested that the National Vessel Documentation Center (NVDC) update NAHOKU II's Certificate of Documentation to reflect the vessel's new length. It had been shortened from 46.5 feet to 45 feet to comply with Hawaii State Law. Enclosure (2). Changes were made to the Certificate of Documentation and the local Coast Guard Marine Safety Office updated the vessel's COI to reflect the change

1.2.6 Vessel Modifications not submitted to, accepted or approved by the Coast Guard.

As indicated above, on 11 June 2001 the owner was discovered making unapproved alterations to the vessel by replacing the forward deck area with a trampoline. In addition, as discussed throughout this report, the investigation identified three material alterations to the vessel that probably were completed during the summer of 2000. These alterations included: the removal of the boom and replacement of the mainsail with a modified jib and jib furling system; the addition of eight shrouds to the rigging; and other mast modifications discussed herein. Enclosure (13). These alterations had not been submitted to the OCMI for review and/or approval as required by 46 CFR § 176.700: The implications of these modifications are reviewed in Section 2, Analysis and Section 3, Conclusions.

1.2.7 Post-Casualty Inspection and Investigation.

After the accident on December 1, CG Investigators and an inspector met the vessel at the fuel dock. All passengers that did not require immediate medical attention were required to wait until they could be interviewed by investigating officers on scene. All three crewmembers were interviewed and statements were taken. Interviews were conducted in person and by phone with Station Honolulu and Honolulu Fire Department (HFD) personnel, inspectors, surveyors and others who had contact with the vessel prior to the casualty.

The shrouds, stays, chain plates and other associated hardware were found to be in serviceable condition – none of the shrouds, stays and other associated hardware failed. Investigating officers removed the mast, sails, and all associated standing and running rigging from the vessel for further inspection and examination.

The mast was sent to the NTSB in Washington, D.C., for metallurgical testing to determine whether there was any corrosion and/or metal fatigue associated with the mast failure.

Measurements and descriptions of how the sail plan was set up, the original sail plan, and photographs of the vessel after the casualty, were submitted to the Coast Guard Marine Safety Center (MSC) in Washington, D.C.

1.3 Environmental Conditions

Forecasted weather:

Winds:	15 to 20 knots from the northeast
Seas:	3 to 5 foot
Visibility:	Clear with unlimited visibility
Wind gusts:	20 knots

Observed weather: (by master)

Winds:	15 to 25 knots from the northeast
Seas:	3 to 5 foot
Visibility:	Scattered clouds with unlimited visibility
Wind gusts:	30 knots

*Weather on the water that day included a steady wind with higher gusts. Enclosure (14).

1.4 Crew and passengers onboard at time of incident

At the time of the incident were one master, two crewmembers, and twenty-three passengers.

Crew	Last Name	First Name	Location on vessel	Injured?	License desc.
Master	[redacted]	[redacted]	Pilot station	N	Licensed*
Crew			In cabin	N	Unlicensed
Crew			Forward of cabin	N	Unlicensed
Passengers	**Last Name**	**First Name**	**Location on vessel**	**Injured?**	**Injury Desc**
Passenger	[redacted]	[redacted]	Starboard side	N	
Passenger			Starboard side	N	
Passenger			Forward of cabin	N	
Passenger			Forward of cabin	N	
Passenger			Forward of cabin	N	
Passenger			Forward of cabin	N	
Passenger			Top of cabin	N	
Passenger			Port Aft	N	
Passenger	[redacted]	[redacted]	Port Forward (near bottom of steps)	Y	Laceration to head and forearm
Passenger			Top of cabin	N	
Passenger			Top of cabin	N	
Passenger			Top of cabin	N	
Passenger			Forward of cabin	N	
Passenger	[redacted]	[redacted]	Port Forward (near top of steps)	Y	Bruised back & shoulder
Passenger			Forward of cabin	N	
Passenger			Forward of cabin	N	
Passenger			Forward of cabin	N	
Passenger	Loser	Jordan	Top of cabin	D	Deceased **
Passenger	[redacted]	[redacted]	Port Forward	Y	Fractured left foot and pelvic bone
Passenger			Top of cabin	N	
Passenger			Port Forward	N	
Passenger			Port Center	N	
Passenger			Port Center	N	

* [redacted] was issued a Master's License on June 10, 2003. It was authorized for Steam, Motor, or Auxiliary Sail Vessels of no more than 100 registered gross tons upon Inland waters. The License number was [redacted]. Enclosure (15).

**According to the Honolulu Medical Examiner report, the victim, Jordan Loser, died as "a result of blunt force injuries of the head and neck sustained when he was hit by a falling mast on a catamaran." Enclosure (16).

1.5 Narrative of Events of the Marine Casualty

*All times and locations are approximate.

On December 1, 2006 at 1530, sailing vessel NAHOKU II departed Waikiki Beach with 23 passengers and three crewmembers for its third round trip sightseeing tour of Mamala Bay in Oahu, Hawaii. Enclosures (17,18).

At 1620 the master sailed NAHOKU II towards Diamond Head Reef Lighted Buoy 2 and then prepared the vessel for the return leg to Waikiki Beach. Enclosures (18-28).

