National Transportation Safety Board

Flooding of Cargo Holds

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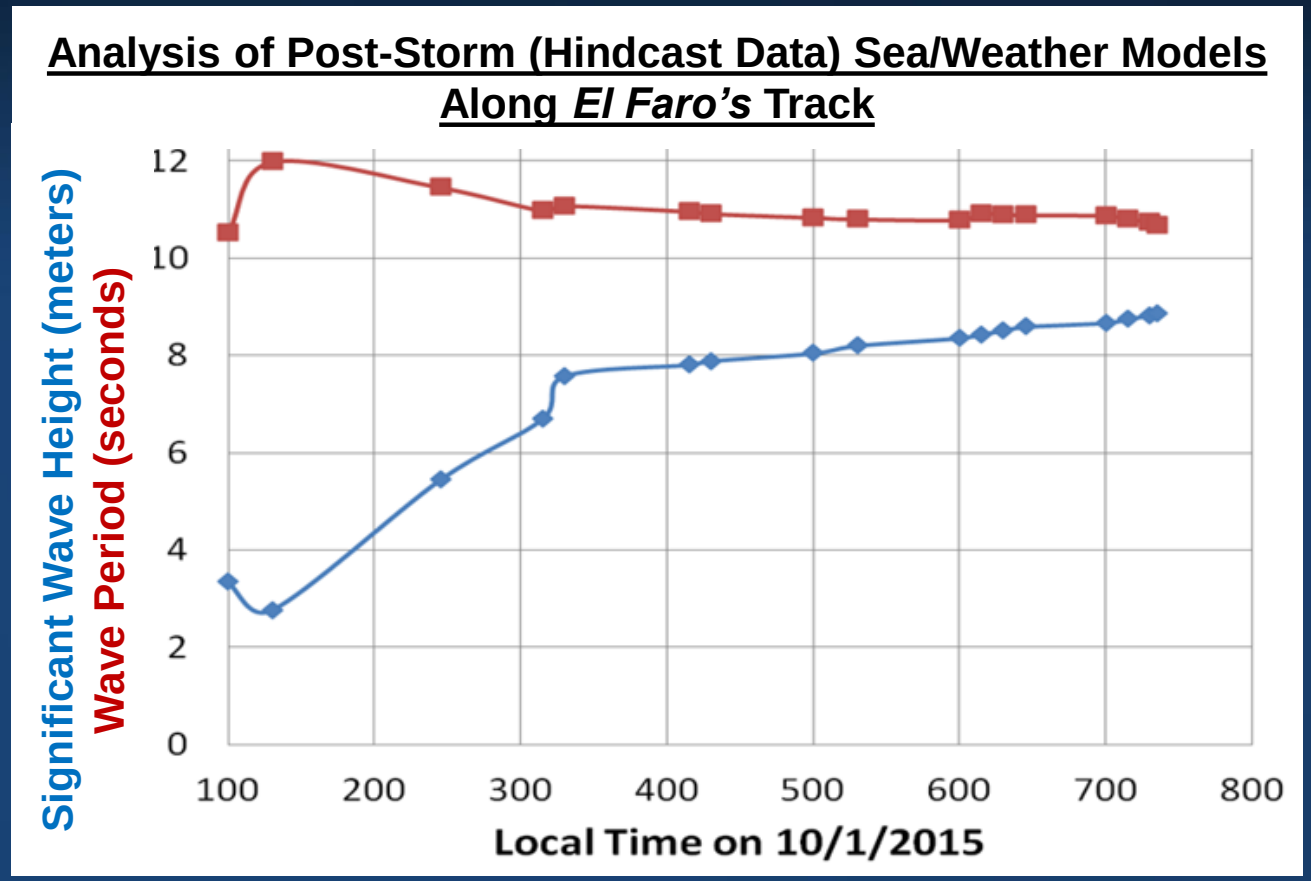
Naval Architecture Group Chairman

Overview

- Increasing seas and waves, resultant windheel
- Flooding sources
- Car lashings
- Bilge pumping
- Bilge high-level alarms in cargo holds
- Watertight hatch open/closed indicators
- Cargo hold ventilation closures
- Hull wreckage examination

