An Overview of Japan National Project on Rescue Robotics

Special Project for Earthquake Disaster Mitigation in Urban Areas (DDT Project)
III. Advanced Disaster Management System
4. Development of Advanced Robots and Information Systems for Disaster Response

Program Manager:
Prof. Satoshi Tadokoro, Kobe University
International Rescue System Institute

Kobe Earthquake (Jan. 17, 1995)

- Magnitude 7.3
- Serious Damage Region 20 x 1 km (13 x 0.6 mi)
  People seriously effected: 2,300,000
  Deaths: 6,432 ++ Seriously Injured: 43,800 ++
  Buildings Damaged: 530,000
  fully destroyed: 104,906, fully burnt: 6,148,
  half destroyed: 144,272
  Fire: 285 large scale: 14
  (>10,000m^2 (3600 mi^2))
- Direct Damage: 10 trillion yen
  (100 billion US$)


Kobe, 1995

My student's

Large-Scale Earthquakes

- Frequency > 3 times/year

Year	Country or Region	Magnitude	Number of Death
1976	China	M7.8	242,700
1920	China	M8.6	220,000
1923	Japan	M7.9	142,800
1908	Italy	M7.0	110,000
1927	China	M7.9	80,000
1970	Peru	M7.6	66,800
1935	Pakistan	M7.6	60,000
1990	Iran	M7.3	41,000
1939	Turkey	M7.8	32,700
1915	Italy	M6.9	32,600

Large-Scale Earthquake Disasters in 20th Century

International Rescue System Institute

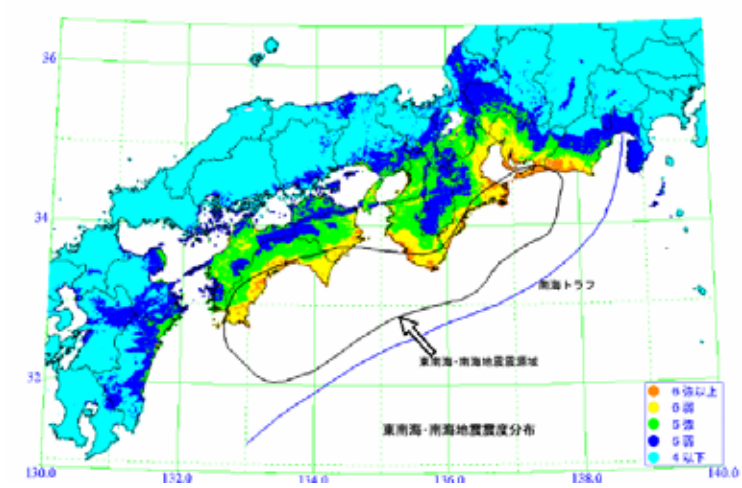
Nankai, To-Nankai, Miyagi-Oki Earthquake Predicted

	Magnitude	Probability in this 30 years
Nankai	M8.4	40%
To-Nankai	M8.1	50%
Nankai + To-Nankai	M8.5	
Miyagi-Oki	M7.5~	98%

(Cabinet Office, Central Disaster Prevention Committee, To-Nankai Nankai Earthquake Subcommittee, 2002)

International Rescue System Institute

Seismic Intensity Predicted (Nankai + To-Nankai)



(Cabinet Office, Central Disaster Prevention Committee,
To-Nankai Nankai Earthquake Subcommittee, 2003)

International Rescue System Institute

Predicted Damage by To-Nankai + Nankai

Building Destruction

Type of Damage		Number of Buildings Destroyed		
		5 AM	Noon	18 PM
Shake		Wooden: 141,700 RC: 24,800		
Liquefaction		Wooden: 70,000 RC: 18,300		
Tsunami Wave		38,800 (if water gates function well)		
Slope Collapse		20, 600		
Fire	Wind: 3 m/s	13,000	12,700	114,000
	Wind: 15 m/s	39,100	38,500	301,800
Total	Wind: 3 m/s	327,100	326,800	428,200
	Wind: 15 m/s	353,200	352,600	615,900

(Cabinet Office, Central Disaster Prevention Committee,
To-Nankai Nankai Earthquake Subcommittee, Internal Material, 2003)

