Development of robotic arm and sensor for pipeline inspection AUV

Kawasaki Heavy Industries, Ltd.
AUV Department

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AGENDA

- **Project background**

- **Summary of the Project**

- Development of water pressure tolerant motor and robotic arm
- Development of the ITU
- Sensor and detection R&D

- **Relationship to DeepStar program**

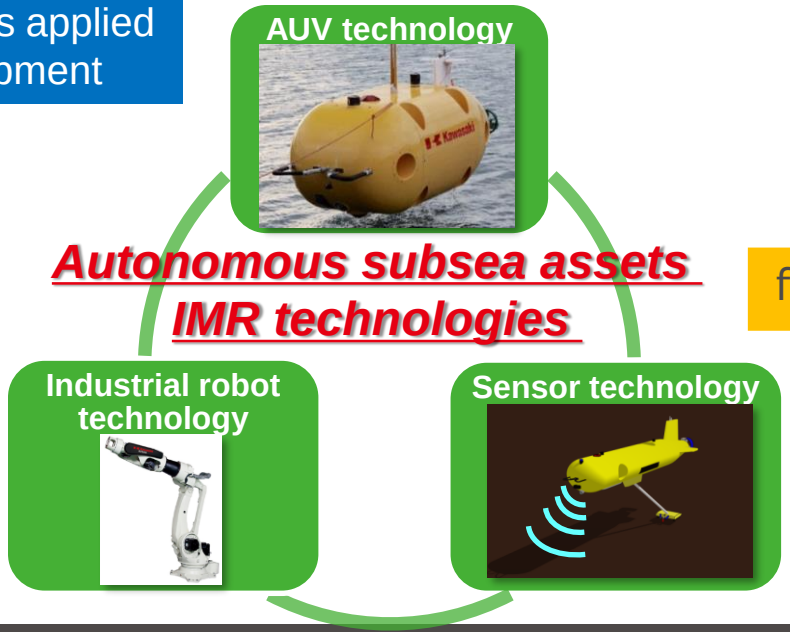
- **Future Prospects of the Project**

Project Background

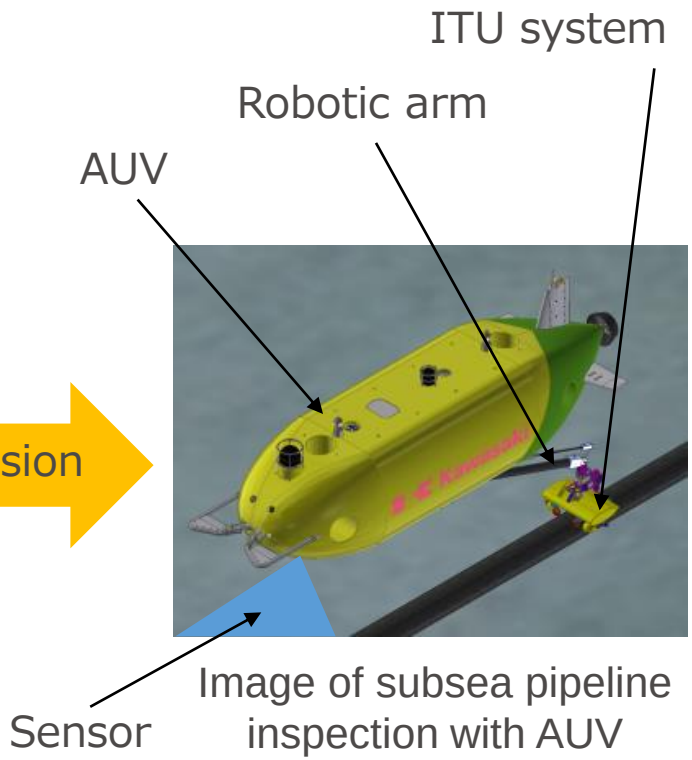
Objective of the Project

The development of autonomous maintenance technologies applying the technologies of industrial robot arm.

Key technologies applied to the development



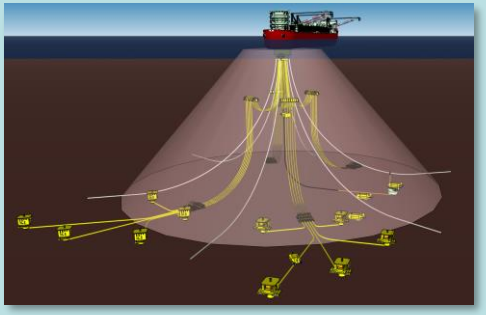
fusion



Project Background

Technology Application

- Subsea infrastructure inspection
- Inspection for decommissioning and continuous environmental research after decommissioning etc.



