Remote operated aspiration device for waste lying on the floor of casemates of the STEL installation in Marcoule

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Abstract: This article describes the study project and the implementation of the aspiration remote operated device called GOBIE. This robot is being used as part of a project for waste recovery and conditioning. After a presentation of the project context, the missions and objectives of this system, together with the core features shall be detailed hereafter. This includes interesting and innovative sub-systems like aspiration, communication, transport and control.

KEYWORDS: remote operation, dismantling, robotics, aspiration, bitumen

Introduction

As a nuclear operator, the CEA is in charge of the dismantling of its installations and the management of waste they have produced. Some of these operations include the recovery and the conditioning of old waste. This specifically applies to bitumen coated barrels produced and stored in the liquid effluent and waste treatment facility in Marcoule. These recovery operations have been performed since 2007 thanks to operated devices called “Rascasse”. To achieve higher recovery capacity and limit contact operations, it was decided by the CEA to move from a “controlled” recovery system into a “remote operated” system. The first step consists in the implementation and commissioning of an aspiration robot called “GOBIE” intended to keep the facilities accommodating the recovery operations clean and safe. For that purpose, a work service contract has been awarded in 2013 to company Bouygues Construction Nuclear Services (Robotics and Special Device Department) in order to study the implementation of this robot. The factory acceptance was delivered in July 2017 and the application for an authorization to operate was transmitted to the nuclear safety authority in June 2017. The first implementation tests shall take place during the second half of 2018.

Missions and objectives

The casemates are reinforced concrete vaulted buildings of 9 to 10 m wide by 35 to 65 m long. Such casemates allow storing bitumen coated barrels containing radioactive sludge produced by the liquid effluents treatment facility since 1966.
They are connected through an interface to a workshop in charge of identifying barrels, overpackaging and transport packaging.
The remote operated aspiration device must allow to vacuum the casemates and the transfer airlock floor and to collect the aspired waste in filter pots.
The purpose of the system thus conceived is to vacuum the following waste:

- Concrete dust (fine dusts <2.5 µm),
- Slight volatile dust (> 25µm),
- Non-adhesive solid balls (bitumen for example) (<3 cm),
- Metal particles present as small sized traces < 5 mn.

The system is in charge of:

- Conditioning the aspired waste in filter pots,
- Insure the compatibility with the aspiration device by limiting exposure of staff during implementation and maintenance operations, the spreading of contamination according to the installation installation security and safety rules.

Features

The system duly accepted in July 2017 is composed of the GOBIE robot (900kg mass, length : 2.18 m, width : 1.2 m, height : 2.01 m), a trolley loading 5L filter pots with relay beacons, a remote control cockpit and a battery loading station.

Picture 1: **Overview of GOBIE robot and trolley**

Two turbines in parallel allow the aspiration of waste with three operational modes:

- Aspiration of dusts with a retractable clip in front of the robot,
- Aspiration of medium particles by sweeping with a 6 axis arm mounted with a fine nozzle ,
- Aspiration of big particles or a specific area with a large nozzle mounted 6 axis arm mounted with a wide nozzle.

Omnidirectional movement is made by a system of holonomic wheels, each wheel with an independent motorization without permitting to change rotation. In addition, the intermittent contact of wheels allows to limiting the spreading of contamination.

The aspired waste is conditioned in a new type of pot (1) allowing to follow up its physical and radiological filling level. Also, it presents a more important effective volume (50% jacket volume against 15% for a usual pot) and can make remote handling with the 6 axis arm to load and unload it.

The communication is ensured by a secure WiFi network distributed by stationary antennas in interfaces and mobile antennas in production areas. Mobiles antennas are settled by the robot itself, ensuring a continuous signal and a redundant coverage in the case of failure.

The control system is managed by the Robot Operating System (ROS) which is widely used in the modern robotic community, although rather on the academic level than on the industrial one. This Middleware allows to re-using technological bricks which are already well developed (simulation, viewing, debugging, trajectory generation, …) and offer unequalled modularity.

All batteries ensure a 5h autonomy in normal use for a 3.7 h reloading time. Such batteries are safe designed with a lithium iron phosphate (LiFePO4) electrolyte non-releasing hydrogen during loading or unloading, including a protection against short-circuits, overvoltage and overload, which are directly monitored from the cockpit.

This robot also comes with additional features which allow to following up the dose rate, fire extinguishing, obstacle detection and viewing.

Conclusion

The device implemented by the CEA has been qualified and duly accepted in July 2017. All features are have been ensured and the expected performances have been achieved.
The switch to remote operation is a technical and technological step which will allow improving cleaning performances and recovery rates. In addition, it allows to limiting human intervention during recovery operation or for the device maintainability.
Such device must also be considered as a “technological brick” for developing other remote operating devices. The various assemblies of this device are modular enough to be used for other projects, specifically for communication, energy storage, moving or the electric arm.

References

(1) Filing PCT/EP2017/055637 dated 10/03/2017.