International Rescue System Institute

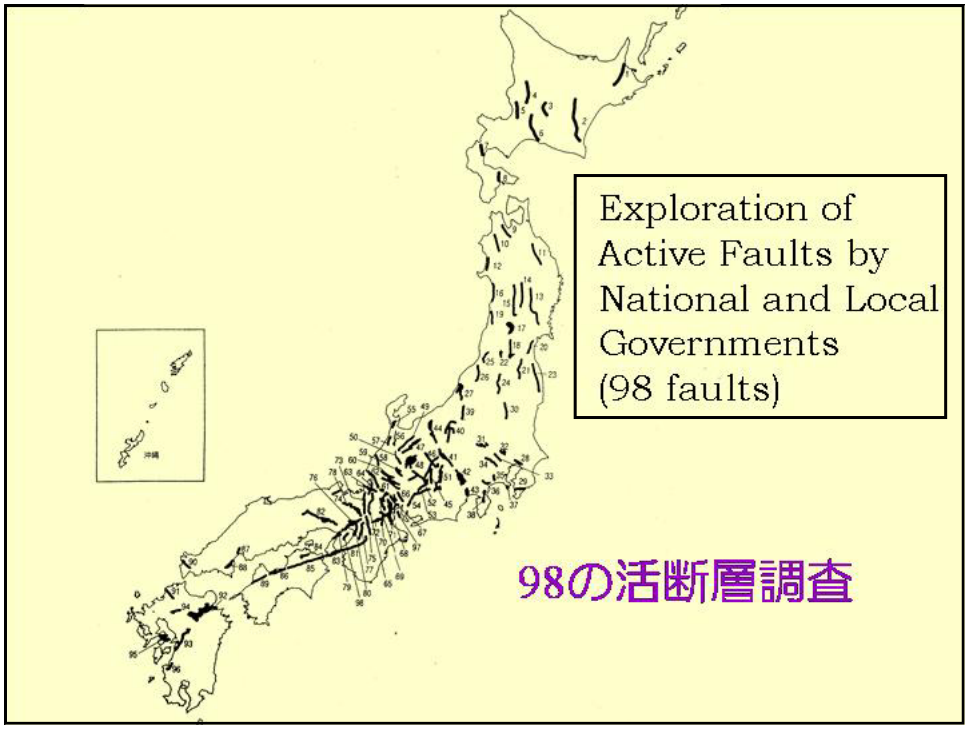
Predicted Damage by To-Nankai + Nankai

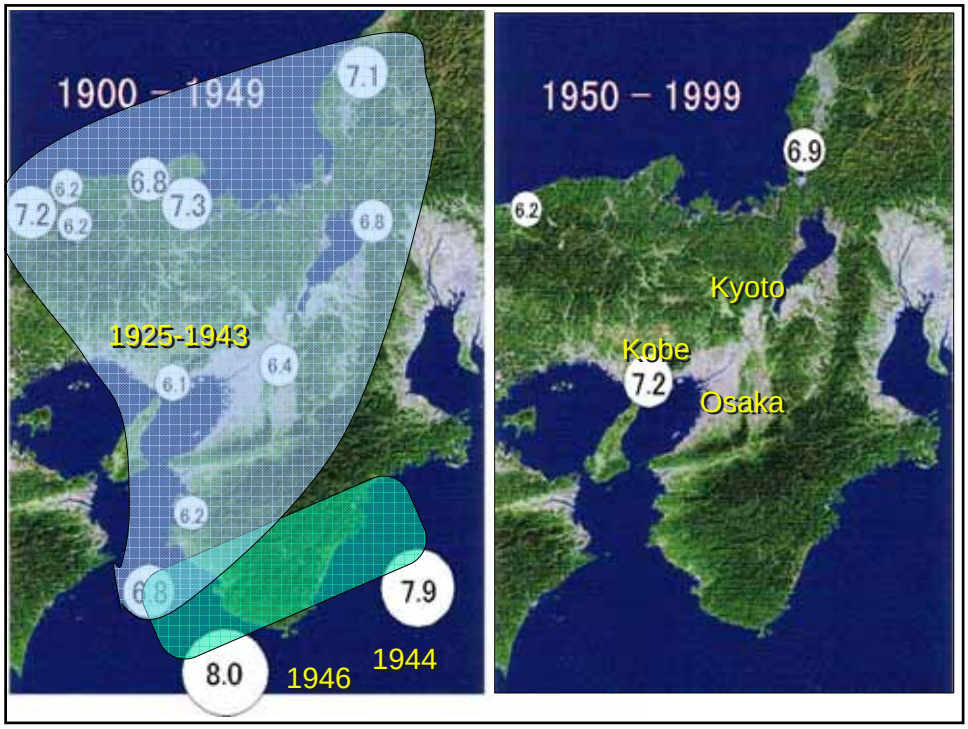
Human Damage

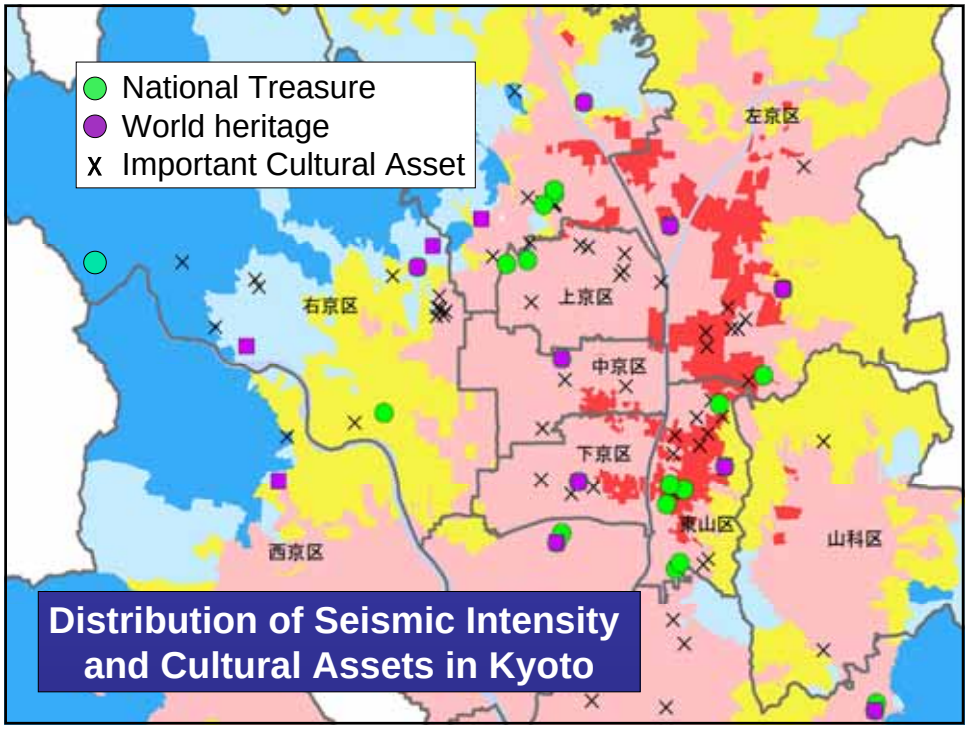
Type of Damage		Number of Dead		
		5 AM	Noon	18 PM
Shake		6,500	2,900	2,300
Tsunami Wave	Good Awareness of Evacuation	3,300	2,200	2,300
	Poor Awareness of Evacuation	8,600	4,100	5,000
Slope Collapse		1,900	1,000	1,300
Fire	Wind: 3 m/s	100	60	800
	Wind: 15 m/s	400	200	2,100
Large-Scale Land Slide		A number of victim could be very large.		
Total	Wind: 3 m/s	11,900 - 17,100	6,100 - 8,000	8,300 - 11,000
	Wind: 15 m/s	12,100 - 17,400	6,200 - 8,100	9,600 - 12,300

