Submarine Operations – New Technology Insertion Impacts on the Practice of Navigation & Piloting

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"The traditional and trusted piloting methods, which rely heavily on visual observation (of varying acuity), use of radio and radar, and the application of expert local knowledge, are being weighted against high-technology solutions that offer real-time information and support for precision navigation and decision making – but that have yet to inspire confidence and trust."

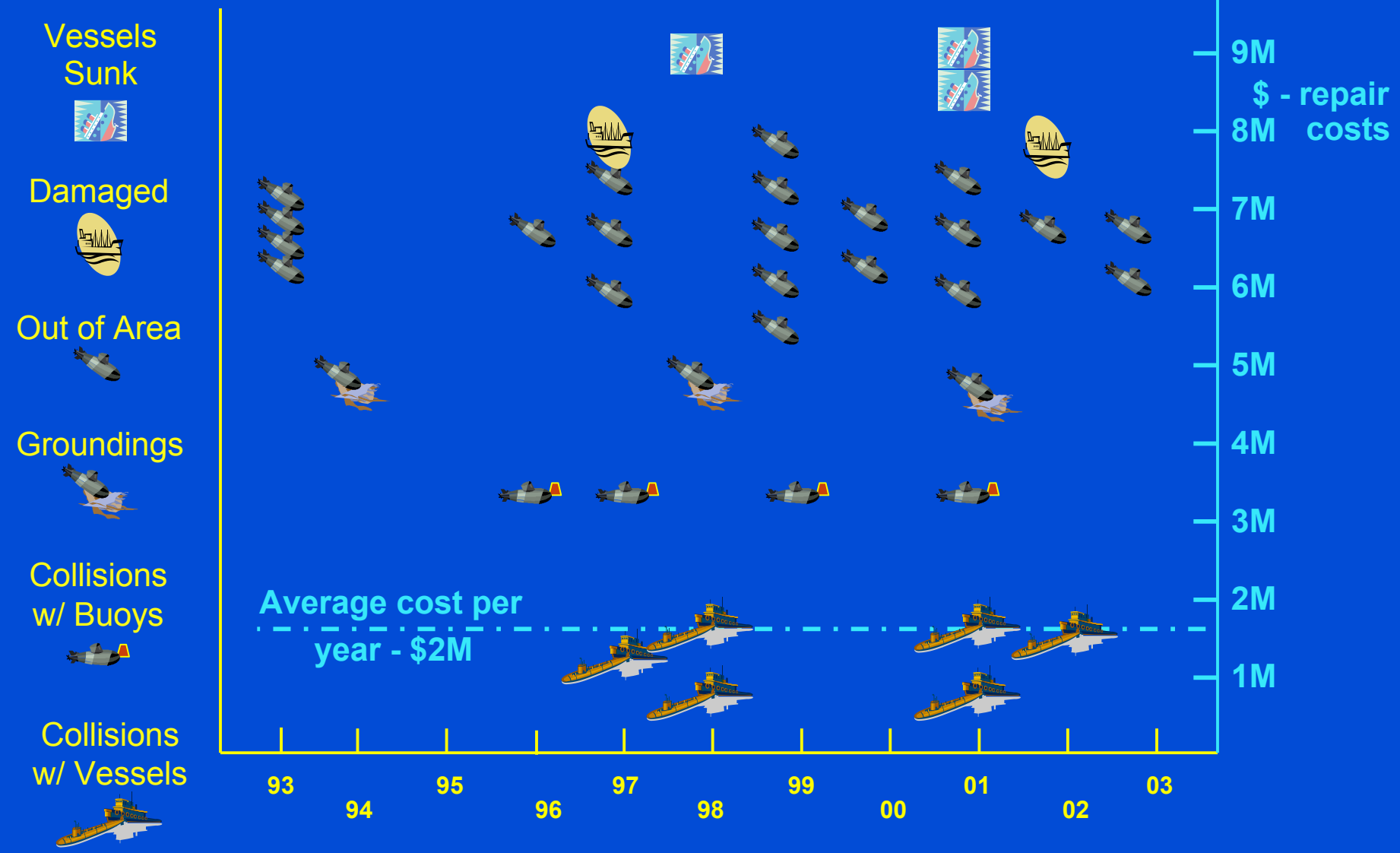
Minding the Helm: Marine Navigation and Piloting,

