REPORT DOCUMENTATION PAGE

Form Approved

OMB No. 074-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
1-19-2005	Final Report	28 February 2004 to 1 December 2004

4. TITLE AND SUBTITLE

Final Technical Report – Autonomous Underwater X-Ray

5a. CONTRACT NUMBER N00014-04-M-0079

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Matthew Dock, Project Manager

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)

Nomadics, Inc.
1024 S. Innovation Way
Stillwater, OK 74074

8. PERFORMING ORGANIZATION REPORT NUMBER

13050006

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

UNCLASSIFIED, UNLIMITED RELEASE.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

In this SBIR Phase I, Nomadics documented the penetration and backscatter of an underwater X-ray system. The system consists of an X-ray source, water tank, and a gamma ray detector capable of sensing the high-energy scattered X-rays. Using the results of these tests the model of X-ray penetration and backscatter can be verified and used to extrapolate expected performance of the final system.

15. SUBJECT TERMS

X-ray, underwater detection

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Matthew Dock
U	U	U	UU	8	**19b. TELEPHONE NUMBER** *(Include area code)* (405) 372-9535, x116; e-mail: mdock@nomadics.com

"Science in Motion"

Nomadics, Inc.

1024 S. Innovation Way
PO Box 2496
Stillwater, OK 74076

Tel (405) 372-9535
Fax (405) 372-9537

Contact: Matthew Dock,
Project Manager
(mdock@nomadics.com)

Final Technical Report

Period Covered by the Report:
February 28, 2004 through December 1, 2004

Project Title: ***Autonomous Underwater X-ray***

SBIR Topic: N03-225
Contract: N00014-04-M-0079, CLIN 0001AC

Prepared for:
Office of Naval Research
Arlington, VA

Date of Report: January 19, 2005

Security Classification – Unclassified, Unlimited Release

Distribution List and Addresses

Note: all copies should be submitted electronically

One copy submitted to:

DODAAD Code N00014
Program Officer, Office of Naval Research
Ballston Tower One
800 N. Quincy Street
Arlington, VA 22217-5660
Attn: Nicholas Chotiros, 321OA
Ref: Contract N00014-04-M-0079
chotrin@onr.navy.mil

One copy submitted to:

DODAAD Code N00014
Program Manager, Office of Naval Research
Ballston Tower One
800 N. Quincy Street
Arlington, VA 22217-5660
Attn: Cathy Nodgaard, Code 362
Ref: Contract N00014-04-M-0079
nodgaac@onr.navy.mil

Transmittal letter only to:

Code S4402A
DCMA Dallas
1200 Main St.
Dallas, TX 75202-4399
Fax: 214-670-9212

Two copies submitted to:

DODAAD Code S47031
Defense Technical Information Center
8725 John J. Kingman Rd, Suite 0944
Fort Belvoir, VA 22060-6218
Attn: Pat Mawby
Email: pmawby@dtic.mil

One copy submitted to:

DODAAD Code N00173
Director, Naval Research Lab
Attn: Code 5227
4555 Overlook Avenue, SW
Washington, D.C. 20375-5320
E-mail: reports@library.nrl.navy.mil

Autonomous Underwater X-ray
Final Technical Report

Nomadics, Inc.

January 19, 2005

1.0 Introduction

Under this SBIR Phase I contract, Nomadics documented the penetration and backscatter of an underwater X-ray system. The system consists of an X-ray source, water tank, and a gamma ray detector capable of sensing the high-energy scattered X-rays. Using the results of these tests the model of X-ray penetration and backscatter can be verified and used to extrapolate expected performance of the final system.

2.0 Work Completed

Over the course of the contract, Nomadics completed the test apparatus, configured the system for multiple tests, and documented the results of those tests. Figure 1 shows a typical arrangement with an x-ray source on one side of the tank (right side) and a radiation detector on the left side of the tank. A lead shield to prevent any direct crosstalk between the two devices separates the source and detector. Therefore, the x-ray source will emit radiation that penetrates into the water for a short distance and the detector on the opposite side of the plate will detect the scatter from that emission.

Figure 1 - X-Ray source and detector as placed underwater.

