# Rescue Robotics Challenge


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International Rescue System Institute

International Rescue System Institute

Workshop on Intelligent Systems:
A Festschrift for Richard Volts
2010.4.9

# 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

# Predicted Earthquake Disaster

| | Magnitude | Probability in this 30 years |
|---|---|---|
| Tokai | M8.0 | 87% |
| Nankai | M8.4 | 50% |
| To-Nankai | M8.1 | 60% |
| Nankai + To-Nankai | M8.5 | |
| Miyagi-Oki (Sendai area) | M7.5 | 99% |

cf. Hanshin Awaji (Kobe): M7.3

(Cabinet Office, Central Disaster Prevention Committee)

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

(out of 49)

- CBRNE Disaster
  - Identification of CBRNE materials by sensors 39
  - Transfer of victims to safe area 30
  - Removal of CBRNE 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)

# Expected Functions of Robots

- Contribution of Rescue Robots
  - Rescue operations that are impossible by human
  - Prevention of secondary damage of responders
  - Improvement of rapidness

As Good Tools of Human Responders

- Expected Functions of RT
  - Surveillance of overview information
  - Information gathering of hazmat and environmental conditions
  - Search and diagnosis of victims
  - Quantitative investigation of damage
  - Support for recovery
  - Life support at refuge
  - Removal of rubble piles
  - Medical examination and treatment

To Give Sensors Mobility

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# Japan MEXT DDT Project on Rescue Robots

**2002-2007, PI: Prof. S. Tadokoro, Intl. Rescue System Inst., Budget: US$20M**

## Information Integration

### Protocol and Database

- Protocol standardization (MISP)
- Disaster info. database (DaRuMa)
- Network integration and operation

## Overview Info. Gathering

### Surveillance from Sky

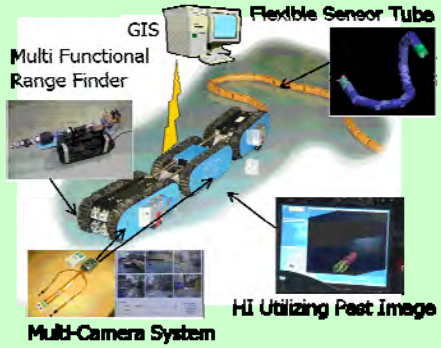
- Small-size helicopter (automatic surveillance)
- InfoBalloon (monitoring from fixed points)

### Distributed Sensors

- Rescue Communicator (victim search sensor)

## Advanced Rescue Instruments

### Surveillance in Rubble Pile

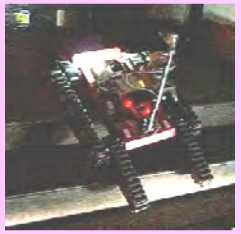



- ActiveScope Camera
- Integrated serpentine robot
- Rescue tools (jacks, search cam, power tools, etc.)
- Wireless triage tag (for rescue logistics)

### Surveillance in Underground

- Integrated UGV
- Connected mobile mechanism
- Jumping robot
- Human interface for teleop. (virtual bird-eye view, 3D map, standardization, etc.)
- UWB human body sensor
- Adhoc network

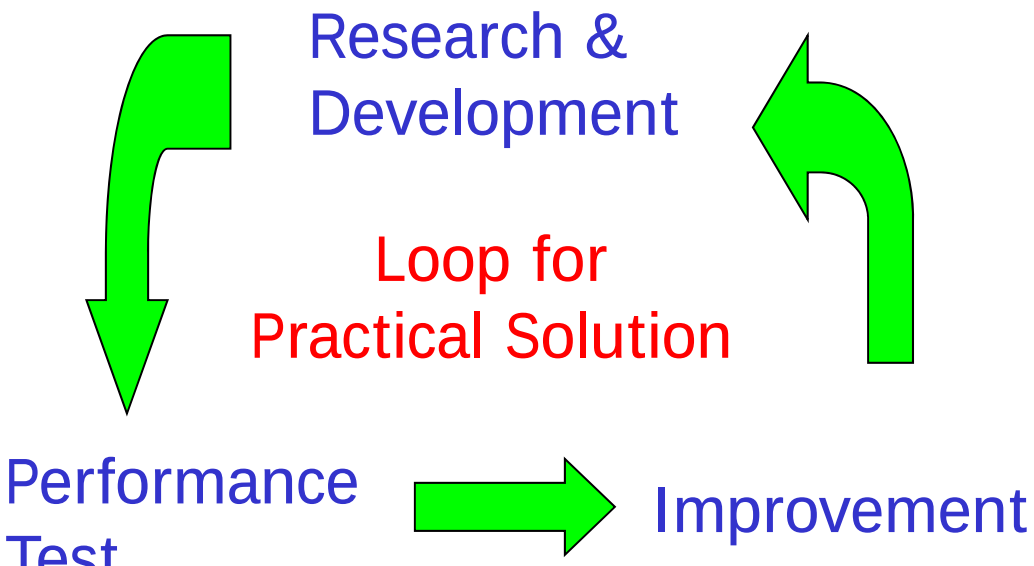
## Verification, Training, Demonstration



- Tokyo FD training site
- Niigata Chuetsu EQ.
- JICA Intl. Rescue training
- FEMA training site
- Collapsed House Simulation Facility in Kobe Lab.
- Firefighters unit, IRS-U

# Field+User-Based Development

- Collapsed House Simulation Facility (2003-2007)
  - Research and development by repetitive testing and improvement using test field
- IRS-U (2006-)
  - Volunteer responder corp
  - Captain: Mr. Kenichi Makabe
  - Feedback to research



# Active Scope Camera for Search in Confined Space

Video Scope with Active Surface

(Oct.3, 2006 @ Intl. Disaster Relief Team Exercise)

(Tadokoro, Tohoku U)

Search in 3 cm gap

(Intl. Rescue System Inst. Kobe Lab., Collapsed House Simulation Facility)

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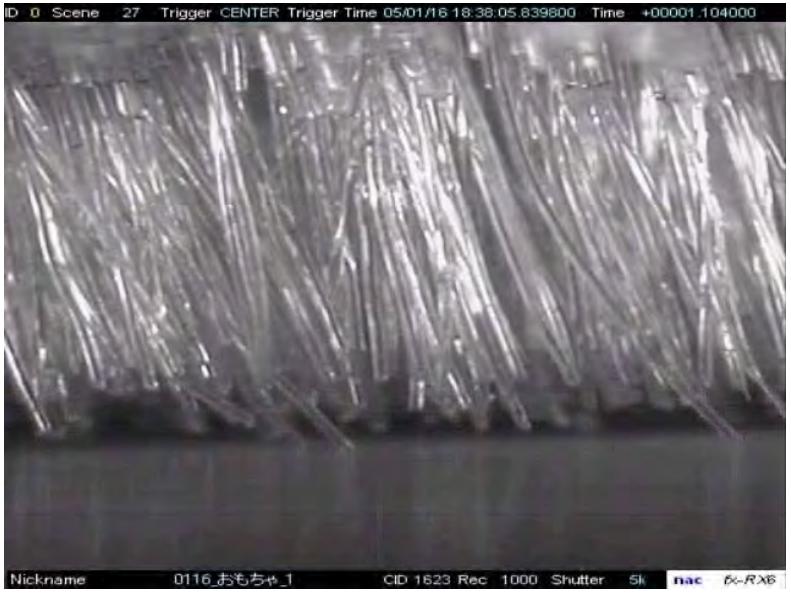
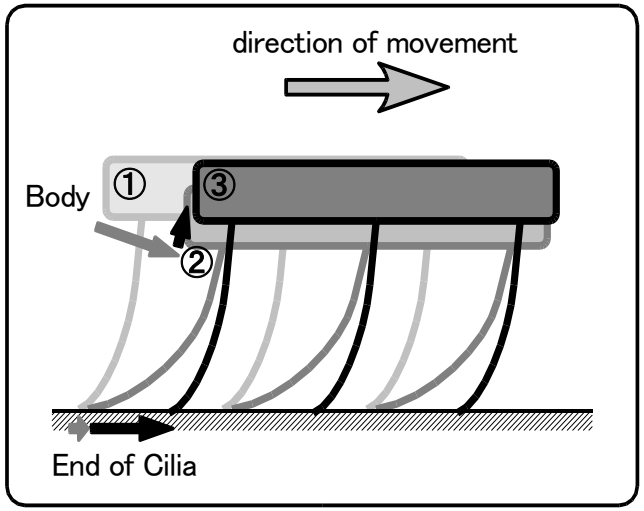
# Ciliary Vibration Drive Mechanism