National Academy Press, Wash DC, 1994, p. 263

Overview

- Situation models and mental models for team situational awareness (SA)
  - Team SA in submarine navigation
- Navigation performance assessment
- Impacts of digital electronic navigation aids
- HPI, HSI and system design

Sample Data – Collisions, Groundings, & OOAs



Situational Awareness

- An understanding of the state of a complex, dynamically changing environment, including relevant parameters of the system

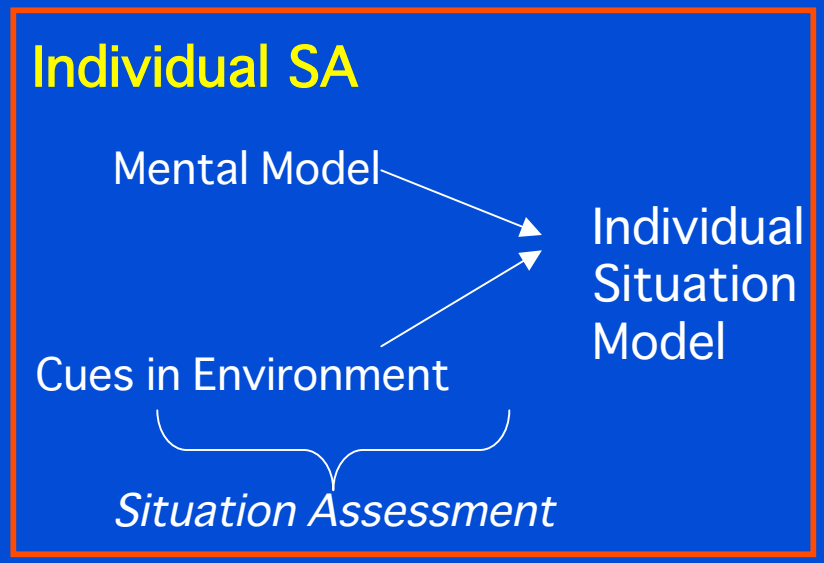
- Perception, comprehension, projection (Endsley, 1995)

USS *Vincennes* and Iran Air Flight 655
USS *Greeneville* (SSN 772)
Aviation and air traffic control mishaps