(Cabinet Office, Central Disaster Prevention Committee,
To-Nankai Nankai Earthquake Subcommittee, Internal Material, 2003)

International Rescue System Institute



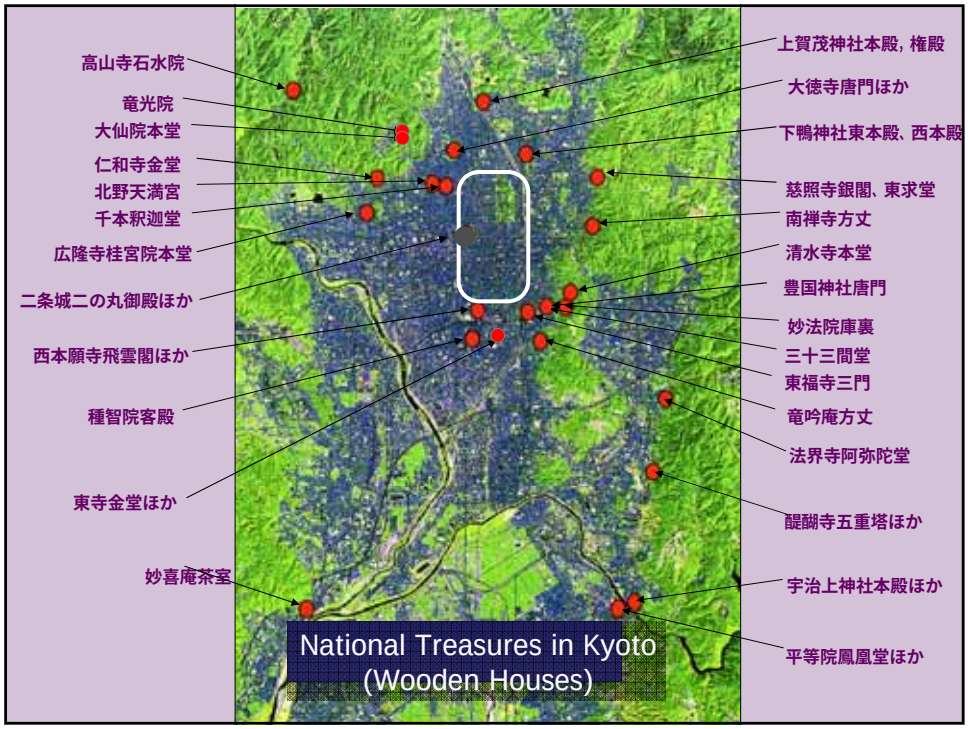

1900 – 1949
1950 – 1999
7.1
6.2
6.8
7.2
6.2
7.3
6.8
1925-1943
6.4
6.1
6.2
6.8
7.9
8.0
1946
1944
6.9
6.2
Kyoto
Kobe
7.2
Osaka


National Treasure
World heritage
x Important Cultural Asset
左京区
右京区
上京区
中京区
下京区
東山区
山科区
西京区
Distribution of Seismic Intensity and Cultural Assets in Kyoto

History of Kyoto = History of Fire

Large-Scale Fire in 1788

80% of the city,
more than 200 shrines and
more than 900 temples
were burnt down.



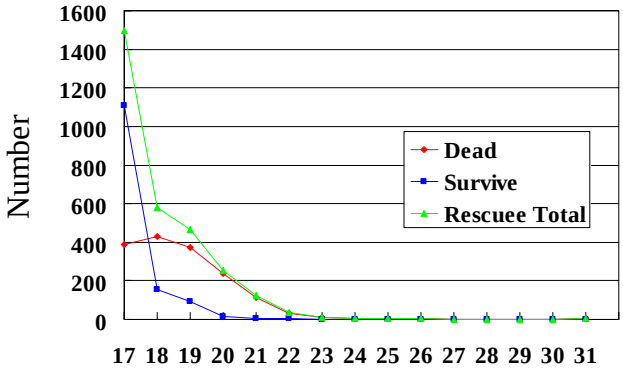
Major Causes of Death in Kobe Earthquake

Major Causes of Death	Victims	Percentage (%)
Death by Collapse of Buildings	3,043	83.3
Suffocation (Compression on Chest, Abdomen or Trunk)	1,967	53.9
Crushing Death (Pressure and Injury on Chest, Head or Whole Body)	452	12.4
Traumatic Shock (Burn, Contusion, Bleeding etc.)	82	2.2
Head Injury (Traumatic Subarachnoid Bleeding, Skull Fracture etc.)	124	3.4
Visceral Injury (Thoracic or Abdominal Injury)	55	1.5
Cervical Injury	63	1.7
Bruise or Contusion	300	8.2
Death by Causes other than Collapse of Buildings	466	12.8
Burn Death or Whole-body Burn (incl. Carbon Monoxide Poisoning)	444	12.2
Failing Organs etc.	15	0.4
Freezing Death	7	0.2
Others	142	3.9
Total	3,651	100.0

Ref. Medical Examiner of Hyogo Prefecture. 1995 *Autopsy Statistics in Kobe*

International Rescue System Institute

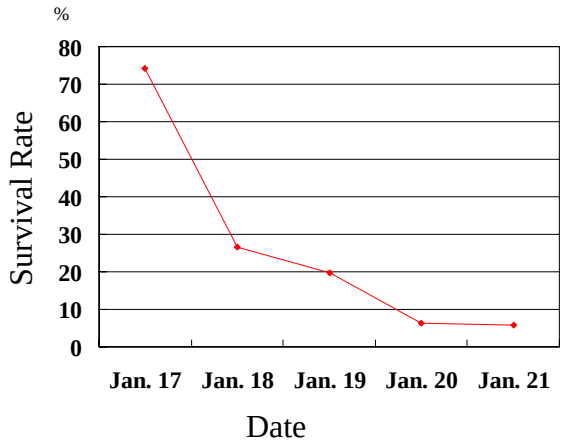
Dead & Survive in Kobe Earthquake



Date (Jan. 1995)