At 1629, NAHOKU II was about ¼ nautical miles northwest of Lighted Buoy 2. The master observed ripples in the water heading towards the vessel, so he changed course (fell off to port) to mitigate the effects of the wind. From the helm, which was located at the very stern of the vessel, the master heard a whoosh as the sail filled rapidly with wind and he felt the vessel accelerating. He noticed that the lower portion of the mainsail furling rig began to pump – a potentially hazardous side-to-side movement – and attempted to release the strain on the mainsail by slackening the port sheet. At that time he heard a loud pop. Enclosure (17).

The mast buckled in three places, falling aft and to port of the vessel. The lowest buckle occurred 44 inches above the mast step, which was slightly above the mounting brackets for the modified mainsail roller furler. The midsection buckled 123 inches above the mast step and the top section buckled at approximately 442 inches above the mast step. Enclosures (29,49).

The portion of the mast between the lowest buckle and the midsection buckle fell towards the back of the boat. This portion struck and fatally injured a [redacted] boy and then came to rest on the cabin top, left of the centerline and angled towards the back left side of the vessel. The portion of the mast between the midsection buckle and the top section buckle remained vertical, while the remainder of the mast bent towards the back of the vessel at an approximately 45 degree angle to its midsection and came to rest with the mast tip in the

water, creating two sides of a triangle with an apex approximately 40 feet in the air. Enclosures (29,49).

The buckled mast pinned the boy face down on the cabin top, where he had been sitting during the trip. A second passenger standing at the front port side of the vessel was struck on the head by falling rigging and knocked unconscious. A third passenger suffered a fractured left foot and pelvis. A fourth passenger was struck on the back by stays and shrouds and suffered lacerations to her right shoulder and hand. The latter two passengers were also in the front of the vessel and forward of the cabin at the time of the incident. Enclosures (18-21,23-26,28,30-37).

At 1630, the master notified CG Sector Honolulu Command Center (SCC) via a mayday call on VHF-FM Channel 16 and said the vessel's mast had broken and trapped a passenger. He started his starboard engine to regain control of his vessel and motored west towards Waikiki Beach. SCC directed Station Honolulu (STA Hono) to respond to the incident. Enclosures (17,34-39).

The crewmembers and several passengers onboard tried to free the trapped [redacted] boy, but were unsuccessful. Enclosures (18,19,22-26,28,30). A passenger checked the boy's vital signs, but was unable to locate his pulse or confirm breathing. Enclosure (33).

At 1633, MLB 47317, a Coast Guard 47 foot Motor Lifeboat, was heading towards Ala Wai, but diverted to Diamond Head Reef Lighted Buoy 2 and arrived on scene within three minutes of the call from SCC. CG personnel boarded NAHOKU II and unsuccessfully attempted to lift the mast off the boy. They requested a MEDEVAC helicopter and lifting equipment. Enclosures (35-37).

At 1635, Honolulu Fire Department (HFD) advised their helicopter and boat would be on scene in 15 minutes.

At 1650, the MLB 47317 took NAHOKU II in side tow. HFD arrived. HFD and CG personnel attempted to lift the mast with airbags.

At 1711, the mast was finally raised, freeing the [redacted] boy. EMT commenced CPR, and the boy was airlifted by a Honolulu Fire Department helicopter from the vessel. At 1720, a request for a second MEDEVAC helicopter was made for the passenger who suffered from head injuries.

At 1757, NAHOKU II docked at Ala Wai fuel dock. Some time thereafter, the remaining injured passengers were transported to a local hospital.

Drug and Alcohol testing was conducted on all the crew members in accordance with federal regulations.

1.5.1 U.S. Coast Guard and Other Agencies Timeline[7]

Start Date/Time	Message
1629 01DEC06	Initial notification: CG Sector Command Center (SCC) received a mayday call on VHF CH16 from the NAHOKU II. NAHOKU II reported broken mast, in position 21-15n 157-49.5w. Also reported that a [redacted] male was stuck under the mast.
1630	SCC notified Honolulu Fire Dept (HFD). HFD will send helicopter. 47 Foot Motor Life Boat(MLB47) - 47317 USCG – CG STA HONOLULU launched
1633	MLB47 - 47317 USCG – CG STA HONOLULU onscene
1635	HFD will send fire-1 rescue-2 ladder-7 and battalion-2. They reported units would arrive onscene in 15 minutes.
1640	SCC requested helicopter for MEDEVAC from D14CC.
1645	SCC received report of second injury to the head of a [redacted] female, bleeding but conscious.
1650	CG STA HONOLULU reports the person under the mast is a young boy and they are unable to give him CPR until they get the mast off of him. He has no pulse.
	Vessel ENDO is 1/2 mile outside Ala Wai fuel dock. ENDO master is offering to assist if someone will meet him with equipment.
1700	CG STA HONOLULU and HFD worked together to raise the mast enough to get the boy out from under it. They took the deck plates from the CG MLB 47 and wedged them under the mast and then put airbags under the mast and inflated them until they could get the boy out.
1701	CG MLB 47317 has NAHOKU II in tow for Ala Wai fuel dock. HFD attempting to raise mast.
1702	M/V AMERICAN ISLANDER, with crane, out of Keehi, offered to assist in

[7] Source: Sector Honolulu Command Center Rough Log.

lifting fallen mast.

1711 CG MLB 47 reports that the mast has been lifted from the victim enough to take him out. SCC released assisting private vessels.

1712 HFD helicopter MEDEVAC'd first seriously injured victim. Fire 1 took victim to Kapiolani Park where EMS was standing by.

