

# The Japanese 2012 Robotics Industry – A Strategic Crossroad for The World’s Leader –

Mark Haley<sup>†</sup> and James Bass<sup>‡</sup>

<sup>†</sup>ProvenRobots.com Inc., Texas, USA

<sup>‡</sup>U.S. Army International Technology Center, Tokyo, Japan

**Abstract**— Japan has dominated the production and use of industrial robots since it pioneered this technology over forty years ago however its leadership is rapidly slipping to Asian rivals. This paper reviews the history and the current status of Japan’s industrial and service robotics and: 1) it addresses the strategic decisions Japan faces in order to maintain its technological lead given the strong competition from China, Korea, Germany and the U.S.; and 2) it focuses on identifying the ideal market segments in service robots where joint U.S./Japanese collaboration would benefit both countries.

**Keywords**— Japan industrial robots, service robots, Japan financial crisis.

## I. INTRODUCTION

Japan has had a long fascination and tradition of mixing technology and entertainment since the 1600s when they first used mechanical dolls for plays. Japan’s mechanical/electronics expertise ultimately led in 1969 to the creation of the first commercial production of industrial robots in Japan by Kawasaki Heavy Industries, Ltd. Japanese companies such as FANUC, Denso Corporation, and Mitsubishi have led the development of a wide range of robotic and manufacturing technologies. In addition, Japan also dominates a wide range of service robotics sectors including Humanoid Entertainment robots such as Honda’s ASIMO which can run, dance, play instruments and talk. On the other hand, the U.S. leads the world in military and rescue robots and during the Fukushima nuclear disaster most of the first key unmanned air and ground systems on site were American since the Japanese robots weren’t tested as extensively as the American robots in real-world emergencies. Industrial robots used in manufacturing comprise over 85 percent of the \$20 billion revenue in 2010 for service and industrial robots.

The trends in the industrial sector are summarized in **Table 1**. References [1][2] show that while Japan has dominated manufacturing robotics production and use since 1969 in 2010

Corresponding author: Mark Haley (e-mail: [m\\_haley@faculty.chiba-u.jp](mailto:m_haley@faculty.chiba-u.jp))

Mark Haley is the President of ProvenRobots.com Inc. and a Professor at Chiba University, Chiba Japan

This paper was originally presented at The 8th International Conference on Intelligent Unmanned Systems, Singapore Oct 22-24, 2012.

It was submitted on December 25, 2012; revised on February 14, 2013; and accepted on March 4, 2013.

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for the first time, shipments to Korea exceeded those to Japan and in 2014 shipments to China could also surpass Japan. As a result while in 1995 Japan monopolized automated manufacturing technology with over 71 percent of the installed robots in Japan’s factories. By 2014, it’s projected that only 20 percent of the world’s robots will be operating inside Japan [1]. This paper also identifies key decisions faced by Japan in order to maintain its robotics leadership including strategic partnerships and future investments in technology.

**Table 1 – Estimated Shipments of Industrial Robots (Units)**

	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2014</b>
China	7,879	5,525	14,978	19,500	32,000
Japan	33,138	12,767	21,903	26,000	30,000
North America (US, Canada, Mexico)	16,242	8,417	16,356	21,000	24,000
Republic of Korea	11,572	7,839	23,508	24,500	21,000
Germany	15,088	8,507	14,000	15,500	16,500
Rest of world	<u>29,053</u>	<u>16,963</u>	<u>27,592</u>	<u>32,800</u>	<u>43,200</u>
Total	<b><u>112,972</u></b>	<b><u>60,018</u></b>	<b><u>118,337</u></b>	<b><u>139,300</u></b>	<b><u>166,700</u></b>
% (China, Japan, NA, Germany & Korea)	74.3%	71.7%	76.7%	76.5%	74.1%

## II. BACKGROUND – JAPAN FACES A FINANCIAL CRISIS AND MUST FOCUS ON ITS BEST INVESTMENT OPTIONS

### A. Japan’s Financial Crisis – Potential Bankruptcy in 5 years

Japan faces severe budgetary constraints with a debt load the highest in the world at 228.77 percent of the GDP, higher than the worst economies in the world which are on the brink of economic meltdown including Greece, Italy, Portugal and Ireland. Japan’s debt is massive, more than double the United States as a percent of the GDP as shown in **Table 2** [3]. In fact, Takeshi Fujimaki, the former adviser to investor George Soros, said that Japan could go bankrupt within 5 years and the yen might weaken to 500 yen to the dollar [4]. With a declining population, manufacturing robots offer Japan has become a key opportunity to remain competitive in international markets. So it’s crucial that Japan focuses its limited financial resources on this key sector which helps it to compete in world markets in automobiles and electronics.

