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# A New Mechanical Engineering Curriculum at the University of Tokyo

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R. LATORRE

*School of Naval Architecture and Marine Engineering  
University of New Orleans*

Y. HATAMURA AND H. OHASHI

*Department of Mechanical Engineering for Production  
University of Tokyo*

## ABSTRACT

A new Mechanical Engineering curriculum has been introduced at the University of Tokyo. It was developed in response to changes in Japan's industrial infrastructure, as well as to new developments in mechanical engineering. This paper summarizes these developments and presents the concept of the new mechanical engineering curriculum which allows an increased number of electives in comparison to the traditional, structured mechanical engineering degree program.

## I. INTRODUCTION

Responding to ongoing developments in Japanese industry, the mechanical engineering faculty at the University of Tokyo have changed its undergraduate program from a tightly prescribed course of study into a curriculum of three core courses with an increased number of electives. This is a fundamental shift that reflects Japan's transition from heavy industry to high technology development and the current need for engineers with appropriate knowledge and creativity to develop these new technologies. This flexibility in the Mechanical Engineering curriculum design allows for technological change that impacts mechanical engineering. This paper briefly describes these developments, the reorganization of the mechanical engineering program, and the new Mechanical Engineering curriculum adopted at the University of Tokyo.

## II. JAPAN'S "INFORMATION REVOLUTION"

In the past decade there has been a fundamental change in Japanese consumer product design using information, computation and control techniques. The automobile and camera are two examples of this change. An automobile built in the 1980's did not utilize sensors or CPU's, while recently built automobiles have up to 200 sensors and ten CPU's for controlling the engine's fuel injection, exhaust emission, automatic transmission, anti-skid brakes, active suspension, air conditioning, as well as audio system.

A similar trend has occurred in cameras. Before the intro-

duction of the current generation of auto-focus cameras, a photographer had to manually set the focus, lens opening, and exposure time to get a "good" picture.

Analogously, mechanical engineering students of the 1970's and 1980's studied how to design machines rated by power, strength, and force loading. Today's engineers must now deal with system integration, intelligence, and handling information for machine design and its manufacture. The frontier of mechanical engineering has shifted from classical power driven machines (muscle-substituting machines) to machines controlled by sensor information (brain-substituting machines). This is the second industrial revolution, the "Information Revolution," using computers and software to augment and replace manual operation. One consequence of this development is the overhaul of mechanical engineering education.

## III. ENGINEERING DEVELOPMENTS AT THE UNIVERSITY OF TOKYO

Although engineering in Japan began over 150 years ago in a set of "initial conditions" quite different from those of the U.S., this new curriculum reflects the needs of a technologically advanced country and is useful to U.S. engineering educators developing an appropriate mechanical engineering program for the year 2000.

Mechanical engineering education in Japan can be traced to specialized training in the period of the Tokugawa Bafu federal government as described in reference (1). With the opening of Japan in the 1860's to foreign technology, American and European professors taught Japanese students mechanical engineering, civil engineering and shipbuilding (naval architecture) in a six-year course in the Imperial College of Engineering (Kobu-gakko)<sup>2</sup>. This course became formalized with the organization of Tokyo Imperial University in 1883. The educational framework of an initial two-year course in basic science and mathematics followed by advanced studies in mechanical engineering (years 3 and 4) and a practical training course (years 5 and 6) was introduced. Today, the undergraduate mechanical engineering curriculum at the University of Tokyo follows a two year general course at Komaba campus followed by a two year engineering course at the Hongo campus. Table 1 summarizes the sequence of training. Figure 1 shows the organization of Japanese education along with the representative student age. Japanese and U. S. engineering education have several differences which are summarized in Table 2<sup>3,4,5,6</sup>. At the University of Tokyo one difference is the absence of an industrial engineering department. This reflects the fact that the engineering graduate is trained by his/her

Year/Mo.	Item	Lectures/ Thesis	Faculty
1/April	Matriculation Orientation	General Education Lectures	Arts & Sciences
2/May	Guidance for Entering Eng. Students	General Education Lectures	Arts & Sciences
2/Sept.	Selection of Students by Engineering Departments		
3/April	Entrance into Engineering Departments	Engineering	Engineering
4	Graduation Thesis		Engineering

*Table 1. Undergraduate Engineering Education at the University of Tokyo<sup>10</sup>.*

company in its design, manufacturing, and technology development approaches. A second difference is that while the U. S. engineering curriculum is developed by a faculty committee following ABET guidelines, Japan's engineering education accreditation is not yet established so the Japanese faculty must rely on a number of inputs to develop the curriculum. Consequently, the mechanical engineering curriculum at the University of Tokyo has evolved reflecting new technology developments, faculty expertise, and employment trends.