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Presentation of « GOBY »

Remotely Vaccum Device

DEM 2018



CEA/DEN/DDCC/UDBE/CPCE
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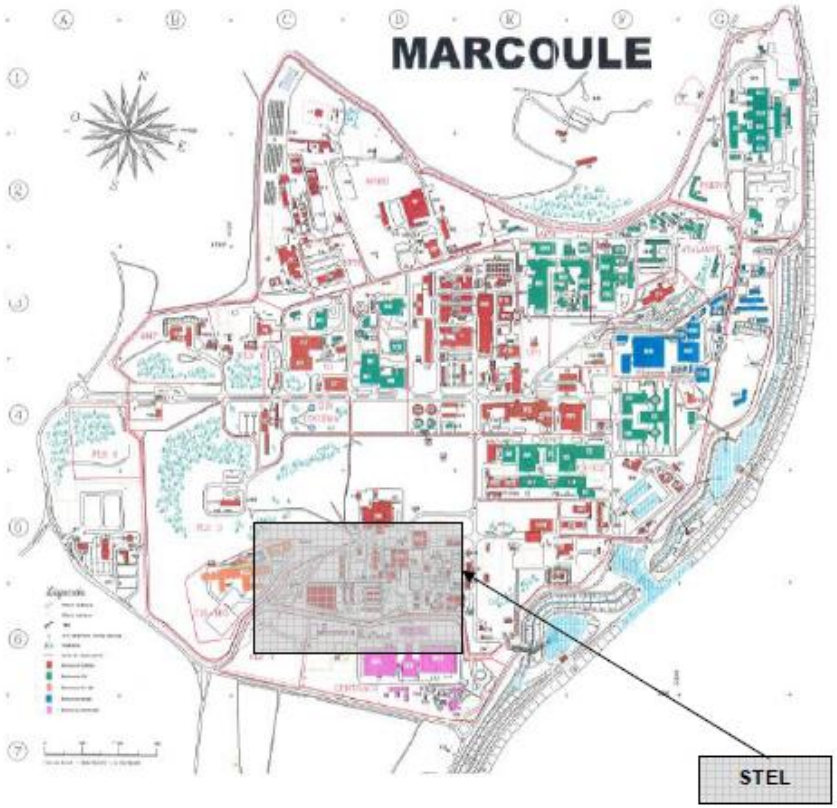
SCOPE AND CONTEXT



55000 bitumen drums
Industrialization / production goals
Safety and security evolution

=> Need news technologies

SCOPE AND CONTEXT

Cleaning operation

Wired Brokk

Washer

Wastes composition:

- Metal (drum corrosion)
- Vynil
- Organic material
- Clay
- …

Recovery operation

Forklift

EXPERIENCE FEEDBACK

Waste retrieval operations in bunkers 1 and 2 are currently performed with nuclearised forklift requiring the presence of a human driver.

All operations in connection with waste retrieval impact drastically the production flow.

Targets:

- operating contraints must be limited (contamination management, human intervention, etc.),
- production speeds must be increased.

The RCD-B project has therefore implemented an evolving strategy including the development of remote-handled devices to reach a better performance on facility operating as well as continuing retrieval operations of drums in bunkers :

The goals are :

- reducing operators' working time spent on devices,
- improving daily cleaning procedures,
- combine retrieval and cleaning operations in the long run,
- improving the safety level of cleaning and retrieval operations.

NEED'S DEFINITION

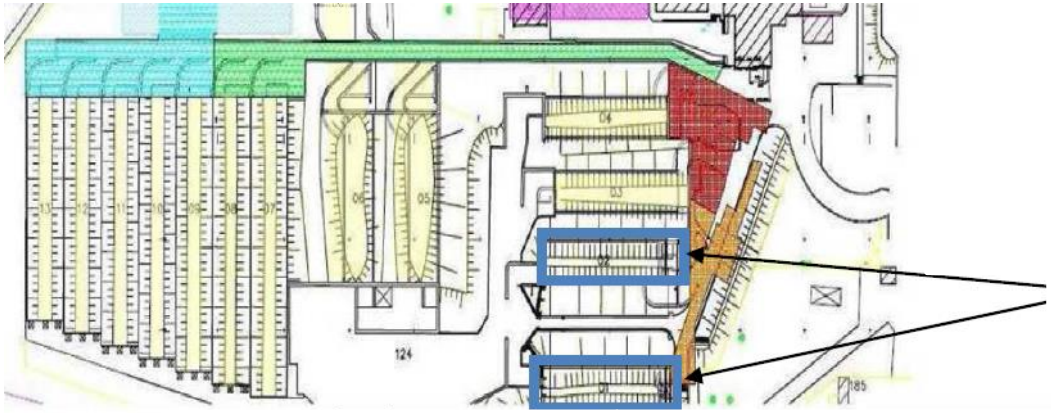
Definition and set-up area :

We made the choice to study a remote device to clean the floor in bunkers in order to limit contamination spreading. 33 requirements have been defined to reach to following aims:

- Increasing production speed,
- Cleaning traffic areas everyday,
- Limiting operators' interventions,
- Insuring the area control, material follow-up and monitoring,
- Establishing strict security and safety rules meeting the regulation requirements.

