

Antineutrino applications: Highlights from 46+ years of ideas

Rachel Carr, United States Naval Academy

with contributions from

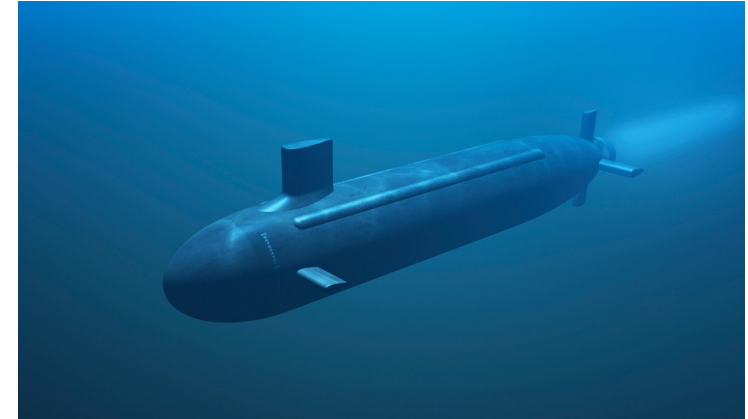
Tomi Akindele, Lawrence Livermore National Laboratory

Applied Antineutrino Physics Workshop – September 2023 – York, UK



Cooperative reactor monitoring
for NPT & regional agreements

Submarine tracking
& core verification



Long-range reactor
discovery & surveillance

Spent fuel & reprocessing
waste analysis



Nuclear explosion
monitoring

Communications

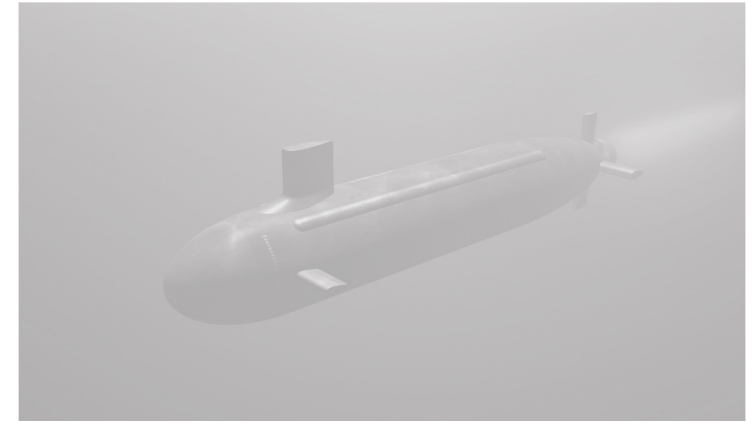
and other ideas...





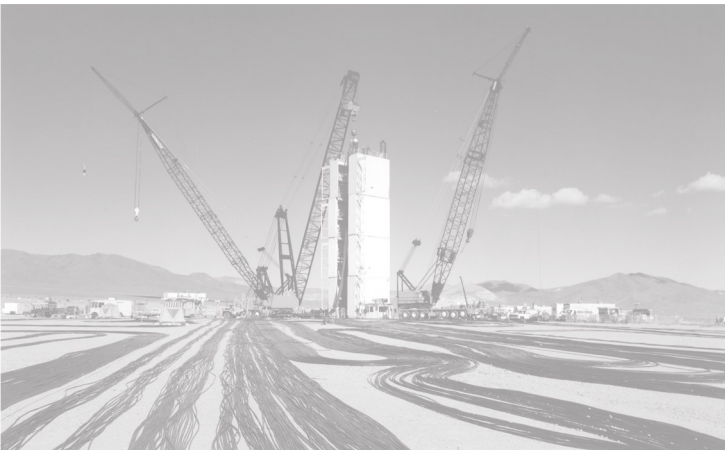
Cooperative reactor monitoring
for NPT & regional agreements

Submarine tracking
& core verification



Long-range reactor
discovery & surveillance

Spent fuel & reprocessing
waste analysis



Nuclear explosion
monitoring

Communications

and other ideas...



A Message Through Earth, Not Around It, Hinted Soon

A beam of cosmic particles has been used to carry a message through the earth rather than around it, a scientist has hinted.

The message, which was sent from the Massachusetts Institute of Technology to the University of California at Berkeley, was carried by a beam of cosmic particles in early 1977.

The message was a simple one: "A message through earth, not around it, hinted soon." The message was sent from the Massachusetts Institute of Technology to the University of California at Berkeley.

The message was sent from the Massachusetts Institute of Technology to the University of California at Berkeley.

MR. JACOB ROBINSON, HISTORIAN, DIES AT 88



Mr. Jacob Robinson, a noted historian and author, died at the age of 88 on Oct. 27, 1977. He was born in New York City and spent much of his life in the United States and Europe. He was a member of the American Historical Association and the American Academy of Arts and Letters.