- Principle of Motion

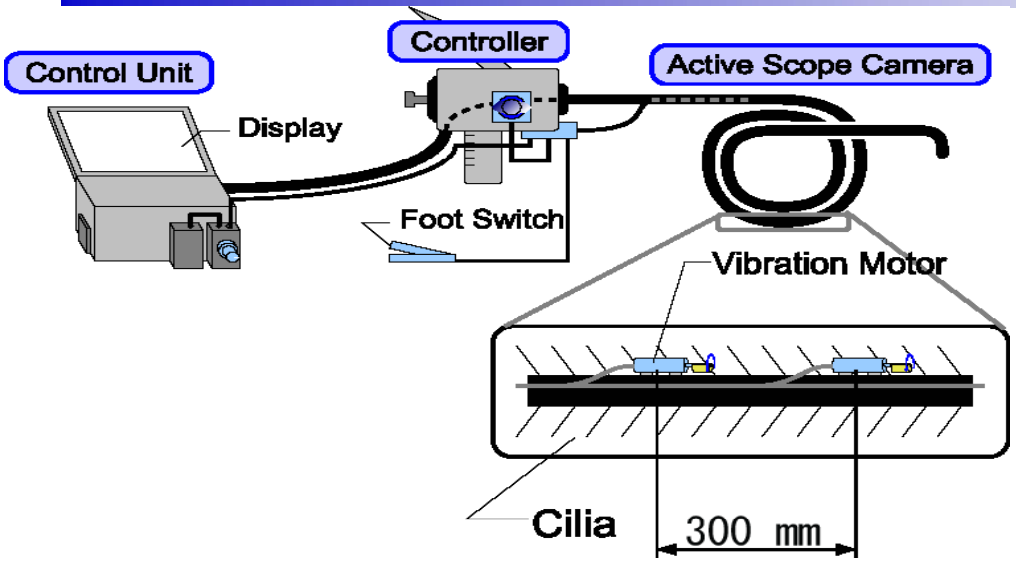
[Actuator2006, IROS2006]

  - Drive by reaction force produced by pressing inclined cilia using vibration
  - Tips of cilia repetitively stick and slip



# Active Scope Camera [IROS2007]





Actuation by the whole surface

Change the direction of motion

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# Active Scope Camera

- Advantages
  - Cable penetrates deep into debris by distributed actuators.
  - Horizontal insertion is possible as well as vertical insertion.
  - Direction of cable motion is controllable.
  - Cable can avoid or get over obstacles 20 cm high (max).
  - Cable can climb slopes 20 deg. (max).
  - Cable are pulled out smoothly and seldom gets stuck.
- Evaluation by Sam Stover (FEMA US&R IN-TF1 Search Team Manager, CRASAR)
  - Operated Active Scope Camera at the site
  - Effective also for searching victims in collapsed structures
  - Expects deployment ASAP

# Disaster City, FEMA TX-TF1 Training Site


World-largest simulated disaster situations for training of Urban Search and Rescue (USAR)

Victim Search in Trains

Search under Train


Search in Drain Pipe

Search through Small Hole

Search in RC Rubble Pile

# ActiveScope Camera

@ FEMA Texas TF1 Training Site
Disaster City, 6/18-22/2007

Negotiation with Obstacles

(Tadokoro, Tohoku U)

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# ActiveScope Camera

@ FEMA Texas
TF1 Training Site
Disaster City
6/18-22/2007

(Tadokoro, Tohoku U)

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The New York Times June 25, 2007

Jessica Kourkounis for The New York Times

Satoshi Tadokoro operates the Active Scope Camera, an optic robot that inches along like a snake.

NHK Morning Show 1/16/2007


# ActiveScope Camera

New York Times 6/25/2007

(Tadokoro, Tohoku U)

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# Construction Site Collapse

- Berkman Plaza II Parking Garage, Jacksonville, FL, USA
- Dec. 6, 2007  Collapse when workers were pouring concrete on the top floor
- 1 death, 23 injury
- Forensic investigation: OSHA, owner, developer, contractor, sub-contractors
- Fiber scopes, robots, etc. could NOT penetrate deep into the debris.

# Deployment at Construction Site Collapse

- Dec. 12, 2007 Call-out of Active Scope Camera
- Jan. 4-5, 2008 Investigation by Active Scope Camera
- Responders Team
  - Prof. Satoshi Tadokoro (Grad. School of Info. Sci., Tohoku U.): inventor, instruction, operation, recording
  - Prof. Toshihiko Nishimura (US Office, Tohoku U.): MD, recording
  - Prof. Osachika Tanimoto (SFO Center, Osaka U.): structural collapse specialist
  - Mr. Sam Stover (FEMA IN-TF1 Tech. Search Team Manager, CRASAR USF): operation, safety guidance
  - Prof. Robin Murphy (U. South Florida, Center for Robot Assisted Search and Rescue): recording, HI analysis
  - Mr. Bill Brack (Bracken Eng.): chief investigator, direction
  - Researchers from USF: recording, HI analysis

# Use for Forensic Investigation

- Data Collected at Investigation by Active Scope Camera
  - Movie image of 7 m deep in debris
  - Shape and direction of concrete cracks
  - Shape of concrete flakes, stripped planes
  - Situation of spaces in rubble pile
- Why Good?
  - Compact ----------> can enter narrow gaps
  - Distributed Actuation --> stable robust drive
  - Flexibility ----------> adaptable to complex shapes
  - Controllability ----> search in large spaces in debris
  - Simple ----------> high reliability in disaster situation

