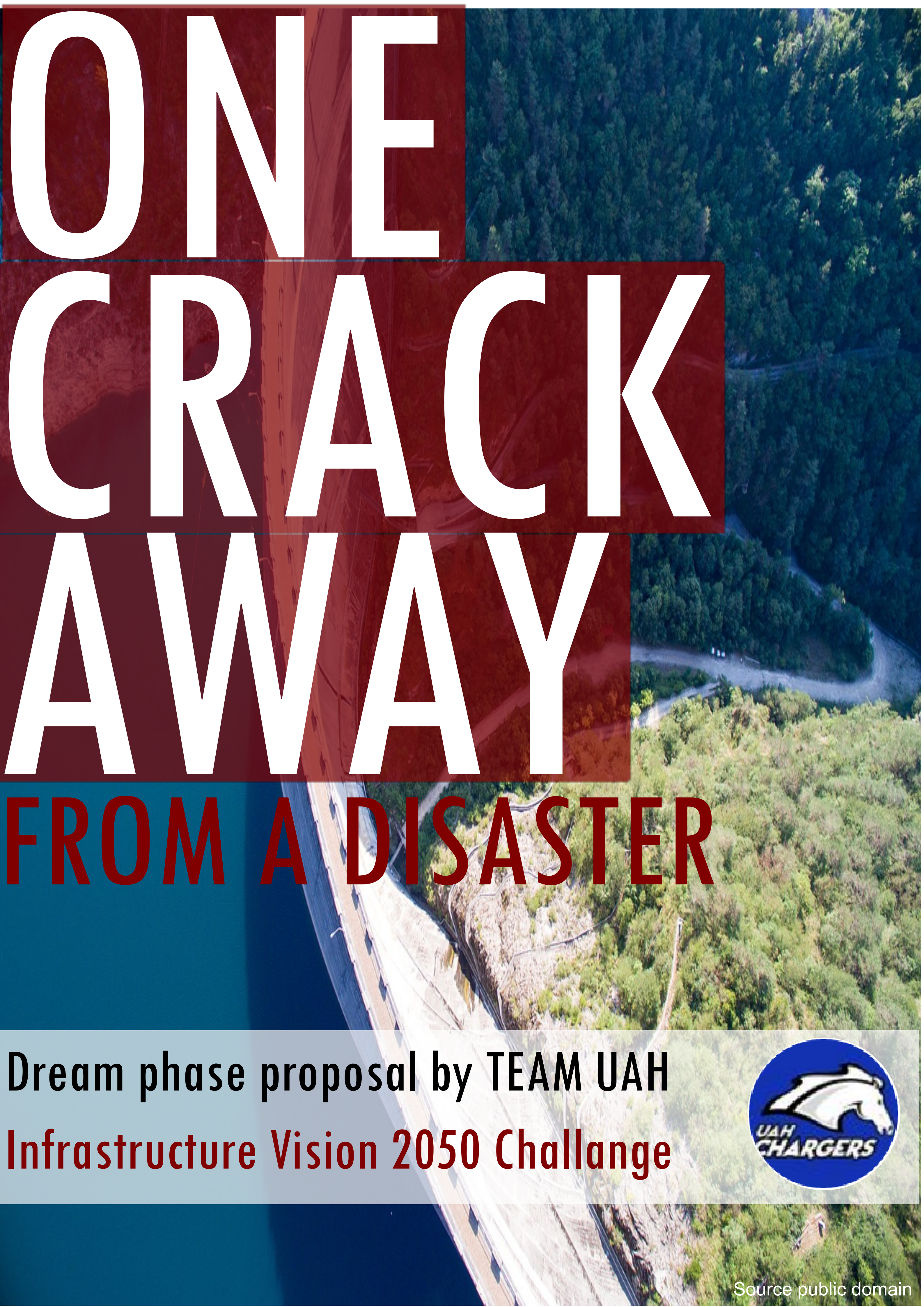
ONE CRACK AWAY

FROM A DISASTER



Dream phase proposal by TEAM UAH

Infrastructure Vision 2050 Challange

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Dams and Water Infrastructures for 2050

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Alabama is the only state that doesn't have a dam safety program, and only two percent of Alabama's dams are inspected. The number of deficient dams in the U.S. is estimated at more than 4,000 and req- -uire an investment of $21 billion to repair [1].