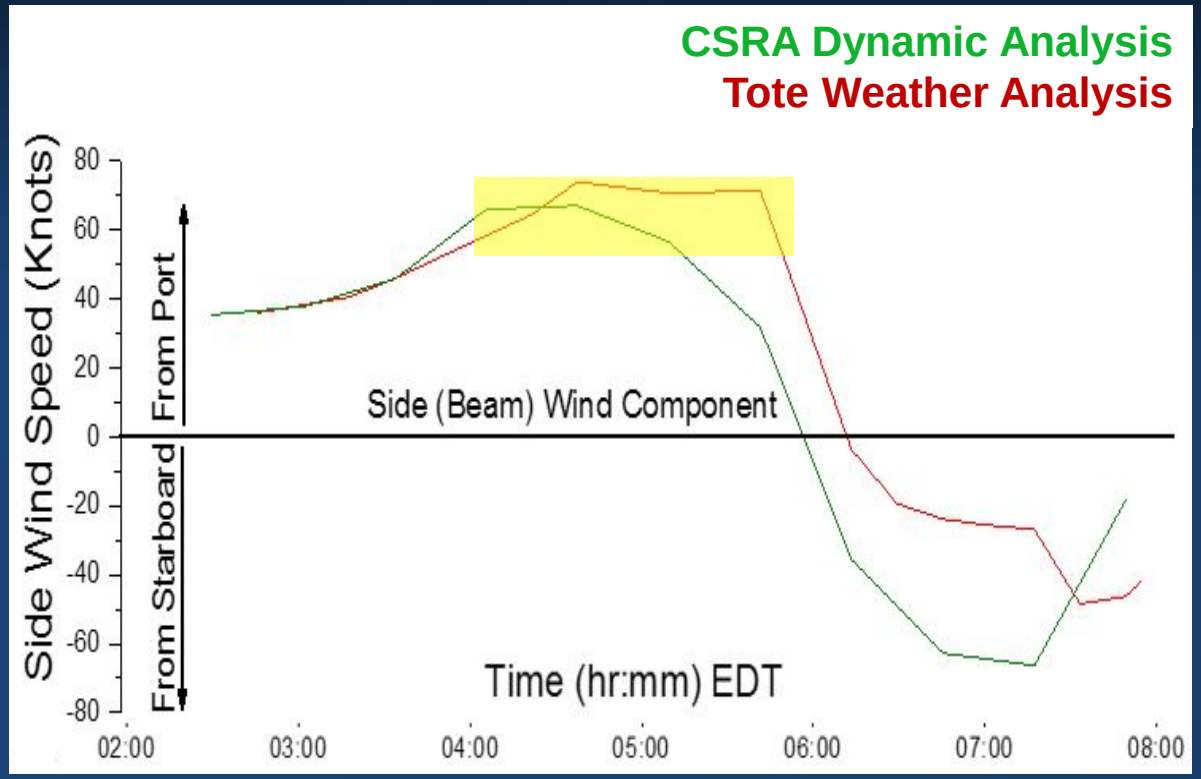
Increasing Seas

- Seas increase rapidly after 0130
- Over 7 meters (23 feet) by 0300
- Build to 9 meters (30 feet)
- Wave period of 11 seconds

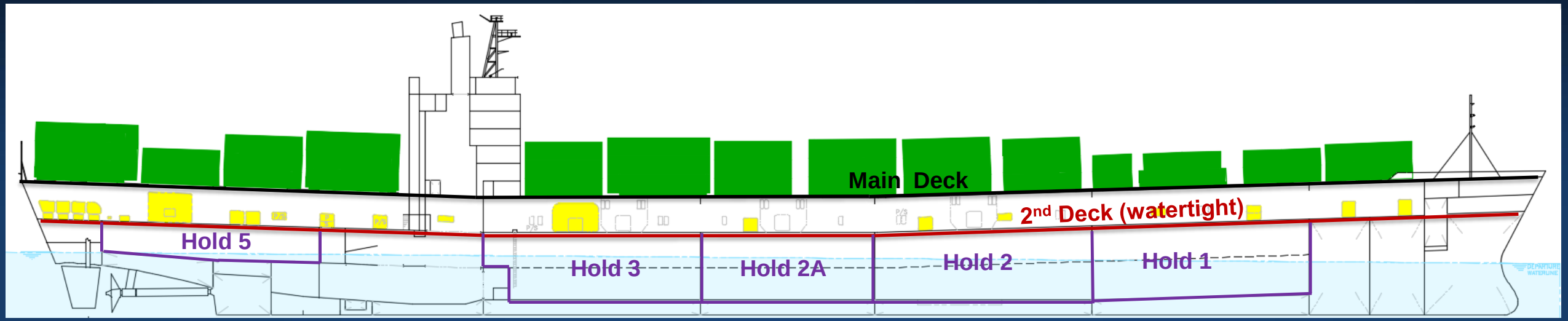


Sustained Windheel

- Increasing winds after 0200 on vessel's port beam
- Wind near 70 knots by 0400
- Effect: increasing and sustained heel (windheel) to starboard
- Hydrostatic analysis shows heel from 5º to 8º for winds 60 to 80 knots on beam

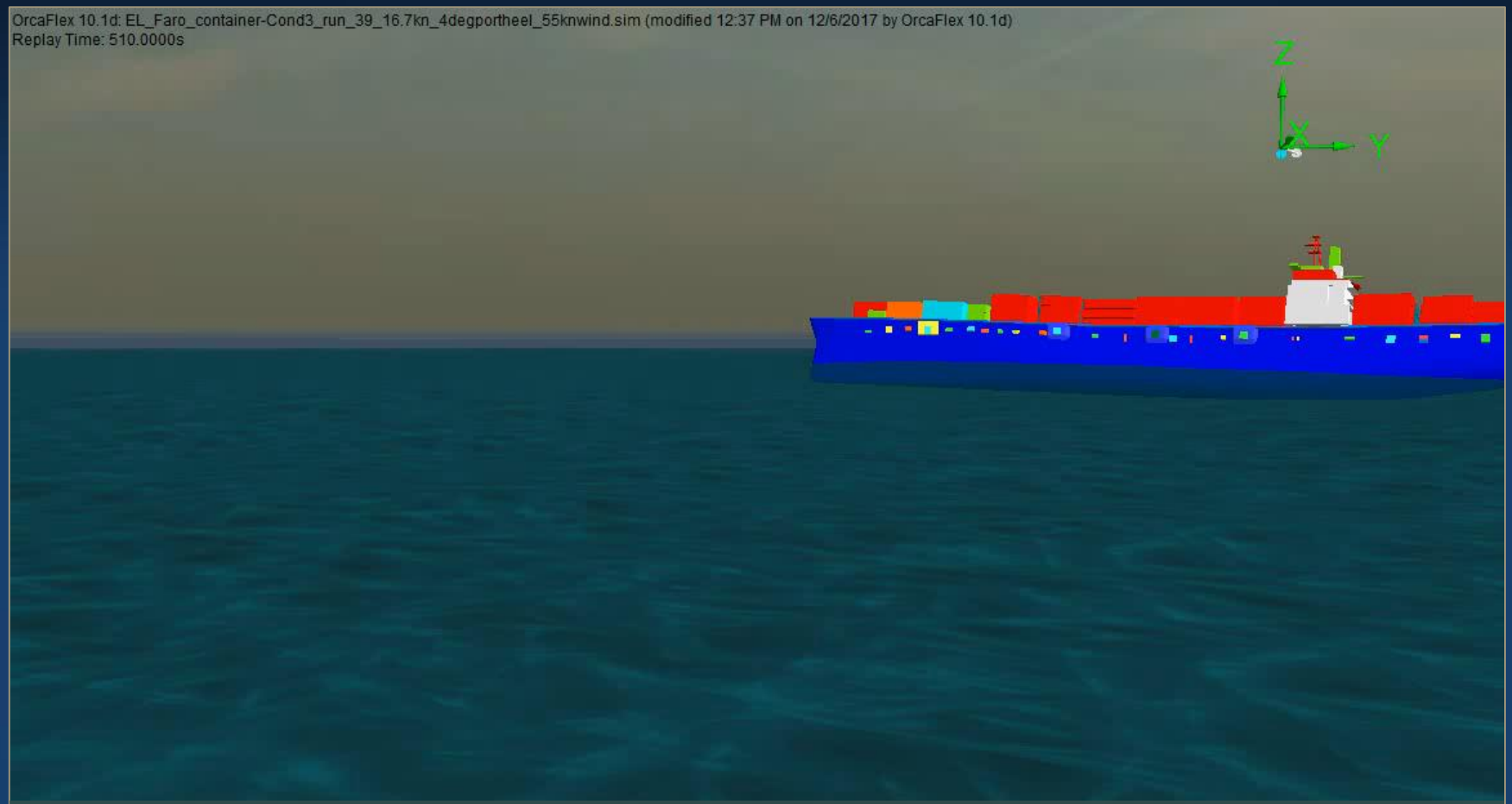


Watertight Deck



- Boarding seas (green water) was known to enter onto 2nd deck in past
- Partially enclosed 2nd deck was watertight

