AR-009-953

DSTO-TN-0065

# Underwater Acoustic Imaging Innovation Program

Ian S.F. Jones

APPROVED FOR PUBLIC RELEASE

19970624 094



DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

# Underwater Acoustic Imaging Innovation Program

*Ian S F Jones*

**Maritime Operations Division**
**Aeronautical and Maritime Research Laboratory**

DSTO-TN-0065

**ABSTRACT**

This paper discusses a number of issues in the innovation process being undertaken to solve the problem of producing high resolution images in turbid waters. Strategies to increase the success of the attempted innovation are discussed as well as an estimate of the costs involved. This document reflects the situation as of June, 1996.



DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

*Published by*

*DSTO Aeronautical and Maritime Research Laboratory*
*PO Box 4331*
*Melbourne Victoria 3001*

*Telephone: (03) 9626 8111*
*Fax: (03) 9626 8999*

*AR-009-953*
*December 1996*

**APPROVED FOR PUBLIC RELEASE**

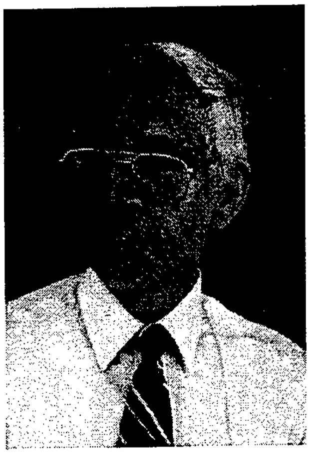
# Acoustic Imaging Innovation Program

## Executive Summary

An innovation program is underway to develop a novel underwater acoustic imaging system with both defence and commercial applications. As innovation implies risk, some of the steps taken to address this issue in the context of public investment in innovation are discussed. In particular, strategies for increasing the prospect of invention (reducing the risk of failing to overcome key technical problems) are described.

The program of innovation is near its mid point and the plans for the remainder of the program are presented.

# Author




**Ian S F Jones**

Maritime Operations Division


*Ian S F Jones is a professional engineer with a PhD from the University of Waterloo, Canada. He has worked in USA, UK, Canada and Japan. His interests include the process of innovation, ocean technology and air sea interface problems. He is the co author of two books and 60 papers.*

# Contents

# Acronyms

| | |
|---|---|
| DSTO | Defence Science & Technology Organisation |
| A&L | Acquisitions & Logistics |
| DGFD(Sea) | Director General Force Development (Sea) |
| MHC | Mine Hunter Coastal |
| DID | Defence Industry Development |
| IP | Intellectual Property |
| FFT | Fast Fourier Transform |
| DoD | Department of Defence |
| ROV | Remotely Operated Vehicle |
| R&D | Research & Development |

# 1. Overview

## Background

There are a number of situations where there are no obvious solutions to a perceived need, within a price constraint that would encourage people to employ the solution. When a solution is founded and it goes into general use, it is an innovation. This is a narrow use of the word that we will employ in this paper. Many problems resolved by engineers are undertaken in an evolutionary manner and we will not use the word technical innovation for these situations. Evolutionary development is much favoured as it is a controlled risk approach. This approach however is not available in a number of situations where no assured solution exists.

Carnegie and Butlin (1993) suggest that most attempts at innovation fail. Despite this there is a general belief that those that do succeed justify the expenditure on those that fail.

## Mine Imaging Program

An innovation program was developed in 1992 to overcome an perceived operational deficiency in the Mine Hunter Coastal program. The ability to image underwater objects in turbid water was required. A bold approach was adopted such that, if successful, a major innovation would be achieved. It was recognised that, as a global experience, only a fraction of good technical ideas eventually go on to produce a significant commercial impact and so become an innovation in the sense used here.

A six stage innovation plan was proposed with the first three stages being designed to assess the probability of achieving particular performance goals. The risks in the project have been greatly reduced by the successful construction of acoustic sensor elements that can be mass produced and the deployment of the concept demonstrator in the ocean to demonstrate the feasibility of high resolution imaging in such a medium. These achievements provided a basis to recommend proceeding to the next stage, the engineering prototype development. The fifth stage of the plan involves commercial risk money, while the final stage is customer acceptance.

