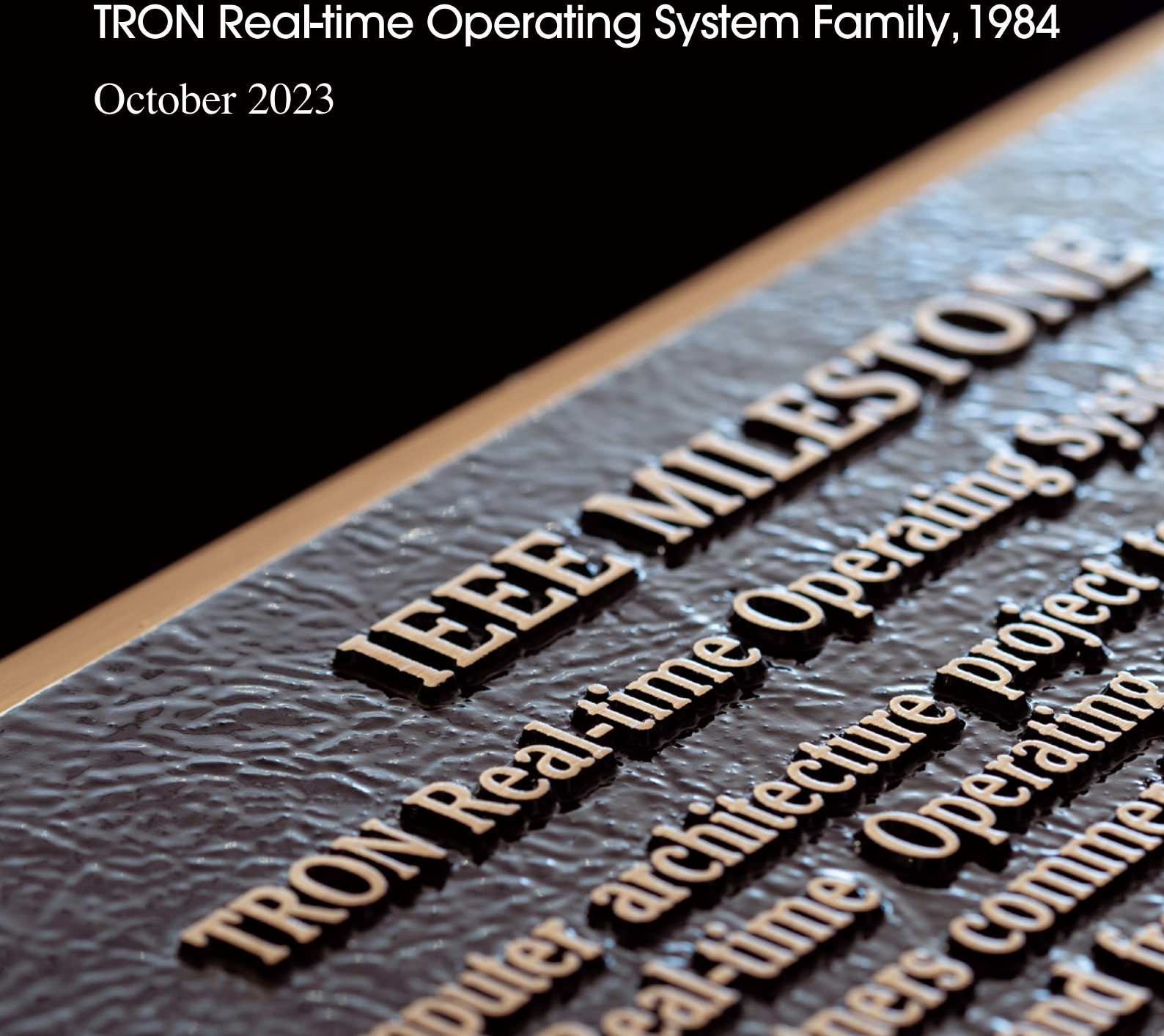
TRON Forum

IEEE MILESTONE

TRON Real-time Operating System Family, 1984

October 2023



TRON Real-time OS Family Honored as an IEEE Milestone

In May 2023, "TRON Real-time OS Family" was recognized as an IEEE Milestone by the Institute of Electrical and Electronics Engineers (IEEE) [1].

The IEEE Milestone program honors significant historical achievements in the extensive field of electrical and electronic engineering, particularly those groundbreaking innovations that, having been made public at least 25 years ago, have contributed significantly to the development of society and industry.

The subject of this Milestone is the "TRON Real-time Operating System Family, 1984." Proposed in 1984 under the guidance of Ken Sakamura (then a research assistant) at the University of Tokyo, TRON Project aimed at future computer applications, resulting in the proposition of ITRON Specification OS, CTRON, BTRON, and MTRON [2]. Among these, the ITRON real-time OS (RTOS) specification was first proposed in 1984, and the OS implementing this specification has been widely used. These systems continue to improve and evolve. TRON Forum has announced and released many versions, including the T-Kernel, the compact µT-Kernel, the multi-processor AMP T-Kernel, and the SMP T-Kernel. The current IEEE Milestone encompasses the entire group of these RTOSs (Fig.1).

The full citation of the Milestone is as follows:

> In 1984, a computer architecture project team at the University of Tokyo began designing The Real-time Operating system Nucleus (TRON) OS family and helping external partners commercialize it.

