Improving Decommissioning Success using the Tool of Virtual Reality; Increasing Worker Safety and Project Schedule Stability – 17193

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ABSTRACT

In active High-Radiation Decommissioning settings, having clear vision of operations, especially underwater, is essential. Equally essential is a precise game plan for disassembly which focuses attention on the skilled remote handling operators who must produce the results. Project success is based on clean, efficient cuts and take-aways, prepared paths for waste placement and containment, programmed return paths; and practice, practice, practice on the part of the operators.

Recently, our Partner, WAK Rückbau- und Entsorgungs- GmbH (Decommissioning and Waste Management Company) was tasked with dismantling and decommissioning the Karlsruhe Reprocessing Plant. The most difficult task in this project is the dismantling of the vitrification plant. Wälischmiller was selected to address this high-consequence project. Together, WAK and Wälischmiller determined that development of a virtual reality suite, where management and operators could create a virtual vitrification layout and subsequently map and rehearse their dismantling plan was essential.

This approach, using Virtual Reality (VR) as a tool in streamlining operations and rehearsing difficult moves and cuts, will be a game changer for this and future projects. It will be a first-of-a-kind in Germany. The VR suite is contained in a room at the Karlsruhe facility with a large screen, control cabinet, simulation computer, a Wälischmiller Joyarm and Masterarm.

To support the dismantling of the vitrification plant, WAK/HWM will conduct interactive feasibility studies for each dismantling step. All movements; cuts, takeaways and vessel segment insertion into transportation and disposal casks will be established, programed and practiced within virtual test suite. This allows savings in cost-intensive and complex construction of test rigs. Operating personnel can be trained in the VR suite, without taking the risk of damaging expensive remote handling equipment.

While the operators are working on the operating element, they stand in front of a wide screen. Instead of a real TELBOT®, a virtual TELBOT® is moving on the screen in virtual reality. While practicing, the operators cannot damage the arm and the equipment, which is a big advantage. Moreover an interactive feasibility study can be realized without building a real test rig (mock-up). Consequently significant cost-expenses can be reduced.

This paper will describe the virtual suite used by the WAK in Karlsruhe and the advantages of this new and innovative approach, which is unique in decommissioning of nuclear facilities. The viewpoint of each (WAK & HWM), and the decisions and benefits realized along the project path will be detailed in the paper.

INTRODUCTION

The WAK Rückbau- und Entsorgungs- GmbH (Decommissioning and Waste Management Company) pools all activities relating to the decommissioning of nuclear facilities and waste management at the premises of the former Research Center Karlsruhe, today´s KIT. Partner of WAK is the Federation-owned Energiewerke Nord GmbH (EWN). The company is financed by the Federal Ministry of Education and Research and the Baden-Württemberg State Ministry of Finance and Economics. [1]

The vitrification plant Karlsruhe (VEK) has been built and used until the end of 2010 for the conditioning of the high active waste concentrate (HAWC) of the WAK. Due to the local dose rate, the dismantling of the operational facilities in the process cells is carried out by remote handling.

To support the dismantling operations, which will be conduct with the robotic system TELBOT®, the WAK realized in cooperation with Wälischmiller a virtual test suite. The suite combines the available 3-D models of the facilities and the interior equipment (hot cells, components, pipelines, etc.) with a virtual TELBOT®. In the future, the operating personnel can practice in this virtual suite and familiarize with the projects. Cutting procedure for dividing objects with special tools and automatic detecting of suitable objects for cutting can be trained.

DESCRIPTION OF THE VIRTUAL SUITE

The virtual reality suite is contained in a room with a large screen, control cabinet, simulation computer, a Wälischmiller Joyarm and Master-Arm. A short description of the main components is necessary to have a better understanding of the virtual suite.

Between 2012 and 2015 Wälischmiller delivered five complete robotic systems TELBOT® for the dismantling of several high-activity radioactive storage buildings at the WAK. (figure 1.). The TELBOT® arms are operated via the Joyarm and the Master-Arm. In total Wälischmiller delivered 3 Joyarms and 3 Master-Arms.

The virtual suite integrates a 3-D Model of the TELBOT® arm (figure 2.). While the operators are working on the Joyarm or Master-Arm, they stand on front of the wide-screen. Instead of a real TELBOT®, a virtual TELBOT® is moving on the screen in virtual reality.

