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**THRUST**  
**Second Annual Report**

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**Richard R. Behn**

**Pacific Marine Environmental Laboratory**

**Seattle, WA 98115**

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## EXECUTIVE SUMMARY

AID awarded PMEL a contract in June, 1983 to proceed on the Tsunami Hazard Reduction Utilizing System Technology (THRUST) Project. The project crystallized in September 1983, when the project team conducted a site visit of Chile. After discussions of the THRUST concept with Instituto Hidrografico de la Armada (Chilean Navy Hydrographic Institute), the Chileans endorsed the project. Since that time, utilizing the knowledge and skills of three NOAA components, two subcontractors, an AID advisor, a program director and project coordinator, 95% of the second year's proposal of work has been completed and capsulized into the following list:

- 1) publication and distribution of a "Tsunami in the Pacific Basin Map," Peru and Chile Tsunami Catalog and Pacific Basin Tsunami catalog
- 2) Numerical modeling of the Valparaiso area providing inundation limits
- 3) Final operating procedures and addresses for the utilization of the GOES satellite system
- 4) Procurement and assembly of all the THRUST instrumentation
- 5) Continued working relationship with the Chilean Navy Hydrographic Institute
- 6) The Earthquake/Tsunami of March 3, 1985
- 7) Publicity (conferences, meetings, publications)

Specifics on each above item and other accomplishments are explained in detail in this report.

## INTRODUCTION

One of the most destructive natural hazards within the Pacific Basin is the seismic sea wave, or tsunami. More than two million people support themselves or reside in the tsunami prone areas of the Pacific Basin. Since the early 1850's, more than 70,000 of these people have lost their lives due to the devastation of tsunamis (Iida et al., 1967).

Developing countries within the Pacific Basin, with minimal or no regional warning system, cannot be alerted of tsunamis originating close to their shores. The present operating limitations of the existing Pacific-wide tsunami warning network (the Pacific Tsunami Warning Center (PTWC) near Honolulu, Hawaii, USA) allows a warning to be issued 30 to 60 minutes after the generation of a tsunami. A gap, the 30 to 60 minutes after tsunami generation, exists in the present warning structure.

The Agency for International Development (AID), Office of U.S. Foreign Disaster Assistance (OFDA) has commissioned the National Oceanic and Atmospheric Administration (NOAA), Pacific Marine Environmental Laboratory (PMEL) to conduct a pilot project (titled THRUST). AID is authorized by the U.S. Congress to help alleviate suffering from disasters in foreign countries by providing emergency relief and strengthening the ability of developing nations to cope with disasters by increased reliance on their own resources. Helping host countries achieve adequate levels of preparedness and early warning capabilities represents OFDA's principal focus in disaster prevention and mitigation.

The purpose of the THRUST (Tsunami Hazard Reduction Using Satellite Technology) project has been to examine existing technology and to ascertain if an early warning system can be designed that would fill the "gap" in nations with minimal or no regional warning system. Specifically, the

objectives are to design, assemble, test, install and evaluate a system that can deliver early warnings to a developing country (Bernard et al., 1982).

Before a country could be selected, it had to meet certain criteria. Those criteria were: a) potential threat due to a tsunami, b) existing tsunami warning infrastructure compatible with the system technology concept, c) access to the GOES satellite system, d) national commitment to the program, and e) categorized by AID as a developing country.

Chile, which met all the above criteria, was selected as the country in which the THRUST project would occur. The pilot system will be used for the Valparaiso/Vina del Mar areas of Chile. An early warning system would prove to be very beneficial to this large population center.

#### PROGRAM MANAGEMENT

NOAA's Pacific Marine Environmental Laboratory (PMEL) has served as the coordinating organization for the THRUST program. Dr. E. Bernard, Director of PMEL, serves as project director. He is assisted by Richard Behn, project coordinator, who is responsible for the day to day management of the project. Dr. Bernard and Mr. Behn coordinate all efforts in each of the six functional working areas (see diagram 1). The activities of the program management of the project can be categorized into trips, conferences and meetings, monthly notes, and publicity. Each area will now be described in detail.

Pilot Study Schematic (Diagram 1)

**THRUST PILOT STUDY**

<b>TIME FRAME</b>	<b>FUNCTIONAL AREA</b>	<b>DATA COLLECTION</b>	<b>DATA ANALYSIS</b>	<b>DISSEMINATION</b>
	<b>PRE-EVENT</b>	DEVELOP TSUNAMI DATA BASE	EVALUATION OF HAZARD USING SIMULATIONS	DEVELOPMENT OF EMERGENCY OPERATIONS, PROCEDURES
	<b>REAL-TIME</b>	SENSOR DEVELOPMENT INSTRUMENT + PROCESSING + TRANSMISSION	OPERATIONAL "PREDICTIVE" MODEL	INTEGRATION OF EARLY WARNING DEVICE INTO EMERGENCY SYSTEM

**Trips:**

Trips were made to Canada, Chile, Japan, Colorado, Washington, and Washington D.C. by THRUST participants during the second year. All trips were made for THRUST participants to attend scientific conferences or planning meetings which are described in detail in the following sections (Conferences and Meetings).

**Conferences and Meetings:**

The THRUST project was presented at 13 conferences during the past year. The following is a list of conferences (dates, cities and personnel presenting the program):

- 1) Natural Hazards Workshop - July 1984 - Boulder, CO - G. Hebenstreit, J. Lander
- 2) Presentation of THRUST to delegates from the Peoples Republic of China - August 1984 - Seattle, WA - E. Bernard
- 3) THRUST First Annual Review - September 1984 - Seattle, WA - All THRUST personnel

- 4) Chilean Navy Hydrographic Institute (IHA) - October 1984 -  
Valparaiso, Chile - F. Gonzalez
- 5) THRUST personnel meet with TOGA personnel - November 1984 - Seattle,  
WA - R. Behn, H. Milburn
- 6) Organization of American States (OAS) - March 1985 - Washington,  
D.C. - R. Behn
- 7) NOAA/OAR Science Seminar - March 1985 - Rockville, MD - R. Behn
- 8) UJNR (U.S.-Japan Panel on Wind and Seismic Effects) - May 1985 -  
Japan - J. Lander
- 9) OAS Workshop - May 1985 - Miami, Florida - J. Buizer
- 10) AID Workshop - June 1985 - Washington, D.C. - G. Hebenstreit
- 11) IOC/ITSU Tsunami Workshop - July 1985 - Victoria, B.C., Canada -  
E. Lorca, G. Hebenstreit, J. Lander, R. Behn
- 12) International Tsunami Symposium - August 1985 - Victoria, B.C.,  
Canada - E. Bernard, G. Hebenstreit, F. Gonzalez, R. Behn
- 13) THRUST Second Annual Review - August 1985 - Victoria, B.C., Canada -  
All THRUST components

A slide presentation and/or paper was presented at each of the above mentioned conferences. Besides the normal day to day contact with the THRUST personnel, other planning meetings were conducted. Meetings between one or more of the following groups has occurred during the last year: CyberLink, governments of Columbia, Guatemala, Japan, Mexico and Peru, IHA, Kinemetrics Inc., NOAA (ATWC, NESDIS, NOS, NWS, PMEL, PTWC, WDC-A), Paroscientific Inc., SAIC, Synergetics International Inc., TOGA, University of Chile, University of Washington, and USGS.

Monthly Notes:

On the first day of each month a monthly notes is distributed to twenty-five offices around the world. This list includes personnel from the South Pacific, South America, Europe and the U.S. The monthly notes is a summary of the month's activities in a brief capsulized format. A copy of each monthly notes is attached to this report (see section titled "Monthly Notes".)

Publicity:

The THRUST project has received some publicity throughout the year. The list of periodicals in which articles were featured are:

Natural Hazards Observer	March 1985	pg. 4
Tsunami Newsletter	July 1985	pg. 10
Esquire Magazine	December 1984	
This Week in NOAA	January 18, 1985	
Interview on local (Seattle) T.V. station	December 1984	

A poster capsulizing THRUST was developed and has been displayed at various conferences and meetings.

PRE-EVENT

As seen in Diagram 1 the project can be broken down into six working areas. The next two sections are summaries of work in each area by its area coordinator.

Diagram 2

**THRUST PRE-EVENT  
Objectives and Personnel**

<b>DATA COLLECTION</b>	<b>DATA ANALYSIS</b>	<b>DISSEMINATION</b>
<b>DEVELOP TSUNAMI DATA BASE</b>	<b>EVALUATION OF HAZARD USING SIMULATIONS</b>	<b>DEVELOPMENT OF EMERGENCY OPERATIONS, PROCEDURES</b>
<b>NATIONAL GEOPHYSICAL DATA CENTER James Lander</b>	<b>SCIENCE APPLICATIONS, INC. Gerald Hebenstreit</b>	<b>NATIONAL WEATHER SERVICE-ITIC George Pararas-Carayannis</b>
<b>PROGRAM MANAGEMENT: PMEL / E. Bernard, R. Behn</b>		

1) Pre-Event Data Collection

Mr. James Lander of NOAA's National Geophysical Data Center is coordinating all efforts for the collection and organization of a tsunami data base. All of the first year's effort was placed on the collection of the tsunami data. The second year work has focused on the design and publication of the data bases. A "Tsunamis in the Pacific Basin" map was produced and distributed in early 1985. The map contains information on local and remote effects of tsunami's in the Pacific Basin from 1900 to 1983. This information includes earthquake location, and magnitude, tsunami runup heights, and death and destruction associated with an event. In addition to the copies that were distributed to the THRUST participants, NGDC has received 155 requests from other government agencies, colleges and universities, and others in natural hazards research and mitigation.

A Pacific Basin tsunami digital data base is nearing completion. This data base still needs verification which is being completed at this time. A digital data base of tsunamis in the Atlantic and Indian Ocean, Caribbean and Mediterranean Sea is also being assembled.

A publication entitled "Tsunamis in Peru-Chile" is now completed and being distributed by NGDC. This publication is a catalog of tsunamis that have occurred in these two South American countries.

Further in-depth studies using this data base have been on-going since the development of this data. Examples of these studies are included in this report (see section titled "Pre-Event" for further details).

## 2) Data Analysis

Dr. Gerald Hebenstreit of Science Applications International Corporation in McLean, Virginia, is coordinating the modeling efforts for this area of the project. SAIC, under contract with PMEL, has produced computer simulations which provided estimates of potential inundation levels, flood hazard areas, and worst case effects of observed and potential tsunamis. Dr. F. I.

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Gonzalez, PMEL Oceanographer, joined the project in May, 1985 with no cost to OFDA to augment modeling activities.