The development parties and their respective development role

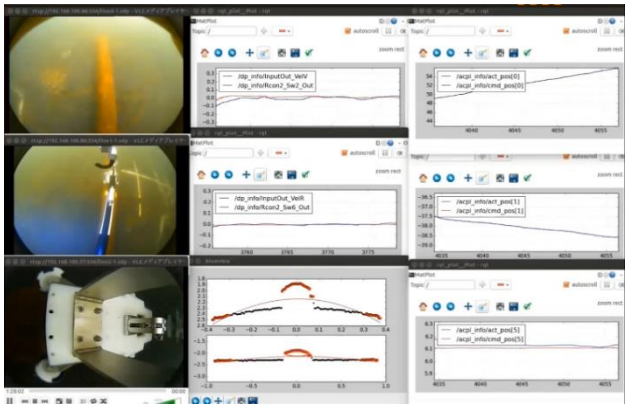
	Japanese side	**Scottish side**
Key technologies	AUV & Robot arm	Sensor
Lead company	Kawasaki Heavy Industries Ltd.	Hydrason Solutions Limited
Partners	Kobe University	Heriot Watt University

Summary of the project

- Development of water pressure tolerant motor and robotic arm -

- KHI had internally developed prototype robotic arm and ITU system.
- KHI has conducted performance confirmation trials with AUV installed our prototype robotic arm and ITU system with a grant received.
- As a result, KHI has confirmed that prototype robotic arm could capture the pipe top.
- KHI has also found some improvements, such as actuator‘s responsivity, necessity of gearless, ITU followability and localization these product.
- KHI has been able to develop these improvements.

Prototype robotic arm

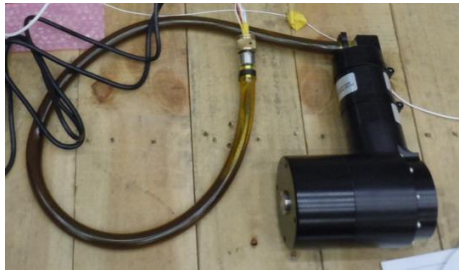


Picture of a trial

Summary of the project

- Development of water pressure tolerant motor and robotic arm -

From the result of the sea trials, for improving performance of robotic arm, KHI has developed water pressure tolerant motor which has high torque and high response compared to ready-made motor which we used.