Virtual Reality

Virtual Reality or VR has been defined as "...a realistic and immersive simulation of a three-dimensional environment, created using interactive software and hardware, and experienced or controlled by movement of the body" or as an "immersive, interactive experience generated by a computer". Virtual realities artificially create sensory impressions, which can include sight, touch, hearing, and, less commonly, smell. Some advanced haptic systems in the 2010s now include tactile information, generally known as force feedback. [2] The use of VR finds multiple fields of application, e.g. education and training, video games, entertainment, engineering…

The most known VR is the flight simulator, which artificially re-creates an aircraft flight and its environment. Pilots can practice cockpit procedure and get familiarized with the instruments. The most important reasons on using simulators over learning with a real aircraft are the reduction of transference time between land training and real flight, the safety, economy and absence of pollution.[2]

Based on this idea, WAK and Wälischmiller developed the VR suite.

Robotic System TELBOT®

The TELBOT® is a modular robot with selectable drives, arm lengths and joint modules. The motors and gears are located in a base behind the arm. Movements are effected by concentric tubes inside the arm link and concentric bevel gears inside the joints. Consequently, there is no wiring either inside or outside the arm and all axes can rotate freely.

The components of the TELBOT® have been carefully selected to resist harsh environments such as those in the nuclear or chemical industries. The smooth and sealed arm parts facilitate decontamination of the manipulator. Sleek construction and high dexterity enable the TELBOT® to access confined spaces.

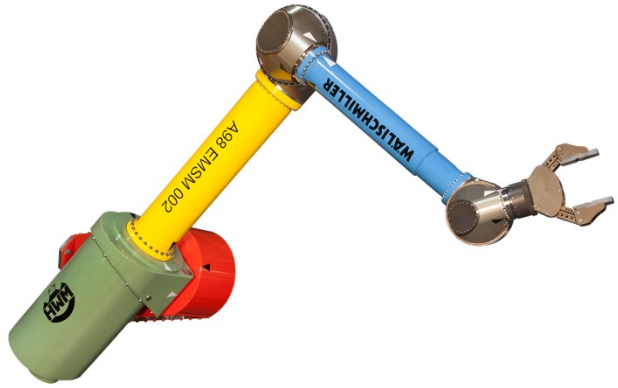

Fig. 1. Robotic System TELBOT® delivered at WAK

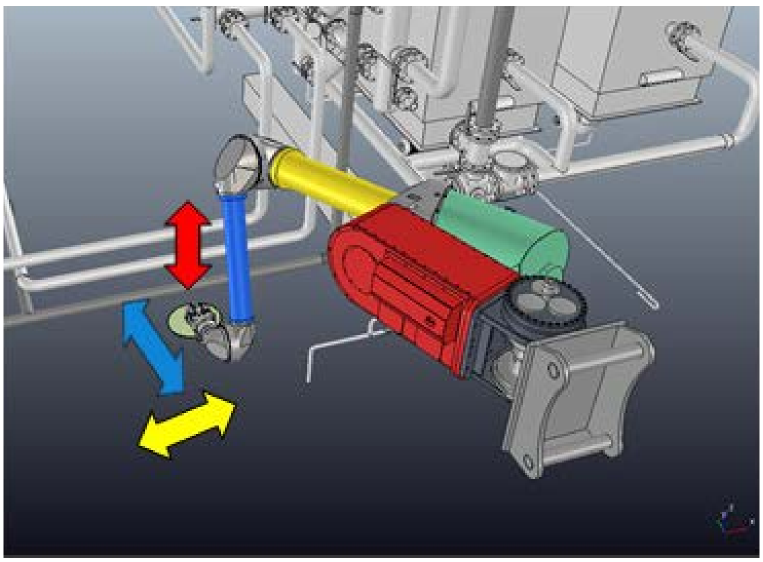

Fig. 2. 3-D Model of the TELBOT®

Joyarm

JOYARM (figure 3.) is a universal operating device for all kinds of multi-axis robots. In the past, many kinds of remote operating devices for robots have been developed worldwide: joysticks, master-arms, haptic devices, etc. Operators sometimes need intuitive, more precise control, and other times rough but very quick positioning. What counts in real-life applications is a low level of stress and fatigue resulting from operation. JOYARM has been developed to solve these problems.