**Table 2 – 2011 Debt as % of GDP**

<u>Country</u>	<u>% of GDP (IMF)</u>
<b>Japan</b>	<b>228.77</b>
Greece	160.81
Italy	120.11
Portugal	106.79
Ireland	104.92
United States	102.94

### B. The Key Option to Maintain Japan's Competitiveness – Manufacturing Robots

Japan's population is declining and its workforce is decreasing even faster as the Japanese population becomes increasingly older. HSBC predicts that Japan's working population will contract by 37 percent in 2050 versus 2010 (Table 3 [5][6]). While population estimates for Japan vary, the U.N. predicts that the Japanese population will decline by over 17 percent by 2050. Japan's key option to remain competitive is to increase its worker's productivity using manufacturing robots to maintain the volume and quality of its products. Japan should provide tax incentives, R&D and other funding to insure that it maintains its leadership in this key. While service robots such as Home Healthcare robots are also important, to maintain Japan's ability to export key technologies such as automobiles and electronics Japan needs to focus its limited financial resources into the manufacturing sector to remain in the top four economies of the world for the next 40 years.

**Table 3 – World's Leading Economies**

<u>Country</u>	<u>Economic Rank</u>		<u>Population (Millions)</u>		<u>Population % Change</u>
	<u>2010</u>	<u>2050</u>	<u>2010</u>	<u>2050</u>	
China	3	1	1,341	1,296	<b>-3.5%</b>
U.S.	1	2	310	403	23.1%
India	8	3	1,225	1,692	27.6%
<b>Japan</b>	<b>2</b>	<b>4</b>	<b>128</b>	<b>109</b>	<b>-17.4%</b>
Germany	4	5	82	75	<b>-9.3%</b>

### C. The World's Largest Militaries

Even though both the U.S. and Japan have massive deficits, they also are the leading spenders on their militaries (Table 4, [7]). The U.S. has recently set its new priorities to move military personnel and major weapon systems from Europe and other sites to Asia and the Mid-east to confront terrorism, the North Korea threat and the growing influence of China. Given that the U.S. and Japan are strong allies, significant cost savings would occur if there was better integration of their militaries. Japan –with its massive debt load, its declining population and the economic challenges it faces in robotics to remain competitive– has no other viable choice to save money, it must integrate its military operations with its key allies such as the U.S. Even though Japan maintains a low profile for its military expenditures, they are massive. It outspends countries such as Germany, India, South Korea and Australia.

**Table 4 – World's Largest Militaries**

<u>Country</u>	<u>Spending (\$ Billions)</u>
U.S.	711.0
China	143.0
Russia	71.9
United Kingdom	62.7
France	62.5
<b>Japan</b>	<b>59.3</b>

### III. INDUSTRIAL ROBOTS – JAPAN SHOULD FOCUS ITS LIMITED FUNDS ON PRESERVING ITS LEAD IN THIS TECHNOLOGY

Japan is still the leader in manufacturing robots and the Japanese government and industry should work together to preserve the crown jewel of Japan's technology which helps it maintain its competitive edge. As noted previously, Industrial robots used in manufacturing comprise over 85 percent of the \$20 billion revenue in 2010 for service and industrial robots. Therefore the key focus of Japan's robotics development should be to maintain its leadership role in manufacturing robots. While the details of that strategy are beyond the scope of this paper, it is crucial that the Japanese government and industry should address this challenge. The remaining part of the paper focuses on the sectors of the service robotics market where Japan can gain the most advantages in joint R&D projects with other countries, primarily the United States.

