

Final Report for Period: 02/2008 - 04/2008**Submitted on:** 07/14/2008**Principal Investigator:** GangaRao, Hota V.**Award ID:** 0742050**Organization:** WV Univ Research Corp**Submitted By:**

GangaRao, Hota - Principal Investigator

Title:

US-India Workshop on Fiber Reinforced Polymer Composites: Developing Research and Educational Programs; Mumbai, India; February 7-9, 2008

Project Participants

Senior Personnel

Name: GangaRao, Hota**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Hota Gangarao, West Virginia University, ghotam@mail.wvu.edu, was the PI and director of the workshop.

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Other Participant

Name: Liang, Ruifeng (Ray)**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Ruifeng (Ray) Liang, West Virginia University, rliang@mail.wvu.edu, joined the PI -Dr Hota Gangarao in India and participated in the workshop.

Name: Bank, Larry**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Larry Bank, University of Wisconsin-Madison, bank@engr.wisc.edu, joined the PI -Dr Hota Gangarao in India and participated in the workshop.

Name: Karbhari, Vistasp**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Vistasp Karbhari, University of California, San Diego, vkarbhari@ucsd.edu, joined the PI -Dr Hota Gangarao in India and participated in the workshop.

Name: O'Connor, Jerome**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Jerome S. O'Connor, University at Buffalo, SUNY, jso7@buffalo.edu, joined the PI -Dr Hota Gangarao in India and participated in the workshop.

Name: Myers, John**Worked for more than 160 Hours:** Yes

Contribution to Project:

John Myers, University of Missouri-Rolla, jmyers@umr.edu, joined the PI -Dr Hota Gangarao in India and participated in the workshop.

Name: Sen, Rajan

Worked for more than 160 Hours: Yes

Contribution to Project:

Rajan Sen, University of South Florida, sen@eng.usf.edu, joined the PI -Dr Hota Gangarao in India and participated in the workshop.

Name: Toutanji, Houssam

Worked for more than 160 Hours: Yes

Contribution to Project:

Houssam Toutanji, University of Alabama in Huntsville, toutanji@cee.uah.edu, joined the PI -Dr Hota Gangarao in India and participated in the workshop.

Name: Zureick, Abdul-Hamid

Worked for more than 160 Hours: Yes

Contribution to Project:

Abdul-Hamid Zureick, Georgia Institute of Technology, azureick@ce.gatech.edu, joined the PI -Dr Hota Gangarao in India and participated in the workshop.

Research Experience for Undergraduates**Organizational Partners****Other Collaborators or Contacts**

Dr. A. Selvam, Executive Secretary, FRP INSTITUTE, NP 23 / 24, Developed Plot, Ekkattuthangal, Chennai 600 097, India, helped as local organizer for the workshop.

Activities and Findings**Research and Education Activities:**

A technical team of 9 faculty members from 8 universities were sponsored by NSF to travel to India and participate in a three-day US-India Workshop on fiber reinforced polymer (FRP) composites in addition to a one-day short course. This event took place in conjunction with the International Conference and Exhibition on Reinforced Plastics (ICERP) 2008, Mumbai, India from 7th to 9th February, 2008. More specifically, US delegates have: 1) participated in US-India Workshop on FRP Composites and contributed 12 technical presentations; 2) conducted a Forum on US-India Collaboration; and 3) taught a one-day short course on FRP Composites. In addition, one-day FRP Composites Workshop was also conducted by the PI- Dr Gangarao at Hyderabad, India on Feb 12, 2008.

ONE-DAY SHORT COURSE ON FIBER REINFORCED POLYMER COMPOSITES

A one-day short course on Fiber Reinforced Polymer Composites was held on February 6, 2008. The short course included five focused sessions:

- 1) Composite Reinforcements: Fiber Types, Fiber Forming, Production, Binder Chemistry and Glass Fiber Products - Dr. V.Velpari;
- 2) Resin Systems: Resin Types, Advantage and Limitations, Chain and Step Polymerization, Catalysts, Inhibitors, Accelerators and Curing Compounds - Dr. Ruifeng Liang;
- 3) Composites Manufacturing: Pultrusion, Compression Molding, High Temperature Infusion, VARTM, and Injection Molding - Dr. Hota GangaRao;
- 4) Basics of Analysis of Composite Laminates - Dr. Abdul-Hamid Zureick;

5) Quality Control and Quality Assurance of Composite Manufacturing- Dr. Al Dorris.