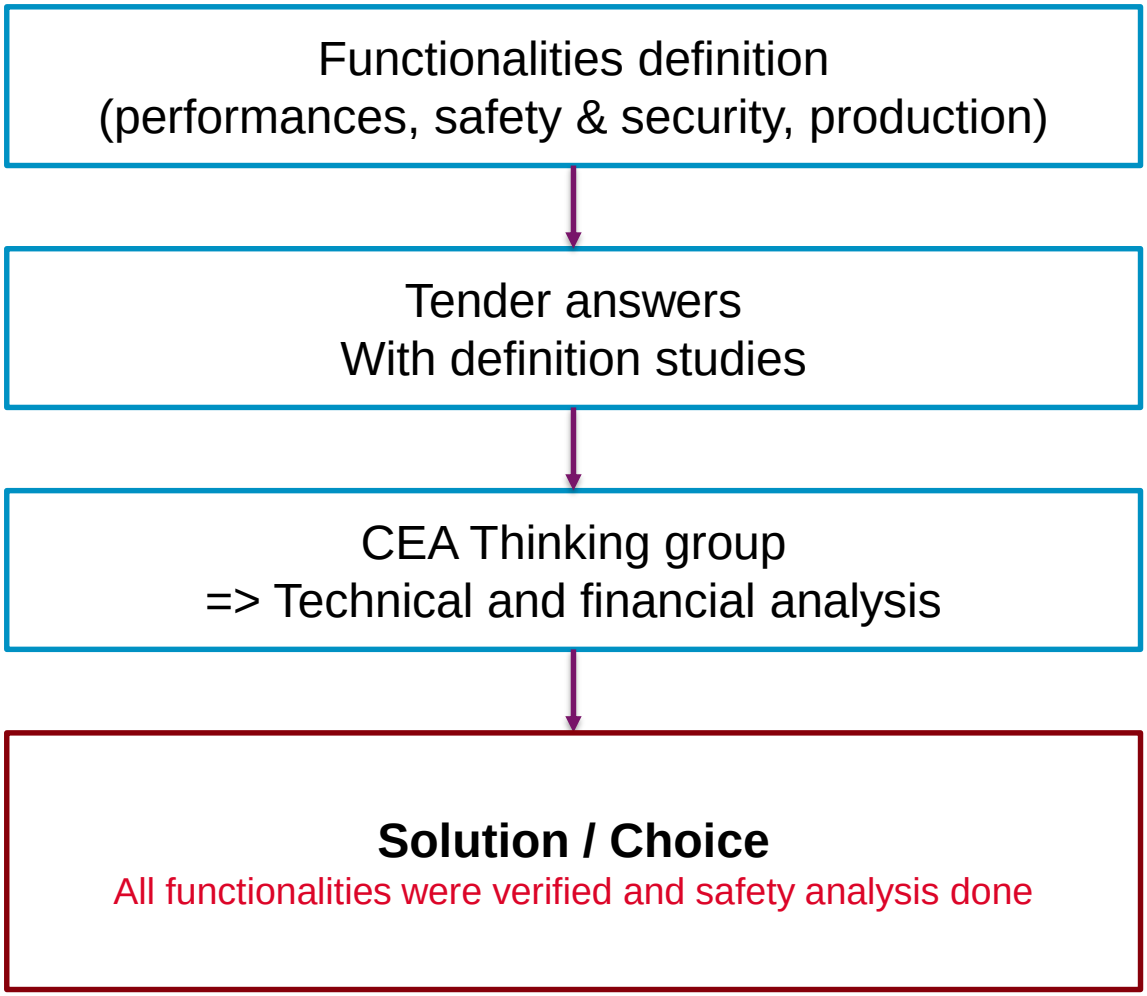
This device is going to be implemented in the ERCF (Drums Retrieval & Reconditioning Shielded Line) site on STEL (Liquid Waste Station) area, as well as in bunkers 1 2 :

