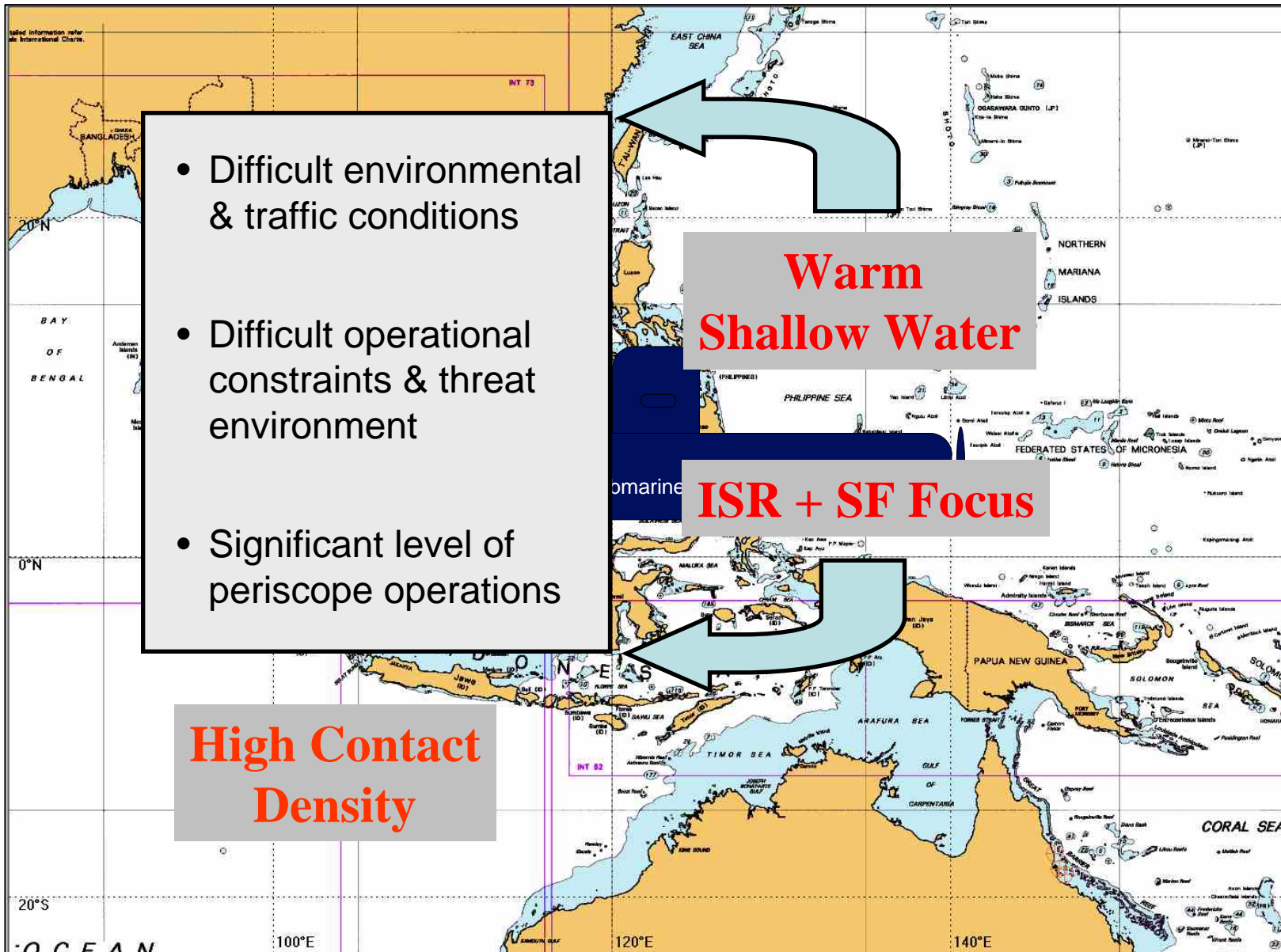# Design for Submarine Command and Control in the 21st Century

Analysis to Design

Thanh Ly, Sam Huf &
Peter Henley (DSTO-WA)