#### A. Service Robots –The Key Opportunity for Joint U.S. and Japanese R&D

Given Japan's severe financial crisis, it should seek collaboration in the service robot sectors where the market opportunities are limited and where Japan has leading technology it can use to interest funding from abroad. Photos of the types of robotics for joint U.S./Japanese collaborative are shown in Figure 1.



**Figure 1 – iRobot's Packbot (left), Global Hawk (right)**  
[Courtesy of U.S. Department of Defense]

As shown in Table 5, the major market opportunities for service robots are in Home healthcare plus humanoid robots for entertainment and companions. On the other hand, the rescue robot market is limited to disaster relief and military Intelligence, Surveillance and Reconnaissance (ISR) and for Bomb disposal. If humanoid robots assume a major role in military operations and actually replace humans in combat, this market would be immense, however it is assumed that it is a market Japan would not want to focus on. Therefore as seen in the following table, the best areas for collaboration for Japan are in Rescue Robots and Humanoid Robots for disaster relief, ISR and bomb disposal.

**Table 5 – Strategic Opportunities for Service Robots**

<u>Robotic Market</u>	<u>Opportunity</u>
Rescue Robots	Disaster Relief, ISR Military & Bomb Disposal
Humanoid -Rescue Robots	Disaster Relief, ISR Military & Bomb Disposal
Humanoid -Companion	Key Market - Entertainment/ Companion Robots
Home Healthcare Robot	Key Market - Treatment of Patients at home

### B. Rescue Robots – Japan Should Collaborate with Other Countries to Save Its Limited R&D Funds

Robots which are used after natural disasters such as Japan's Tsunami, Earthquake and Nuclear Disaster at Fukushima are vital. However the market opportunities are limited since these are only needed periodically and/or for military operations. Moreover, other countries, primarily the U.S. have developed proven technology for ISR and rescue robots and Japan can immediately use these robots without squandering its limited resources. While Japanese may ask why Japan isn't a leader in rescue robots, Japan shouldn't waste its limited resources in this limited market just for its national pride. Instead, Japan should collaborate with the U.S. which dominates air and ground robots for surveillance and military systems such as the Predator Drones, and ground robots such as the Packbot. These units have been field tested by the U.S. military and the U.S. has become the '911' for disaster relief around the world by deploying an armada of ships, planes and robots as shown in **Figure 2** where 20,000 U.S. troops helped Japan after the 2011 Tsunami. The U.S. 7<sup>th</sup> Fleet commander Vice Adm. Scott Van Buskirk called the rescue operation known as Operation Tomodachi, or "friendship" (a name chosen by the Japanese) "the most complex humanitarian mission ever conducted [8]."



**Figure 2 – U.S. Armada of Ships, Aircraft rescuing Japan and the destruction they faced (right)**  
[Courtesy of U.S. Department of Defense]

The U.S. leads in state-of-the-art air and ground robots which can be used after natural disasters, and during intelligence, surveillance and reconnaissance (ISR) for military operations. Japan would save money by teaming up with the U.S. on these systems especially the air robots such as the Predator drone and to a lesser extent ground robots such as iRobot's Packbot. Japan would waste its limited capital if it tried to duplicate this technology which has limited market opportunities. Unfortunately, the Japanese government invested millions in rescue robots prior to the 2011 Tsunami. Ironically, as reported in the Economist magazine, one of Japan's most heavily funded rescue robots was on a playground for display while American air robots including the Global Hawk photographed overhead at Fukushima and the Packbots collected radiation data inside the plant. After Fukushima, the Japanese government (NEDO) continued to fund over \$10 million for

rescue robots however they mainly excluded foreign companies even though at the same time TEPCO ordered 4 Packbots for operations inside Fukushima.

Fortunately, there is promising research and also collaboration between Japan and the U.S. on smaller projects which involve teams of small ground and air robots working to complete reconnaissance or other missions crucial after natural disasters. At MIT, the University of Pennsylvania, Virginia Tech. and at Chiba University, air and ground robots are working together using advanced real-time mapping technology including real-time SLAM which provides precise autonomous navigation plus automotive battery changers which extend the limited flight time of small MAVs by a factor of 6. Japan can benefit from teaming with the U.S. advanced robots such as the Predator, and both Japan and U.S. can benefit from collaboration on enhancing the capabilities of small ground and air robots.