JOYARM was designed to provide ideal ergonomics for operators in order to minimize fatigue, independent from the slave-manipulator structure. To improve the functionality, JOYARM has a feature that combines the advantages of conventional joysticks and bilateral master-arms. The name JOYARM is an acronym of JOYstick and master-ARM. With one device, operators can realize precise motion control such as that provided by a joystick and then switch to the intuitive quick positioning offered by master-slave control systems. JOYARM sends commands with 6 D.O.F. for position/rotation and receives 6 D.O.F. force/torque feedback in a cartesian coordinate frame. JOYARM also offers numerous possible applications as a haptic device.

Fig. 3. Operating device Joyarm

Master-Arm

The HWM Master-Arm is an operating element for manipulators. It has force feedback on its seven degrees of freedom. The advantage is that the operator can sense feedback on the Masterarm from what is happening on the manipulator.

The operation is simple and intuitive because the Master-Arm corresponds to the configuration of the slave (copying manipulator, figure 4.). The operator can directly see and influence the arm position. The force feedback works well, because the joint moments can be coupled back directly to the master (copying manipulator). Moreover, the training and training time for new operators is very short because the Master-Arm has the same configuration as the slave arm and therefore the operator can easily recognize the joint positions. The slave follows the master exactly as in the case of a mechanical manipulator.

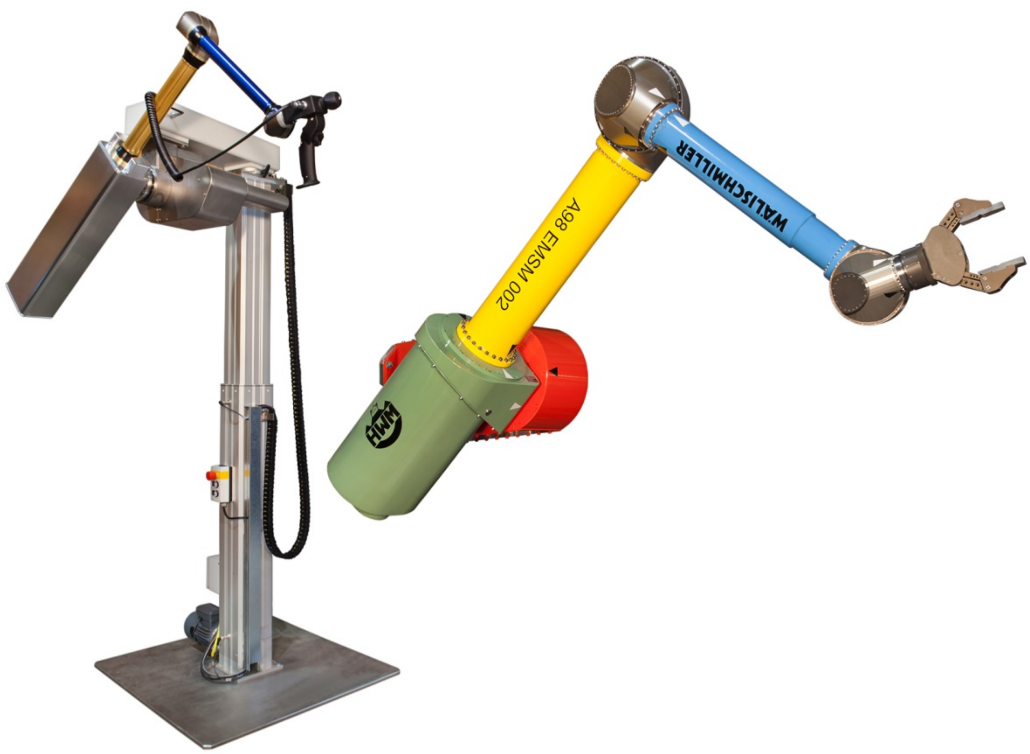

Fig. 4. Left: operating element Master-Arm, Right: Robotic System TELBOT®

TECHNICAL FEATURES OF THE VIRTUAL SUITE

The virtual suite combines different operating elements, also called input devices. The TELBOT® can be operated via the Joyarm or the Master-Arm. The system is based on a real time behavior with external real time controller. It means, that the command on the operating elements is transferred to the simulation nearly without delay. This feature is really important to improve the haptic and receive a force feedback.