OPERATIONAL CONTEXT

- Difficult environmental & traffic conditions

- Difficult operational constraints & threat environment

- Significant level of periscope operations

Warm Shallow Water

ISR + SF Focus

High Contact Density

Australian Government
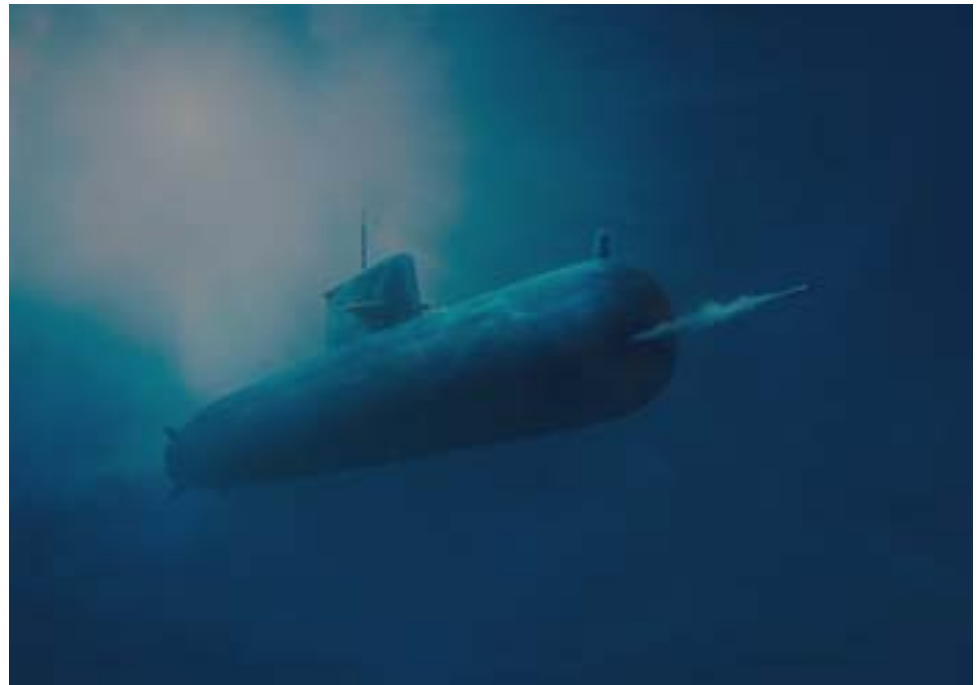**Department of Defence**
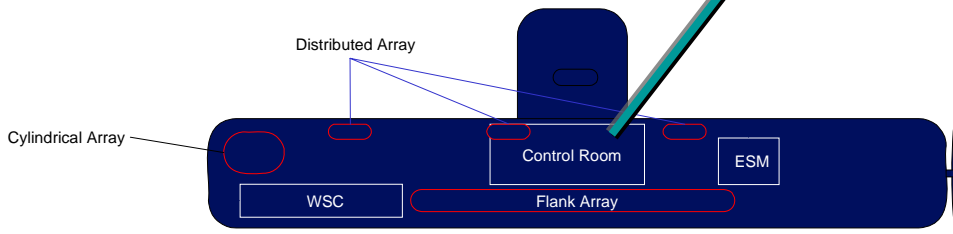Defence Science and
Technology Organisation
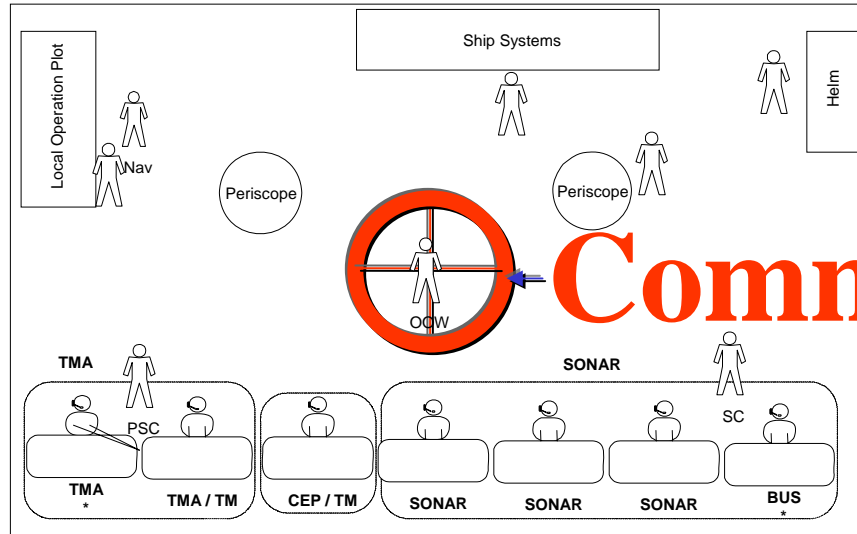
Some Characteristics of Conventional Submarine Operations

- Information is uncertain: Passive sensors

- Communications are intermittent

- Safety and capability depends on stealth
  (Not shock and awe but quiet and clever)

- Picture compilation is a central task
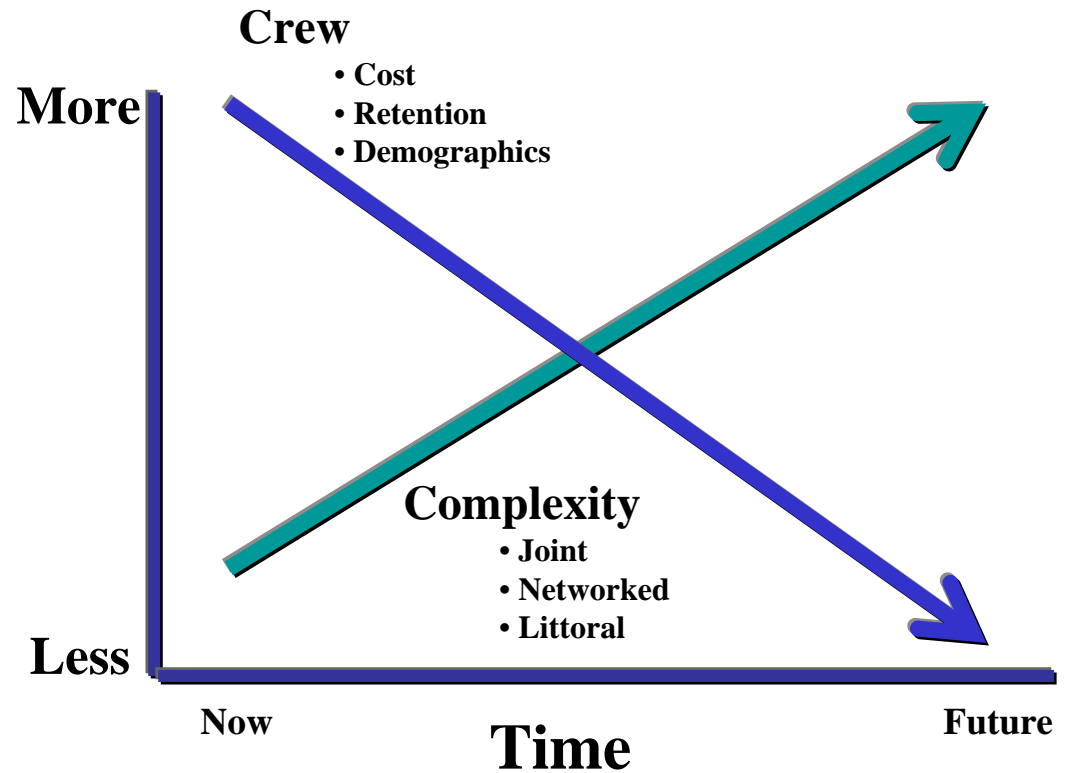 - Cognition + Technology intensive
  - TAKES TIME

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Submarine Command Functions?

