# Representation of Vulnerability on Submarine Tactical Displays

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**Abstract**

*Defence Science and Technology Organisation (DSTO) is currently developing prototypes of Tactical and Command displays. These prototypes will be used to convey to command the situation of the submarine and promote command team confidence that their understanding of the situation is sound. One of these prototypes is the Command Tactical Display. A major part of displaying information to command is the need to be aware of the submarine's vulnerability, that is, factors that impact its safety. The submarine has a suite of sensors that can be used to determine its possible vulnerability. The aim of this project is to investigate and develop prototype(s) to display the submarine's vulnerability using simulated data from the submarine sensors, as layer/s on the Command Tactical Picture prototype. These display prototypes will be implemented and assessed by submarine operators and commanders.*

## 1.0 Introduction

A military submarine within the navy has a wide range of roles. This is due to its unique ability to traverse underwater. This ability alone accounts for its increased stealth compared to surface warships. A submarine's stealth is an integral part of its operations. A submarine can enter a theatre of operation unobserved and remain on station for some time with minimal logistical support. To maximise a submarine's effectiveness as a major force multiplier, most of the time a submarine operates alone at long distances from support, in hostile waters for weeks at a time. This means by simply maintaining a submarine fleet, it creates uncertainty in the mind of any adversary which can result in imposing financial and operational penalties to counter a submarine that may be lurking in any operational theatre.

Even though its role is not limited to independent operations, unlike surface warships, a submarine is a world unto itself. It is therefore imperative that a submarine be aware of its vulnerability or factors that impact its safety. For the purpose of this project vulnerability is defined as the chance that the submarine may fail to detect an entity in the water space that could potentially endanger the submarine or compromise the safety of the submarine. A submarine is a very complex piece of machinery, it has a variety of sensors that gather information within and around itself. It is the purpose of this project to utilise data from these sensors, process said data and display the submarine's vulnerability. Efficiency, interpretability, ease-of-use will be key factors in determining the effectiveness of such a display.

## 2.0 Background

In order to design an effective display, a sound understanding of human-computer interaction (HCI) is required. The factors to consider in HCI with respect to this project include:

- Human factors involved: Submarine command function and its crew
- Information to be displayed and its purpose: Sonar array health
- The human-computer interface: Command Tactical Picture (CTP)

## 2.1 Submarine Command Functions

Despite advances in technology to automate submarine functions, a submarine's ability to maintain operational status is dependent on its crew compliment. The planning, training and preparation of submarine and crew covers every conceivable circumstances. All this effort inevitably supports one aspect of submarine life, Command. Command is the function that brings all the required disciplines together and moulds them into an effective fighting unit. Command is the final stage of any decision making process where all information has been analysed and corroborated such that a single course of action can be decided. To support the Command function, a "Command Team" is a group of people who's role is to work or keep watch in the control room. For the purpose of this project, we will be focussing on only two roles of the "Command Team", the Commanding Officer and Watch Leader, as these two roles will be the principle user of the CTP display.

### 2.1.1 Commanding Officer

A Commanding Officer (CO) has overall "command" of the submarine and its activities. Although the command team operates a variety of submarine systems, as well as manage information, and make decisions within their realm of responsibility, their primary role is to support the CO in a defined chain of command.

### 2.1.2 Watch Leader

A "Watch Leader" can be defined as a person that will orchestrate the "Command Team" on behalf of the CO and while not having "Command" himself. The "Watch Leader" carries out the "Command Function" under the guidance and direction of the CO, freeing the CO to focus on information processing and decision making that directly impacts the submarine's operational status.

## 2.2 Sonar

A submarine collects information from its surrounding water space using a variety of types of sensors. One of these sensors is its bank of sonar arrays. Sonar determines the ability to detect a sea borne noise from either living creature or man made object operating in the vicinity. Noise will be detected provided it is louder than the general ambient noise level (background noise), and will be tracked until the level drops back below background noise.

