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U.S.–Japan Cooperative Research: Realization of a Six-component Force Sensor FS-2*

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There are numerous benefits from U.S.–Japan research collaboration. This paper discusses a three-year project aimed at achieving both engineering laboratory development and fostering internationalism. This was done by the design and manufacture of a six-component force sensor at the University of Tokyo, and the installation and use of this device at the University of New Orleans. Instead of a one/two semester visit, this was accomplished by relatively short visits of 3–4 weeks. The project goals, tasks, and the elements that contributed to the project's success are discussed. It is concluded that this project could be successfully completed and that short visits by Japanese graduate students is one alternative method for U.S.–Japan research cooperation.

INTRODUCTION

THE areas of laboratory development and internationalism have become important aspects in engineering education. In the U.S.A., and many other countries, limited resources have made it difficult to train students using state-of-the-art laboratory equipment. In Japan, and other countries, there is a growing emphasis on reducing technical isolation by fostering multi-level international cooperation and fostering a sensitivity to the social/technical needs of other countries. The authors have attempted to address these points in a cooperative research project. This project, the FS-2 project, involved the University of Tokyo's Department of Mechanical Engineering for Production, and the School of Naval Architecture and Marine Engineering, University of New Orleans. The project concerned the development of a six-component force sensor for use in hydrodynamic research. The sensor was designed and manufactured in Japan and then used at the University of New Orleans towing tank. This project involved some novel ideas useful to other interested engineering educators. First, the difficult problem of arranging student visits of a semester or more was solved by using visits of 3–4 weeks. Secondly, in this project all the details of the design and travel arrangements were made via computer mail (bitnet nodes at the University of Tokyo and the University of New Orleans). This ease in communication enabled the project to be broken down into eight tasks and completed at New Orleans in several relatively short 3–4 week visits by Japanese graduate students. Consequently, this project is an alternative format for developing international cooperation without penalizing the participating student or delaying their graduation date. To foster similar collaboration, this paper focuses on several points that were important to the successful completion of this project.

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BACKGROUND

The major part of Japanese university research is conducted in laboratories headed by a senior professor. This system was developed in the early stages of Japanese engineering education and is called the *koza* (chair) system [1–3]. Typically engineering students in the master's course at a Japanese university will spend two years before graduation. During this time they are involved in lectures and research that will become their master's thesis [3]. Due to a number of factors, it is possible for students taking a Japanese university masters course to adjust their schedule to allow for an absence of one month. This makes the cooperative research discussed here possible.

The FS-2 project began during the 1986–87 academic year. At that time Dr Latorre was a visiting professor in Professor Ohashi's laboratory in the Departmemt of Mechanical Engineering at the University of Tokyo [4]. The master course students were using a multi-axis force sensor to measure the lift/drag and pitch moment of a hydrofoil under different test conditions. It was obvious from their work that a multi-axis force sensor would be an important tool in the study of hydrodynamic loads of submerged and floating bodies.

The acquisition of a multi-axis force sensor consequently is a critical step in laboratory development. Fortunately, the development of multi-axis force sensors is one of Professor Hatamura's research areas [3]. It was possible to match-up the force sensor technology developed in Professor Hatamura's laboratory and the requirement for a multi-component force sensor for hydrodynamic research. The cooperative project between the two laboratories began in 1988 and has continued to the present.

PROJECT GOALS AND PROJECT DEVELOPMENT

The goals for the research cooperation are summarized in Table 1. The first goal focused on the realization of the engineering laboratory development at the University of New Orleans (UNO) and the fostering of internationalism by engineering student interaction/visits between the University of Tokyo (UT) and the University of New Orleans (UNO). The second goal of designing, manufacturing, calibrating, and use of the force sensor in a research project at UNO, was accomplished in two stages: prototype force sensor FS-1 and force sensor FS-2. The tasks and project schedule are summarized in Table 2. In the first stage, Professor Hatamura and his master's course student, Mr Hiroshi Morishita, visited UNO to become acquainted with towing task testing and data acquisition system requirements. The design requirements of the force sensor evolved into the following basic criteria (the values relate to force sensor FS-2):

1. Accuracy during measurement: ±5% or better.
2. Sensor sized to fit inside model ships (see Fig. 1): Sensor disk diameter = 134 mm; Sensor height = 122 mm.
3. Working range:
   $F_x = F_y = F_z = 100$ N maximum.
   $M_x = M_y = M_z = 10$ N-m maximum.
4. Provision for sensor to accommodate differences in magnitude of the measured forces and moments.
5. Interface with UNO NEF 470 data acquisition system and PC-based software.