Tony Holman, at 76, East Indian, Dies at 88



Tony Holman, a noted East Indian, died at the age of 88 on Oct. 27, 1977. He was born in India and spent much of his life in the United States. He was a member of the American Historical Association and the American Academy of Arts and Letters.

Deaths

Deaths

Deaths

"A Message Through Earth, Not Around It, Hinted Soon"

M. W. Browne
New York Times
Oct. 28, 1977

... the first human message to be sent directly through the earth rather than around it could be transmitted along a **beam of neutrino particles** as early as next year.

The test transmission could **revolutionize communications** as profoundly... as did the first experiments in wireless telegraphy performed by Guglielmo Marconi in the 1890s.

Francisco Pignatelli, 61, Overline Revolution Playbook Proposed as Industrialist

Francisco Pignatelli, 61, overline revolution playbook proposed as industrialist.

RADFORD BOESCH, WHITE SLIGHT FROM THE CITY

Radford Boesch, white, slight from the city.

RELIGIOUS SERVICES

Religious services

Deaths

Deaths

Deaths

Deaths

Deaths

Deaths

Deaths

Deaths

Deaths

Deaths

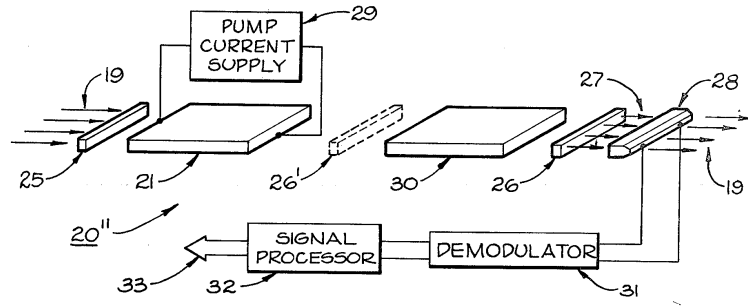


FIG. 8 RECEIVER

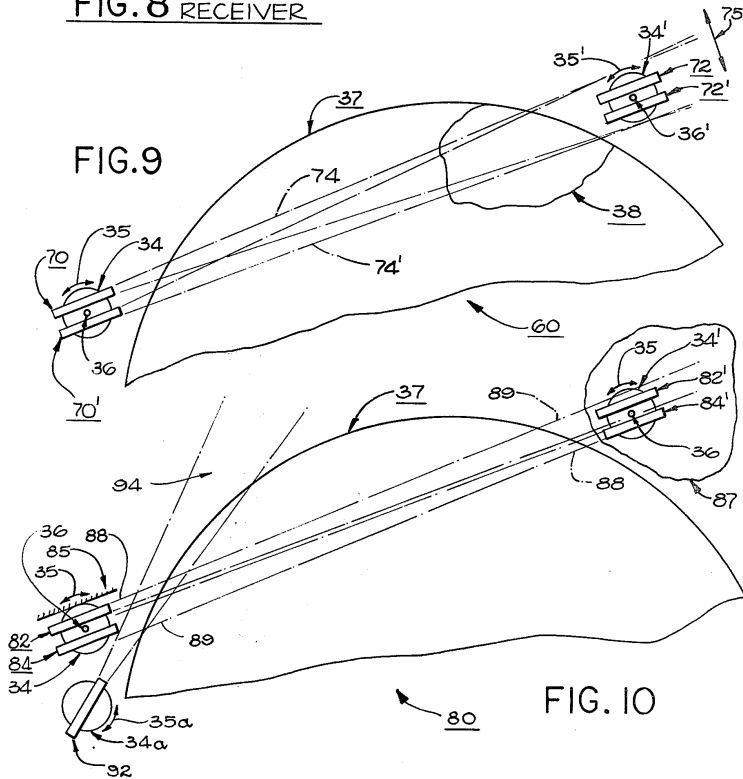


FIG. 9

FIG. 10

“Neutrino communication arrangement”

US Patent 4205268

1977-01-31 • Application filed by Eerkens Jozef W

1977-01-31 • Priority to US05/764,292

1980-05-27 • Application granted

1980-05-27 • Publication of US4205268A

1997-05-27 • Anticipated expiration

Status • Expired - Lifetime

“Galactic Neutrino Communication”

J. Learned et al.

Phys. Lett. B 671 (2009)

*We have outlined a method for **intragalactic communication via directed 6.3 PeV beams of electron antineutrinos**, and other neutrinos. Such beams can be created with reasonable energy efficiency by a civilization **without a long stretch from the technology we now possess...***

“Submarine neutrino
communication”