Dynamic Analysis



Simulation at 0330 hours

Fixed 4^{o} heel, ship speed 16.7 knots, 55 knot wind, 25-foot seas

Downflooding from Watertight Scuttle (Deck Hatch)

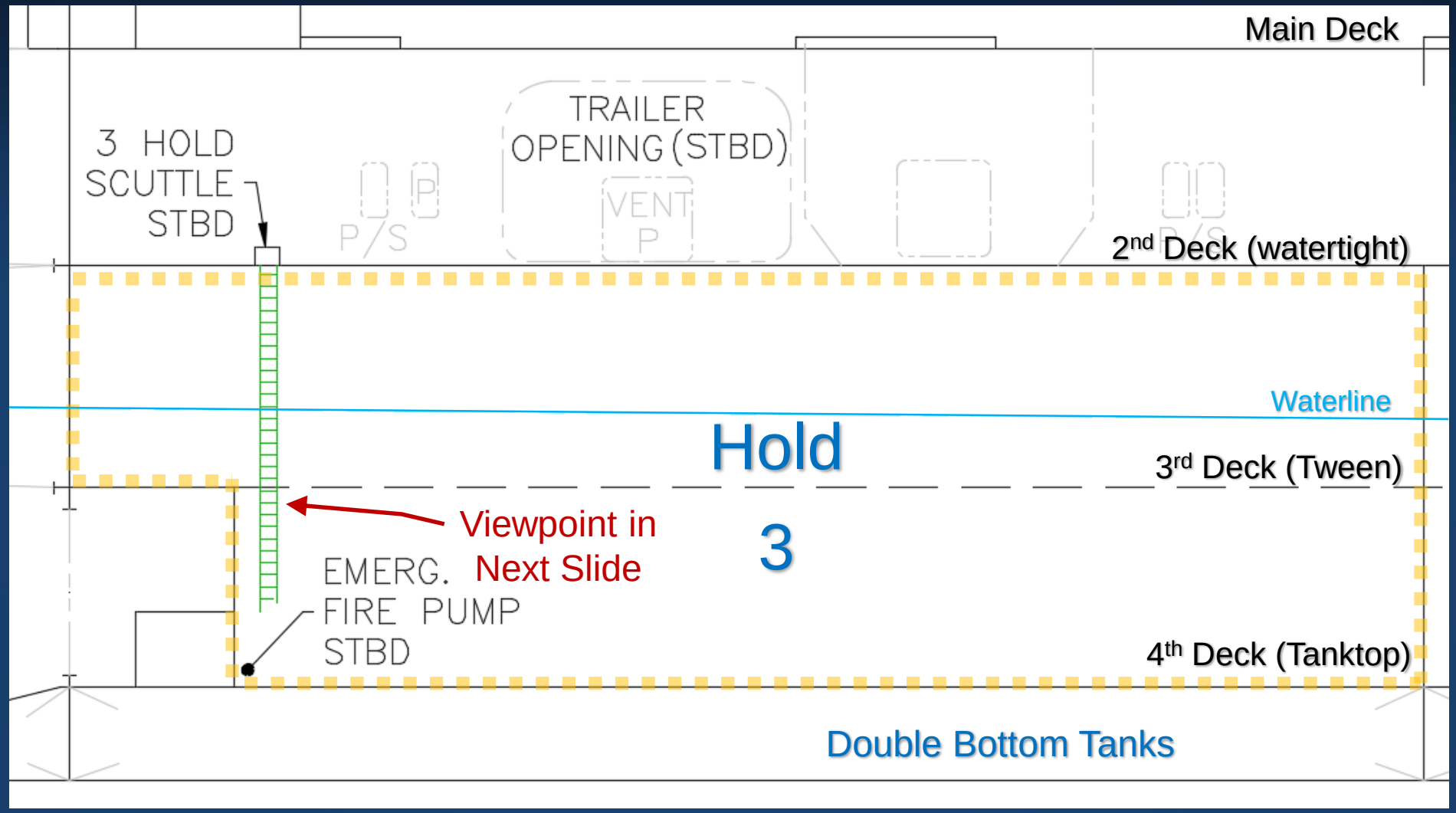
- Hold 3 was flooding at 0543 per VDR
- Small watertight deck hatch (scuttle) to cargo hold 3 on second deck was open
- Open scuttle allowed downflooding through ship's watertight envelope