The SURGE II model was applied to all modeling efforts (Reid et al., 1977). A  $\frac{1}{2}$  km grid was utilized with a seafloor uplift (within the grid) being the source of the tsunami. These simulations provided information that the threat to Valparaiso/Vina Del Mar areas from local tsunamis approaching from the west and/or northwest is quite great. Data obtained from the Chilean Navy Hydrographic Institute (IHA) in Valparaiso, Chile on the May 22, 1960 tsunami in corral, Chile was used to originally verify the model (Hebenstreit et al., 1984).

With the occurrence of the 3 March 1985 earthquake and related tsunami in Chile, THRUST has been able to expand its model efforts. Now, Dr. Hebenstreit, along with Dr. Frank Gonzalez (PMEL), will use this latest tsunami data to verify the model results. They are also able to complete an

extended set of simulations to evaluate the tsunami threat to the Valparaiso/Vina Del Mar area from a larger variety of directions.

Dr. Hebenstreit is continuing to modify the SURGE II model. These modifications will make the SURGE II code much more user friendly and very flexible. (see section titled "Pre-Event" for further details).

### 3) Data Dissemination

Dr. George Pararas-Carayannis of the International Tsunami Information Center (ITIC) in Honolulu, Hawaii, has been responsible for the development of a Standard Operating Plan (SOP) for the Valparaiso/Vina Del Mar area of Chile. The purpose of the SOP is to achieve effective preparedness and understanding of the tsunami hazard in Chile. The SOP will organize in a systematic fashion a prompt, fully coordinated program of tsunami warning dissemination which will insure prompt and flexible response by the populace, thus minimizing loss of life and property when the disaster strikes. -

Mr. Emilio Lorca of the Hydrographic Institute in Valparaiso has assisted Dr. Pararas-Carayannis in the formulation of the SOP. The SOP will become a fully functional manual for Chile when the THRUST instrumentation is installed in May 1986.

REAL TIME

Diagram 3

**THRUST REAL-TIME  
Objectives and Personnel**

<b>DATA COLLECTION</b>	<b>DATA ANALYSIS</b>	<b>DISSEMINATION</b>
<b>SENSOR DEVELOPMENT INSTRUMENT + PROCESSING + TRANSMISSION</b>	<b>OPERATIONAL "PREDICTIVE" MODEL</b>	<b>INTEGRATION OF EARLY WARNING DEVICE INTO EMERGENCY SYSTEM</b>
<b>PACIFIC MARINE ENVIRONMENTAL LABORATORY Hugh Milburn</b>	<b>SCIENCE APPLICATIONS INTERNATIONAL CORP. Jerry Hebenstreit</b>	<b>PACIFIC MARINE ENVIRONMENTAL LABORATORY Hugh Milburn  CYBERLINK, INC. Peter McManamon</b>
<b>PROGRAM MANAGEMENT: PMEL/E. Bernard, R. Behn</b>		

1) Data Collection:

Mr. Hugh Milburn of PMEL's Engineering Design and Development Division is coordinating all efforts dealing with the collection and dissemination of data. THRUST, which will use a satellite-based communications system, will allow the lag time between the time of the event and the receipt of initial data to be reduced to the order of minutes. Two Strong Motion Accelerographs (Kinematics Vertical Seismic triggers), two water level sensors (Paroscientific Digiquartz pressure transducers) and the corresponding GCES radio transmitters (Synergetics) and/or receivers (Kinematics True Time Receivers) will constitute the event detection sensors. A microprocessor/terminal (Commodore 64 with dot matrix printer) will print out the stored warning message to the proper officials.

Diagram 4

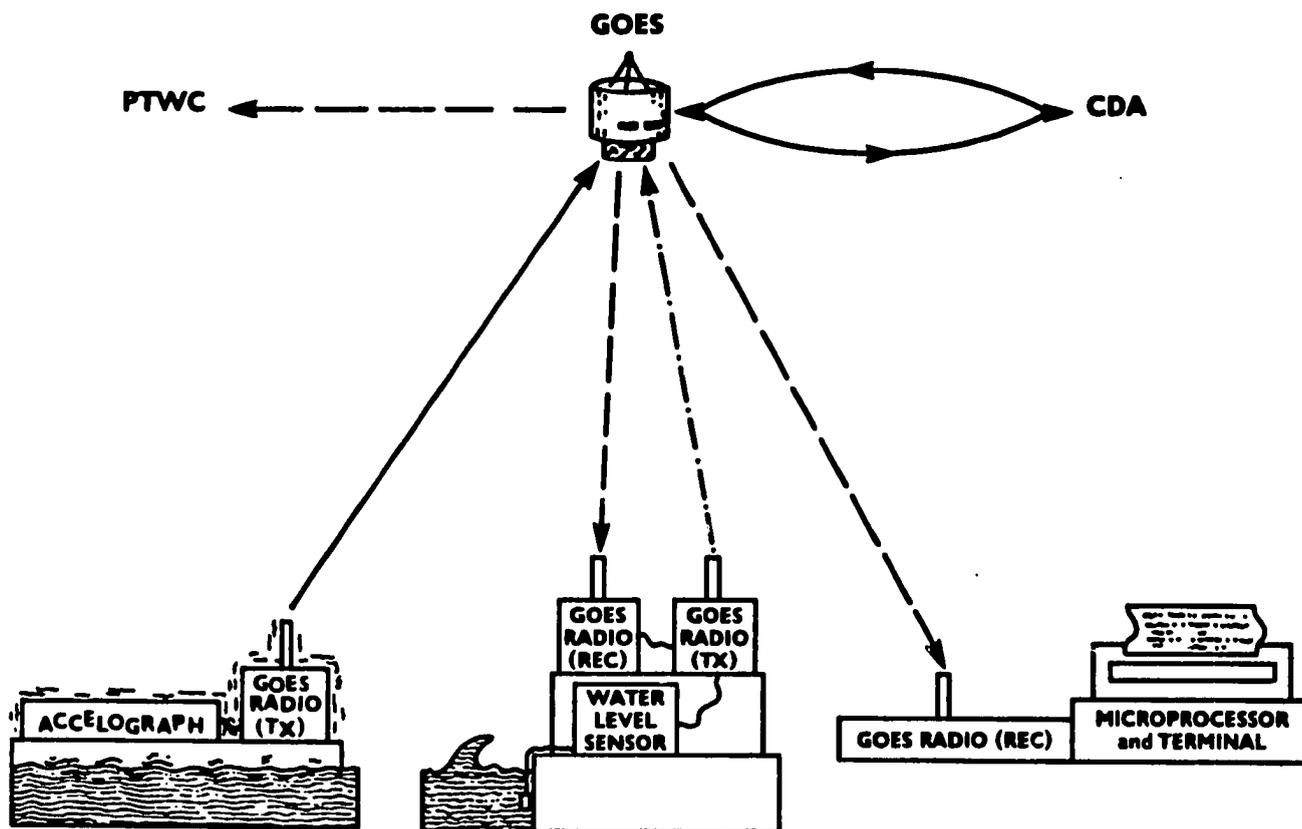


Diagram 4 shows the configuration of instruments for the THRUST prototype early warning system. The instruments have been procured and are being assembled and tested at PMEL in Seattle. Upon completion of a six month test, the instruments will be shipped to Chile for their final installation in February and May 1986 (see section titled "Real-Time" for details).

## 2) Data Analysis

Dr. Gerald Hebenstreit of SAIC is coordinating the efforts in this area. This area deals with the development of the Real Time Processor (RTP). The RTP is the first link between the THRUST instrumentation and the Chilean Tsunami Warning Center personnel. The RTP will consist of a

microprocessor and a printer that will print a stored message (see Figure 5) when it receives an event alert signal through GOES from the seismic trigger. The RTP will:

- 1) Alert Warning Center personnel that the seismic trigger was turned on by an event;
- 2) provide some level of assessment of the tsunami threat;
- 3) remind Warning Center personnel of the procedures to follow (Hebenstreit et al., 1984).

(See section titled "Real Time" for details.)

### 3) Data Dissemination

Mr. Hugh Milburn (PMEL) and Mr. Peter McManamon of CyberLink Corp., Boulder, Colorado, are coordinating all efforts of the transmission through the satellite system of the warning information to a threatened population area. In this final step of the warning process the incoming data and the accompanying analysis are used to determine which areas to warn, in what order to warn them, and what instructions to issue (SOP).

CyberLink's efforts were concentrated on coordinating the transmission scheme and software requirements of the GOES system with the instrumentation configuration and message format of the THRUST system. These efforts have resulted in THRUST being assigned eight Data Collection Platforms (DCP) addresses. Four of these addresses are of the Random Report mode and the remaining four are of the Interrogation mode. These eight addresses satisfy the THRUST requirements.

Modifications to the Synergetic DCP and final configurations of the data transmission scheme's are explained in detail in the section titled "Real Time."

## CHILE

During the second year of the THRUST project the Government of Chile officially approved the Memorandum of Understanding with the United States (THRUST MOU) as Supreme Decree No. 42. This translates to the THRUST project being officially recognized by the Government of Chile.

Emilio Lorca has continued his efforts in completing the SOP. Mr. Lorca has been working closely with ONEMI (Chilean National Emergency Office) in establishing the Tsunami Evacuation Procedures.

The data collection and hazard analysis of 3 March earthquake and tsunami is a continuing effort. IHA has distributed all of the data available to them to WDC-A and other tsunami authorities. (See section titled "Chile" for details).

## THRUST SCENARIO

The typical event scenario for THRUST will occur in the following manner (see Diagram 4).

An earthquake activates a seismic strong motion trigger. The trigger activates a GOES transmitter which transmits a signal through the GOES satellite to the Command Data Acquisition (CDA) facility. CDA will respond by transmitting an alert code back through the satellite to the GOES receiver which will turn on the RTP located at the Hydrographic Institute in Valparaiso. This alert code will turn on the RTP. The RTP instantly responds by sounding an alarm and printing a set of stored messages based on the SOP, numerical simulations, and procedures established prior to the tsunami. The stored message that THRUST will use is similar to the following:

## Diagram 5

### VALPARAISO EARTHQUAKE ALERT

A strong earthquake occurred at        z on        in the vicinity of the city of Valparaiso. Contact the following authorities:

- Oficina Nacional de Emergencia        Telephone N° 718333
- Department of Geophysics            Telephone N° 6968686

and advise them of this earthquake alert and disseminate the attached tsunami watch message.

### TSUNAMI WATCH

Establish a tsunami watch. A tsunami may accompany this earthquake. If a tsunami occurred, the wave will retard in reaching the coast at the shown localities the next specified times:

Valparaiso	minutes
Coquimbo	minutes
Caldera	minutes
Talcahuano	minutes
Chañaral	minutes
Corral	minutes
Antofagasta	minutes
Isla de Chiloé (Ancud)	minutes
Tocopilla	minutes
Iquique	minutes
Arica	minutes

Remember, this is only a tsunami watch. No tsunami has been observed but one may occur.

