

Deployment of Robotics to stabilize the accident at Fukushima Daiichi NPS

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4. Conclusion



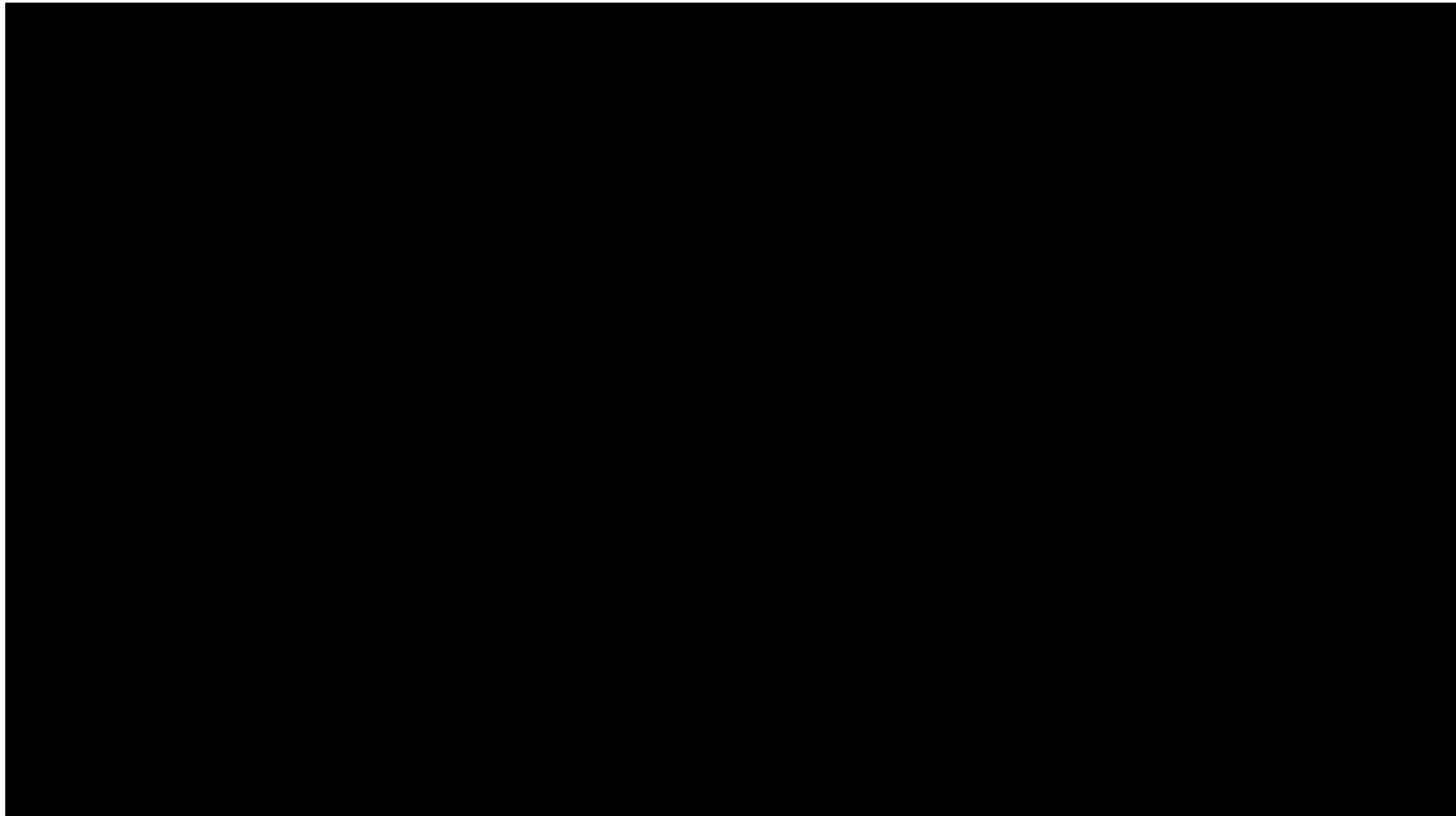
1.1. Overview of Robots Applied for Fukushima Daiichi Site

General presentation video for robotics application:

http://www.tepco.co.jp/en/news/library/archive-e.html?video_uuid=raf8si47&catid=61795



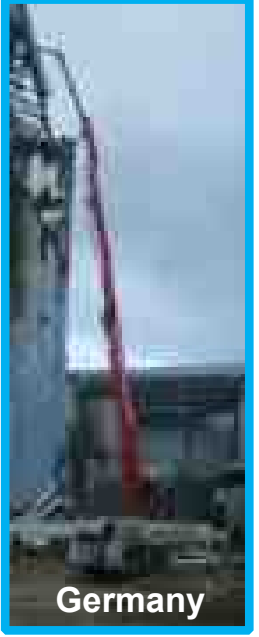
1.1. Overview of Robots Applied for Fukushima Daiichi Site



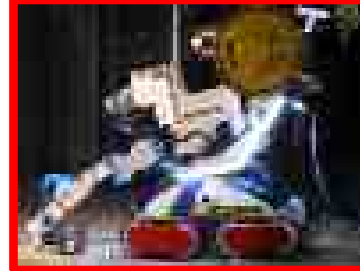
1.2. Robots Introduced to the Fukushima Site