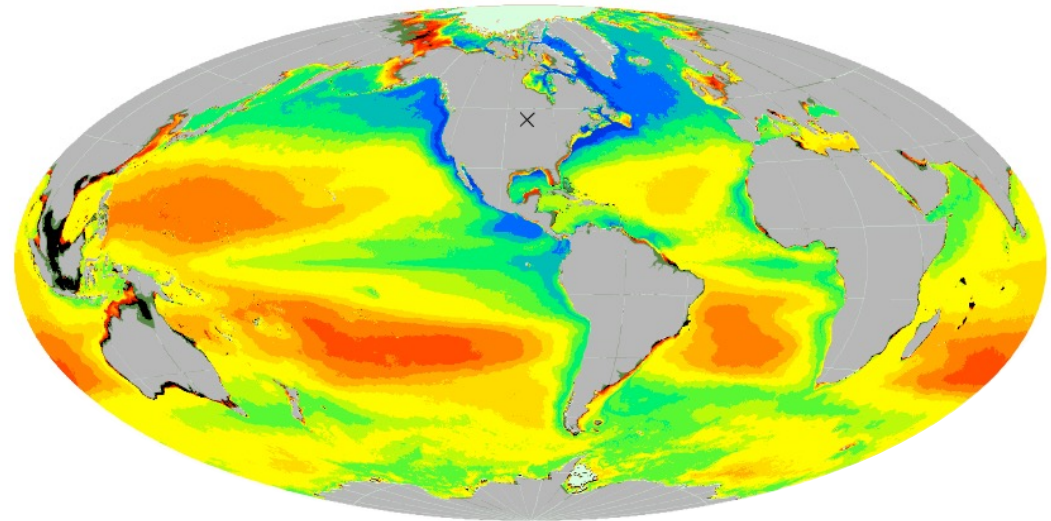
P. Huber
Phys. Lett. B 692 (2010)

How Neutrinos Could Revolutionize Communications with Submarines

Sending messages using neutrinos could improve data rates by up to three orders of magnitude.

By Emerging Technology from the arXiv

October 5, 2009



“Demonstration of Communication Using Neutrinos”

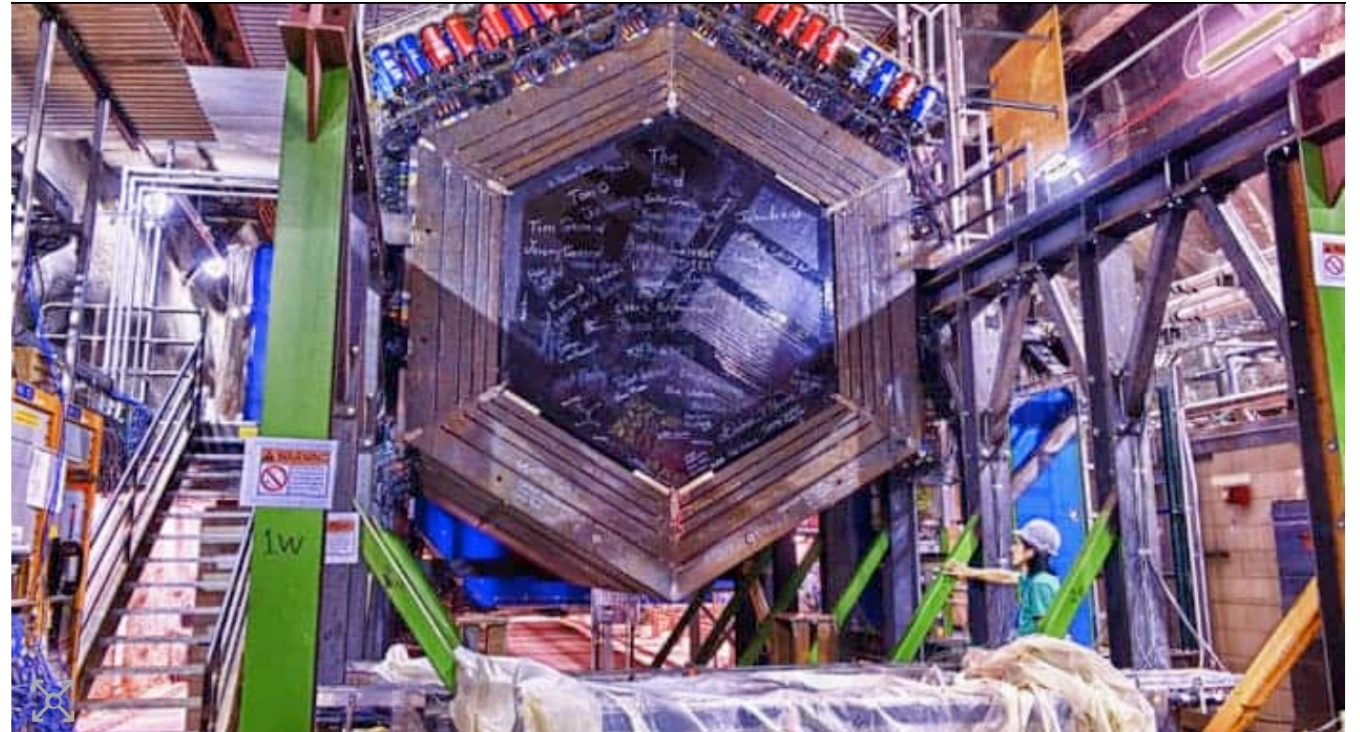
D. D. Stancil *et al.*
Mod. Phys. Lett. A 27 (2012)