Ready-made motor which we used

High response
& high water pressure
tolerant

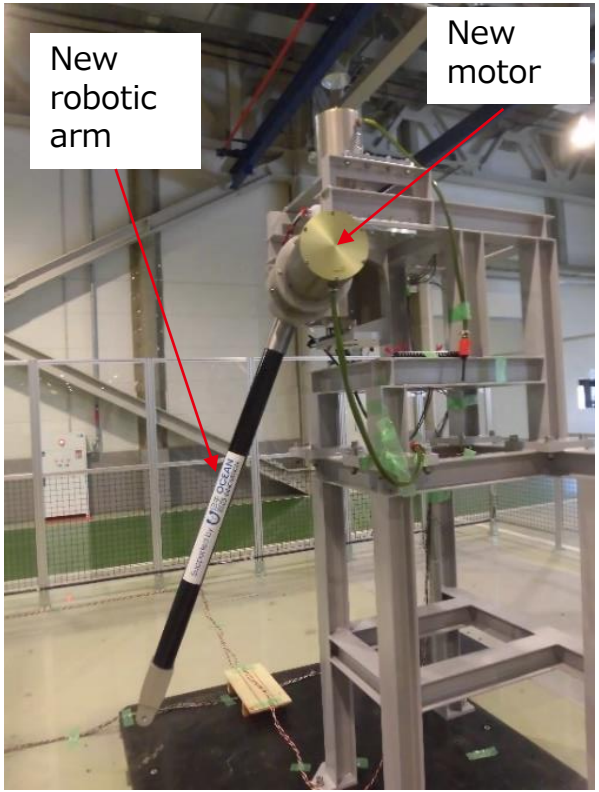
New developed motor

Load test

High pressure test

Summary of the project

- Development of water pressure tolerant motor and robotic arm -

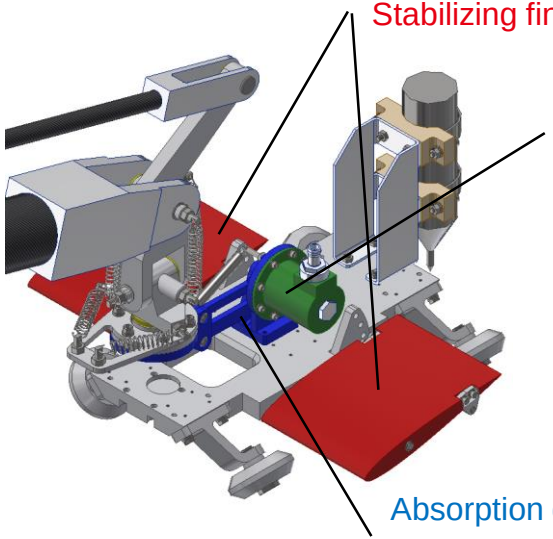


KHI has developed new robotic arm for using new developed motor.

- The new robotic arm have only two drive shafts, pitch axis and yaw axis, based on the roll stability obtained during sea trials.
- Increased output of motor torque and removed external gear.
- Changed bearing type from sliding bearings to ball bearings for improving accuracy.

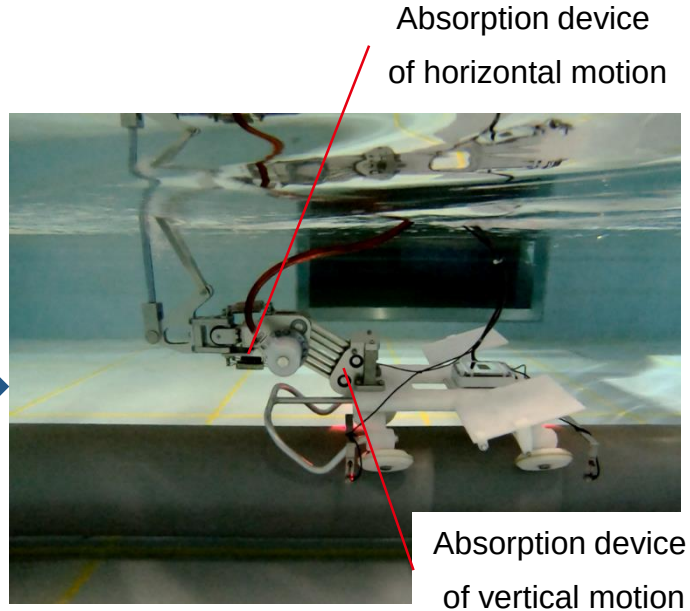
Summary of the project
- Development of the ITU -

KHI has developed inspection tool unit “ITU”.
ITU is the platform of inspection sensors attached to the end of a robotic arm.
The ITU has mechanism to absorb robotic arm end motion.