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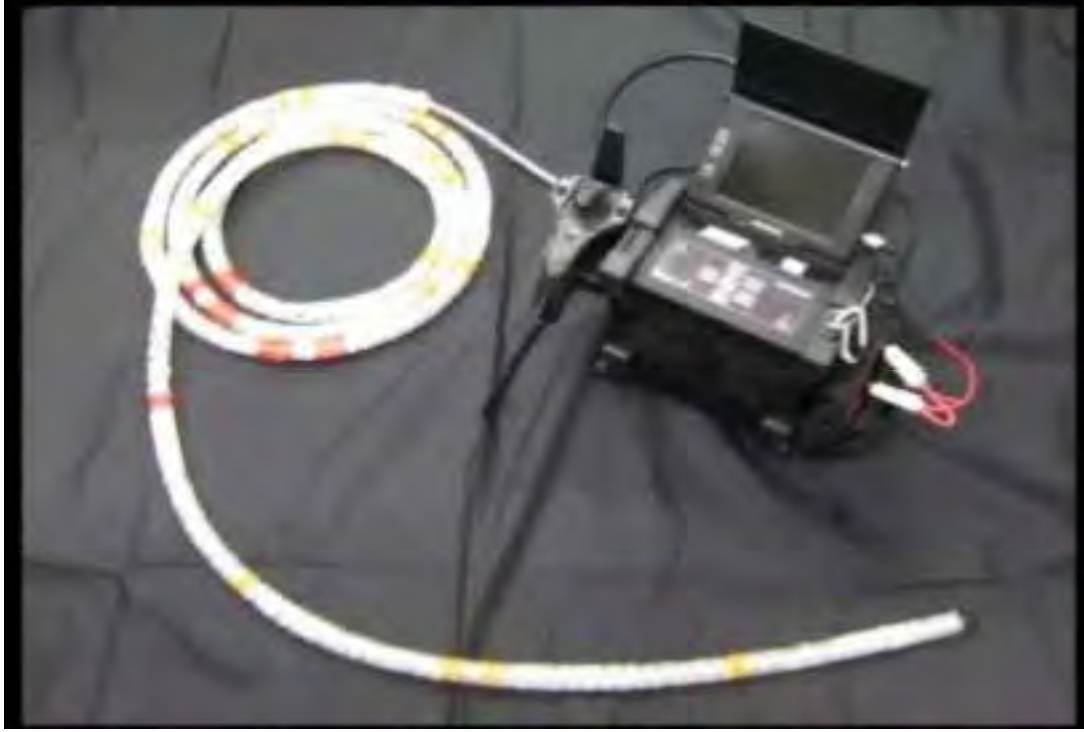
**Major Contribution to Forensic Investigation**
**= Effective in Urban Search and Rescue**

- Removal by construction machines - lose data

# Use at Const. Accident

能動スコープカメラ
(走行性能・実地試験)



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田所研究室

# Cologne Historical Archive Collapse


Germany, March 3, 2009

- Search for 2 victims
- ASC was called out and deployed
- Risk of collapse was too high to operate from top of the rubble pile

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# Letter of Appreciation from Mayer

Der Oberbürgermeister
der Stadt Köln

Professor Dr. Eng Satoshi Tadokoro
Tohoku University
6-6-01 Aramaki Aza Aoba, Aoba-ku
Sendai 980-8679 Japan

Historisches Rathaus, 50667 Köln
Telefon 0221/221-26020, Telefax 0221/221-23384
E-Mail oberbuergermeister@stadt-koeln.de

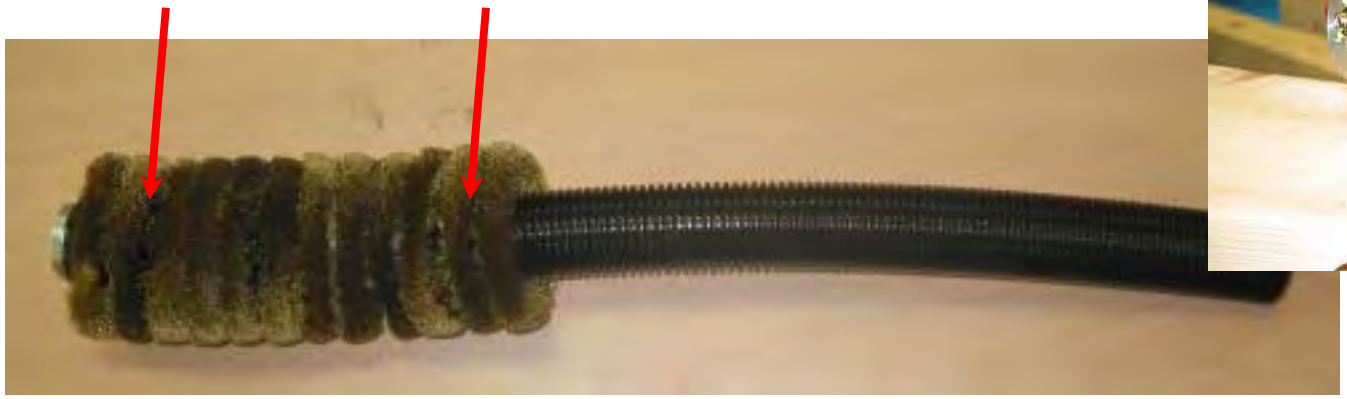
Köln, 16. Oktober 2009

Dear Prof. Tadokoro,

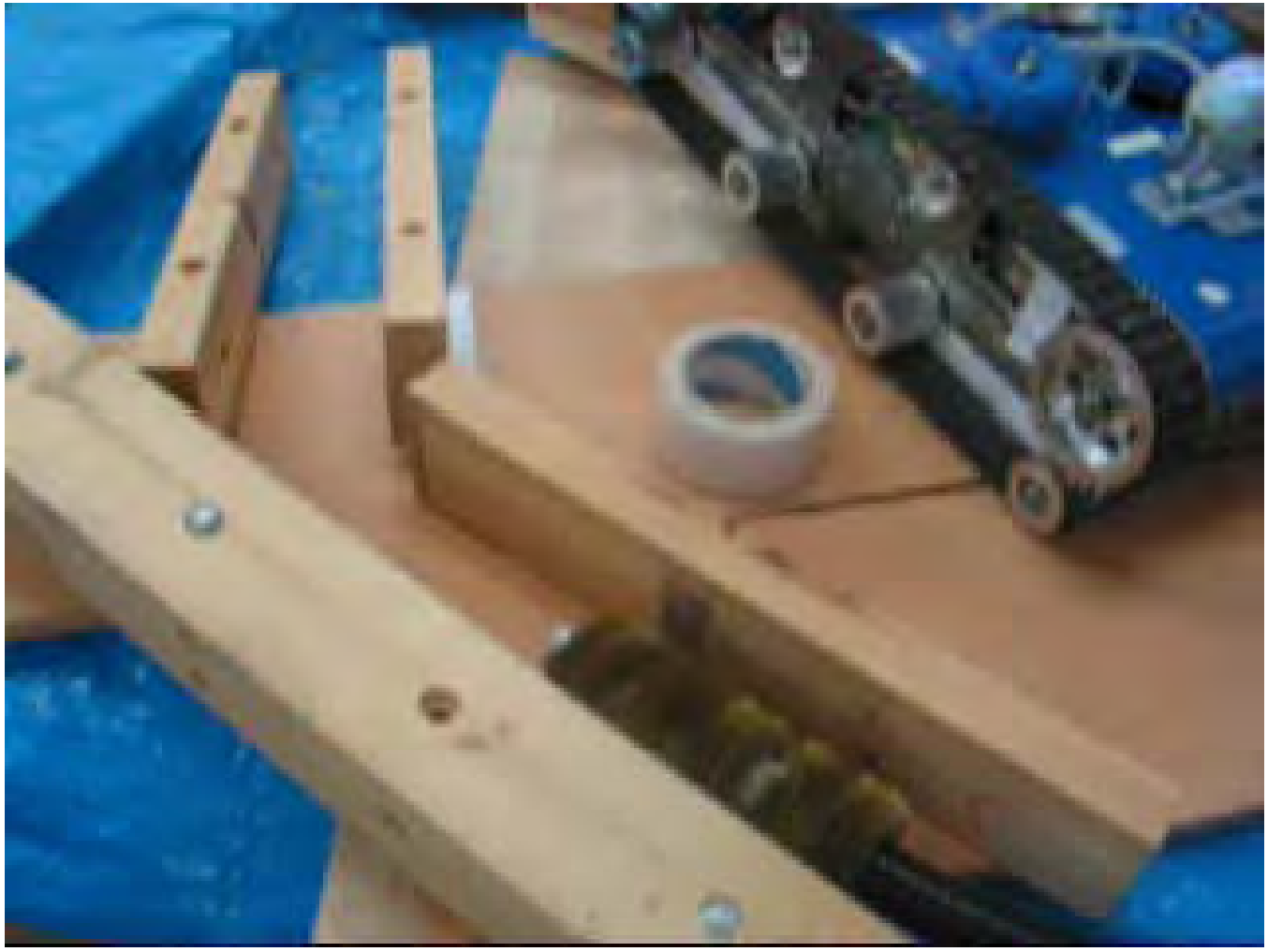
as you are aware, our historical archive suddenly collapsed on March 3rd, 2009. Immediately after its collapse, an unprecedented rescue effort has been initiated. Over the following days, the aim of this rescue mission was to search for the two victims, who have been buried under more than 10.000 tons of rubble, which was a mixture of stone, concrete, and historical papers. One of the two victims was a 17 year old apprentice, who wanted to become a baker, the other one was a 24 year old

