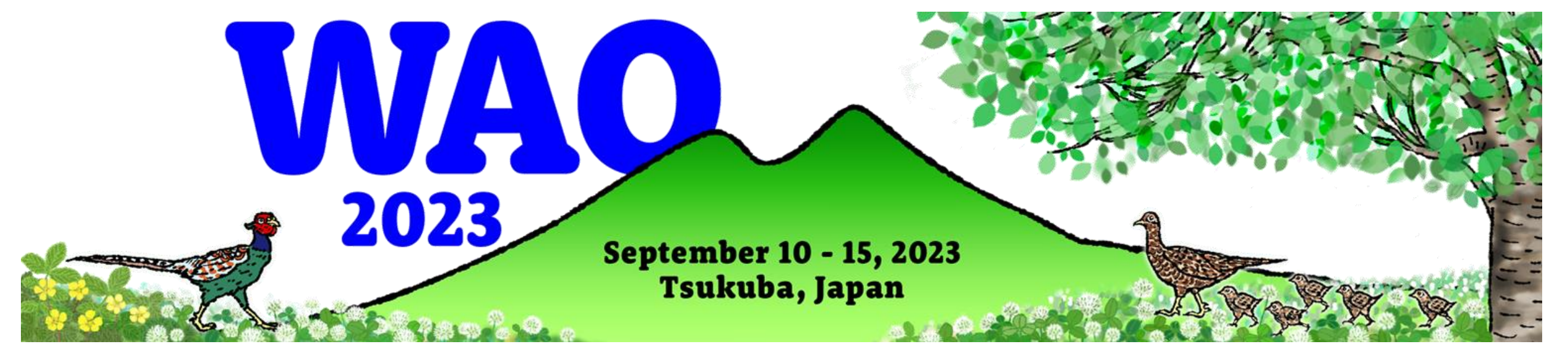
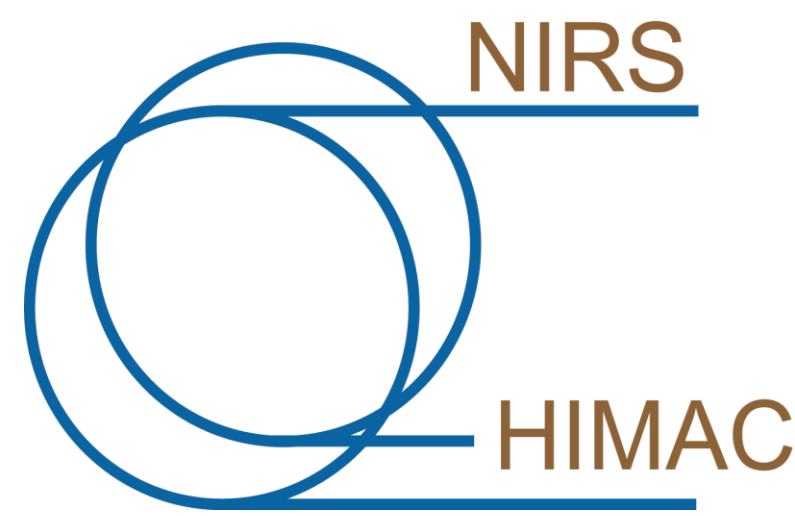