As Japan's economy developed in the 1960's, the University of Tokyo's mechanical engineering program expanded to include mechanical engineering for production focusing on production machinery (1960) and marine engineering focusing on marine propulsion system and control (1964). These departments grew to include over 30 faculty and 150 undergraduate students as shown in Table 3. New advances in technology and marketing have created a redirection of Japanese industry from heavy industry to "high tech" products. This is reflected in the employment trends for mechanical engineering graduate's shown in Fig. 2, adopted from reference (8). Starting around 1982 an employment shift began from production centered activities to service related businesses such as banks, software, etc. There are few consulting companies in Japan, so engineers were directly employed by banks. The banks needed to develop a large distributed information system with automated tellers capable of providing both secure and easy access to accounts and records. So they recruited mechanical engineers to perform this work as cited in references (8,9). This is just one example of the changes mechanical engineering educators are encountering in Japan. At the same time the importance of developing mechanical engineering education for long term success must be recognized. This requires a

	Japanese	U. S.
1: Academic Year	2 Terms Summer: April-Sept Winter: Oct-March	2-1/2 Terms Fall: Sept-Dec Spring: Jan-May (1/2 term) Summer: May-Aug
2: Entrance	Once a year in April by exams in Jan/Feb.	Usually in Sept., other times possible.
3: Graduation	Once a year in March, Completion of Graduation.	Dec, May, Aug at completion of credit.
4: Each Course	1.5 contact hours per week, by 2-3 professors Total 18-20 hours.	3-4 contact hours per week, by 1 professor Total 12-16 hours.
5: Research Components	More Computer and Experimental work.	More Analytical computations due to limited lab access.
6: Laboratory	One affiliated with each full professor (similar to German chair system).	Typically 1-2 per department.
7: Faculty	12 month salary base.	9 month salary base.
8: Research Perspective	Long range following senior professor's research.	Long and short term following funding priorities.

*Table 2. Comparison of University of Tokyo Engineering Program with Contemporary U.S. Engineering Programs.*

		Department		
		A	B	C
Faculty	Professor	6	6	7
	Assoc. Prof.	5	5	6
	Lecturer	1	1	1
Staff	Assistant	17	13	5
	Technician	9	2	9
	Administration	4	3	2
Students	BSE	51	48	58
	MSE	56	36	46
	Ph.D.	19	11	21
	Research	4	1	7
Key:	A: Mechano-Physics B: Design & Production Sys C: Mechano-Informatick			

*Table 3. Profile of Mechanical Engineering Faculty and Students at University of Tokyo<sup>6</sup>.*

mechanical engineering curriculum that not only looks good to prospective students, but also provides a flexible framework to accommodate technical change. Japan's experience has shown that success goes to those who understand that change is the status quo and that yesterday's success can cause failures as technology changes. This viewpoint holds that flexibility instead of a rigid structure is needed to meet the present technical changes.

In 1985-87 the curriculum was reorganized into mechanical engineering for production, mechanical engineering, and information engineering. However, this reorganization was not completely satisfactory. The basic idea of mechanical engineering has expanded to include developing and integrating information for the efficient use of machines. This resulted in a reappraisal of what the new mechanical engineering should be.

#### IV. NEW MECHANICAL ENGINEERING CURRICULUM COMBINING NATURAL SCIENCE AND INFORMATION

Traditionally, mechanical engineering has been a discipline built on applied mechanics such as solid mechanics, fluid mechanics, thermodynamics, and machine dynamics. Basic principles are used to analyze and predict machine behavior and performance. Synthesis and design are also important processes in creating machines. Previously mechanics-oriented courses and design practice constituted the essence of mechanical engineering education. These classes were also supplemented with special courses describing the design operation and state-of-the-art of individual machines such as the internal combustion engine and electrical machines.