This first test was set up to determine the natural scatter from an x-ray source in a free-body of water. No target was placed in front of the x-ray beam. The source and detector were placed initially 12 inches away from a common point in open space. They were placed parallel to each other on opposite sides of the lead shield. Therefore, the total traversal distance is approximately 24 inches (12 inches out and 12 inches back). Figure 2 shows the response from the radiation detector as displayed on a Tektronix oscilloscope. The voltage spike, which should be the summation of all individually received photons is roughly 2 volts. This experiment was repeated at two other distances to generate a distance versus received signal.

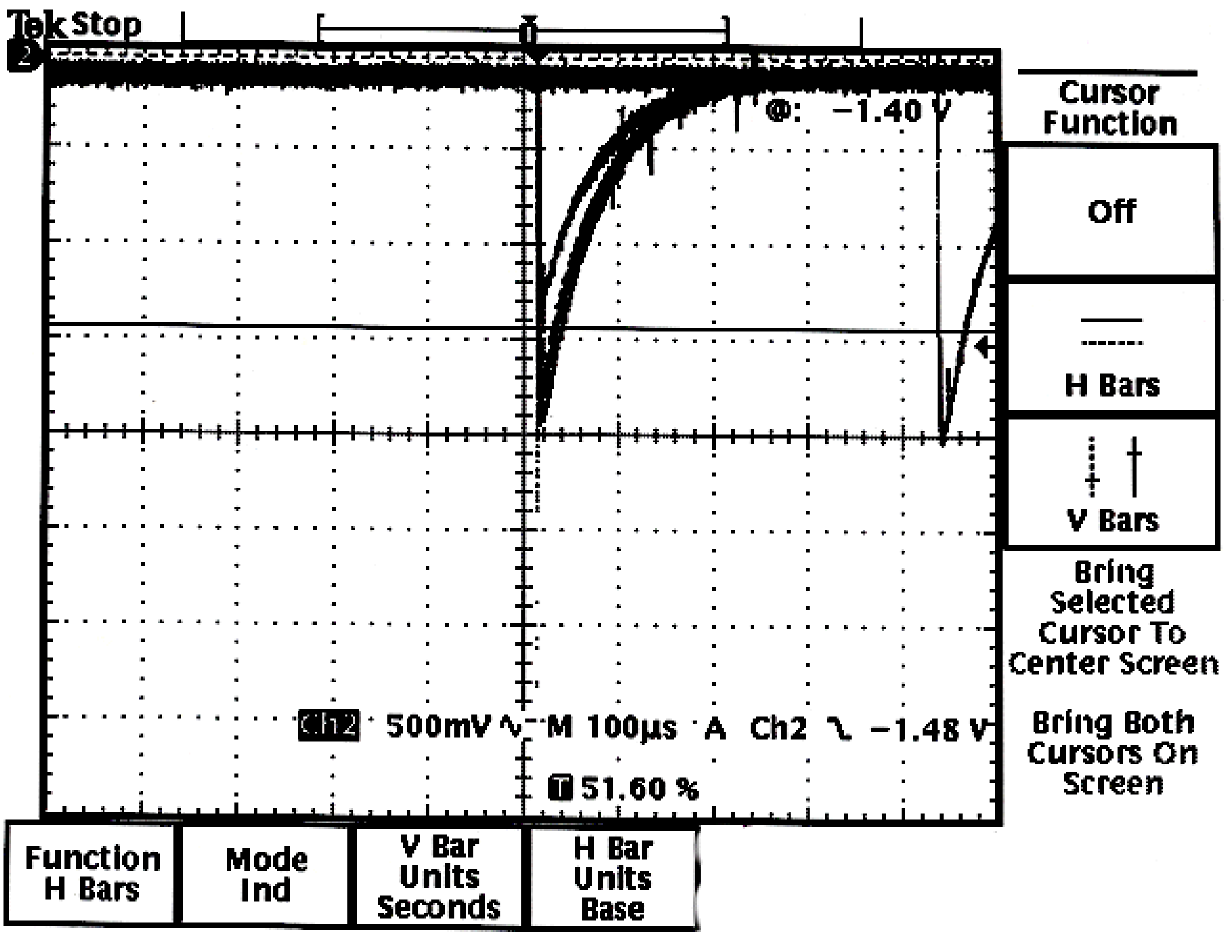

Figure 2 - Oscilloscope image of an x-ray pulse.