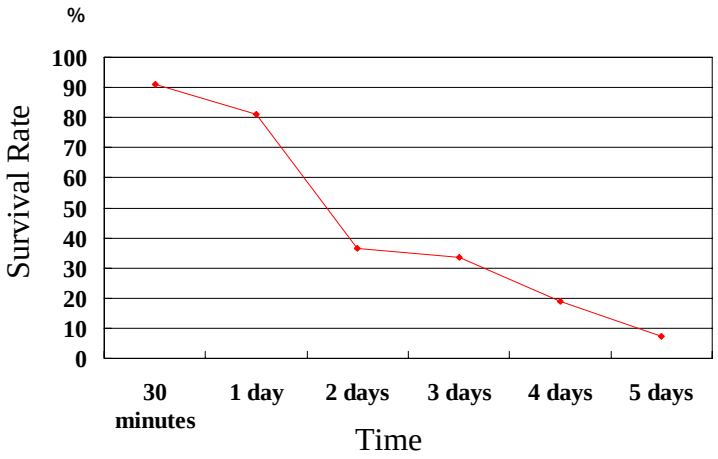
International Rescue System Institute

Survival Rate at Kobe Earthquake



International Rescue System Institute

Survival Rate (FEMA)



International Rescue System Institute

Expectation to Robotics

- Contribution of Industrial Robots
  - Release from terrible working conditions
  - Improvement of efficiency and cost
  - Improvement of quality
- Contribution of Rescue Robots
  - Improvement of rescue ability and efficiency
  - Prevention of secondary damage

  As Good Tools of Human Rescuers

International Rescue System Institute

Challenge of Robotics Researchers in Japan after Kobe Earthquake

- International Rescue System Institute (IRS) Establishment, 2002-
- JSME, Committee for investigation of Search and Rescue in Hanshin-Awaji (Kobe) Earthquake for Research and Development of Rescue Robotic Systems, 1996-7
- JEME, RC150 Research Committee on Rescue Robots in Large-Scale Disasters, 1997-1999
- ISCIE, Rescue System Forum, 2000-
- SICE, TC on Urban Disaster Mitigation System, 1997-
- SICE, Rescue Engineering Section, System Integration Division, 2000-
- RoboCupRescue International Cooperative Research, 2000-
- Rescue Robot Contest, 2000-
- MEXT, DDT Project on Rescue Robots and Systems, 2002-
- MFA, Japan-Italy Cooperative Research, 2002-
- JSME, Robotics-Mechatronics Conference, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003
- RSJ, Annual Conference, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003
- JSME, Robo-Mecha Symposia, 1997
- JSME, Annual Coonference,1998
- SICE, Urban Disaster Mitigation Workshop, 1998
- AI Robot Fare, 1998
- JSAI, SIG-Challenge, 1999
- RoboCupRescue Symposium, 1999
- Intl. Conf. IROS, 1999, 2000, 2001, 2002
- Intl. Conf. ICRA, 2000, 2001, 2002, 2003
- Intl. Conf. SPIE-UMG, 2000
- Intl. Conf. ICMAS, 2000
- Intl. Conf. IROS, 2000, 2001, 2002, 2003
- Intl. Conf. ISR, 2001
- Global Disaster Information Network, 2000
- RoboCup WC, 2000, 2001, 2002, 2003
- IEEE Robotics & Automation Society, TC on Safety, Security and Rescue Robotics, 2001-
- .....

International Rescue System Institute

Current Problem in Earthquake Disasters (Cabinet Office, Central Disaster Prevention Committee, Report of Future Earthquake Countermeasures Subcommittee)

(1) Remaining problems in countermeasures after Hanshin-Awaji (Kobe) Earthquake
- Local governments' ability of practical response against disasters
- Plans and rules of contribution of civilians and companies
- Plans of systematic construction of earthquake mitigation facilities

(2) Problems concerning change of economic and social conditions of Japan
- Slow-down of economic growth
- Decline of local personal communities
- Higher awareness of the citizens on safety and security
- Reduction of birth rate and aging society
- Acceleration of technological revolution such as IT

(2002)

International Rescue System Institute

Strategic Plan to Solve These Problems (Cabinet Office, Central Disaster Prevention Committee, Report of Future Earthquake Countermeasures Subcommittee)

(1) Effective use and social establishment of countermeasures of rules and organization for earthquake disaster mitigation after Hanshin-Awaji (Kobe) Earthquake in order to improve practical response

(2) Disaster mitigation as a part of peace social systems as possible, because the citizens' notice on disaster problems has become weak as time passes

(3) Practical risk management, cooperation of various sectors in disaster, efficient effective disaster mitigation, and active use of advanced technologies

(2002)

International Rescue System Institute

Current Policy Proposal [1/2] (Cabinet Office, Central Disaster Prevention Committee, Report of Future Earthquake Countermeasures Subcommittee)

(1) Practical Risk Management System

(a) Highly practical earthquake disaster mitigation/response

(b) Wide-area disaster mitigation

Plan of wide area disaster response plan, standardization of machinery and materials, equipments, and information

(2) Cooperation in Disaster

(a) Local disaster mitigation by cooperation of local governments with residents, companies, non-profit organizations

(b) Cooperation with volunteers

(c) Improvement of disaster mitigation of companies

(d) Disaster information sharing in societies

System for information sharing between disaster professional organizations and residents

(e) Earthquake-proof urban cities

Utilization of private companies and land owners

(2002)

International Rescue System Institute

Current Policy Proposal [1/2] (Cabinet Office, Central Disaster Prevention Committee, Report of Future Earthquake Countermeasures Subcommittee)

(3) Efficiency and Effectiveness

(a) Focusing of various countermeasures within limited budget

(b) Repair of houses and public buildings for earthquake proof

(c) Introduction of economic principles to disaster mitigation countermeasures

Promotion of market evaluation of disaster-conscious goods by performance standardization, certification, etc.