Mental Models and Situation Models

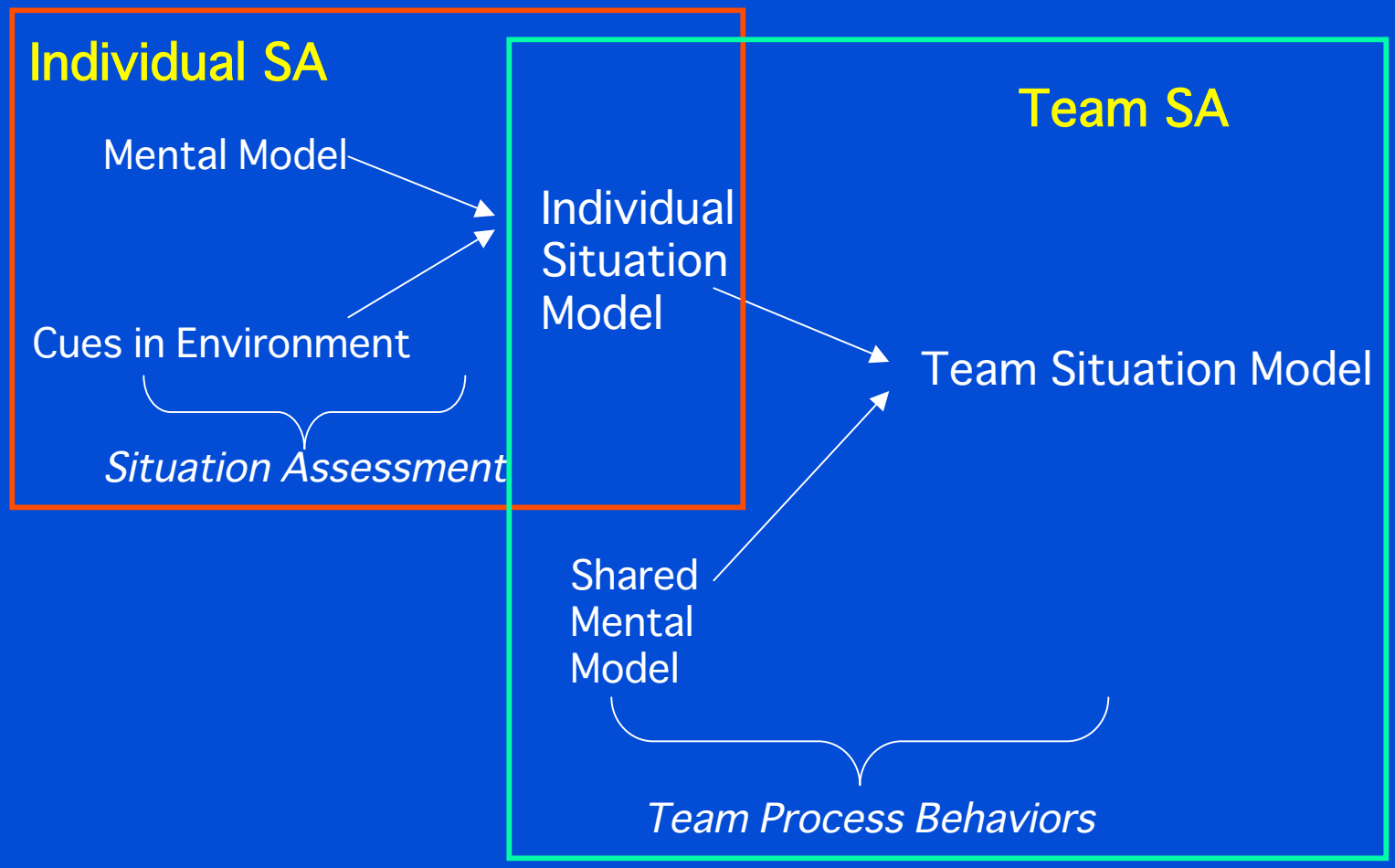
- Mental model (MM)
  - Typically context independent, stable
  - Knowledge in long term memory
    - How a system operates, relevant to the environment, task, and team members
    - Developed via experience, training, & procedures
- Situation model (SM)
  - Context dependent, dynamic
  - Momentary understanding of the current situation according to the task(s) being performed