Distance (Inches)	Actual (Volts)	Measured (# of photons)
24	1.500	4.4E+08
36	0.085	2.1E+06
48	0.050	1.1E+04

Table 1 - Actual response and measured response.

Graphing data from Table 1 in Figure 3 shows a good correlation between expected photon counts and measured output at short ranges, but quickly diverges at larger distances.

This error could be caused by a number of factors, possibly non-linearity in the PMT response to x-ray photons. It is possible that the PMT is operating in a non-linear region. Another possibility is scatter occurring outside of the water media. The water depths used in these tests were fairly shallow, so it may be possible for scatter outside the tank to act as a “DC Offset” to the in-water scatter.

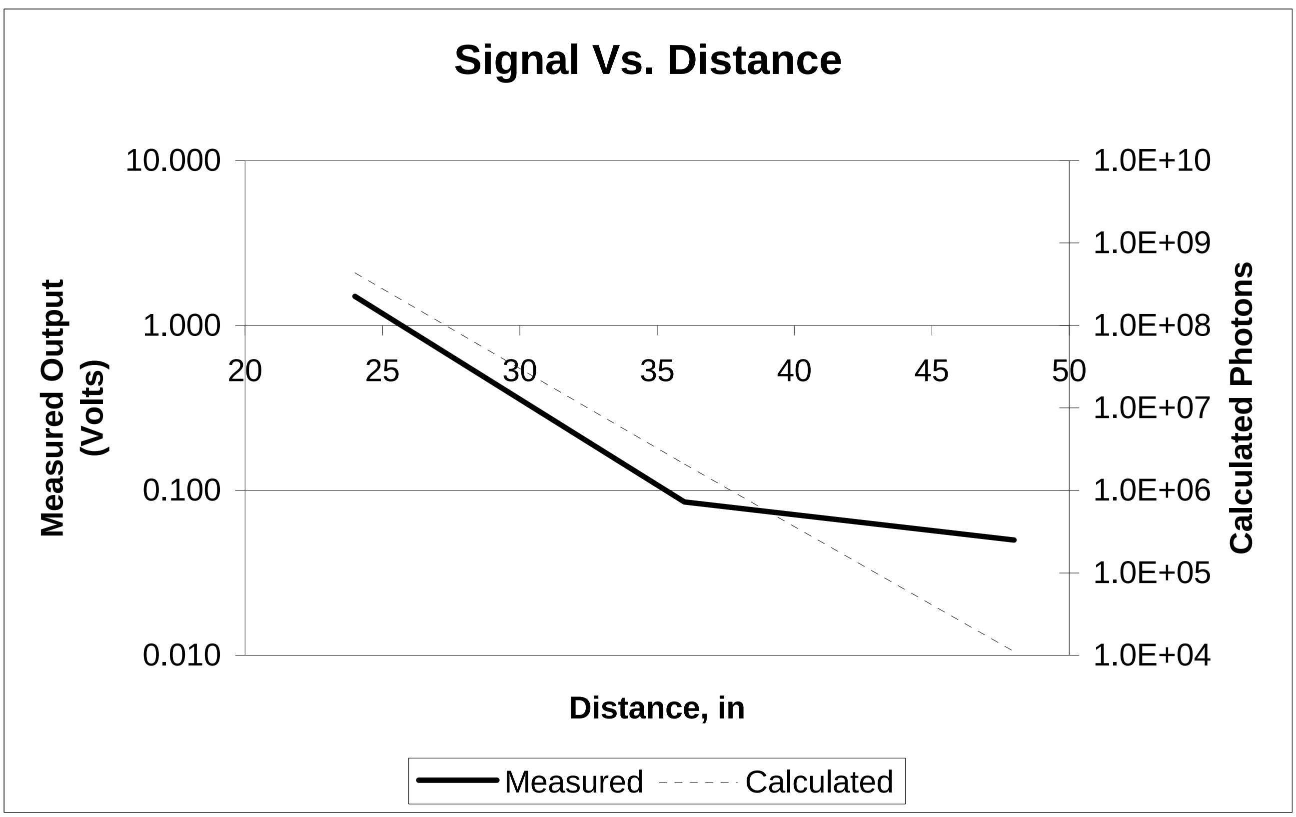

Figure 3 - Measured and calculated energy.