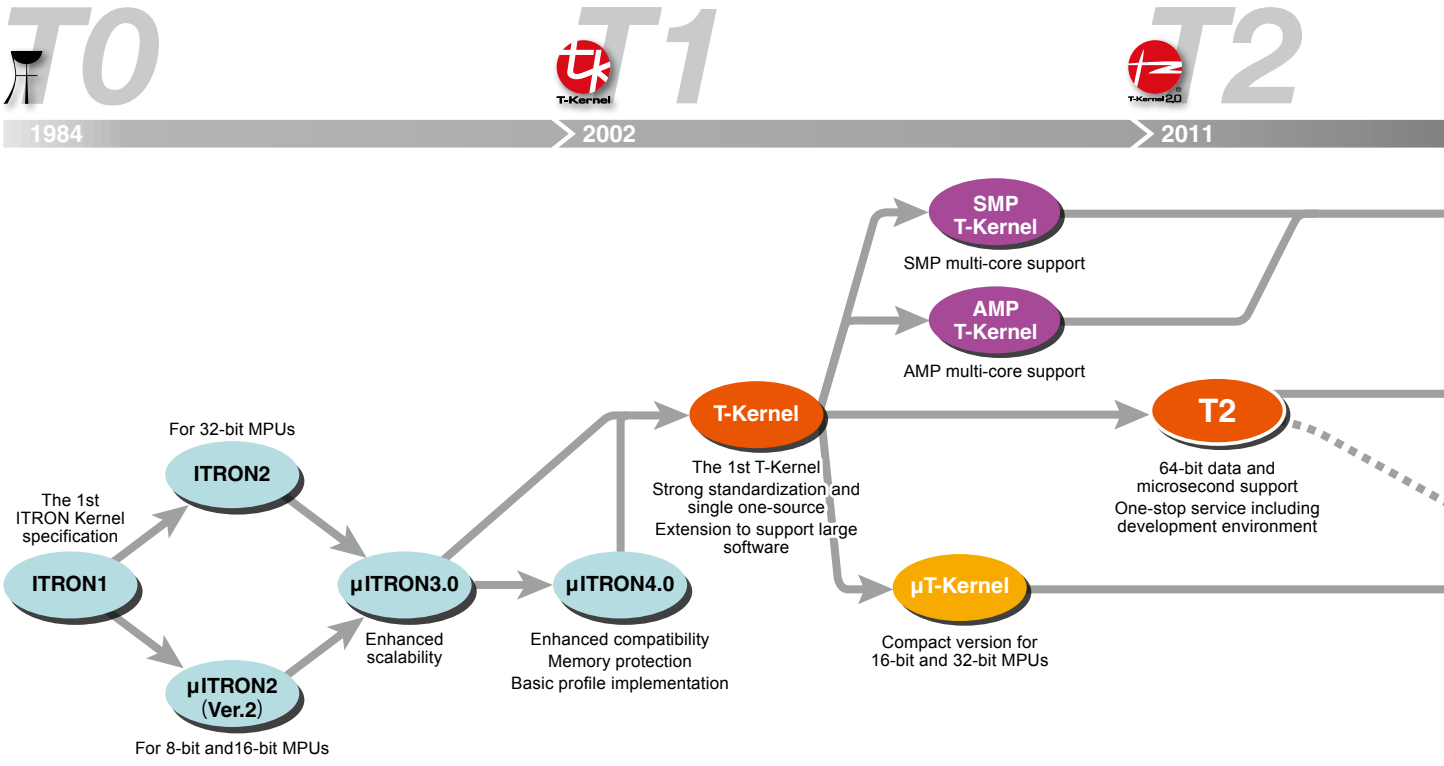


Fig.1 Roadmap of TRON RTOSs

Specifications and sample source code were provided openly and freely, facilitating innovations by developers and users. TRON real-time OS family copies have been adopted worldwide in billions of embedded computer devices, including aerospace and industrial equipment, automotive systems, and home electronics.

The IEEE Milestone is one of the most prestigious awards within IEEE, and it is customary for the commemorative plaque to be presented in a ceremony attended by the IEEE President (or a former or future President). On October 14, 2023, a plaque presentation ceremony was held at the campus of the University of Tokyo, with the participation of the IEEE President-elect, Dr. Thomas M. Coughlin, and the plaque has been placed in a place accessible to the public.

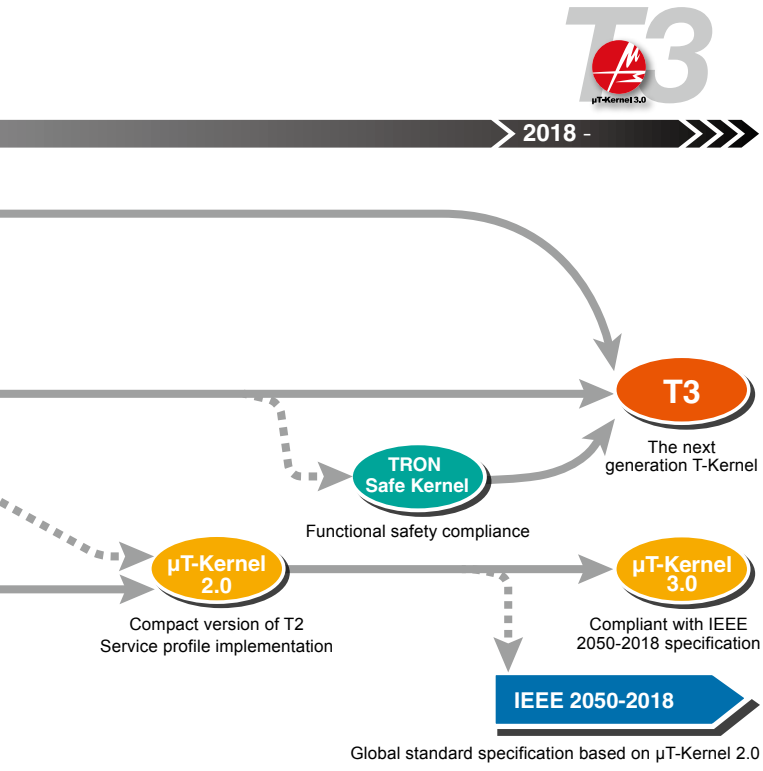
The history of the IEEE Milestone

IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity. IEEE and its members are trusted in a wide range of fields, from aerospace systems, computers, and telecommunications to biomedical engineering, electric power, and consumer electronics, through frequently cited publications, international conferences, standards, and professional and educational activities.

There are numerous achievements around the world that have been recognized as IEEE Milestones. Among the older ones is the letter published by Benjamin Franklin in the Royal Society, which described his use of kites to study lightning in the 1700s. After World War II, the invention and mass production of transistors and the invention of radar were also recognized. In the IT field, recognized Milestones include the Intel 4004, Ethernet, Xerox Alto, Apple I/II, and Apple Macintosh computer. There are also many Milestones that reflect the breadth of fields IEEE deals with, such as in power generation and satellite communications [3].

In Japan, over 40 achievements, including QR Codes, the Mount Fuji Radar System, and the Shinkansen (Bullet Train), have been recognized. These recognitions showcase the industrial strength of Japan's electrical and electronics sector over the past 100 years, especially the momentum of the electrical and electronics industries after the war [4].

The TRON RTOS Family has also been recognized as having similar significance to these achievements.



Application

The IEEE Milestone is evaluated and accredited by a committee called the IEEE History Committee.

TRON Project, which began in 1984, meets the condition of having a history of over 25 years. Therefore, in the summer of 2022, TRON Forum, in collaboration with Professor Emeritus Tomohiro Hase of Ryukoku University, began preparing the necessary application document as specified by IEEE. The final version of these document is available on the IEEE History Committee website [5].