Incidents caused by earthquakes and storms, and how to detect them

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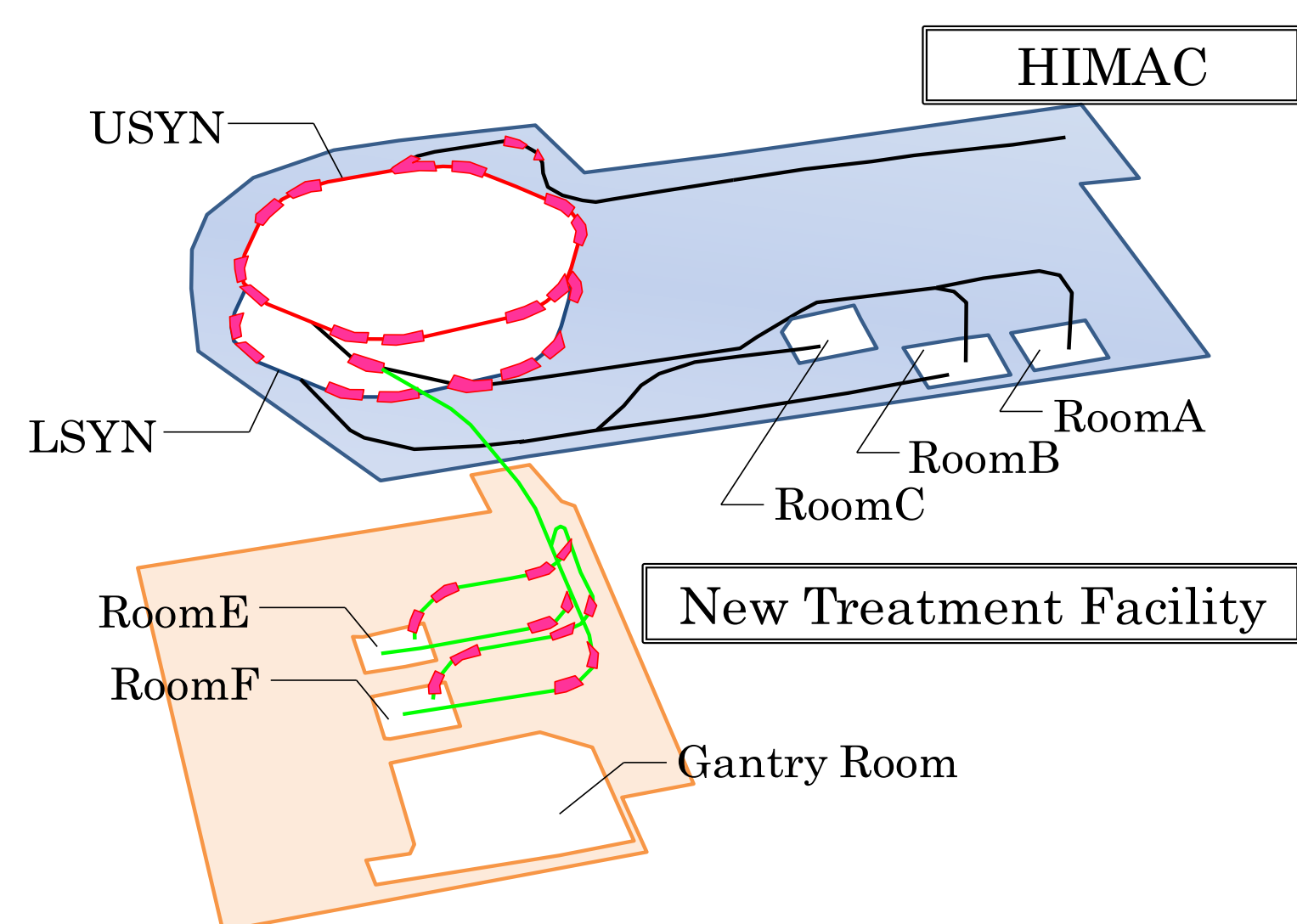
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Introduction

At National Institutes for Quantum Science and Technology (QST), carbon-ion therapy has been carried out since 1994, and a total of more than 15,000 patients have been treated to date. In New Particle Therapy Research Facilities, 50-70 patients are treated per day in three treatment rooms, and one of the treatment rooms has a superconducting rotating gantry.