Today, the importance of information in machine operation is growing. This is reflected in the need for introduction of courses on robots, machines with data acquisition sensors, as well as devices for data conversion, transmission and processing. These machines are readily connected to personal computers by interface cards. In addition to the application of the natural science of applied mechanics, mechanical engineers are increasingly involved with the logic and methodology for modeling human processes for more "user friendly" operation. In Japan this information use is termed "artificial science" as a parallel to "natural science." The term "artificial science" or "artificial intelligence" indicates the process is a product of human intelligence. Figure 3 illustrates the traditional machine design and the concept of the new information based machine technology base.

This expansion in the past would have resulted in the introduction of new courses. However, additional courses would overwhelm the students and create a negative impact. In the past solving this situation resulted in existing courses being reduced/rearranged through a scrap and add process in conjunction with the creation of narrower areas of concentration in mechanical engineering. This narrower concentration will not provide the mechanical engineering student with the integrated knowledge base essential for the future developments in planning, designing, manufacturing, and operating intelligent machines and production facilities. Consequently, the central core curriculum shown in Fig. 4, was adopted. The 140 credit requirement (10 courses per term) remained the same at 56

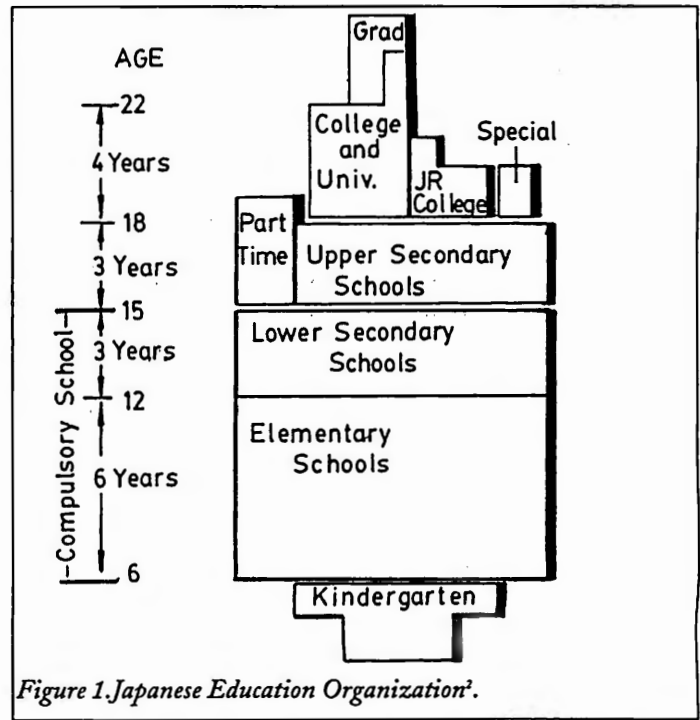


Figure 1. Japanese Education Organization<sup>2</sup>.