Table 1. Goals for research cooperation developed by Professor Hatamura, University of Tokyo, and Professor Latorre, University of New Orleans

1.	Development of engineering laboratory instrumentation and fostering internationalism through a cooperative US–Japan research project.
2.	Design, manufacture and calibration of a six-component force sensor FS-2 at University of Tokyo for use in the University of New Orleans towing tank for hydrodynamic research.
3.	Development of a fruitful interaction between Japanese and U.S. engineering students by arranging 3–4 week visits and encouraging full participation in student life at the University of New Orleans.

Based on these criteria, the force sensor was designed and manufactured following the schedule in Table 2. Mr Morishita made a second visit with the prototype force sensor FS-1 in February 1990. During this visit a number of points were clarified and the basis for the force sensor FS-2 were developed (Figs 1 and 2a). The arrangements for stage 2 were made during a meeting at the University of Tokyo where Professor Hatamura introduced a second masters student, Mr Hirokuni Hachiuma, to Dr Latorre. As evident in Table 3, the design and manufacture of force sensor FS-2 were completed relatively quickly, which allowed Mr Hachiuma to bring the sensor to UNO in November 1990. The force sensor FS-2 was set up and used to measure the lift/drag and moments on a flat plate with small edge emergence moving along the free surface. This geometry represents the flow at the bow of a river barge or push tug, which is an ongoing UNO project [5]. Figure 2(a) shows the sensor and flat plate. Figure 2(b) shows a typical test at $V = 2.44$ m/s with the plate set $\beta = 20°$, and $x/l = 0.20$ in the 38.3 m × 4.6 m × 2.1 m deep UNO towing tank. The completion of these tests represented the realization of the second goal.

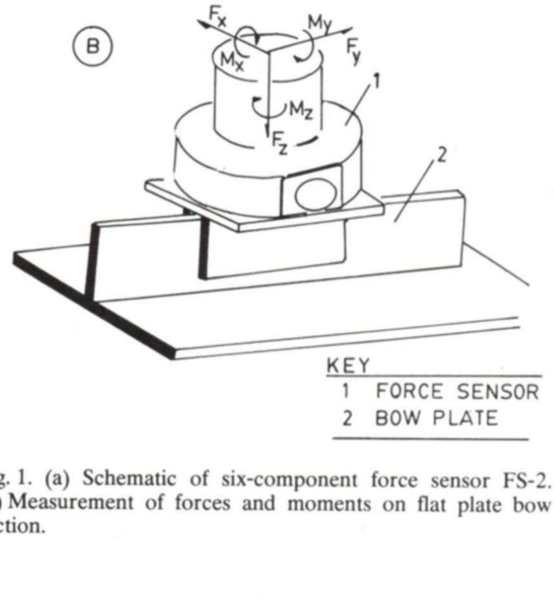

Fig. 1. (a) Schematic of six-component force sensor FS-2. (b) Measurement of forces and moments on flat plate bow section.

Table 2. Tasks and schedule of project FS-2 (1988–1991)

Task	Description	Prototype force sensor FS-1 (1988–90)		Force sensor FS-2 (1990–91) (Figs. 1, 2)	
1	Sensor specification	10/1–24/88	Visit I to UNO by Mr Morishita	8/90	E-Mail (bitnet) Mr Hachiuma
		10/19–21/88	Visit to UNO by Prof. Hatamura		$F_x = F_y = F_z = 100\ N_{max}$ $M_x = M_y = M_z = 10\ N\text{-}m_{max}$
2.	Senior design	7/89–11/89	Mr Morishita	8/90	Mr Hachiuma Mr Morishita
3.	Interface check with UNO data acquisition system	7/85–11/89	Dr Latorre, Mr Morishita	8/90	Mr Hachiuma
4.	Sensor manufacture	12/89–1/30	Prof. Hatamura, Mr Morishita	10/90	Prof. Hatamura, Mr Morishita
5.	Sensor calibration	2/90	Mr Morishita	10/90	Mr Hachiuma
6.	Sensor installation at UNO	2/21–28/90	Visit II to UNO by Mr Morishita, assisted by Dr Latorre, Mr Fox	11/9/90–12/1/90	Visit I to UNO by Mr Hachiuma, assisted by Dr Latorre, Mr Fox, Mr Pratt
7.	Hydrodynamic experiment	2/22–24/90	Dr Latorre, Mr Morishita, Mr Fox, Mr Pratt	11/19–11/21/90	Dr Latore, Mr Hachiuma, Mr Fox, Mr Pratt
8.	Report on project	5/15–18/90	Visit to UT by Dr Latorre on NSF Study Tour	12/90–2/91	Dr Latorre, Mr Pratt
		6/25/90	Presentation by Dr Latorre at ASEE Meeting Toronto, Canada Japan–U.S. Coop Session		