State-of-the-art robotics technologies around the globe applied for:

- Survey (interior appearance, rad. dose, temp., water leakage, ...)
- Decontamination
- Debris Removal
- Emergency Pool Cooling



Pool Cooling



Interior Decontamination & Debris Removal



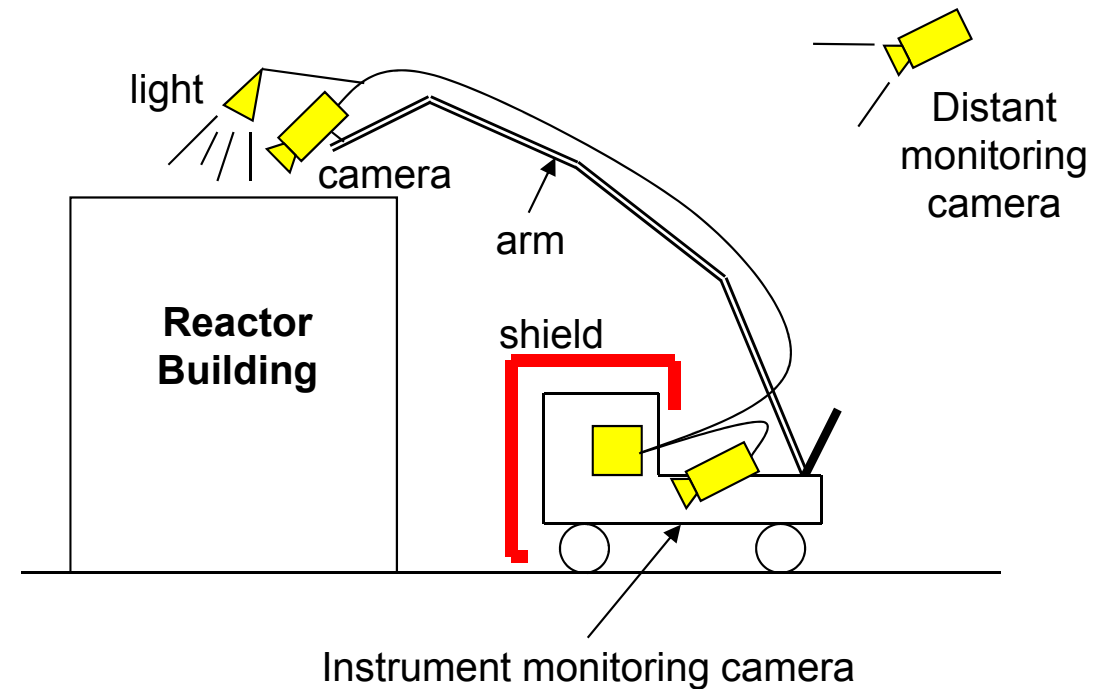
Interior Survey



Yard Operation

2.1. External Activities: Emergency water supply

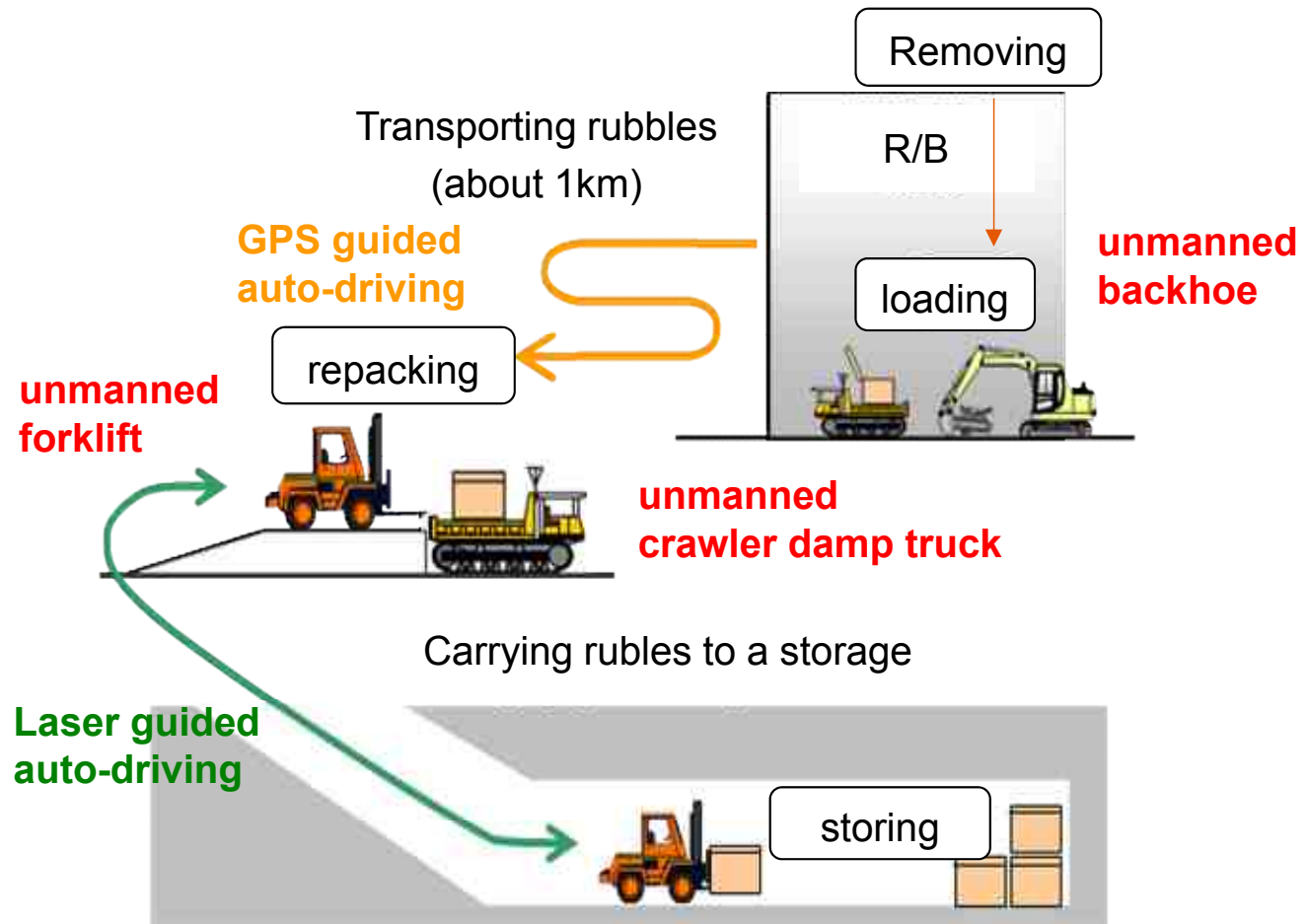
- Modified a concrete pumping vehicle.
- Move an arm to observe pool areas and inject water into a spent fuel pool by remote control
- Stand by for emergency