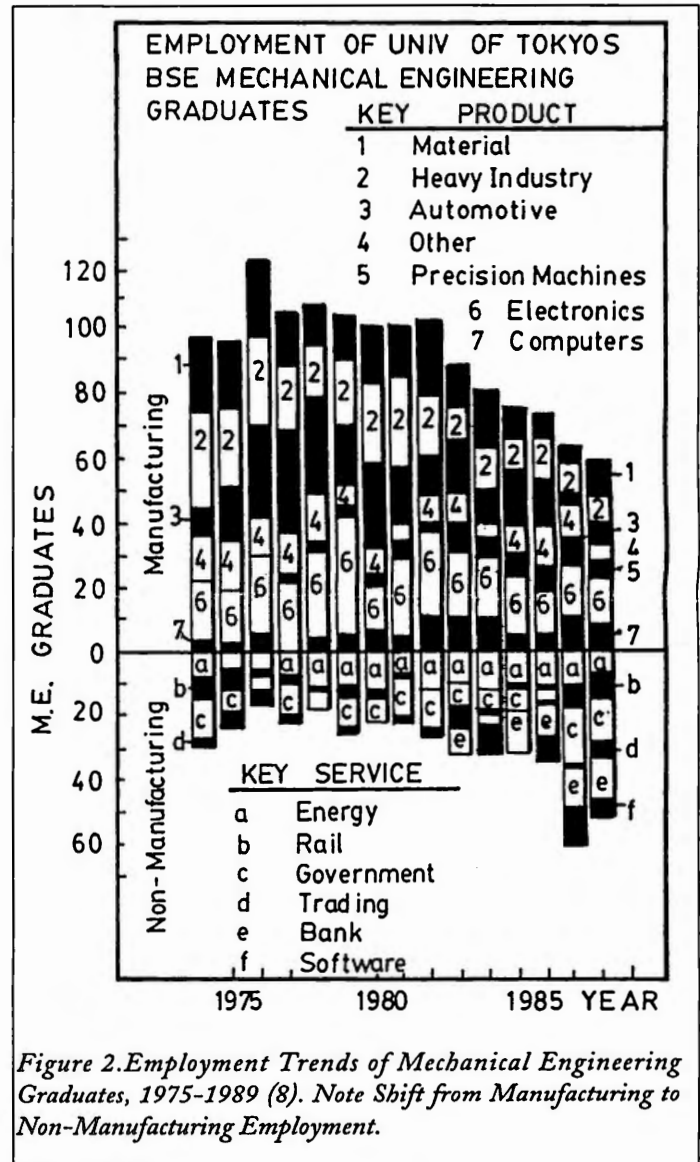
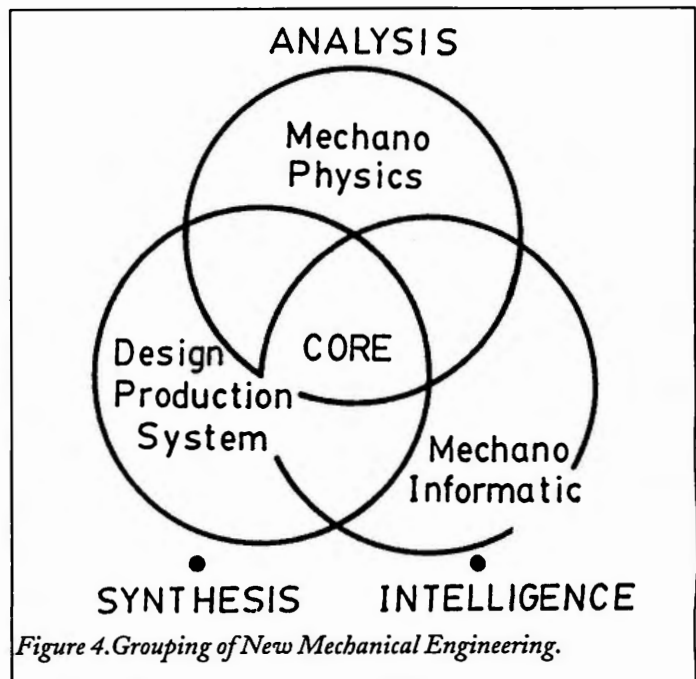
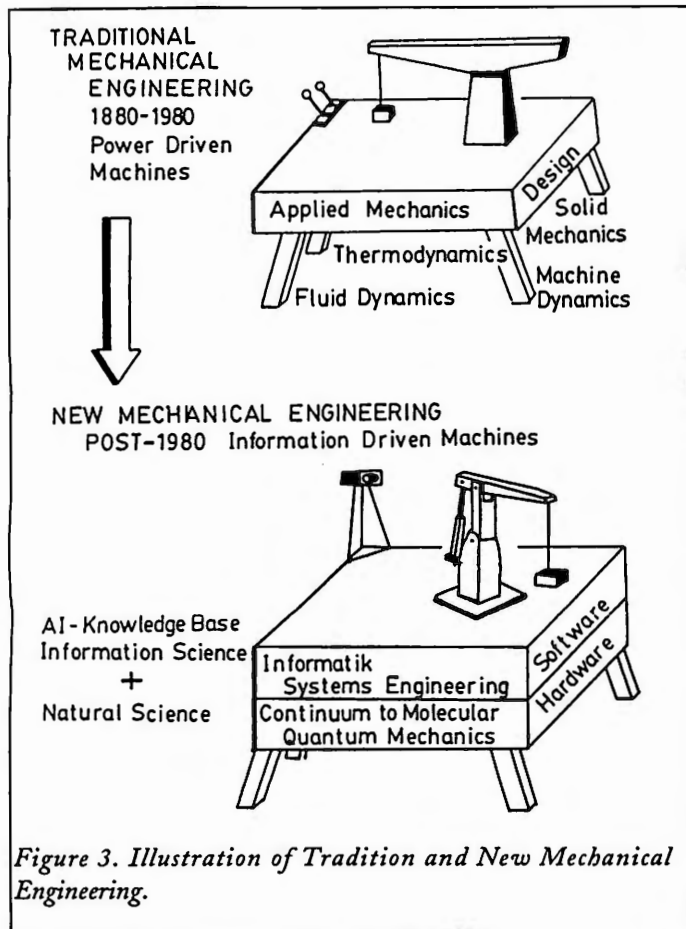