### IV. ANALYSIS OF THE GOVERNMENT RESEARCH MODELS USED IN JAPAN TO DEVELOP HUMANITARIAN ASSISTANCE AND DISASTER RELIEF ROBOTICS (HA/DR)

While many Japanese may indeed wonder why Japan (an undisputed powerhouse in industrial and humanoid robotics) was forced to use HA/DR robots from other countries to effectively support disaster operations during the Fukushima incident, a more important point of research and analysis may be why external robotic support was needed despite Japan's twelve year and ¥14.2B (\$178 million at 80 yen/dollar) R&D investments to develop such technology starting after the 30 September 1999 nuclear incident in Tokai-mura.

An analysis of the R&D techniques utilized by MITI (IRFATC) in the 1980's, METI (MSTC) in 1997, and METI (NEDO) starting in 2003 [10], show a deliberate process to find the best model for developing national programs using a mix of government incentives, private industry, academia, and some international collaboration with or without an industrial profit incentive. The highest degree of success came in the 1980's with various initiatives for development of industrial robotics. This series of projects had some common indicators of success: Government and Industrial consensus as to the merits and profitability of the effort; "Buy-in" from the academic community as to the merits of the research; Creation of an incubator to provide a delivery point for academia and a risk mitigation facility for industry; and, international collaboration to rapidly move research and reduce redundant discovery and engineering lessons already learned by other collaborators.

Starting with the 2000 MSCT program for Nuclear Disaster Relief Systems, MSCT (and later NEDO) modified the research model looking for ways to create a viable set of products that did not have the high profit potential as that of industrial robotics. Program period of performance (some as small as a single year), the mix of Industry and Academic participation, development of specialized and/or generalized DR robotic systems, and use of international and/or exclusively Japanese

development teams were changed and modified during the past twelve years to try and find the right mix to overcome the constantly reducing pool of government dollars and a lack of industrial profit incentive that drove previous successes.

Three factors came up as the most significant: the decline in international collaboration; the loss of an incubator facility; and lack of profit potential for Industrial partners. While profit potential cannot be easily overcome, this paper will not comment on export policy decisions that are, as they should be, left for the Japanese government and people to decide, the other two factors are within the immediate realm of possibility and reflect the growing realization that collaborative efforts in an era of declining R&D resources represent potential savings and efficiencies for well formed, complementary, consortia based research teams and that transition of highly complex technologies need an incubator facility for risk mitigation and technology maturity. This is especially true for nonlinear and compound-complex systems with direct human interaction. Note that in many industrial robotics applications, humans are not even allowed on the assembly line floors during operation. Finally, though incubator facilities are expensive, when faced with a national level research effort (especially when there is little industrial profit potential), the creation of a government or private, not-for-profit incubator may be the best opportunity to transition technologies and intellectual property to industrial partners for final development and delivery (technology transition to industry).

This topic is too broad for a paper of this scope; however, the concept of supporting both national and international R&D is here. The research community must perform internal analysis of current methods and models and help their government partners, industry, and academic institutions understand when particular models should be implemented based on a multitude of parameters based on national and practical goals.

## V. SERVICE ROBOTS AND HUMANOID RESCUE ROBOTS

Japan is a leader in human-like robots which can run, dance, talk and perform many human tasks such as pouring a drink – as demonstrated by Honda’s ASIMO. Japan has a long history of developing these types of robots inspired by the *karakuri ningyo*, or mechanical dolls. These were developed during the Edo period (1603–1867).

ASIMO has 34 degrees of freedom (DOF), it can run up to 3.7 mph (6 km/ hour), it has a five hand for grasping and it can operate for an hour on its battery. This system is too expensive for most applications yet this technology would be ideal for collaboration with the U.S. to develop affordable rescue robots. However, Korea has developed a competitor to the ASIMO called Hubo. The project was headed by Professor Jun-Ho Oh of the Machine Control Laboratory in the Department of Mechanical Engineering at KAIST and originally developed from 2002–2005 at an estimated costs of less than \$1 million versus an estimated \$300 million over 20 years for the ASIMO [10]. While Korea’s Hubo is not as advanced as ASIMO, Japan should exploit its service robot technology in collaborative projects before it is surpassed by its rivals.