The short course took place at Oyster Hall, Sahara Star Hotel, Domestic Airport, Vile Parle (East), Mumbai, India and began at 10:00 am and ended at 6:00 pm with one hour lunch break.

Dr. Hota GangaRao was the Director of the short course and also taught Session 3 on Composite Manufacturing. Dr. Ruifeng Liang taught Session 2 on Resin Systems. Dr. Abdul-Hamid Zureick taught Session 4 on Basics of Analysis of Composite Laminates. Dr. V.Velpari of PPG Industries (Cheswick, PA, USA) was invited to teach Session 1 on Composite Reinforcements while Dr. Al Dorris of XERXES Corp. (Minneapolis, MN, USA) was invited to teach Session 5 on QA/QC of Composites.

There were a total of 43 Indian researchers and industrial representatives who participated in the workshop. They represented the following industries and universities mainly from southern part of India:

- Calcutta Composites Co., Kolkata
- Arham Hi-Tech Design & Solutions Pvt. Ltd, Vidyavihar (W), Mumbai
- Meena Fiberglass Industries, Kattukuppam, Pondicherry
- Indo Cool Engineering Services, Vellappan Chavadi, Chennai
- Dow Chemical international Pvt. Ltd., Chembur, Mumbai
- Pullcast Industries, Nagpur, Maharashtra
- ADK corporation, Vasai, Thane
- Montex Glassfibre Industries Pvt Ltd, Nasik, Maharashtra
- Lubrizol Advanced Materials India Pvt Ltd, Powai, Mumbai
- Maa Fibre Products, Jyotikuchi, Guwahati
- Aum Aromal, Delhi
- ISPAT Industries Ltd, Maharashtra
- Rawji Industrial Corporation, Sion, Mumbai
- Arihant Industrial Corporation Pvt. Ltd., Vasai, Thane
- Institute of Chemical Technology, University of Mumbai
- Shri Bhagubhai Mafatlal Polytechnic, Mumbai
- Institute of Technology, Banaras Hindu University, Varanasi
- Indian Institute of Technology, Guwahati, Assam

The responses from the short course participants were positive. They expressed this type of short courses should be taught on a regular basis annually to meet the needs and demands of industry engineers. It was also suggested that the short courses should be designed at different knowledge levels of audience, for example one for beginners and the other for more experienced engineers.

THE FORUM ON US-INDIA COLLABORATION

As part of US-India Workshop on FRP Composites, a two hour forum was held to develop strategies for collaborative R&D work between US and India universities, government agencies, private laboratories, and industry partners. The forum took place immediately after the short course on February 6, 2008. Dr Hota Gangarao coordinated and facilitated the discussions among university researchers and industrial representatives from US and India.

The objectives of the forum were: 1) to recommend strategies for collaborative research, development and implementation between US and India; 2) to develop educational programs; and 3) to share field experiences on FRPs and meet customers' needs.

There were broad discussions on many subjects such as materials (resin, fiber/fabric) development and supply, durability/aging, failure/fatigue analyses, nondestructive testing and evaluation methods, specifications for design & manufacturing, and rehab of structures with composites. However, extensive discussions focused on cost-effective manufacturing techniques, market penetration/new applications, composites made of natural fibers/sustainability/recycling, sharing US experiences, inter-university collaborations between US and India.

As noted under the short course activity, the participants expressed the needs for trained engineers and workers for the growth of Indian composite industries. For example, Pullcast Industries that is a construction company located in Nagpur, Maharashtra, sent two Engineers to attend the short course as well as the US-India workshop. They would like to learn about composites and their applications in concrete with intention to start a FRP re-bar program within the company. Currently, training facilities are being provided by Indian Institute of Technology (IITs), FRP Institute (local organizer of the US-India Workshop) and some consultants like NGN Composites.

In particular, recognizing that the US annual production of FRP composites is 2,100,000 tons; while the annual composites production in India

is less than 100,000 tons in year 2006, but booming at an annual growth rate of 25% to 30%, a mechanism is much needed for composite industries in India and US to share their experiences and success stories to meet the needs and demands of growing Indian composites markets. This requires cooperative efforts between government agencies, professional societies, and trade organizations in India as well as US.