Fig. 5. Setting of the virtual suite

Preparation of Virtual Reality Scenario

During the construction phase of the VEK, 3-D CAD data (mostly in Autodesk Inventor Professional) have been created. These data have been partly implemented in V-REP PRO and will be implemented step by step, depending on the actual dismantling stage. For the data import, the STL-interface (Surface Tessellation Language) is used. In addition to the data of the VEK, the kinematics of the manipulator technics and the required manipulator carrier systems have been integrated. The preparation of the VR scenario also required the programming of Plug-Ins for the control of the manipulator axes.

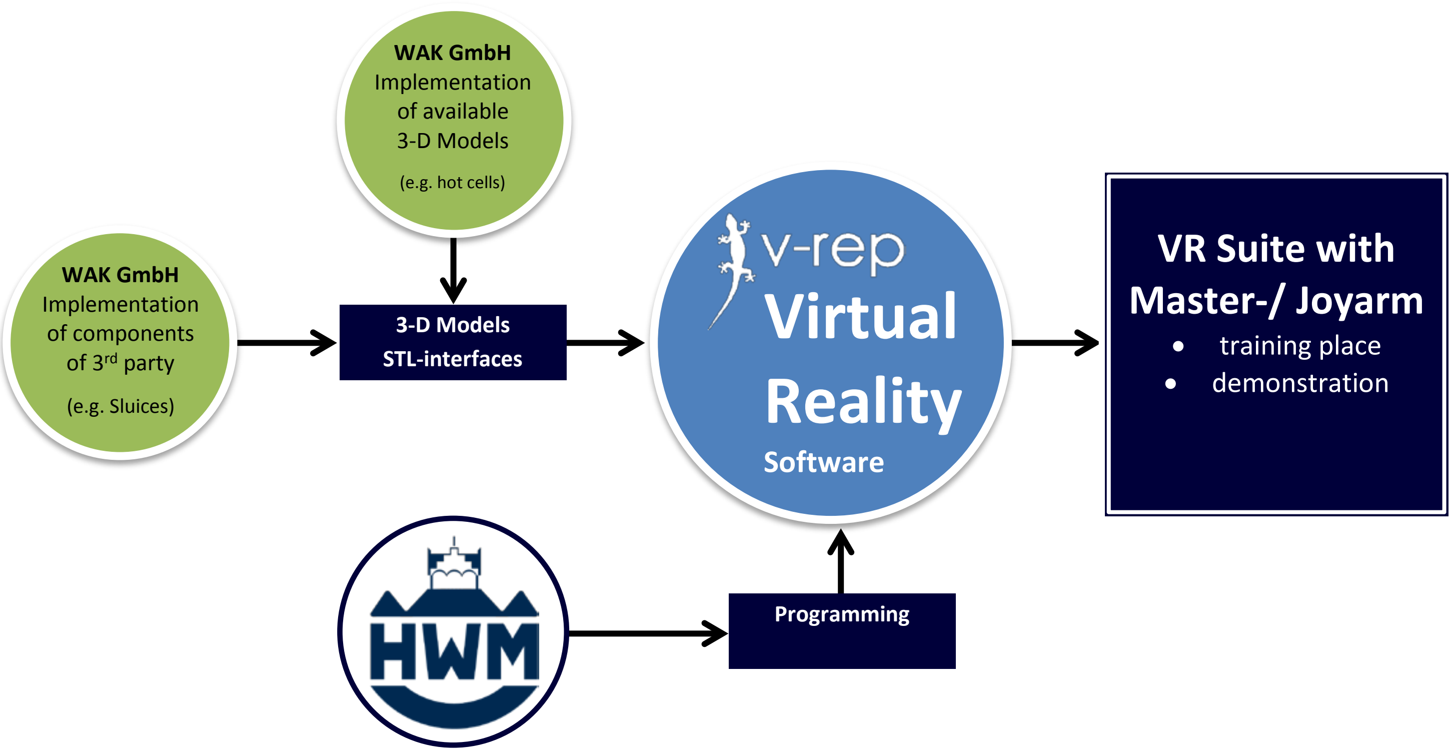

Fig. 6. Structure of the VR simulation

Generally, the virtual reality enables a various range of features. Some of them have already been implemented in the virtual suite at the WAK. In contrary, some of them have not been implemented, e.g. the path planner.