### A. Other Japanese Humanoid Robots

The HRP-4 from Kawada Industries Inc. has 34 DOF and responds to voice commands. The HRP-4C from the National Institute of Advanced Industrial Science and Technology is a life-like woman which is over 158 cm tall and weighs 43 kg and has facial expressions and even appeared in a fashion show in 2009.

### B. Home Healthcare Robots

The U.S. and Japanese Home Healthcare markets are very large since there is a rapid increase in older people who need to be cared for in their homes. In the U.S., home healthcare cost exceeded \$70.2 Billion in 2010. While the bulk of these expense are for doctors, nurses, or others who care for patients at home, robots will play an increasing role since they can significantly reduce costs. While collaborative research is already occurring between the U.S. and Japanese in this market, in the long-term since the market is so large companies will independently fund and develop robots targeted at the home. For example, Chiba University and Virginia Tech received a 3-year research project to develop home healthcare robotics technology funded by JST and the National Science Foundation (NSF). However, corporations are also investing in this market. iRobot, the leading developer of robotics in the U.S., announced that it’s targeting on the home healthcare market. In addition, Toyota Motor Corporation (TMC) announced on November 1<sup>st</sup>, 2011 that it had four target markets for their Partner robots: 1) Nursing and Home Healthcare, 2) Personal Transport, 3) Manufacturing, and 4) domestic robot. As they announced in their press release these robots are “being developed to assist humans in their everyday activities.” In addition, these robots are very advanced “Each robot incorporates the latest in advanced technologies developed by TMC, including high-speed, high-precision motor control technology, highly stable walking-control technology advanced through development of two-legged robots, and sensor technology that detects the user’s posture as well as their grasping and holding strength.”

### C. Entertainment and Companion Robots

This market will also be very large and targeted at providing companions for humans. Disney pioneered advanced animated robots which entertain in their amusement parks. While the Disney robots were initially expensive, with the reduction in costs the capabilities of these robots and their number should rapidly increase. Some of the same robots which Toyota is developing for its Partner robots such as their domestic robots could serve to both help and provide a companion for patients at home. Since industry will aggressively pursue both the home healthcare and entertainment markets, the Japanese government should focus its limited resources on investments in industrial robots.

### D. Dual Use Technology

Dual Use Technology is equipment (**Figure 3**) which can be used for both military and civilian purposes. Notice that the exact same robot was used to fund research in three areas (ISR, home healthcare robots, and Fukushima-type rescue robots).

This robot which only costs a few thousand dollars and was successfully used in R&D project for: 1) a contest of ISR robots for surveillance where it was ranked in the top 6<sup>th</sup> and the team led by Analytical Software Inc. won \$100,000; 2) Fukushima-type rescue robots for the next nuclear disaster which was funded by a grant from the National Science Foundation (NSF); and 3) this same robot was used for Home Healthcare robots which assist patients in their homes and was funded by both NSF and JST. This dramatically illustrates dual-use technology – the same robots can be used for many applications.



**Figure 3 – Left to right: Robots for Home Healthcare, Fukushima-type Rescue, and ISR**  
[Courtesy of Tomonari Furukawa]

#### VI. REPORTERS WITH LIMITED TECHNICAL UNDERSTANDING JEOPARDIZE JAPAN’S FUTURE

Unfortunately, some reporters in Japan seem unaware of dual use technology and they tried to portray toy-like R&D robots as major weapon systems. The most dangerous type of dual-use technology is nuclear energy which can be used for nuclear power plants or nuclear weapons. A less dramatic but far more widespread and still deadly example is the common automobile which could be used in everyday living to drive to work or to the store, or the same car could be packed with explosives by terrorists and turned into a deadly car bomb.

Two reporters at Asahi either didn’t understand dual use technology or chose to ignore it and portrayed the toy-like R&D robots shown in **Figure 3** like King Kong on the front page of Asahi. Because of their biased reporting, Japanese researchers panicked and avoided working with the U.S. and the Japanese rescue robots stagnated. Nine months later at Fukushima in March 2011, no Japanese robots were ready and the American robots flew overhead and went inside. Fortunately after Fukushima, clearer minds prevailed and the U.S. and Japan teamed up on a number of robots projects.