After the application is submitted, the History Committee appoints an Advocate, who will ask for peer review, conduct further interviews if necessary, and submit

1) https://jp.ieee.org/、https://www.ieee.org/
2) ITRON: Industrial TRON (Real-time Operating System). CTRON: Communication and Central TRON (OS for communication control). BTRON: Business TRON (OS for Personal Computers). MTRON: Macro TRON (OS for distributed computing, connecting various TRON specification OSs).
3) https://ethw.org/Milestones:List_of_IEEE_Milestones
4) https://ieee-jp.org/activity/jchc/milestone_jusho.html
5) https://ieeemilestones.ethw.org/Milestone-Proposal:TRON_Real-time_Operating_System_Family,_1984

a final report to the History Committee, which makes a decision on suitability.

We are very grateful to Mr. Robert Colburn (Milestone Administrator), who was the contact person for the History Committee, and Dr. Sergei Prokhorov (Chair of IEEE Computer Society Russia Chapter), who was the Advocate this time.

Peer Review and Evaluation

For the evaluation of this application document, the following experts conducted specialist peer reviews:

Mr. Steve Diamond, former President of the IEEE Computer Society: Mr. Diamond was the editor-in-chief of the IEEE MICRO magazine until just before TRON Forum's Chair Sakamura took over the role from 1999 to 2001.

Mr. Masaki Gondo, CTO of eSOL Co., Ltd.: eSOL is a member of TRON Forum and has been selling numerous TRON RTOS-related products. The peer review was conducted from a market perspective.

Dr. Tan Su Lim, Associate Professor at the Singapore Institute of Technology: Dr. Lim has co-authored a paper comparing the performance of µITRON and µT-Kernel with other RTOS products [6], and conducted the peer review in this specialized field.

Final Submission Following Discussion

During the peer review process, an electronic bulletin board was set up for discussions, where the following individuals provided favorable comments:

Mr. James J. Farrell III, former editor-in-chief of IEEE MICRO (1985-1987): During Mr. Farrell's tenure as editor-in-chief, Chair Sakamura of TRON Forum was invited as a guest editor to publish a special issue on TRON Project (April 1987). Several articles in this issue related to the TRON RTOS were good English reference materials for Milestone evaluation, and Mr. Farrell supported the Milestone accreditation.

Dr. Konstantinos Karachalios, the managing director of the IEEE Standards Association (SA): He was involved in the procedures such as the transfer of copyright when IEEE SA developed the specification for an RTOS for IoT edge nodes based on µT-Kernel 2.0, which is now the IEEE 2050-2018 standard. He provided favorable comments on the TRON RTOS.

IEEE MICRO, April 1987 issue

µITRON 3.0 Specification
(Published by IEEE in 1997)

Proceedings of TRON Project Symposium from 1991 to 1996
(Published by IEEE)

Mr. Masao Isshiki, Special Professor at Kanagawa Institute of Technology: Mr. Isshiki commented on the importance of the TRON RTOS in TRON Project's pioneering research on smart houses.

To gather support for the accredication, TRON Project's past research activities, academic contributions, interaction in practical application and commercialization, and the open nature of the project helped .

The application was submitted on October 3, 2022. It was approved by the History Committee on February 10, 2023. Subsequently, it received approval from the IEEE Board of Directors (BOD), and official accreditation notification was received on May 23.

In Conclusion

For this IEEE Milestone recognition, we received support from many individuals, including Professor Emeritus Tomohiro Hase of Ryukoku University. We also received considerable support from Toshio Fukuda, former IEEE President, and members of the IEEE Japan Council and the IEEE Tokyo Section. We would like to take this opportunity to express our deep gratitude to all who supported us.

6) Tran Nguyen Bao Anh, Su-Lim Tan, "Real-Time Operating Systems for Small Microcontrollers", IEEE Micro, vol. 29, no. 5, Sept-Oct. 2009 https://ieeexplore.ieee.org/document/5325154

Column 1 IEEE Milestone

The IEEE Milestones program honors significant technical achievements in all areas associated with IEEE [7]. Milestones recognize the technological innovation and excellence for the benefit of humanity found in unique products, services, seminal papers and patents. It is a program of the IEEE History Committee, administered through the IEEE History Center.

IEEE established the Milestones Program in 1983 in conjunction with the 1984 Centennial Celebration to recognize the achievements of the Century of Giants who formed the profession and technologies represented by IEEE.

Each Milestone recognizes a significant technical achievement that occurred at least twenty-five years ago in an area of technology represented in IEEE and having at least regional impact. As of October 2023, more than 240 IEEE Milestones have been approved and dedicated around the world.

In Japan, the following achievements have been recognized [4]:

