Advanced Robot Technology Project in Japan

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ABSTRACT:

This report presents the current status of the "Advanced Robot Technology" Project in Japan.
The "Advanced Robot Technology" project is aimed at research and development on advanced robot systems capable of carrying out inspection, maintenance, rescue, and other complex tasks in dangerous environments that preclude any direct human intervention.
R&D efforts have continued steadily from 1983 to perfect the element engineering skills covering three major application areas of robot systems, that is, nuclear power, undersea, and fire-fighting/rescue operations. As expected progress to date has been satisfactory, and is deemed to offer good potential for establishment in the foreseeable future of the technologies needed to achieve advanced robot systems.

1. Overview of Research and Development

Research and development on advanced robotics requires substantial capital, prolonged research, and in addition, involves high risks. For these reasons, advanced robotics has been nominated as a national project under the National R&D Program of the Agency of Industrial Science and Technology, Ministry of International Trade and Industry. To achieve the project objectives, R&D activities are actively moving forward at two national research laboratories and the "Advanced Robot Technology Research Association" to acquire the engineering skills tailored to each individual objective and to perfect the fundamental technologies underlying them all.
This project aims at establishing the engineering skills necessary to build advanced robot systems capable of carrying out inspection, maintenance, rescue, and other highly complex tasks in environments that preclude any direct human intervention because of high radiation levels, high water pressures or high temperatures.
The three major application areas of nuclear power plants, undersea and fire fighting/prevention are the R&D tasks currently being concentrated on for the advanced robot systems.

2. R&D Scheduling and Budgeting

The R&D project started in 1983 and is slated to extend over an 8-year period. The aggregate R&D capital investment will amount to approx. ¥20 billion, of which some ¥2.5 billion has been earmarked for fiscal 1988. The cumulative direct expense over the last 5 years has already reached ¥7.5 billion.

3. Major R&D Objectives

The three advanced robot systems each have individual research and developmental objectives.

Nuclear Power Plant Robot	Mobility Engineering	System capabilities to climb stairs up/down, to step over piping or other impediments, and to relocate itself at high speed.
	Manipulating Skills	Equipped with two arms each terminating in at least a 3-finger mechanism (a 4-finger mechanism is currently under development), the system should be capable of dismantling inspection of valves and pumps.
	Sensor Technology	Sufficient system capabilities to transfer realistic video images and to identify objects for handling dismantling inspection of valves and pumps.
	Radiation-Withstanding Technology	System capabilities sufficient to operate within an operating reactor containment vessel.
Undersea Robot	Undersea Position Holding Skills	System capabilities sufficient to accurately hold 3-dimensional positional relationships (within ± 15cm) with any operating object, even when exposed to tidal currents (by utilizing propellers, gyroscope, and seating/anchoring devices).
	Manipulating Skills	Capacity to operate while adjusting to any depth-caused pressure differences, the system should be made capable of most cleaning or inspecting tasks.
	Sensor Technology	System capabilities sufficient for visual (acoustical) identification in a muddy environment.
Fire-Fighting/Prevention Robot	Sensor Technology	System capabilities sufficient to grasp any situation in the midst of smoke or flames.
	Durability Engineering	System capabilities sufficient to withstand 400°C for about 30 min and 800°C for about 3 min by employing an appropriate cooling system and heat-resistant materials.

4. Current research and Development Status

This is the sixth year since the start of R&D in 1983, and the below-listed R&D achievements indicate progress in the various application areas.

4-1 Nuclear Power Plant Robot

(a) Mobility Engineering

After fabricating and trially operating a 1/3-scale model of a four-legged mechanism for traversing floor surfaces, we built a full-scale four-legged trial walking machine and tested its walking behavior. Additionally, as a wall-climbing mechanism, we also fabricated suction cups for climbing and connecting body segments, and have run climbing experiments and performance tests thereon.