#### VII. FOR JAPAN’S CITIZENS TO MAKE THE RIGHT DECISIONS, THE JAPANESE PRESS MUST CLEARLY EXPLAIN THE CHALLENGES AHEAD

If the Japanese people were well informed by the press of these crucial challenges, perhaps the Japanese voters would support the investment strategies needed to prevail. Unfortunately parts of the Japanese press either through lack of understanding of these problems or because of sensationalism have reported totally misguided analysis. While Asahi reporters attack the U.S.–Japan alliance, the Vietnamese government is seeking U.S. joint military cooperation. The Vietnamese are even considering welcoming U.S. Naval ships

at Cam Rahn Bay, the strategic port and former military base of the U.S. forces during the Vietnam War. As reported by the U.S. and Chinese press, during a visit by U.S. Defense Secretary Leon Panetta with the Vietnamese Defense Minister Phung Quang in June 2012, Panetta said “Hanoi would play a pivotal role in the U.S. military’s shift toward the Asia-Pacific” [11]. In addition, the U.S. Defense Department was funding joint research projects with Vietnamese scientists. That is an amazing contrast: At the same time Vietnam was seeking military collaboration and dual use research opportunities with the U.S., the Japanese press was attacking any researchers working with America.

In fact, in 2010 during a robotics contest for dual-use Fukushima-type rescue robots and ISR rescue robots, two Asahi reporters went to a Japanese Professor’s home in the middle of the night to have him confess he was working with Americans on rescue robots. These reporters claimed a U.S. Professor was a CIA spy even though this Professor was asked by the Japanese government to come to Japan to encourage the transfer of technology from the USA to Japan.

#### VIII. CONCLUSIONS AND FUTURE WORK

**Japan’s Investments in Robotics** – As discussed in this paper, the following outlines Japan’s investment priorities in robotics – a key industry that will keep Japan in the top four world economies even as Japan’s population shrinks.

- (1) **Manufacturing Robots** – The Japanese government should provide tax-incentives, R&D funding and other support since Japanese’s robotics industry must continue to automate production in its plants as Japan’s population declines. While details of this strategy are beyond the scope of this paper, this report underscores the need for Japan to focus its robotics investments in state-of-the-art manufacturing technologies.
- (2) **Service Robots** – This smaller, less strategic segment of the robotics industry accounts for 15 percent of the total robotics market (Service and Industrial Robots). The Japanese government should only sparingly make investments in this market and instead seek collaboration with the U.S. in rescue robotics which can be used for after disasters, such as the Fukushima nuclear crisis, and for military ISR.
- (3) **The Japanese Press** – If Japan hopes to remain in the top 4 economies of the world, it must continue to lead the world in robotic manufacturing as its population decreases. Unfortunately, the Japanese press doesn’t appear to understand these issues and is focusing on sensational stories about the danger of toy robots, while terrorist plot how to develop better car bombs and acquire nuclear weapons. Moreover, as Japan teeters on the brink of financial catastrophe, and even Vietnam recognizes the benefits of collaborating with the U.S. in the dangerous economic and military world ahead, the Japanese press attacks the U.S. alliance. Japan spends for the world’s 6<sup>th</sup> biggest military as it

struggles with massive budget deficits and should therefore seek integration with the U.S. military to reduce costs and preserve its security.

#### IX. ACKNOWLEDGMENT

This work was primarily supported by the U.S. Army International Technology Center – Pacific (ITC-PAC) with additional funding from the Office of Naval Research Global (ONRG), the Asian Office of Aerospace Research & Development (AOARD), the Deputy Assistant Secretary of the Army for Defense Exports and Cooperation (DASA-DEC) and the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC), plus additional assistance from the National Science Foundation (NSF).

**Additional Information** – This paper was originally presented at ICIUS October 2012 in Singapore by Professor Mark Haley. There have been no significant changes which impact the recommendations of this paper since it was presented. However international tensions are increasing and the trends on industrial robots and rescue continue as predicted in the paper. Therefore the conclusions are the same, Japan’s collaboration with international partners on rescue robots, especially the U.S. is even more important given the financial and political crisis Japan faces and the competition in industrial robotics.

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