The focus of this project will be how to effectively process and display data from three different sonar arrays. The input data will represent the *health* of each array. Array health is defined as the performance or effectiveness of a particular sonar array. 100% health indicates that the array is operating at full capacity. This figure decreases as array performance deteriorates due to damage or malfunctions, etc. This data could be utilised on the command tactical display as a representation of vulnerability to support the CO or Watch Leader in making Command Decisions. The three different sonar arrays and locations are as follows:

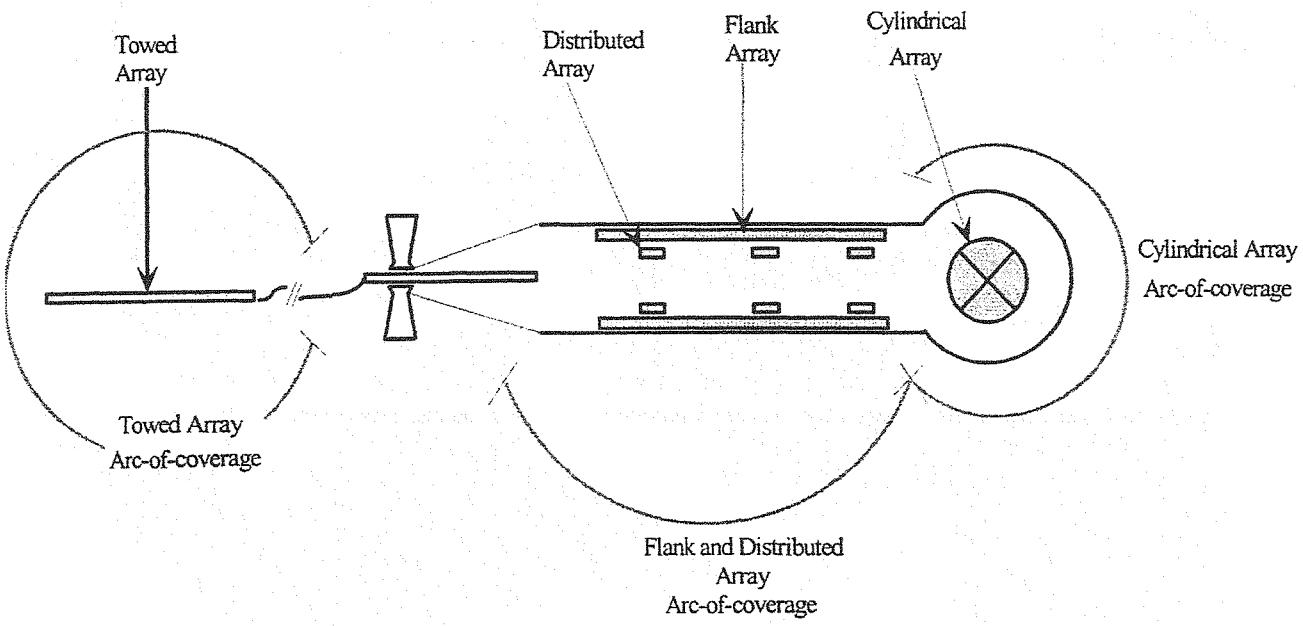


**Figure 1 Sonar Sensor Coverage**

### 2.2.1 Cylindrical Array (CA)

Capable of short to medium detection, localisation as well as tracking of ships and submarines. Functions as the primary "safety" sonar.

### 2.2.2 Distributed Array (DA)

There are three arrays along both sides of the submarine, providing medium to long range detection.

### 2.2.3 Flank Array (FA)

The FA provides medium to long range detection.

## 2.3 Current Command Tactical Display

The Command Tactical Picture (CTP) is a software prototype that is intended to provide a tactical display of a submarine's surrounding region. The CTP is considered a "concept demonstrator" in that it is being used to demonstrate, in an interactive manner, new ideas that may or may not prove useful to submarine command. This means that any solutions, including those proposed here, have been developed for the problems driving the development of the CTP are just concepts that are being trialled to gauge their effectiveness.

The main component of the CTP, the Situation Display, provides a tactical display of the submarine's situation in relation to other vessels and landforms. This display has incorporated layers that can be removed or displayed, controlled with the use of function keys, a command line input and selection keys. The functionality to add or remove layers is an intended solution to the screen clutter problem. By allowing users to filter out information from the screen, it is possible to concentrate on data that is most useful during a tactical decision. Some of the available layers of interest include:

- Track Information
- Bathymetric Information
- Bottom Type
- Shoreline Topography