First type ITU

Feedback
from test data
at Kobe University

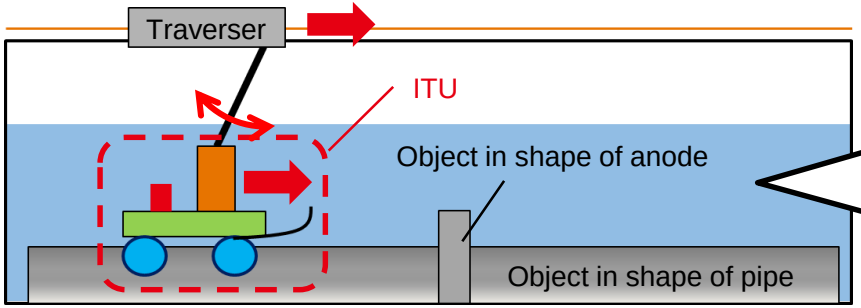


Revised type ITU

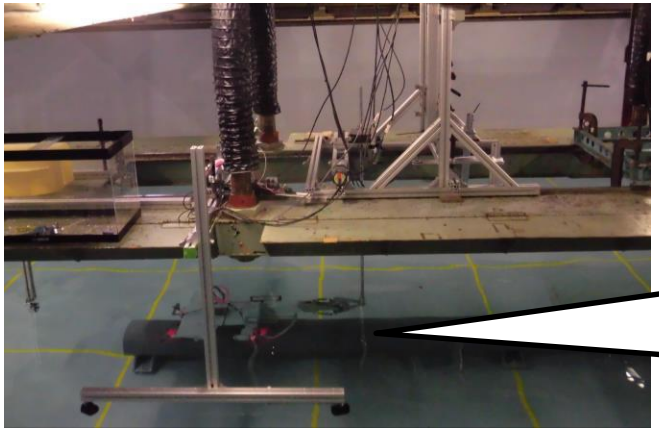
Summary of the project

- Development of the ITU -

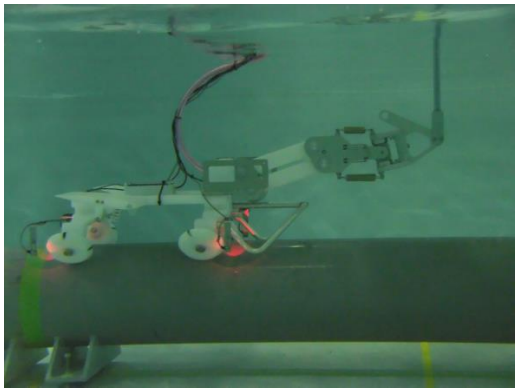
Towing tests of ITU at Kobe University



Towing tank at Kobe Univ.



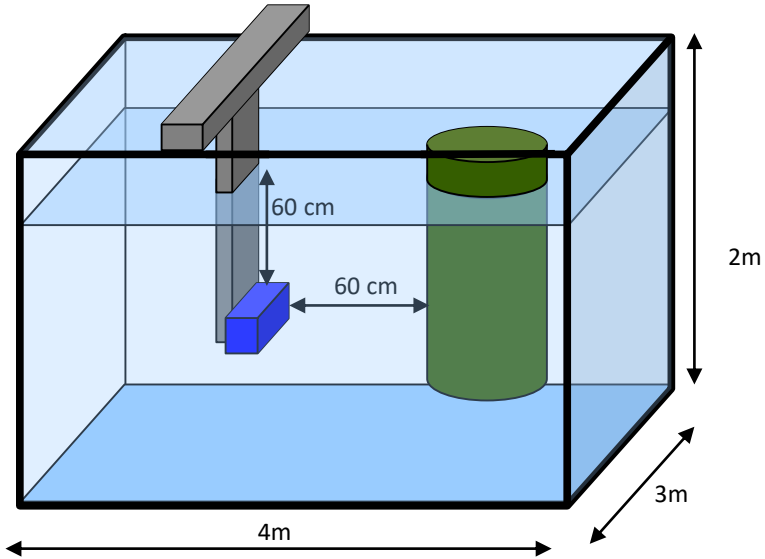
Test devices



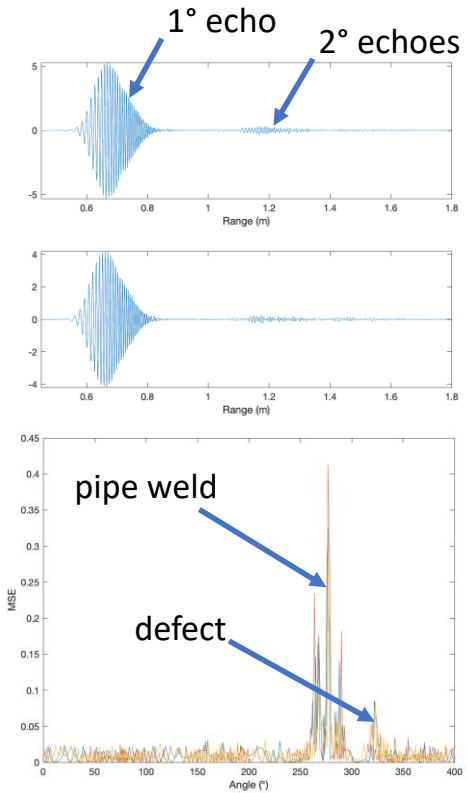
Towing test

Summary of the project
- Sensor and detection R&D -

Experimental Setup and WBS Data



Test tank setup
WBS transducers mounted on rail
Cylinder rotates



Sample WBS signals
1° echo is highly consistent
2° echoes contain most information

Processed data
Data over one complete revolution >360°
Mean-squared error (MSE) wrt ‘normal’ response