## Need

The Director General Force Development (Sea) identified the ability to identify mines in turbid waters as a potential operational deficiency of the new coastal minehunter. Such conditions exist in most Australian northern ports and approaches. Early considerations by DSTO suggested the need for imaging in turbid waters was not confined to defence applications but existed in the offshore inspection and salvage industries as well. A "dual use" technology could be a goal of the program.

## Technical Feasibility

The pre-feasibility, feasibility and concept demonstrator phases have established that high frequency acoustics can image mines at adequate resolution and that the sensors can be mass produced at attractive prices. More technical details are provided in section 2 and 3.

## Potential Market

The potential market between 1999 and 2005 for the Acoustic Imaging Sonar is 12 units in the Australian MHC project, 20 units from foreign DoD sales (10% of 200 mine sweeping ROVS) and 40 commercial underwater inspection systems (1% of 4000 ROV). These estimates need to be strengthened by market surveys. The nearest competitor to the Acoustic Imaging Sonar has one tenth the resolution proposed for the current innovation. This is a situation were the potential commercial market for the Acoustic Imaging Sonar is larger than the defence market.

The commercial advantage of the Australian development is the prospect of "first to market" and the intellectual property of the acoustic sensor tile construction technique.

## Business Strategy

The innovation plan envisaged investment of Commonwealth funds to the end of stage 4 with the production or commercialisation stage being funded by industry money secured by a firm order from MHC. The intellectual property generated to date belongs to the contractor with the Commonwealth having a restricted licence. This intellectual property provides the basis on which the contractor could launch a new commercial technology.

## Risk Management

The financial risks of the first four stages are being borne by the Australian Government. The resources for the first three stages were provided predominantly by DSTO and DID and, as they are now completed, do not represent a future risk. The engineering prototype development still contains considerable risk. There is no experience to suggest that innovation can be accomplished without significant risk. Without risk a program might better be classified as evolutionary engineering rather than innovation. The strategy adopted is to identify the risks and attempt to manage them by techniques such as regular risk focused progress reviews and by formal risk identification documentation.

## Intellectual Property

While the Australian Government maintained the rights to licence free use of the technology developed under the acoustic tile innovation phase, the contactor has been allowed to own the IP developed. This strategy encourages the contractor to feel "ownership" of the program and provides encouragement for the contractor to use some in house funds to cover cost overruns and support evolution of hardware created in the program. However, if the contactor does not have the will to exploit any commercial market that might created from the innovation, then the Commonwealth has not obtained the best value for its investment. Some commitment by the contractor to exploit the technology is needed. Retaining the right by the Commonwealth to licence the technology to third parties, if it is not exploited, is one strategy to encourage commercial investment.

### Continuity

It is generally agreed that continuity of effort in converting an idea to an innovation is desirable. It keeps the team together. This was not achieved in this project, in part because the general issues of funding an innovation program in the Defence sector through all stages to commercialisation were addressed contemporaneously with this project.

### Invention Strategy

An innovation project is one characterised as heading towards a system capability that is ill defined at the start of the program and where even the minimum acceptable performance may need to await the trialing of the product of the Full Scale Engineering Development. If the potential innovation is to provide a new capability in which there is no experience, one may need to find out how to use the capability before determining the minimum performance that is useful. Our current view is that *performance critical* elements of such developments need to commence with a number of parallel strategies and the number of these strategies be progressively reduced during the early phases of the program. The developers of concepts within these different strategies need to be *quarantined* from each other for the first phases of their activities so that they have the opportunity to develop novel ideas.

# 2. High Resolution Underwater Imaging

The transmission of electromagnetic radiation in the ocean is poor. In turbid waters light is strongly scattered. In water loaded with suspended sediments, long wavelength radiation is less strongly attenuated than short wavelengths. There is a band of acoustic frequencies where scattering and attenuation are low and wavelength is short enough to allow the construction of imaging devices of modest size. This acoustic oceanic window, which is in the low megahertz frequencies is shown in Figure 1. It can be seen that it offers considerable promise over the current technology of attempting to use light.

To achieve resolution of the order of public television, but less than photography, one requires of order $10^3$ by $10^3$ pixels. Television provides a two dimensional image, but with acoustics, it is practical to provide a true three dimensional image. The same resolution as above in the viewing direction implies $10^9$ voxel resolution. Both the processing and the display of such information presents a challenge.