(b) Manipulating Skills

A four-fingered model equipped with tactile sensors at each finger tip was fabricated, and by conducting multi-sensor bilateral controlled screw-turning, spanner-switching, and other experiments, the feasibility of the basic operations was confirmed. With regard to operating actuators, we successfully reduced their size and weight to 1/8 the level available with conventional technology, and have run performance tests on them.

(c) Image Data Processing Technology

On-line system software was developed for robot positional checking and for detection of space available for continued mobility, and its performance testing has yielded satisfactory results. Not only have algorithms been developed to measure an operating environment 3-dimensionally, but part of the measuring system was also designed and fabricated to verify validity of the algorithms using actual TV images.

(d) Radiation-Withstanding Technology

Radioactive irradiation tests have been conducted at room temperature and standard humidity on electronic components which will be employed in the robots, and the test performance was stored in databases. Also, we built radiation-resistant bipolar IC devices, subjected them to the same irradiation tests, and examined the feasibility of enhancing the radiation-withstanding capabilities still further.

4-2 Undersea Robot

(a) Undersea Cruising and Position-Holding Skills

Relative to mobility, cruising tests were run inside a dock using a model. In addition, cruise-simulating tests were also run using a simulator. In connection with the 3-dimensional propelling mechanism, underwater performance tests were run by combining a pitch varying mechanism and the propellers. As an undersea position/attitude detector, a second phase of trial fabrications was carried out with a fiber optics gyroscope, and new factors for enhanced component performance were successfully elicited.

To check the viability of seating and anchoring devices, we fabricated a full-scale model of an end effector, and conducted anchoring performance and other tests under water pressure.

(b) Manipulating Skills

Not only was a single-freedom-degree model of an arm mechanism successfully fabricated and subjected to underwater performance tests, but a 6-freedom degree model of arm control equipment has also been built and its waterproof sensors subjected to trial performance tests.

(c) Visual Sensor Technology

To serve as acoustic image sensors, a high-resolution, high water pressure withstanding transceiver array was built, and through underwater tests, its basic response successfully confirmed. Also, not only were video image processing algorithms newly developed, but were part of their higher speed signal processors were also trially built.

4.3 Fire Fighting/Prevention Robot

(a) Heat-Withstanding Technology

Focusing on a transpiration cooling system, basic tests have been conducted, both on the cooling structure and test pieces of its constituent members, and system feasibility determined to be sound.

(b) Manipulating Skills

For gas pressure actuators, models have been fabricated of a gas pressure servo motor, controller, reduction gear, and control valve, and these parts subjected to basic tests. A trial design was also made for the control system.

(c) Visual Sensor Technology

For a CO_2 laser sensor not only were basic ranging tests conducted, but the conversion of any scene into an image has also been verified.

For an ultrasonic proximity sensor, we built and evaluated a relevant ultrasonic sensor device, and have also conducted basic testing of the image playback system employed.

5. Future Developments

Planned for achievement in fiscal 1988 is to assemble most of the element technologies unique to individual robots, and to embark on detailed designing as well as some manufacturing of the total systems and subsystems. It was prior to this phase, that is in fiscal 1987, that interim assessments were made on related element technology research achievements as of that time, and we are pleased to report a favorable outlook for the establishment of the timing of the technologies that will be required to perfect advanced robot systems.

From this point forward, it is important for all R&D personnel to fully recognize the role of each individual, and to advance their own R&D efforts under close mutual collaboration, toward the perfection of a total system. The introduction of appropriate research achievements concerning any of the fundamental technologies must be reviewed as well in terms of the above process.