The same signal that was transmitted through GOES to the RTP will be received by the GOES receiver at the water level gauges located in Valparaiso harbor. That signal turns on the water level gauges which begin sending data via GOES to CDA. This information can then be accessed from commercial telephone lines.

Note that this process is entirely automatic and should take no more than 7 minutes to complete. The local officials now have information that the possibility of a tsunami may exist, but no real decisions have been made, except possibly a predetermined one to sound a general alert. Final authority to make decisions on whether to issue further alerts or sound the evacuation

alarm must rest with the local officials. This task will be made simpler to the local officials because of several factors. The local officials will be familiar with the historical and potential hazard analyses performed during the pre-event phase and thus will be aware of the general type of threat the coast of Chile faces. Also, because of the Standard Operating Plan implemented during the project, the Hydrographic Institute will have a complete set of procedures to follow which will ensure the proper response to the event. In addition, because of the public awareness program, the local officials will be confident that the threatened local population will know how to respond to ensure their own safety. And lastly, the Chileans can be sure that the sensors and the real-time analysis package is providing them with the most timely and dependable information available to them.

### 3 March 1985 Earthquake and Tsunami:

On 3 March 1985 at 2247 (GMT) an earthquake of  $M_s$  7.8 occurred off the coast of Valparaiso. Within minutes all normal lines of communications (microwave, telex, phone, radio) within and outside of Chile were severed. 3 minutes after the earthquake a 1.5 meter tsunami struck the Valparaiso harbor. IHA at this time had no communication capabilities with ONEMI or University of Chile (Seismic Center). The only communication that was available was VHF radio to other Chilean Navy Bases. Warnings were able to be issued to other Chilean ports with Navy Bases.

The Pacific Tsunami Warning Center located the earthquake in Argentina. No tsunami warning was issued. It was not until 5 hours after the event that Emilio Lorca (IHA) was able to telephone PTWC and report the occurrence of a tsunami. PTWC, at this time, issued a tsunami warning.

If a THRUST type system had been in place PTWC would have known within minutes that a large earthquake had occurred and its location. The Chilean warning center would have reacted immediately and ONEMI would have initiated the evacuation of tsunami prone areas. Based on this event, we are recommending the installation of a dissemination system at ONEMI.

#### CONCLUSIONS

At the completion of the THRUST project, title to all instruments will be transferred from the U.S. government (NOAA/PMEL) to the government of Chile. It will be the responsibility of the government of Chile to use this new technology and to keep the system in proper working order.

The original goals of THRUST are 1) to show that an instrumentation system can be designed and developed and placed in a successful active status, 2) to work with a foreign government (Chilean) and to integrate this technical system into their existing disaster control structure, and 3) to train the local personnel in the operation and maintenance of this system. Each phase of THRUST, then, will be conducted in conjunction with personnel from Chile. In this way, the technology behind THRUST can be demonstrated to other tsunami-prone (and, indeed, geophysical hazard-prone, in general) nations, while concurrently enhancing the technological capabilities of Chile. Successful completion of the THRUST project will not only enhance the tsunami protection of Chile but will, by adding addition input to PTWC, improve the protection of the entire Pacific community. The March 3 earthquake and tsunami illustrated the need for the new technology with more reliable communications.

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MONTHLY NOTES

THRUST

SECOND ANNUAL REPORT



**U.S. DEPARTMENT OF COMMERCE**  
**National Oceanic and Atmospheric Administration**  
**ENVIRONMENTAL RESEARCH LABORATORIES**  
Pacific Marine Environmental Laboratory  
NOAA Building Number  
7600 Sand Point Way N.E.  
Seattle, WA 98115

July 18, 1984

R/E/PM:RRB

TO: All THRUST Participants

FROM: R/E/PM - Richard R. Behn

SUBJECT: THRUST Newsletter

This month's quote: "One of the things man can do that the lower animals can't is stand upright before a crowd and put both feet in his mouth."

NESDIS informed us that our application for frequency allocation would be accepted if it would be resubmitted with some minor changes. These changes will be made and the application will be resubmitted.

The final report has been completed and is enclosed. The final report gives an overall look at the project. It refers to many other documents which have not been included due to their size. If you require a certain document for further details, please let me know. I will be happy to supply you with them.

**THRUST**



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**U.S. DEPARTMENT OF COMMERCE**  
**National Oceanic and Atmospheric Administration**  
ENVIRONMENTAL RESEARCH LABORATORIES  
Pacific Marine Environmental Laboratory  
NOAA Building Number  
7600 Sand Point Way N.E.  
Seattle, WA 98115

August 1, 1984

R/E/PM:RRB

TO: All THRUST Participants

FROM: R/E/PM - Richard R. Behn

SUBJECT: THRUST Newsletter

This months quote is: "If you've got money to burn you won't ever have trouble getting a light."

The American Embassy in Chile has all documents that need approval by the Foreign Ministry of Chile. A slight problem with the Spanish translation has kept these documents from proceeding through the necessary channels. The translation problem has been resolved.

Mr. J. Lander and Dr. G. Hebenstreit presented the THRUST project at the Natural Hazards Workshop which was sponsored by the University of Colorado in Boulder on July 15-18.

SAI has completed all the numerical modeling for THRUST and submitted it's corresponding final reports.

The final proof of the tsunami occurrence and effects map of the Pacific produced by NGDC has been approved and sent to the printers. The map should be available in a couple of months.

**THRUST**





**U.S. DEPARTMENT OF COMMERCE**  
**National Oceanic and Atmospheric Administration**  
ENVIRONMENTAL RESEARCH LABORATORIES  
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7600 Sand Point Way N.E.  
Seattle, WA 98115

September 5, 1984

R/E/PM:RRB

TO: All THRUST Participants

FROM: R/E/PM - Richard R. Behn

SUBJECT: THRUST Newsletter

This month's quote is: A chip on the shoulder may be a positive indication of wood higher up!! Dr. Bernard presented the THRUST project to a group of delegates from the Peoples Republic of China at a seminar at PMEL.

AID has approved and signed the PASA for the THRUST project. The money will not be transferred to NOAA until the MOU returns from Chile with all the proper signatures. The MOU is at the Chilean Foreign Ministry at this time.

Emilio Lorca has arrived at ITIC in Honolulu, Hawaii for a 6 week visiting scientist program. Sr. Lorca is in charge of the Chilean Tsunami Warning System and is involved very closely with the THRUST project.

Sr. Lorca will be visiting Seattle after his visit in Honolulu for a review of the progress of the project. This visit will occur at the end of September.

The failure of the GOES 5 (east) satellite and the movement of the other satellites will not effect the THRUST project at all. There will still be a satellite at 135 W.

NESDIS has agreed with the DCS that we have proposed. The allocation of the address and channel will occur in early September.

The Tsunami map compiled and drafted by NGDC will be available sometime in early October.

**THRUST.**



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**U.S. DEPARTMENT OF COMMERCE**  
**National Oceanic and Atmospheric Administration**  
ENVIRONMENTAL RESEARCH LABORATORIES  
Pacific Marine Environmental Laboratory  
NOAA Building Number 3  
7600 Sand Point Way N.E.  
Seattle, WA 98115

October 2, 1984

R/E/PM:RRB

TO: All THRUST Components  
FROM: R/E/PM - Richard R. Behn  
SUBJECT: THRUST NEWSLETTER

This month's quote is: If you want the world to beat a path to your door, don't pay your bills.

The game of politics has once again plagued the THRUST project. The MOA which was suppose to have been at the Chilean Foreign Ministry on Sept. 1st had not left the Embassy as of Sept. 14th. After numerous phone calls, we were finally able to be assured that the MOA would be out of the Embassy that afternoon. Captain Barison has been informed about this matter and has assured us his assistance in helping the document through the Chilean system.

The numerical model which was used for the simulations of the Valparaiso harbor by SAI has been transferred to PMEL. PMEL is in the process of training personnel who will be responsible for the model.

CyberLink has completed its first year's work for THRUST. A final report is being prepared by them and will be submitted to PMEL in the near future. Anyone wanting a copy, please let me know.

The Tsunami map, compiled and composed by NGDC, will probably be ready for distribution sometime in November. I will send you information on how to request one of the maps in the next newsletter.

AID/OFDA has released part of the funds to lead the contracts for SAI and CyberLink. Requests will be submitted to AID for approval of funds for the other THRUST components.

A THRUST annual review was held at PMEL in Seattle on Sept. 24th and 25th. Sr. Lorca (Chile) was present to review the work which had been completed by the the U.S. side, as well as to give us a presentation on what the Chileans had completed during the last year. Copy of the meeting minutes can be obtained by sending your requests to PMEL.

**THRUST**



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**U.S. DEPARTMENT OF COMMERCE**  
**National Oceanic and Atmospheric Administration**  
**ENVIRONMENTAL RESEARCH LABORATORIES**  
Pacific Marine Environmental Laboratory  
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November 1, 1984

R/E/PM:RRB

TO: All THRUST Components  
FROM: R/E/PM - Richard R. Behn *R. Behn*  
SUBJECT: THRUST Monthly Notes - October

This month's quote is: "Only a mediocre person is always at his best."

Captain Eduardo Barison, Director, Instituto Hidrografico de la Armada (Navy Hydrographic Institute) in Chile has been transferred and a new director has been named. He is Captain Humberto Garcia. Captain Garcia replaced Captain Barison as of November 1. Please direct all correspondence to his office.

A cable was received (10/18/84) from the American Embassy in Chile stating that Captain Barison says that the MOA will be finalized within two weeks of the above mentioned date.

F. Gonzalez (PMEL) visited the Hydrographic Institute in Chile in October. Mr. Gonzalez was able to acquire charts and marigrams that were needed for future work on THRUST. Three scientists from the Hydrographic Institute will be visiting PMEL later this month and will be bringing with them more data that is required for future work.

NESDIS has assigned THRUST its channel frequency and user ID's for its instrumentation.

Communication between PMEL and Chile will now be handled utilizing TELEX. Regular mail was taking approximately one month to reach Chile. It was the same for return mail. Utilizing TELEX should speed up communication between PMEL and Chile.

**THRUST**





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Pacific Marine Environmental Laboratory  
NOAA Building Number 3  
7600 Sand Point Way N.E.  
Seattle, WA 98115

December 5, 1984

R/E/PM:RRB

TO: All THRUST Components  
FROM: R/E/PM - Richard R. Behn *Reel*  
SUBJECT: THRUST Monthly Notes - November

This month's quote is: " If the way to a man's heart is through his stomach, then love makes the world grow round."

This has been a very active month for the THRUST project with the following activities taking place. We received another letter from NESDIS supplying us with four other addresses for the test modes of all the equipment. It has also been established that the downlink will be relayed through the GOES-west satellite to enable Hawaii to receive the data.