To make a practical imaging system at this time, four major technical decisions must be taken. First, the wavelength that finds the best window in the turbid ocean water must be determined. The range of operating temperatures is important in this decision because molecular attenuation is significant. Secondly, sparse random array sensor technology is needed to keep the number of acoustic signals that must be processed within practical limits. Thirdly, one bit digitisation and the noise penalty this implies must be embraced. Fourthly, massively parallel processing must be used if an image is to be produced in near real time. With these constraints, there is considerable scope to optimise the design of an imaging system.

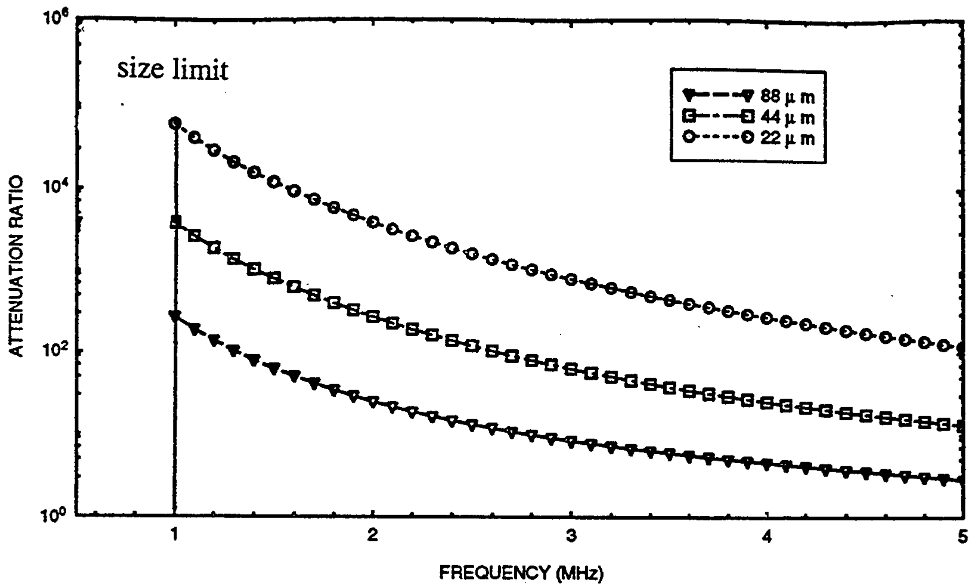



*Fig 1. Diagram of acoustic window in the ocean for various levels of turbidity. The vertical axis is the ratio of attenuation by scattering of blue light to that of acoustics over a path of one meter. The array size limitation is for a field of view one quarter the acoustic path length. The ratio is independent of concentration of sediment and depends only on particle size.*

The display of three dimensional data presents a challenge. The exterior surfaces of most underwater objects are continuous and this allows opportunities for pattern recognition algorithms to enhance and render the exterior surfaces in a three dimensional image. The ability to view the object from a number of directions may be useful, as may perspective images.

# 3. Concept Development

Two issues were resolved during the concept development stage. These have been reported in Robinson et al (1996).

The proposed imaging system could consist of a number of acoustic tiles forming an acoustic array. The resolution is determined by the extent of the array and the signal to side lobe noise by the sparseness of the array. Ensonification of the volume to be imaged could be carried out by a broad beam acoustic projector operating in the Mhz range and capable of producing a "chirp" or frequency changing signal. The output of the receiving array can be sent by fibre optical cable to the surface where it is preproceessed to produce range/acoustic pressure information and then sent to a beam forming computer. A search mode is desirable to locate objects and this implies that having located an object, only part of the field of view of the array needs to be imaged at the maximum resolution.

# 4. Engineering Development stage

This phase of the project is to allow the determination of a number of the design parameters of the acoustic imaging system and to demonstrate that the system can be constructed to meet the space, weight and depth constraints. While the concept demonstration phase has shown that underwater acoustic imaging in turbid waters is possible, it has not resolved the issues of the sparseness of the array, the efficiency of the computer programs forming an image or the robustness of the approach of forming a high resolution image over only that portion of the volume that contains the object of interest. These issues need to be determined from tests of a prototype system operating in realistic environments.

The above issues are critical to the success of the acoustic imaging program because the computer resources required to produce an image quickly over a safe range of the above parameters exceed those currently available at a price consistent with a commercially successful acoustic imaging system.