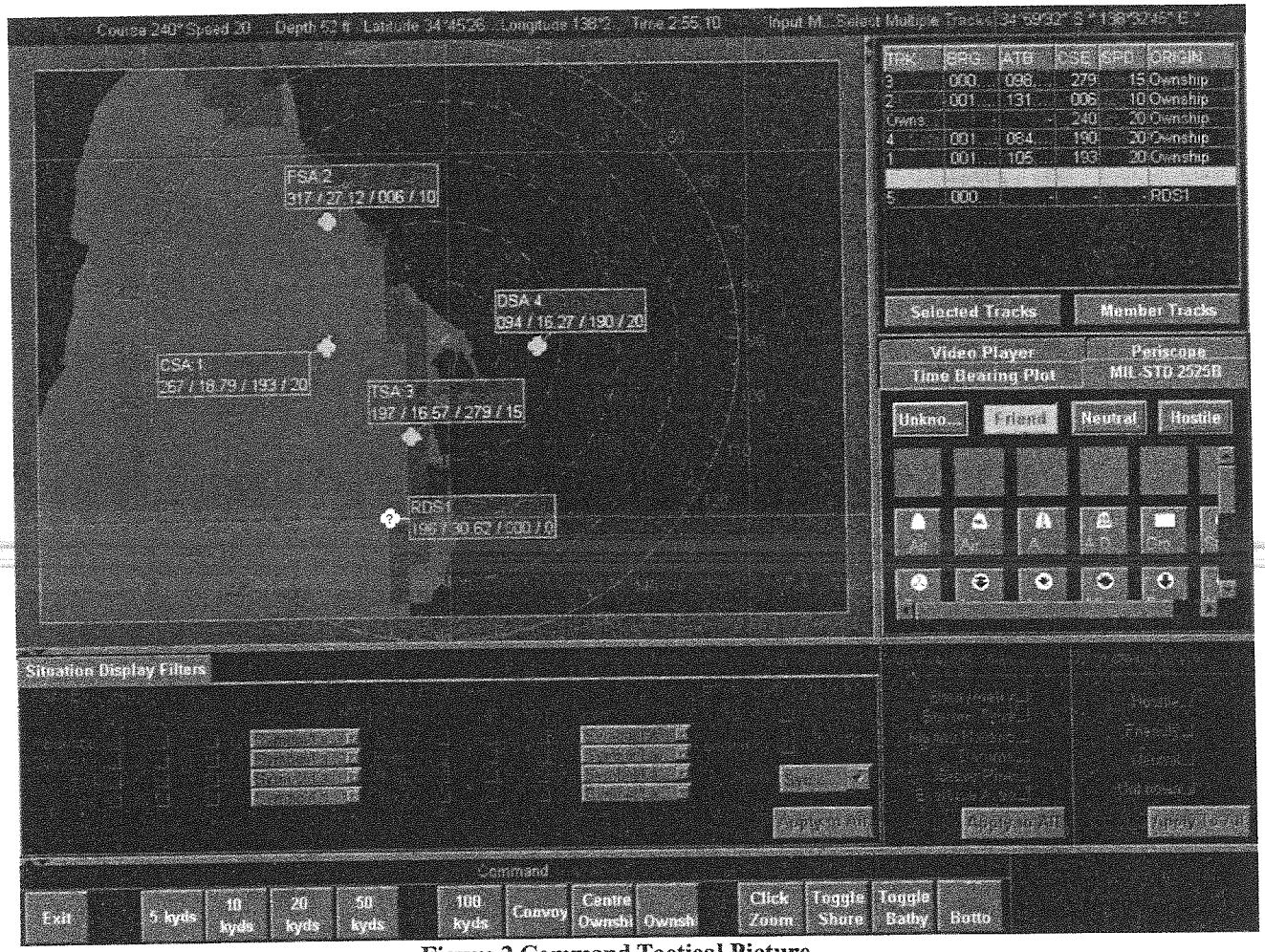


**Figure 2 Command Tactical Picture**

Located within the situation display or map is the 'ownship' (i.e. the submarine), symbolised by a small circle with a cross in its centre. The ownship represents the submarines position within the map relative to other landforms and vessels. The CTP has the ability to zoom in and out relative to ownship or other points of interest. The map is not necessarily centred on the ownship, in certain cases it might be usefull to centre the map on other contacts or focus on certain areas. Around the centre of the map are bearing markers which indicate bearing angle relative to the centre of the map at any given moment. Range rings are arranged in concentric circles arround the centre of the map to show relative distances from the centre of the map. The value of these range rings depends on the current viewing scale or zoom setting.