(4) Promotion of Use of Advanced Technologies

(a) Development of advanced information systems

Systematic disaster information system from incidence to recovery

(b) Technologies and systems for break-down of various barriers

Development of technologies for information collection of and evacuation guidance for sufferers, and of **robots for hazardous environments**

(c) Development of technologies to improve convenient-but-fragile society

Normal-time systems usable in blackout and communication cut

(2002)

International Rescue System Institute

Focus Points in Research and Development (Policy of Disaster Mitigation Research, MEXT, Council of Science, Technology and Academy, Subcommittee on Research Planning and Evaluation)

1) Strategic planning of disaster countermeasures (risk management, etc.)
2) Advancement of hazard map
3) Investigation on collapse process of structures by earthquakes
4) Evaluation and reinforcement of strength of existing structures
5) Optimization of recovery process
6) Active use of advanced technologies for disaster mitigation
7) Disaster information

(2002)

International Rescue System Institute

Expectation for Robotic Systems by Firefighting Departments of Major Urban Cities in Japan

■ NBC Terror	40	(out of 49)
■ Fire	36	
■ Earthquake	30	
■ Water	30	
■ Nuclear	29	

Japan Fire and Disaster Management Agency, Workshop on Future Firefighting & Disaster Response Robots, Questionnaire to Fire Fighting Departments of 49 Major Cities, 2003

International Rescue System Institute

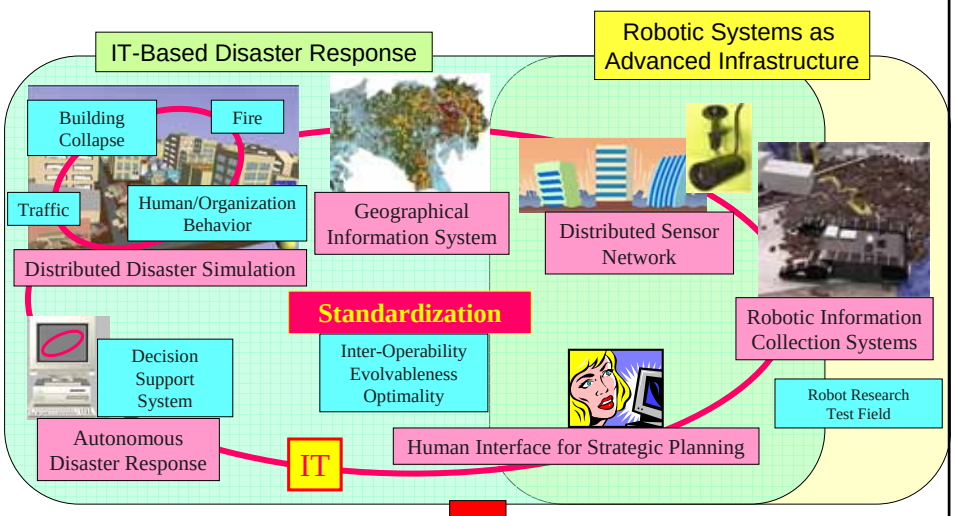
Expectation for Robotic Systems by Firefighting Departments of Major Urban Cities in Japan

	(out of 49)
■ NBC Terrors	
■ Identification of NBC materials by sensors	39
■ Transfer of victims to safe area	30
■ Removal of NBC material	24
■ Fire	
■ Extinguishment in buildings	30
■ Search in buildings	25
■ Extinguishment irrespective of heat radiation	24
■ Earthquake	
■ Search from above the rubble pile	26
■ Search in the rubble pile	22
■ Remove heavy rubbles	21
■ Water	
■ Search of victims	27
■ Rescue from water	24

(Japan Fire and Disaster Management Agency, Workshop on Future Firefighting & Disaster Response Robots, Questionnaire to Fire Fighting Departments of 49 Major Cities, 2003)

International Rescue System Institute

A Disaster Response RT Project



(MEXT, 2001)

International Rescue System Institute

DDT (DaiDaiToku) Project

- Special Project for Earthquake Disaster Mitigation in Urban Areas (DaiDaiToku)
  - I. Regional Characterization of the Crust in Metropolitan Areas for Prediction of Strong Ground Motion
  - II. Significant Improvement of Seismic Performance of Structures
  - III. Advanced Disaster Management System
    - 1-3. Simulation-based strategic planning
    - 4. Development of Advanced Robots and Information Systems for Disaster Response
  - IV. Integration of Earthquake Disaster Mitigation Research Results

International Rescue System Institute

DDT Project (Robotics) Overview

- R&D of robots, intelligent sensors, PDA, and human interface to support human search, information collection and transfer for emergency response (such as search and rescue) on large-scale earthquakes
- For example,
  - R&D of technologies of robotic systems for effective victim search and information collection in hazardous disaster environments
  - It contributes search and information collection in/under collapsed buildings and underground malls, and prevention of secondary damage of firefighters.
  - R&D of technologies of robots, PDA, and distributed sensors for collection and integration of disaster information to support realtime decision in emergency
  - It contributes realtime mapping of disaster information for monitoring disaster conditions, simulation of damage propagations, and emergency decision support.

International Rescue System Institute

Earthquake Disaster Site and Robotic Solution

Tokachi-Oki Earthquake, 2003/10

Robot Training, 2003/9

International Rescue System Institute

Research Themes (FY2002)

- Sensing Group
  - Methods of sensing, sensors, sensory systems
- Mobile Mechanism Group
  - Mechanisms to move in/on rubble piles
- Aero Robot Group
  - Helicopters
- Information Collection Group
  - Data carriers, balloons
- Environmental Mapping Group
  - Mapping, sensor integration
- Human Interface Group
  - Information display, teleoperation, mapping

International Rescue System Institute

Research Themes (FY2003)

- Sensing Group
  - Sensing methods, sensors, sensor systems
- Mobile Mechanism Group
  - Mobility on rubble piles
- Serpentine Mechanism Group
  - Snake-type robots in rubble piles
- Mapping Group
  - Environment modeling, sensor integration
- Human Interface Group
  - Information display, teleoperation, mapping
- Global Information Collection Group
  - Aero robots, cable robot, distributed sensing