1715 SCC called Ala Wai fuel dock: Magic Island Petroleum and requested they clear the dock and direct all other traffic away from scene.
HH65C 6505 CG AIRSTA BARBERS PT launched
STA HONO'S EMT was assessing [redacted] the second person with injury and assessing the needed for a second MEDEVAC'd

1720 HH65C 6505 on scene and located target. SCC notified Sector Investigations Duty Investigator Investigators are enroute to fuel dock to interview witnesses.
[redacted] Medical Evacuation (MEDEVAC)'d to Kapiolani Park by HFD helicopter

1725 SCC requested HFD arrange police presence at the fuel pier.

1730 SCC briefed D14 and requested they brief duty Public Affairs officer.

1757 CG MLB 47317 moored NAHOKU II safely at Ala Wai fuel dock.

1815 HH65C 6505 departed scene
Investigating officers on scene

1816 LT [redacted] from investigations notified SCC that there were three people who were taken to the hospital. The first was a [redacted] boy named [redacted]. He was later pronounced dead. The second person was a [redacted] woman, named [redacted]. Her condition has been raised from critical to serious. The third person was a [redacted] woman who was transferred over to EMS when NAHOKU II moored.

1818 LT [redacted] reported the vessel was rounding Diamond Head and the wind stopped. Because of this, they turned around and headed back towards Waikiki. When they got back around Diamond Head, a sudden gust of wind hit the vessel and the mast snapped.

1820 HH65C 6505 sortie ended.

1856 CG MLB 47317 enroute ISC HONOLULU.

1858 SCC contacted Queens Hospital and asked them if they had any updates. They said they were busy and we needed to call back.

1900 MLB47 - 47317 USCG – CG STA HONOLULU departed scene

1915 SCC received a call from MKC Quinones in investigations, he reports that there were 19 adults onboard and 3 children, all under 10. SCC informed the IO that subject who was hurt was a [redacted] boy. He said that was what the roster said and they will look into it.

1919 MLB47 - 47317 USCG – CG STA HONOLULU sortie ended

2113 SCC contacted [redacted] at Queens Medical Center and she said she was unable to give us any updates due to patient confidentiality.

2200 Investigation team stood down from the investigation for the night and would start again at 0800W the following day.

2205 SCC monitored the local TV news who reported that the [redacted] boy was deceased.

2220 CDO briefed CO/D14

1.6 Drug and Alcohol Testing Results

At the time of the incident, the owner had in effect a Drug and Alcohol Program for NAHOKU II. Immediately after the incident, the master and both unlicensed deckhands were tested for alcohol and drugs in accordance with federal marine casualty regulations. All alcohol test results were [redacted]. Two drug tests were [redacted]. The master, [redacted] and one deckhand, [redacted] tested [redacted]. Mr. [redacted] elected to voluntarily surrender his license for this infraction, in lieu of undergoing Suspension and Revocation proceedings. Enclosures (40,41).

2.0 Analysis

The analysis focuses mainly on the following areas:

Environmental factors (weather, crew, etc.), **Technical issues regarding the structure, design, and modifications of the vessel,** and **Rigging report.**

Environmental factors:

The vessel's voyage, manning, and environmental conditions were found to be typical of the vessel's normal operation. Its master also had extensive catamaran experience and was familiar with his chosen route through Mamala Bay. Although the master and one of the crew members tested [redacted] for THC, the metabolite for marijuana, the evidence was inconclusive as to whether the presence of THC in the master's and crew member's system impacted their ability to respond to the changing conditions on-scene in a manner that might have prevented the casualty. The investigating officers who responded immediately to the scene of the casualty did not notice any evident impairment, and none of the passengers indicated that the master appeared to be impaired in his speech or movements. Enclosures (40,41)

At the time of the incident NAHOKU II had a current temporary Certificate of Inspection (COI). A vessel is required to have a Certificate of Inspection that is valid for five years. Every year within those five years, the vessel is required to have an

annual inspection to evaluate the vessel for compliance with current federal laws and regulations. As indicated above, once a vessel is found compliant at the COI inspection, the Inspections Division issues the owner/operator a temporary COI until a permanent COI can be issued. The temporary COI authorizes the owner/operator to engage in the same service authorized under the permanent COI. NAHOKU II's COI permitted the vessel to operate in "lakes, bays, and sounds plus limited coastwise route (Pacific Ocean area, southern and western coasts of the Island of Oahu between Koko Head and Kaena Point, not more than 20 miles from a harbor of safe refuge)." The vessel was operating within the scope of its route at the time of the incident. However, the master's license was limited to operating on "Inland Waters," which is defined in 33 CFR 80.1420 as all the waters within the boundary line from Barbers Point light to Diamond Head light to the shoreline. Enclosure (15). Diamond Head Reef Lighted Buoy 2 is outside the demarcation line. Accordingly, on this particular cruise, prior to the time of the incident the master of the NAHOKU II was operating the vessel in coastal waters at an undetermined distance outside the boundary line and outside the scope of his license. However, the vessel remained well within sight of land and there is no reason to believe that this violation played a causal role in the mishap.

Technical issues regarding the structure, design, and modifications of the vessel.

The owner of the NAHOKU II made several alterations to the vessel that were discovered during the post-casualty investigation, and that most likely contributed to the collapse of the mast.

- Replacement of the mainsail with a modified jib and furling system;
- Addition of eight shrouds to the rigging;
- Removal of the boom from a mast that was undersized for its designed use; and,
- Drilling of holes in the unsupported span of the mast.