The MOA has reached the American Embassy in Santiago. A couple of minor word changes had to be made before the Chileans agreed to sign the document. The MOA should be signed and returned to Santiago by the end of the year.

The Tsunami map should be ready for distribution by the end of the year. All THRUST components will be receiving a copy through the mail.

SAIC has submitted the final reports for the modeling efforts and criteria needed for setting up the RTP. CyberLink has submitted their final report for Task I (GOES communication) of their contract. All requests for these reports should be sent to the above address.

Sr. Lorca (IHA) reviewed and revised the messages that will be printed on the RTP. His revisions included new Chilean cities, correct phone numbers and proper spanish translation.

Personnel (U.S., Chilean and Peruvian) working on the TOGA (Tropical Ocean-Global Atmospheric program) project met at PMEL during the Thanksgiving week. A meeting was held in which TOGA and THRUST personnel reviewed their respective projects. A cooperative for instruments and data is being established. David Enfield of Oregon State University will be the TOGA contact.

The TSUNAMI NEWSLETTER has given THRUST a spot in all it's future issues until the project is completed.

**THRUST**



The header for the May '83 tsunami in Japan video tape is being reviewed and edited. The tape will be distributed through the NOAA/National Geophysical Data Center in Boulder, CO. Details of the distribution process will be outlined in a future monthly notes.

On the behalf of the THRUST personnel, we'd like to extend to all a happy and healthy Holiday Season and a joyous New Year.



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January 11, 1985

R/E/PM:RRB

TO: All THRUST Components  
FROM: R/E/PM - Richard R. Behn *RRB*  
SUBJECT: THRUST Monthly Notes - December

This month's quote is: "We can't all be heros, somebody has to sit on the curb and clap as they go by".

Only two items of great significance occurred during the month of December. The first item is that the tsunami maps have arrived and are being distributed. If you have not received one yet, please be patient. They are on their way.

The second item is that the MOA has returned from Chile with all the necessary signatures. AID has released the money for THRUST and we are now back on track with a 9 month delay. January's monthly notes will give the new dates of testing and installation of the instrumentation for the remainder of the project.

**THRUST**





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Seattle, WA 98115

February 11, 1985

R/E/PM:RRB

TO: All THRUST Components  
FROM: R/E/PM - Richard R. Behn *R. Behn*  
SUBJECT: THRUST Monthly Notes - January

This months quote is: "There is no psychologist in the world like a puppy licking your face."

The following are items that occurred in the month of December; both SAIC and CyberLink submitted their final reports which would fulfill the last requirement of the contract. This concludes Task I for CyberLink and the contract for numerical modeling with SAIC.

The "Tsunamis in the Pacific Basin" map has been distributed to all personnel. If you have not received one, please let me know so I can forward one to you. Any extra maps can be obtained from NGDC in Boulder.

Attached is a page that reflects the new dates that the THRUST project will attempt to maintain for the duration of the project, provided no delays are encountered.

As of 1 Febuary, PMEL has submitted the paperwork for the procurement of the Kinemetrics true time receivers and the Synergetics GOES radio sets. The procurement could take as long as 4 to 6 months.

An article that appeared in "This Week in NJAA" is attached that reflects the publication and distribution of the Tsunami map.

Attachment

**THRUST**



**NEW SCHEDULE FOR THE THRUST PROJECT AS OF 1 JANUARY 1985**

This new schedule takes into account a 6 month procurement process, a 3 month assembly process and a 6 month bench test period at PMEL.

- 1 Jan 85 Received MOA - begin work again - begin the procurement process
- 1 July 85 Complete procurement of instruments and begin assembling
- 1 Oct 85 Assembly completed and bench testing of all instruments begins at PMEL in Seattle
- 1 April 86 Submit last budget (16 month duration)
- 1 May 86 Bench testing completed - disassemble instruments - pack and ship to Chile - then install in Chile
- 1 May 87 One year of testing instrumentation while in Chile completed Assemble data and begin writing results
- 1 Sept 87 All final reports submitted to AID

# **This Week In NOAA**

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**Activities for the week ending**

**January 18, 1985**

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**January 18, 1985**

**NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE**

**New Tsunami Map Published.** A 7-color map "Tsunamis in the Pacific Basin 1900-1983," has been published and is being distributed by the NESDIS National Geophysical Data Center (NGDC). The map was produced by NGDC for the Office of U.S. Foreign Disaster Assistance, Agency for International Development. Data shown on the map include symbols which indicate locations of earthquakes, volcanic eruptions, landslides, and explosions which cause tsunamis. Symbols indicate the maximum tsunami runup height recorded for each event. The symbols are numbered and keyed to a table giving more detailed information about the events. A list of destructive tsunamis is also included on the map. (R. Smith, FTS 320-6175)



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Seattle, WA 98115

March 14, 1985

R/E/PM:RRB

TO: All THRUST Components  
FROM: R/E/PM - Richard R. Behn *R. Behn*  
SUBJECT: THRUST Monthly Notes - February

This month's quote is : "Life is like a hot bath, the more you stay in, the more you get wrinkled!"

AID requested a time line (chronological history of the THRUST project) for future OFDA decisions on the project. This time line has been completed and is available to you if you so request.

Some of you should have received information on the Tsunami 85 conferences in Victoria and Sydney, B.C. If you have not received any information and you would like to obtain the packet of information on the conference, you should contact Sydney Wigen, Tsunami 85, P.O. Box 2267, Sidney, B.C., Canada V8L 3S8. THRUST is still planning to hold its Annual Meeting sometime during the Tsunami 85 time frame. A final date has not been established as of this time.

An article appearing in the March '85 issue of the Natural Hazards Observer is attached.

**THRUST**





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April 3, 1985

R/E/PM:RRB

**TO:** All THRUST Components  
**FROM:** R/E/PM - Richard R. Behn  
**SUBJECT:** THRUST Monthly Notes - March

This month's quote is "Even a stopped clock is right twice a day!" The month's major event was of course the earthquake of March 3rd. The final lat and long of the quake was 33.1S and 71.9 W (just off the coast of Valparaiso, Chile) with a Ms of 7.8. The earthquake did generate a tsunami that affected the Pacific Basin. A 1.1 meter wave was encountered in the Valparaiso, Chile area. No other wave action was reported in Chile. Small tsunamis (below 50 cm) were reported in Hawaii, Alaska, Japan, Ecuador, French Polynesia and Tahiti.

NGDC is attempting to obtain the tide gauge record from the Hydrographic Institute which will be used to supplement the numerical modeling that has been done for the Valparaiso harbor. PMEL is attempting to gather the seismic data from the University of Chile to aid in the seismic trigger threshold setting. If anyone does obtain the above mentioned data, I would appreciate knowing about it. This data is very important to the THRUST project.

PMEL has received one of the Kinematics True Time Receivers and some of the Synergetics Gues communication equipment. All instrumentation will be tested in the near future. Modifications to the Synergetics equipment is necessary before testing will begin.

Abstracts on THRUST were submitted for the UJNR conference to held in Japan and the ITS conference to held in British Columbia, Canada. Presentations on THRUST were given at Organization of American States, for the Interagency Coordinating Committee on the National Earthquake Hazards Reduction Program, as a Ocean and Atmospheric Research Science Seminar and at the University of Washington.

**THRUST**





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May 3, 1985

R/E/PM:RRB

**TO:** All THRUST Components  
**FROM:** R/E/PM - Richard R. Behn  
**SUBJECT:** THRUST Monthly Notes - April

This month's quote comes from George Pararas-Carayannis: "To scare a bird is not the way to catch it." If you have a quote you want me to include in the monthly notes, please send it to me.

The video tape of the Japanese Tsunami of May '83 is finally complete. The tape has now been edited down to about 27 minutes. I will distribute the tape out of this office. I have five copies in hand. I will fill requests on a first come, first serve basis. I would rather not let the tapes be out on loan for extended periods of time. I have had many requests for these tapes already. So please, if you know someone who wants to use the tapes, have them drop me a line to reserve it. Any questions, give me a call.

IHA has informed PMEL that complete reports on the March 3rd earthquake and tsunami (which include marigrams, pictures, and maps) are being forwarded to PMEL, ITIC and WDC-A. I will keep you informed of their arrival.

A paper was submitted to UJNR entitled THRUST, which is the most up to date paper on the project. It will be presented in Japan by Jim Lander some time this month. I would be happy to send you a copy of the paper if you so request.

An abstract was submitted to the Oceans 85 conference to be held on November 12-14 in San Diego, California.

**THRUST**



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June 5, 1985

R/E/PM:RRB

TO: All THRUST Components

FROM: R/E/PM - Richard R. Behn *Reel*

SUBJECT: THRUST Monthly Notes - May

This month's quote - When I'm right, no one remembers, when I'm wrong, no one forgets.

This month's activities were minimal. Many of the instruments have been arriving at PMEL during the last month. Some modifications have to be made to the GOES receivers before they can be tested. PMEL has begun some testing of the True Time Receivers. Procurement of all instrumentation is expected to be complete in 6 weeks.

The Hydrographic Institute in Chile has sent PMEL and World Data Center in Boulder a detailed report on the 3 March earthquake and tsunami. Copies of this report can be forwarded to you upon request.

A tentative date of 5 August has been arranged for the THRUST Annual Review. It will be held in either Victoria or Sydney B.C., Canada. I will keep you informed of all developments.

**THRUST**



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July 3, 1985

R/E/PM:RRB

**TO: All THRUST Components**  
**FROM: R/E/PM - Richard R. Behn**  
**SUBJECT: THRUST Monthly Notes - June**

This month's quote comes from Mr. J. Buizer with NOAA's International Affairs Office: "One can't help hoping even if he is a scientist, he can only hope more accurately."

The National Geophysical Data Center has recently published a Data Announcement about the tsunami data that is available (data announcement #85-EHB-01 April 1985). Anyone in need of tsunami data which includes the Pacific Basin Tsunami map, tsunami photos, publications relating to tsunamis, tide gauge records and bathy data can request this data from NGDC.

The purchase order for the modifications to the Synergetics DCP's has been cut and working its way through the system. This is the last p.o. that has to be cut for the project. Upon completion of this modification, the system can be assembled and test at PMEL.

The Hydrographic Institute has informed us that three representatives from Chile will be attending the Tsunami 85 conferences. They included Captain Humberto Garcia, Mr. Emilio Lorca, and another representative from the Institute.

Presentations on the THRUST project will be made at Tsunami Workshop, ITSU and ITS of the Tsunami 85 conferences in Sydney and Victoria, B.C., Canada.

THRUST was presented at an OAS meeting in Miami which included an audience of many South American countries. The presentation was given by Mr. Jim Buizer of the International Affairs Office in Rockville, MD. The presentation was well received by the group, especially by Columbian, Panamanian and Peruvian representatives.