THE US-INDIA WORKSHOP ON FRP COMPOSITES

Nine (9) US university professors attended a three-day US-India Workshop on Fiber Reinforced Polymer (FRP) Composites. This event took place as part of the program of the International Conference and Exhibition on Reinforced Plastics (ICERP) 2008, Mumbai, India from 7th to 9th February, 2008. More specifically, US delegates: 1) have made twelve (12) oral presentations; 2) have published thirteen (13) technical papers in the conference proceedings; 3) have served as co-chairs for six (6) sessions; and 4) have interacted with Indian researchers and industry representatives in addition to other international delegates.

Note that the proposed technical team also included Prof. Kent Harries of University of Pittsburgh (kharries@engr.pitt.edu) and Prof. Lawrence Drzal of Michigan State University (drzal@egr.msu.edu). Both of them had to cancel their trips due to illness. The paper by Harries was presented by Prof. Hota on his behalf at the workshop. The paper by Drzal was not presented at the workshop but was published in the Proceedings.

Participated Sessions:

Bridges and Infrastructure - Connor, Myers, Bank, Karbhari, GangaRao
 Process Equipment and Pipelines - Toutanji
 FRP in Structures and Constructions - Liang, Gangarao
 Marine Applications - Rajan Sen
 Design and Testing - GangaRao, Harries, Zureick
 New Products and Trends - Drzal

Co-Chaired Sessions:

Process Equipment and Pipelines - Karbhari
 Offshore Structures - Rajan Sen
 FRP in Structures and Constructions - Larry Bank
 Manufacturing and Applications - Zureick
 Marine Applications - Houssan Toutanji
 Design and Testing - Jim Connor

Contributed Papers:

- 1) GFRP Composite Bridge Decks and Super Structures in the United States - O'Connor
- 2) An Overview of Composites Usage in Bridge Facilities in Missouri - Myers
- 3) New Application of Pultruded FRP Planks in Bridges - Lawrence Bank
- 4) FRP Structural Stay-in-Place Formwork as a means of Rapid, Durable & Cost Effective Construction & Rehab - Vistas Karbhari
- 5) Local Deflection Limit State for Light Weight Multicellular FRP Decks - GangaRao
- 6) Stress Modeling of Pipelines Strengthened with Advance Composite Materials - Toutanji
- 7) Design and Manufacturing of Load Bearing FRP Composite Panel System - Liang
- 8) Modeling and Evaluation of Load Bearing FRP Composite Panel System - Liang
- 9) Polymer Nanocomposites with Enhanced Mechanical, Thermal, Electrical and Barrier Properties - Lawrence Drzal
- 10) Effect of Fiber Architecture on Properties of Pultruded Composites - GangaRao
- 11) Behavior of FRP Retrofit Concrete Flexural Members Subject to Fatigue Loading - Kent Harries
- 12) Proposed Short Term Design Strength Equation for Pultruded Single Angle Composite Members - Abdul-Hamid Zureick
- 13) FRP Repair of Corroding Piles in a Marine Environment - Rajan Sen

OTHER ACTIVITIES

Not funded as part of the Workshop activities, some professors also visited Indian universities and gave oral presentations at the universities.

Dr Hota Gangarao visited Jawaharlal Nehru Technological University (JNTU), Hyderabad and conducted one-day workshop (Feb 12, 2008) on Composite Fundamentals and Applications at JNTU along with Dr. Al Dorris. Dr Gangarao also visited Andhra Pradesh (AP) Government to

develop Business to Business contacts between US and India. Note that the city Hyderabad is being proposed to host the next ICERP 2010.

Dr Ruifeng Liang visited Indian Institute of Technology, Department of Chemical Engineering, Mumbai and Indian Institute of Technology, Centre for Polymer Science & Engineering, New Delhi. Dr Liang gave a seminar on Development and Evaluation of Load Bearing FRP Composite Panel System at IIT Delhi.

Findings:

The US-India Workshop on Fiber Reinforced Polymer Composites: Developing Research and Educational Programs (Mumbai, India; February 6-9, 2008) included the following activities: 1) One day short course on FRP Composites; 2) Forum on US-India Collaboration; and 3) The US-India Workshop on FRP Composites. In addition, FRP Composites Workshop was also held on Feb 12, 2008 at Hyderabad, India.