=> EXPERIENCE FEEDBACK

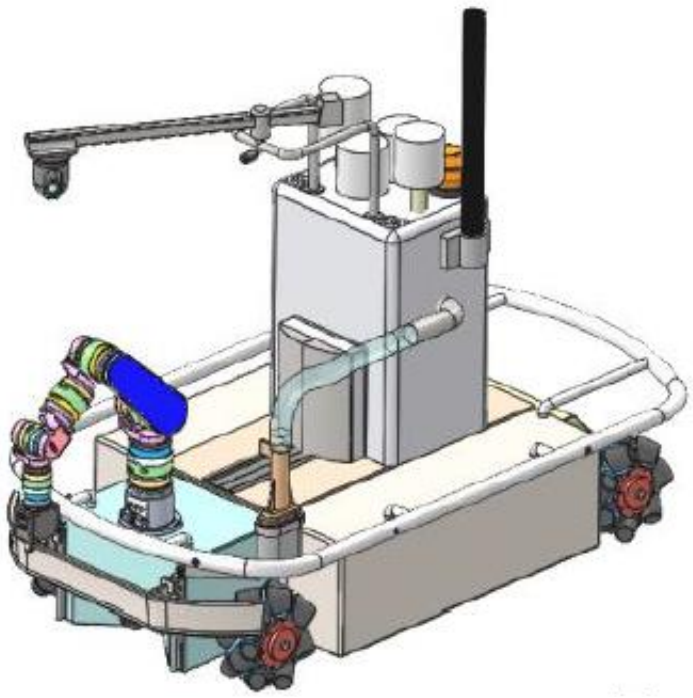


Bunkers 1 & 2

TENDER STRATEGY



SOLUTION



Holonomic wheels
High performances vacuum
HD Camera with night vision

BOUYGUES CONSTRUCTION
SERVICES NUCLÉAIRES

Robotic arm
Wastes optimization
Long batteries life

GOBY – GENERAL INFORMATION

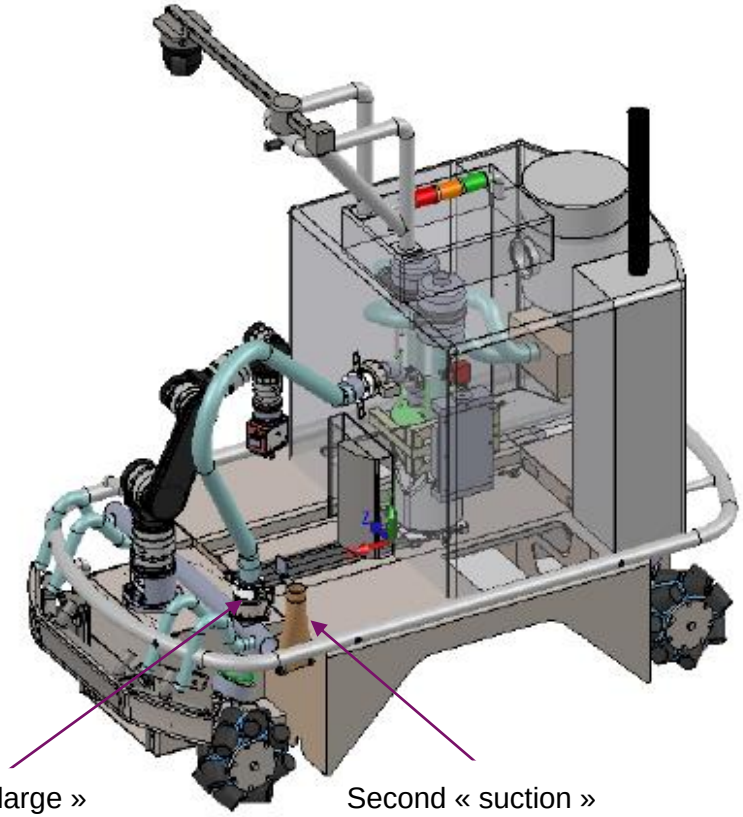
The GOBY is a remote vacuum device :

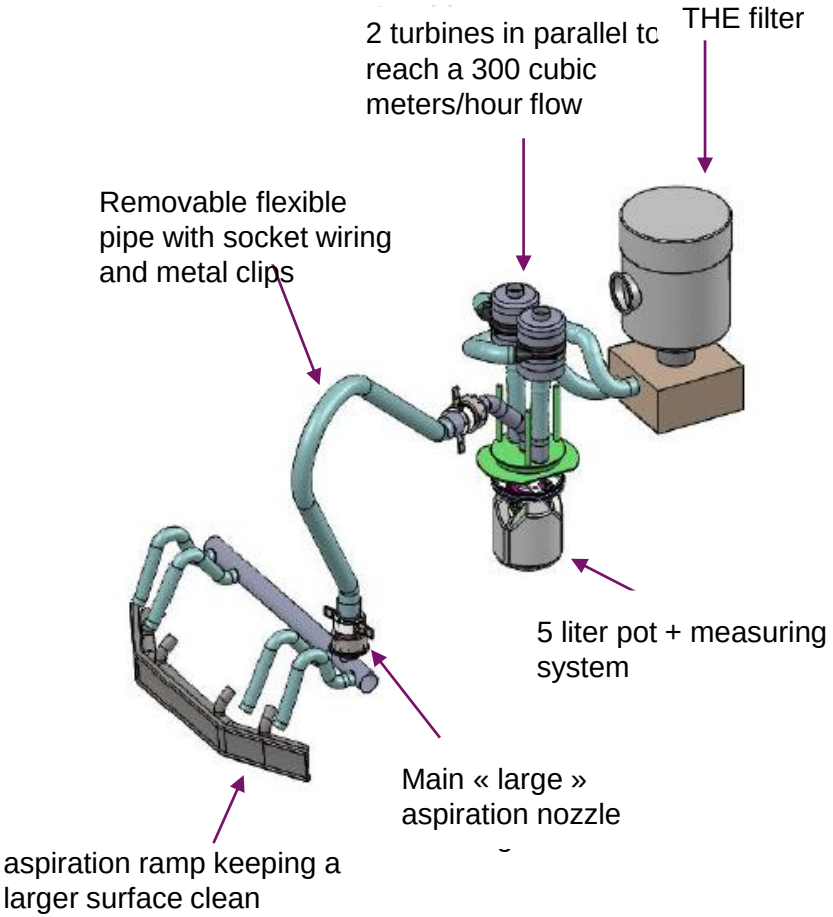
- Supplied with embarked batteries charged by a loading station
- Guided from a wireless network,
- Equipped with a « filter cart » and specific fittings to maintain the device.

The GOBY device mainly includes the following fittings:

- A vacuum system including a patented 5 liter pot,
- A discharge filtration system (THE filter)
- A chamber keeping the main electrical and electronic components,
- Four holonomic wheels and a geared motor,
- A robotic arm,
- A dose rate sensor,
- A room sensor,
- An obstacle detection system,
- A high definition viewing system.

GOBY / VACUUM CLEANER SYSTEM – 3D VIEWS





GOBY / ELECTRONIC BOX

All electrical and electronic components are available in the box : Super LiFePO4 battery (smart batteries without H2 release).

The box is dustproof.

It is connected to a passive embedded extinctor system : 1 CO2 reserve bottle of approximately 1kg, 1 Direct HP injection valve, 1 pressure switch (dry contact) and 1 FIREDETEC pipe.