Capability DRIVERS: Less Crew x More Complex Operations

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Department of Defence

Defence Science and
Technology Organisation

CHALLENGES FOR INFORMATION SUPPORT DESIGN

- Support correct command response to unfamiliar or unplanned situations

- Support cognitive processes that underlie discretionary decision-making

- Exploit human capabilities and nullify human limitations

- Allow Command personnel to excel by providing opportunities to develop and exercise skills

- Improve job satisfaction

- Attempt to give Australian submarine commanders an UNFAIR ADVANTAGE

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Department of Defence
Defence Science and
Technology Organisation

WHY COGNITIVE WORK ANALYSIS?
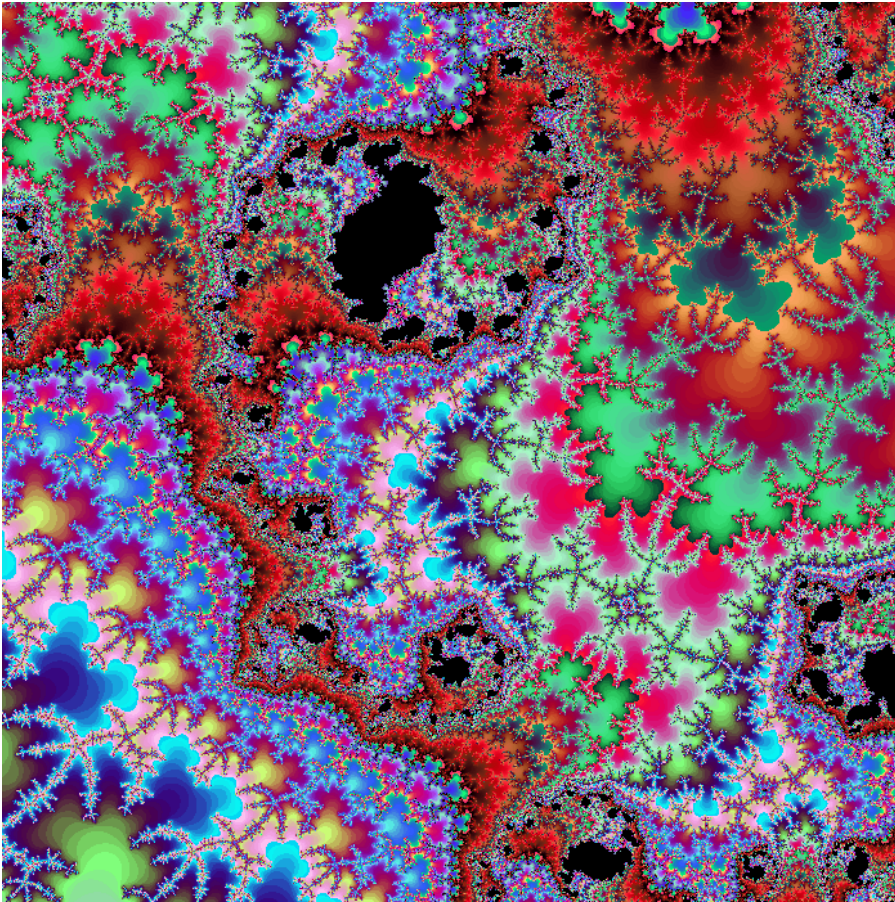
- A submarine in its working environment is a good example of a complex socio-technical system

- The command team of a submarine is faced with a very large problem space where no two operational situations will ever be exactly identical, and which may not be predictable

- A submarine is not a closed system – it is affected by external environmental and tactical disturbances which cannot be predicted with any certainty

- How do you design information support for situations that may not have been predicted during design?

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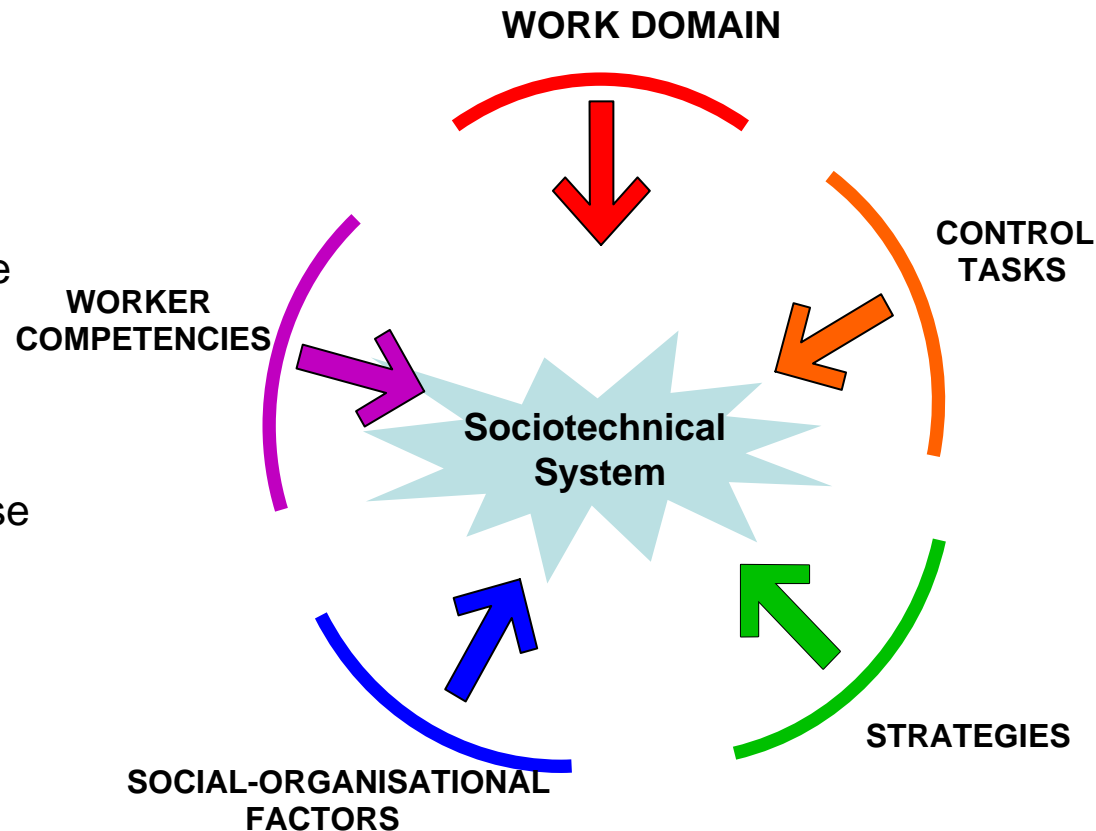Defence Science and
Technology Organisation

WHAT IS COGNITIVE WORK ANALYSIS?