PARTICLES AND INTERACTIONS | RESEARCH UPDATE

Neutrino-based communication is a first

19 Mar 2012



Not-so-portable neutrino receiver

“Neutrinos to Give High-Frequency Traders the Millisecond Edge”

B. Dorminey
Forbes
 Apr. 30, 2012

Communication times between financial centers

	Distance Earth Surface	Distance Through Earth	Time Surface Fiber optics	Time Surface Air	Time Through Earth	Time saved Through Earth versus Fiber	Time saved Through Earth versus Air
New York London	3,465	3,337	28.2	18.6	17.9	10.3	0.7
New York Tokyo	6,749	5,817	54.9	36.3	31.2	23.7	5.0
London Tokyo	5,946	5,394	48.4	31.9	29.0	19.4	3.0
New York Hong Kong	8,054	6,630	65.5	43.3	35.6	29.9	7.7
London Hong Kong	5,979	5,423	48.6	32.1	29.1	19.5	3.0
London Sydney	10,572	7,691	86.0	56.8	41.3	44.7	15.5
New York Sydney	10,377	7,487	84.4	55.7	40.2	44.2	15.5

Distances in miles, time in milliseconds, calculations by professor Espen Gaarder Haug
 Optical fiber assumed 66% speed of light. Neutrino speed assumed approximately speed of light.

Neutrino communications concept has:

- Investment from defense/national security agencies
- Articulation of specific use cases & customers
- Advantages over existing technology
- Scientific publications & patents
- Demonstration of technology
- Media attention

Neutrino communications concept has:

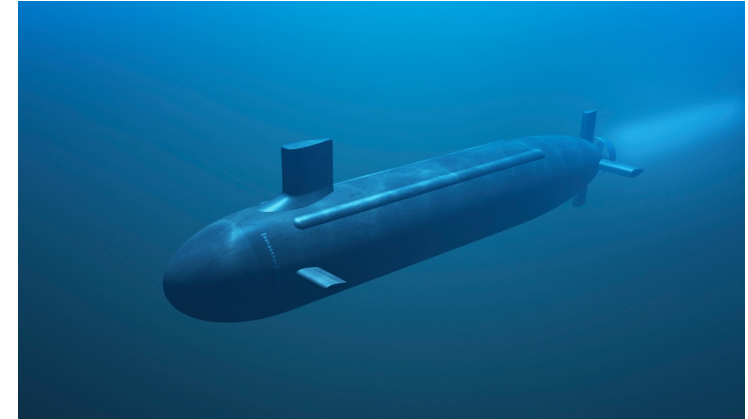
- Investment from defense/national security agencies
- Articulation of specific use cases & customers
- Advantages over existing technology
- Scientific publications & patents
- Demonstration of technology
- Media attention

Not yet in use. What else is needed?



Cooperative reactor monitoring
for NPT & regional agreements

Submarine tracking
& core verification



Long-range reactor
discovery & surveillance

Spent fuel & reprocessing
waste analysis



Nuclear explosion
monitoring

Communications

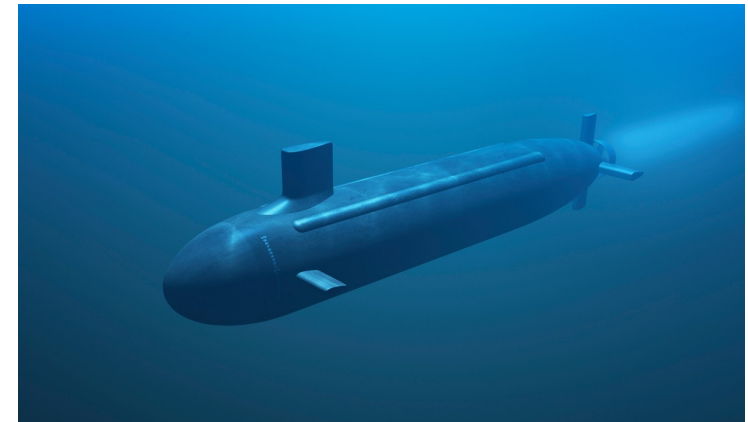
and other ideas...