No.	Name	Dedication ceremony	No.	Name	Dedication ceremony
1	QR (Quick Response) Code, 1994	September 26, 2022	21	Line Spectrum Pair (LSP) for high-compression speech coding, 1975	May 22, 2014
2	Inverter Air Conditioners, 1980-1981	March 16, 2021	22	Birth and Growth of Primary and Secondary Battery Industries in Japan, 1893	April 12, 2014
3	Physical Contact Push-Pull Technology For Fiber Optic Connectors, 1986	March 5, 2021	23	Toshiba T1100, a pioneering contribution to the development of laptop PC,1985	October 29, 2013
4	First Commercial Digital Signal Processor Chip, 1980	December 15, 2020	24	International Standardization of G3 Facsimile, 1980	April 5, 2012
5	First Operational Large-Scale Latent Fingerprint Identification System, 1982	December 15, 2020	25	First Practical Field Emission Electron Microscope, 1972	January 31, 2012
6	High Electron Mobility Transistor, HEMT, 1979	December 18, 2019	26	First Direct Broadcast Satellite Service, 1984	November 18, 2011
7	Outdoor Large-Scale Color Display System, 1980	March 8, 2018	27	Commercialization and Industrialization of Photovoltaic Cells, 1959-83	April 9, 2010
8	Discovery of the Principle of Self-Complementarity in Antennas and the Mushiake Relationship, 1948	July 27, 2017	28	Kurobe River No. 4 Hydropower Plant, 1956-63	April 9, 2010
9	Nobeyama 45-m Telescope, 1982	June 14, 2017	29	First Transpacific Reception of a Television (TV) Signal via Satellite, 1963	November 23, 2009
10	Invention of a Temperature-Insensitive Quartz Oscillation Plate, 1933	March 6, 2017	30	Development of Electronic Television, 1924 - 1941	November 12, 2009
11	Map-Based Automotive Navigation System, 1981	March 2, 2017	31	Development of Ferrite Materials and Their Applications, 1930-1945	October 13, 2009
12	Keage Power Station: Japan's First Commercial Hydroelectric Plant, 1890-1897	September 12, 2016	32	Yosami Radio Transmitting Station 1929	May 19, 2009
13	High Definition Television System, 1964-1989	May 11, 2016	33	The First Word Processor for Japanese Language, 1971 - 1978	November 4, 2008
14	Emergency Warning Code Signal Broadcasting System, 1985	May 11, 2016	34	Railroad Ticket Examining System	November 27, 2007
15	Vapor-phase Axial Deposition Method for Mass Production of High-quality Optical Fiber, 1977-1983	May 21, 2015	35	Development of VHS, a World Standard for Home Video Recording, 1976	October 11, 2006
16	The MU (Middle and Upper atmosphere) radar, 1984	May 13, 2015	36	Pioneering Work on Electronic Calculators, 1964-1973	December 1, 2005
17	TPC-1 Transpacific Cable System, 1964	November 12, 2014	37	Electronic Quartz Wristwatch, 1969	November 25, 2004
18	20-inch Diameter Photomultiplier Tubes, 1979 - 1987	November 5, 2014	38	Tokaido Shinkansen (Bullet Train),1964	July 13, 2000
19	Gapless Metal Oxide Surge Arrester (MOSA) for electric power systems,1975	August 18, 2014	39	Mount Fuji Radar System, 1964	March 6, 2000
20	Sharp 14-inch Thin-Film-Transistor Liquid-Crystal Display (TFT-LCD) for TV, 1988	June 10, 2014	40	Directive Short Wave Antenna, 1924	June 17, 1995

Column 2 International Standards Related to TRON Project

TRON Project not only makes its specifications and source code open but also actively proposes standard specifications to international standardization bodies such as International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) and International Organization for Standardization (ISO), contributing to the international standardization of infrastructure technologies.

The specification of µT-Kernel 2.0, developed by TRON Forum, was adopted as the basis for the international standard for "A Real-Time Operating System (RTOS) for Small-Scale Embedded Systems," IEEE 2050-2018, established by the American standardization body IEEE SA in 2018. The latest µT-Kernel 3.0 is an RTOS that fully complies with the international standard IEEE 2050-2018.

Furthermore, TRON Project proposed ucode, an identification number system for identifying various devices and data in the IoT era, and a coding system based on it has been standardized by ITU-T (Y.4804/H.642.1). TRON Project has also contributed to the establishment of related standards, ITU-T Y.4551/F.771 and Y.4802/H.642.2.

7) https://ieeemilestones.ethw.org/

IEEE Milestone Commemoration Ceremony

Date: October 14, 2023
Venue: Daiwa Ubiquitous Computing Research Building, The University of Tokyo

In May 2023, the "TRON Real-time OS Family" was recognized as an IEEE Milestone, titled "TRON Real-time Operating System Family, 1984," by the IEEE. A commemoration ceremony, including an award presentation, a memorial lecture, and an unveiling ceremony, took place on October 14. The venue was the Daiwa Ubiquitous Computing Research Building at the University of Tokyo's Hongo Campus, where a commemorative plaque is permanently displayed. The ceremony was held in the familiar hall of this building, where Professor Ken Sakamura was involved in the design and construction while he, who led the development of the TRON RTOS, was affiliated with the University of Tokyo. It was a warm and celebratory ceremony, carried out by his colleagues who had shared many ups and downs over the years.

The ceremony was attended by Dr. Kiyoharu Aizawa, the IEEE Tokyo Section Chair; Dr. Takao Someya, Executive Director and Vice President of the University of Tokyo; Dr. Toshio Fukuda, former IEEE President; Dr. Akinori Nishihara, former Director of IEEE Region 10; Dr. Isao Shirakawa, Chair of the IEEE Japan Council History Committee; Mr. Masaki Gondo from eSOL Co., Ltd.; Professor Noboru Koshizuka from the Graduate School of Interfaculty Initiative in Information Studies, the University of Tokyo; and other parties from TRON Forum. Speeches and congratulatory messages were given by the attendees.

After the speech by Dr. Thomas Coughlin, IEEE President-elect, Professor Sakamura was presented with the plaque by Dr. Coughlin, followed by a photo session. Afterward, Professor Sakamura gave a memorial speech. Following the ceremony, the attendees moved to the entrance hall on the first floor of the venue, where the plaque was unveiled by Professor Sakamura and Dr. Coughlin.

The ceremony was conducted entirely in English. This article quotes the greeting messages from the attendees and the content of the memorial speech.

IEEE Milestone Commemorative Plaque

IEEE MILESTONE

TRON Real-time Operating System Family, 1984

In 1984, a computer architecture project team at the University of Tokyo began designing The Real-time Operating system Nucleus (TRON) OS family and helping external partners commercialize it. Specifications and sample source code were provided openly and freely, facilitating innovations by developers and users. TRON real-time OS family copies have been adopted worldwide in billions of embedded computer devices, including aerospace and industrial equipment, automotive systems, and home electronics.

October 2023

Organizer's Speech

Kiyoharu Aizawa
(IEEE Tokyo Section Chair)

I'm truly delighted to celebrate this occasion with Professor Ken Sakamura, IEEE President-elect Dr. Thomas Coughlin and all of you.

The IEEE Milestone program was established in 1983 to honor significant innovations in the fields of electrical, electronics and information technology that have made considerable contribution to the advancement of the society and industry for at least 25 years. Until 2022, 237 Milestones have been recognized worldwide. Among them, these include achievements of the Benjamin Franklin's work and Volta's electrical battery in the 18th century. Among those the 20th century innovations, many telecommunication fields, radio, television, semiconductors, computers, and the Internet were recognized.

The first Milestone presentation ceremony in Japan was held in 1995 at Tohoku University for the shortwave antenna, commonly known as the "Yagi Antenna." Until 2022, 40 Milestone have been recognized in Japan and 22 of them are in the Tokyo section area. And last week, the 41st Milestone in Japan was dedicated to Tohoku University for the invention of perpendicular magnetic recording. This was the area covered by the IEEE Sendai Section. TRON RTOS is the 42nd Milestone in Japan, and the 23rd in the Tokyo section.