- Wifi controlled from a distant room
- Operation monitored through webcams

2.2. External Activities: Rubble removal & floor decontamination

- Collect rubbles, reduce volumes, and transport to storages with unmanned devices
- Decontaminate a reactor building top floor with remotely operated choppers/water jet grinders



Unmanned rubble removal and transport

3.1. Robot Operations inside Reactor Buildings in the Early Days

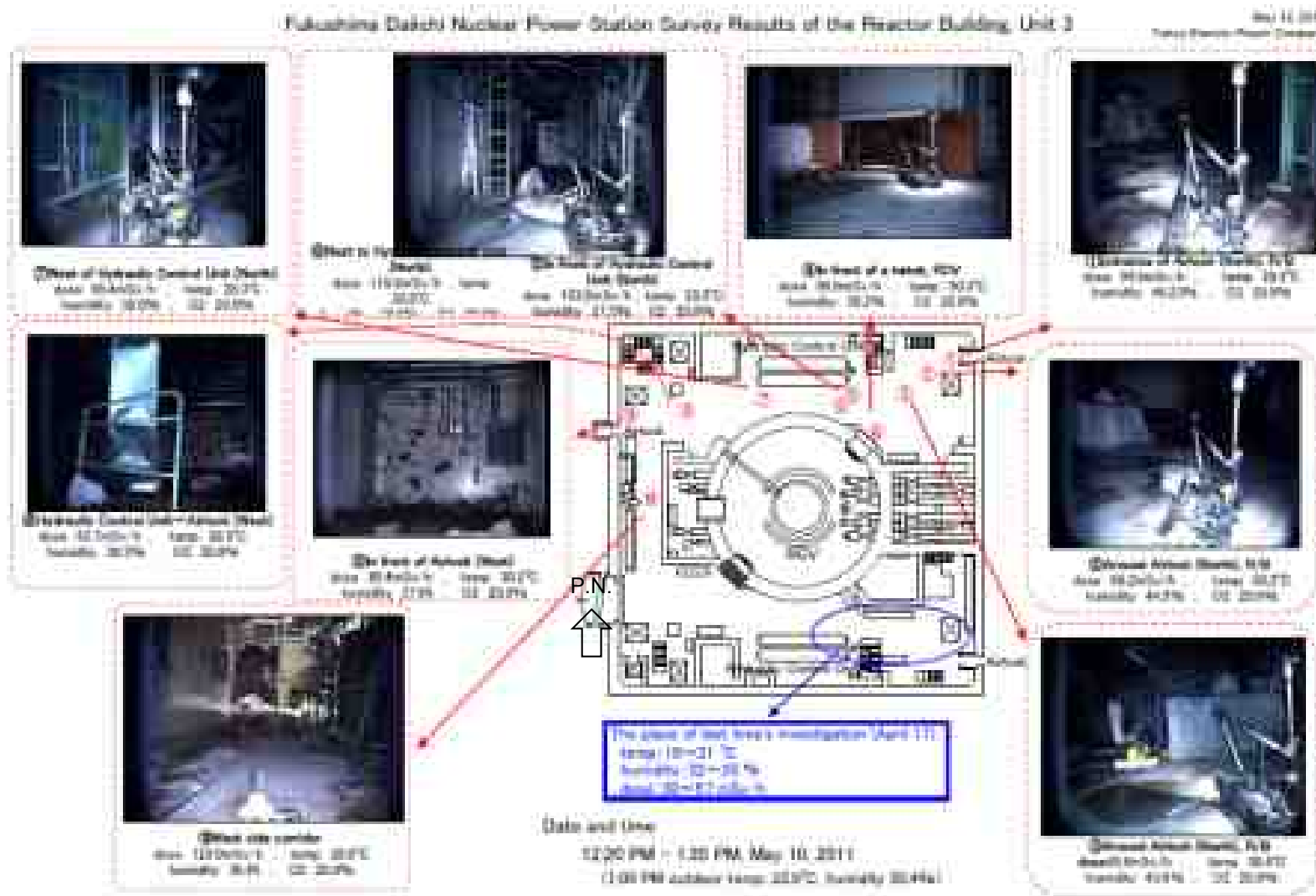
- Just after the accident :Emergency Response
 - No robot operation
- Till cold shutdown: Stabilization
 - Collecting information inside reactor buildings