Batteries Box

Embarked
CO2 bottle

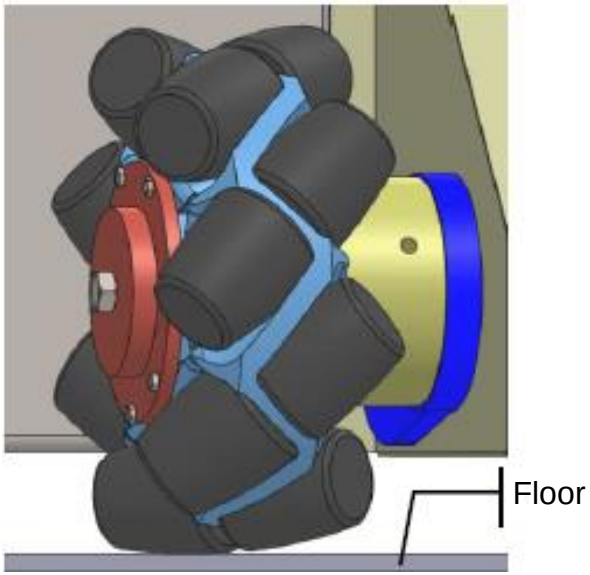
GOBY / HOLONOMIC WHEELS

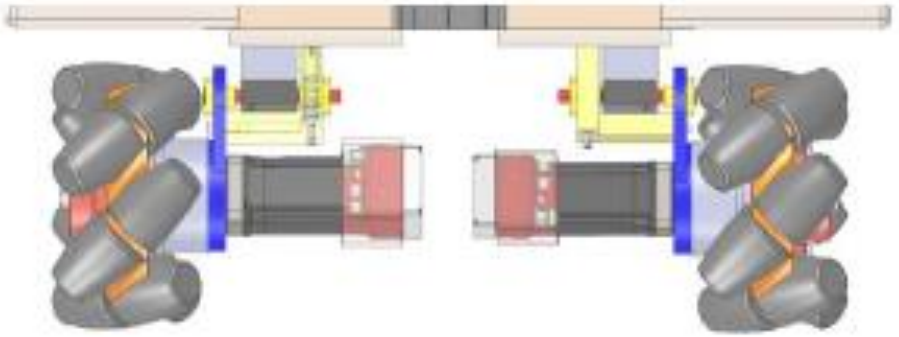
The GOBIE is equipped with 4 holonomic wheels ; each one is connected to a geared motor.

The rollers of each holonomic wheel are covered by an elastomer coating.

The holonomic wheels allow to roll over 5cm high obstacles. They are multidirectional without friction => free moves.

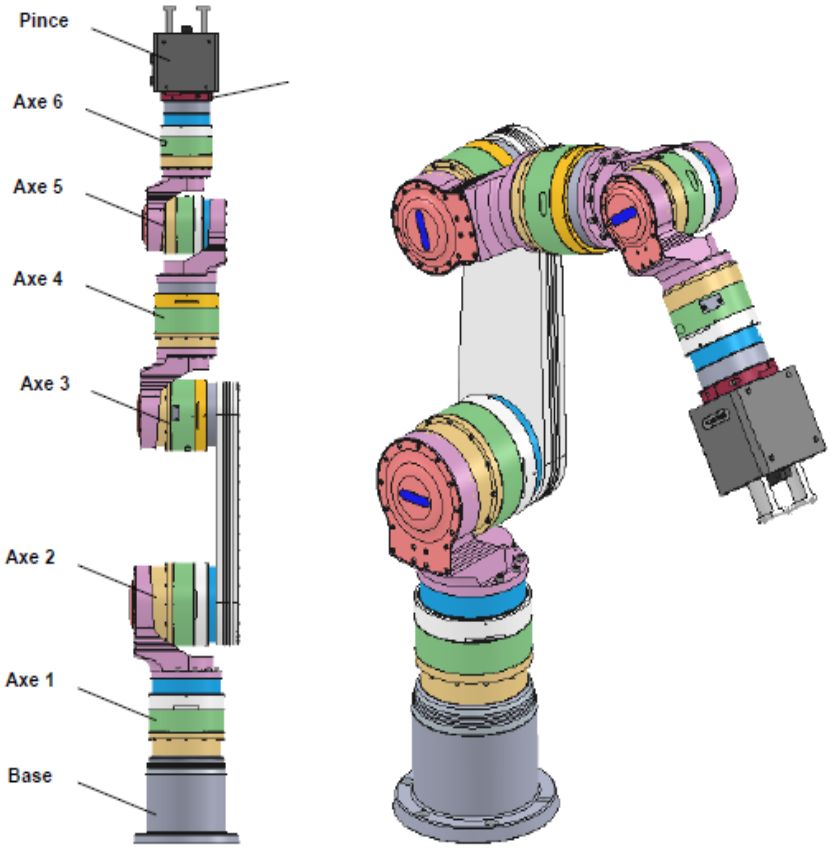
The nominal moving speed is 3,2km/h (i.e. 0,89m/s, while the maximum moving speed reaches 4,7 km/h (i.e. 1,31 m/s).





GOBY / REMOTE HANDLED ARM

The GOBIE is equipped with a 6 axes arm (SCHUNK) allowing the following operations:

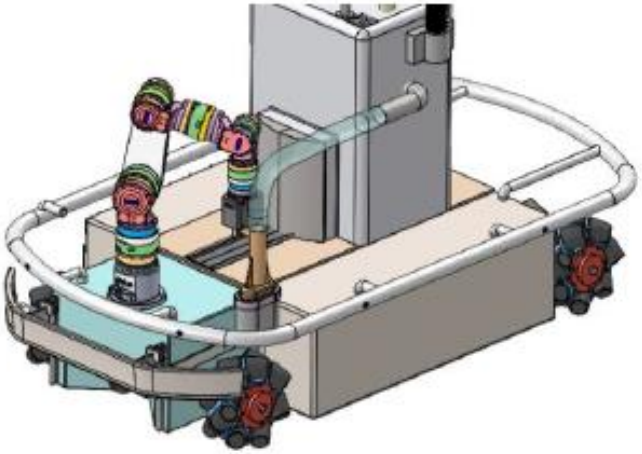


- one-off aspiration with the aspiration nozzle (pile, gutters, etc)
- whipping aspiration with large nozzle
- loading of one empty 5L pot in the aspirator
- unloading of one full 5L pot from the aspirator tank
- closing of the 5L pot lid
- loading of one 5L pot on the filter pots transport trolley
- unloading of one 5L pot from the filter pots transport trolley
- loading of the large/aspiration nozzle
- opening and closing of aspirator tank
- make DdD measurements on filter pot
- laying wireless beacons on the floor
- laying beacons on GOBIE device or on a transport trolley
- laying beacons on loading station
- connect and disconnect the GOBIE to loading station
- remove nozzle or terminals laid on the floor
- disconnect the aspiration pipe to replace it
- connect the aspiration clip to the aspirator via the nozzle