**THRUST**



**PRE - EVENT**

**Data Collection  
Data Analysis  
Data Dissemination**

**THRUST**

**SECOND ANNUAL REPORT**

**DATA COLLECTION**

**Principal Investigator:  
James Lander  
National Geophysical Data Center  
Boulder, CO**

THRUST STATUS REPORT  
Pre-event Data Activities through July, 1985

Pacific Tsunami Data Base

Almost all data from available catalogs have been entered into the digital data base. The data still needs verification, and coordinates must be added for some areas reporting tsunami runups. Information on focal mechanisms and areas of aftershocks will be added. At the 17th Joint Meeting of the UJNR Panel on Wind and Seismic Effects, the Japanese agreed to review our digital catalog for completeness and accuracy of entries for Japanese tsunamis later this year.

Tsunamis in the Pacific Basin (1900-1983) Map

In addition to the free copies of the map that were distributed earlier, 155 requests for this map have been received by NGDC. Requests have come from other government agencies, colleges and universities, and others in natural hazards research and mitigation. A copy of the map was prominently displayed at the July 15,16, 1985, U.S. Government Interagency Conference on Developing Predictive Capabilities for Disaster Early Warning Worldwide sponsored by AID.

Chile Tsunami Publication

The publication entitled "Tsunamis in Peru-Chile, Report SE-39, has been completed and is now available. A flier describing this publication is available from NGDC. Copies will be sent to THRUST Project participants in quantities requested.

Chile Earthquake and Tsunami Photographs

Thirteen photographs of the March 3, 1985 Chile tsunami have been acquired from Instituto Hidrografico de la Armada de Chile, Santiago, Chile. Thirteen mareograms have been received from Chile (7) and Hawaii. Copies of Japanese mareograms on this event were requested through the UJNR. Digital copies of the Chilean records are expected.

Special Studies

In-depth studies using the digital tsunami data have been prepared (see attached illustrations). These included a study of tsunamis generated throughout the Pacific Basin affecting Hawaii, a study of destructive tsunamis and the characteristics of their generating earthquakes, source regions and a study of tsunamis generated by or accompanied by volcanic eruptions.

Tsunamis of the Atlantic and Indian Oceans, Caribbean and Mediterranean Seas

NGDC has begun a listing of events in these areas, beginning with the dates and locations of the tsunami events. Later other known parameters such as earthquake and tsunami magnitude, earthquake epicenter, tsunami runup information and description of destructive effects will be added.

J.F. Lander and P.A. Lockridge

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## Tsunami-Related Data

**Bathymetry**      Surveys; 30 million points; covering U.S. coastal waters  
Gridded; 5' x 5' worldwide oceans depth values, DBDB5.

**Mareograms**     3,000 analog records for 350 tsunamis  
45 digital records for 9 tsunamis

**Seismic**          Epicenters and magnitudes for 20th century earthquakes  
Seismogram coverage good since 1960, fair for earlier part of 20th century.

**Photographs**     About 75

**Publications**    Catalogs published for Hawaii, Alaska, and Peru-Chile  
"Tsunamis of the Pacific Basin" map published

**Digital History**  
About 790 tsunamis and effects at 2,000 places,  
including wave height, damage, and fatalities

1. There is an average of 1 damaging tsunami per year.
2. 90% of damaging tsunamis have only local effects.
3. 99% of tsunami fatalities are local to source region.
4. Indonesia, Philippines, Peru-Chile, and Japan have histories of greatest loss.
5. Few areas have produced damaging Pacific-wide tsunamis.
6. The effect of Pacific-wide tsunamis beyond the source area is greatest in Hawaii.
7. Only Hawaii has a greater threat from distant tsunamis than from local tsunami.
8. Tsunamis maximum effects are highly directional.
9. Local damage from tsunamis with magnitude less than 7.5 is more than the damage from Pacific-wide tsunamis beyond their source regions.
10. The correlation between earthquake magnitude and maximum run-up height is poor.

MAREOGRAPHIC AND PHOTOGRAPHIC DATA AVAILABLE FOR REPRESENTATIVE TSUNAMI EVENTS

EVENT DATA	EPICENTER	MARIGRAMS		PHOTOGRAPHS
		ANALOG	DIGITAL	
1856 03 02	CELEBES, N. MOLUCCAS	3		1
1868 08 13	PERU-N. CHILE	13		
1923 09 01	TOKAIDO, JAPAN	10		
1933 03 03	SANRIKU, JAPAN	19	4	322
1946 04 01	ALEUTIAN IS.	43		
1952 03 04	HOKKAIDO, JAPAN	68	7	16
1952 11 05	KAMCHATKA, USSR	69	7	26
1957 03 09	ALEUTIAN IS.	61	12	60
1960 05 22	CHILE	62	1	
1961 10 18	CHILE		7	
1963 09 26	PERU		7	194
1964 03 27	ALASKA	104		1
1964 06 16	NIIGATA, JAPAN	32		
1966 10 17	PERU	37		3
1968 15 16	HONSHU, JAPAN	44	2	1
1974 10 03	LIMA, PERU	3		
1971 07 09	CHILE		3	
1975 07 26	SOLOMON IS.			3
1975 11 29	HAWAII	61		93
1976 08 16	MINDANAO, PHILIPPINES			2
1983 05 26	JAPAN SEA	57	*	17
1985 03 03	CHILE	13	(7) **	13

A TOTAL OF 3,000 TIDE GAGE RECORDS ARE AVAILABLE IN ANALOG FORM FOR 350 TSUNAMIS.

\* ADDITIONAL RECORDS EXPECTED FROM ALASKA, JAPAN, ECUADOR, AND TAHITI

\*\* EXPECTED

**DATA ANALYSIS**

**Principal Investigator :  
Dr. Gerald Hebenstreit  
Science Applications International Corp.  
McLean, VA**

PROGRESS REPORT: January-March 1985  
CONTRACT No: NA84-ABC-00216  
PRINCIPAL INVESTIGATOR: G.T. Hebenstreit

Activities during this quarter centered on several specific tasks:

1. CHILEAN BATHYMETRIC DATA

A tape of bathymetric data for Valparaiso Harbor was obtained from IHA (Chile). Analysis of the data showed positioning errors, which render it useless for modeling purposes. A request has been sent to IHA to examine the data and apply corrections if possible. Once corrected data is received, it will be included in the simulation data set as soon as feasible.

2. HIGH-RESOLUTION MODEL

At the request of IHA, a version of the model data set was assembled using 0.25 km resolution, rather than the 0.5 km used in earlier simulations. The data set was tested during a visit to PMEL from 25 Feb to 1 Mar. Sample calculations were completed to verify that the new data set is properly configured for SURGE II. Comparisons between the earlier coarse-grid simulations and the new fine-grid simulations will be carried out at PMEL.

3. UPLIFT ALGORITHM

During the trip to PMEL, Dr. Hebenstreit and Dr. Gonzalez (PMEL) worked out an improved technique for specifying bottom uplift patterns in the model. This new algorithm has been added to the code.

4. CODE SIMPLIFICATION

Dr. Hebenstreit is currently working to improve and simplify the code and make it easier to modify. The emphasis is on improving SUBROUTINE PART2.

5. IUGG PAPER

An abstract has been submitted (and accepted) to present a paper at the IUGG Tsunami Symposium at Victoria, B.C. in August. A copy is attached.

PROGRESS REPORT: APRIL-JULY 1985  
CONTRACT NO: NA84-ABC-00216  
PRINCIPAL INVESTIGATOR: G.T. HEBENSTREIT

Activities during this period centered on the continuation of the simulations of tsunamis in Valparaiso harbor. The extent of the Real Time Processor (RTP) coding has been greatly reduced from the initial estimate because of the limited amount of warning information that the Chilean Tsunami Warning System can broadcast during an emergency. Thus SAIC has been able to carry out both the RTP task and continued model support without any additional NOAA funding over and above the existing amount incurred on this contract. This continued modeling effort has met with the approval of both NOAA's COTR and the Chilean Tsunami Warning officials.

Specific activities undertaken:

1. EXTENDED HARBOR SIMULATION

Dr. Hebenstreit visited PMEL during the period 9-15 June. He and Drs. Gonzalez and Bernard laid the groundwork for an extended set of simulations to evaluate the tsunami threat to Valparaiso from a larger variety of directions than previous studies have examined. These simulations are being performed at PMEL.

2. CODE SIMPLIFICATION

Dr. Hebenstreit continues to modify the SURGE II code to make it more easily used and more flexible.

3. MARCH TSUNAMI

Dr. Hebenstreit has compiled a set of earthquake parameters based on the 3 March 85 earthquake and tsunami offshore from Valparaiso. These data have been passed to PMEL and will serve as the basis for simulations.

4. PRESENTATION

Dr. Hebenstreit presented a paper on the THRUST program, entitled "Advanced Tsunami Warning Systems for Near-shore and Open Ocean Tsunami Surveillance" at the US Government Interagency Conference on Developing Predictive Capabilities for Disaster Early Warning Worldwide. This conference was held at the US State Department on 15-16 July.

## **DATA DISSEMINATION**

**Principal Investigators :  
Dr. George Pararas-Carayannis  
International Tsunami Information Center  
Honolulu, HI.**

**Sr. Emilio Lorca  
Instituto Hidrografico De La Armada  
Valparaiso, Chile**

A copy of the Standard Operating Plan was not available at the time of printing. When the final version becomes available, one will be forwarded.