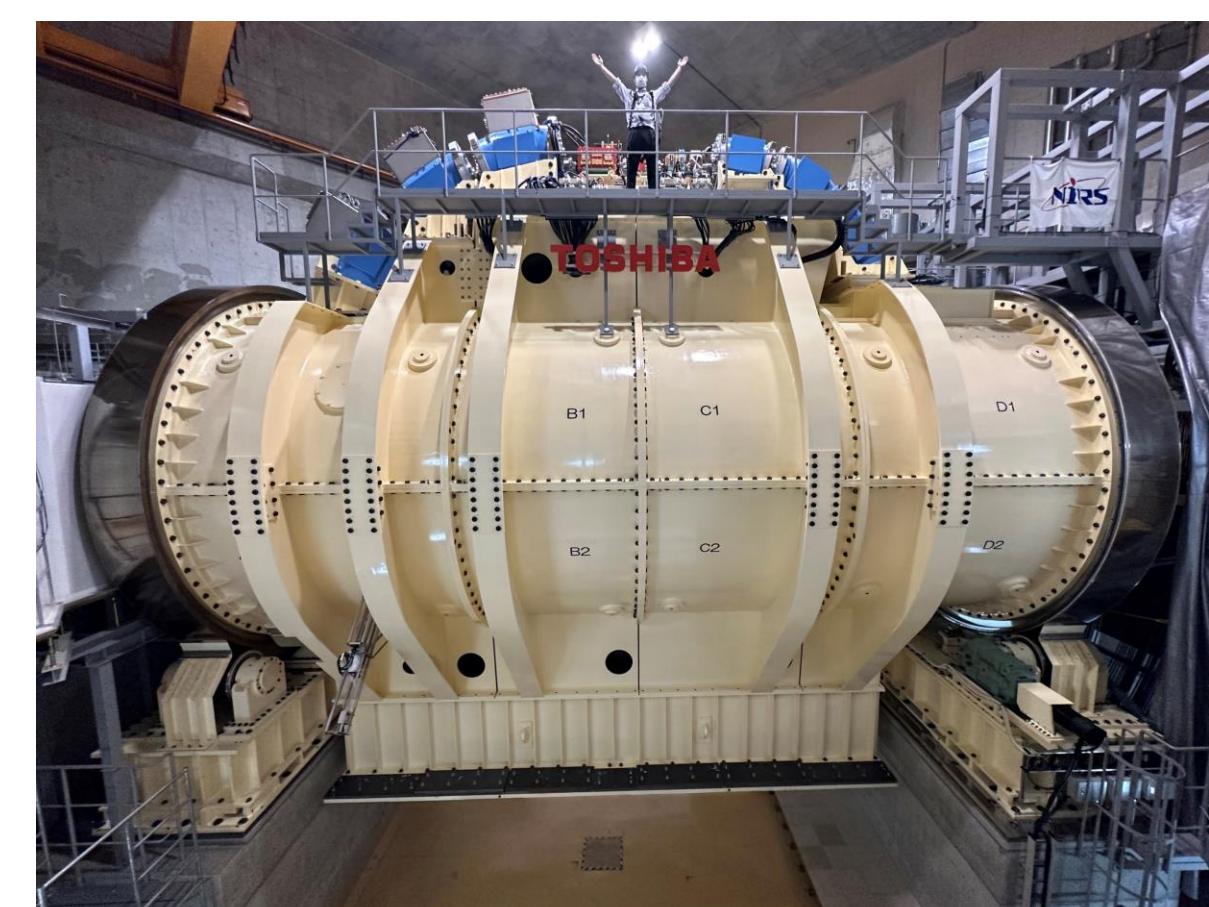
Points with potential failures due to disaster

A potential problem with earthquakes is the misalignment in equipment. Especially at points where high stresses are subjected, even small misalignments can lead to serious failures.

The greatest threats in storms are power outages caused by lightning strikes and lightning strikes themselves. In particular, computers and control devices can be expected to make irreversible errors due to sudden stops or lightning surges.

Disasters in Japan

Japan, where QST is located, is susceptible to natural disasters. Although Japan covers only about 0.3% of the world's land area, about 20% of earthquakes with a magnitude of 6 or greater occur in Japan, and about 7% of tropical cyclones with speeds of 64 knots or greater (so-called hurricanes or typhoons) make landfall in Japan.