The next test was to determine the amount of backscatter variation caused by the addition of a target. Various targets should have different absorption characteristics, which should cause different backscatter amounts. By monitoring the change in backscatter with different materials, the ability to discern materials should be possible and in future equipment, images should be possible.

Unfortunately, through the series of tests performed, no variation in backscatter energy could be detected. It seems that the amount of backscatter never changed with the different materials. It is our conjecture that the amount of scatter in the first few inches outside of the x-ray machine is sufficient to completely obscure any scatter at target ranges. Because the system must be utilized with some minimal standoff, the ability to place the x-ray source directly on the target is limited. Also, sediment covering any targets of interest would act as semi-transparent material allowing the sever scatter to obscure any later scattering events.

Looking at the radiation level as a function of distance (Figure 4) from the source, the build-up affect of scattered energy in the water causes a sharp rise in the amount of radiation (number of photons, not total energy) exiting the source followed by a reduction as the radiation is absorbed. Because of this, the scattered energy in the first three to four inches is significantly greater than all the energy sent further into the target to be probed.

It appears that this would limit the range of the system to less then a few inches, not because of the systems ability to detect radiation at greater distances, but because the system is unable to distinguish between a distant target and the energy scatter near the exit of the source.

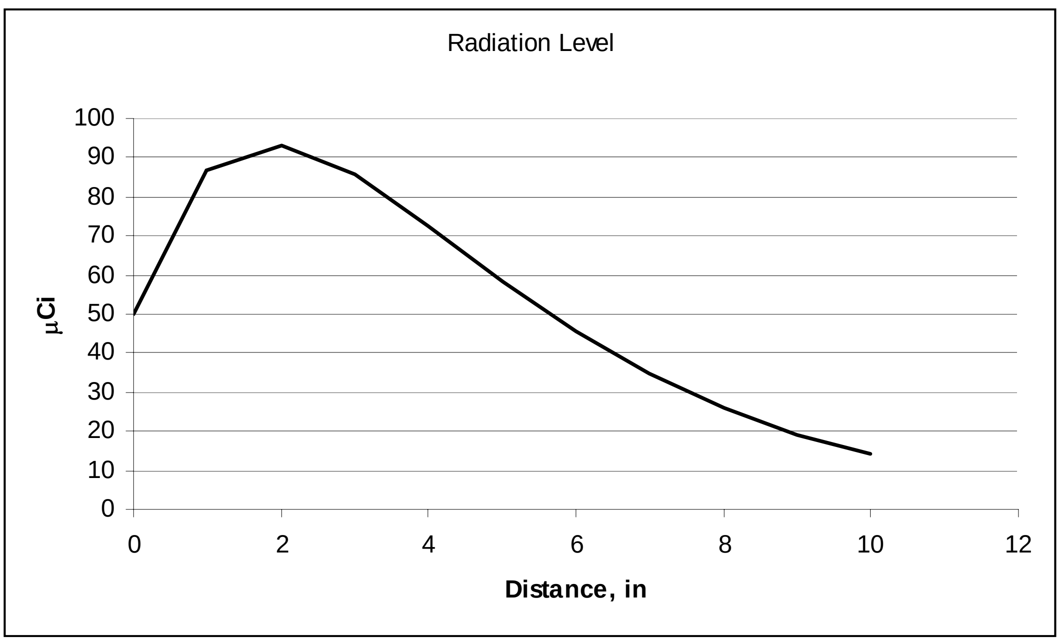

Figure 4 - Radiation level vs. distance from the source.

3. Conclusions and Recommendations

The intense photon scatter from the first few inches of the x-ray beam is significantly greater than available down-range radiation. For this reason, the distance between the x-ray aperture and the target is severely limited. It may be possible to shield the x-ray emission or build an evacuated tube that allows the beam to progress to the target without scattering, but the terminus of that chamber would need to be in close proximity to the imaged target. The system could be used for very lightly covered targets with less then a few inches of sediment cover, but at any substantially greater distance the signal will be overcome by the amount of scatter generated during beam transit to the target. The scattering from sediment and other materials is expected to be similar to water, so there is little advantage to building a system that lies on the bottom and attempts to project energy solely through the sediment. Since it appears that the system would be restricted to seeing only a few inches into the sediment layer, the utility of the system is questionable.