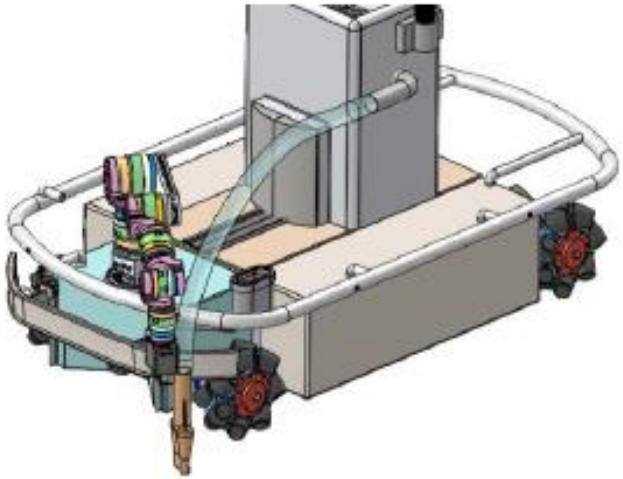
The 6 axe arm includes 2 control modes:

- **Manual mode**: to perform unpredictable or time to time different operations;
- **Semi-automatic mode** : for anticipated or repeating opertions.

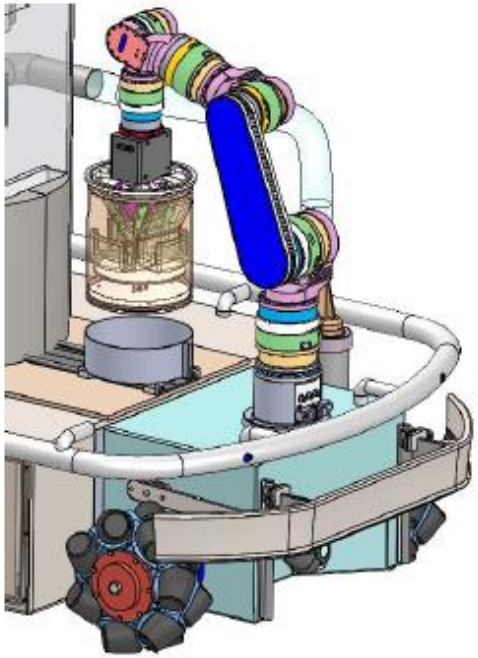
GOBY / REMOTE-HANDLED ARM CONFIGURATIONS



Grip of aspiration nozzle from its location



Grip of aspiration nozzle



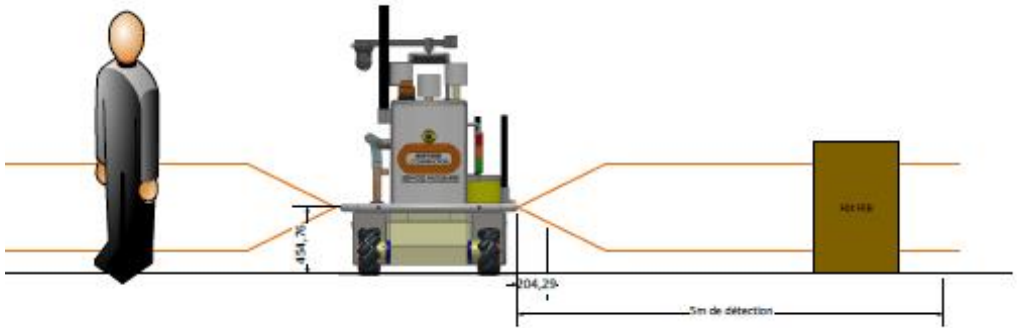
Grip of filter pot

GOBY / OBSTACLE DETECTION SYSTEM

The virtual protection provides a physical barrel to define the space needed for the robot.

It depicts the area whithin which the robot fittings are operating. It is equipped with a 14 ultrasonic sondes constituting « obstacle detection radars ».

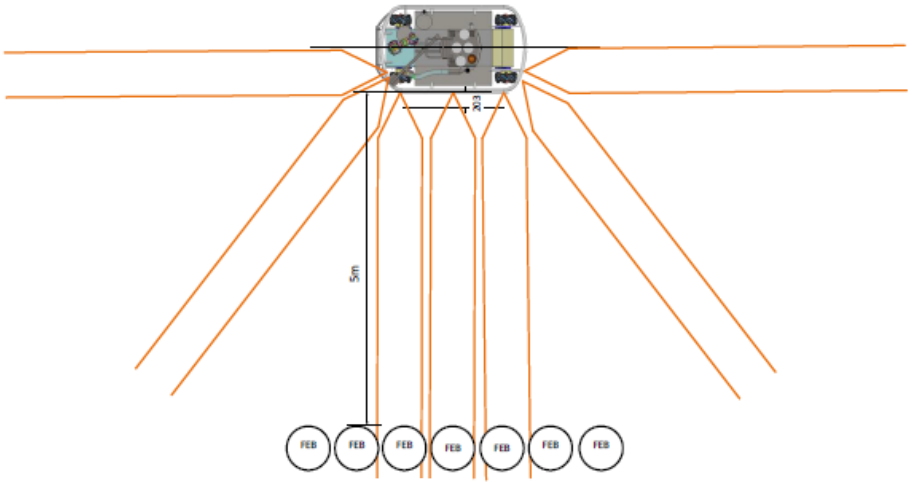
The system provides obstacle detection on 360° around the robot.