Through these activities, US delegates have showcased research findings, development advancements, field implementation experiences and success stories on advanced FRP composites to rapidly growing FRP composites industries and markets in India. These activities should help in promoting transfer of the state-of-the-art of composite sciences and technologies in US to India. Also, these activities should promote and penetrate US composites industry into Indian markets. Through these workshop efforts, we have also identified opportunities for collaborative research and development activities with faculty from Indian universities and personnel from composite industries of India. In addition, collaboration is possible in educational programs such as short course development, exchanges of faculty and graduate students, and text book preparation.

OVERVIEW OF THE ICERP 2008

ICERP 2008 (International Conference and Exhibition on Reinforced Plastics), one of the biggest reinforced plastics shows in South Asia, was organized by the FRP Institute of India from February 07-09, 2008 at Bombay Exhibition Centre, NSE Complex, Goregaon (East), Mumbai, India. The FRP Institute is a leading society for the reinforced plastics industry in India, with a function similar to American Composite Manufacturers Association (ACMA) in US. The event was sponsored by Owens Corning India Ltd. and co-sponsored by Kemrock Industries & Exports Ltd. and JEC group, France.

With the Indian economy recording a 9 % growth annually, the Indian Reinforced Plastics industry is booming with 25% annual growth. The economic indicators are all favorable for India as the new destination for global business including FRP composites business. ICERP-2008 had more than 100 exhibiting companies, 250 stalls over an exhibition area of 7,000 plus sq.m, with participation from more than 30% international companies. ICERP-2008 attracted over 250 delegates (registered for Technical Conference) and over 3000 visitors for the exhibition.

With the objective to promote the potential of reinforced plastics as materials of choice for performance, ICERP-2008 brought out the technological advances and new application avenues for reinforced plastics. The exhibition at ICERP-2008 provided a platform for the Indian and international companies to showcase the advanced materials, processes, machinery and product possibilities, while networking with the wide spectrum of material suppliers, manufacturers, consultants and end users.

Some interesting state-of-the-art achievements from Indian Composites Industries are noted below. Advances in raw materials included printed veil 'Phantom' from FRP Accessories, Directional Fabrics from Saertex India and Rohacell Core Material from Evonik Degussa India. Process equipment advancements included Filament winding machines from CNC Technics and Pultusion machinery from SVS Hydrolics. A range of new products included Composite laminate cabins/shelters for disasters such as Tsunami from Suvarna Fibrotec Pvt., Super thin metallised FRP for use in radomes from Chem Plas India, FRP Bund blasting device box from Suvarna, Composites lamp poles from Kemrock Industries, and FRP skylight structure from Industrial & Commercial Enterprises. Other new products included SMC auto rickshaw mudguard from Mahindra Composites and Filament wound composite water tank for railway passenger coaches from Kineco Pvt. Ltd. Many of the above were recognized with receipt of JEC Innovation Awards.

THE US-INDIA WORKSHOP AND TECHNICAL CONFERENCE

The three day technical conference sessions started in the afternoon, Feb 7, 2008, following the inaugural session in the morning that included a theme lecture entitled 'Reinforced plastics - materials of choice for performance' by Sunil Saxena of Owens Corning India Ltd. The US-India Workshop was integrated as part of the technical conference program under arrangement of the FRP Institute of India. There were 12 sessions covering Automotive and Mass Transport (2 sessions), Bridges and Infrastructure, FRP Trends û Current and Future, Process Equipment and Pipelines, Offshore Structures, Manufacturing and Applications, FRP in Structures and Constructions, New Products and Trends (2 sessions), Design and Testing, and Marine Applications.

These sessions included both invited speakers and contributed speakers focusing on current and future applications and trends in the composite industry globally. There were 26 invited lectures and 34 contributed papers, giving a total of 60 presentations. Out of 26 invited lectures, 15 were from India mainly representing Indian composite companies and 10 were from US composite companies, with the remaining one from an Italian pultruder. In other word, US composite industries contributed 39% to the invited lectures. On the other hand, out of 34 contributed papers, US universities, as part of the US-India Workshop, contributed 13 papers and US composite industries had 2 papers. There were 9 contributed presentations from India and the remaining 10 papers came from Korea (4), Switzerland (2), France (1), Germany (1), Iran (1), and South Africa (1). Similarly, US delegates contributed 44% to the program. There were over 250 registered delegates for the conference.