## 3.0 Vulnerability Layer Development

The basic underlying problem that drives the current project is that of human computer interaction (HCI). The current sonar array health is represented with technical data with no clear visual representation. Not only is the data difficult to process, the CO has no direct way to acertain the submarine's vulnerability. The CO must either request the information from the sonar console operator or read over the heads of operators to view technical data. These issues might be eased if technical data can be displayed in a way that intuitively represents sonar array health on the CTP.

The required outcomes of this project is to:

- Develop concepts of vulnerability displays
  - Include detailed specification and clarification of concepts
  - Include detailed documentation of rationale involved in each concept development
  - Include a measure in which to compare different concepts
- Design and construct non-functional prototypes
- Develop a full functional dynamic prototype as an additional layer on the current CTP
- Full documentation and report of the project

### 3.1 Constraints

It was evident from the beginning that getting access to classified submarine systems and sensor data was impossible. Therefore any development would be based on simulated data or "made up" data. The use of flashing graphics is prohibited to minimise visual clutter and unnecessary distractions. Furthermore, the use of sound as a means of warning is prohibited as it may obstruct communication between control room personnel. The functional prototype of the system would have to be compatible with the current CTP framework and would function as an additional layer on the situation display or map. The vulnerability layer would have to be configurable in such a way that the operator can remove it from the display if the situation requires it.

### 3.2 Assumptions

The simulated data provided are bound by certain assumptions to simplify the problem. Though it may be unrealistic to abide by these assumptions, for the purpose of this concept demonstrator, the ammount of detail represented is enough to convey the purpose of the display and its characteristics, as follows:

- The user of the display will only be the Commanding Officer and Officer of the Watch
- Data input to represent the submarines current vulnerability will be extracted solely from the submarine sonar arrays
- The sonar arrays will only consist of CA, FA, DA as outlined by section 2.2
- Submarine data inputs from the sonar arrays will be in the form of a .csv file.
- The file will have the following information: sensor type, bearing (angle between -180 and 180 degrees and relative to ownship) and a health level (a value between 0 - 100 percent that describes the health of the array at that bearing)

### 3.3 Prototype Concepts

Although many approaches were considered to solving the problem, two solutions stood out as showing potential in terms of efficiency, interpretability, and ease-of-use above the rest.