Robotics R&Ds expanded after the early days...

Date	Unit	Area	robots	notes
3/11/2011		Great East Japan Earthquake		
4/17,18	1,2,3	1FL	<i>PackBot (iRobot)</i>	first robot entry into R/B
7/1	3	1FL	<i>Warrior/PackBot (iRobot)</i>	first clean-up work by robot
7/8	2	3FL	<i>Quince</i> (Chiba Institute of Technology, etc)	first robot access to upstairs
12/16/2011		Cold shutdown achieved		
4/18/2012	2	B1FL	<i>Survey Runner</i> (Topy Industries)	first robot access to downstairs
To date	<ul style="list-style-type: none"> • Surveys and decontamination operations by robot continued • Large scale robotics R&D programs for fuel debris retrieval gradually expanded 			

3.2.1. General purpose robot (1): PackBot

- Gathered information: interior appearance, dose rate, temperature, oxygen content, etc.



PackBot

Made by iRobot

- weight : about 30Kg
- length : 700mm
- width : 530mm
- height : 190mm

Survey result at reactor building of unit 3 (5/12/2011 press)

3.2.2. General purpose robot (2): Warrior

- Off-the-shelf robot with heavy-duty character, bigger and heavier than Packbot



vacuuming by *Warrior*
@R/B of unit 3 (2011.6.30)



removing obstacles with tools by *Warrior*
@R/B of unit 3 (2011.11.3)

Warrior



Made by iRobot

- weight: 222Kg
- length : 889mm
- width : 768mm
- height : 438mm

3.3.1. Specially designed robot : Survey by Quince

- Needed for activities at hard-to-access places
- Learned from on-site application experience

Original



1st application to the site



Jun/2011

➤ Modified for Fukushima use
(in two months)

- Change from radio wave to cable
- Improve stair climbing capability
- Install more camera & sensor
- Improve operability
- Improve reliability

➤ Lessons learned on-site

- Cable: automated winding
 - Backup for communication: added radio wave
 - Operability: further improved
- and more...