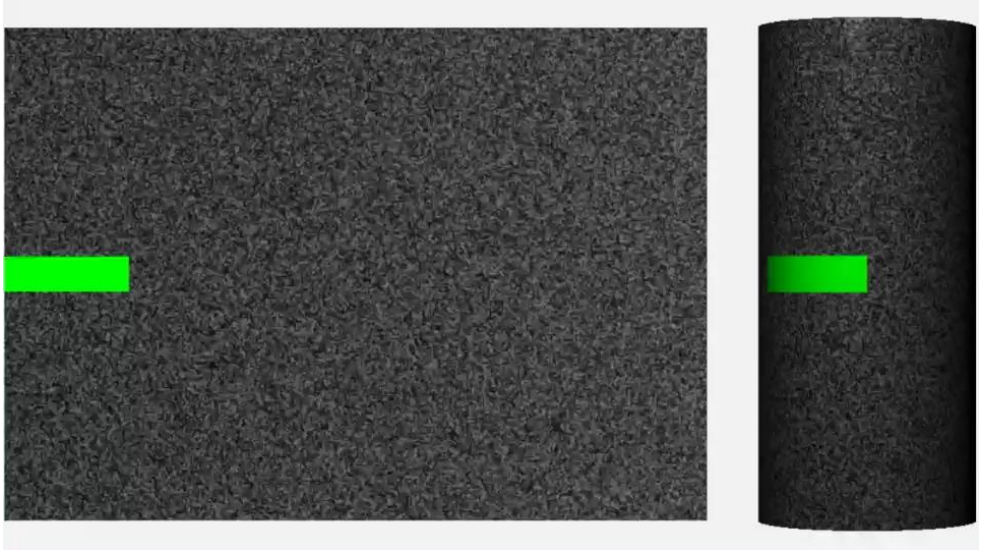
Test Piece for WBS* Inspection

- Large diameter pipe
- Models structural element for offshore platform/jacket
  - eg 1:8 – 1:4 scale subsea pile/leg
- 620 mm outer diameter
- 12.7 mm (½”) wall thickness

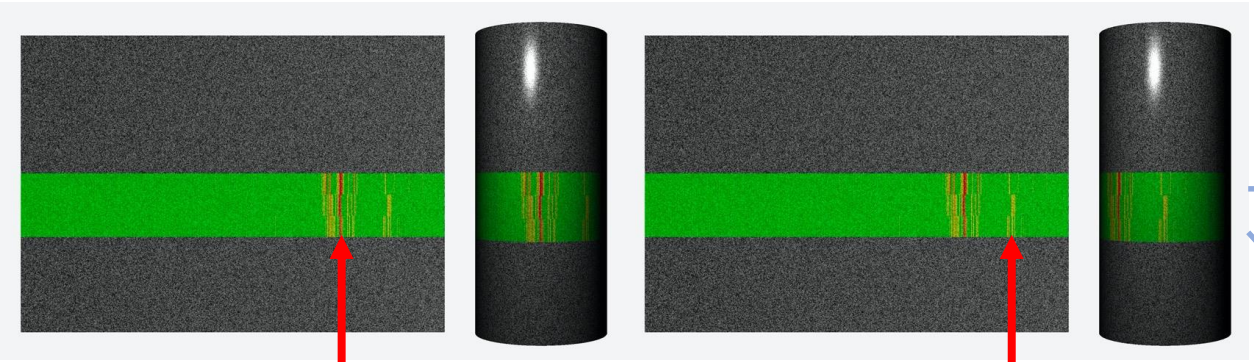
*Wideband sonar

WBS Data: colour map highlights defects

- Video screen capture
  - Maps MSE values onto 3d model
- Three successive 360° scans
  - Approx. ½° between pings
  - 10 cm vertical offset between scan lines
- Traffic light colour mapping
  - **GREEN**: normal wideband cylinder response [OK]
  - **RED**: largest deviations from normal
  - **YELLOW**: smaller deviations from normal



Data Presentation:
colour mapped to highlight defects



- Pipe weld gives biggest change in response
  - Seen in every 360° scan

- Yellow response indicates structural defect away from pipe weld
  - Detection corresponds to small dent or abrasion in steel wall
  - Defect is not visible on initial inspection
  - White chalk line through region of detection indicates defect (<1mm depth)

Relationship to DeepStar program

The robotic arm and ITU which have developed in this project have used in DeepStar program. KHI has confirmed that AUV equipped this developed system is capable of stable tracing along pipeline.