Unsecured Scuttle to Hold 3

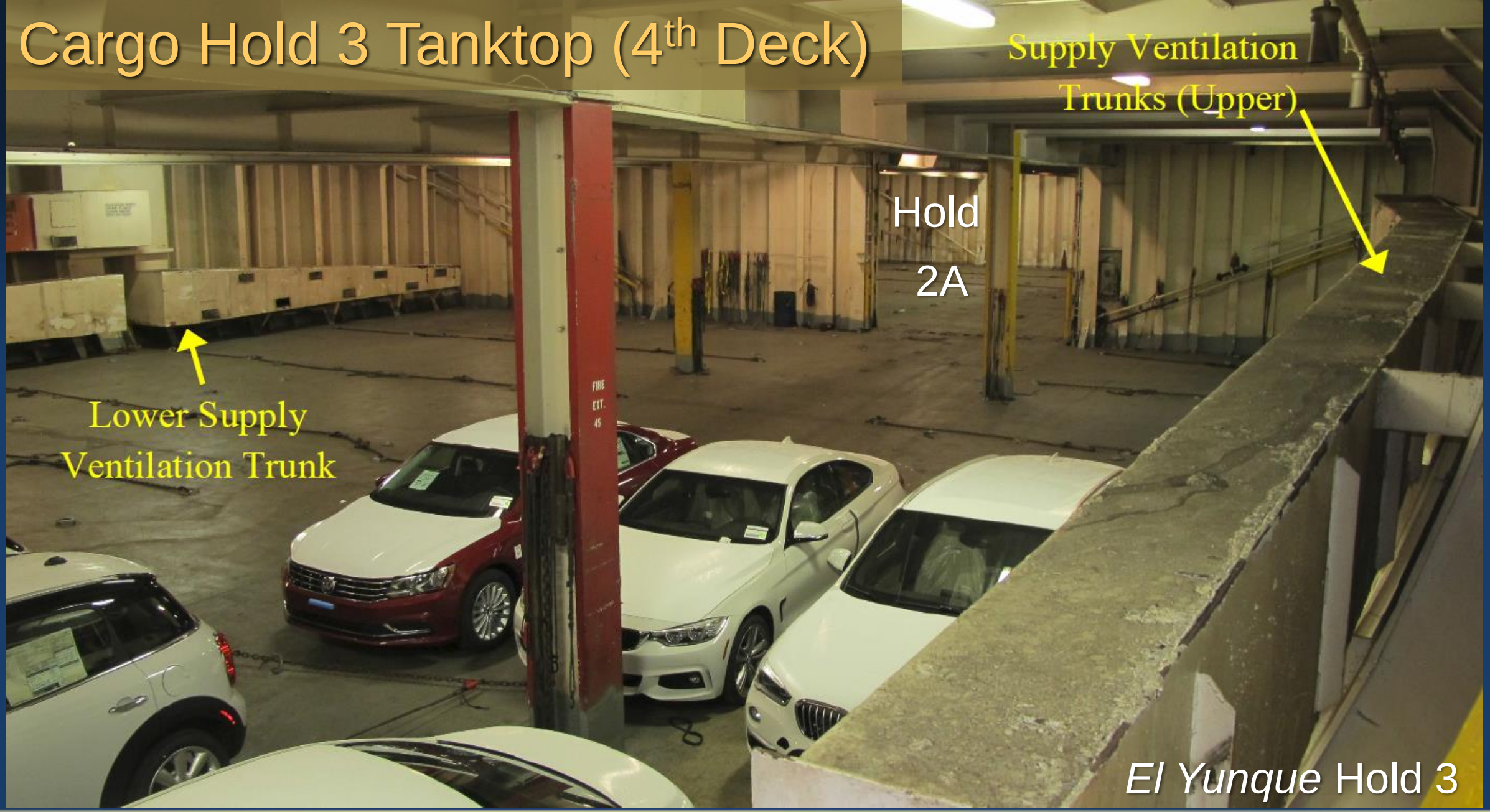
- Crew did not know when or how scuttle to hold 3 opened
- If bridge had open/close indicator, crew would have known scuttle was open

El Faro Scuttle

El Faro Cargo Hold 3

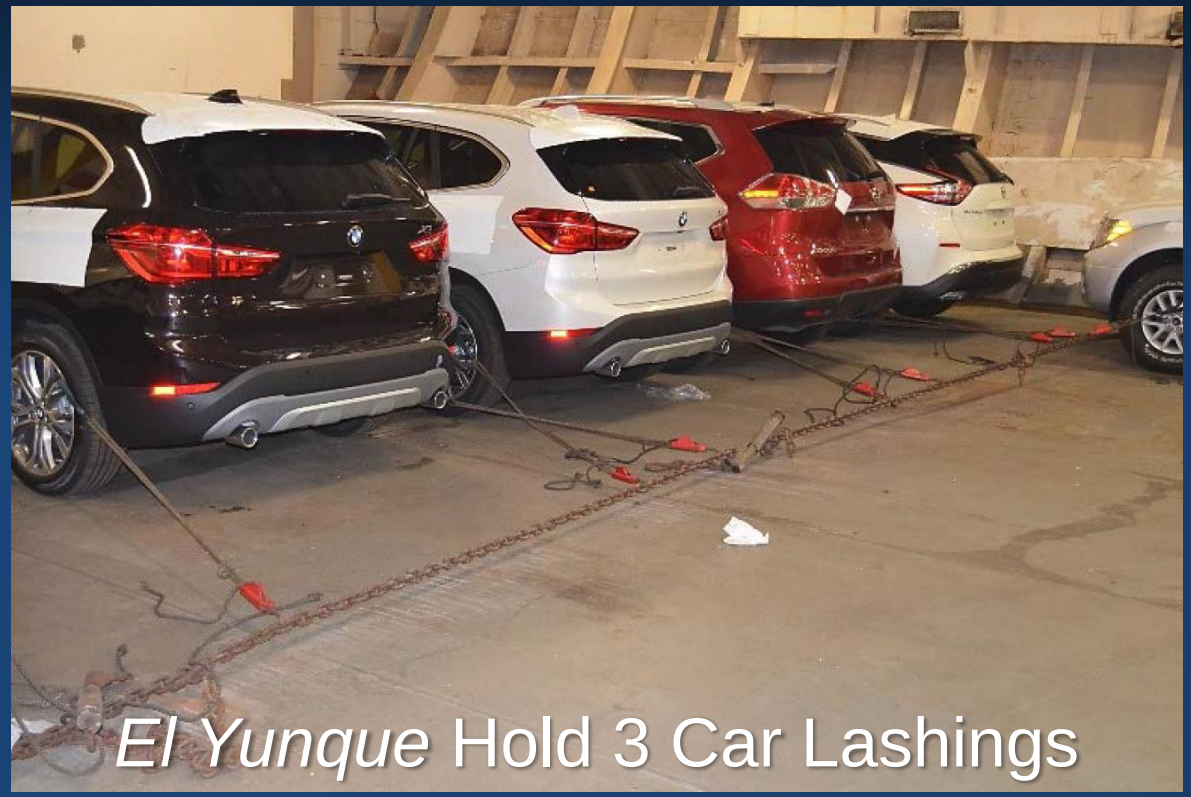


Cargo Hold 3 Tanktop (4th Deck)