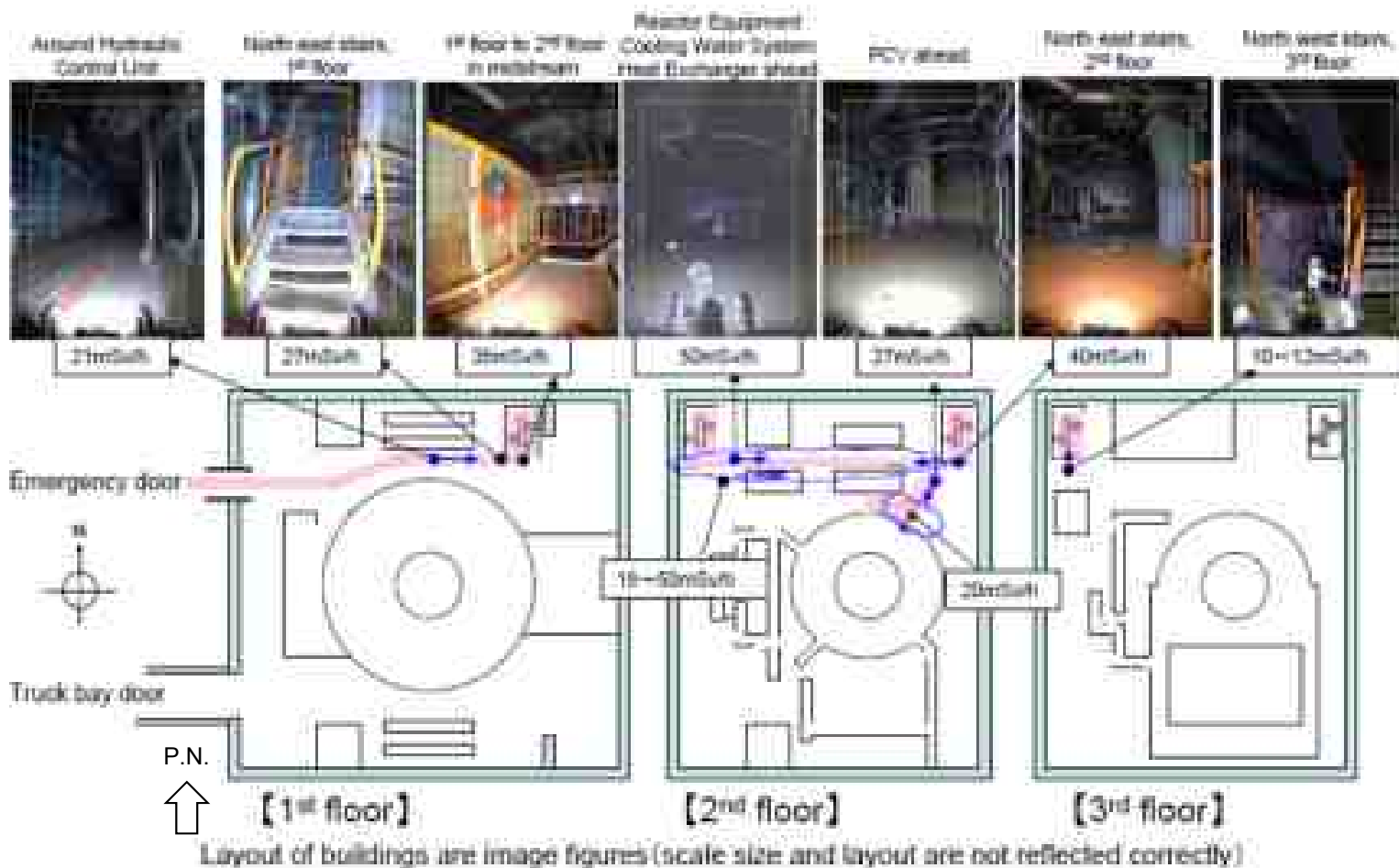
2nd application to the site



Feb/2012

3.3.2. Specially designed robot: Survey by Quince

- Climbed upstairs and taken photos



Survey result at reactor building of unit 2
(7/11/2011 press)

Quince



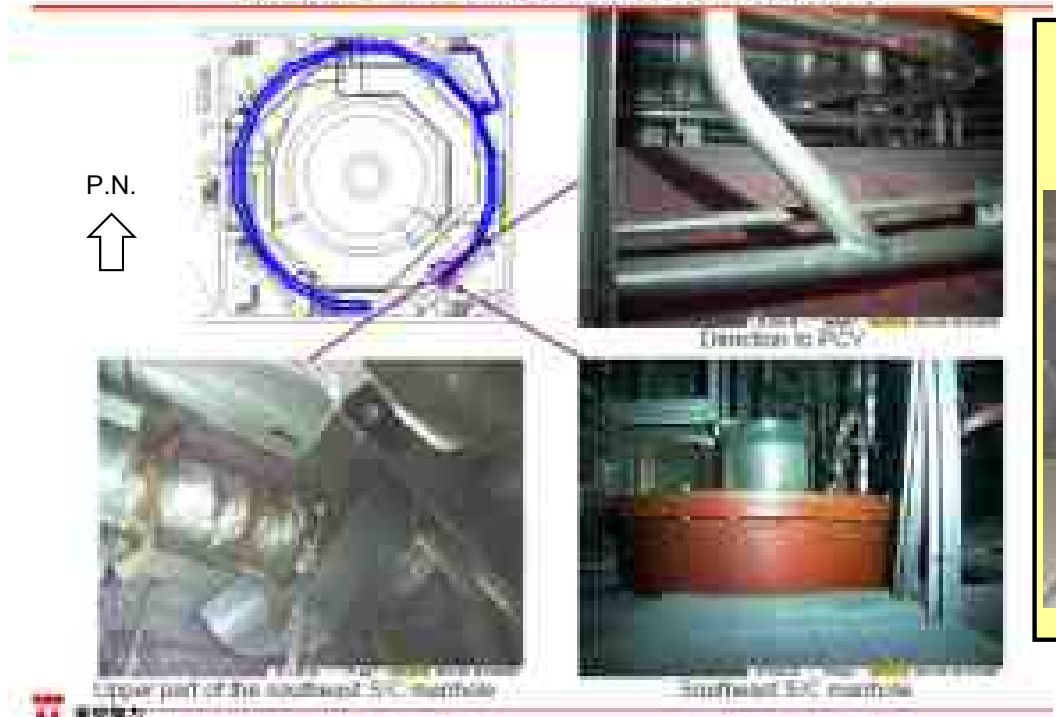
Made by
Chiba Institute of Technology,
Tohoku University,
International Rescue System Institute

- weight : about 50Kg
- length : 720mm
- width : 490mm
- height : 1080mm

3.3.3. Specially designed robot : Survey by small robots

- Accessed basement floors and narrow spaces

Result of the Investigation (Photos) 1/3



Made by Topy Industries

Made by Mitsubishi Electric TOKKI Systems

survey result by *Survey Runner*
at R/B B1FL of Unit 2
(4/19/2012 press)