Situational Awareness, Mental Models and Situation Models



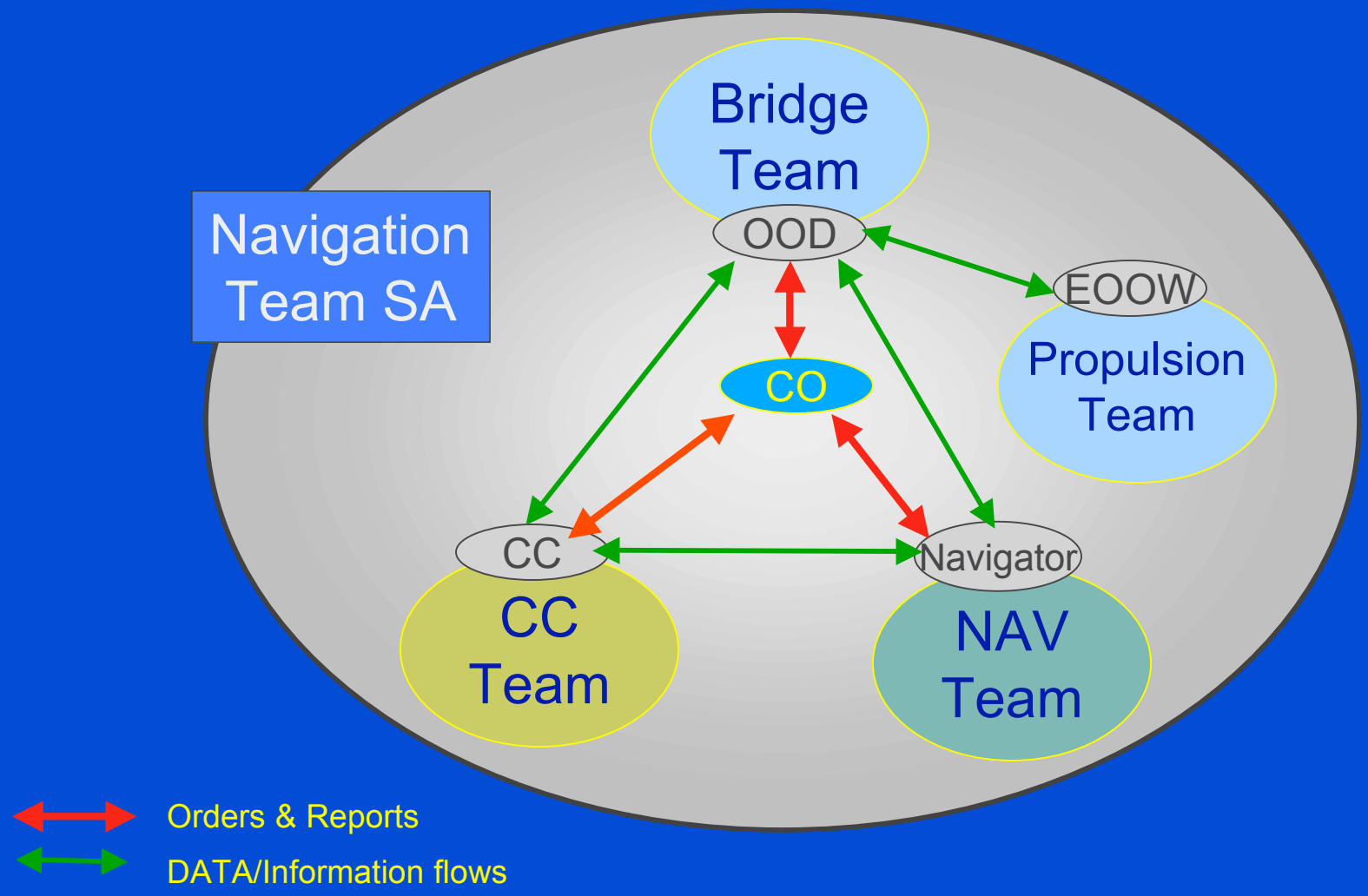
[Adapted from Cooke, Stout, & Salas (2001)]

Situational Awareness, Mental Models and Situation Models



[Adapted from Cooke, Stout, & Salas (2001)]

Team SA during Navigation & Piloting - Surfaced Condition



Navigation Performance Assessment

- Standardized metrics do not exist
  - Subjective evaluations
  - Baseline performance of current system cannot be established
- 37 cases evaluated from 1992-2003
  - No centralized database exists
  - Incomplete database
  - Data taken from Lessons Learned, Non-Nuclear Incident Reports, Type Commander Readiness and Training Memorandum, etc.

Contributing Factors

	Collisions w/other vessels (6)	Collisions w/buoys (4)	Near misses (4)	Groundings (3)	OOA (20)	Total
Situation Model	6	4	4	6	15	35
Mental Model	3	1	0	0	5	9
Navigation Aid	3	4	4	2	4	17
Operations Planning	0	0	0	0	6	6

Causes of Collisions, Near Misses, Groundings, and Out Of Area's (OOAs)

	Collisions	Groundings	OOAs
Ship control issues	x		x
Contact coordination issues	x		
Failure to follow procedures	x	x	
Wrong corrective action taken	x		
Navigation/charts issues	x	x	
Failure to make use of SA inputs	x	x	x
Operator distractions			x

Navigation Performance Findings

- Our preliminary data show:
  - Reduction in crew's ability to recognize & react correctly when automated functions drop offline
  - Navigation plan *changes* tend to invalidate the inputs upon which automated equipment operates, rendering the "plan" inaccurate
- Either occurrence represents a change to a Situation Model – the changed situation may not be recognized by automated equipment

Impact of Automated Systems on Navigation Performance

- Success of automation depends on
  1) Operator's trust in the system
  2) Operator's self confidence in his ability independent of the system (Parasuraman & Riley, 1997)