Professor Sakamura at the University of Tokyo proposed TRON RTOS family in 1984. Its code is openly and freely available without any restriction. So it has been used in billions of devices such as industrial equipment, automotive devices, and household appliances. It plays an indispensable role in the IoT today. We consider it is truly an achievement worthy of Milestone.

Greetings by Guests of Honor

Takao Someya
(Executive Director and Vice President,
The University of Tokyo)

It is a great honor to join you to celebrate this significant IEEE Milestone, the recognition of the TRON real-time operating system. Our president Teruo Fujii conveys his warmest regards to all the guests gathered here today for this

festive occasion. And I'd like to offer a greeting on his behalf.

The TRON Project is an industry academia cooperative effort initiated in 1984 by Dr. Ken Sakamura at the time a research assistant at the University of Tokyo. Based on a long-term vision, this project anticipated the arrival of the IoT era, and promoted development of RTOS for a wide variety of application scenarios. I understand that the RTOS is a system software that runs like a black box in home appliances, industrial equipment, automobile and many others. The TRON RTOSs have been adopted in wide range of products. It also aimed at the standardization of the technology. It is now widely used not only in Japan but also in many other countries.

I'm pleased to learn that such a basic technology for industry was born in our university about 40 years ago and is still evolving. I'm also happy that one of the largest professional organizations in the world, IEEE has recognized the impact of the technology on industry and recognized the technology as an IEEE Milestone. Besides, I'm very delighted that an IEEE plaque will be permanently displayed in our university building.

Toshio Fukuda
(IEEE President 2020)

The IEEE, the world's largest professional organization, has recognized TRON RTOS as a Milestone for its outstanding achievements. As you may know, for a technology to be recognized as a Milestone, it must have contributed to the industry and society for over 25 years.

Dr. Sakamura and I know each other for a long time. It has been more than 40 years. Perhaps it is good that we have both studied in different fields. I'm in robotics. He works in computer science, and promoted TRON Project. I invited him to give a talk at IEEE robot automation annual conference in New Orleans 2004, because his talk is so fantastic. I have many fond memories with him. We have a mutual student, and I've had the honor of giving lectures with the invitation of Professor Noboru Koshizuka. Dr. Koshizuka is one of the students of Dr. Sakamura. Our relationship has developed quite well.

I have truly enjoyed my relationship with Dr. Sakamura, Dr. Koshizuka and all of you here. I am so happy today because TRON RTOS has been recognized as the Milestone.

Isao Shirakawa
(Chair, IEEE Japan Council History Committee)

I can clearly state one thing on the occasion of this Milestone dedication. I must say that Dr. Sakamura's great work is very good and successful invention. I hope that this TRON Project will achieve a great success.

Thomas Coughlin
(IEEE President-elect)

It is my pleasure to participate in today's IEEE Milestone dedication as we celebrate the innovative spirit and pioneering work undertaken by Professor Ken Sakamura and his computer architecture project team here at the University of Tokyo in the development of the TRON RTOS Family, which is now instrumental in billions of embedded consumer devices around the world.

Without delving into a detailed description of IEEE at this moment, I would like to discuss its legacy. IEEE's legacy is a story of innovation and collaboration. Our founders came together in a spirit of cooperation to support the public with technological improvement. Among them were notable figures such as Alexander Graham Bell and Thomas Edison. And since 1884, when the American Institute of Electrical Engineers (AIEE), the predecessor of IEEE, was founded, IEEE has been fostering technical advancement for the benefit of humanity.

IEEE reflects nearly 140 years of being at

the forefront of the technical revolutions in energy, communications, and computing; the underlying disciplines in hardware and software that have supported these technological advances and the many fields of application in industrial activities, consumer products, transportation, medicine, and many other domains that have shaped our modern standard of living. In fact, it will turn 140 years old in 2024.

The profession of engineering has a long, rich, and important history. And it is essential that our pioneering technological developments and discoveries, and the people behind them, such as Professor Ken Sakamura and his team at the University of Tokyo, are recognized and celebrated for generations to come.

As the largest technological association in the world, it is an important part of IEEE's mission to preserve the legacy and heritage of our professions, to recognize great achievements, and to promote the importance and impact of engineering.

Since our inception, IEEE has had a standing History Committee that advises the IEEE Board of Directors on matters of the legacy and heritage of IEEE and its members and their related professions and technologies, and carrying out some activities in those areas.

The mission of the IEEE History Center, which celebrated its 40th anniversary in 2020, is to preserve, research, and promote the history of information and electrical technologies. The Center maintains many useful resources for engineers, students, historians of technology, and for anyone interested in the development of electrical and computer engineering and its role in modern society.

The Center plays an essential role in helping communities around the world understand how engineers, scientists, and technologists contribute to our global society and have contributed to building today's technologically advanced world. One way they do that is through the IEEE Milestone program.

Funded by donations to the IEEE Foundation, the Milestone program recognizes great moments throughout our world's long history of technical innovation. The program began in 1983 as part of IEEE's Centennial Celebration. Today's Milestone is our 240th worldwide and is the 23rd for the IEEE Tokyo Section.

IEEE Milestones help to increase the public's understanding of the contributions to society made by electrical, electronics, and computer engineers, and the strides made by countless technologists as they sought to advance technology to benefit humanity.

Milestones are also a way for members in IEEE Sections to take pride in their profession and its accomplishments. They demonstrate to their local community how engineers, scientists, and technologists have contributed not only to

that community, but also to our global community, helping to build today's technologically advanced world.

The TRON RTOS Family has always been open and free, an approach that has proven novel and powerful. Today, RTOS based on TRON specifications are used across the consumer electronics industry and beyond, from engine controls on automobiles, satellites, mobile phones, game consoles, and many other appliances.

Thank you very much for the opportunity to speak to you today.

Congratulatory message from the industry

Masaki Gondo
(SEVP/CTO/Head of Software, eSOL Co., Ltd.)

It is my honor to be here to share with you some of eSOL's successes using the TRON RTOS Family invented by Dr. Sakamura.

I started my career in the embedded software industry 28 years ago. One of my memorable projects as a young kernel developer was developing µITRON compliant real-time kernel for an SoC for DSC or digital still cameras designed by Texas Instruments Japan back then. It was one of the early SoC that contained ARM7TDMI, the first popular ARM processor IP and DSP. Our RTOS and Driver Stacks were at the core of their DSC/SDK. This was a huge success, and it was deployed in more than 100 million devices across many OEMs all over the world. And more than anything, this was not possible without Dr. Sakamura.