Automobile Lashings in Hold 3

- Automobile lashings did not conform to cargo-securing manual
- Cars were more likely to shift during heavy weather



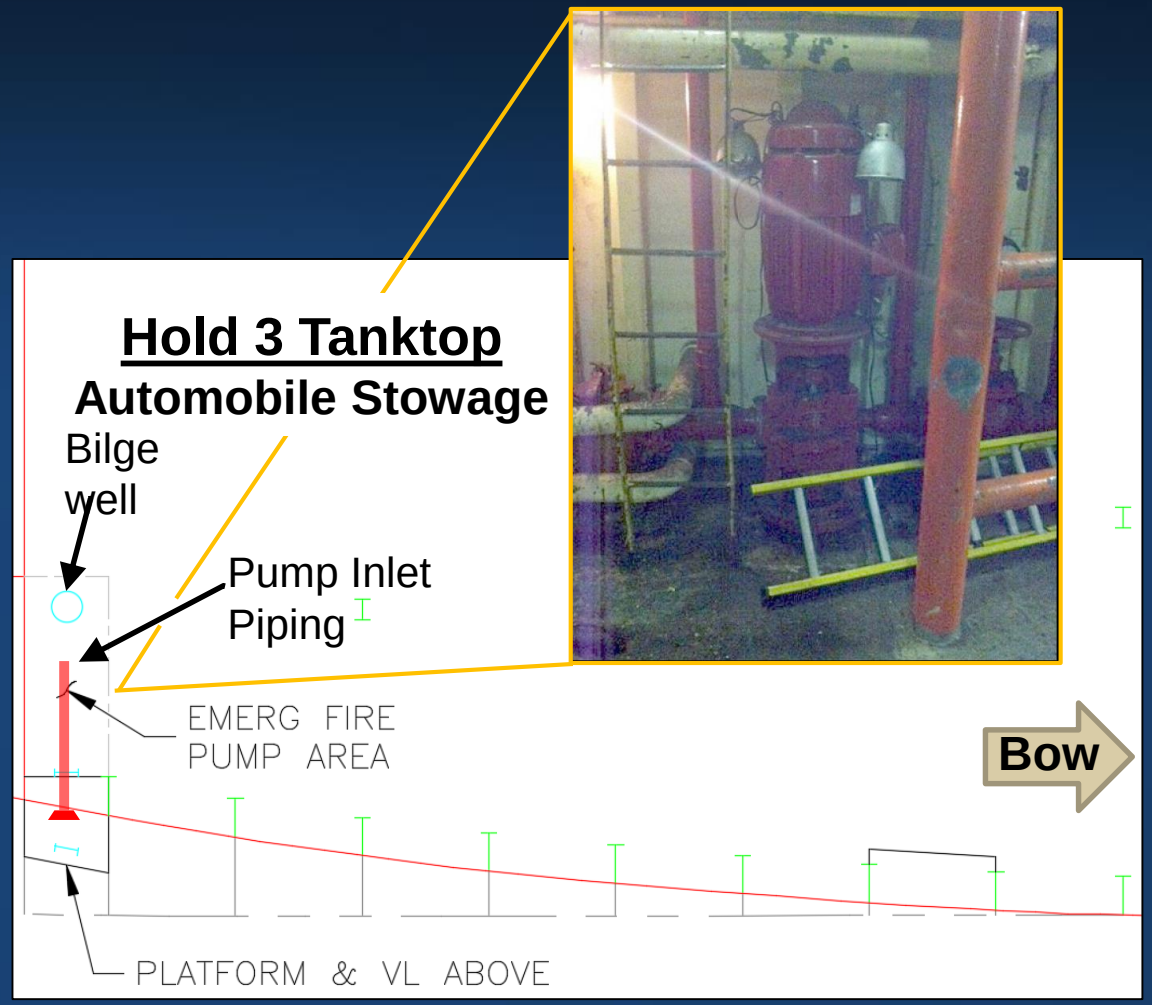
El Yunque Hold 3 Car Lashings

Flooding Effect on Car Lashings

- Adverse effects:
  - Small amount of water decreases friction
  - Rising water begins to float cars
  - Mass of sloshing water acts on cars
- Crew said cars were loose
- Water plus vessel's motion loosened cars

Seawater Inlet Piping to Emergency Fire Pump

- Cars loose in hold 3 at 0544
- Bilge pumps already running
- Scuttle secured about 0600, but hold 3 still flooding
- Piping to fire pump possible source of flooding
- Loose cars could have struck piping to fire pump



Hold 3 Flooding Effect

- Damaged piping potentially flooded hold 10% to 20% by 0716
- MSC hydrostatic analysis
  - Beam-to 80-knot wind after loss of propulsion
  - Hold 3 flooded 10% to 30%
  - Rolling about sustained windheel
  - Vessel susceptible to capsizing
- Damage to seawater piping in hold 3 most likely led to flooding in the hold, which significantly compromised vessel's stability

Bilge Pumping

- Two bilge wells per cargo hold (port and starboard)
- Bilge system operated continuously from at least 0544
- Flooding in hold 3 exceeded design capacity of bilge pumps
- Water level continued to rise despite pumping