- Single integrated framework for analysis of complex systems – Five Windows on a System
- Based on identifying and exploiting **behaviour-shaping constraints**
- Constraints can be used to guide design of INFORMATION DESIGNS: Decision Support Tools
- Aim to maximise the context-conditioned variability of response of humans to the situations in which they find themselves
- "The worker finishes the design"
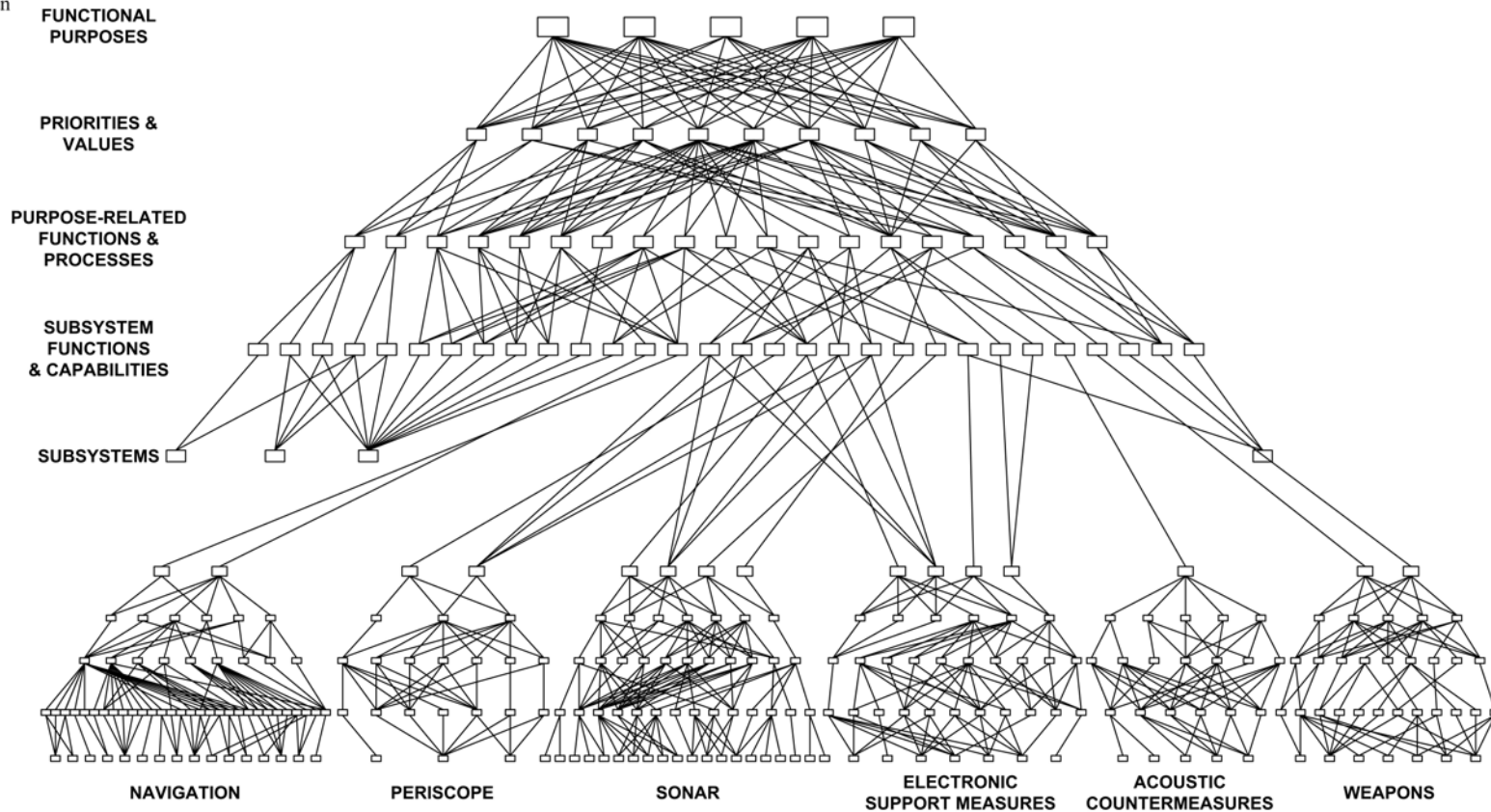
  DON'T just automate

  DO maximise use of human expertise.