Since the engineering prototype is for testing by engineers, it need not be manufactured for serviceability, reliability or ruggedness. Nor need its hardware and software be documented at the level appropriate for commercial or military systems.
The acoustic imaging system can be thought of as two components, the sparse array and the computational system (software and hardware). The array constructed for the engineering prototype needs to allow parameters such as sparseness and resolution to be examined over a reasonable range. With a large array of low sparseness, the impacts of reducing the array size or reducing the number of acoustic elements can be determined. With the computation, the issues are mostly to do with the time of

calculation. The performance of different software solutions and different slice thicknesses can all be determined on any computer of reasonable capacity.

Finally there is the issue of approach to choosing the design parameters. A linear engineering approach, the extrapolation from existing experience from what we know today, will constrain the acoustic imaging system to a certain performance. An innovation in the computational problem will allow a more capable acoustic imaging system at a lower unit cost, but at higher development cost. The steps described below are designed to encourage this innovation to occur.

The approach proposed is to break the development into six steps.

a. A project definition study. This will provide cost and estimate times for the other five steps.

b. Development of the "acoustic tile" to prepare for large scale manufacture. Issues such as reliability of manufacture and demonstration of the elimination of difficulties experienced in the concept demonstration phase need to be addressed.

c. Construction of the complete array and "in water components". The array is to be able to fit the "Double Eagle" ROV and use (or supply a new) communication cable to the vessel. It will also be able to be used alone with its own frame and cable. Once the signal is onboard it is to be recorded for non real time processing on modified DSTO hardware. Some software development is needed to support the collection of data such as low resolution array processing.

d. Development of signal processing and display approaches. Three signal processing and display concepts are to be developed at this stage. Acoustic imaging implies enormous computer processing load. While this computer will be above the water and away from the risks inherent in ROV deployment, its cost must be kept in bounds. Three independent approaches will be pursued to reduce the "obvious" approach by a factor of 1000 to produce search mode image updates every second and to "development times" of high resolution in less than 5 minutes. The more promising of these approaches will be evaluated on the data collected by the array. The outline of the options for this approach are contained in Blair and Jones (1996)

e. Construction of prototype hardware and software for image processing. With the rapid improvements in computation power to cost ratio, the prototyping will use an evolutionary procurement concept.

f. Installation and evaluation of the engineering prototype system. DSTO and the Minehunter squadron will contribute to these tests, some of which will be trialed in mine hunting exercise areas.

If the general goal is to image a region 3m by 1m by 1m with a resolution of 1mm by 1mm by 1mm the implied computational load is very large. If this imaging is to be done with a search mode refreshed every 1 second and high resolution mode with a development time of less than 5 minutes, then the off the shelf computer resources needed would appear to be large. This would impact badly on the cost benefit ratio for a underwater imaging sonar.

Three strategies can be identified to address this problem.

1. Reduce the volume to be imaged at high resolution to a "slice" of interest. This implies the risk that objects of interest (but not recognised in the search mode) will not be examined as they lie outside the slice.

2. Find an improvement in the software that provides the image of the type found for FFT processing. A FFT of N points is a log N rather than N computational load. With the imaging load for a volume N by M by P proportional to N by M by P the savings would be attractive.

3. Take some of the computing load in special purpose computing. Such a thought is to treat each tile as a separate problem with dedicated hardware and form the complete image only in off the shelf hardware.

These three approaches embrace either reducing the volume of the problem, enhancing the software or enhancing the hardware. Concepts such as "zone focusing" or aperture increasing to move the imaged zone to the far field can be broadly grouped in the first strategy.

# 5. Commercial Development stage

With the completion of the engineering prototype phase, the design parameters of an operational mine imaging system can be chosen and a production prototype constructed. This problem can be carried out, it is hoped, by linear engineering extensions to the developed experience. This is a low technical risk phase but has a high market risk. Will the device fit within a performance cost window that will produce the predicted sales?

The construction of a production prototype is needed to verify that the manufacturing techniques are suitable for routine operations and to qualify the system for military and commercial operations.

Marketing for foreign military and commercial sales will need to begin at the start of this phase to produce orders to coincide with the completion of the production prototype.