The conference aimed to promote active exchange of scientific and technical information on the rapidly changing trends of advanced reinforced plastic materials. It essentially served as a forum for the consultants, end users, researchers, and industry representatives to network and share past experiences. At the conference, a wide array of technological aspects of reinforced plastics was addressed. There were presentations on applications of reinforced plastics in key economic sectors such as transportation, aerospace, infrastructure & buildings, energy, marine, process industry, and on- & off-shore structures. Other presentations also encompassed new materials including nano- composites and green composites made of natural fibers, new processes, testing & evaluation, and reinforced thermoplastics. The new concepts, techniques and case studies will lead to greater exploitation of advanced composite materials in India.

The conference was concluded with the panel discussion that was chaired by Prof. S. C. Lakkad (IIT Mumbai) and co-chaired by Dr. Srinivasa Iyer (BVS Consultants, USA) along with 7 other panelists to answer the queries raised by the participants in the afternoon, Feb 9, 2008.

COLLABORATION POTENTIAL BETWEEN US AND INDIA

The United States of America is not only the largest producer and user of FRP composites, but also leading the world's composites technology development and implementation. About half of the global demand for FRPs resides in the US, accounting for 4.2 billion lbs today. There are more than 13,000 facilities processing composites in the US, employing 236,000 people and contributing over \$24 billion to the nation's economy. Of the 4.2 billion lbs of composites, major market share includes about 32% in transportation, 21% in construction, 12% in corrosion resistant equipment, 10% in marine, and 10% in electrical or electronic industries while only 0.6% is used in aircraft and aerospace industries. In contrast, the total production of FRP composites in India is about 165 million lbs.

The infrastructure in both the United States as well as India are extensive in terms of housing, transportation systems, pipelines for water, gas, and chemicals, and other constructed facilities. In India, especially, this infrastructure is in an advanced state of disrepair due to rusting and spalling /scaling of steel structures or steel reinforced concrete structures leading to cracking, and even leaking harmful chemicals and contaminating surrounding ground.

The wide range of implementation of advanced FRP composites for rehabilitating existing facilities and constructing new infrastructure systems in US is attributed to extensive research, development, field study and monitoring of performance on these materials. These R&D activities including development of specifications and design guidelines, in addition to training of students and engineers on composites, have been conducted by US government laboratories, universities and composite industries in US for the past several decades. For example, the United States of America has 450,000 underground tanks in service which are made of advanced polymer composites without cracking and leaking because they are non-corrosive. Some of these FRP tanks have a service life of nearly half a century. Also FRP composites have twice the strength of steel at one quarter of steel's unit weight, making it cost effective to transport and install. These FRP composites consume much less energy during manufacturing over energy intensive conventional construction materials, and these savings are in trillions of BTUs.

Through the US-India Workshop on FRP conducted from Feb 6th to 9th, 2008, US delegates have identified a great potential for university and industry collaborations between US and India.

1) Composite Research at University: Currently, there are few research teams in Indian universities (IIT Mumbai, IIT G, IIT KGP, IIT Madras) working on composites. Such low level of R&D activities can be attributed to a small percent (less than 4% of US composites usage) of existing applications of FRP composites in India. However, recognizing the future needs of technical innovations and breakthroughs, several universities such as Banaras Hindu U and JNTU are beginning to develop their composite programs. On the other hand, US universities have the state-of-the art of composite programs. Hence, collaborations should be encouraged between US and Indian Universities in terms of research, development and implementation activities on advanced composites as well as educational programs such as short courses, conferences, exchange of faculty and graduate students, and text book collaborations.

2) Technology Transfer between US and India: Current applications of FRP composites in India mostly are limited to relatively low-tech applications such as pallets, grids/grating, filament wound small diameter pipes, water tanks, door panel etc. More advanced developments will be needed to expand the boundaries of composite structural applications such as in field of bridges and marine vessels. US composite industries

are presented with great opportunities to penetrate into Indian composites markets either through joint ventures or technology transfer.