Program to prevent from collisions

➔ Stop at 30cm

Up to 5M detection

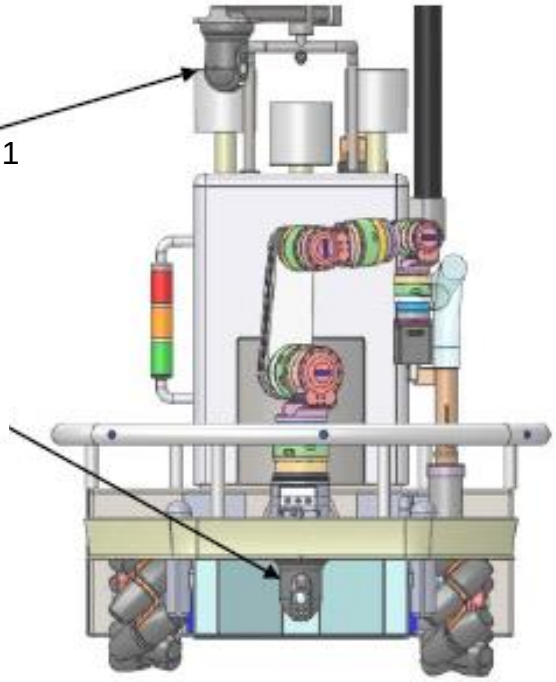


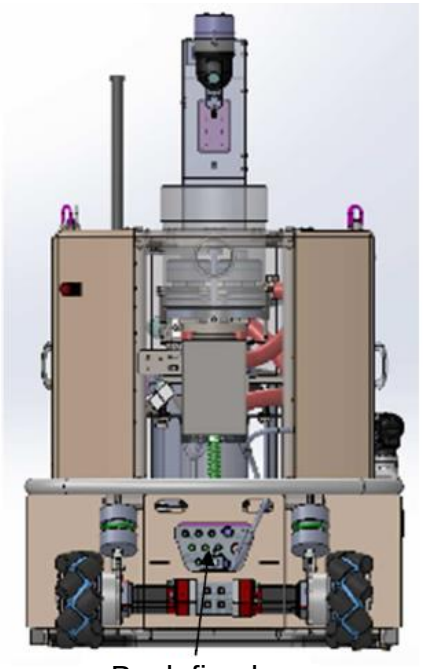
GOBY / VIEWING SYSTEM

3 motorized video cameras : 1 PTZ (motorized camera on site, azimuth and zoom) and 2 wide angle HD cameras on the aspiration robot.

Each video camera includes white LED (high brightness) or IR (infrared) lightning moving simultaneouosly with the vision sensor.

The pictures taken by both cameras are displayed and integrated into the robot control computer.





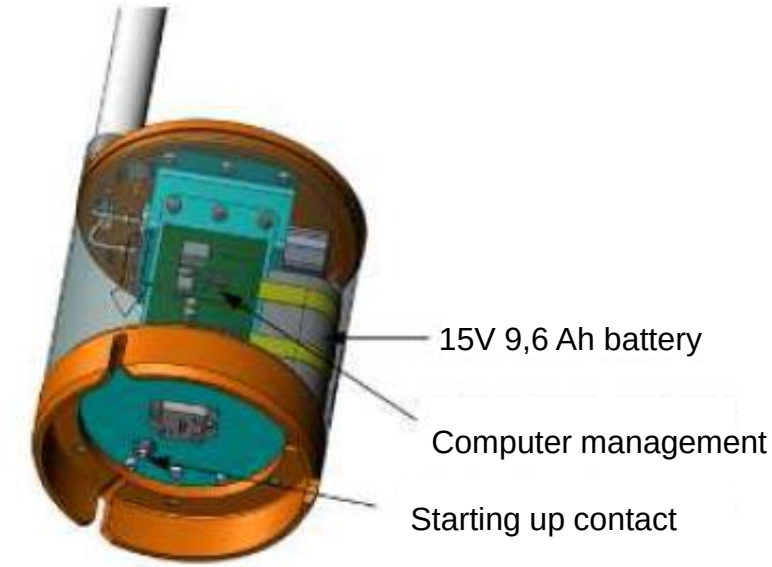
GOBY / COMMUNICATION AND NETWORK

Wireless communication network with signal transmission antennas.

Optical fibre wiring towards control room allowing a 100% clean signal.

=> 3 wireless network beacons are deployed for the reception of the signal in bunkers.

The beacons may be directly loaded on the GOBIE.