Replacement of the mainsail with a jib furling system:

In 2000, the owner removed the vessel's boom and replaced the original mainsail equipment with a modified jib and roller furling system. The installation of a jib furling system likely altered the compression loading on the mast in a manner never intended, which increased the risk of a buckling failure. See MSC Analysis, Enclosure (29). The traditional purpose-designed mainsail furling systems maintain even mast loading along the length of the mast by ensuring that the luff of the mainsail is attached all along the mast. This more or less evenly distributes the dynamic forces of the wind along the entire mast. In the case of NAHOKU II, however, the owner attached the top of the jib furler to the top of the mast, and the bottom of the jib furler to the lower section of the mast (roughly where the boom attached to the mast before it was removed). Under this configuration, the sail wraps around a wire strung between the two ends of the furling system, i.e. the sail is no longer held captive in the mast's luff groove. This change concentrated the dynamic forces at the top and bottom of the mast, rather than uniformly along the mast, resulting in substantial compressive forces to the mast depending on wind and sea conditions.

In addition, the positioning of the roller furler attachment at the lower section of the mast introduced an approximately 14-½ inch lever arm between the furler's attachment point and the center of the mast. This configuration potentially introduced significant twisting forces on the mast when the vessel was under sail. The owner installed an adjustable bar with one end secured to the furler's bottom bracket and the other end attached to the deck of the vessel. One possible use of the adjustable bar was to stabilize the mast by opposing twisting forces that were introduced on the mast by this lever arm. Post-accident examination, however, revealed rust and corrosion cracks on the fittings attaching the bar to the deck, and it was apparent that the bar had not been tightened or adjusted for a considerable period of time. Improper tuning of this bar could have contributed to the mast collapse by allowing it to twist when the vessel was under sail.

A possible accident scenario involved the mast twisting and moving out of column under the compressive forces of the improperly tuned rig, possibly until it contacted the cabin top which would have introduced a hard spot on the mast itself. Enclosure (42). This in conjunction with the forces exerted on the mast from the furling system could have caused the mast to initially buckle in one of two places – at the mid-span between the foot and the attachment points of the lower shrouds at a height of ten feet above the step, or at a point roughly level with the cabin top. There is no means to determine which failure occurred first or even if they occurred simultaneously.

Adding eight shrouds to the rigging

The installation of the jib furling system required the installation of additional standing rigging to compensate for the non-uniform distribution of the compressive load of the sail along the entire height of the mast. The owner added eight 3/8" stainless steel shrouds that were not reflected in the original sail plan. The Coast Guard did not discover the additional shrouds until the post-casualty investigation. The owner informed investigators that he had installed the additional shrouds because he was concerned about preventing mast failures since they had occurred on other beach catamarans in the past.

Since the installation of a roller furler system can produce higher compressive loads on a vessel's mast, particular care is required to properly tune the rig. The addition of eight extra shrouds had the potential to introduce several thousand pounds of static compression forces on the mast. The MSC analysis concluded that " [t]he principal factors which affect the column's likelihood of buckling are: ... compressive load..." The investigation was unable to determine the specific compressive loads on the mast as a result of the additional shrouds.

Mast Size:

Removal of the vessel's boom further reduced the distribution of compressive forces and concentrated the load on a mast that was undersized for its intended use. MSC post-casualty analysis determined that as built, the mast had a transverse buckling

factor of safety of approximately 1.75. This safety factor is a measure of the mast's ability to resist buckling under side-to-side compressive forces. By reverse engineering the Nordic Board Standard (NBS) equations for transverse mast strength, MSC calculated that the NAHOKU II mast required a minimum factor of safety of 3.38.[8] Based on the NBS, and after controlling for variables such as the installation of the main roller furler system and the improperly drilled equipment, MSC determined that "the mast appears to have been 50 percent undersized." It should be noted that MSC was not able to determine the exact compressive loads on the mast and rig that caused it to buckle during actual operations. The conclusion that the mast was 50% undersized is an estimate based on the structural properties of the mast and the stability properties of the vessel, as reflected in design plans. Enclosure (43).

Other Mast modifications:

The owner explained to investigators that he relocated winches to the mast to present a more nautical appearance. The owner also decided to attach an EPIRB mount to the mast. Enclosure (44). To this end, numerous holes were drilled in the mast and two brackets were mounted at the midpoint of the unsupported span in the mast (the MSC report refers to these brackets as "speaker mounts"). MSC analysis noted that the holes drilled in the side of the mast, and the corrosion, degraded the cross sectional properties of the mast by reducing the mast's transverse moment of inertia and increasing the likelihood of a buckling failure. According to the Principles of Yacht Design,[9] the middle 70% of the unsupported span of the mast should not be drilled because it is most vulnerable to buckling failure.

The National Transportation Safety Board's (NTSB) metallurgical report dated May 16, 2007 found, in relevant part, that the mast contained "numerous threaded holes," several with localized corrosion, with no evidence of general corrosion on exterior surfaces of the mast. Several of the holes were filled with threaded fasteners, some

[8] The MSC report noted that while there is no regulatory standard which mast structures must meet, the Nordic Boat Standard (NBS) is commonly used. The safety factor reflects a margin of safety, or residual capacity, to resist buckling.