Ten years later, ARM developed its first symmetric multi-processing processor, ARM11 MPcore. We developed the first commercial operating system that supported ARM11 MPcore, both SMP and AMP, based on an open source T-Kernel. Based on this, NEC Electronics back then developed a series of SoCs for automotive car navigation system. Our operating system supported all of them. This was another huge success, deployed in millions of vehicles across the world. And, more than anything, this was not possible without Dr. Sakamura.

Now, computer technology has become more crucial than ever, meanwhile Japanese manufacturers not only the automotive ones, but also other industries face huge challenges. Their devices now need to transform into software defined intelligent devices.

I believe we can overcome the challenge with what we have learned from Dr. Sakamura. Congratulations Dr. Sakamura.

IEEE Milestone Acceptance Speech

Ken Sakamura

1. Acknowledgment

I am honored to receive the IEEE Milestone for TRON Real-time Operating System Family, 1984.

TRON Project which has produced the TRON Real-time OS Family, 1984 is into its 40th years of operation today. The project name, TRON, stands for The Real-time Operating system Nucleus. And as the name suggests, it started as a project to create a real-time OS for then emerging 16-bit microprocessors. The TRON Real-time OS Family, 1984 is still used and being improved and maintained.

A real-time OS should be small and compact, which is why today's ceremony is kept small and compact as well.

Today, I would like to thank IEEE and its History Committee to recognize the TRON RTOS Family, 1984 as an IEEE Milestone. This is appreciated by all the members, present and past, who have been involved in TRON Project in creating and maintaining the OS family.

Personally, earlier this year, I have received another prestigious IEEE award, Masaru Ibuka Consumer Technology Award. I feel very delighted that my leadership of TRON Project over the last 40 years is now recognized this way by the award and now Milestone additionally.

2. Positioning of this Milestone

IEEE Milestones have recognized many achievements from the past. Some of them are easy to understand. For example, Ethernet, and Apple II computer, Television research in Hamamatsu, a Japanese city, and transmission of transatlantic radio signals in 1901. These are examples of easy-to-understand Milestones.

On the other hand, there are other Milestones that are hard for lay people to understand. For example, Enrico Fermi's Major Contribution to Semiconductor Statistics (1924-1926), Raman Effect (1928), Development of CDMA for Cellular Communications (1989), Our Milestone is in the latter category.

It may not be obvious to the lay people why the TRON RTOS Family, 1984 matters. It matters because it is used widely all over the world. The RTOSs of the TRON RTOS Family, 1984 is used in many devices, but in an invisible manner. It is different from desktop OS or smartphone OS which are familiar to many of us. For example, it is used in the following places and devices: automobile engine control, space probes and launcher rockets, household electronic appliances.

The developers and people who use the TRON RTOS Family know that they have created technological social infrastructure. However, it is not visible to ordinary people usually.

But IEEE Milestone is a spotlight that illuminates their

achievements so far. So being recognized as an IEEE Milestone is very encouraging for them. And I am grateful for the recognition as the leader of TRON Project.

Let me explain a bit about TRON Project which has produced the TRON Real-time OS Family, 1984. This shall give some insight into why the TRON RTOS Family was created.

3. TRON Project

I said that the name stands for The Real-time Operating system Nucleus. The project started as a project to create a real-time OS for then emerging 16-bit microprocessors. It began in 1984, and has been going on for almost 40 years.

40 years ago, microprocessors were adopted to control many devices such as home electronic appliances and industrial equipment. Earlier, back in the 1970s, 4-bit microprocessor Intel 4004 had appeared.

The engineers of the era tried to use the microprocessors to control "things," "objects in our living sphere." That was the driving force to make microprocessors popular. It was not used as a general computer in the beginning.

Microprocessor is a very general device. Creating an application software that controls a specific device was the approach taken then. Before that, hardware control circuits, Programmable Logic Controllers were used. Microprocessors replaced them with the addition of application software.

However, the control software, the application, was difficult to create from scratch.

Trying to cope with the difficulty of creating application for automobile industry, aerospace, home electronic appliances, telecommunication industry, and other fields, engineers gradually realized that it would help them to create a whole application system by having an underlying OS.

One can create an application for each different control application above an OS.

Real-time OS vs general information processing OS

Here I should mention the difference between real-time OS and an OS for general information processing on desktop PC or servers.

1. Priority-based scheduling vs. round-robin scheduling

   Industrial application requires real-time OS. The essence of real-time OS is priority-based scheduling. This is very different from round-robin scheduling of general information processing OS.

2. Scarce hardware resources for computers used for real-time control

   While servers or desktop PCs for general information processing have many gigabytes of memory, computers used for real-time control often have only very limited memory and other hardware resources. Power-supply also is very limited. Many so-called embedded computers need to run on batteries for a long time.

3. Reliability: simple is beautiful

   When you consider the usage of software on space satellites, you must realize that it is not easy to fix a software bug there. So the reliability must be high and testing the code should be easy in principle. So small compact OS is necessary.

These differences were behind the design of the first member of the TRON RTOS Family, 1984, namely ITRON-specification OS for RTOS. "I" in ITRON stands for Industrial control.

Companies such as NEC, Hitachi, Fujitsu, and others created OSs according to the specification, and there were many products that used such OSs inside. The usage expanded very quickly. Engineers who designed control application needed such real-time OSs.

Around this time, IEEE helped the project in many ways. For example, there was a special issue of IEEE MICRO that picked up TRON Project as a main theme. That was April 1987 issue (Fig.1). This helped us to disseminate the knowledge of the project including the project goal and the achievements so far.

Fig.1 IEEE MICRO Magazine Featuring TRON Project

4. Popularizaion

We held symposiums to disseminate the technology. Springer-Verlag published the proceedings of the first few symposiums. Subsequently, IEEE Computer Society became the technological sponsor, and we published the proceedings via IEEE CS press. I would like to thank IEEE CS for the collaboration.

Furthermore, in 1997, IEEE CS Press published a book that combines the specification of µITRON 3.0 and a few introductory chapters (Fig.2). Back then, the technology dissemination took place using printed publication. Thus, this specification book from IEEE CS press helped the TRON RTOS Family to reach various corner of the world. I saw the book in many university libraries when I visited overseas cities to give speeches.

Also, I was the Editor-in-Chief of IEEE MICRO from 1999 to 2001 and thus I could interact with many people and could introduce TRON Project to many contacts.

5. Typical applications

Let me list well-known examples of usage of the TRON RTOS Family, 1984.