WORK DOMAIN

CONTROL TASKS

WORKER COMPETENCIES

Sociotechnical System

STRATEGIES

SOCIAL-ORGANISATIONAL FACTORS

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WORK DOMAIN ANALYSIS

Diagram labels (left column, top to bottom): FUNCTIONAL PURPOSES; PRIORITIES & VALUES; PURPOSE-RELATED FUNCTIONS & PROCESSES; SUBSYSTEM FUNCTIONS & CAPABILITIES; SUBSYSTEMS

Bottom labels: NAVIGATION; PERISCOPE; SONAR; ELECTRONIC SUPPORT MEASURES; ACOUSTIC COUNTERMEASURES; WEAPONS
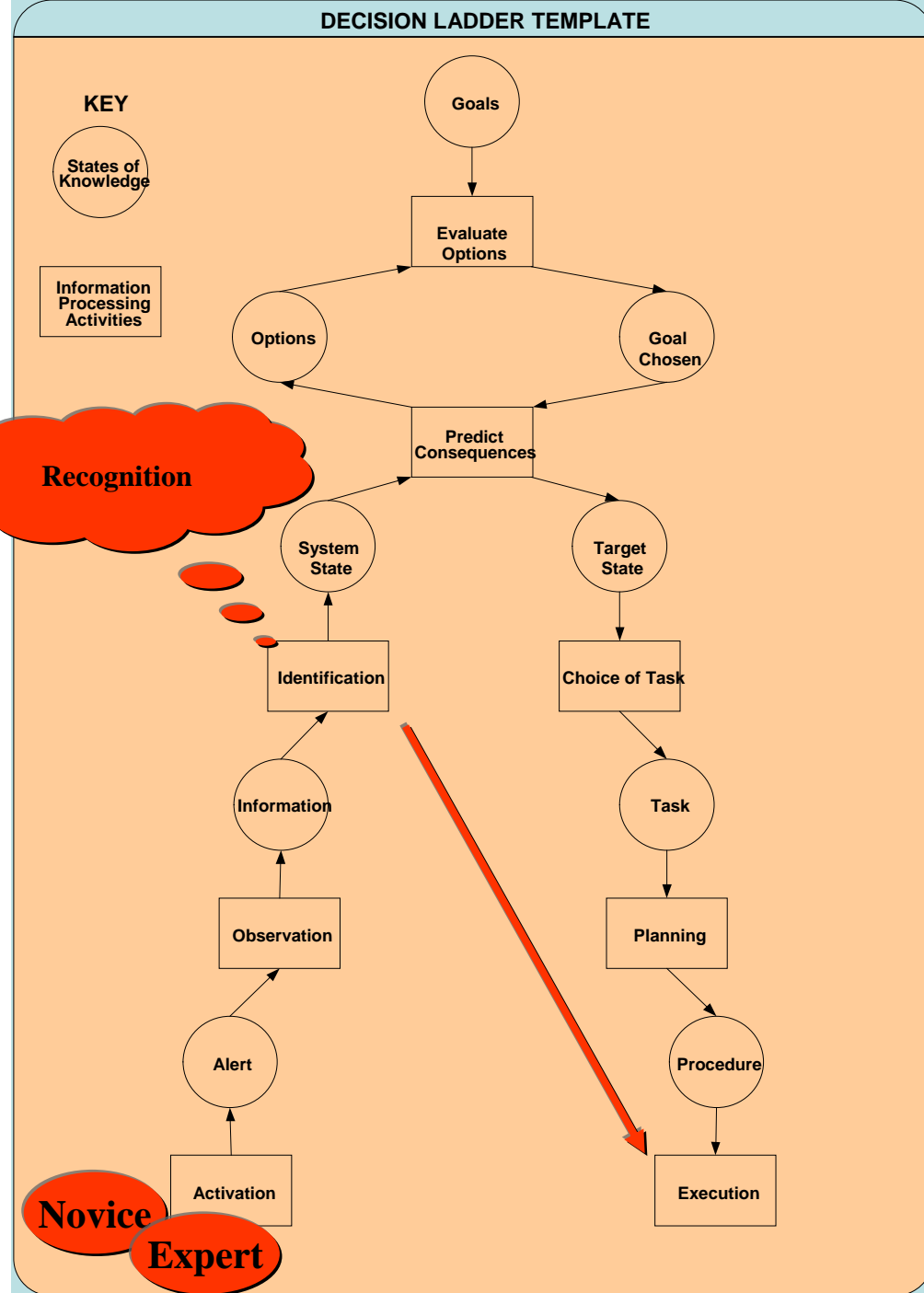
- Purpose-orientated, functional mapping of the entire work domain
- Device independent
- Task & situation independent
- Identifies structure of functionalities, affordances and constraints

- Formally links purposes of the system, its processes and its physical components
- Examines the work domain at different levels of physical deconstruction, as well as at different levels of functional abstraction
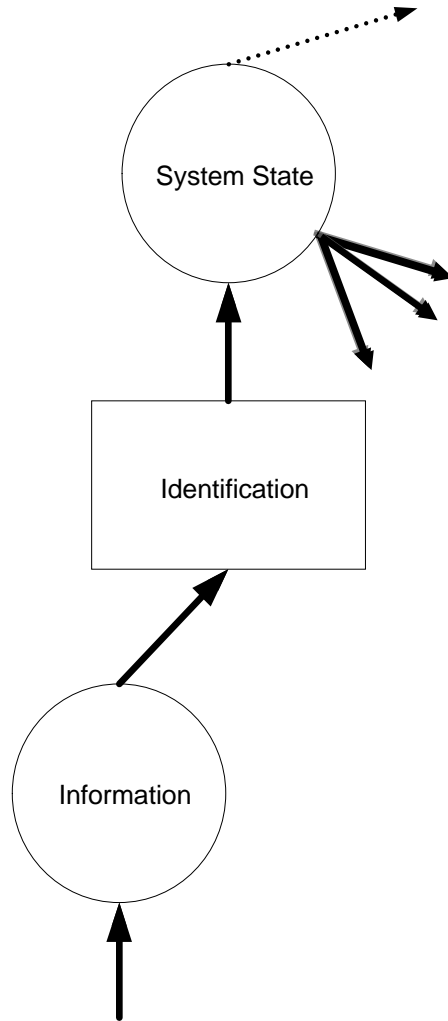
CONTROL TASK ANALYSIS

- Examines WHAT is done within the work domain

- Formative task analysis method to provide support for unforeseen circumstances

- Identifies prototypical work situations or functions

- Maps the 'cognitive trajectories' of expert operators
  - Identifies intermediate states of knowledge
  - Identifies necessary information processing steps
  - Identifies the cognitive shortcuts that typify expert behaviour.