# 1st Prototype

- 2 vibration motors, 12 brush rings
- Motor units and cables for bending
- Length of brush: 160 mm, Diameter: 68 mm
- Weight: 1 kg



# Motion of 1st Prototype



# Active Scope Camera

- Technical Future Issues
  - More mobility and operability
  - Wider field of view
  - Position estimation
  - Recording functions
- Non-technical Future Issues
  - Operation methods and guidelines
  - Training
  - More application to real situations
  - Deployment

Testing by IRS-U at Collapsed House Simulation Facility in Kobe

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# NEDO Strategic R&D PJ on Advanced Robot Components
# High-Speed Search Robots for Confined Space

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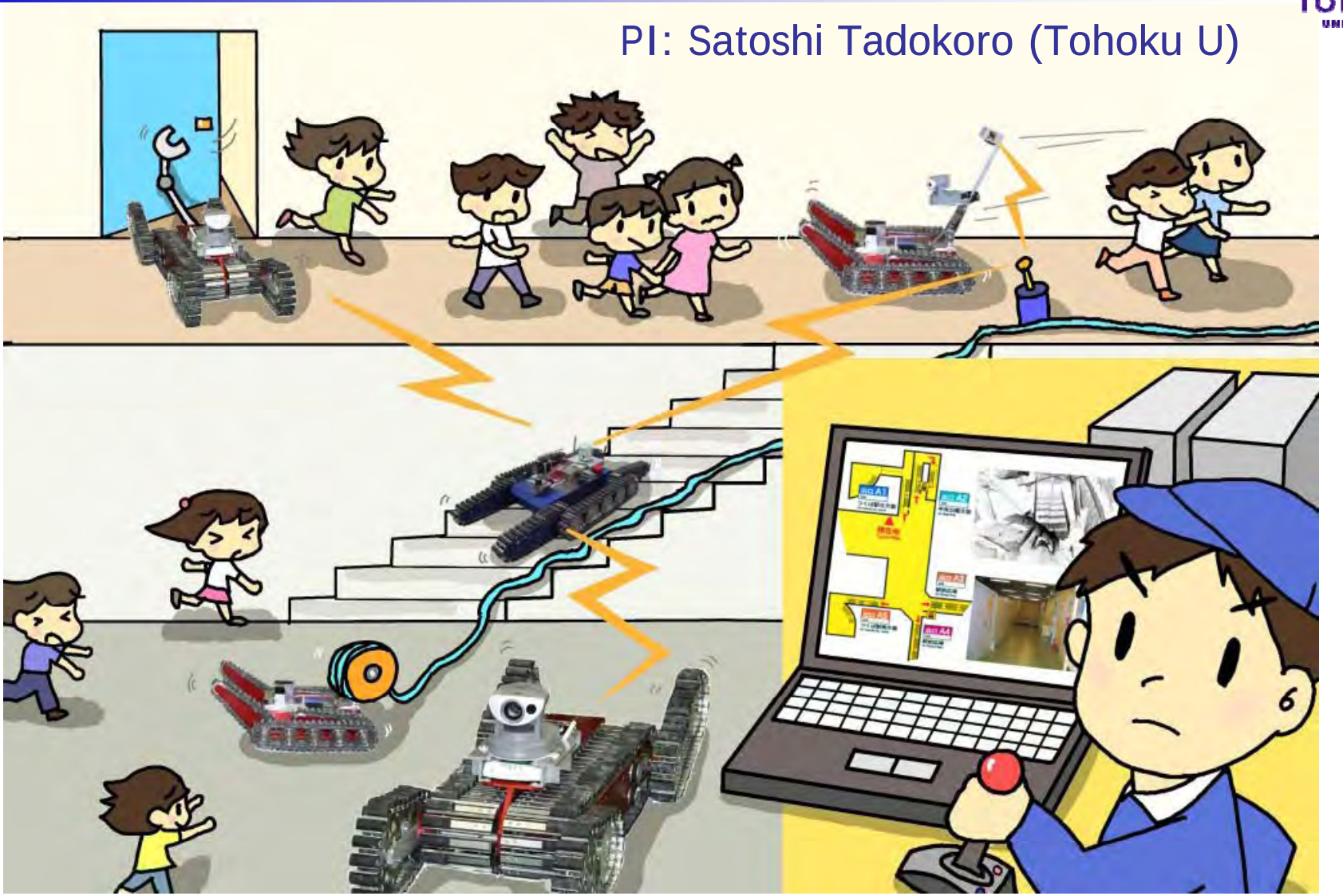
PI: Satoshi Tadokoro (Tohoku U)