The rotating gantry of 300 tons



The X-ray tube suspended from the ceiling

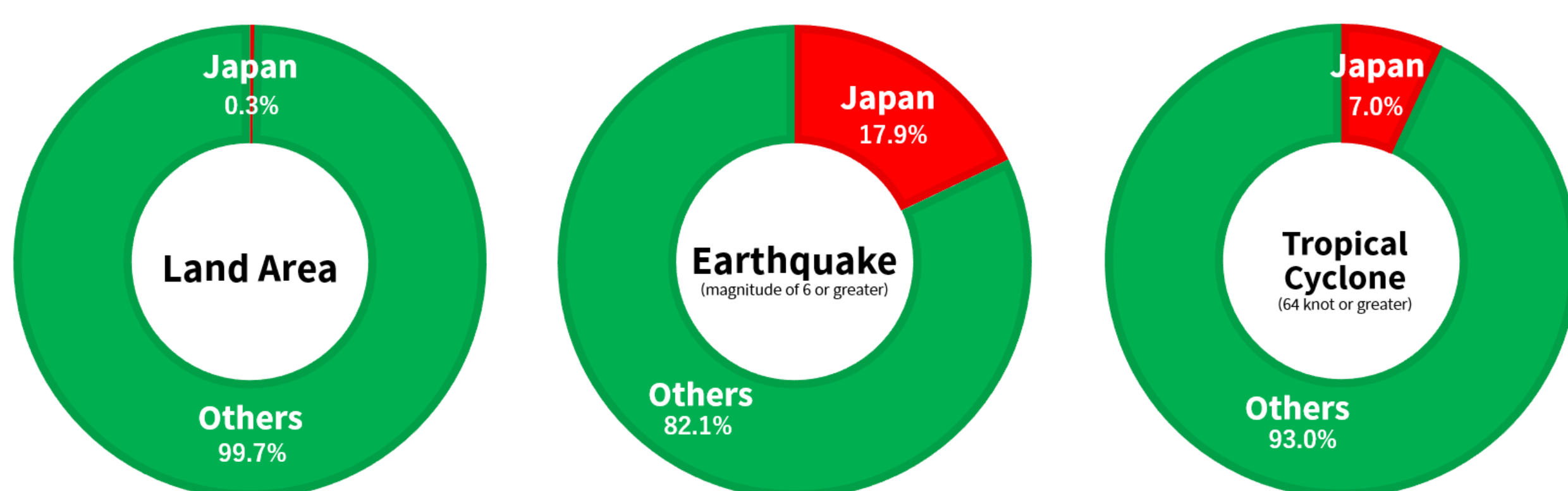


The turbo-molecular pump



The flanges sealing coolant piping

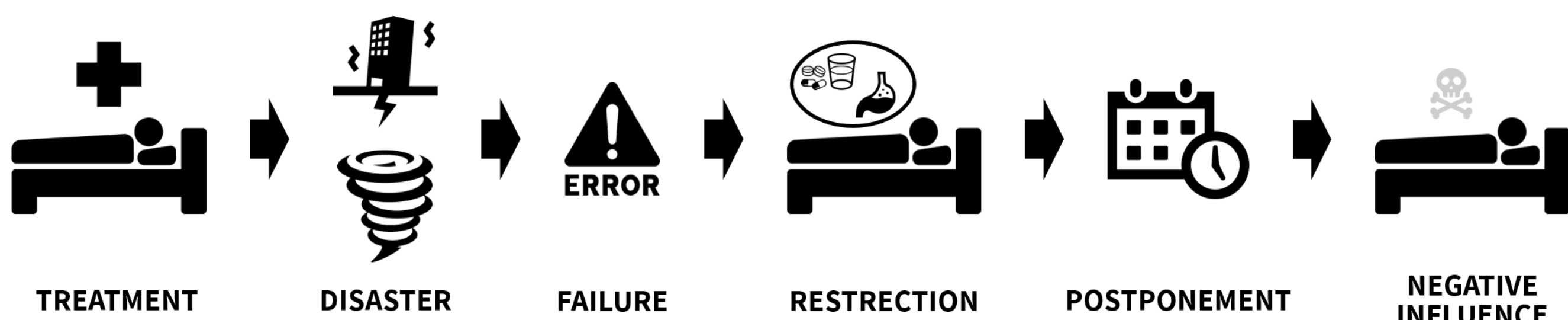
World's ratio



Risk of disasters in treatment facilities

Treatment facilities are required, not to mention patient safety, to assure the quality of treatment and to record the results of treatment properly. Therefore, when disaster strikes, it is necessary to ensure not only what the devices work, but also what the quality of treatment is not compromised.

However, restoration should also be prompt. This is because the shutdown of the devices, even if only temporarily, can cause significant disadvantages to the patient.



Items to be checked when disaster strikes

Basically, even if operating is started with failures due to a disaster, the equipment can be shut down immediately by the global interlock. However, running the faulty equipment, even temporarily, can lead to more serious failures. Especially in treatment facilities, it should be avoided to start operation without quality assurance. In order to avoid these problems while ensuring prompt restoration, it is necessary to establish inspection items before events of disasters and find signs of failure as much as possible between the occurrence of a disaster and the start of operation.

Earthquakes of experienced scale	Earthquakes of inexperienced scale	Power outage
<input type="checkbox"/> Working of vacuum equipment <input type="checkbox"/> Unusual noise from vacuum equipment <input type="checkbox"/> Coolant leak <input type="checkbox"/> Marking on the rotating gantry <input type="checkbox"/> Misalignment on the X-ray image	<input type="checkbox"/> Working of vacuum equipment <input type="checkbox"/> Unusual noise from vacuum equipment <input type="checkbox"/> Coolant leak <input type="checkbox"/> Marking on the rotating gantry <input type="checkbox"/> Alignment of each equipment <input type="checkbox"/> Gantry rotating <input type="checkbox"/> Beam transport <input type="checkbox"/> Beam position	<input type="checkbox"/> Starting up of vacuum equipment <input type="checkbox"/> Computers and control devices <input type="checkbox"/> UPS <input type="checkbox"/> Beam irradiation sequence

We will refer to Japan's own standards for the scale of an earthquake.