[9] [redacted] and [redacted] International Marine/McGraw Hill (3rd edition 2007).

were filled with hardened organic material, and some were open. The analysis did identify spotty pitting corrosion on the interior surfaces in the area of the deformation. The report did not offer any conclusions as to the cause of the mast collapse. Enclosure (29)

Rigging report

As stated in the Vessel History (section 1.2.1), the rigging survey stated that the NAHOKU II's rig was satisfactory. The complete report was as follows:

> I visually inspected the rig on your catamaran on April 26, 2006 at Ala Wai Marine and found no obvious problems. The cable was clean and smooth and the terminals and turnbuckles appeared to be in good shape.

No additional documentation was submitted in support of the report, which the Coast Guard apparently accepted as evidence of the satisfactory condition of the rigging. According to the owner, the ANS rigging manager who performed this survey also designed the modifications to the rig that used a Harken jib furling system as a mainsail furler in 2000. The ANS rigging manager disputed this claim, indicating that the owner gave him the design plans, while also explaining that the use of the jib-furler as a mainsail furler "is done all the time." Enclosure (17, 45). There is no dispute that the owner initiated the foregoing alterations to the vessel's rig.

3.0 Conclusions

Investigation finds that the fatality and injuries to passengers aboard NAHOKU II resulted from the collapse of the mast and rig that most probably was caused by a combination of improper rig configuration and tuning and use of a mast that was undersized for the service performed. Although the investigation could not identify a specific sequence of events that led to failure, the most likely scenario involved the twisting or movement of the mast under excessive compressive loads, ultimately causing it to buckle. Investigation identified a number of likely contributing factors, including the unapproved removal of the boom and the

installation of a jib furling system that concentrated high compressive loads at the masthead and mast bottom rather than uniformly along its length; the addition of eight shrouds to the rigging that introduced additional compressive loads, and the drilling of holes in the unsupported span of the mast that further weakened its resistance to buckling.

The owner failed to submit the above-described alterations to the vessel's rig and sail configuration to the Coast Guard for review and approval. 46 CFR 176.700(a) requires that "repairs or alterations to the hull, machinery, or equipment that affect the safety of the vessel must not be made without the approval of the cognizant OCMI, except during an emergency." In addition, the owner failed to submit a proposed sail plan to MSC reflecting the change in sail configuration. Given the owner's prior history of making unapproved alterations to the vessel, there can be little doubt that the owner actually knew of his responsibility under Coast Guard regulations to provide the OCMI with advance notice of these alterations. The owner's inexcusable failure to provide such notice deprived the Coast Guard of its best opportunity to identify potential hazards and prevent the tragedy.

Notwithstanding the owner's failure to notify the Coast Guard of the unauthorized modifications noted above, Coast Guard inspectors also repeatedly missed opportunities to identify the unapproved alterations during periodic annual inspections conducted in 2001, 2002, 2004, 2005, and 2006, inclusive.[10] An important function of the Coast Guard inspection program is to identify changes in the vessel's material condition and equipment so that the OCMI remains satisfied that the owner continues to meet his responsibility to provide a vessel that is safe for its intended service.[11] Although at least one Coast Guard inspector on the NAHOKU II had attended a sail rigging course during the 2000 time period, none was a highly experienced inspector of passenger sailing vessels. A meticulously

[10] The inspection history does not reveal that an inspection was conducted in 2003.

[11] The Marine Safety Manual (MSM), Volume II, Section B, Chapter 1, provides in relevant part that during periodic inspections, the inspector will:

> ascertain that the vessel and its equipment are being maintained in a safe condition, in accordance with applicable laws and regulations, and determine whether changes have occurred in the vessel tending to make its continued operation unsafe.

The MSM further provides that the inspector "shall be especially alert to detect unauthorized changes to the vessel and its equipment."

conducted inspection by an experienced Coast Guard inspector may have identified subtle warning signs of a developing hazardous condition, such as from the presence of drilled holes in the unsupported span of the mast, or the improperly secured adjustable bar that connected the jib furler to the deck. In addition, the owner's unconventional use of a jib furling system as a mainsail furler should have been carefully scrutinized, given the increased compressive loads that this type of equipment placed on the mast. Finally, a comprehensive plan and inspection history review, in conjunction with on-site visual verification, may have helped identify the unauthorized alterations to the mast and rig.

Investigation also revealed that during the vessel's COI inspection in April 2006, Coast Guard inspectors accepted a third party-prepared rigging survey report as evidence of the mast's and rig's satisfactory material condition and suitability for service. The surveyor's report consisted of little more than a declarative statement that he had inspected the vessel's rig and "found no obvious problems" with it. The report did not identify the scope of the survey, the specific components inspected, whether any non-destructive tests were performed on any equipment, or whether or not the rigging design and configuration were fit for the service intended. The report did not indicate that any consideration was given to the rig's maintenance or design history, and contained no specific recommendations with regard to mast removal and inspection, rig tuning, or inspection, lubrication, and replacement of marine hardware. Ultimately, the rigging survey report was fundamentally flawed in that it failed to identify the improper tuning of the rig, including the installation of the unapproved jib furling system, extra shrouds and stays, and the improper drilling of holes in the mast, which most probably caused excessive compression loading that led to the mast collapse.