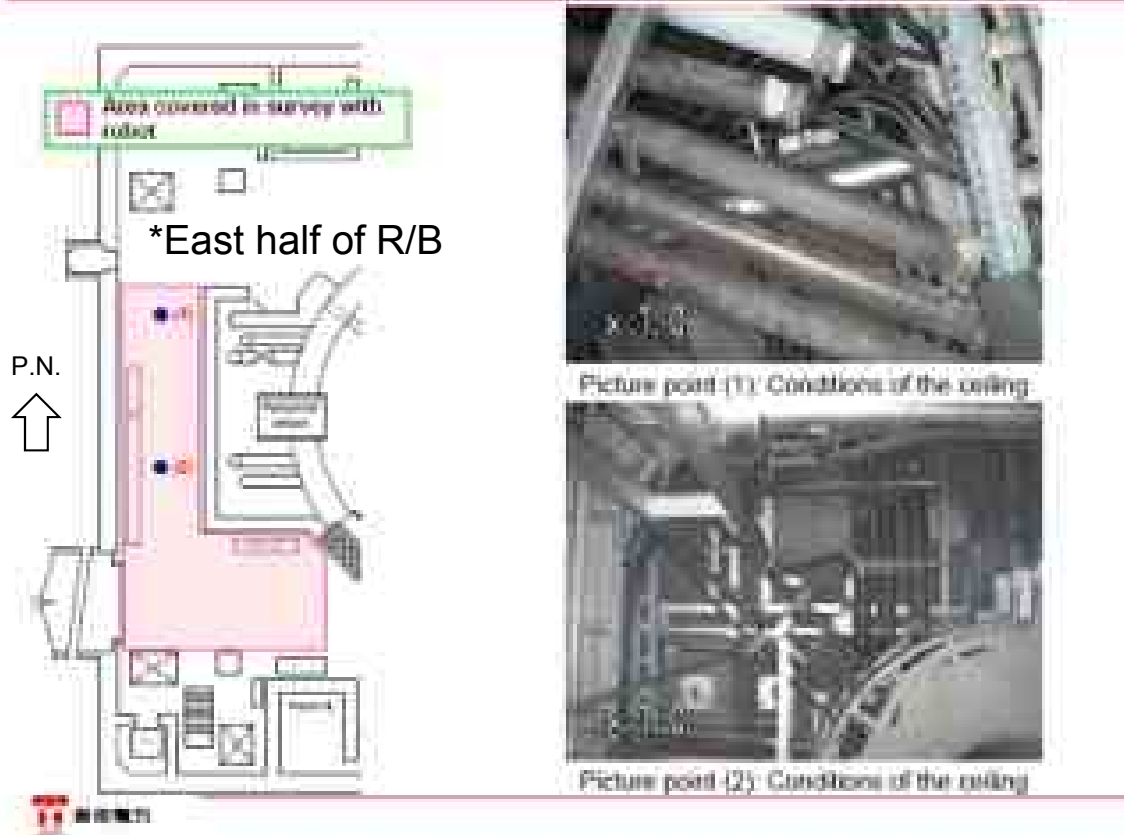
- weight : around 45kg
- length : 505mm
- width : 510mm
- height : 830mm

- weight : around 38Kg
- length : 650mm
- width : 490mm
- height : 750mm

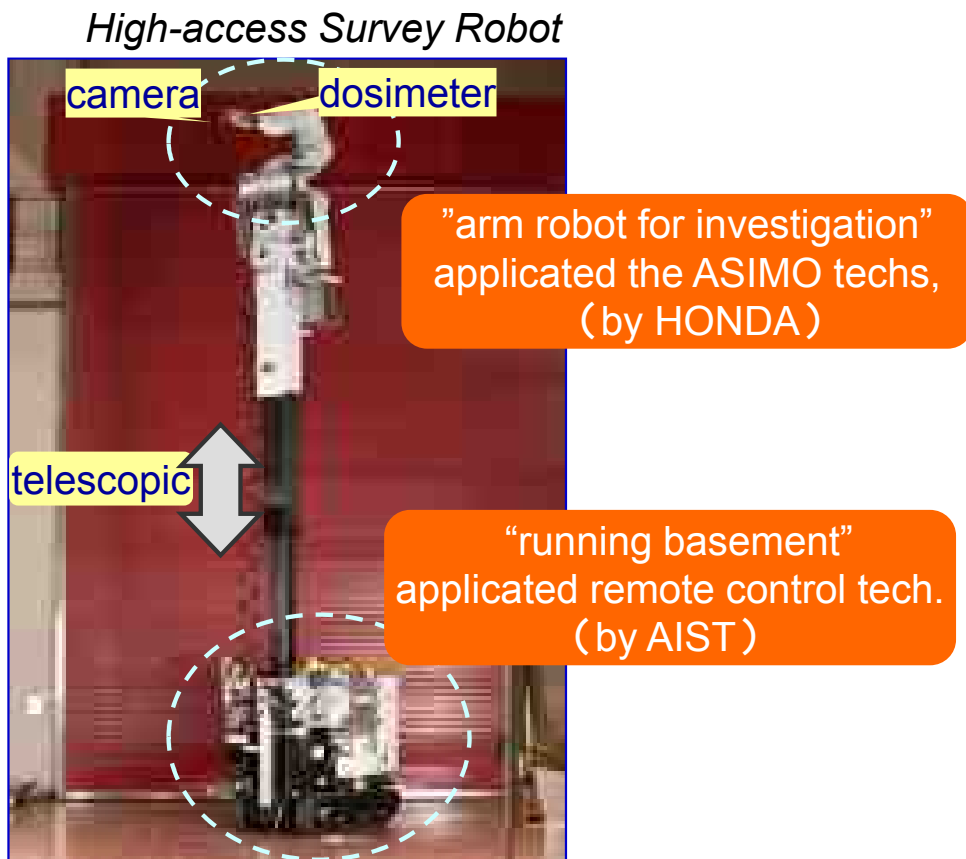
3.3.4. Specially designed robot : High-access Survey Robot