DECISION LADDER TEMPLATE

KEY

States of Knowledge

Information Processing Activities

Goals

Evaluate Options

Options

Goal Chosen

Predict Consequences

Recognition

System State

Target State

Identification

Choice of Task

Information

Task

Observation

Planning

Alert

Procedure

Activation

Execution

Novice

Expert

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INPUT/OUTPUT/CONSTRAINT ANALYSIS

System State

Identification

Information

- Examines the cognitive activities of the operator in terms of knowledge transformations

- Identifies the input knowledge required by the operator

- Identifies the output knowledge state from each transformation

- Identifies individual cognitive processes and the constraints or 'rules' that govern them

- Provides insight into the different strategies that might be used by operators to achieve the same transformations
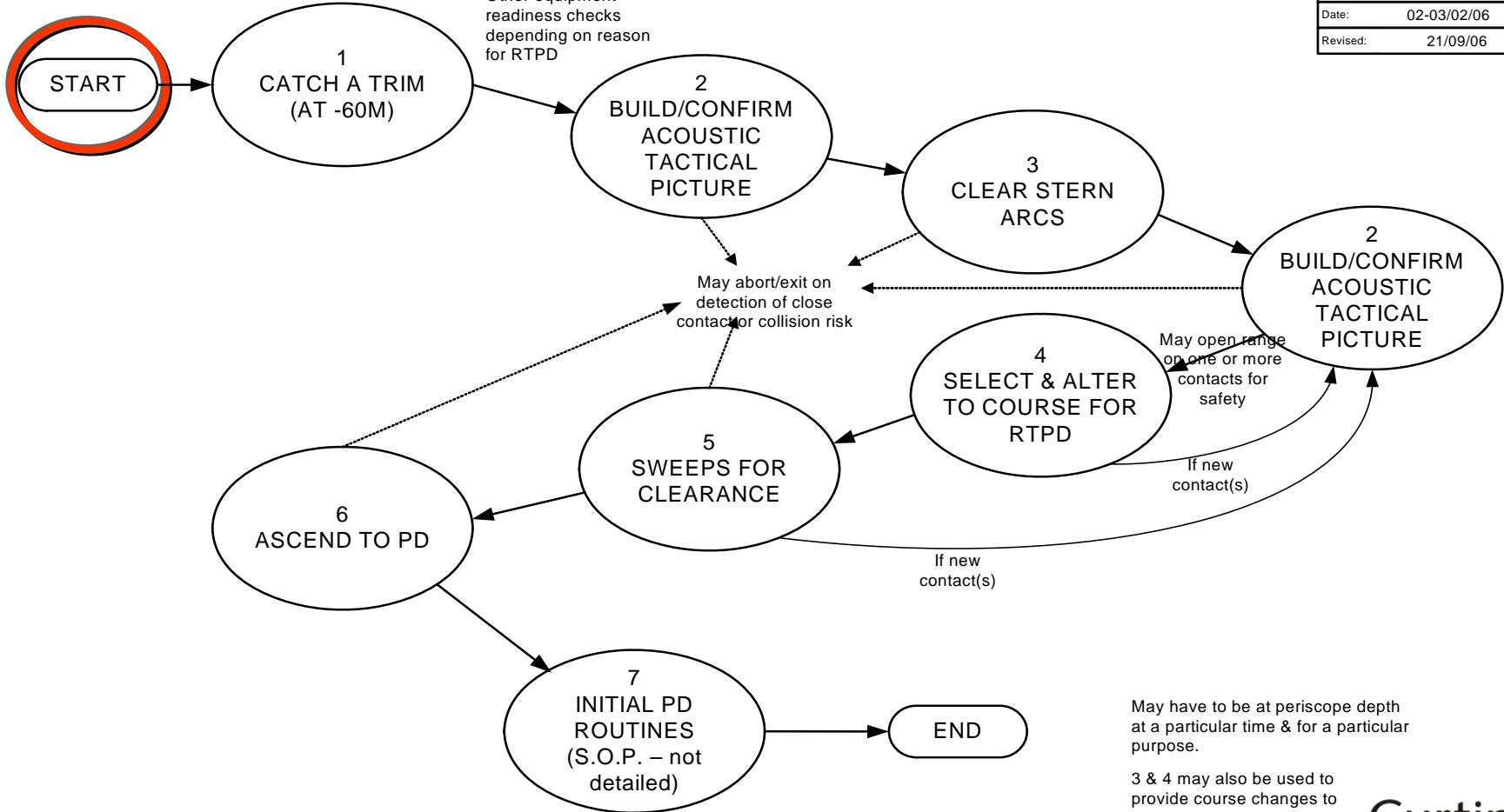
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Control Task Analysis: Return to PD

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Control Task Identification Diagram

TASK SITUATION/FUNCTION	
Return to Periscope Depth (No Track History)	
Interviewee Rank:	CO
Date:	02-03/02/06
Revised:	21/09/06

Man up for RTPD
Closing up checks
ESM and sonar
equipment checks
Other equipment
readiness checks
depending on reason
for RTPD

START

1 CATCH A TRIM (AT -60M)

2 BUILD/CONFIRM ACOUSTIC TACTICAL PICTURE

3 CLEAR STERN ARCS

2 BUILD/CONFIRM ACOUSTIC TACTICAL PICTURE

May abort/exit on detection of close contact or collision risk

4 SELECT & ALTER TO COURSE FOR RTPD

May open range on one or more contacts for safety

5 SWEEPS FOR CLEARANCE

If new contact(s)

6 ASCEND TO PD

If new contact(s)

7 INITIAL PD ROUTINES (S.O.P. – not detailed)

END

May have to be at periscope depth at a particular time & for a particular purpose.