International Rescue System Institute

International Rescue System Institute

- Mission:
  Research, development, spread, their support, international collaboration for advanced emergency response systems to contribute advancement and popularization of science, technology and academy, and for realization of the safe secure social system
- Current Main Works
  - MEXT, DDT Project (Development of Advanced Robots and Information Systems for Disaster Response)
  - Kanagawa Prefecture, Planning of International Rescue Complex
- Organization

  President / Kobe Lab. Leader: Prof. Satoshi Tadokoro
  Trustee Chairman: Dr. Hiroaki Kitano
  Kawasaki Lab. Leader: Prof. Fumitoshi Matsuno
  Secretary General / Solution G Leader: Mr. Shu Ishiguro

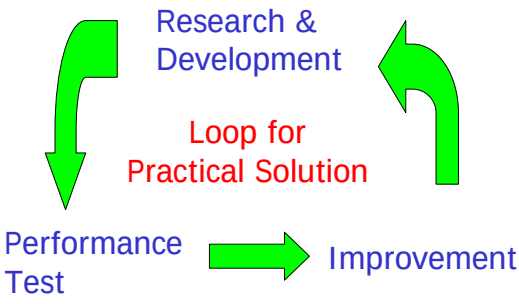
Kawasaki Lab.
(Tokyo Area)

Kobe Lab.
(Osaka/Kyoto/Kobe Area)

International Rescue System Institute

Test-Field-Based Development

- Research and development by repetitive testing and improvement using test field
  - Test of elementary technologies
    Kobe 2002 Field
  - Synthetic Test
    Kobe 2003 Field
    Kawasaki 2002 Field



International Rescue System Institute

Kobe Laboratory & Field

-Reality
-Variety
-Reconfigurability
-Observability
-Reproductibity

- Osaka/Kyoto/Kobe area
- Field: 200m^2

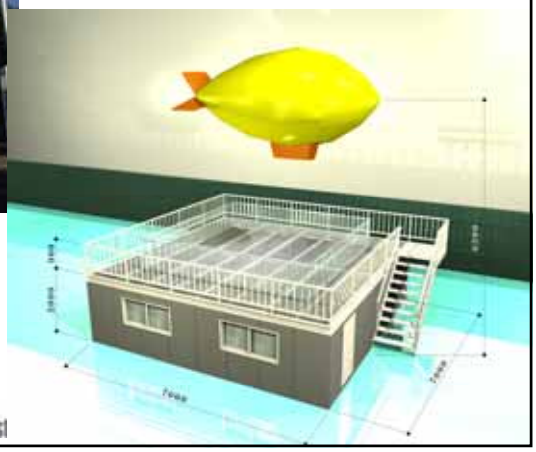
Kobe Field

International Rescue System Institute

Kawasaki Laboratory & Field

Kawasaki Laboratory
(NIED/EDM & IRS)

- Tokyo area
- Field: 320m^2



Kawasaki Field

International Rescue System Inst

RoboCupRescue Robot League

Melbourne: August 2000
demonstration
Seattle: August 2001
with AAAI
Fukuoka: June 2002
8 groups + 3 demos
Padova: July 2003
12 groups
more sensor info.
mobility, intelligence
more difficult field
Lisbon: July 2004

Real Deployment to NY WTC

International Rescue System Institute

RoboCupRescue Vision

When disaster happens, minimize risk to search and rescue personnel while increasing victim survival rates by fielding teams of collaborative robots, which can:

- Autonomously negotiate compromised and collapsed structures
- Find victims and ascertain their conditions
- Produce practical maps of their locations
- Deliver sustenance and communications
- Identify hazards
- Provide structural shoring

...allowing human rescuers to quickly locate and extract victims.

International Rescue System Institute

RoboCupRescue Scenario

A building has partially collapsed due to earthquake.

The Incident Commander in charge of rescue operations at the disaster scene, fearing secondary collapses from aftershocks, has asked for teams of robots to immediately search the interior of the building for victims.

The mission for the robots and their operators is to find victims, determine their situation, state, and location, and then report back their findings in a map of the building and a victim found data sheet.

The section near the building entrance appears relatively intact while the interior of the structure exhibits increasing degrees of collapse. Robots must negotiate the lightly damaged areas prior to encountering more challenging obstacles and rubble.

The robots are considered expendable in case of difficulty.

International Rescue System Institute

2003 RoboCupRescue Robots

Participants of RoboCupRescue Robot League 2003

ROBRNO, The 2003 Champion

International Rescue System Institute

Clips in RoboCupRescue

Robots in Orange Field

International Rescue System Institute

1ST PLACE TEAM: ROBRNO (CZECH REPUBLIC)

International Rescue System Institute

DDT Project Groups

- Global-Aero Robots (Helicopters)
  - global surveillance (< some km) for information collection at the initial state of incidents
- Local-Aero Robots (Balloons, Cable Robots)
  - local surveillance from sky (< 200 m) for victim search and support of ground vehicles as the second deployment
- On-Rubble Robots (Crawlers, Wheels, Jumping)
  - local surveillance on the rubble pile (< 50 m) for victim search and environmental check such as Hazmat
- In-Rubble Robots (Serpentine, Crawlers, Sensor balls)
  - local information collection in the rubble pile (< 30 m) for victim search and environmental check
- Underground Robots (Wheels)
  - local surveillance in underground structures (< 200 m) for victim search and environmental check
- Infrastructure
  - global information collection (> 10 km) using ad hoc networks, RF ID tags, air planes, home facilities, etc.
- Field and Evaluation
  - Test field, dummy and evaluation method to test robots developed

International Rescue System Institute

DDT Project Road Map

2002
2003
2004

Trial of Various Technologies Applicable & Development of Effective Element Technologies