1. Small hand-held devices such as CASIO digital cameras and mobile phones. Nikon digital cameras and a Samsung digital camera
2. Large scale telephone switch PBX
3. Automobile usage - Engine control
4. Japanese satellites and rocket launchers
5. Industrial control such as semiconductor manufacturing devices

6. How its usage widened

For the last two dozen years, the usage widened thanks to the use of the Internet.

Figure 4 shows the countries and regions where somebody downloaded the source code of the TRON RTOS Family. From the beginning of the project, we adopted the philosophy of Open Architecture. This means that the specification of the OS family and the source code were made available. This is the "Open" approach.

This open approach was recognized by the Takeda

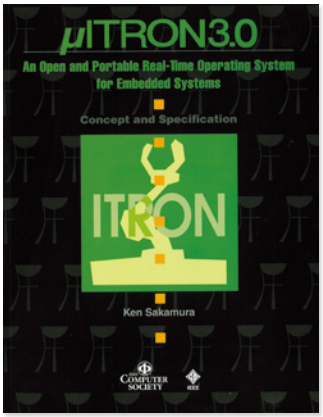


Fig.2 µITRON3.0 Specification Document

Fig.3 Examples of the TRON Real-time OS Usage

Fig.4 Countries and Regions that Downloaded the Source Code of the TRON Real-time OS Family

Fig.5 Award Ceremony of the Takeda Award

Award (Fig.5). Richard Stallman of GNU project fame, and Linus Torvalds of Linux fame and I shared the Takeda Award for the open approach in the industry in 2001. Both Stallman and Torvalds contributed to the general information processing OS. I contributed to the development of widely used real-time OS instead.

7. Evolution of microprocessors

Microprocessors have evolved from 4-bit CPU to, 8-bit, 16-bit, 32-bit and finally to 64-bit CPU.

These days, a single chip contains a CPU and many other peripheral devices inside. They are called single-chip microprocessors. These CPU chips are used inside devices that are connected to the Internet.

That brings the topic of the IoT, the Internet of Things paradigm, up front. With the IoT application framework, many objects in our surroundings are connected to the computer network, the Internet.

The TRON RTOS Family now is being used increasingly in such objects that are connected to the network. For example, the TRON RTOS Family is now used inside network-enabled multi-function laser printers, RF modules inside the mobile phones, and many consumer electronic devices.

8. Geographical Expansion

Geographically speaking, the usage has moved from USA and Japan to countries like Korea, China, countries in Southeast Asia such as Vietnam, Singapore, Malaysia, and India. These countries are where electronic goods are now manufactured. So the TRON RTOS Family is now being studied and used there. There are textbooks that were translated into regional languages (Fig.6).

From the viewpoint of TRON Project, I am very happy to report that there are entities in Singapore, Malaysia and China who have learned the TRON RTOS Family and offered to help establish regional development centers. Here, again IEEE has helped TRON Project in a sense.

In 2018, IEEE Standards Association adopted 2050-2018, "IEEE Standard for a Real-Time Operating System (RTOS) for Small-Scale Embedded Systems" which is

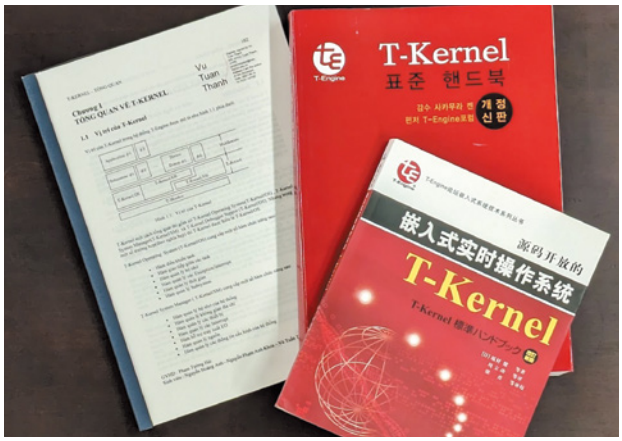


Fig.6 T-Kernel Textbooks Translated into Various Languages

based on micro-T-Kernel 2.0 specification.

This adoption has given a momentum behind the TRON RTOS Family and people in various regions have come to study the TRON RTOS Family seriously.

9. The IoT edge node is not standalone

In the IoT application framework, the nodes are often called edge nodes. These edge nodes have to talk to the cloud services today.

The TRON RTOS Family is now being used for such IoT edge nodes like Figure 7. The preferred protocol is 6LoWPAN, a subset of IPv6 protocol. There is a 6LoWPAN stack that runs on the TRON RTOS Family.

Summary

TRON Project owes its existence to the supporting members. They are commercial enterprises, academic entities, and government labs.

The TRON RTOS Family, 1984 is not a glittering topic that attracts many people. But receiving the IEEE Milestone helps us to highlight its importance and this is very good for the moral of the engineers and for courting young generation to this specialized field of computing.

I would like to thank IEEE and IEEE History Committee for this honor and would like to extend my appreciation to all who helped the project over the years. I would also like to thank Professor Emeritus Tomohiro Hase of Ryukoku University and Mr. Chiaki Ishikawa of my office for submitting the Milestone application.

I have heard that there was guidance from various members of IEEE Tokyo Chapter, Prof. Isao Shirakawa and Dr. Toshio Fukuda, the former President of IEEE during application review process. I would like to thank them all. But I cannot list all of them.

Again, on behalf of the engineers who developed the TRON RTOS Family, 1984, I would like to express my sincere appreciation of receiving IEEE Milestone plaque recognizing the "TRON RTOS Family, 1984" today. So, this concludes my acceptance speech. Thank you very much.