Since the technical risk has been reduced in the earlier phases, the investment decisions needed in this phase are easier. An order of magnitude estimate of the capital needed can be made and compared with expected returns from sales.

An order of magnitude estimate of the costs can be provided. For stages 1 to 4 the expenditure is listed as this money is provided (mostly) from Government revenue. It includes DSTO costs but not the management costs of the Acquisitions program. For stage 5 we imagine commercial risk capital for construction of the production prototype, the manufacturing facility and inventory. The production prototype is estimated at $7.5M and the marketing costs, inventory and other expenditures might bring this figure to $10M. At the end of the program the capital invested in inventory would be recovered. The sixth stage of acceptance into Naval service is not costed to this program.

| | |
|---|---|
| 1. pre feasibility studies and | |
| 2. feasibility | $0.5M |
| 3. Concept demonstrator | $1.1M |
| 4. Engineering prototype | $4.2M |
| 5. Commercialisation capital | $10M |

Possible sales price is of the order of $2M for a military version. A replacement array might be $0.5M. Commercial models might sell for 50% of this number. Of course this price depends on the performance required. We assume for these calculations a 2 mm resolution and image production in 10 seconds for the commercial system.

If the Australian defence market alone was achieved, the sales would be of order $14M. With a 20% profit component as a reference value, the cost of the production prototype would not be completely recovered. Some of the commercialisation capital would need to be supplied by the Commonwealth. If the whole of the potential market was realised, the sales would be of order $90M. At 20% profit, this would be a good return on the commercialisation capital. The financial plan in the appendix assumes a mix of these options.

As well as potential return to the contactor of exploitation of the innovation, there is the prospect of returns to the Commonwealth in the form of taxes, both on the company profit and on the salary of the additional people employed on the commercial program.

# 6. Managing the Innovation Program

Managing innovation represents a considerable challenge. It is necessary to obtain resources to advance the technical understanding without being able to show that it is probable that a successful conclusion will be achieved. Typically the early phases of an innovation program involve a small fraction of the total resources and so do not undergo such careful scrutiny. However, attempting to achieve an innovation without a commitment of resources, if successful, remains one of the main causes of failure to capitalise on technical success. This is often caused because those with the research funds, in this case DSTO, do not have the mission for development and commercialisation

While the present program is an attempt to plan the program from early identification of a need for an innovation through to commercialisation, it has not been possible to obtain commitment to resource the total program, even if each stage is successful. This is not so much a difficulty to define a criteria for success of each stage but rather a cautious approach to resource management. Such an approach in many senses increases the risks of not achieving the innovation because it adds to the risks of technical failure, the risk of resource failure.

The first risk to an individual program is that the inventions needed to achieve a technical innovation will not be realised. The strategy adopted here was to start a number of parallel efforts simultaneously.

There are a number of difficulties with the above approach. It costs more money to have multiple groups travelling much the same ground. If the different groups are from different commercial enities, the issue of intellectual property and future business can cause difficulties. It may put more items on the critical path and produces more complexities in project management.

The benefits, in a number of situations, will outweigh these costs. There is increased possibility of a superior technical solution as the parallel approach provides more opportunity for a substantial innovation. It also signals that the Commonwealth is looking for innovation. It reduces the risk of the system performance being below the minimum required.

There was no simple evolution of existing technology that would satisfy this need, regardless of the cost. Linear engineering would not provide a solution. A number of inventions were required to overcome the technical difficulties.

The strategy was to provide three initial approaches to the two main problem areas. The first problem area was the manufacture of an acoustic sensor with many extremely small elements. The second was the computation of the required images and their display in a short enough time. Here the computer resources used must not cost so much that the acoustic imaging system is priced out of the market.

The sensor technology was pursued by three independent groups. One used existing solid block technology and advanced the technology slightly. This was the bench mark for the other two approaches that were much bolder. This approach has lead to the required innovation, an acoustic sensor tile that is able to be mass produced at a low cost.

The success of the three independent quarantined approach for the second issue has yet to be determined.

Even with a parallel approach for tackling the critical inventions needed there is no guarantee that suitable people can be motivated to undertake the work. A related issue is that of the transfer of the technology from the researcher and development engineer to the production team. Often the researcher has knowledge in depth on the underpinning technologies and this is often not able to be transferred to others in the short times usually made available. Attempting to maintain access to the "inventor" is one of the strategies adopted in this program. This is expressed as continuing the development of the prototype as a co-operative program between DSTO and the contractor.