3 & 4 may also be used to provide course changes to facilitate 2 by means of dual-leg ranging (1936)
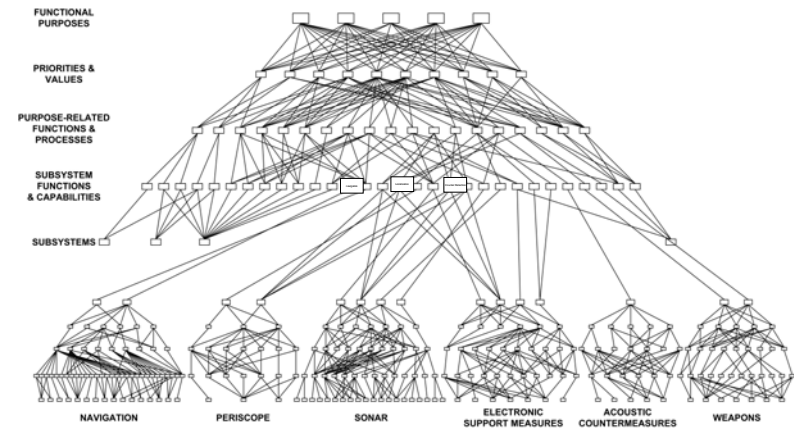
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Exploring: Analysis To Design (Category for Requirements.)

Category   Information   Knowledge Process

Physical Function

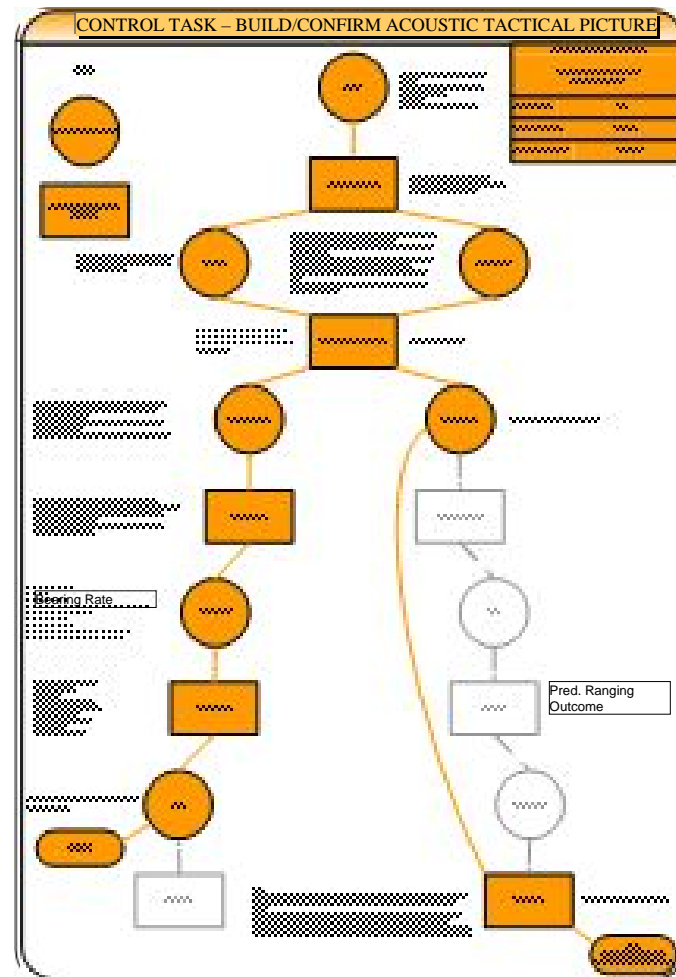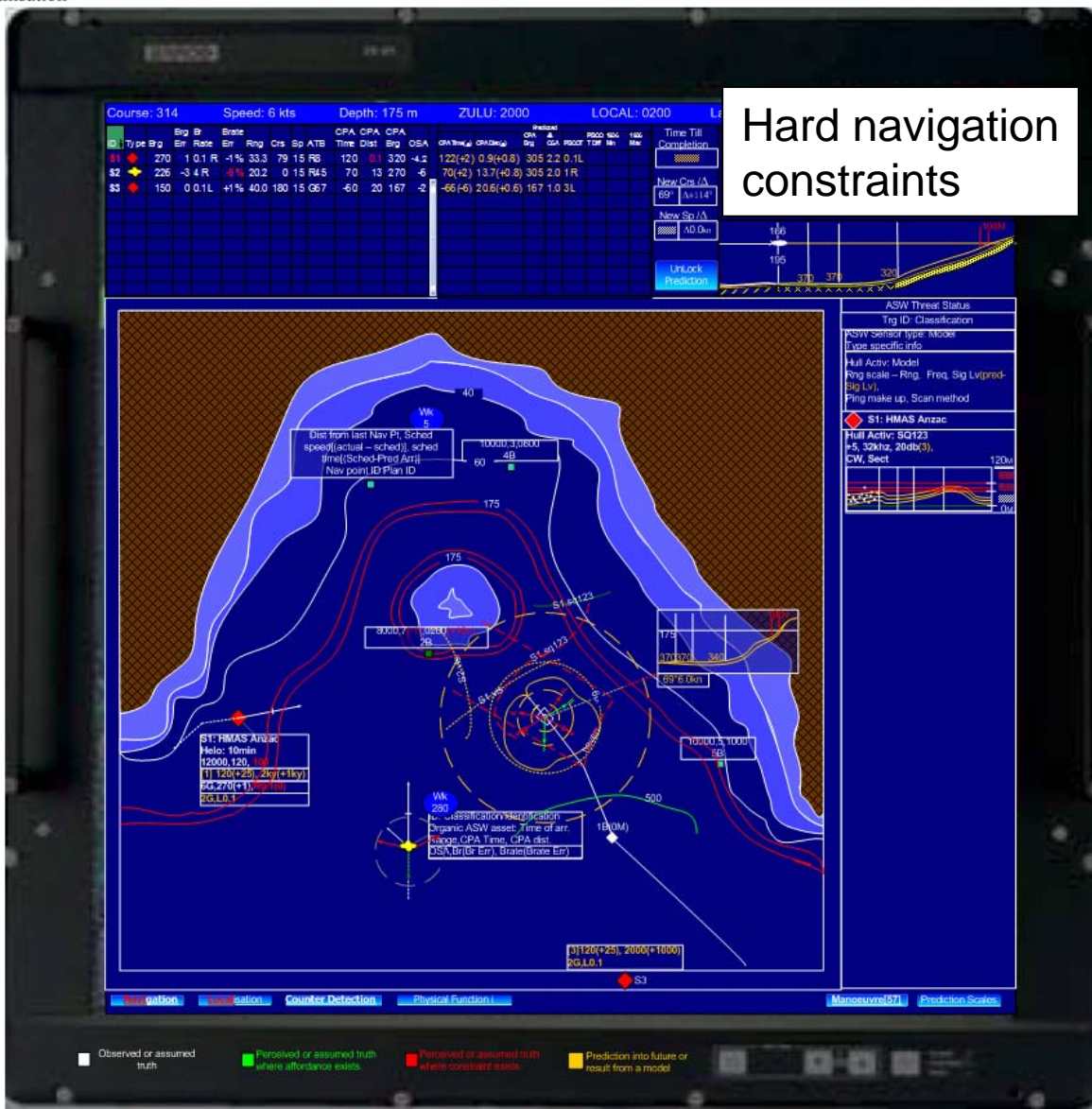| Navigation		
Localisation		
Counter Detection		