El Yunque Bilge Well, Hold 3

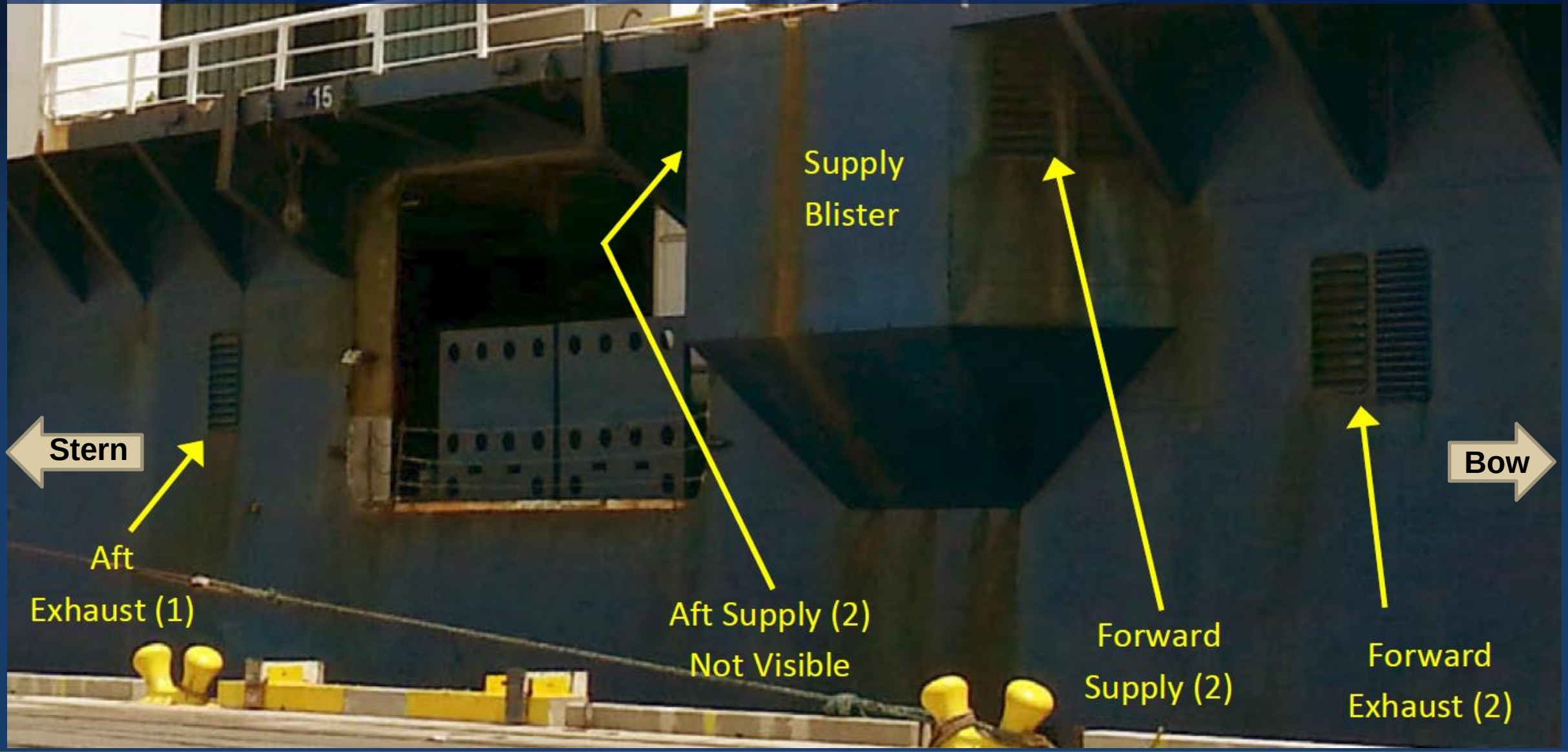
Bilge Alarm System

- Visible and audible alarms in engine room only
- Hold 3 alarms typically investigated by engineering watch
- No evidence of how flooding in hold 3 detected
- Discussion on VDR of hold 2A alarm
- Crew most likely alerted to water in hold 3 by bilge alarm system

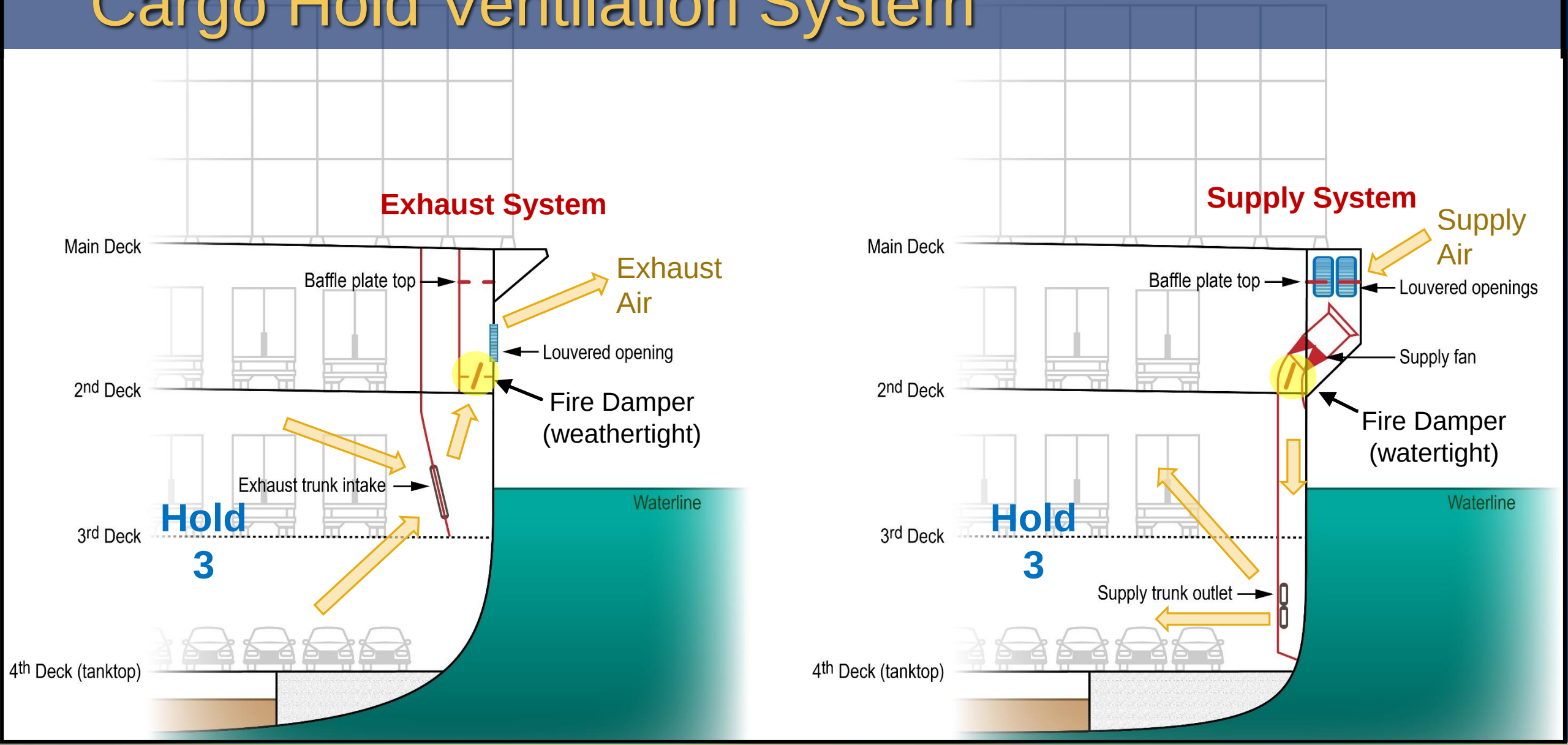
Bilge Alarm Requirements

- Alarms quickly identify flooding
- Alarms not required on cargo vessels
- Cargo vessels should be equipped with bilge alarms