Figure 2. Employment Trends of Mechanical Engineering Graduates, 1975-1989 (8). Note Shift from Manufacturing to Non-Manufacturing Employment.



credits in the first and second year general education and 84 credits in Mechanical Engineering in the third and fourth year, including the graduation thesis. However, the compulsory courses have been reduced to a minimum level, and the student

Lecture	Course		
	A	B	C
Mechano-Molecular Eng.	2	2	2
Solid Mechanics	2	2	2
Fluid Mechanics 1	2	2	2
Applied Thermodynamics	2	2	2
System Dynamics	2	2	2
Mechanism & Information	2	2	2
Software Design 1	2	2	2
Introduction to ME	2	2	2
Engineering Mathematics 1	2	2	2
Elect. & Electron. Eng. 1	2	2	2
Introduction to Instrumentation	3	3	3
Metallurgy	3	3	3
Machine Design Practice 1	1	1	1
Mathematics & Dynamics Seminar	2	2	2

**Notes:** 1: Compulsory  
2: Strongly Recommended  
3: Free Elective

**Key:** A: Mechano-Physics  
B: Design & Production Sys  
C: Mechano-Informatick

*Table 4a. Mechanical Engineering Lectures, 2nd Year, 4th semesters, University of Tokyo*

Lecture	Course		
	A	B	C
Machine Dynamics	2	2	2
Production Technology	2	2	2
Machine Design	2	2	2
Automatic Control 1	2	2	2
Mechano-Thermophysics	2	3	-
Structural Systems Engineering	2	3	2
Fluid Mechanics 2	2	3	2
Heat Transfer	2	3	2
Experiment & Measurement	2	2	3
Mechatronics 1	2	3	2
Software Design 2	3	3	2
Numerical Analysis	2	3	2
Engineering Mathematics 2	2	3	2
Elect & Electron (E&E) Engineering 2	2	3	2
Machine Design Practice 2	2	3	1
ME Seminar 1	2	2	2
Experiment in ME 1	1	1	1
On-Site Factory Practice	3	1	2

**Notes:** 1: Compulsory  
2: Strongly Recommended  
3: Free Elective

**Key:** A: Mechano-Physics  
B: Design & Production Sys  
C: Mechano-Informatick

*Table 4b. Mechanical Engineering Lectures, 3rd Year, 5th semesters, University of Tokyo*

elective courses have been expanded as described in reference (10). Three courses of study were introduced following Fig. 4:

1. Mechano-Physics (formerly Mechanical Engineering) focusing on the understanding and utilization of the basic physical and information sciences in machine and system design.

2. Design and Production Systems (formerly Mechanical Engineering for Production) focusing on the development of systems for the integrated design and production of intelligent machines.

3. Mechano-Informatick (formerly Marine Engineering) focusing on the development and utilization of information in the design, manufacture, and operation of intelligent machines. To illustrate this new curriculum, the Mechanical Engineering undergraduate course offerings are summarized in Table 4. In Table 4 these three courses of study are denoted by M-P (Mechano-Physics), D & P (Design and Production Systems), and M-I (Mechano-Informatik). In each course there are only 5-7 compulsory lectures with the remaining lectures either

strongly recommended (denoted by R) or free elective (denoted by O). The compulsory and strongly recommended lectures make up 75% of the new curriculum. The remaining 25% of the classes are allotted to free electives. In this manner the goal of flexibility for accommodating future changes is realized, as well as a better curriculum for allowing new technologies to be introduced into the undergraduate mechanical engineering education.