Mr Morishita and Mr Hachiuma are graduate students in Professor Hatamura's Laboratory at the University of Tokyo. Mr Fox is a technician and Mr Pratt a student in Dr Latorre's department at the University of New Orleans (UNO).

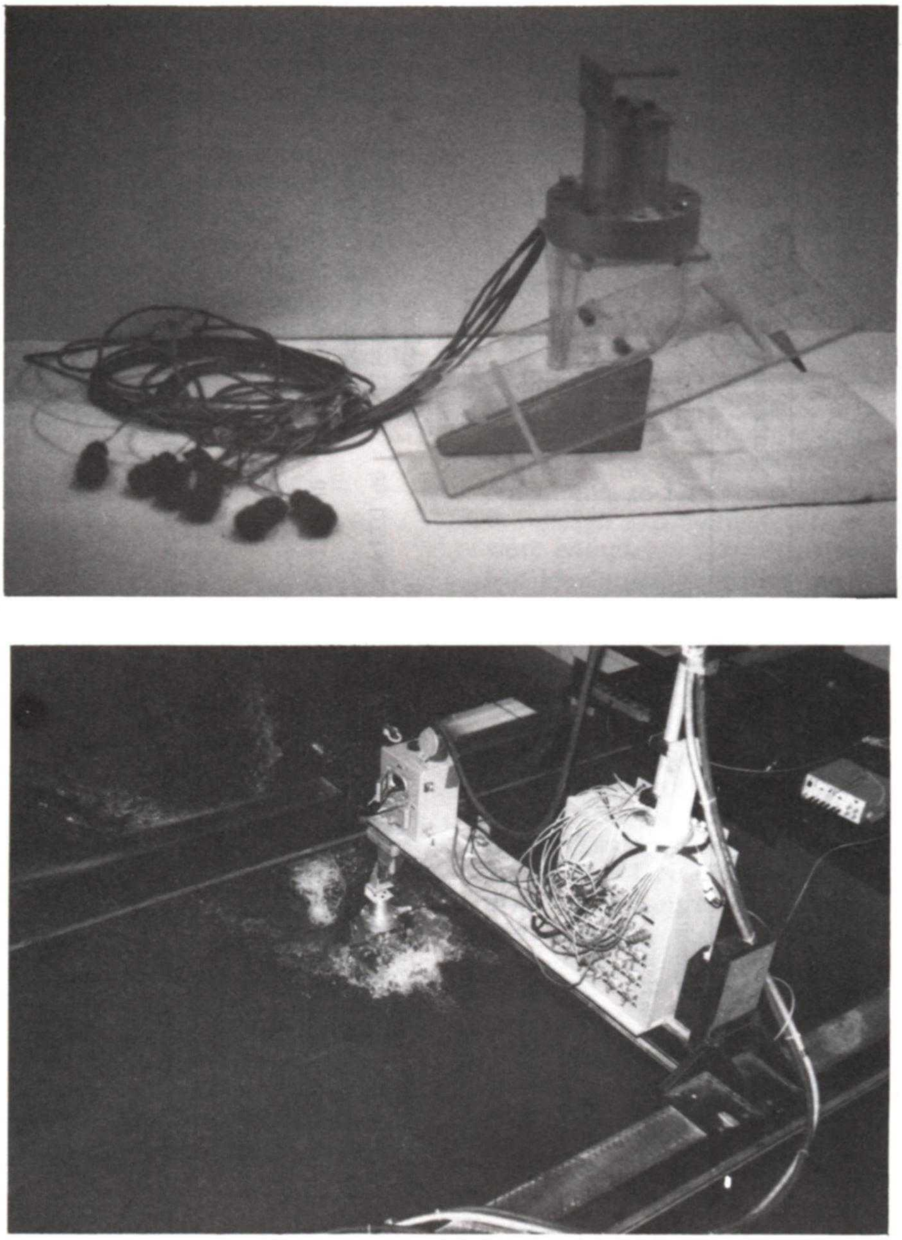

Fig. 2. (a) Force sensor FS-2. (b) Force sensor in UNO towing tank.