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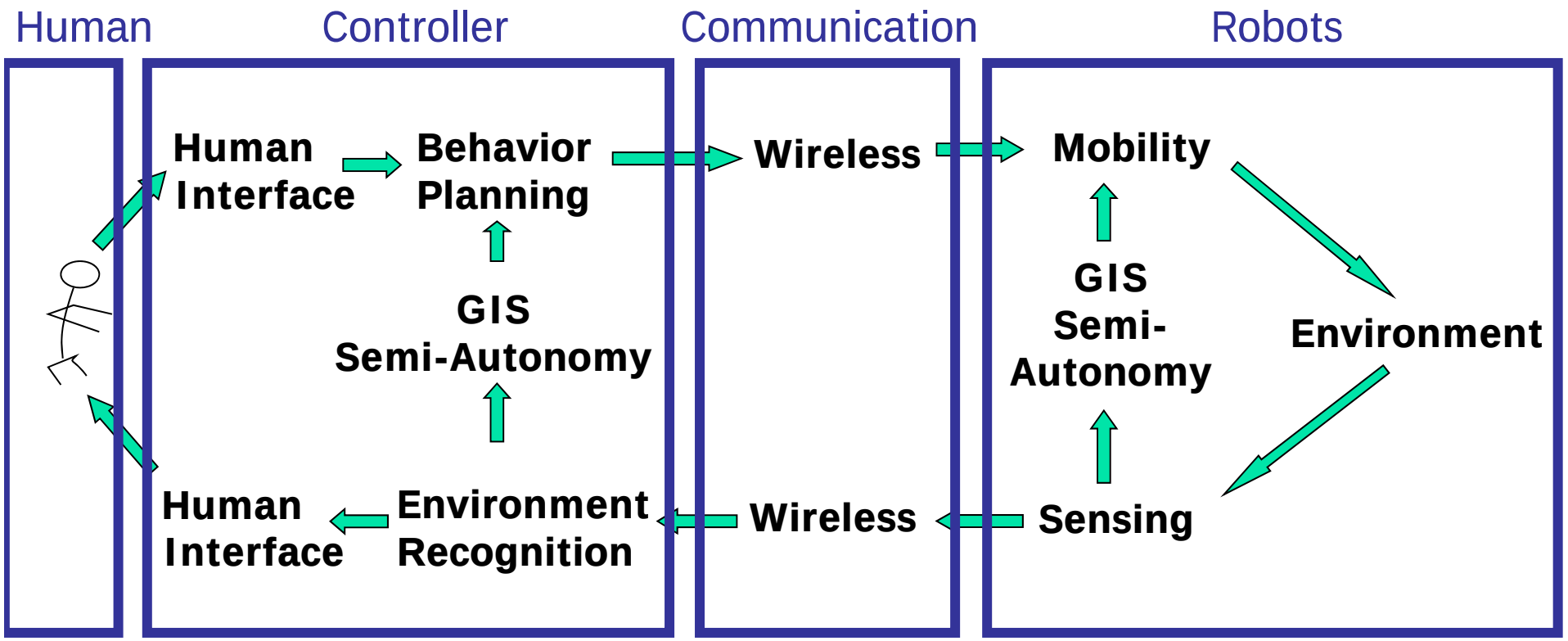
# Technical Problems of Teleoperation



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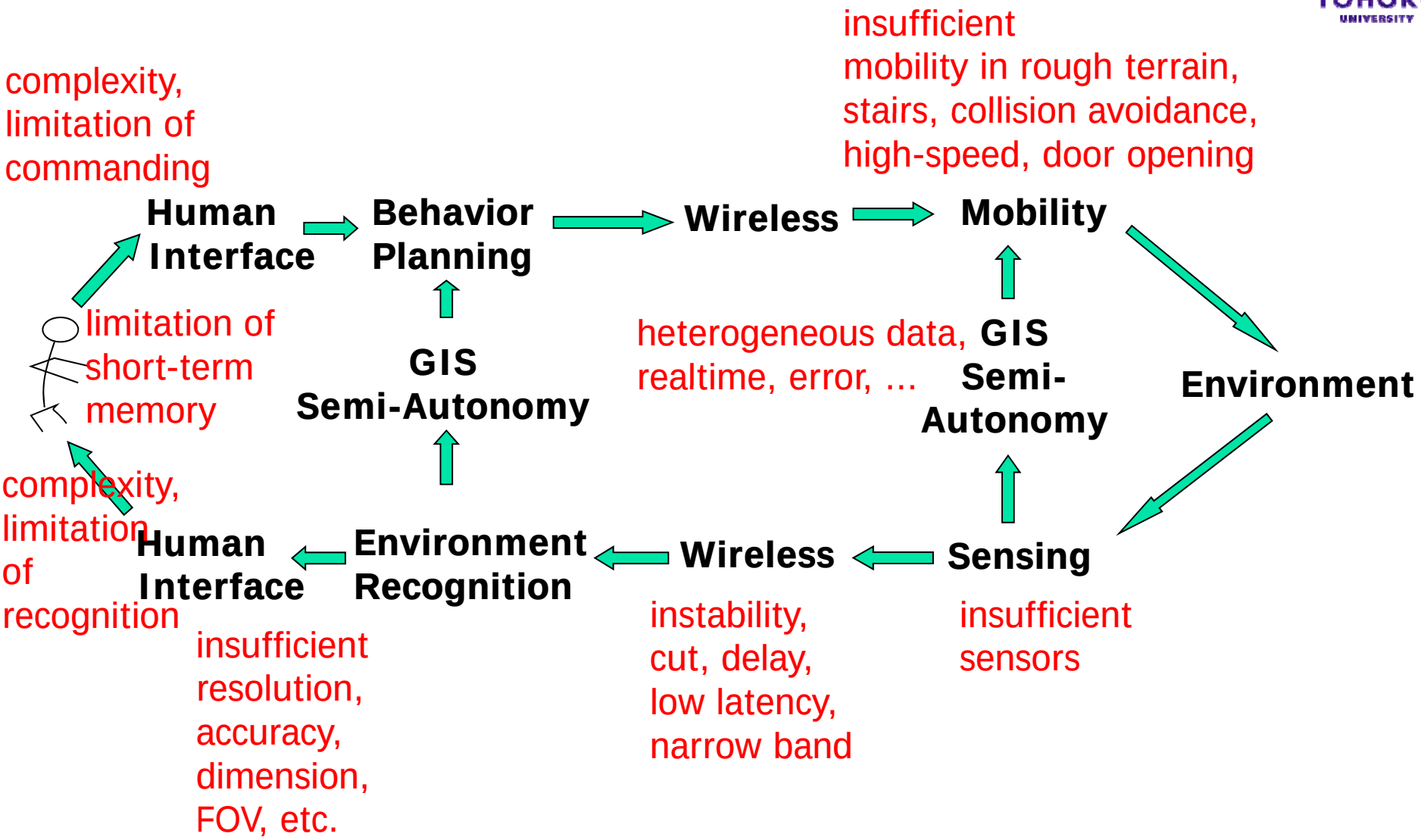
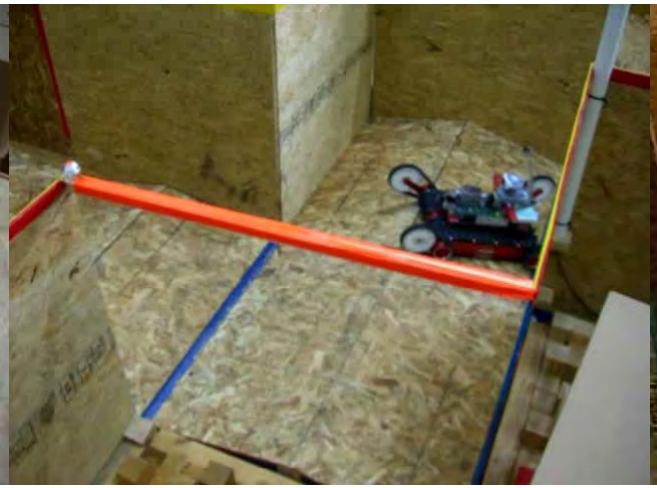
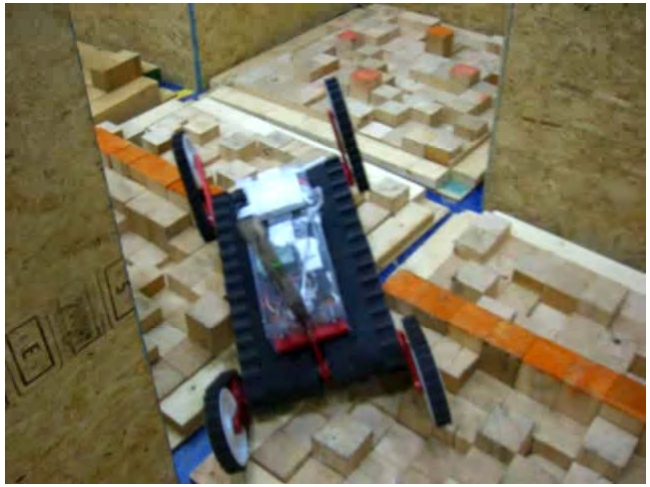


# Kenaf: Mobility Challenge Champion @ RoboCupRescue 2007 Atlanta and 2009 Graz



Kenaf showed the best mobility in the world using the NIST rescue robot evaluation field, which is proposed as international standard by ASTM.