Different Controlling Modes

- Changing of tool frame position
- Moving tooling unit in screen and camera view perspective
- Rotating around center point of end-effector
- Tool direction changing

Minimum Distance Check

- Runtime distance check between arm and environment
- Robot-robot distance control
- Automatic stop if minimum distance reached
- Collision avoidance

Collision Detection

- Collision check between multiple collidable dynamic and static entities
- Self-collision and arm-environment collision avoidance
- Visualization of collision areas with security distance

Working Range Precalculation

- Field of view visualization
- Point cloud of reachable positions
- Considering of arm self-collisions, arm-environment collisions and minimum distances

Path Planner

- Automatic path generation between teach points
- Teaching mode. Teaching means recording of positions (single points) which may be run in sequence as complete trajectories.
- Linear and point-to-point interpolation
- Speed and direction control during playback
- Rollback mode

Intuitive Graphical User Interface

In order to have a virtual reality as realistic as the real system, the working environment is the same as with the real equipment.

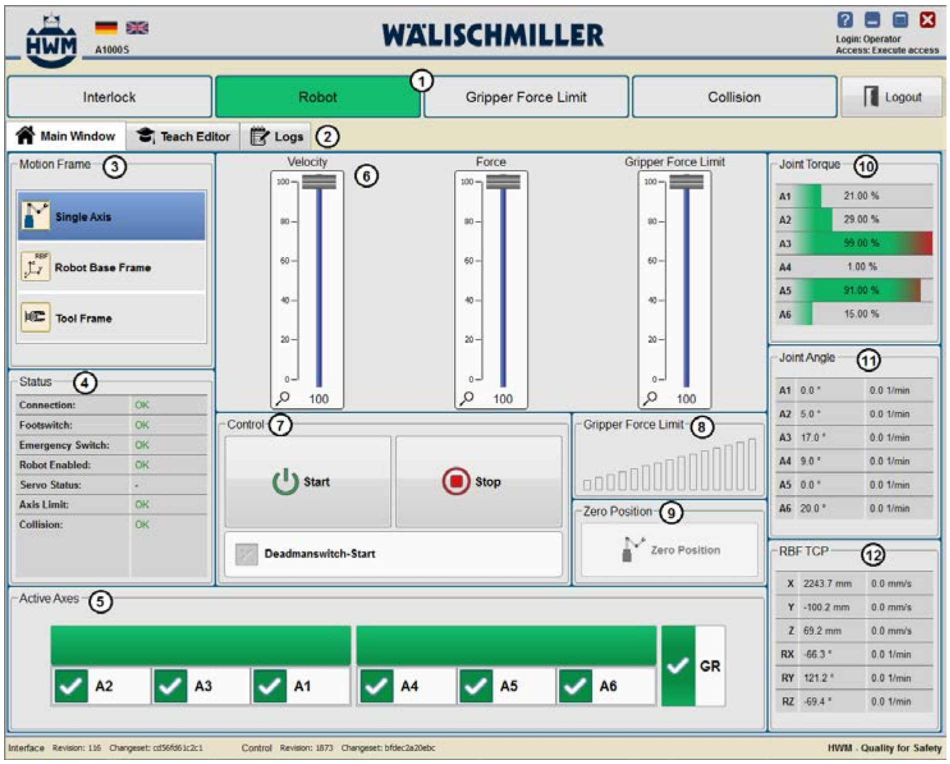

Fig. 7. The main window gives a status overview
and allows various settings.

The Graphical User Interface consists of various elements:

1. Information of the manipulator status is given in the status bar. With different colors the current status is displayed.

2. The tabs allow fast switching between the different windows.

3. The selected motion frame allows moving the manipulator in different ways.

4. Detailed status overview is displayed in the status window.

5. Depending on the selected motion frame, individual axes can be locked. In case a coordinate system is active (Robot Base Frame or Tool Frame), the selection will inhibit linear movement directions and rotation movements around any of the coordinate system axes.

6. Different settings can be set by slide controls.

7. The Deadmanswitch-Start allows switching the manipulator into the control mode only by pressing the deadmanswitch. Otherwise it is required to first press the deadmanswitch and then activate the control mode by tapping on the Start button.