An Alabama Power engineer inspecting a crack using conventional techniques [2].

Dams are often out of sight, but play a critical role in our daily lives in addition to drinking water facilities. Also, hydropower is the biggest source of green energy in the United States and farms that are the main food supply in the market also rely on dams for irrigation in many regions. Industries such as food processing, chemical manufacturing and power plants were built near dams or nearby. Drinking-water systems in many states collect source water from dams, besides rivers and lakes. But like most infrastructure, dams go largely unnoticed until something goes wrong.

Despite dams being so vital, there are more than 87,000 dams in the United States and at least 14,000 dams are in need of repairs, deficient, or stressed [1].

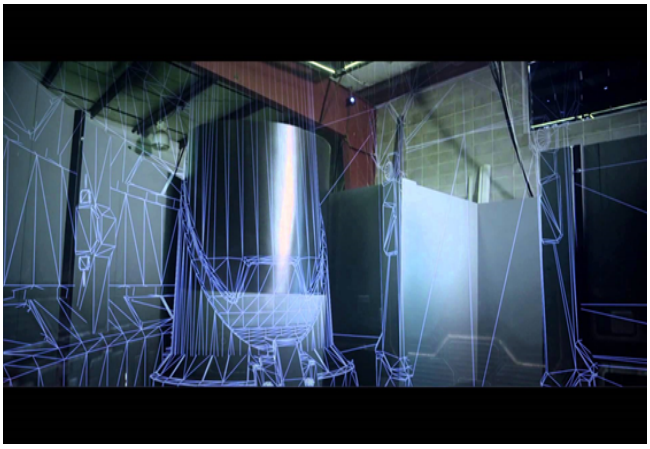
The problem with dams is not confined to the reported and inspected ones because thousands more are not inspected.

In the Complain phase of the Infrastructure Vision 2050 Challenge, we proposed to tackle the issue of water resources and dams because they directly impact the quality of life of people and communities in the U.S., and because they have a deep impact on the economy. In the Dream phase, a novel technology is proposed for inspection and maintenance of existing structures that can even revolutionize the planned ones. If the capacity and safety of existing infrastructures are achieved, more resources can be dedicated to building new ones. For example, it is estimated that dams will require an investment of $21 billion to be repaired [1]. This figure will increase by 2020 when 70% of the total dams in the United States will be over 50 years old, which is more than the maximum service time these dams were designed for. If we were able to lower the figure of the required investment in 30%, and increase the efficiency of inspection and maintenance by up to 70%, newer project could be funded to boost the economy and people's quality of life will be considradly improved .

SUMMARY OF THE SOLUTION

Inspecting the vast number of dams requires allocating a greater portion of resources for mobilizing the inspection engineers and their tools. This is not a cost efficient model and a limits any further growth of the magnitude and scale of the infrastructure of tomorrow. What if we are able to bring the dam, the bridge, and any structure to the engineers to inspect them. What if we had a centralized center to reconstruct the infrastructures in virtual reality and let the engineers walk and fly around the structure and inspect thousands of dams in the same spot where they work.