Although the Marine Safety Manual, Vol. II expressly allows inspectors to consider the information in survey reports, the MSM also requires Coast Guard inspectors to consider other evidence, including the results of their own inspections, which would enable them to reach an "independent conclusion as to vessel and equipment conditions." In dealing with a commercially-prepared survey report, it is essential that Coast Guard inspectors look beyond the four corners of the report and not be passive or disinterested. In this case, it appears that inspectors over-relied on a commercial survey report that consisted of a few declarative

statements and that contained no factual basis to support its ultimate conclusion. An independent and thorough Coast Guard review was particularly appropriate in this case, where the person who had performed the rig survey also had participated in the original alterations to the rig in 2000.

Notwithstanding the above, the Coast Guard's existing policy on rig inspections did not provide inspectors with the appropriate tools with which to evaluate the NAHOKU II's rigging survey report. Although 46 C.F.R. § 177.330 authorizes the OCMI to require the owner to submit calculations on the strength of the mast and rigging, the Federal Register comment on the rule indicates that this requirement is specifically intended to ensure that appropriate consideration is given by the manufacturer or the designer to the adequacy of the rigging. Enclosure (46). Coast Guard policy states that because suitable design, engineering, and tuning standards for modern rigging do not exist, the Coast Guard currently does not require that any particular rigging standard be met. Enclosure (47). Here, where the alterations were made to an older, custom-built vessel using off-the-shelf equipment, including the installation of a jib furler system for a purpose it was not designed, the absence of rigging standards left Coast Guard inspectors with few tools with which to objectively evaluate the rig survey. Improper tuning does not readily lend itself to detection through visual or non-destructive testing, particularly during dockside examinations when the rig is not exposed to the compression forces of actual operation.

Although the Coast Guard failed to identify the unauthorized alterations to the rigging system and sail configuration as reflected in the vessel's original sail plan, it is not certain that earlier detection of these alterations alone would have prevented the mast's collapse. Nor is it certain that the submission of a revised sail plan would have identified the structural or tuning problems with the existing mast and rig. At a minimum, however, earlier discovery of the altered rig and sail configuration should have prompted a requirement to submit a revised sail plan to MSC for review. Moreover, given the owner's prior history of making unapproved alterations to the vessel, earlier detection of these changes should have brought increased scrutiny to the vessel's overall material condition, and may have prompted a review of the sail configuration and rigging by a credentialed naval architect.

As indicated above, the Coast Guard reviews the owner's sail plan to determine the vessel's stability, but it does not evaluate the mast and rigging equipment for structural integrity, suitability of design, or suitability for intended service. When sail vessel owners submit sail plans or design and engineering plans for approval by MSC, these calculations are reviewed under basic engineering principles for internal correctness and accuracy, but the plans are not subjected to scrutiny under any external classification standard or regulation, because no accepted standards currently exist. In practice, this means that the Coast Guard may only identify design and safety flaws if the plan contains obvious errors, or if the plan does not conform to other plans involving similar vessels. Moreover, while in this case MSC was able to complete a post-casualty analysis using the Nordic Boat Standard equations to arrive at an estimate that the vessel's mast was 50% undersized, these engineering principles do not necessarily transfer to the pre-casualty plan review context. In the case of NAHOKU II, knowledge of the point and mode of failure was essential to determining the mast's resistance to buckling. In short, the mast collapse aboard NAHOKU II has refocused attention on a critical gap in the Coast Guard's program of ensuring passenger safety through a layered approach of plan review, testing, and periodic inspections – that gap being the absence of accepted standards by which naval engineers and inspectors may evaluate the structural integrity and suitability for service of a sail vessel's mast and rig.

The sail area in use at the time of the mishap was approximately 1,165 ft^2. With only 23 passengers onboard, NAHOKU II was authorized under the existing permanent stability letter to operate with up to the maximum sail area of 1,370 ft^2 on protected waters, but only under 1064 ft^2 of sail area on exposed waters. These requirements were based on the vessel's original 1994 sail plan, and it is possible that the center of the sail area had changed following the unauthorized alterations in 2000. At the time of the mishap, the vessel was operating in partially protected waters, with 15 to 25 knots of wind and three to five foot seas. The stability letter does not directly address operation in partially protected waters. If considered operating under the more rigorous "exposed" water conditions, the vessel would have been in violation of the stability letter requirement that the vessel operate under no more than 1064 ft^2 of sail. Nevertheless, it should be emphasized that the passenger carriage and

sail area requirements contained in the stability letter are calculated based on considerations of vessel stability; i.e., the vessel's ability to resist capsizing, rather than on the mast's ability to resist buckling. This is an important distinction because the additional weight from an increased passenger load, while it will help resist capsizing, will not necessarily resist forces that cause mast buckling. There is little reason to believe that either increasing the number of passengers or reducing the sail area to 1064 ft^2 or less would have prevented the mast collapse.

Investigation produced the following additional conclusions with respect to the cause of the accident:

- The corrosion identified on NAHOKU II's mast probably was not a significant causal factor in the mast buckling, but could not be ruled out as a possible contributing factor.

- The mast buckling was not caused by the material failure of any shrouds, stays, chain plates, link plates, turnbuckles, or any other marine hardware.

- The master was operating the NAHOKU II within the scope of the vessel's COI, but outside the scope of his inland master's license. The fact that NAHOKU II was operating marginally outside the demarcation line and therefore outside the scope of the master's inland license was a technical violation and not likely a contributing factor to the accident.

- While the investigation could not determine whether drug use was a contributing factor in the casualty, the possibility that drug usage had some appreciable affect on the master's ability to avoid and/or respond to the mishap could not be entirely ruled out.