### 3.3.1 Color Based Display Arranged in a Ring around the Ownship

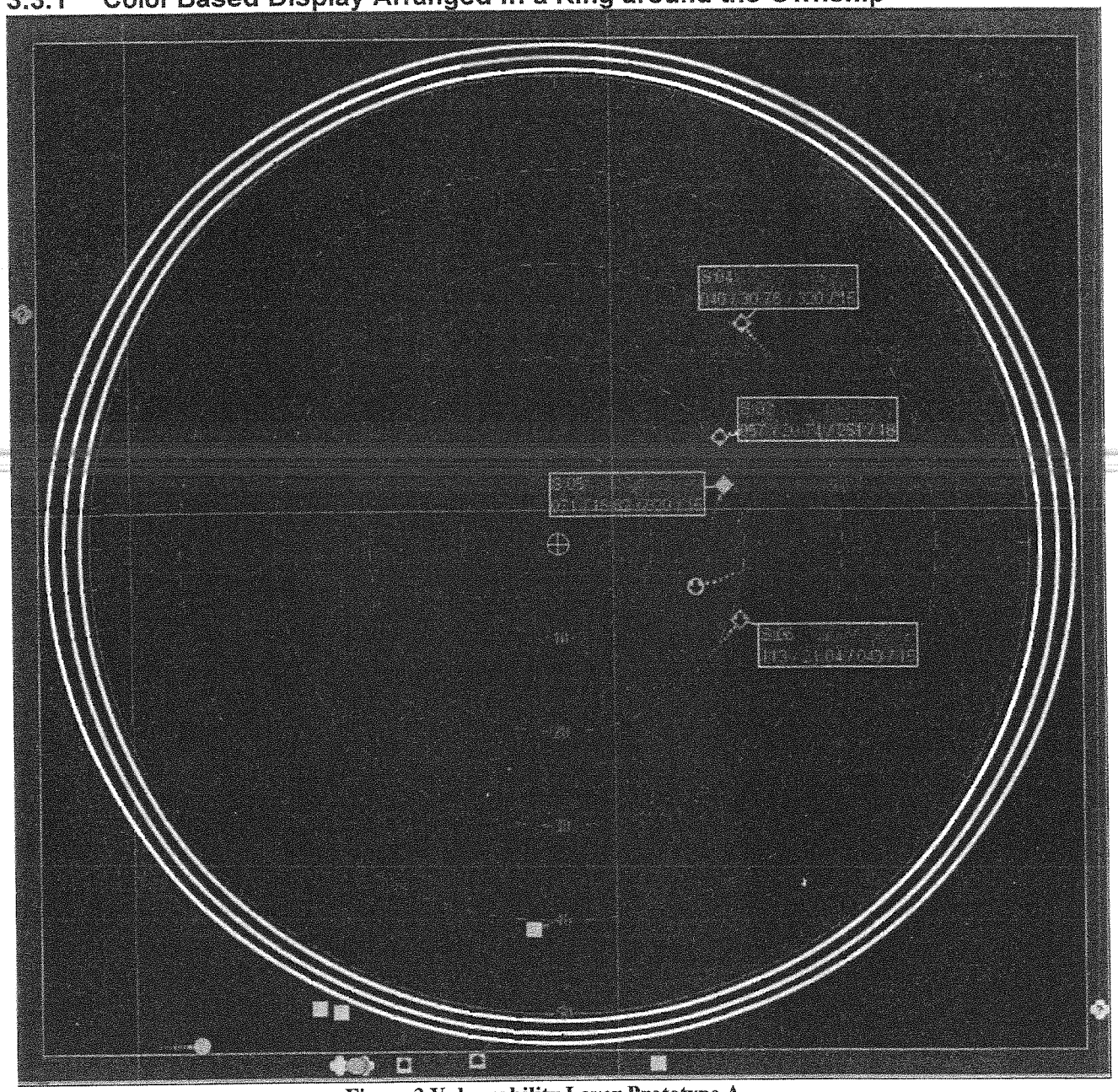

**Figure 3 Vulnerability Layer Prototype A**

At any given bearing around ownship, the sonar array health is represented by color. Light green represents 100% array health. As health degrades, color turns amber and eventually red for poor array health. Bearing angles where the submarine is most vulnarable will be clearly indicated by an orange or red hue. The color pattern represents the level of vulnerability in that direction from the ownship. The color pattern is arranged at a specific radius from the ownship, it creates a ring like image of vulnerability. Each sonar array type has its own spcific ring at a unique static radius about the ownship, resulting in three rings. Visual clutter is a risk because information at the ring location is overlapped by the vulnerability layer and it may be confusing to distinguish one sensor from another. This risk can be reduced by allowing the user to configure the display. For example, the operator can specify which sonar array to display rather than displaying all three. The radius or transparency of the ring can be adjusted such that it does not conflict with objects of interest.

#### 3.3.1.1 Pros:

- Keeps the areas near and around the own ship clear and easily viewable

- Perception of array performance at a particular bearing is easily processed and understood to the operator.

#### 3.3.1.2 Cons:

- It is difficult to relate a location inside or outside the ring to its particular array health when it is not relatively close to the vulnerability ring.
- Difficulties distinguishing the different sensor types
- Distracts attention from contacts near ownship