Fig.1. Advanced Robotics R&D Flow chart

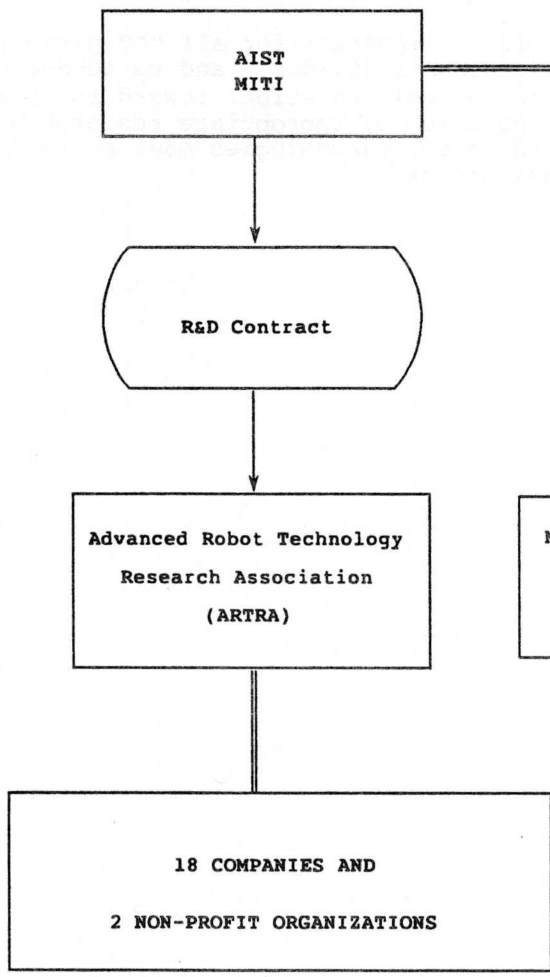

Fig. 2. Outline of Advanced Robotics R&D

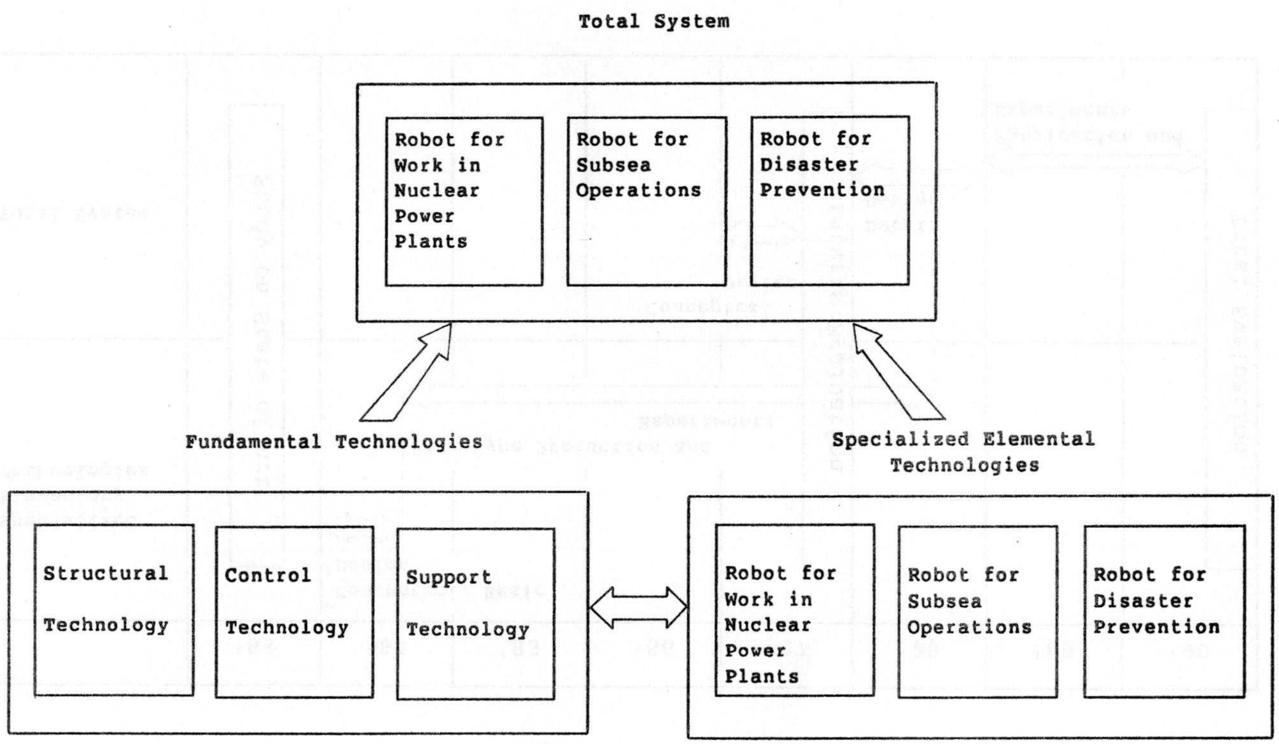

Fig.3. R&D Schedule

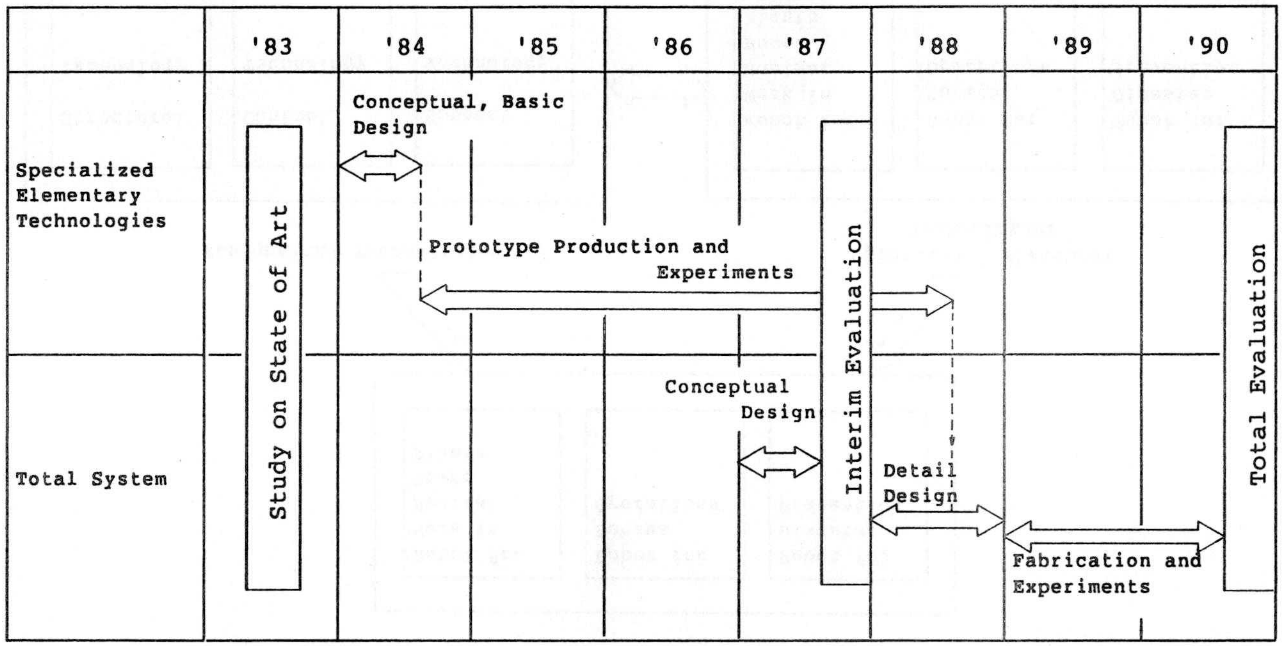

Table 1. Trend of R&D Budget

(Unit: million yen)

Fields Fiscal Year	1983	1984	1985	1986	1987	1988
Fundamental technologies	40	319	406	368	351	291
Nuclear Power Plant Robots	-	465	814	1,000	1,131	1,182
Fire Fighting Robots	-	-	512	732	648	756
Undersea Robots	-	-	165	304	295	251
Total	40	784	1,896	2,405	2,425	2,479