4.0 Recommendations

National Standards for Standing Rigging

Recommend that Coast Guard Marine Safety Center partner with industry to develop a national minimum standard for masting and rigging of sailing vessels, or to incorporate by reference an existing rigging standard. This can be augmented with guidance via Navigation and Vessel Inspection Circulars and the Marine Safety Manual. In addition, develop a standard time interval for the un-stepping of the mast for inspection and third party surveys.

Sail Plan Review.

Recommend that a regulations working group be chartered to investigate and, as appropriate, propose the establishment of uniform design and construction standards for mast and rigging equipment on inspected sail vessels. Pending completion of the project, the Coast Guard should consider requiring the submission to MSC of a naval engineer's or marine architect's report certifying that the proposed sail plan and rigging configuration have been reviewed and that they are appropriate for the proposed service. The report should identify with particularity the methodology used to ascertain the mast and rig's suitability.

Rigging surveys

Due to the complexity of modern sail boats, the Coast Guard must continue to rely on third party-prepared surveys, furnished at owner expense, to assist in determining the material condition of the mast and rig equipment during periodic inspections. In order for the Coast Guard to perform its oversight function, standards should be developed that will enable the OCMI to critically evaluate the survey against objective criteria. Recommend that the Coast Guard publish uniform minimum standards for rig surveys. An abbreviated example of a qualitative and quantitative rigging survey should include the following parameters:

- Initial review of the rigging system and comparison to the original sail plan
- Inspection of all fittings and terminals (with magnification where appropriate);

- Inspection of chain plates, clevis pins, toggles, terminals and wires for corrosion and wear;
- Measurement and recording of rigging tension of all stays and shrouds;
- Inspection of mast column and comparison to previous surveys;
- Inspection of spreaders and their alignment;
- Inspection of gooseneck and fittings;
- Inspection of mast step, including Magnaflux dye penetration.

Marine Inspection Training.

Existing guidance in the Marine Safety Manual, Volume II, requires marine inspectors to carefully review the vessel's case file, all associated paperwork, surveys, and all pertinent vessel plans and photos for comparison purposes prior to conducting a vessel inspection. In addition, existing guidance instructs marine inspectors to be especially alert for unauthorized alterations that may adversely impact vessel safety. Although faithful attention to these best practices helps to ensure the safety and suitability of the inspected sailing vessel fleet, these practices failed to produce the identification of the serious hazards aboard NAHOKU II before the mishap, most probably because marine inspectors did not have the specialized training in sail rigging to know what to look for. As indicated above, the ability to identify an improperly configured or mis-tuned rig often turns on the inspector's ability to look beyond the material condition of the vessel and its equipment and to pick up highly subtle warning indicators of a potential hazardous condition. Accordingly, it is recommended that Headquarters review the existing rigging inspection component of the marine inspection training program at RTC Yorktown, and develop an advanced curriculum addressing the unique requirements of sail configuration, rigging design, and rigging maintenance and inspection. Job aids and checklists based on peer-reviewed best practices should also be developed for distribution to marine inspectors in the field. In addition, program managers should consider establishing a sailboat rigging Course of Excellence or a third party training center for marine inspectors assigned to ports with auxiliary sail vessels. Successful completion of an appropriate rigging course should be required for any inspector conducting inspections of sail

vessel rigging systems. Any such course should include a case study of the NAHOKU II mishap, including a technical analysis of the mishap and potential warning indictors for the marine inspector. Sectors with auxiliary sail vessels assigned should periodically review the results of this investigation report and incorporate the lessons learned in their local training program.

Inspected Sail Vessel Compliance Check Program.

As a result of the NAHOKU II demasting and a fatal mast collapse aboard another Hawaii catamaran, the Coast Guard implemented a surge compliance check program targeting all of Hawaii's 59 inspected passenger sailing vessels for increased scrutiny. The surge consisted of a careful plan and record review followed by an on-site safety examination of rigging, un-reported vessel modifications, and various other safety and structural concerns. The results of this program and several recommendations were forwarded separately to Coast Guard Headquarters in Sector Honolulu's letter of November 2, 2007.

5.0 Referral for Enforcement Action

The following are referrals for enforcement actions that have been determined based on the evidence that was collected during this investigation. The enforcements are referred to in accordance with 46 USC 33 and 46 USC 77 along with 46 CFR Part 10 and 176.

Pursuant to 46 USC 3306, a civil penalty should be brought against the owner for failure to submit plans for review and approval for the modifications made to the vessel as required by 46 CFR 176.700.

Pursuant to 46 USC 7702, suspension and revocation proceedings were not pursued in this case for the [redacted] drug results or for any other matter. The owner/master had voluntarily surrendered his license before any suspension proceedings were initiated. Enclosure (15).

6.0 Current Vessel Status

The NAHOKU II has been returned to service as an inspected auxiliary sail vessel engaged in small passenger vessel operations. A new mast and boom were installed that were designed by Morreilli & Melvin Design & Engineering out of Huntington Beach, California. On 1 August 2007, the vessel received approval from MSC to conduct a Dead Weight Survey. This was completed and on 21 August 2007 the vessel was issued a new Stability Letter. The owner no longer serves as master of the vessel.