8. Indicates the gripper force.

9. Set a new zero position.

10. A color code (green / red) indicates whether any joint is within limits or overloaded.

11. Displayed the actual joint angle and rotation speed.

12. Displayed the actual Tool Center Point.

ADVANTAGES OF THIS NEW AND INNOVATIVE APPROACH

As professionals in the remote handling industry, we aim to achieve a fine balance between customer's need for better technology, user friendliness, and economical constraints, as budget, return on interest and life time of the equipment. It is in this effort that we progress and develop our manipulators and systems.

User friendliness has always been a driving force behind our design and manufacturing. For decades, computer assisted technology and force feedback have solicited considerable sums in R&D and sales, along with significant customer desire and attention.

There is a large diversity of remote handling equipment on the market today, all with varying technologies and functions. Yet, it is customer desire for advanced solutions and comfort that encourages manufacturers to develop smarter equipment.

Today's remote handling technologies have reached a new breakthrough stage. Operations can be prepared in a virtual environment, which presents several advantages over traditional preparation and testing methods:

Interactive Feasibility Studies

The virtual reality suite adds more dimensions to the planning of single dismantling steps at the WAK, especially those requiring critical handling procedures. The situation and the operation which have to be done can be analyzed from different view and any angle, which are not possible with traditional cameras. The view selector makes it possible to create different views and perspectives. Additionally the virtual test enables an ideal positioning of the cameras in the hot cells. This modern technics opens new possibilities for planning the tasks, which have to be done. Different scenarios can be conducted to find the best way and solution for effective and safe dismantling operation.

Saving in Cost

Until now challenging dismantling steps have to be tested and trained on complex construction of test rigs. The commissioning of these rigs are cost-intensive and time consuming. The virtual suite offers a fast and cost-effective test environment close to the reality.

Additionally, the operations can be trained as often as necessary. Actually the test environment can be re-build in next to no time in the virtual reality. In contrary, when the test rig is used, it cannot be re-build so fast.

Operating personnel can be trained on a virtual test stand without taking the risk damaging expensive remote handling equipment. Consequently, the remote handling equipment will not be used which also lead to cost saving.

Improvement of Safety at Work

Operating personnel can practice in the virtual suite and familiarize with the projects. Cutting procedure for dividing objects with special tools and automatic detecting of suitable objects for cutting can also be trained. As this happen in a virtual environment, operators cannot damage the arm, the in-cell equipment and injure someone. Consequently, the safety at work is improved.

The inhibition to damage expensive equipment by making a wrong handling is minimized in a virtual reality. Consequently, the self-confidence is improved and gives operators a feeling of safety.

The detailed structure of the manipulator and the operational facilities in the hot cells are modelled and simulated in real time. The optical collision detection during the simulation avoids damages on the manipulator and the facilities. The collision detector sends the signal to stop the arm before collision occurs.

Future Development

For the moment, the virtual suite at the WAK integrates a TELBOT® system. In the future, 3-D models of the power manipulators A1000 and of the remote controlled handling vehicle V1000 employed at the WAK will be integrated in the virtual suite. The standard control console of the A1000 will be linked with the suite. This enables a wide scope of possibilities for the feasibility studies.

The virtual technic can be used as training workplace for future remote handling operators by using a Physic Engine. In addition, the technic demonstrated also its efficiency during qualifying examination for job interviews.

CONCLUSION

As shown through this paper, the application of virtual reality reached the field of remote handling and robotics. More than ever, the budgets available to solve huge remote handling challenges like the Hanford Tanks and the Sellafield Ponds & Silos are constrained. By developing technology, which allows a vendor to use a virtual reality, great cost and time savings on a current project can be reached. The concept of virtual reality for training and interactive feasibility studies is essential, as well as the necessity to keep personnel exposures as low as achievable dictates the increased use of remote handling and virtual reality.

Products continue to improve to meet customers' needs. As we enter the next stages of decommissioning in both the commercial and government arenas; we must look for new solutions and equipment that meet the precise need of the situation and protect the workers and the environment in new and effective ways. Virtual reality is one of these new and innovative approaches. The WAK recognized the potential and advantages of employing VR, which will lead to the success of the dismantling and decommissioning activities in Karlsruhe. Because Wälischmiller has always been at the forefront of remote handling and robotic innovation, we are not to much surprised if the WAK appeal to us to develop with them this innovative technology. Thank You!!

REFERENCES

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