# Rubble Pile Negotiation at Disaster City

Traverse of RC rubble pile (40 m x 40 m)

Traverse of wooden rubble pile (10 m)

Traverse of slope

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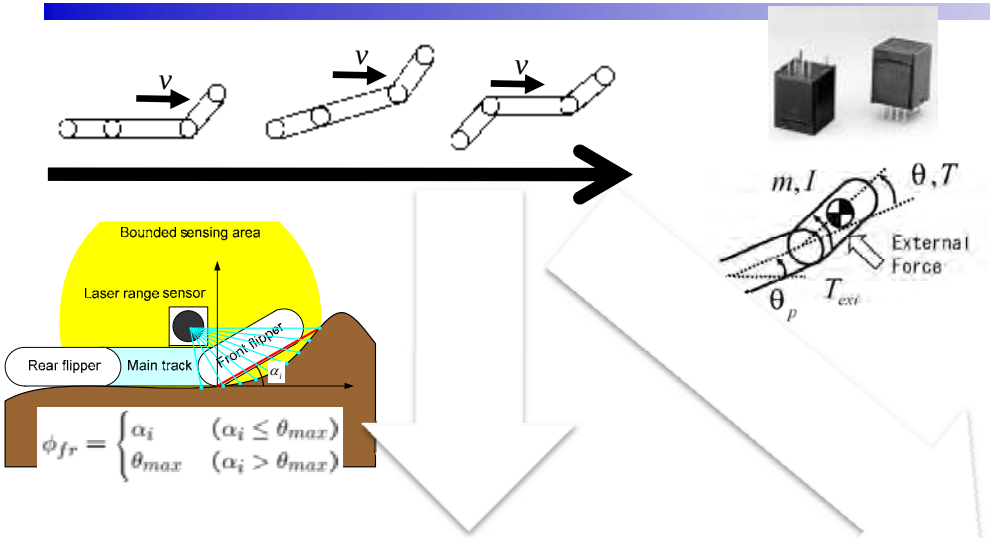
(2008.11.18-20)

# Operator Support by Semi-Autonomy







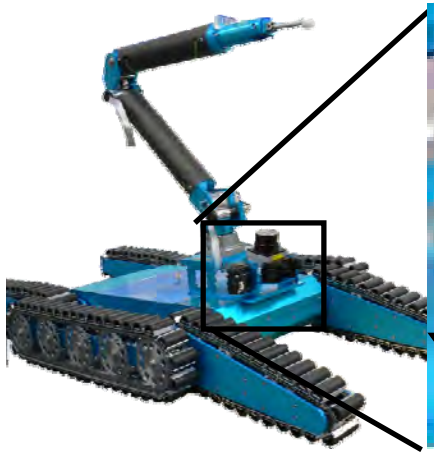


(1) By Using Touch Sensors
+ Distance Sensors

(2) Based on Measurement of
Terrain Shape by Laser Range Finders

# 3D Scanner and 3D Mapping

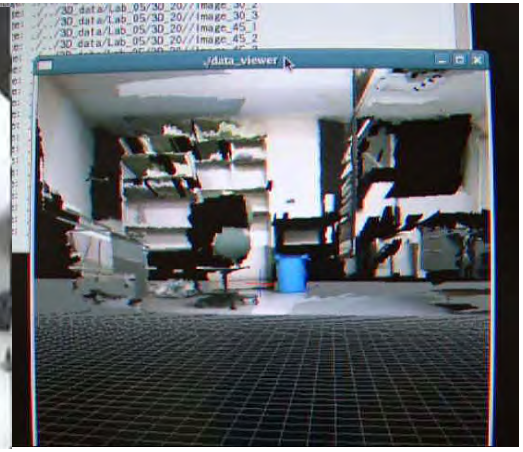
(Ohno, Tadokoro, Tohoku U)