The prospect of failure in an individual innovation program is high. On way to address this problem is to develop a portfolio of innovation programs so that within the portfolio there is a high probability of one successful innovation. This often implies a large organisation as the supplier of the resources needed.

# 7. Conclusion

A plan has been prepared to produce an innovation in imaging objects underwater where the current optical technology is unable to perform in turbid waters. The approach of acoustic imaging was chosen because the physics of wave propagation in an inhomogeneous medium favours the longer acoustic waves over the shorter waves of light. At the start of the program there was no extrapolation of existing experience (linear engineering) that would produce a viable system to image underwater objects with the required resolution. An innovation was needed.

Innovation implies risk and so the program of gradual risk reduction was devised. Its schedule is shown in the appendix. It was also recognised that the commercialisation of a technical invention was a major hurdle in innovation. To reduce this risk, commercial firms were involved from the very outset of the program. This approach, it was hoped, would keep the manufacturing and marketing consideration to the fore.

As the program moves forward, the role of a R&D organisation such as DSTO becomes less. However the transfer of the relevant knowledge and experience to the managers of the later stages is not necessarily a solved problem. The use of the term co-operative development phase is an attempt to address this issue.

Progress on the plan up to June, 1996 is reported and a philosophy for facilitating innovation has been presented. Some important dates and the innovation schedule are shown in the appendix. While the risks of failure inherent in deviating from a linear engineering approach are large, it is assumed that averaged over a large number of programs, that those innovation attempts that succeed will justify the expenditure on both the successes and the failures.

# 8. References

Blair, D G (1993) Array design: literature survey for a high resolution imaging sonar system - part 1. DSTO Australia MRL-TN-658, pp37.

Blair, D G and I S F Jones (1997) Underwater Acoustic Imaging: Signal Processing. DSTO Australia TN-XXXX (under review).

Carnegie, R and M Butlin (1993) Managing the Innovative Enterprise. McKinsey & Company.

Jones, I S F (1994) High resolution underwater imaging. Proc. Int. Conf. Underwater Acoustics. Aust. Acoustical Soc. Darlinghurst pp135.

Robinson, D E, P. Ho, Y. Li, I.G. Jones, D Fox and M Bell (1996) Coherence measurements for evaluating Megahertz ultrasonic imaging in sea water. (under review JASA)

Thuraisingham, R A (1994) Theoretical estimates of high frequency acoustic attenuation and backscattering from suspended sand particles in the ocean and in an estuary. DSTO Australia, TR-0078, pp16.

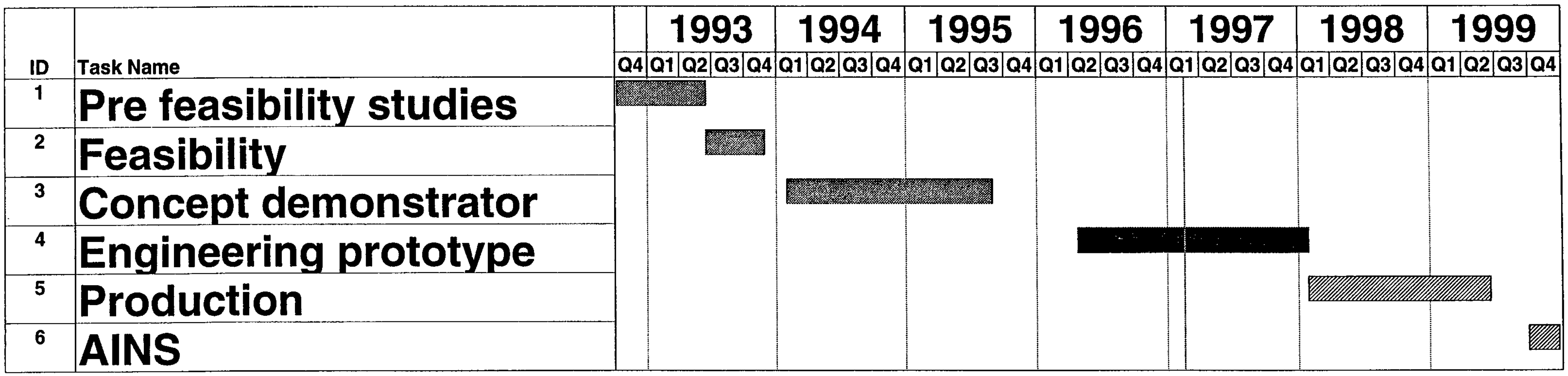
Thuraisingham, R A (1994) Models to estimate high frequency acoustic scattering due to thermal fine-structure and micro-structure of the ocean. DSTO Australia, RR-0001