### 3.3.2 Display based on continuous points drawn around the ownship with varying lengths

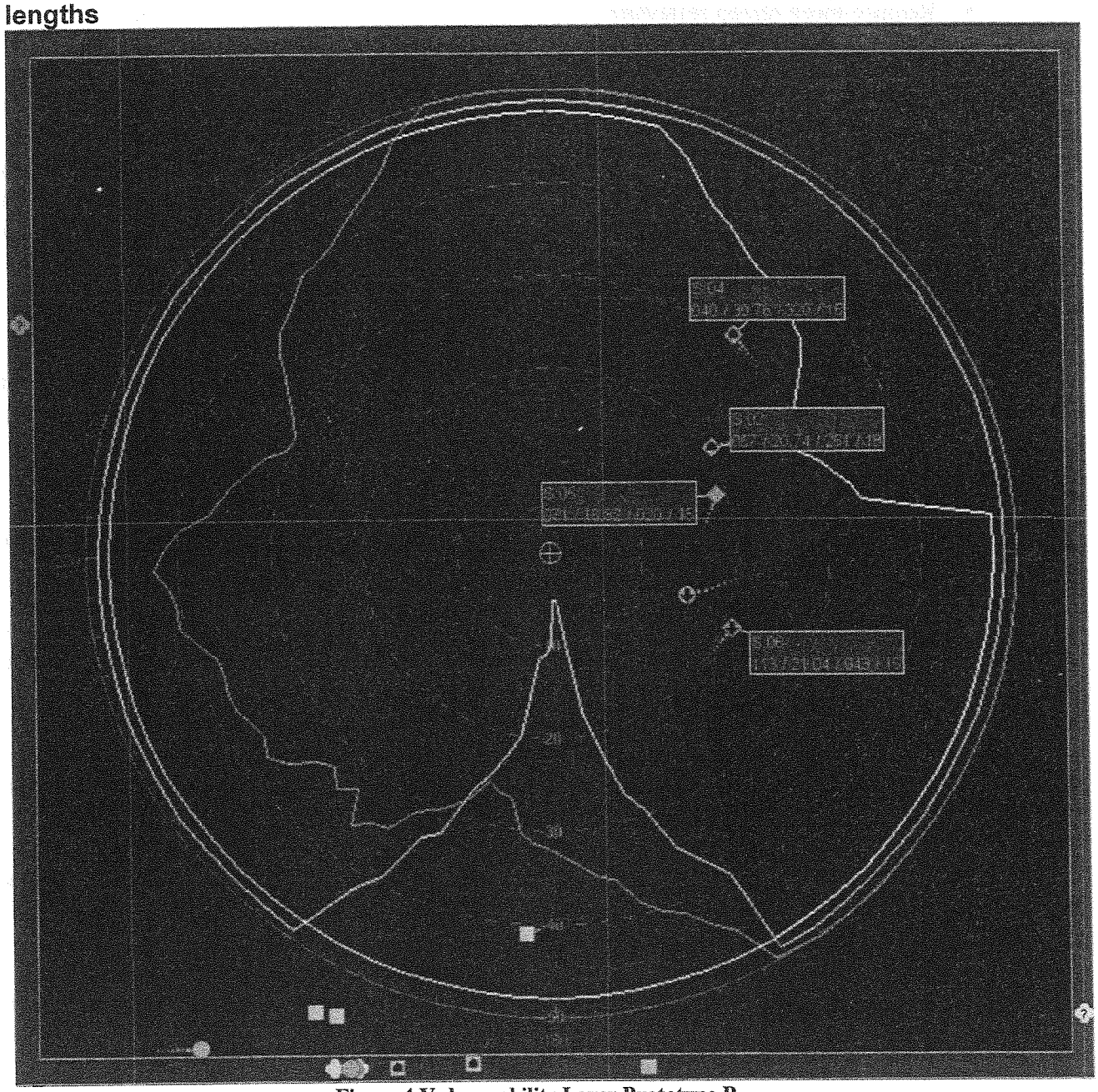

**Figure 4 Vulnearability Layer Prototype B**

Continuous points are drawn around ownship to correspond with each sonar array at a particular bearing. Distance of points from ownship varies depending on sensor health at that particular bearing, the higher the health the larger the radius and lower array health is displayed by a smaller radius. The different colors represent different types of sonar arrays. Once again, the operator can choose which sensor array data to display. The radius to indicate a zero and full

array health could also be configured. There is still a risk for excessive visual clutter as the vulnerability layer takes more screen realestate but the differences between the three different sonar arrays are more easily distinguisable.

#### 3.3.2.1 Pros:

- Less image overlap as display relies on only thin lines
- Differences between sonar arrays more apparent

#### 3.3.2.2 Cons:

- Higher learning curve to understand the dynamics of the display
- Require more screen realestate

### 3.4 Current and Future Work

This paper shows a general overview of the development of prototypes to display the submarine's vulnerability using simulated data from the submarine sensors. At the time of writing, several non-functional prototypes have been completed and a simple surveying software have been created to gather feedback from prospective users of the display. Development of the a prototype as a layer on the CTP is also well on the way using various software engineering development techniques and methodology. Testing of these prototypes will commence shortly to determine their potential in terms of efficiency, intrepretability, and ease-of-use.

## 4.0 References

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