Cargo Hold Ventilation System



Cargo Hold Ventilation System

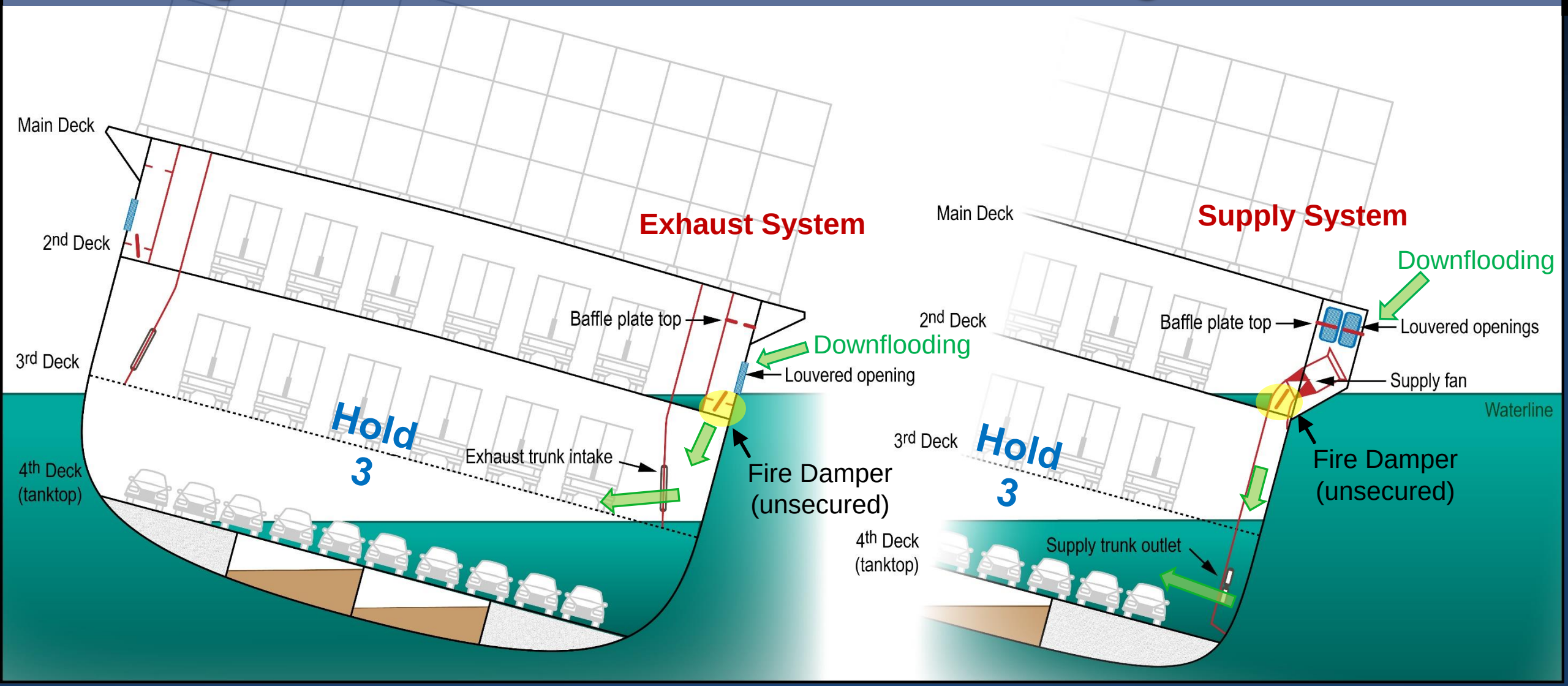


Schematics based on Coast Guard Marine Safety Center Analysis

Cargo Hold Ventilation Closures

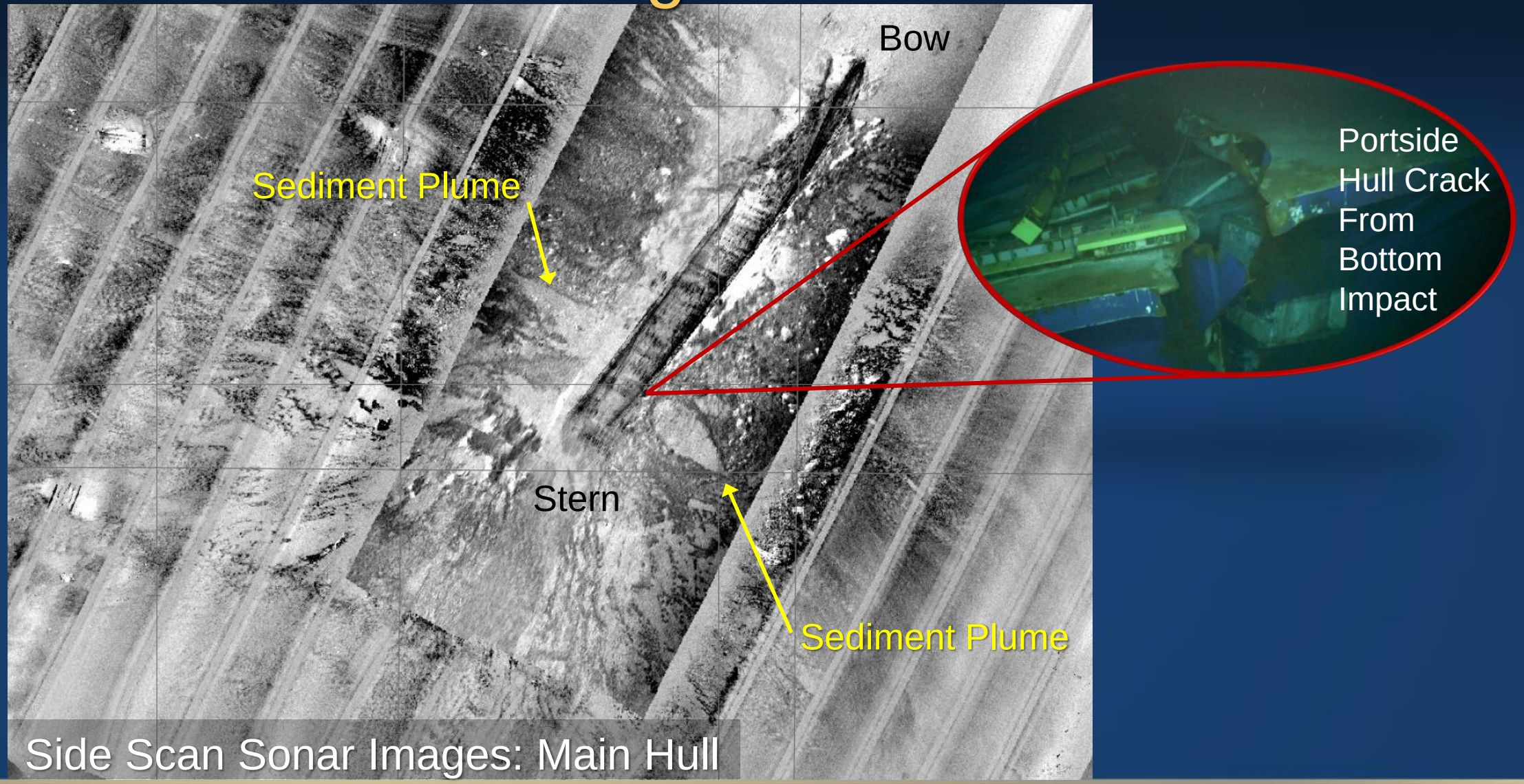
- Ventilation closures most likely remained open throughout sinking
- COI required ventilation of holds at sea