3) Advanced Mass-production Technology: India does not have large manufacturing plants for composites as US. India has about 25 medium scale production units with annual production ranging from US \$1-10 million. There exist well over 1200 small scale units. Almost 80% of these units are still using hand lay up methods versus 10% to 15% of hand lay up in US. High end manufacturing techniques including advanced resin transfer molding, resin film infusion, pultrusion, automated prepreg lay up will be needed in order to mass-produce high quality composite products and meet the demands of rapidly growing Indian composites markets.

Hence, there is a great opportunity to conduct technology transfer, exchange research and development ideas, and develop collaborative research/educational programs between scientists and engineers in US and their counterparts in India. Such advances can be made in a cost effective manner in the field of high volume and low cost composite materials and systems. Exchange of graduate and undergraduate students between US and Indian universities will be very beneficial by creating tuition exemptions/reductions and taking course work in the home country and conducting research in the guest country.

Currently, the researchers at CFC-WVU are being contacted for potential collaboration by Oil and Natural Gas Corporation Ltd. (Panvel, Navi Mumbai). ONGC is interested in technical feasibility of applications of composite materials in deep water. This technology is needed for ONGC's deep water production. Many composite material applications exist like tethers, umbilicals, tendons, subsea completions, risers etc. ONGC is interested in having collaboration with an US university wherein the technology transfer for use of these advanced composite material components will be benefiting ONGC and CFC-WVU has been corresponding with ONGC.

Training and Development:

Outreach Activities:

During the US-India Workshop on FRP Composites, US delegates have interacted with 25 seniors who are interested in Polymer Composites, including 16 students from University of Mumbai, Institute of Chemical Technology, Department of Polymer Engineering and Technology and 9 from Shri Bhagubhai Mafatlal Polytechnic, Department of Plastics Engineering. Some of them expressed their interests in pursuit of higher degrees in area of composites, including applying for study in US.

Journal Publications

Gangarao, H. and R. Liang, "US-India Workshop on Fiber Reinforced Polymer Composites: Developing Research and Educational Programs; Mumbai, India; February 6-9, 2008", Composites Manufacturing, p. , vol. , (2008). in preparation,

Books or Other One-time Publications

Web/Internet Site

URL(s):

<http://www.cemr.wvu.edu/cfc>

Description:

This final project report will be available on the above CFC-WVU internet site. The report will be useful for those working in FRP composites in US to learn about the potential to collaborate with universities and composites industries in India.

Other Specific Products

Contributions

Contributions within Discipline:

Through those workshop efforts, we have identified opportunities for collaborative research and development activities with faculty from Indian universities and personnel from composite industries of India. In addition, collaboration is possible in educational programs such as short course development, exchanges of faculty and graduate students, and text book preparation.

Contributions to Other Disciplines:

Through the workshop activities, US delegates have showcased research findings, development advancements, field implementation experiences and success stories on advanced FRP composites to rapidly growing FRP composites industries and markets in India. These activities should help in promoting transfer of the state-of-the-art of composite sciences and technologies in US to India. Also, these activities should promote and penetrate US composites industry into Indian markets.

Contributions to Human Resource Development:

For some of US delegates, this is the first time to partner with Indian organization to organize the workshop. The experience gained from this workshop will be useful to conduct similar activities in the future.

Contributions to Resources for Research and Education:

We are hopeful that specific collaboration on FRP composite research and education will take place soon between US and India. For example, Dr. Anup K. Ghosh, Head & Reliance Chair Professor, Centre for Polymer Science & Engineering, Indian Institute of Technology, New Delhi, visited West Virginia University on June 27-28, 2008 and invited Dr Gangarao to organize and chair a Theme Symposium on Polymers and Composites in Infrastructure at the 25th Annual Meeting of International Polymer Processing Society (PPS-25) that will be held in Goa, India, March 1-5, 2009.

Contributions Beyond Science and Engineering:

The Workshop provided a unique opportunity for some of US delegates who have never visited India before to experience Indian culture and interact with the people there. This cultural interaction is brought home with us and is impacting the way we view our many Indian graduate students and the way we feel about the needs of the many beyond the US borders. The PI and other US delegates thank the NSF for funding this workshop.

Categories for which nothing is reported:

Organizational Partners

Activities and Findings: Any Training and Development

Any Book

Any Product