# 9. Appendix

## Historical Dates

| | |
|---|---|
| 1991 | Coffee table discussions at DSTO |
| 9 June, 1992 | TTCP Ceramic Materials Panel Workshop on Ferroelectric Materials and Applications presentation "Array requirements for underwater imaging" |
| 1 July, 1992 | Commenced task- J Thompson, Manager |
| 29 July, 1992 | Industry briefing to encourage commercial participation |
| 21 May, 1993 | feasibility contacts let |
| 4 Nov, 1993 | Innovation seminar at DSTO |
| 22 March, 1994 | concept demonstrator contract let |
| Aug, 1996 | established as part of the Five Year Defence Program |
| 3 Sept, 1996 | PDS contract for stage 4 let |

INNOVATION SCHEDULE, AMI



## Financial Plan

The Commonwealth and the contractor share the phase 5 costs (production prototype)
Innovate in the area of computation to produce clear technical supremacy
Plan to make some commercial sales of tiles. Plan to make two foreign military sales of 10 systems each.
Make commercial system with 2mm resolution, selling price $1M.

| year | income $k | AUSDEF sales | profit on DoD business | notes | TMS investment | foreign mil sales | commercial | profit | |
|---|---|---|---|---|---|---|---|---|---|
| 1997 | 2000 | | 200 | | 100# | | | | |
| 1998 | 1000 | | 100 | | 50# | | 6 | 4 | 2tile |
| 1999 | 750 | | 75 | | 50# | | 30 | 20 | 10tile |
| 2000 | 5000 | | 500 | | 100* | | | | |
| 2001 | 2500 | 2000 | 650 | | 1500@ | | 1000 | 200 | 1 commercial |
| 2002 | | 2000 | 400 | | 100 | 10000 | 9000 | 3600 | 5 fms +9c |
| 2003 | | 2000 | 400 | | 100 | 10000 | 10000 | 4000 | 5fms +10c |
| 2004 | | 2000 | 400 | | 100 | 10000 | 10000 | 4000 | 5fms +10c |
| 2005 | | 1000 | 200 | improv manuf | 400** | 10000 | 5000 | 3000 | 5fms +5c |
| 2006 | | 5000 | 1000 | 4 spares | | | 5000 | 1000 | 5c |
| total | 11250 | 14000 | 3925 | | 2500 | 40000 | 40036 | 17624 | |

Assumptions
working capital and office space covered in ovrheads. $7.5M investment in manufacturing protype, $2.5M inventory, factory and sales costs.
all costs are 1996 $
profit 10% on contracts
20% on system sales
200% on tiles

# tiles sales effort
* foreign military , fm, sales effort
@ commercial demonstration model, production line,
** contingency
There needs to be a 5% licence fee to Commonwealth for fm sales

DISTRIBUTION LIST

Underwater Acoustic Imaging Innovation Program
Ian S.F. Jones

**AUSTRALIA**

**1. DEFENCE ORGANISATION**

**a. Task Sponsor** DGFD(Sea)

**b. S&T Program**
Chief Defence Scientist }
FAS Science Policy } shared copy
AS Science Corporate Management }
Director General Science Policy Development
Counsellor Defence Science, London (Doc Data Sheet )
Counsellor Defence Science, Washington (Doc Data Sheet )
Scientific Adviser to MRDC Thailand (Doc Data Sheet )
Director General Scientific Advisers and Trials/Scientific Adviser Policy and Command (shared copy)
Navy Scientific Adviser
Scientific Adviser - Army (Doc Data Sheet and distribution list only)
Air Force Scientific Adviser
Director Trials

**Aeronautical and Maritime Research Laboratory**
Director

Chief of Maritime Operations Division
Research Leader, OE
B. Ferguson, MOD
J.L. Thompson, MOD
Ian S.F. Jones (20 copies)