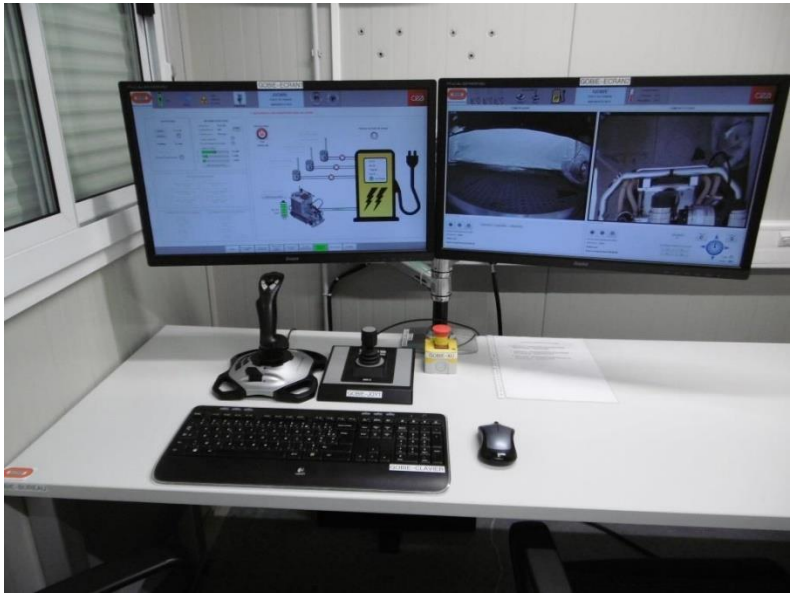
GOBY / DRIVING UNITY

The man/machine interface in the control room allows :

- To communicate in real time with the GOBIE,
- To control the different equipments of the GOBY (arm, cameras, aspiration system…)
- To move the GOBIE (different speeds)

- To view and manage various parameters to help performing operations such as :
    - o viewing obstacles around the robot,
    - o in the form of mapping of already vacuumed areas,
    - o dose rates in real time at the filter pot level,
    - o filter pot and DDD filling level,
    - o differential pressure at the HE filtration level (filter pot),

- To view and manage the monitoring parameters of equipments proper functionning in particular such as:
    - o the rate of loading and temperature of batteries,
    - o motors and servomotors parameters,
    - o inside temperature of the box,
    - o differential pressure in THE terminal filtration level.



+ Sound return

GOBY / 5 LITERS DRUM – CEA PATENT

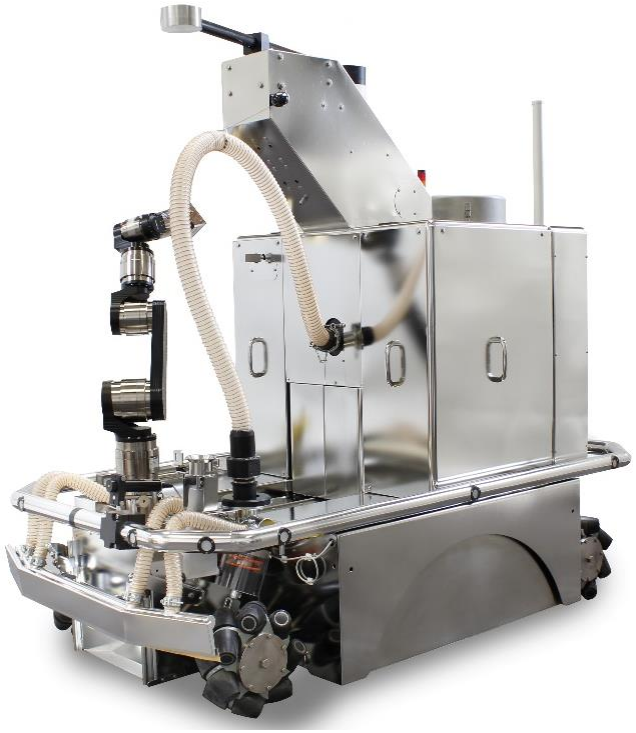
The dismantled prototype pot includes:
- 3 HE filters
- Guide grid
- PE material
- 30 kg magnetic lid

Top view

A plate on spring allows to take the following measurements:
- Volume
- Activity
- Mass
- Designed integrated sensor

IN REAL TIME

GOBY
PICTURES & VIDEOS



GOBIE remote-handled vaccum device with beacons and 5L pots transport trolley
6 hours autonomy ;
3 hours loading time

General presentation

GOBY
PICTURE & VIDEOS

On-site test

Motion test

Ramp test

On-site motion

Sweeping with nozzle

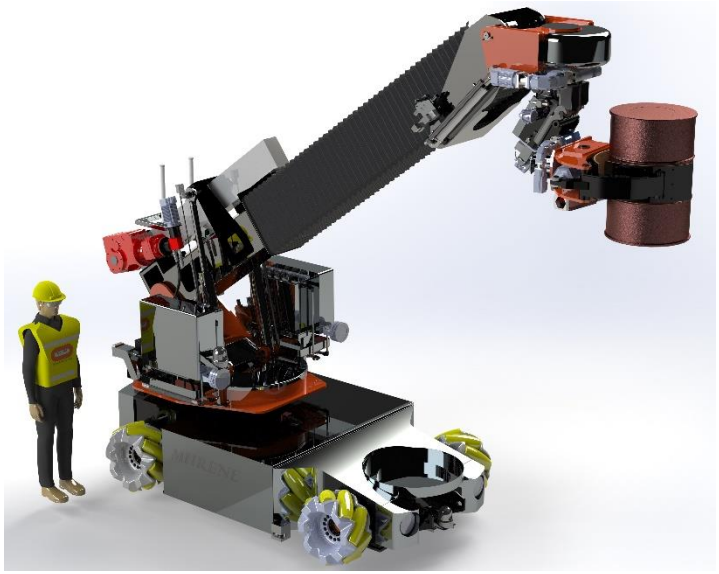
CONCLUSION

- High performances device

- Tender strategy (response with studies) allowed to fix the technical perimeter and validate the solution in the project context

- **Feedback :**
  - R&D's Integration for industrial needs
  - Technical functions associated to safety
  - Continuous CEA validation
  - CEA patent for a new drum wastes type
  - Human security increases

- **Next step :**



Remote device to take drums

Moray 2019