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REAL - TIME

Data Collection  
Data Analysis  
Data Dissemination

THRUST

SECOND ANNUAL REPORT

- JB

**DATA COLLECTION**

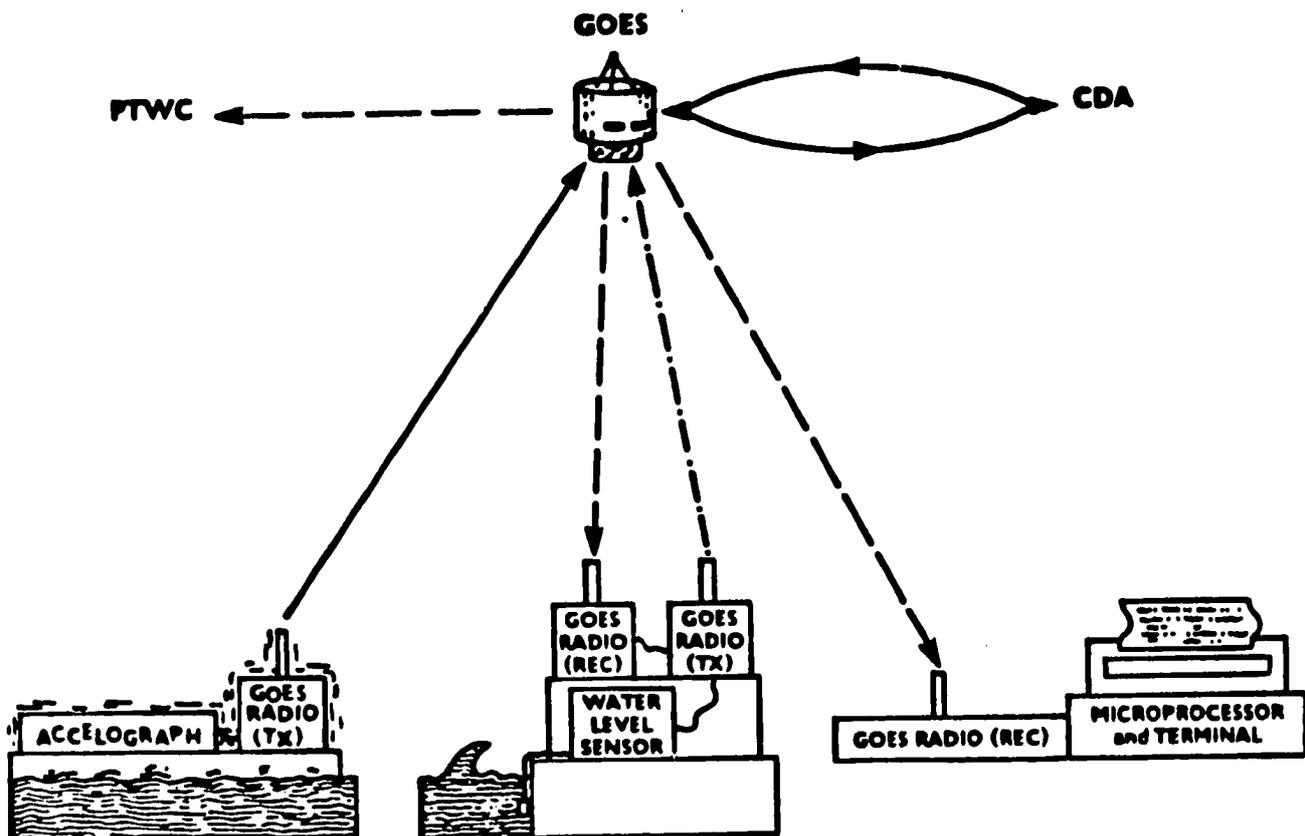
**Principal Investigator :  
Hugh Milburn  
Pacific Marine Environmental Laboratory  
Seattle, WA**

# THRUST

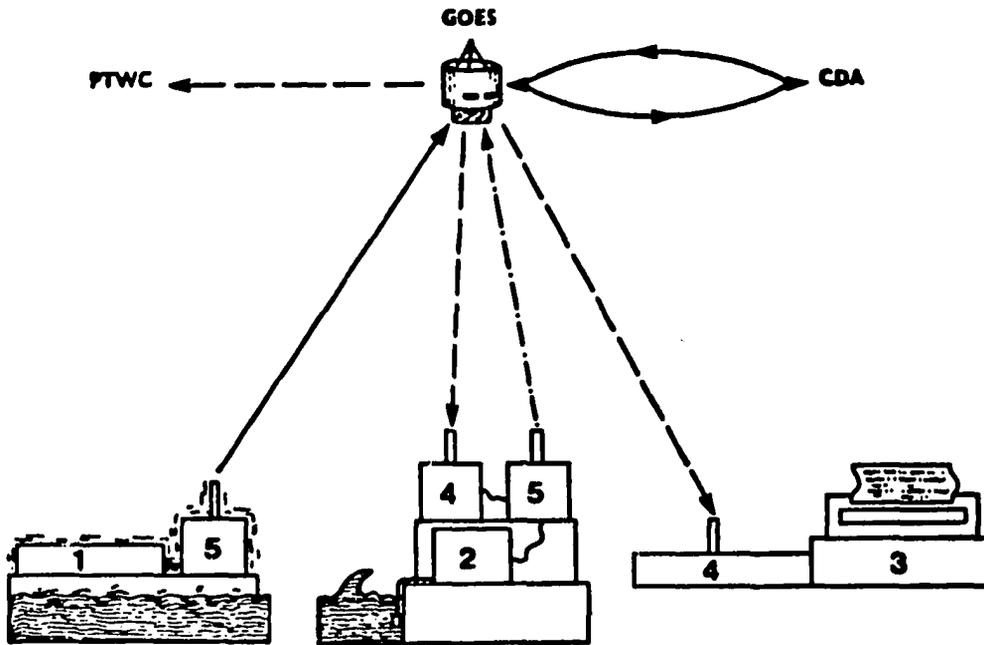
## Second Annual Report

### Real Time Data Collection

One of the goals of the THRUST project has been to use a satellite based communication system to transmit data from an event detector to a local population warning center in a matter of minutes. PMEL's Engineering, Design and Development division has designed such a system that will utilize NESDIS's Geostationary Operational Environmental Satellite (GOES) system to deliver the early warnings to the local population centers. The diagram below shows the system design.



The first years' efforts were concentrated on the design and development of the THRUST system. The most critical factor in designing the system was the compatibility of all the instruments. After thorough research, the following instruments and configuration was chosen.



**INSTRUMENTATION:**

1. Accelerograph: Kinometrics Vertical Seismic Trigger (VS-1)
2. Water Level Gauge: Paroscientific Digitiquartz Pressure Transducer (2100AS-002)
3. Microprocessor/Terminal: Commodore 64 with Dot Matrix Printer
4. GOES Radio Receiver: Kinometrics True Time Receiver (468-DC)
5. GOES Radio Transmitters: Synergetics (3401A)

After reviewing the requirements of the seismic system, it was decided that strong motion triggers would be well suited for the THRUST system. Two Kinometrics vertical seismic triggers will initiate the system when a seismic event occurs. One of the triggers will be located in Valparaiso and the other will be located in Santiago, Chile.

Pressure digital water level sensors were proven to be well suited for the THRUST system because of their large dynamic range. Paroscientific Digitiquartz pressure transducers will be used as the water level gauges. Both water level gauges will be located on the large concrete pier in the Valparaiso harbor.

The GOES radio sets that will be used in the THRUST system are made by two manufacturers. The transmitting GOES radio sets are manufactured by Synergetics. These transmitters are used in conjunction with the seismic triggers and water level gauges. The receiving GOES radio sets are manufactured by Kinometrics. These sets are the Kinometrics True Time Receivers which have been modified to output other data as well as the normal UTC. These receivers will be connected to the water level gauges and the Real Time Processors (RTP). The RTP will be located at the Hydrographic Institute in Valparaiso.

These above instruments have been procured and are being assembled at this time at PMEL in Seattle. As soon as the assemble of these instruments has been completed, a rigorous testing period will occur. Upon a successful testing period, the instruments will be packed and shipped to Chile.

Two trips will be made to Chile to install the instrumentation. The first trip is scheduled for February '86 for the installation of water level gauges, seismic sensors and GOES radio antennas. The second trip is scheduled for May '86 for the remainder of the equipment. The instrumentation will be in Chile for a one year test period.

**DATA ANALYSIS**

**Principal Investigator :  
Dr. Gerald Hebenstreit  
Science Applications International Corp.  
McLean, VA**

See the Pre-Event Data Analysis section of this report  
for details on the development of the Real Time Processor

**DATA DISSEMINATION**

**Principal Investigators :**

**Hugh Milburn  
Pacific Marine Environmental Laboratory  
Seattle, WA**

**Peter MacManamon  
CyberLink Corp.  
Boulder, CO**

THRUST PROGRAM PROGRESS REPORT  
August 5, 1985  
CyberLink Corporation  
Peter McManamon and Joseph Cateora

The second year of the CyberLink effort in support of the PMEL THRUST program is nearing completion. The major effort has been devoted to the development of equipment designs, specifications, and software for the various components of the warning system.

A design was developed for standard Synergetics GOES random reporting radio sets. The design involved software modifications to the radios to enable operation which satisfied the THRUST requirements. Basically, the design allows for two different messages to be sent via the GOES satellite to the NOAA/NESDIS central computer in Suitland, MD. One message is the alert message sent when the vertical Kinematics strong-motion seismometer threshold is exceeded. This is the real warning message which would be triggered by a sufficiently strong earthquake. The other message is the test message. It will be sent twice a day at random times selected by the Synergetics equipment internal computer.

The alert message and the test message to be sent from the seismometer site in Valparaiso, Chile will consist of an address word followed by message sequence numbers, the date and time of the seismometer threshold crossing (or time of initiation of the test message transmission), and some equipment status data for the radio set and Kinematics seismometer. The alert message will have an address and a code word that are different than those in the test message. Otherwise, the same procedure will be followed in both cases.

The specifications and software flow charts for the necessary modifications to the Synergetics radios were developed. Meetings have been held with Synergetics to review the modifications, obtain cost estimates, and initiate the work.

Work with NESDIS was performed to obtain the assignment of the addresses and to finalize the computer software changes needed in the NESDIS computers at Suitland, MD and at Wallops Island, VA. The computers are programmed to receive the alert message and data, store the data in the NESDIS computer user data file, and generate a corresponding warning message to be sent on the GOES interrogation downlink. The alert message will be sent by the Synergetics radio within 15 seconds of the seismometer threshold crossing. The actual time delay will be random. The delays in the NESDIS computer are not known but are expected to be in the range of 30 seconds to two minutes. As a result, the warning message will be sent on the GOES interrogation downlink channel between 30 seconds to 135 seconds after the seismometer threshold crossing. The same procedure is followed with the test messages.

Additional work was done with the Synergetics radios and NESDIS to develop a complex set of software procedures to repeat each alert message three times, and separately, to repeat each warning message three times on the GOES interrogation channel. Similar procedures were developed for the test messages.

The design for the modifications to the Kinometrics True-Time receiver was developed and the modifications were made to one receiver provided by PMEL. The modifications provide a special output signal which has the warning or test message.

Computer software specifications were developed to decode the message, either warning or test, correct errors detected, and to generate a printed message that was stored in the computer memory. A Commodore 64 micro-computer was selected since it is the least expensive 8-bit microprocessor unit on the market. It uses a microprocessor chip which is compatible with the Apple II micro-computer. An Epson RX-80 printer was selected because it has excellent reliability and has a type font and character set for both Spanish and English. An interface between the Commodore 64 and the Epson printer was also specified.

The necessary equipment was available at CyberLink (Commodore 64, Epson RX-80, and printer interface). An interface board was modified to connect the Commodore 64 to the Kinematics True-Time receiver. Computer programming was started in machine assembly language. At the time of this report, the Commodore 64 is decoding the messages and displaying them on the computer display.

Three program review meetings have been conducted with PMEL. Two were held in Seattle at PMEL and the third was conducted in Victoria, B.C. All of the project work has been documented in three quarterly reports.