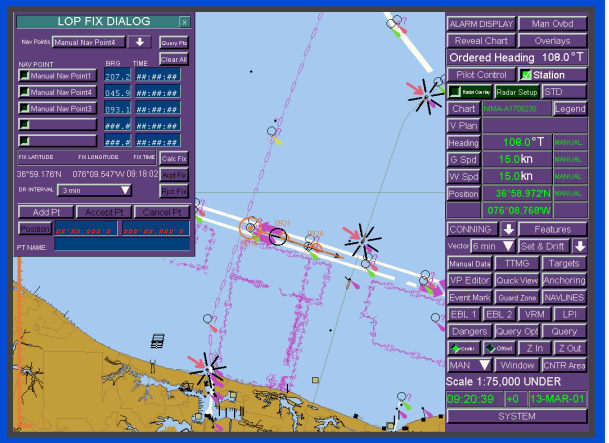
- *Potential* problems with automation

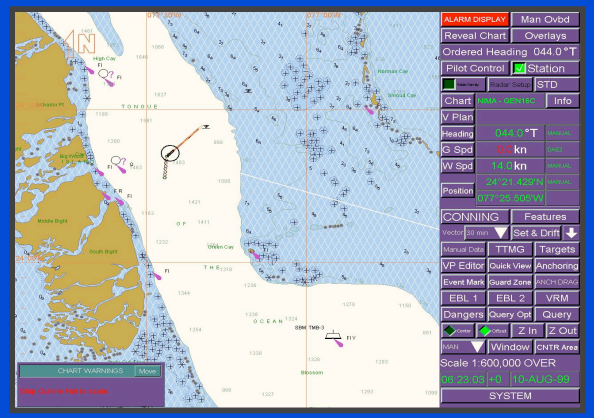
- More data needed to support our hypothesis:
  - Loss of SA adversely impacts the art and science of navigation

Human Systems Integration

Electronic Navigation Systems Use

- Not just a training issue
  - What mix of automation and human control/monitoring best optimizes performance?
- Operator responsible for “operating” the new system
- New skills involved
- Concept of “system SA”





System Design Issues

- How can system designers support SA via the navigation system?
  - Focus on the process of developing and maintaining situation models
  - Preliminary design effort to analyze human operator to automated systems interfaces, from both a HPI and a HSI perspective
  - Standardize human interfaces where possible
  - Investigate limits in operator abilities to manage the operation of automated systems
  - Recognize concept of “system SA”

Performance Metrics

Investigation issues:

(1) How well does the set of automated tools support the generation and display of navigation data to decision makers?

(2) How well organized, trained, and drilled are operators in the use of navigation data for making proper decisions with respect to navigation of the boat?

(3) How well can the navigation team process navigation information and communicate it among team members to ensure maintaining shared situational awareness?

Summary

RESEARCH HYPOTHESIS: As automated systems' use reduces submariners' active role in navigation, the navigation team tends more easily to lose SA, which has led to mishaps – including collisions and groundings.

ISSUES:

- As technology insertion proliferates to address and correct identified deficiencies in human performance, a point is reached beyond which further insertion of "technology solutions" can become counterproductive.
- As automated systems proliferate, submarine crews are losing skills needed to develop and maintain situational awareness (based on MMs and SMs) – skills needed to help prevent mishaps.
- Advances in use of electronic nav aids demand different skill sets for operators charged with their use.

Summary

Needs & Solutions:

1. Collect additional operational data
   - Need a system that captures and retains more specific data on navigation mishaps

2. Develop performance measurement metrics

3. Develop procedural modifications that recognize the changed relationship between operators and systems having significant automated capabilities