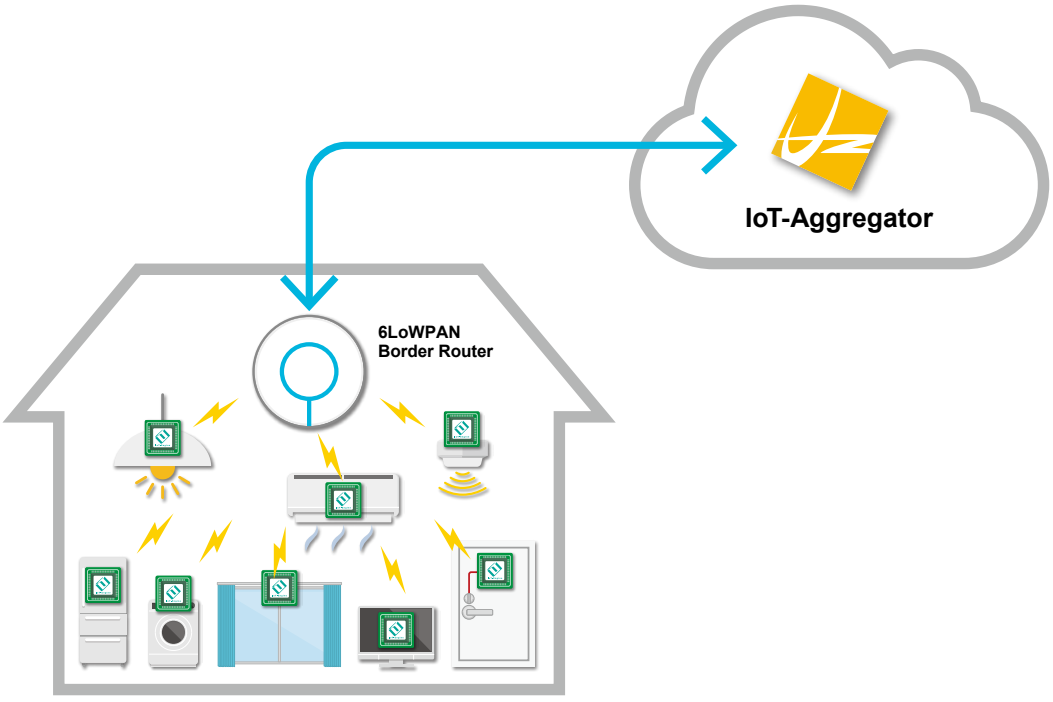


Fig.7 IoT Edge Node Connecting to IoT-Aggregator via 6LoWPAN

Reference information

About IEEE

Institute of Electrical and Electronics Engineers (IEEE) is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity. IEEE and its members are renowned through frequently cited publications, international conferences, standards, and professional and educational activities. They are trusted in a wide range of fields, from aerospace systems, computers, and telecommunications to biomedical engineering, electric power, and consumer electronics.

About IEEE Milestones

In electrical and electronic engineering as well as computing programs, the IEEE Milestones celebrate significant technical achievements in all fields related to IEEE. They are part of the IEEE History Committee program and are operated through the IEEE History Center.

IEEE Milestones recognize and evaluate technological innovations and excellence that contribute to human benefits, as seen in unique products, services, significant papers, and patents.

IEEE established the Milestones Program in 1983 in conjunction with the 1984 Centennial Celebration to recognize the achievements of the Century of Giants who formed the profession and technologies represented by IEEE.

Each milestone recognizes a significant technical achievement that occurred at least twenty-five years ago in an area of technology represented in IEEE and having at least regional impact. As of October 2023, more than 240 Milestones have been approved and dedicated around the world.

About TRON Project

TRON Project, launched in 1984, is an industry-academia collaborative project for the development of computer architecture. Led by Ken Sakamura, IEEE Life Fellow/IEEE Computer Society Golden Core Member and Professor Emeritus of the University of Tokyo, also serving as the Dean of Information Networking for Innovation And Design (INIAD), Toyo University and Director of YRP Ubiquitous Networking Laboratory, the project advances development in various computer fields, ranging from RTOSs and development environments for embedded systems to IoT networks.

The results of TRON Project are widely used in embedded systems around the world, from consumer products such as automotive engine controls, digital cameras, and mobile phones to industrial applications such as factory machinery control.

TRON Project promotes an open architecture and has conducted its activities under this principle. Furthermore, it has contributed to the international standardization of infrastructure technologies by actively proposing technical specifications as standard proposals to international standardization bodies.

About TRON Forum

TRON Forum was established in 2002 to promote TRON Project. It has actively engaged in initiatives centered around T-Engine Project, which establishes development environments for embedded systems, and the operation of Ubiquitous ID Center, including ucode.

In May 2015, Chair Ken Sakamura was awarded the ITU's 150th Anniversary Award, as the sole recipient from Asia alongside figures such as Bill Gates, for advocating the open architecture TRON, which became the origin of ubiquitous networking and the IoT. In addition, in January 2023, Chair Sakamura received the IEEE Masaru Ibuka Consumer Technology Award from IEEE for his leadership in developing an open and free OS for embedded computers used in consumer electronic products. These activities have garnered international acclaim. TRON Project has been actively promoting an open architecture and conducting its activities under this principle. Moreover, it has contributed to the international standardization of infrastructure technologies by actively proposing technical specifications as standard proposals to international standardization bodies.

Ken Sakamura Profile

Born in Tokyo in 1951.
Dean and Professor of Information Networking for Innovation And Design (INIAD), Toyo University, Doctor of Engineering, and Professor Emeritus of the University of Tokyo.

Since 1984, he has been developing the open computer architecture TRON. TRON RTOS is now widely used around the world in mobile devices, home appliances, automotive engine controls, and spacecraft controls, and

in 2018, it was adopted as the embedded OS IEEE 2050-2018 for the IoT by the IEEE. In 2023, the "TRON Real-Time OS Family" was recognized as an IEEE Milestone. He is also extensively engaged in the broad-range design development for furniture, housing, museums, buildings, and cities.

IEEE Life Fellow, Golden Core Member. Editor-in-Chief of “IEEE MICRO” magazine" (1998-2002).

In 2015, he was one of the six individuals globally chosen for the International Telecommunication Union (ITU) 150th Anniversary Awards (ITU150 Awards) for his significant contributions to the improvement of people's lives worldwide through innovation, promotion, and development in information and communication technology. In 2023, he received the IEEE Masaru Ibuka Consumer Technology Award.

2001 Ichimura Academic Award, Special Prize
2001 Information Processing Society of Japan, 40th Anniversary Best Paper of '90s Award
2001 Minister of Economy, Trade and Industry Award
2001 The Takeda Award
2002 Director of YRP Ubiquitous Networking Laboratory
2002 Chair of T-Engine Forum (now TRON Forum)
2002 Minister for Internal Affairs and Communications Award
2003 Medal with Purple Ribbon
2004 The Okawa Prize
2005 Prime Minister Award of the Industry, Academia and Government Cooperation Contribution
2006 Japan Academy Prize
2006 C&C Prize
2015 ITU150 Award
2017 Professor Emeritus, the University of Tokyo
2017 Dean and Professor of INIAD, Toyo University
2018 TRON-based Embedded OS IEEE 2050-2018 established as IEEE standard
2023 IEEE Masaru Ibuka Consumer Technology Award
2023 TRON Real-Time OS recognized as an IEEE Milestone
2023 The Institute of Environmental Art and Design, Grand Prize

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