The third goal of developing a fruitful interaction between the Japanese student and the U.S. engineering student was also realized. This is dependent on four factors:

1. The ability to communicate in English.
2. Properly matching the time required to complete project tasks with the length of stay.
3. Time of school year when the visit occurs.
4. Human factors involving personality, interests, living arrangements, etc.

In spite of the fact that the UNO visits were their first trip to the U.S.A., both Mr Morishita and Mr Hachiuma were able to develop a positive interaction with the UNO students, faculty and staff (Fig. 3(a, b)). Mr Hachiuma's remarks sum up the experience of both Japanese students: 'I did experience the friendliness of my hosts and co-worker, Mike Pratt, and the other American people I met in this trip. I don't feel much difference between Japan and the U.S.A. in what people think and feel.' A similar impression was expressed by many of the students after their interaction with Mr Morishita and Mr Hachiuma.

APPLICATION OF MULTIPLICATION PRINCIPLE IN PROJECT ORGANIZATION

One factor that contributed to the successful completion of the force sensor project was adopting the idea that each individual effort would count

Fig. 3. Student participation in UNO activities. (a) Mr Morishita with UNO dorm roommate. (b) Mr Hachiuma at Annual Party of Faculty Woman's Club with Dr Latorre (left) and UNO Chancellor O'Brien and Mrs O'Brien.

for many uses. This is sometimes called the multiplication principle. The following are four examples of the application of the multiplication principle.

1. Reduction in design/manufacture effort by adopting elements of successful force sensors in designs.
2. Reduction in travel expenses by scheduling UNO visits in conjunction with technical meetings. The 10/88 UNO visit of Professor Hatamura and Mr Morishita was scheduled to overlap with their presentation in Houston, Texas; the 2/90 UNO visit of Mr Morishita was scheduled to overlap with his participation in the third IEEE Workshop on Micro-Electronic Mechanical Systems, Nappa Valley.
3. Adoption of a project schedule so that the force sensor installation and flat plate experiment would be part of an independent study course led by Mr Pratt.
4. Report materials would serve as user manuals for future lab users.

The advantage of scheduling the visits around technical meetings is that there is usually a lead time of 2–3 months. This enables easy scheduling of the tow tank and dormitory accommodation, as well as coordination of the visit with university and local events.

DISCUSSION AND CONCLUSIONS

In realizing the goals in Table 1, a number of important factors emerged, which are summarized in Table 3. Project planning and preparation should be done in detail. Our experience has shown that this ensures that the project work and visits are arranged for the best results. The application of the multiplication principle should also be attempted to ensure a successful activity.

Based on the results discussed in this paper, it is possible to state the following conclusions:

1. It was possible to realize a U.S.–Japan research project involving laboratory development and internationalism by the design, manufacture and utilization of a six-component force sensor.
2. The project was successfully completed in short visits of 3–4 weeks by masters course students from the University of Tokyo who completed a series of eight tasks as shown in Table 2.
3. The utilization of the multiplication principle in the project organization of the elements in Table 3 contributed to the successful conclusion of the project.

It is hoped that this paper will assist in fostering more exchanges. The use of computer mail and short visits of 2–3 weeks in this project represents a unique approach to successfully achieving the project results.

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Table 3. Important elements contributing to project success

No.	Element
1.	Clear project purpose and scope
2.	Project part of larger research/educational activity to ensure continuity
3.	Project schedule arranged to overlap meeting with visit of 2–4 weeks
4.	Delegation of project responsibility to students
5.	Advance orientation to host university and city by maps and brochures sent 1–2 months prior to arrival, as well as introduction of student counterpart
6.	Early confirmation of student dormitory/guest housing
7.	Encouragement to use university as 'home base' to make one or two visits to other laboratories or cities
8.	In initial meeting to prepare schedule to mark out free time, social events, etc., for student to use at university
9.	Provide a room with key so visiting student can work without interruption, and introduce visitor to colleagues and students
10.	Communicate to students the importance of the project and the visit and the good results achieved

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