Ali-Baba


3D Scanner

Environment



3D Scan Data

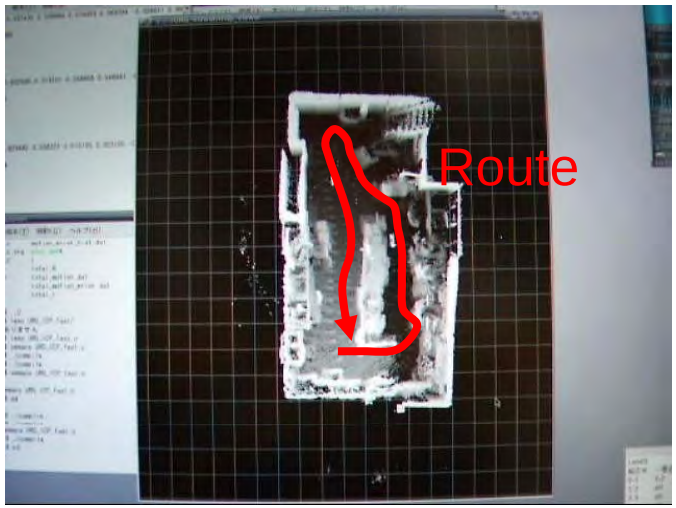
## 3D Scanner

- 2D LRF
- Color Camera

## 3D Scan Match

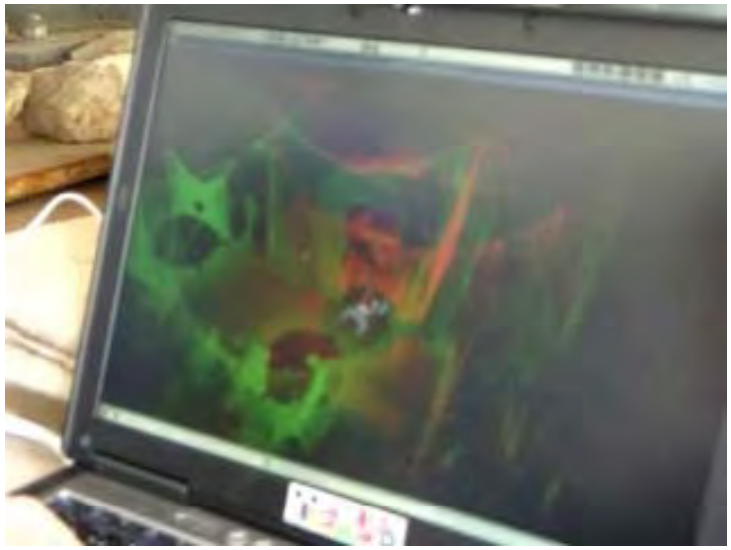
- Fast ICP
- Gravity Condition

Environment




Scan Matching

# 3D Teleoperation Interface @ Disaster City

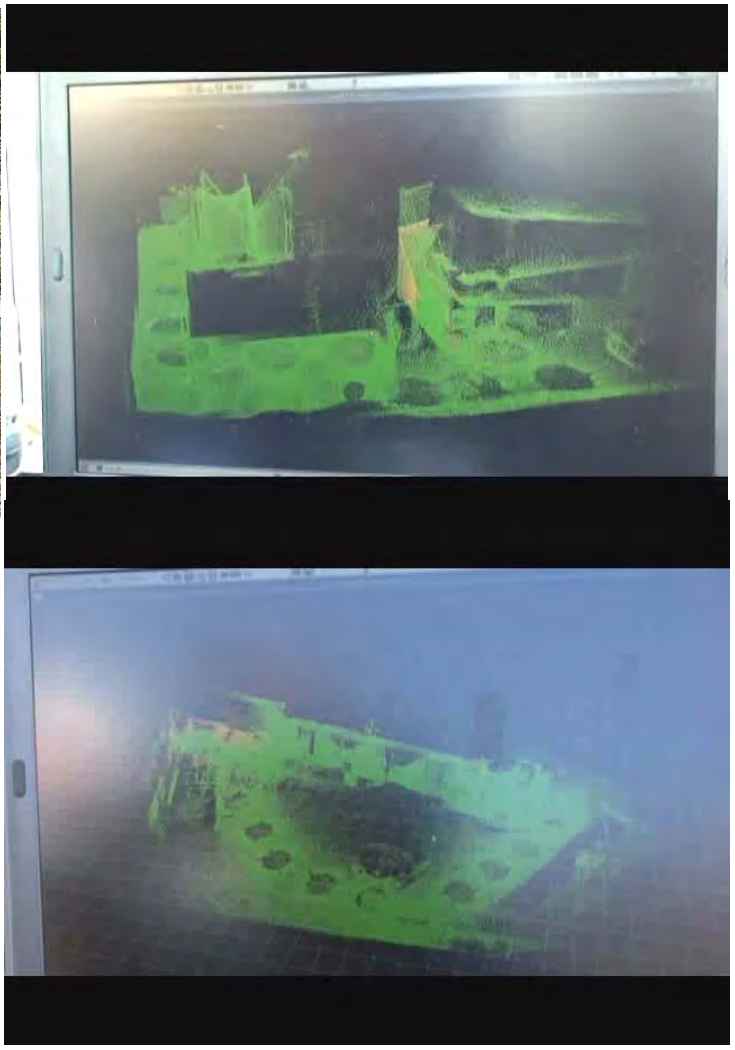


3D interface + semi-autonomous
rubble pile negotiation
in pancake crush structure

cf. 2D maps
are useless

(2008.11.18-20)

# 3D Mapping @ Disaster City



Pancake Crush Building

Train Accident

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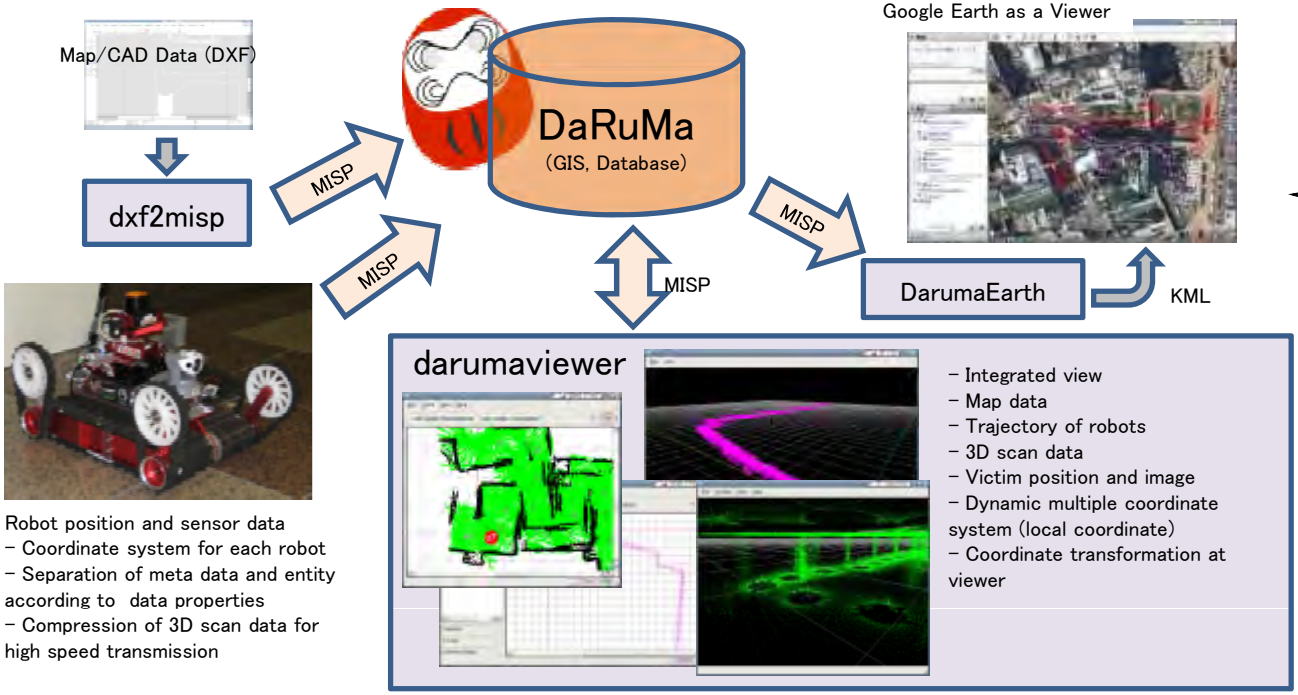
# Integration of Sensor Data from Multiple Robots by GIS

- Technically Important Points
  - General data format, access method
  - Error of locaoization
  - Speed and high-tech func.

MISP + GML

Dynamic multiple coord. systems

Separation of sensor data and meta



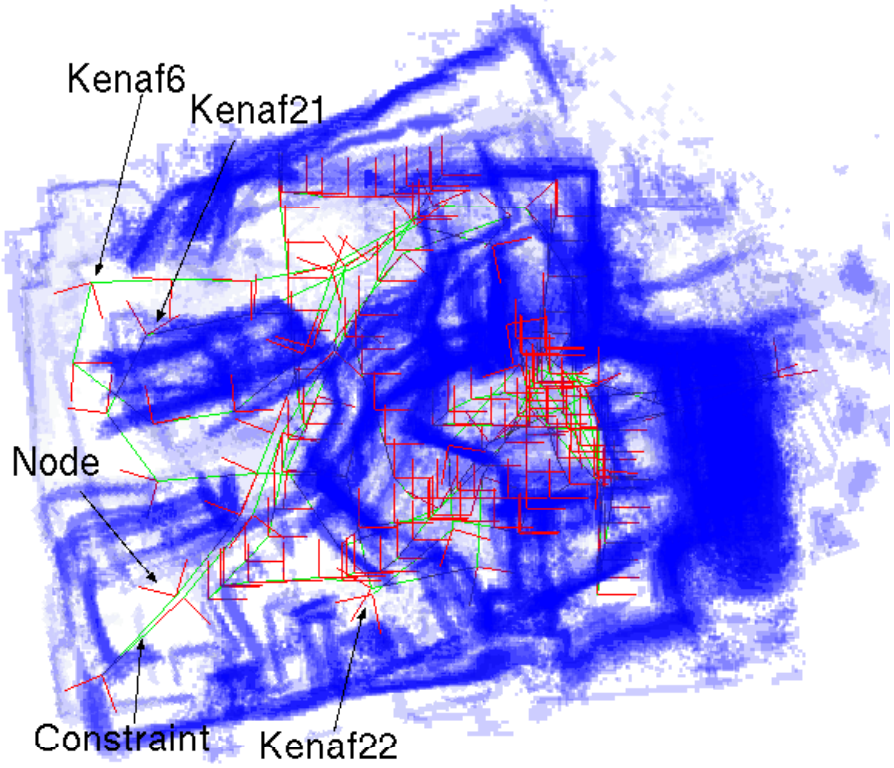

Robot position and sensor data
- Coordinate system for each robot
- Separation of meta data and entity according to data properties
- Compression of 3D scan data for high speed transmission