NF - DeepStar Joint R&D Program – Expression of Interest (EOI) -
[Demonstration of Capability of ITU mounted on AUV]

1	2	3	4	5	6	7	8	9
Initiation	Concept	Proof of Concept	Integration	Demonstration	Prototype	Pre-production	Production	Field Proven

Application:	Subsea Integrity	**DeepStar Director:**	Shak Shamshy, shakir@chevron.com
Focus Area Theme:	Subsea Flowline Inspection	**DeepStar Project Manager:**	Joseph Gomes, joe@theooc.us
Strategic Drivers/Category:	Cost Effective Subsea Flowline Inspection	**Project Champions:**	Daniel Byrd, Daniel.byrd@total.com Total Hani El Shahawi , Hani.Elshahawi@shell.com Shell
Technology Development Stage:	3 - 6	**Proposed Contractors:**	Minehiko Mukaida, mukaida_m@khi.co.jp Kawasaki Heavy Industry (KHI)

Project Overview: (2-3 lines)
Demonstrate capability of AUV to track target pipeline and for an Inspection Tool Unit (ITU), to maintain inspection capabilities (alignment with flowline under inspection) during AUV flight.

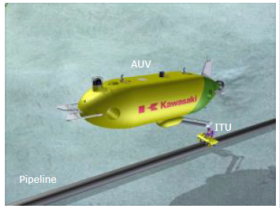
Business Case / Impact: (2-3lines)
To improve range of data obtained during AUV flowline inspection, and to improve on the time taken and quality of data currently obtained by ROV flowline inspection.

Objective: (within 2lines)
Demonstrate the technical capabilities of an AUV to maintain the required flight envelope during pipeline following, allowing ITU to maintain contact with the target.

Scope:
Evolve testing philosophy, identify suitable test environment and demonstrate capability of the ITU during a typical AUV Pipeline inspection campaign.

Deliverables: (2-3lines)
Testing philosophy to include controlled environment and field conditions, field demonstration report and capability assessment.

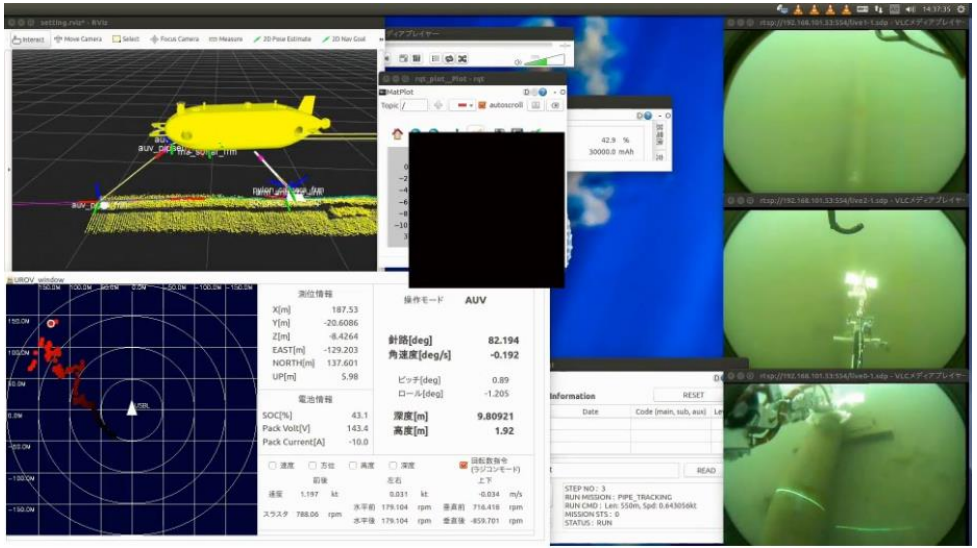
Other Comments
- ***Total may have a test section of pipe to offer to the tests***



AUV with retractable sensor arms
(It will be amended in the future)

Schedule		
Start Date	**End Date**	**Budget**
June 1, 2019	12 months	¥25,000,000

NF-DeepStar Joint Ocean Innovation R&D Program



Future prospects of the Project

Based on the results obtained in this project, KHI will continue to develop pipeline inspection AUV with robotic arms system for more efficient pipeline inspection.

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