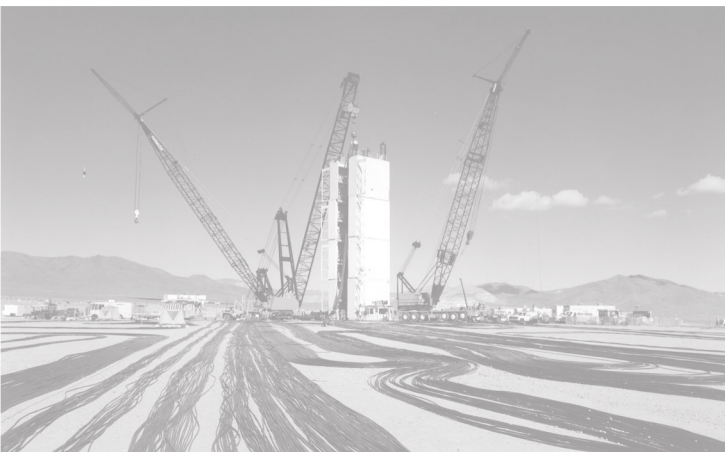
Cooperative reactor monitoring
for NPT & regional agreements

Submarine tracking
& core verification



Long-range reactor
discovery & surveillance

Spent fuel & reprocessing
waste analysis



Nuclear explosion
monitoring

Communications

and other ideas...



REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b RESTRICTIVE MARKINGS	
2a SECURITY CLASSIFICATION AUTHORITY N/A SINCE UNCLASSIFIED		3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.	
2b DECLASSIFICATION/DOWNGRADING SCHEDULE N/A SINCE UNCLASSIFIED			
4 PERFORMING ORGANIZATION REPORT NUMBER(S) JSR-84-105		5 MONITORING ORGANIZATION REPORT NUMBER(S) Defense Advanced Research Projects Agency	
6a NAME OF PERFORMING ORGANIZATION The MITRE Corporation JASON Program Office	6b OFFICE SYMBOL (If applicable)	7a NAME OF MONITORING ORGANIZATION Defense Advanced Research Projects Agency	
6c ADDRESS (City, State, and ZIP Code) 7525 Colshire Drive McLean, VA 22102		7b ADDRESS (City, State, and ZIP Code) 1400 Wilson Boulevard Arlington, VA 22209	
8a NAME OF FUNDING/SPONSORING ORGANIZATION	8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F19628-86-C-0001	
8c ADDRESS (City, State, and ZIP Code)		10 SOURCE OF FUNDING NUMBERS	
		PROGRAM ELEMENT NO	PROJECT NO
		TASK NO	WORK UNIT ACCESSION NO
11 TITLE (include Security Classification) Neutrino Detection Primer			
12 PERSONAL AUTHOR(S) C. Callan, F. Dyson, S. Treiman			
13a TYPE OF REPORT Technical	13b TIME COVERED FROM TO	14 DATE OF REPORT (Year, Month, Day) 870623	15 PAGE COUNT 90
16 SUPPLEMENTARY NOTATION			
17 COSATI CODES		18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP	
19 ABSTRACT (Continue on reverse if necessary and identify by block number) This report is intended to provide for non-expert readers a survey of natural and man-made neutrino sources and a critical review of various methods which have been proposed for their detection. Detection methods may be divided into two classes, those which have very modest performance and might actually work, and those which promise spectacular performance but violate the laws of physics. Emphasis in this report is on the second class of methods. The purpose is not to describe in detail what is possible, but to establish firm limits beyond which all schemes for detection capability are impossible. The last two sections of the report are for advanced students only and should be skipped by the non-expert. They provide precise mathematical statements and proofs of the limits which the laws of physics impose upon neutrino cross-sections. The limits are neither simple nor obvious. Consequently, it may be useful to have their technical justification here put on record.			
20 DISTRIBUTION/AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS		21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a NAME OF RESPONSIBLE INDIVIDUAL		22b TELEPHONE (include Area Code)	22c OFFICE SYMBOL

"Neutrino detection primer"

C. Callan, F. Dyson, S. Treiman
JASON advisory group, 1988

“Neutrino detection primer”

C. Callan, F. Dyson, S. Treiman
JASON advisory group, 1988

*For imagined applications of the above sorts, neutrinos have the **great advantage that they interact weakly with matter**, so can easily pass through vast thicknesses of matter without absorption or deflection. For imagined applications of the above sorts, neutrinos have the **great disadvantage that they interact weakly with matter**, hence do not register easily in neutrino detectors.*

Tracking Nuclear Material Aboard Submarines

June 14, 2022 • *Physics* 15, s79

Monitoring the fissile material aboard nuclear-powered submarines is notoriously difficult. Researchers may now have a way to safeguard this weapons-grade substance.