CHILEAN NATIONAL  
REPORT

THRUST  
SECOND ANNUAL REPORT

**CHILE**

**Principal Investigators :  
Captian Humberto Garcia  
Emilio Lorca  
Instituto Hidrografico De La Armada  
Valpariaso, Chile**



THRUST ANNUAL REVIEW 1985

5 August 1985

PROGRESS REPORT FROM CHILE

1. The Government of Chile officially approved the Memorandum of understanding with the U.S. Government, as Supreme Decree N° 42 and published it at the Official Newspaper N°. 32.143 dated April 11, 1985 with a Complement published at the Official Newspaper N° 32.166 dated May 9, 1985.
2. Historical Data Collection and Tsunami Hazard Analysis completed and will be presented at the International Tsunami Symposium.
3. Tsunami Warning Standard Operating Plan not ready:
  - Chapter VIII Tsunami Evacuation Procedures is under preparation by the National Emergency Office.
  - Annex 3. Tsunami Preparedness Measures for Valparaíso area has not been completed by the Regional Emergency Office.
4. New set of bathymetry data for Valparaíso Bay is ready on tape.



Humberto GARCIA  
CAPTAIN  
DIRECTOR

## NATIONAL REPORT OF CHILE

### 1. INTRODUCTION

This report sums up Chile's activities in the operation and maintenance of the Tsunami Warning System in the Pacific during the period July 1983 to April 1985.

### 2. ACTIVITIES CARRIED OUT DURING THE PERIOD

#### 2.1 EXERCISES

In order to increase the efficiency of the different tide stations, tsunami exercises for individual stations are now being held more frequently, i.e. at two-monthly intervals. Each exercise is evaluated and the participating stations are informed of any comments and/or criticisms concerning their procedures. All the stations have now managed to reduce their response time to a maximum of 10 minutes.

#### 2.2 COMMUNICATIONS WITH THE PTWC

In order to improve communications with the PTWC, a telex connected with the international and national services was installed in November 1983. As a result, response times of less than five minutes have been obtained in tsunami exercises and immediate responses in real situations.

#### 2.3 TSUNAMI EXPERTS TRAINING PROGRAMME

At the Ninth Session, in Honolulu, it was agreed that in 1984 two candidates from Chile and China would take the ITIC training course. Chile nominated Mr. Emilio Lorca, who received intensive training from 13 August to 21 September 1984.

The training course included the following:

- (a) Knowledge of the Tsunami Warning System and the Pacific Tsunami Warning Centre (PTWC)
- (b) Operations of the Tsunami Warning System
- (c) Instrumentation of the PTWC
- (d) Interaction between the PTWC and Chile
- (e) Applied research.

les carr: in Hawaii as part of the training programme produced two important achievements:

- The PTWC response times have been halved for real situation of information concerning earthquakes in Chile.
- A Handbook of Emergency Operations has been produced for Chile.

#### 2.4 SESSIONS OF THE NATIONAL TIDAL WAVE WARNING SYSTEM (SNAM)

The Chilean national system (SNAM) consists of the Naval Hydrographical Institute, which heads it, the National Emergency Office of the Ministry of the Interior and the Department of Geophysics of the University of Chile.

Since 29 May 1984 representatives of these bodies have been meeting periodically with a view to improving the operation of the SNAM system.

#### 2.5 ESTABLISHMENT OF NEW TIDE STATIONS

On 8 October 1983 a new tide station was brought into service under the National Tsunami Warning System. Its characteristics are as follows:

- (a) Name: Iquique
- (b) Location: Lat. 20°12' 05"S.  
Long. 70°09' 27"W.
- (c) Instrument: Ballauf automatic tide gauge  
Standard type with float

At the end of April 1985 another tide station is to be brought into service within the SNAM system. Its characteristics are as follows:

- (a) Name: Corral
- (b) Location: Lat. 30°58'S.  
Long. 73°25'W.
- (c) Instrument: Ballauf automatic tide gauge  
Standard type with float.

#### 2.6 NEW PUBLICATION ON TSUNAMIS

While the Ninth Session of ITSU was being held in Honolulu, the Chilean Delegation gave each of the national representatives present a copy of the Naval Hydrographical Institute's publication No.3017, in Spanish, entitled Nociones Fundamentales sobre Maremotos e Tsunamis, produced to inform the general public of the characteristics of the tsunamí phenomenon.

subject to the risk of a tsunami.

## 2.7 ABANDONMENT OF THE PROJECT FOR A SEISMOLOGICAL NETWORK FOR TSUNAMI WARNING

As a result of the damage caused to the Naval Hydrographic Institute's installations by the earthquake of 3 March 1985, the project mentioned in Chile's report for the Ninth Session of ITSU had to be cancelled.

The small budget available will be used to improve communication systems within the SNAM system.

## 2.8 ACTIVATION OF THE WARNING SYSTEM

Various seismic occurrences during the period covered by this report brought the tsunami warning system into action. The main ones were as follows:

DATE	LATITUDE	LONGITUDE	MAGNITUDE	ACTION TAKEN
4 October 1983	25.9 S.	70.0 W.	7.4	Integrated tide stations Informed PTWC
15 December 1983	33.0 S.	70.5 W.	7.0	Informed PTWC of earthquake
11 December 1984	22.2 S.	68.2 W.	6.6	Informed PTWC of earthquake
18 January 1985	30.4 S.	71.8 W.	6.0	Informed PTWC of earthquake
3 March 1985	33.2 S.	72.0 W.	7.6	Local Tsunami Warning

## 2.9 REPORT OF THE EARTHQUAKE AND TSUNAMI OF 3 MARCH 1985

At 23h47 GMT on 3 March 1985 a violent earthquake shook the central area of the country, its effects being felt in a highly populated area more than 300 km wide. It was most intense at Puerto de San Antonio, 36 nautical miles south of Valparaiso, having a value of IX in the Mercalli modified scale.

The official data for the earthquake are as follows:

- Time of origin: 23h46'54" GMT
- Latitude: 32°14' 24"S.
- Longitude: 72°02' 24"W.
- Magnitude: 7.7
- Depth: 15 km.

The epicentre, located beneath the sea, produced a small tsunami, the maximum amplitude being recorded by the Valparaiso tide station.

The tsunami was clearly recorded in Chile, but with amplitudes below 1 m.Ø from Arica to Talcahuano. A full report on the occurrence was sent to the International Tsunami Information Center in Hawaii and the World Data Center-A in Boulder, Colorado.

### 3. FUTURE ACTIVITIES

#### 3.1 THRUST PROJECT

On 21 December 1984 an agreement was signed between the Governments of Chile and the United States of America on assistance for the establishment of a tsunami early warning system by means of the project entitled 'Tsunami Hazard Reduction through the Use of Systems Technology' (THRUST).

This project includes:

- (a) the construction and installation of two high-intensity seismic detectors and two sea-level sensors with telemetric links via operational geostationary satellite for the study of the environment (GOES), for installations already planned on mutually agreed sites on Chilean territory;
- (b) the preparation of a standard operational plan for tsunami warning;
- (c) the compilation of up-to-date data bases on tsunamis recorded in Chile with a view to conducting a detailed analysis in Valparaiso of the tsunami hazard.

#### 3.2 PARTICIPATION IN THE TOGA PROGRAMME

Under the United States of America's TOGA Programme the need is recognized to carry out monitoring operations in meteorological stations and tide stations in key areas in the eastern Pacific. The State University of Oregon made a proposal to NOAA for an improvement in the existing network of South American tide stations by the establishment of stations in Chile linked up with the GOES satellite by means of HANDAR data collecting platforms in Arica, Antofagasta, San Félix Island and the Isle of Pascua, which would be programmed to detect tsunamis. This project is now being financed by NOAA, and it is hoped that the first platform will be installed by the end of 1985.

THRUST

AT THE

TENTH SESSION OF THE INTERNATIONAL  
COORDINATION GROUP FOR THE  
TSUNAMI WARNING SYSTEM  
IN THE PACIFIC

SIDNEY, B. C., CANADA

1 - 3 AUGUST 1985

(30)

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by  
Norman M. Ridgway

#### PURPOSE OF MISSION:

- 1) Investigate the seismic, tide-measuring and communication instrumentation presently in existence.
- 2) Offer advice on the most effective use of such equipment to provide tsunami warnings.
- 3) Make recommendations regarding the measures necessary to develop and establish an efficient and reliable tsunami warning system.

#### INTRODUCTION

##### 1 - OUTLINE OF VISIT

An excellent programme of activities for my visit, drawn up by Capitan de Fragata Ernesto Cajiao Gomez, Secretary-General, Colombian Commission of Oceanography (Comision Colombiana de Oceanografia - CCO) was very well prepared and enabled me to visit all organisations involved with the national tsunami warning system in Colombia and thereby gain a good understanding of the present situation and an appreciation of future possibilities. An inspection was made of the tide gauge installation at Buenaventura but the planned inspection of the installation at Tumaco did not occur due to unforeseen circumstances.

#### INSTRUMENTAL REQUIREMENTS

The instrumental requirements for an automated TWS are discussed by the immediate-past ITSU Chairman, Mr. G.C. Dohler in the publication "Tsunami-Where Next?" (1983), a compilation of data and information for the preparation of a Master Plan for the Tsunami Warning System in the Pacific. The draft of this plan is to be presented at ITSU-X.

The THRUST (Tsunami Hazard Reduction Using Systems Technology) project, sponsored by the U.S. Office of Foreign Disaster Assistance (OFDA), is conducting a pilot programme in Chile. It aims to provide warnings for locally-generated tsunamis whose travel times are between 10 and 60 minutes i.e. tsunamis for which PTWC cannot, in general, provide adequate warnings. The THRUST project is based upon using one of the Geostationary Operational Environmental Satellites, GOES West, to instantly collect seismic and water level data from appropriate sensors and transmit these to ground stations (see Bernard et al, pp117-130 in Proceedings, 1983 Tsunami Conference, Hamburg, F.R.G.). The THRUST programme is very important to Colombia because it provides a model for the establishment of an automated TWS. Thus CCO, or some other appropriate agency, should closely monitor the progress and the developments being made by the THRUST project.

FOR TSUNAMIS  
TSUNAMI DATA ACTIVITY

The World Data Center-A for Tsunamis is operated by the U.S. Department of Commerce as part of its National Geophysical Data Center. Its principal activity since ITSU IX has been working on a project sponsored by the Office of U.S. Foreign Disaster Assistance, Agency for International Development to determine the feasibility of applying current technology to the tsunami warning problem for a developing country. This pilot study for Chile is called THRUST, (Tsunami Hazard Reduction Utilizing Systems Technology). The National Geophysical Data Center (NGDC) and the World Data Center-A it operates have a major role in the pre-event data collection including the compilation, cataloging, and synthesis of all available information on tsunami sources and effects to support modeling, planning, and education purposes.