Normally each lecture meets once a week for two hours for 2 credits. The students are required to complete 10-12 lectures per semester in order to graduate. In the final semester they join a laboratory and receive the equivalent of 12 credits for their graduate thesis. The first group of "new" mechanical

Lecture	Course		
	A	B	C
Mechano-Solid Physics	2	3	3
Strength Design	2	3	2
Fluid Mechanics 3	2	3	3
Energy Systems Engineering	2	2	3
Internal Combustion Engine	2	3	3
Vibration & Waves	2	3	3
Mathematics for ME	2	3	3
Machine & Aesthetics	2	3	3
Creation of Machines	3	2	2
Informative Production Systems	3	2	3
CAD/CAM	3	2	2
Systems Management	3	2	3
Automatic Control 2	3	2	2
Mechatronics 2	3	3	2
Software Design 3	3	3	2
Information Systems 1	3	3	2
Human Interface	3	3	2
Computational Mechanics 1	3	3	2
Elec & Electron Engineering 3	3	3	3
Engineering Mathematics 3	3	3	3
Machine Design Practice 3	3	1	2
ME Seminar 2	3	2	2
Experiment in ME 2	1	1	1
Experiment in E&E Engineering	3	3	3

**Notes:** 1: Compulsory  
2: Strongly Recommended  
3: Free Elective

**Key:** A: Mechano-Physics  
B: Design & Production Sys  
C: Mechano-Informatick

*Table 4c. Mechanical Engineering Lectures, 3rd Year, 6th semesters, University of Tokyo*

Lecture	Course		
	A	B	C
<b>7th Semester</b>			
Mechano-Optical Physics	3	3	3
Structural Optimization Design	3	3	3
Turbulence Engineering	3	3	3
Combustion Engineering	3	3	3
Energy-Conv. Machines	3	3	3
Tribology	3	2	3
Advanced Manufacturing Technology	3	2	3
Overview of Industries	3	2	3
Industrial Systems	3	2	3
Design Engineering	3	2	3
Automotive Engineering	3	2	3
Automation	3	2	3
Vehicle Dynamics	3	2	3
Robotics	3	3	2
Micro-Intelligence Machine	3	3	3
Advanced Software	3	3	3
Signal & Image Processing	3	2	3
Information Systems 2	3	3	2
Bio-Systems Engineering	3	3	2
Computational Mechanics 2	3	3	3
ME Seminar 3	3	3	3
Topics in ME	2	2	2
Graduation Thesis 1/2	1	1	1
<b>8th Semester</b>			
Function of Bio-Systems	3	3	3
Security Engineering	3	2	3
Systems Planning	3	2	3
Graduation Thesis 2/2	1	1	1

**Notes:** 1: Compulsory  
2: Strongly Recommended  
3: Free Elective

**Key:** A: Mechano-Physics  
B: Design & Production Sys  
C: Mechano-Informatick

*Table 4d. Mechanical Engineering Lectures, 4th Year, 7th & 8th semesters, University of Tokyo*

engineers graduates in April 1993. While Japan is in a recession period, they began employment in major Japanese engineering firms. The feedback has been positive indicating that a flexible curriculum for Mechanical Engineering education is successful. Most of the students enrolled in the strongly recommended lectures as if they were required lectures, and made the typical trade-offs between the scheduled time and what they need and would like to take. The Design and Production course of study is viewed as being the more structured course reflecting the lesser need for curriculum change in contrast to the Mechano-Physics and Mechano-Informatik courses of study.

## V. CONCLUDING REMARKS

The challenge for Mechanical Engineering education is to develop an appropriate response to the rapid advances in technology and future engineering needs. This paper has described the development in Japanese industry, as well as mechanical engineering employment trends. In response to these changes, and the emergence of new technology involving the use of information in the design and operation of the machines, the mechanical engineering program at the University of Tokyo has been revised. This has resulted in three courses of study:

1. Mechano-Physics
2. Design and Production Systems
3. Mechano-Informatik

In order to insure that the next generation of mechanical engineers are properly prepared for these changes, a new curriculum with a large number of recommended and elective courses has been introduced. While this is a change from the traditional structured mechanical engineering degree program, it reflects a similar U. S. viewpoint discussed in reference (11). Judging from the positive feedback received from students and faculty, this new program has created an environment which encourages students to acquire knowledge and utilize it in creative ways for the benefit of society.

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