2005
2006

Integration of Element Tech.
Development of Practical Prototypes

Core Organization:
International Rescue System Institute

International Rescue System Institute

Serpentine Robots

K. Osuka
(Kobe Univ.)

H. Tsukagoshi
(Tokyo Inst. Tech.)

S. Hirose
(Tokyo Inst. Tech.)

International Rescue System Institute

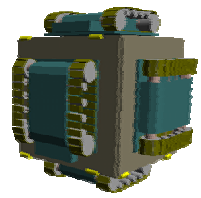
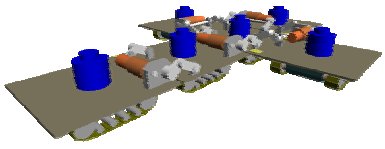
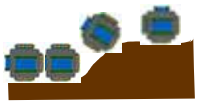
Jumping Robot




H. Tsukagoshi
(Tokyo Inst.
Tech.)

International Rescue System Institute

Folding Mobile Mechanism




A. Inaba (Gifu Pref. Lab.)
H. Amano (Fire Research Institute)

International Rescue System Institute

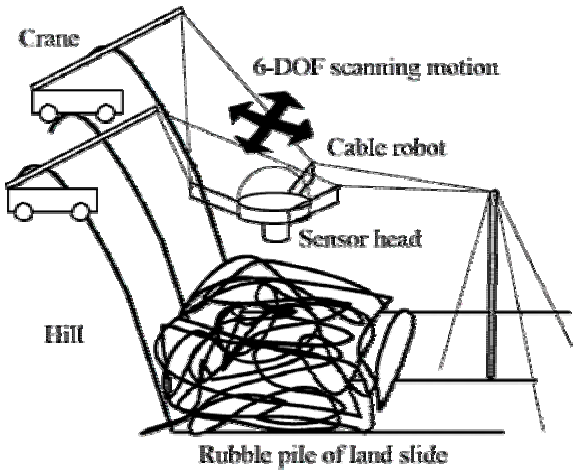
Aero Robot

Nakanishi (Kyoto U)

International Rescue System Institute

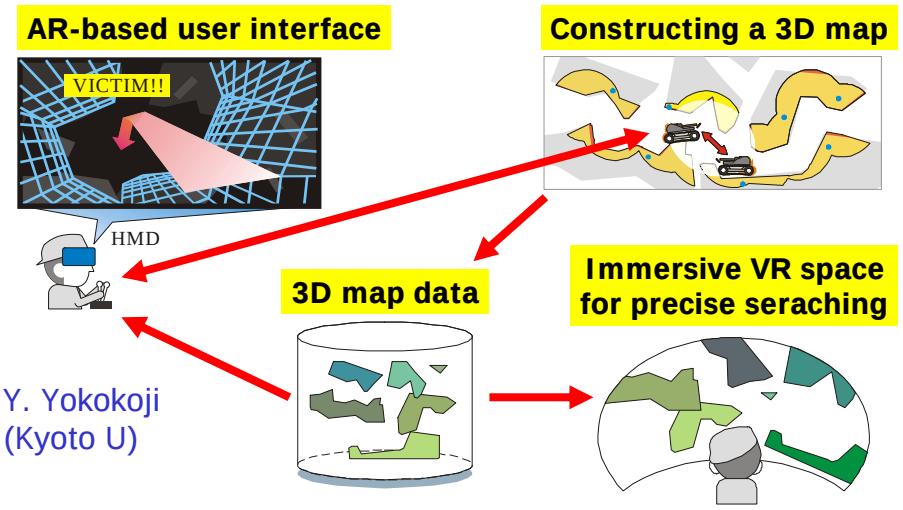
Cable Robot for Search

S. Tadokoro (Kobe U)



International Rescue System Institute

Augmented Reality Human Interface



Y. Yokokoji
(Kyoto U)

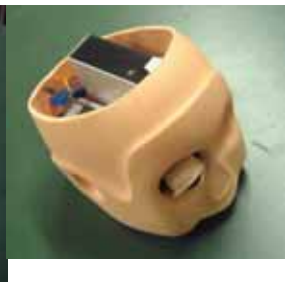
International Rescue System Institute

Balloon for Information Acquisition

M. Onosato (Hokkaido U)

International Rescue System Institute

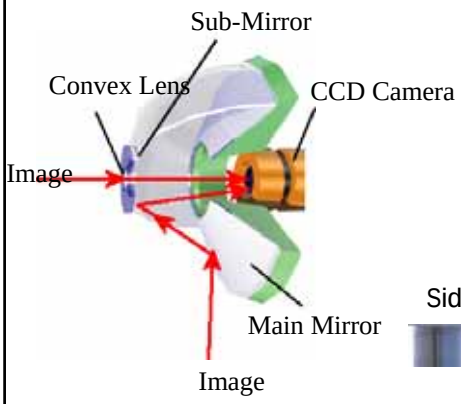
Robotic Dummy for Robot Test



Y. Masutani (Osaka U)

International Rescue System Institute

Omni-Vision



Original CCD Image

Side Image

T. Hashizume (Waseda U)

International Rescue System Institute

Image Processing

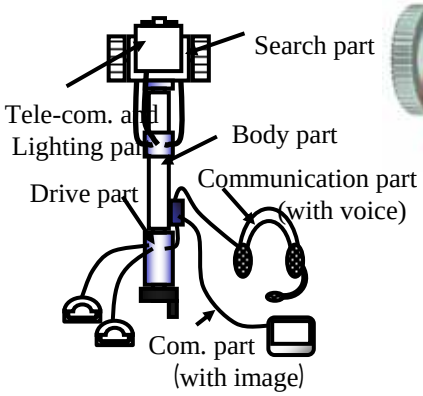
Before

After

K. Miura (Shizuoka U)

International Rescue System Institute

Mobile Tool for Search



T. Doi
(Osaka Pref. College of Tech.)

International Rescue System Institute

Fieldable Power Source

H. Tsukagoshi
(Tokyo Inst. Tech.)

International Rescue System Institute

DDT: A System Integration

NTT DATA

Integration with Robots

SOLEM, Foster Miller

Integration with Human using PDA

Integration with Disaster Response Center

Phoenix, Hyogo Prefecture

Integration with Sensor Network

eTec
Seismometer,
Akashi

International Rescue System Institute

Two Types of Robots & Systems

HIROBO

1. Professional Systems
   - Firefighter, Military, Police
   - High performance
2. Consumer-type Systems
   - Civilian-based preparedness
   - Large number & Distributed system
   - Daily use in normal situation