Acknowledgements

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  - COMSUBLANT, COMSUBPAC
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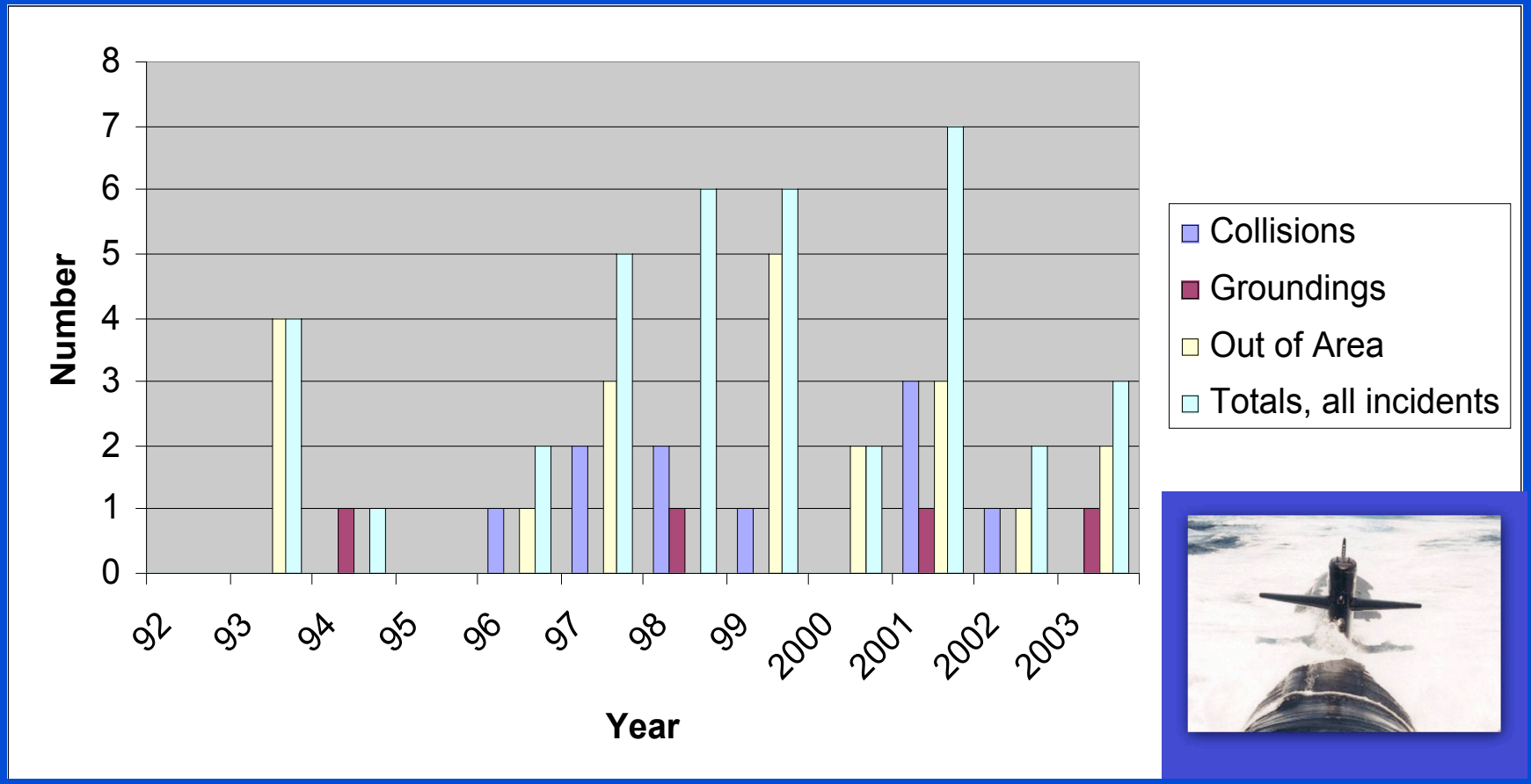
- Naval Submarine Medical Research Lab
  - Dr. Jerry Lamb