International Standardization

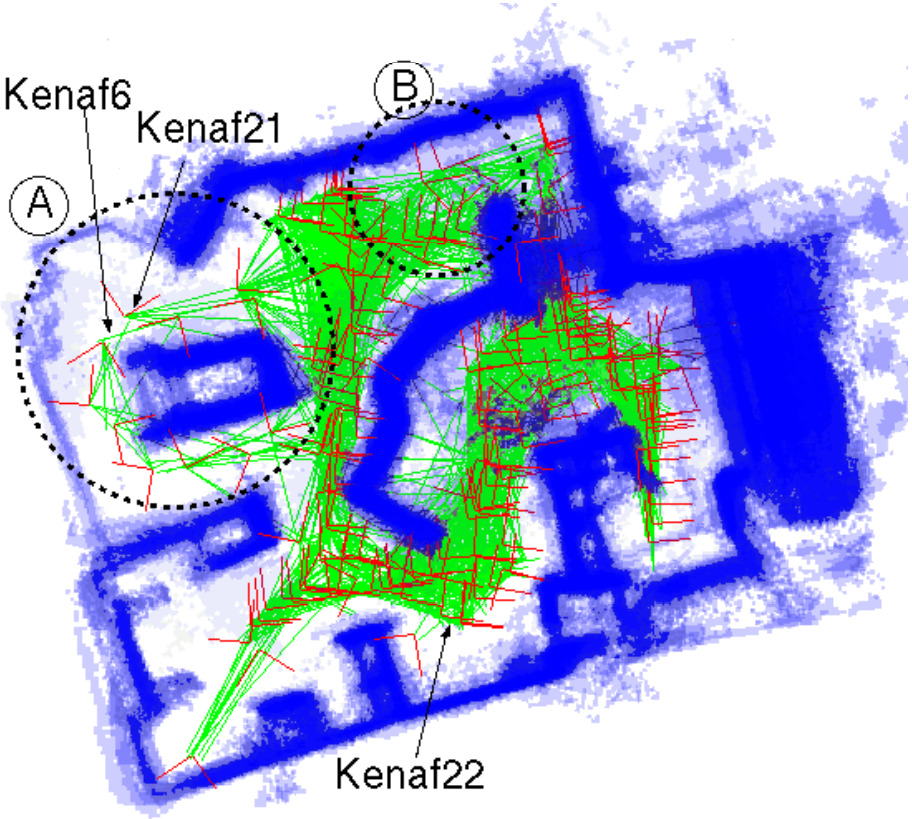
OMG Robotics DTF

Robotic Localization Service

# Mapping by 3 Robots




Raw data from three robots




Corrected map using three robots' data

# Expected Functions of Robots

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As Good Tools of Human Responders

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  - Medical examination and treatment

To Give Sensors Mobility

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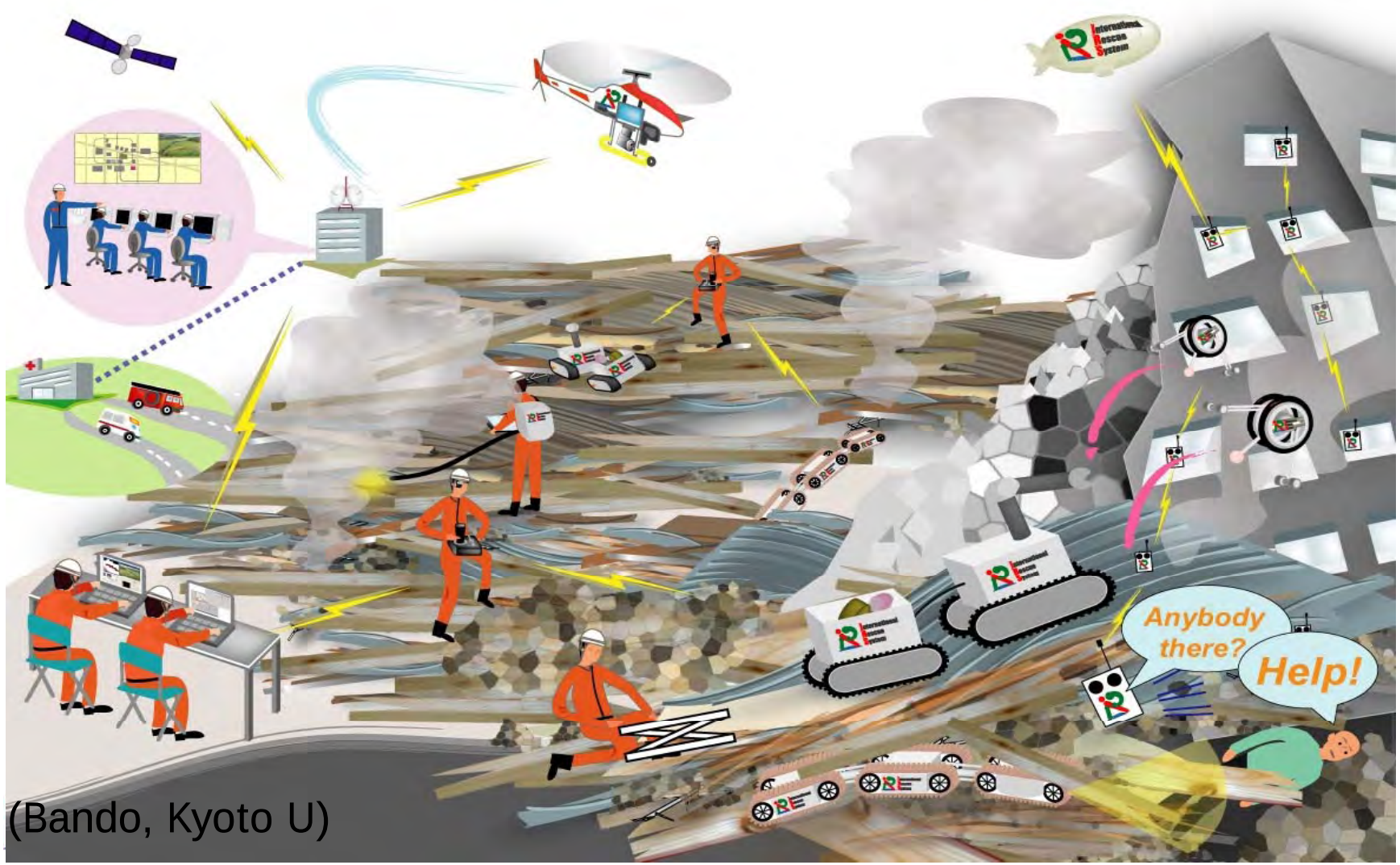
# Future Advanced Infrastructure for Safe Secure Social System




(Bando, Kyoto U)