- Measured dose rates and took pictures for upside locations

3. Survey results (visual verification) - Ceiling of west-side passage -



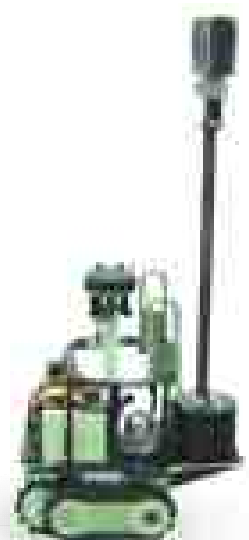
survey result with *High-access Survey robot*
at 1st floor of unit 2 (6/19/2013 press)



- weight : around 1100Kg
- length : 1760mm
- width : 830mm
- height :
1800mm (running state)
7030mm (max arrival point)

3.3.5. Specially designed robot : Attachment for survey

- Variety of attachments for variety of surveys inside reactor buildings



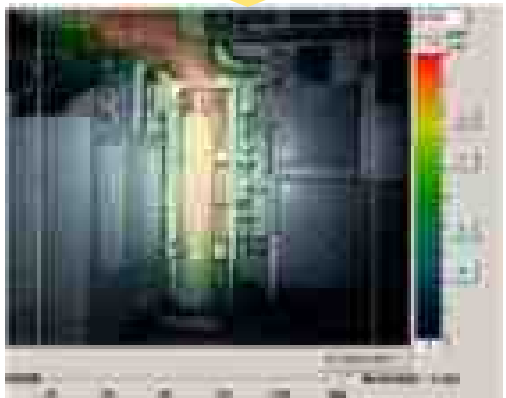
3D scanning sensor on *Survey Runner II*



3D scan data of a torus room



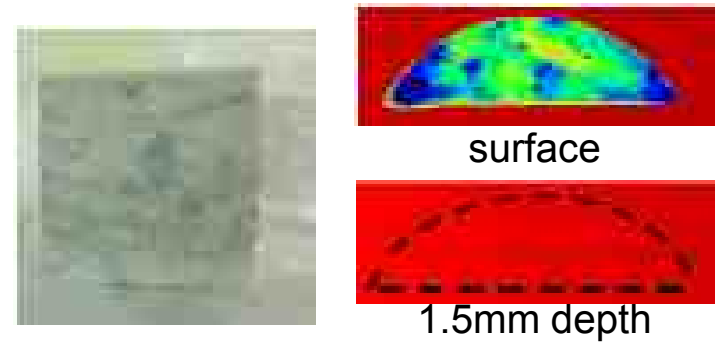
Gamma ray camera on *PackBot*



Dose rate map



Concrete core sampling by *MEISTeR*



Contamination data of a core sample

3.3.6. Specially designed robot: Decontamination

- Improved internal environment with remote devices
- Selected depending on contamination types and locations

Key: *Device Name/Developer*

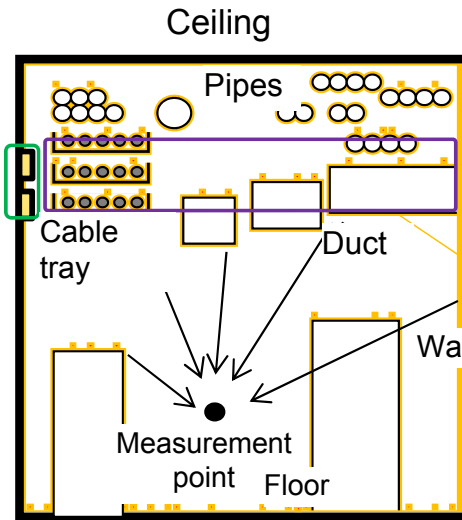
rubble removal, etc



device for upper locations
(in development by IRID)



ASTACO-SoRa/
Hitachi-GE/
Rubble removal

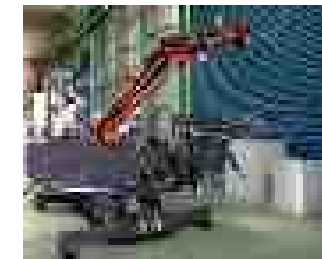


Dose rate contribution

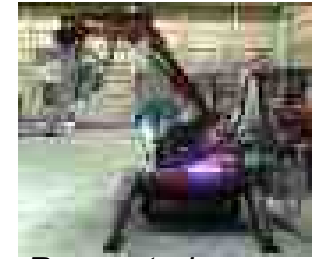
upper
(~8m)

middle
(~4m)