**DSTO Library**
Library Fishermens Bend
Library Maribyrnong
Library DSTOS (2 copies)
Australian Archives
Library, MOD, Pyrmont (2 copies)

**d. Navy**
SO (Science), Director of Naval Warfare, Maritime Headquarters Annex, Garden Island, NSW 2000 (Doc Data Sheet only)

**e. Army**
ABCA Office, G-1-34, Russell Offices, Canberra (4 copies)

g. **S&I Program**
Defence Intelligence Organisation
Library, Defence Signals Directorate (Doc Data Sheet only)

h. **Acquisition and Logistics Program**
FASDM
ASDPM

i. **B&M Program (libraries)**
OIC TRS, Defence Regional Library, Canberra
Officer in Charge, Document Exchange Centre (DEC), 1 copy
US Defence Technical Information Centre, 2 copies
UK Defence Research Information Centre, 2 copies
Canada Defence Scientific Information Service, 1 copy
NZ Defence Information Centre, 1 copy
National Library of Australia, 1 copy

2. **UNIVERSITIES AND COLLEGES**

Australian Defence Force Academy
Library
Head of Aerospace and Mechanical Engineering
Senior Librarian, Hargrave Library, Monash University
Librarian, Flinders University

3. **OTHER ORGANISATIONS**

NASA (Canberra)
AGPS
Australian Graduate School of Engineering Innovation

**OUTSIDE AUSTRALIA**

4. **ABSTRACTING AND INFORMATION ORGANISATIONS**
INSPEC: Acquisitions Section Institution of Electrical Engineers
Library, Chemical Abstracts Reference Service
Engineering Societies Library, US
American Society for Metals
Documents Librarian, The Center for Research Libraries, US

5. **INFORMATION EXCHANGE AGREEMENT PARTNERS**
Acquisitions Unit, Science Reference and Information Service, UK
Library - Exchange Desk, National Institute of Standards and Technology, US

SPARES (10 copies)

**Total number of copies: 80**

Page classification: UNCLASSIFIED

**DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION**
**DOCUMENT CONTROL DATA**

1. PRIVACY MARKING/CAVEAT (OF DOCUMENT)

| | |
|---|---|
| 2. TITLE<br><br>Underwater Acoustic Imaging Innovation Program | 3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION)<br><br>Document (U)<br>Title (U)<br>Abstract (U) |
| 4. AUTHOR(S)<br><br>Ian S F Jones | 5. CORPORATE AUTHOR<br><br>Aeronautical and Maritime Research Laboratory<br>PO Box 4331<br>Melbourne Vic 3001 |

| | | | |
|---|---|---|---|
| 6a. DSTO NUMBER<br>DSTO-TN-0065 | 6b. AR NUMBER<br>AR-009-953 | 6c. TYPE OF REPORT<br>Technical Note | 7. DOCUMENT DATE<br>December 1996 |

| | | | | |
|---|---|---|---|---|
| 8. FILE NUMBER<br>510/297/0715 | 9. TASK NUMBER<br>ADS 94/195 | 10. TASK SPONSOR<br>DGFD(Sea) | 11. NO. OF PAGES<br>14 | 12. NO. OF REFERENCES<br>7 |

| | |
|---|---|
| 13. DOWNGRADING/DELIMITING INSTRUCTIONS<br><br>None | 14. RELEASE AUTHORITY<br><br>Chief, Maritime Operations Division |

15. SECONDARY RELEASE STATEMENT OF THIS DOCUMENT

*Approved for public release*

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DOCUMENT EXCHANGE CENTRE, DIS NETWORK OFFICE, DEPT OF DEFENCE, CAMPBELL PARK OFFICES, CANBERRA ACT 2600

16. DELIBERATE ANNOUNCEMENT

No limitations

17. CASUAL ANNOUNCEMENT Yes

18. DEFTEST DESCRIPTORS

Innovation, sonar, underwater acoustics, acoustic imaging

19. ABSTRACT
This paper discusses a number of issues in the innovation process being undertaken to solve the problem of producing high resolution images in turbid waters. Strategies to increase the success of the attempted innovation are discussed as well as an estimate of the costs involved. This document reflects the situation as of June, 1996.

Page classification: UNCLASSIFIED