SOLEM, Foster Miller

PackBot, iRobot

AIBO, SONY

Toyota

Preferred Healthcare

FOMA, NTT DoCoMo

Zaurus, Sharp

eTec

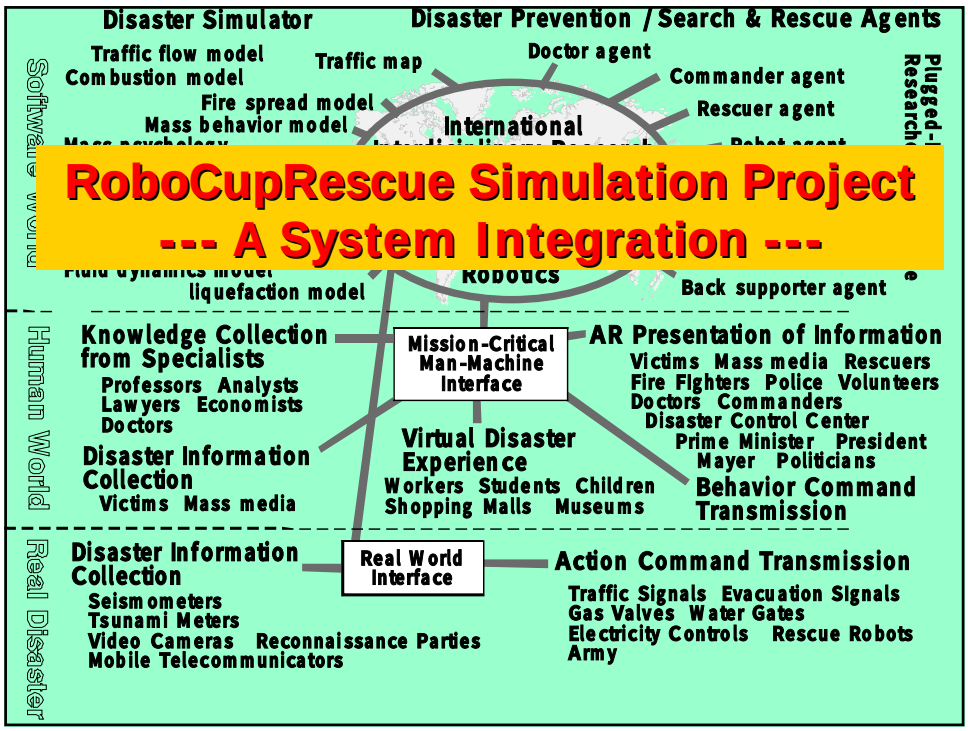
International Rescue System Institute

Robotic System Integration

- Robotic Room:
  Room is a Robotic System
- Do you have any reason to call the mechanical arm a robot, and not to call the bed a robot?
- ITS (Intelligent Transportation System) integrates roads and cars into a type of Robotic System

Robotic Room
(T. Sato, U. Tokyo)

International Rescue System Institute



CCC for Advanced Technologies

Coordination, Collaboration & Continuity

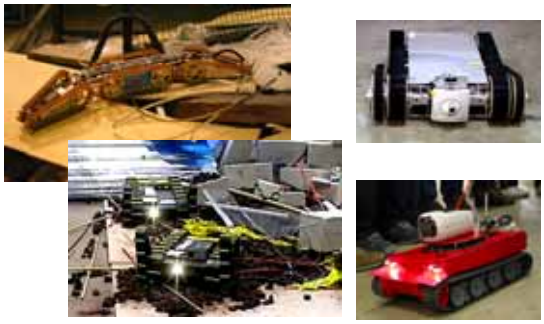
- Coordination
  - Products -- Prototypes -- Development -- Research -- Idea
  - User -- Marketing -- Fabrication -- Development -- Research
  - On-Site Level -- Practical Level -- Prototype Level -- Research Level
  - Specialist Use -- General Use -- Daily Use
- Collaboration
  - Intergovernmental collaboration, Intercity collaboration
  - Inter-university collaboration, Inter-institute collaboration
  - Interdisciplinary collaboration
- Continuity
  - Short-range development --- Long-range research
  - 1 year -- 3 years -- 5 years -- 10 years -- 50 years

International Rescue System Institute

RT (Robot Technology)

Robots and Related Technologies:

Future Advanced Infrastructure for
Safe Secure Social System



International Rescue System Institute

Italy-Japan Cooperation Research

"Post Earthquake Emergency:
Methods, Techniques and Support Instrumentations"

- Program:
  - Executive Program of Cooperation in the Fields of Science and Technology between the Government of Italy and the Government of Japan for the period from 2002 to 2006
- Researchers:
  - DI PILLO Resp. Struttura, NARDI Daniele Resp. Sc., Dipartimento di Informatica e Sistemistica, Università di Roma "La Sapienza"
  - TADOKORO Satoshi, Kobe University, International Rescue System Institute
- Cooperation:
  - (i) Research projects
  - (ii) Exchange of researchers, experts and University professors
  - (iii) Organization of workshops, conferences, seminars, exhibitions and advanced training courses
  - (iv) Establishment of joint research centers
  - (v) Participation to multilateral activities

International Rescue System Institute

International Symposiums and Demonstration

- DDT (Robot) International Symposium
  - January 22-23, 2004
  - The University of Electro-Communications, Tokyo
  - Presentations of the newest R&D results
- IEEE SSRR 2003
  - May 22-23, 2004
  - Bonn, Germany
  - IEEE Robotics & Automation Society, TC on Safety, Security and Rescue Robotics
- DDT (Robot) Demonstration
  - Spring, 2004
  - Demonstration of the newest R&D results

International Rescue System Institute