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Exploring: Analysis To Design (Source of Requirements)

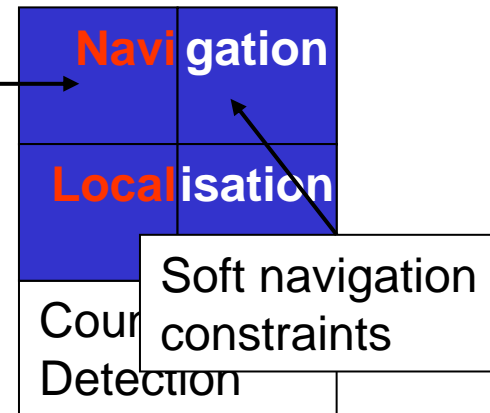| Category	Information	Knowledge
Navigation	Nav. Hazard	Predict Change Collision Risk
Localisation	Bearing Rate	Pred. Ranging Outcome
Counter Detection	Current Risk	Pred. Chng Risk

CONTROL TASK – BUILD/CONFIRM ACOUSTIC TACTICAL PICTURE

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Exploring: Analysis To Design (Overlaying information)

Category overlay
Display overlay

Hard navigation constraints

Navigation

Localisation

Counter Detection

Soft navigation constraints

Exploring: Analysis To Design (Visualising Information)

Maritime Operations Division

Information

Navigation	Nav. Haz.
Localisation	Bearing Rate
Counter Detection	Curr. Risk

EXAMPLE:
• As part of Tote and as part of label of contact of interest.
• Practicing: "information proximity". control information overload.

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Exploring: Analysis To Design (Knowledge Process)
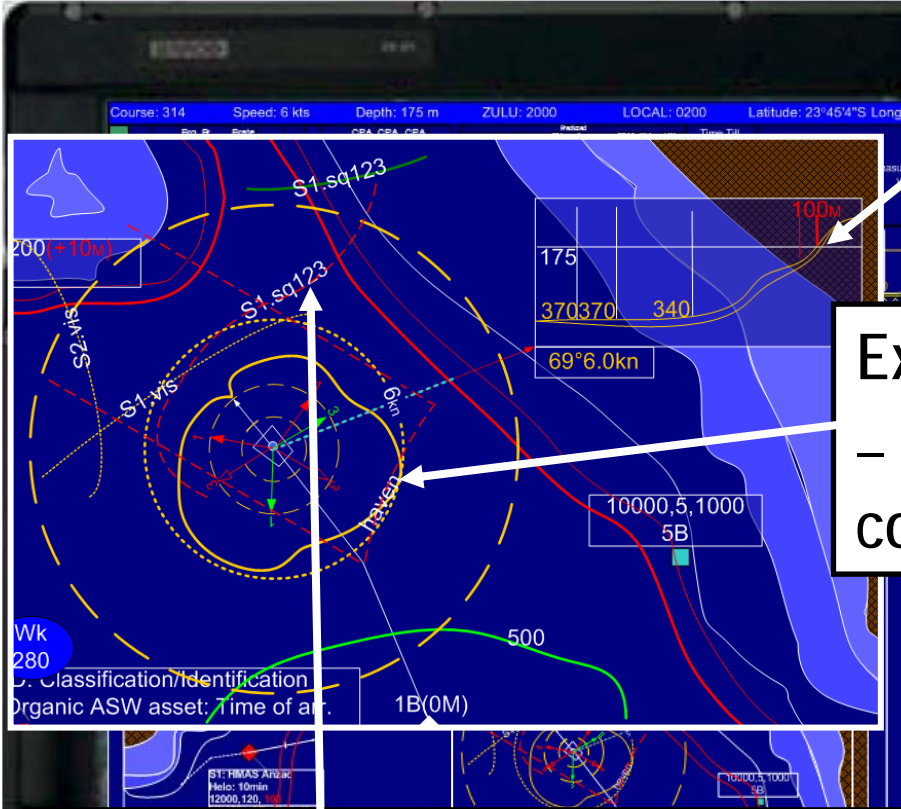
Example: Pred. Chng Collision Risk

– Future kneel depth on selected Manoeuvre.

Example: Pred. Ranging Outcome

– Quality of ranging for selected contacts.

Practicing

– Reduce command workload by relieving mundane computation and info access.

–Highlights constraints not "best solution".

Example: Pred. Chng Cnt. Detection Risk

– Barrier for points where counter detection by given contact sensor exist.

Concluding Remarks

- We are attempting to develop a prototype Command Decision Support System for Australian Submarines

- We have chosen CWA as an analytical tool

- We have explained here how we relate design to that analysis

- A working prototype that enables us to conduct simulation testing is a next step