- Intact and damage stability standards consider ventilation openings to be closed
- Vessels should not have conflicting requirements

Cargo Hold Ventilation Downflooding

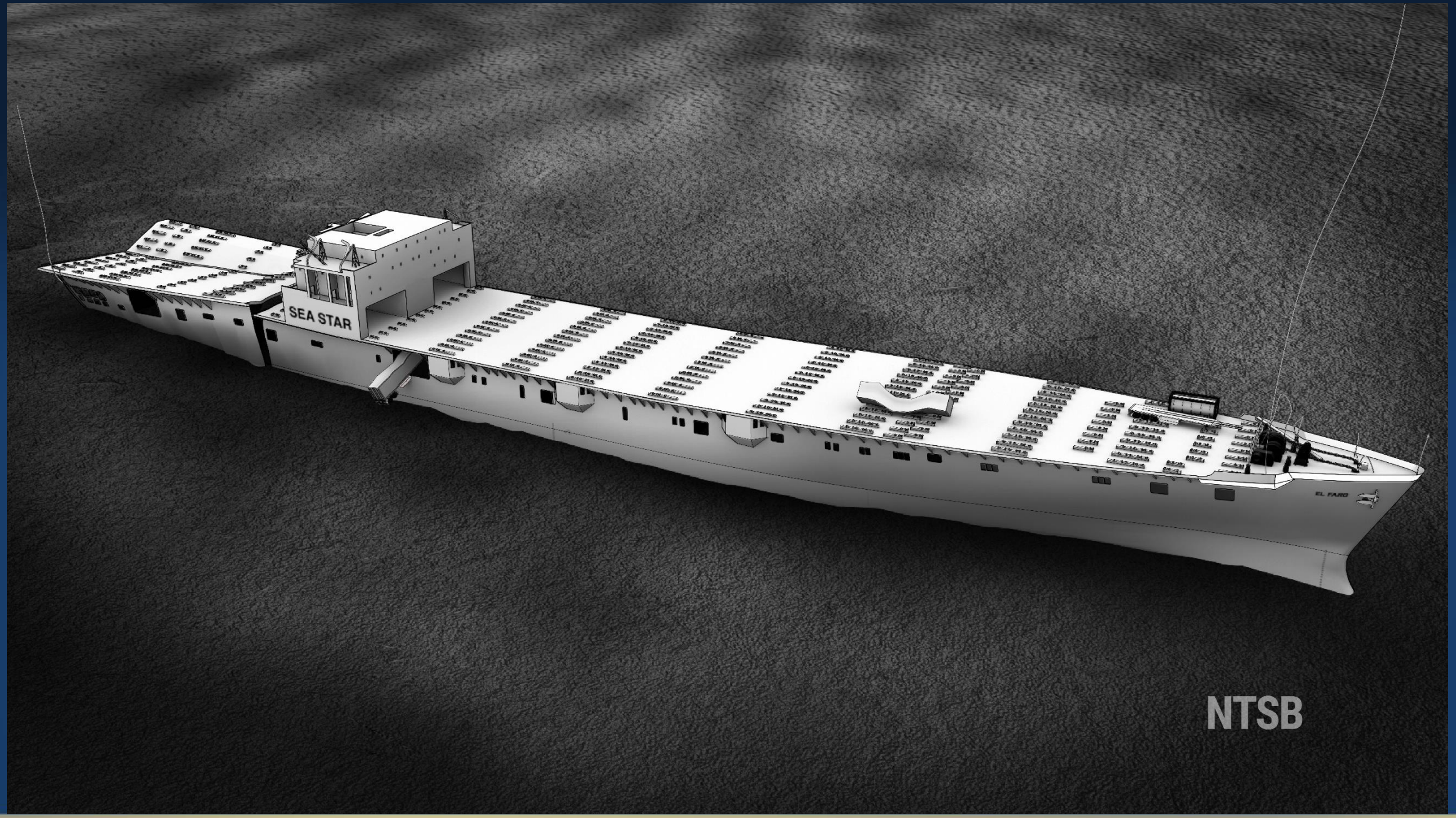


Schematics based on Coast Guard Marine Safety Center Analysis

Examination of Wreckage



Side Scan Sonar Images: Main Hull



Summary – Flooding of Cargo Holds

- Findings
- Recommendations