A major effort of this pre-event data collection was the development of a digital tsunami data base consisting of information on the source (location, cause, validity, and magnitude) and effects (location of effects, wave heights, damage, and numbers of deaths). The initial event list was prepared by Doak Cox during a sabbatical at the World Data Center in an effort to revise and update the Preliminary Catalog of Tsunamis Occurring in the Pacific Ocean by Iida, Cox, and Pararas-Carayannis. Additional information was added from World Data Center files for earthquake epicenters, magnitudes, and depths. Tsunami effects including wave heights, damage, and numbers of deaths were added from several sources including the Catalogues of Tsunamis of the Western and Eastern Coasts of the Pacific Ocean by Soloviev and Go. Currently, the data base consists of about 1450 events since 49 BC, all Pacific locations reporting tsunami effects in the 20th century and all earlier tsunamis reporting waves of 1.5 meters or larger. More information is available for some areas such as Hawaii and Chile. Other indepth regional studies will be completed as time permits. The tsunami data are useful in the preparation of tsunami maps and lists of tsunamis having certain characteristics such as location, wave height, damage, and effects.

A wall size, multicolor map depicting Pacific Basin Tsunamis (1900-83) has been published using the NGDC/WDC-A digital data base. The map shows the locations of 405 events (including earthquakes, volcanic eruptions, and landslides) that caused tsunamis. Tables list dates of the events, event parameters, number of deaths, and destruction. An initial free distribution of about 100 copies of the map has been made to all THRUST participants, key emergency and civil defense offices, and international tsunami organizations including members of the International Oceanographic Commissions, International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU), and members of the Tsunami Commission of the International Union of Geodesy and Geophysics (IUGG).

In addition to the digital tsunami data, NGDC/WDC-A continues to acquire analog data primarily in two formats: marigrams (tide gage records showing evidence of a tsunami) and tsunami photographs. Interesting acquisitions in the past year include a set of digitized marigrams for 33 Chile station events, 28 digitized records of five major tsunami events recorded at U.S. stations in the Pacific, and a set of 35 marigrams for the May 1983 tsunami in Japan, and 6 marigrams from Hawaiian stations that recorded the March 1985 Chilean tsunami. Additional records of this latest event have been requested. The World Data

3

Center received photographs of the May 1983 tsunami in Japan, of the March 1957 tsunami in Alaska, and of the 1960 tsunami in Chile

Bathymetric data and seismograms of tsunamigenic earthquakes continue to be available. The World Data Center supplied a request for 5-minute gridded bathymetric data for the Pacific Ocean to Norman Ridgeway of the New Zealand Oceanographic Institute to be used in the calculation of tsunami travel times. The World Data Center also receives requests for information on occurrence of tsunamis in specified regions and for historical information about a specific event.

A publication describing Chilean tsunamis, which will be completed in 1985, includes locations, operation dates, and characteristics of tide stations, available recorded seismographic data, historical occurrences and effects, analyses, available photographs, and references. This report will be prepared jointly with Chilean experts and issued as World Data Center-A report.

Future projects include a continual refining and supplementing of data now in the data files and an extension of the data to include tsunamis in the Mediterranean and Caribbean Seas and Atlantic Ocean. Information on source dimensions, as inferred from earthquake aftershocks, and information on focal mechanism will also be added to the file over the next several years.



## **INTERNATIONAL TSUNAMI INFORMATION CENTER**

### **A PROGRESS REPORT FOR 1984-1985**

#### **I. THRUST PROJECT**

Work on this project continued during the intersessional period. Specifically the THRUST project involved the application of technological advances with land and sea based sensors and satellite-based communications to the problem of early tsunami warning. The pilot study named THRUST (Tsunami Hazard Reduction Utilizing System Technology) is presently centered on one tsunami susceptible area in Valparaiso, Chile for the purpose of proving the concept and developing a prototype for similar early warning systems elsewhere.

In designing a complete regional system, warning dissemination has to be based on a complete and thorough examination of the host country tsunami response infrastructure to determine lines of responsibility, how the system works, where it can be improved, what its basic requirements are, and how best to integrate the early warning technology into it.

ITIC was asked to assist in the development of this information and in the development of a comprehensive emergency standard operations plan for Chile with special emphasis on Valparaiso. The purpose of this plan is to achieve effective preparedness and understanding of the tsunami hazard in Chile and to organize in a systematic fashion a prompt, fully coordinated program of tsunami warning dissemination which will insure prompt and flexible response by the populace, thus minimizing loss of life and property when the disaster strikes.

A site visit was completed in early October 1983 by a THRUST team to collect the necessary information and data. The results of this visit were included in the ITIC Director's report presented to ITSU IX. Since then, a coordinating meeting was held in Hawaii to discuss the approach needed to insure that the numerical modelling effort in support of the overall THRUST project can be readily integrated into the emergency operating procedures effort and that some quantitative results can be obtained for inundation limits along the Valparaiso region. A number of conclusions were reached regarding modelling and verification. This work is being carried out to be a different component of THRUST. Final output results will include flooding maps and maximum predicted wave heights. In support of this effort and the preparation of the Standard Operating Plan, information and data was collected by ITIC on tide stations, wave climatology and the construction of the seawall at Valparaiso Harbor. Dr. G. Hebenstreit has been working on the tsunami modelling.

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The project was greatly supported by the visit of Mr. Emilio Lorca to ITIC last year. Mr. Lorca worked with ITIC staff in the translation of background documents and the preparation of the Standard Operating Plan. Following his visit to ITIC in Hawaii, Mr. Lorca proceeded to Seattle and participated in a coordinating meeting involving other aspects of the THRUST project.

Presently, ITIC's work on the draft Standard Operating Plan is nearing completion. This work is based on input provided by Mr. Lorca and the Chilean Hydrographic Office. It will be a working document of the Chilean National Tsunami Warning System, and as such, it is expected to receive extensive review and editing by the Chilean authorities before its adoption.

In conclusion, the need for applying current technological advances to the problem of early tsunami warning has been demonstrated. The THRUST project is expected to fulfill such a need for a critical Pacific Coastline with the potential for tsunami destruction.

THRUST PRESENTATIONS

AT THE

INTERGOVERNMENTAL  
OCEANOGRAPHIC  
COMMISSION  
TSUNAMI WORKSHOP

SIDNEY, B. C., CANADA

29 - 31 JULY 1985

A paper "Tsunamis Data Base" presented by Mr. J.F. Lauder, contained important information on the activities of the World Data Center-A, Tsunamis.

The World Data Center-A continues to collect microfilmed copies of mareograms and digitized mareograms. It presently holds copies of 3,100 analog records and about 60 digitized records. It also has a collection of 700 photographs of tsunami effects, which are described in published catalogs.

Over a period of years, working with Doak Cox initially, the WDC-A has prepared a digital file of tsunami occurrences and effects. The file now has information on data and location, and, where available, magnitude, runup heights, damage and fatalities for 1,450 reported tsunamis. The file was used to produce a recently published Tsunamis of the Pacific Basin map as part of the AID-sponsored THRUST project.

The file can be interrogated to produce lists or plots of tsunami occurrences and for statistical purposes. While the file is not yet complete, the following observations can be made:

- The reporting of tsunamis has greatly improved since the beginning of the tsunami warning system.
- There has been about one damaging tsunami/year over the last 100 years.
- About 90% of tsunamis have effects limited to source region.
- Only Japan, Kuril-Kamchatka, Alaska, and South America have produced Pacific-wide tsunamis.
- Hawaii has the greatest risk from Pacific-wide tsunamis.
- Remote-sourced tsunamis are a greater threat than local tsunamis only to Hawaii.
- 99% of fatalities (and probably damage also) are in the source region. Hence, regional warnings, education, and engineering defenses are important.
- Indonesia, Philippines, and Japan suffer the greatest hazard.

After the presentation of information on tsunamis data collection, a general discussion on various points raised in the paper followed.

Mr. E. Lorca from Chile made a presentation on the Tsunami Hazard Reduction Using System Technology, a joint USA-Chile project know as THRUST. This 3 year project was embarked by NOAA to create a pilot regional tsunami warning system.

The goal of THRUST is to demonstrate that Regional Systems can be assembled, using existing technology, and integrated into established disaster warning and relief infrastructures in developing nations. THRUST is utilizing existing instrumentation connected to satellite communication has established an early warning system.

Mr. Lorca reported that a simple conceptual model was developed which shows that many aspects of existing technology have potential applications on providing early tsunamis warning information in developing nations which do not have their own regional warning network. Model includes three functional areas of data collection, data analysis and information dissemination. Each area is partitioned into pre-event and real-time frames. All pre-event work has been completed including hazard map, numerical modelling simulations and the creation of an operating plan. Instrumentaion design has been completed and bench testing is expected to begin in summer of 1985.

It was pointed out that from an operational standpoint the tsunami probability problem point studies are a good help.

The problem of duplication of effort in data presentation was stressed and concern expressed that often same data presented differently which may raise certain confusion, participants felt that an increased level of coordination is needed to overcome these problems and make data more useful.

The Workshop therefore recommended recognizing the value of historical data collection in understanding the tsunami phenomenon and the value of the historical data base for operational analysis, that historical documentation of tsunamis be compared and that a data base format be established to serve as a comprehensive standard in the collection of seismic and hydrologic parameters of historical tsunamis.

Recognizing further the diversity of terms used in describing the tsunami phenomenon involving a wide diversity of scientific and non-scientific groups in a variety of interdisciplinary fields, recommends the preparation of a glossary of tsunami related terms to serve as the basis for defining and understanding tsunami terminology.

The paper presented by Mr. R. Hagemeyer of the USA looks at the process of delivering a warning to the public as a fine link chain with the links labeled Detection, Communication, Guidance/Forecasting, Dissemination, and User Response. Within the context of this paper "Communication" includes the Communication and Dissemination links.

The elements of operational communication were defined and the various communication methods used by the Alaska Tsunami Warning Center (ATWC) and the Pacific Tsunami Warning Center (PTWC) for the collection of seismic and tide data were discussed. The need for a communication peace was emphasized and the elements of an effective plan were enumerated.

The participants were two generic problems of the current place. The dependence on commercial telephone / telegraph / telex for the collection of confirming tide information plus the problem in dissemination of warning and the lack of complete coverage in the receipt of warning. The problem that the reliance on conventional communication caused in the handling of the March 3, 1985 Chilean Earthquake was explained in some detail.

The workshop stressed the need to improve the method of receiving tide data after a potentially tsunamigenic event was identified. Two methods, sea bottom pressure sensors and satellite data collection platforms were suggested as solutions. The need to improve warning dissemination was discussed with the specific suggestion regarding the acknowledgement of warning receipt and the expansion of the distribution of warnings.

Finally the Workshop acknowledged the value of a person-to-person exchange in effecting improvements to the TWS. The Visiting Scientist Program and the organization of other types of training exercises was specifically identified as a very important part of this activity.