Questions and Discussion

BACK UP SLIDES

The Problem

Collisions, Groundings, and Out of Areas for 1992-2003

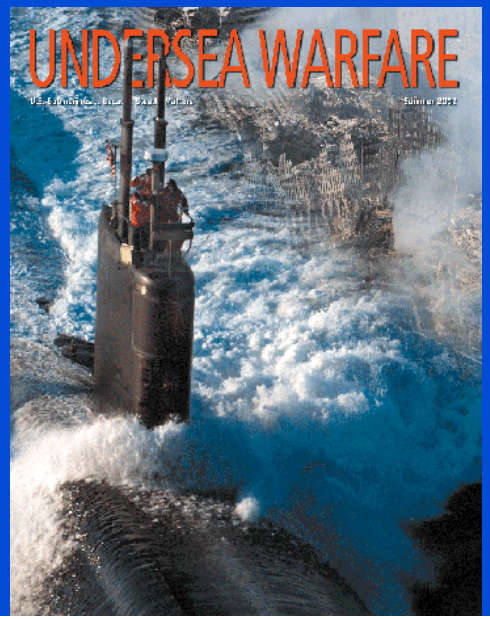


Mishap/Accident Causes

Cause	Total	Percent
SM + Nav Aids	16	43
SM only	12	32
SM + MM	6	16
Ops Planning only	6	16
SM + Ops Planning	5	14
MM + SM + Nav Aids	3	8
MM + SM + Ops Planning	3	8
MM + Ops Planning	2	5
MM only	2	5
Nav Aids only	1	3
MM + Nav Aids	0	0

OOD SA for Submarine Navigation

- Perception and awareness of the relevant informational elements in the environment (Endsley, 1995)
  - OOD needs accurate data on the location, types, and number of all contacts in a given area and their relationship to other points of reference.



OOD SA for Submarine Navigation

- Perception and awareness of the relevant informational elements in the environment (Endsley, 1995)
- Comprehension and integration of various pieces of information in support of goals
  - OOD must understand “present state,” such as knowing set and drift affecting ownship, and/or classifying a contact as an oil tanker or a fishing trawler (e.g., he must comprehend that the maneuvering of a contact within a certain proximity of own ship implies certain things about the contact’s objectives).

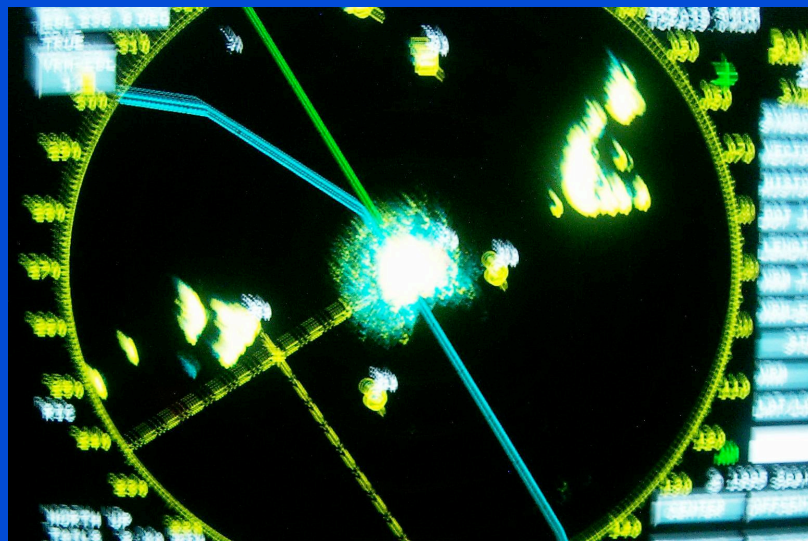
OOD SA for Submarine Navigation

- Perception and awareness of the relevant informational elements in the environment (Endsley, 1995)
- Comprehension and integration of various pieces of information in support of goals
- Future events and system states are predicted based on this understanding
  - Knowing that a contact is an oil tanker currently in a certain location and course allows the OOD to project that the contact is likely to be at a certain location in 30 minutes if course and speed are maintained.
  - Alternatively, if an OOD knows that if, given the operating environment (e.g., San Diego port) a cruise ship typically alters its' course at a specified location, he could use this information in developing a navigation plan for port egress.

Submarine Surface Navigation SA Requirements

- Bridge and Navigation teams
  - Maintain the boat on direct motion/movement to keep within authorized areas & not to collide with anything
- Contact coordination team
  - Maintain all contacts outside a specified area around own ship
- Propulsion
  - Know ordered speed, and/or rudder orders, and execute

Knowledge, Skills, & Abilities

- KSA's needed to monitor and direct the navigation picture
  - Development of situation models (both individual and team)
  - Methods for updating 'equipment SA' while underway
  - Techniques for assessing validity of data extracted from electronic navigation aids

Example: Use of radar as integral to maintaining the navigation picture