Grispb/stock.adobe.com

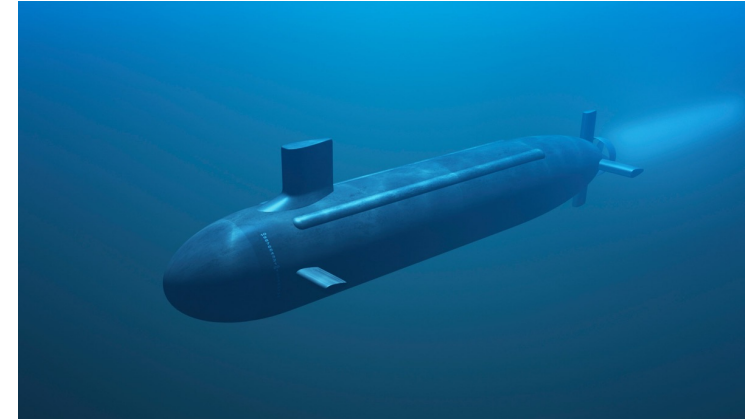
“Cerium Ruthenium Low-Energy Antineutrino Measurements for Safeguarding Military Naval Reactors”

B. Cogswell & P. Huber
Phys. Rev. Lett. 128 (2022)



Cooperative reactor monitoring
for NPT & regional agreements

Submarine tracking
& core verification



Long-range reactor
discovery & surveillance

Spent fuel & reprocessing
waste analysis



Nuclear explosion
monitoring

Communications

and other ideas...



“Possibilities of the practical use of neutrinos”

A. A. Borovoi & L. A. Mikaelyan
Soviet Atomic Energy 44 (1978)



50 years of NPT Comprehensive Safeguards Agreements – The Legal Bedrock of Nuclear Verification

05 Apr 2022
Jennifer Wagman



A Message Through Earth, Not Around It, Hinted Soon

A beam of cosmic particles has been used to send a message through the earth rather than around it, a scientist said today. The message was sent from the United States to a station in Japan in a test that could lead to a new way of sending messages around the world.

The test was conducted by a team of scientists from the University of California at San Diego and the University of Michigan. They used a beam of muons, a type of cosmic particle, to send a message from San Diego to Japan. The message was a simple one: "HELLO JAPAN."

The test was successful. The message was received in Japan within 10 minutes of being sent. This is the first time a message has been sent through the earth rather than around it.

The scientists say that this test could lead to a new way of sending messages around the world. They say that a beam of muons could be used to send messages from one side of the world to the other in a matter of minutes.

The test was conducted in a laboratory in San Diego. The scientists used a particle accelerator to create a beam of muons. They then directed the beam towards Japan. The muons traveled through the earth and were detected in Japan.

The scientists say that this test could lead to a new way of sending messages around the world. They say that a beam of muons could be used to send messages from one side of the world to the other in a matter of minutes.

DR. JACOB ROBINSON, HISTORIAN, DIES AT 88



Dr. Jacob Robinson, a noted historian and author, died today at the age of 88. He was born in New York City and spent most of his life in New York. He was a member of the American Historical Association and the American Academy of Arts and Letters. He is best known for his book "The American Revolution: A History." He also wrote several other books on American history.

Tony Holman, at 76, East Indian, Dies at 88



Tony Holman, a prominent East Indian leader, died today at the age of 88. He was born in India and came to the United States in the 1920s. He was a member of the Indian National Congress and was active in the Indian independence movement. He was also a leader of the Indian community in the United States. He is remembered for his work in promoting the interests of the Indian community in the United States.

Safety on the Proposed Shantel Project

The Shantel Project, a proposed dam on the Shantel River, has been approved by the Federal Energy Regulatory Commission. The project is being developed by the Shantel Project Authority. The dam will be 100 feet high and will have a capacity of 100,000 cubic feet. The project is expected to be completed in 1980. The dam will provide hydroelectric power and will also be used for flood control. The project has been approved after a series of studies and public hearings. The project is expected to provide a significant source of renewable energy.

Shantel Project Safety Study

A study of the safety of the Shantel Project has been completed. The study was conducted by a team of experts from the Federal Energy Regulatory Commission. The study found that the project is safe and that the dam will meet all safety requirements. The study also found that the project will provide a significant source of renewable energy. The project is expected to be completed in 1980. The dam will provide hydroelectric power and will also be used for flood control. The project has been approved after a series of studies and public hearings. The project is expected to provide a significant source of renewable energy.

Francisco Pignatelli, 61, Overline Revolution Playbook Proposed as Industrialist

Francisco Pignatelli, 61, a former revolutionary leader, has proposed a new industrial project. Pignatelli was a leader of the Cuban Revolution and was active in the struggle for Cuban independence. He was a member of the Cuban Revolutionary Council and was active in the struggle for Cuban independence. He is now living in the United States and is planning to start a new industrial project. The project is expected to provide a significant source of renewable energy.

RADFIB BOSS, WHITE SLIGHT FROM THE CITY

Radfib, a prominent figure in the city, has been slighted by the city government. Radfib was a leader of the city's labor union and was active in the struggle for workers' rights. He was a member of the American Labor Union and was active in the struggle for workers' rights. He is now living in the city and is planning to start a new industrial project. The project is expected to provide a significant source of renewable energy.