History of failures caused by disasters

Year	Number of Earthquakes	Failures	Number of Typhoons	Failures
2011	2	Misalignment of the beam ducts position among the buildings Activation of the interlock due to a door opening a few centimeters	3	
2012	1		2	
2013	1		2	
2014	0		4	
2015	0		4	
2016	3		6	
2017	0		4	
2018	2	Activation of the interlock due to a door opening a few centimeters	5	
2019	0		5	Temporary error of control devices Down of vacuum equipment Unsafe shut down of a server due to UPS error
2020	0		0	Power supply error of a UPS due to a lightning strike
2021	3	Activation of the interlock due to a door opening a few centimeters	3	Irreversible error of a control device*
2022	1	Activation of the interlock due to a door opening a few centimeters	3	
2023	2		1	Power failure of a BM Irreversible error of a control device*

* Failures that affected treatment



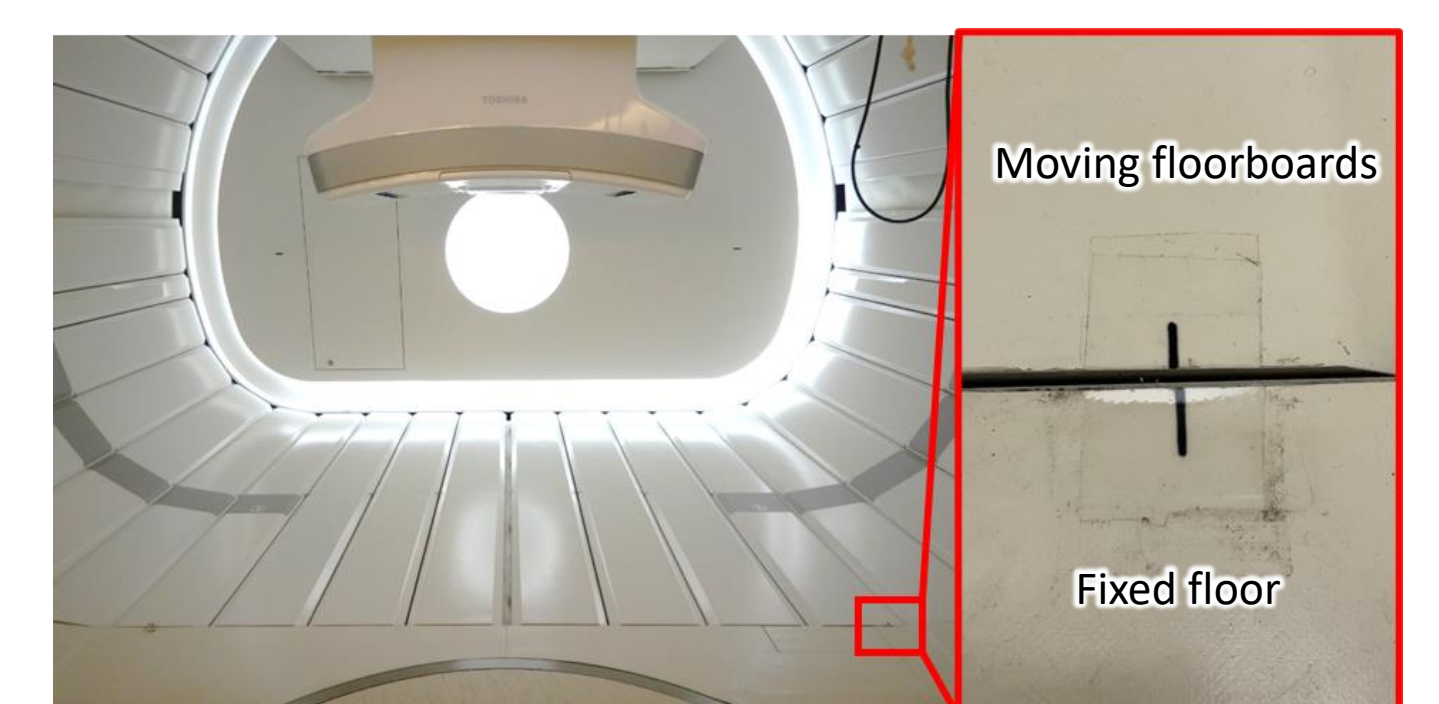
The duct that have been misaligned by the magnitude 9.0 earthquake in 2011 (according to old-timer)



The door that open a few centimeters every time when an earthquake occurs



The marking indicating the origin position of the rotating gantry



The marking on the moving floorboards of the rotating gantry

Summary

From the viewpoint of treatment facilities located in countries prone to natural disasters, the failure that could occur in the event of a disaster and how to detect it were discussed.

Currently at our facility, each operator conducts inspections based on his/her judgment and experience in the event of a disaster. In addition, there are no clear guidelines on what to do in the event of a serious disaster during treatment or criteria for resuming treatment. We would like to prepare for disasters by preparing manuals based on this study so that we can respond promptly even in the event of an emergency.