[redacted] Date: 23 APR 08

Frederick W. Tucher
Captain, U.S. Coast Guard
Chief, D14 Prevention Division

[redacted] Date: 23 APR 08

Randall D. Farmer
Commander, U.S. Coast Guard
Chief, D14 Inspections/Investigations Branch

7.0 Abbreviations

CG	Coast Guard
COI	Certificate of Inspection
CFR	Code of Federal Regulations
DAPI	Drug and Alcohol Inspection Program
EMS	Emergency Medical Service
HFD	Hawaii Fire Department
MSC	Marine Safety Center
MLB	Motor Life Boat
MSM	Marine Safety Manual
NTSB	National Transportation Safety Board
SCC	Sector Command Center

8.0 Enclosure listing

Enclosure 1 Photo of NAHOKU II, 30 Nov 92 with Original Rigging

Enclosure 2 Letter from Owner/Operator dated 29 Nov 94 w/ COD & COI

Enclosure 3 [redacted] Email dated 13 Mar 08 w/Conversation Record dated 7 Dec 06 w/statement dated 1 Jun 03

Enclosure 4 Initial Application for Inspection dated 12 Aug 88

Enclosure 5 G-MSC-1 Letter dated 30 November 1989

Enclosure 6 MSC letter dated 7 Jan 94

Enclosure 7 G-MSC-1 Letter dated 3 Feb 94

Enclosure 8 Stability Calculations and Sail Plan submitted 26 Sept 94

Enclosure 9 Permanent Stability Letter dated 30 Sept 94

Enclosure 10 Temporary Certificate of Inspection dated 23 May 06

Enclosure 11 Enforcement Summary for Violation Activity # 2740579

Enclosure 12 Surveyor's Report dated 28 Apr 2006

Enclosure 13 Two photos of NAHOKU II with alterations

Enclosure 14 National Weather Service forecast dated 958 AM HST Fri Dec 1 06

Enclosure 15 Master's License issued 10 June 2003 & Good Faith Deposit Agreement dated 08 Dec 08

Enclosure 16 Autopsy Report Case No.06-1769- Loser, Jordan Report dated 15 Feb 07, Exam dated 04 Dec 06

Enclosure 17 Statement & Conversation Record from [redacted], Master of NAHOKU II dated 1 Dec 06

Enclosure 18 Conversation Record with [redacted], crew, dated 1 Dec 06

Enclosure 19 Conversation Record, Statement [redacted], passenger, dated 5 Jan 07

Enclosure 20 Statement of [redacted], passenger, dated 2 Mar 07

Enclosure 21 Conversation Record with [redacted], passenger, dated 3 Dec 06

Enclosure 22 Statement of [redacted], passenger, dated 12 Jan 07

Enclosure 23 Statement of [redacted], passenger, dated 10 Feb 07

Enclosure 24 Statement of [redacted], passenger, dated 26 Dec 06

Enclosure 25 Conversation Record with [redacted], passenger, dated 1 Dec 06

Enclosure 26 Conversation Record with [redacted], passenger, dated 1 Dec 06

Enclosure 27 Conversation Record with [redacted], passenger, dated 1 Dec 06

Enclosure 28 Conversation Record with [redacted] passenger, dated 1 Dec 06

Enclosure 29 NTSB report dated 15 May 07, with proposal dated 23 Jan 07

Enclosure 30 Conversation Record with Mr. [redacted] passenger, dated 02 Dec 06

Enclosure 31 Conversation Record with [redacted] crew, dated 1 Dec 06

Enclosure 32 Conversation Record with [redacted] passenger, dated 12 Jan 07

Enclosure 33 Conversation Record with Mrs. [redacted] passenger, dated 3 Dec 06

Enclosure 34 Statement of BM3 [redacted] U.S. Coast Guard

Enclosure 35 Statement of MK3 [redacted] U.S. Coast Guard

Enclosure 36 Statement of BM1 [redacted] U.S. Coast Guard

Enclosure 37 Statement of BM1 [redacted], U.S. Coast Guard

Enclosure 38 2692 filed by [redacted] of NAHOKU II

Enclosure 39 Conversation Record with [redacted] passenger, dated 5 Jan 07

Enclosure 40 Drug Testing Results sent to US Coast Guard from [redacted] dated 13 Dec 06

Enclosure 41 Drug Testing Results sent by [redacted] to US Coast Guard dated 14 Dec 06.

Enclosure 42 Photo of Mast at Cabin Top

Enclosure 43 MSC letter dated 17 August 07

Enclosure 44 Photo of EPIRB Attachment on Mast

Enclosure 45 Conversation Record with Mr. [redacted] Surveyor

Enclosure 46 Federal Register/Vol. 59, No. 9/ Thursday, January 13, 1994, Proposed Rules

Enclosure 47 G-MTH-3 Letter dated 7 Jun 90

Enclosure 48 Chart showing demarcation line

Enclosure 49 Photo of Collapsed Mast

Enclosure 50 Marine Inspection Activity Report MI01019991

Enclosure 51 Letter from Mr. [redacted] received by US Coast Guard dated 24 Aug 94

Enclosure 52 Correspondence between Coast Guard and NTSB

Enclosure 53 [redacted] Surveyor's Report on Mast and Rigging dated 22 Jan 07

Enclosure 54 Conversation Records and statements from Honolulu Fire Dept responders dated 6 Dec 06

Enclosure 55 Conversation Record with Mr. [redacted], Passenger, dated 21 Dec 06

Enclosure 56 Conversation Record with [redacted], passenger, dated 7 Jan 07