RELIGIOUS SERVICES

RELIGIOUS SERVICES
First Synagogue
First Temple
First Church
First Mosque
First Temple
First Church
First Mosque

"A Message Through Earth, Not Around It, Hinted Soon"

M. W. Browne
New York Times
Oct. 28, 1977

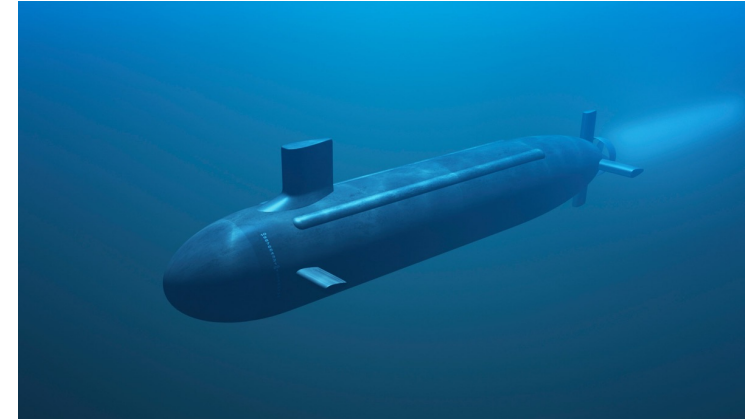
... the first human message to be sent directly through the earth rather than around it could be transmitted along a beam of neutrino particles as early as next year.

The test transmission could revolutionize communications **as profoundly... as did the first experiments in wireless telegraphy** performed by Guglielmo Marconi in the 1890s.



Cooperative reactor monitoring
for NPT & regional agreements

Submarine tracking
& core verification



Long-range reactor
discovery & surveillance

Spent fuel & reprocessing
waste analysis



Nuclear explosion
monitoring

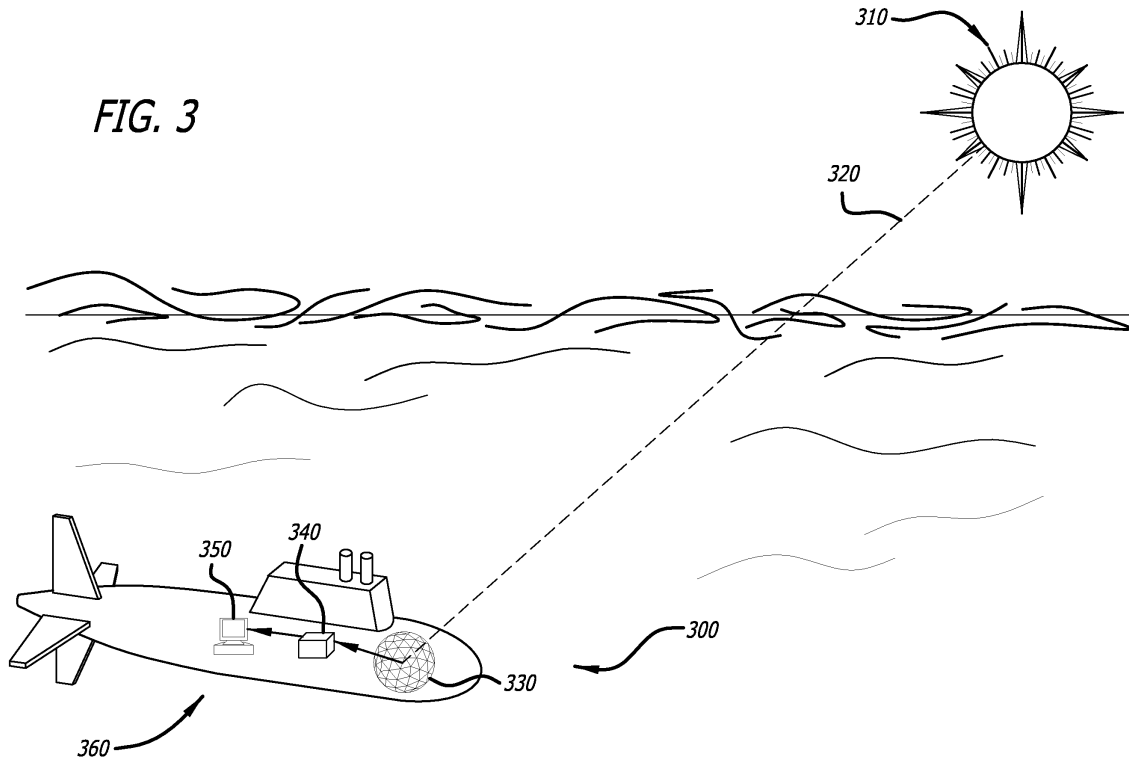
Communications

and other ideas...