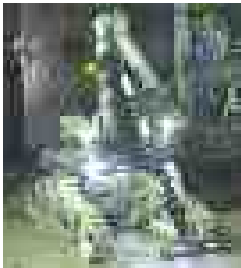
lower
(~2m)



REVI/Toshiba



Renovated
HusqvarnaDXR-
140/Toshiba



Warrior/iRobot/
(various working)



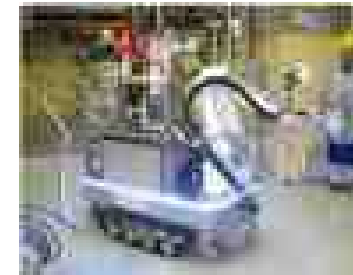
Raccoon/Atox
(Water dispersal,
vacuuming, brushing)



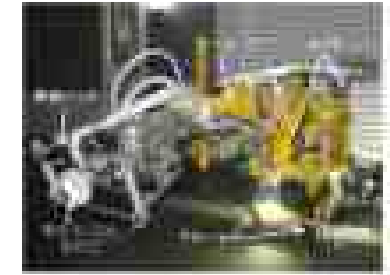
MEISTeR/IRID
(Vacuum/blasting)



contamination statuses

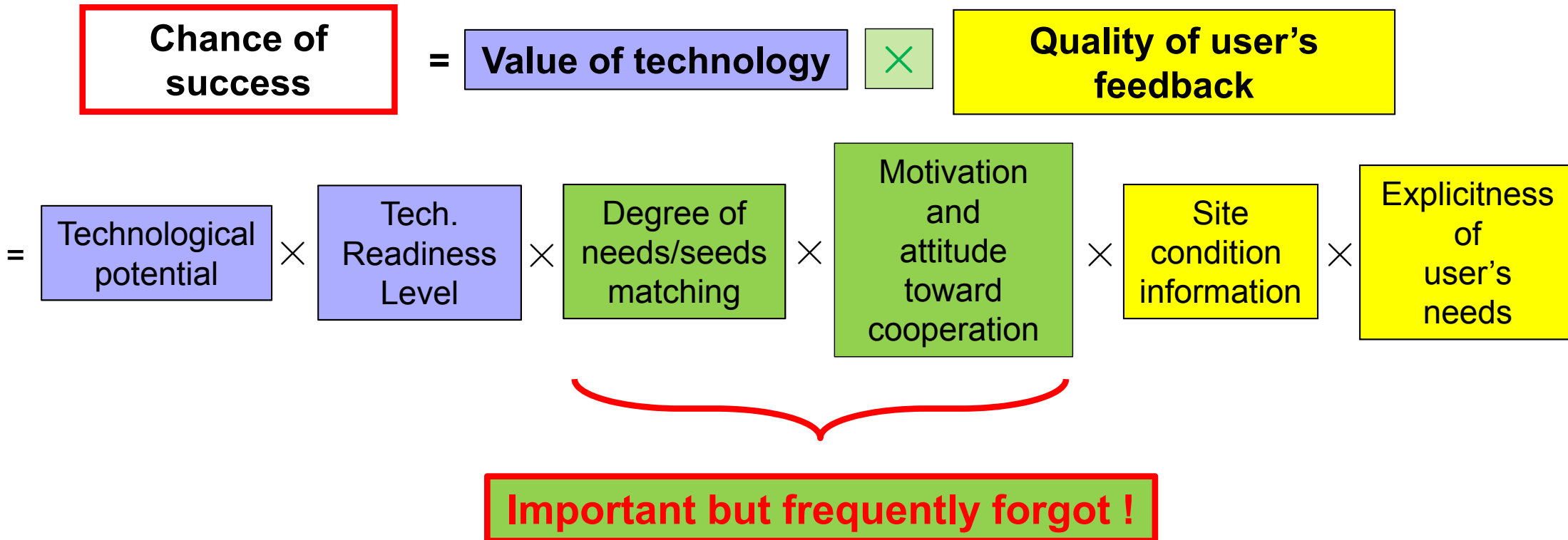


Dry ice blaster
decontamination device
/IRID



Arounder/IRID
(high-pressure water)

4. Conclusion



4. our experience at early stages

- Radiation resistance (\sim several hundred mSv/h)
 - ✓ Dose rate: no problem
 - ✓ Cumulative exposed dose: managed (over 40Sv for PackBot (some parts exchanged))
- Accessibility
 - ✓ Rough, slippery and dusty surfaces, grating plates, etc.
 - ✓ Stairs and narrow spaces
- View
 - ✓ Self posture
- Communication
 - ✓ Cable winding: several hundred meters of cable for climbing to a top floor
 - ✓ High frequency radio wave cannot reach wide areas
- Human interface
 - ✓ Operability: easy to operate with a game controller
- Portability

Thank you for your attention