Additional references

FIG. 3



“Navigation system based on neutrino detection”

US Patent 8849565B1

2007-06-28 • Application filed by Boeing Co

2007-06-28 • Priority to US11/770,652

2007-06-28 • Assigned to THE BOEING COMPANY ©

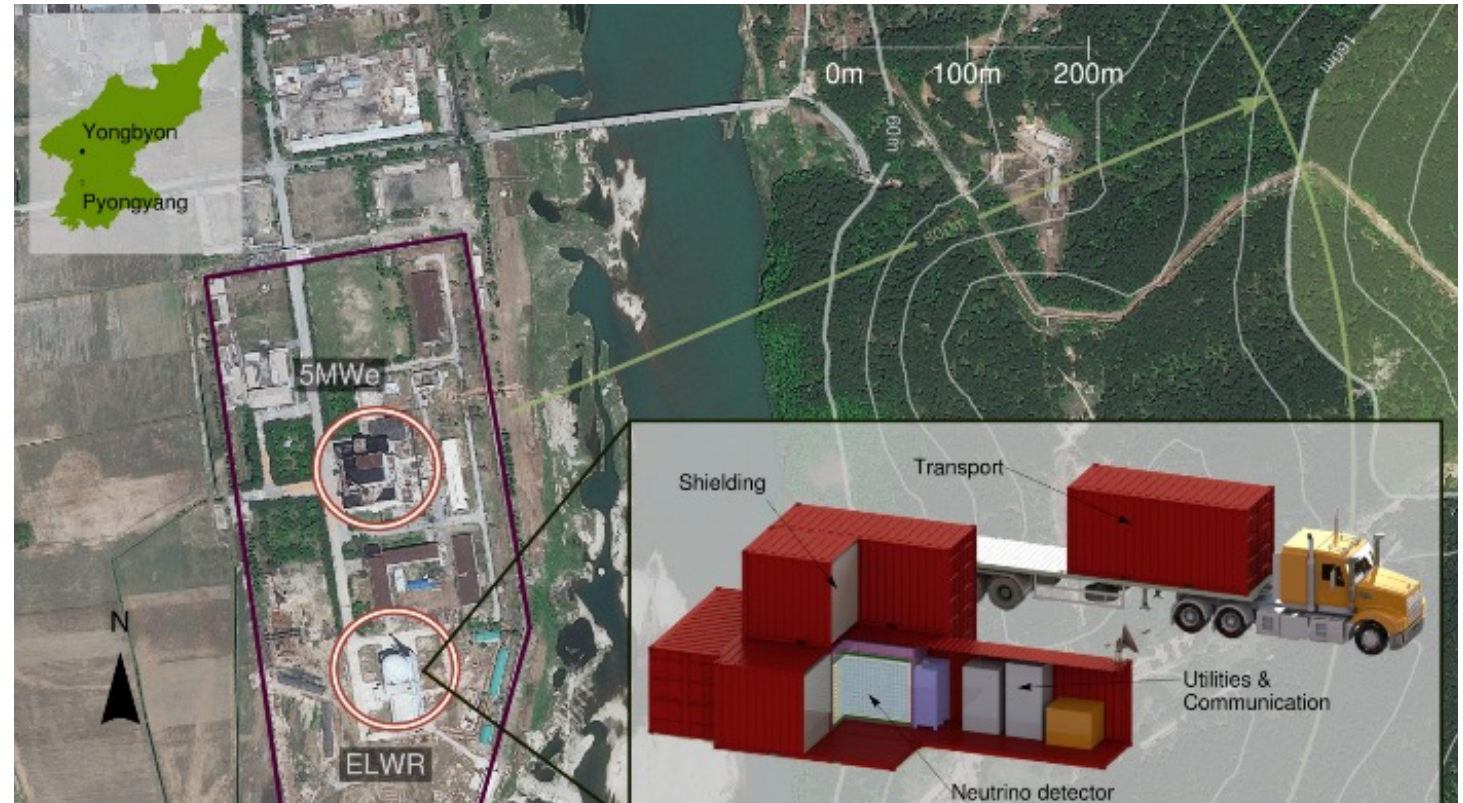
2009-09-10 • Publication of US20090228210A1

2011-03-22 • Priority to US13/069,240

Status • Abandoned

“Neutrino-based tools for nuclear verification and diplomacy in North Korea”

R. Carr *et al.*
Science & Global Security 27 (2019)



Neutrino physics for Korean diplomacy

Science

RACHEL CARR, JONATHON COLEMAN, GIORGIO GRATTA, KARSTEN HEEGER, PATRICK HUBER, YUENKEUNG HOR, TAKEO KAWASAKI, SOO-BONG KIM, YEONGDUK KIM,

JOHN LEARNED, MANFRED LINDNER, KYOHEI NAKAJIMA, SEON-HEE SEO, FUMIHIKO SUEKANE, ANTONIN VACHERET, WEI WANG, AND LIANG ZHAN

[fewer](#) [Authors](#)

[Info & Affiliations](#)