Example, virsual reality in gaming [7]



Example, virtual reality used in gaming [3]

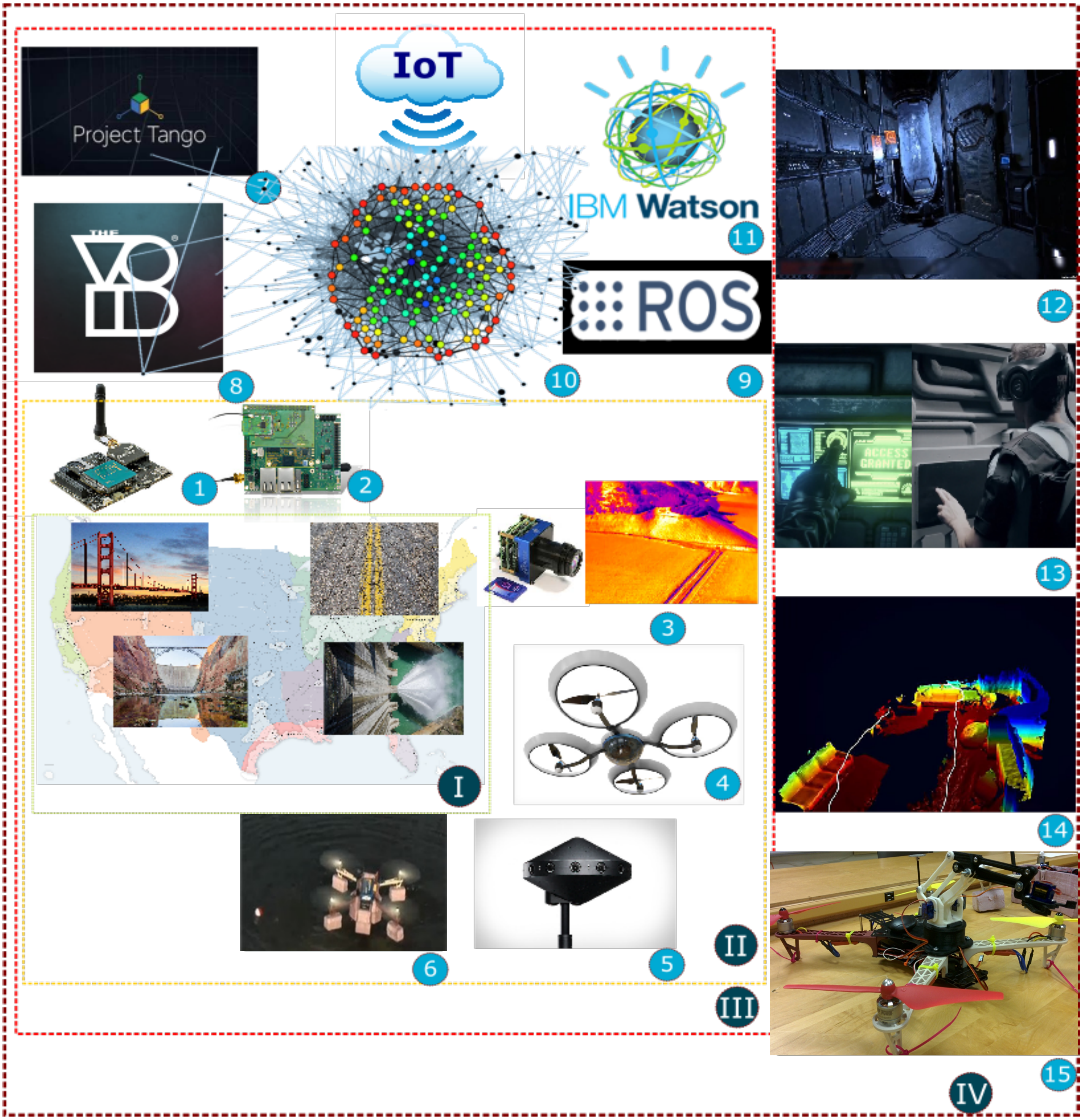
In our vision for a solution for America's dams and water resources problem in general, and for the state of Alabama in particular, we are proposing an architecture for inspecting, repairing and improving the overall safety of the dams. The objective is to revolutio--nize the water infrastructure and reduce the cost of inspect--ion by 70% after the second year of implementing the solution, and to lower the cost of the repairing and maintenance by 40%. We also aim to lower the time required for acquiring the data for disaster response to a real-time acquisition. We will be able to achieve theses goals by creating a centralized virtual reality center, where the engineers could inspect every single dam in the nation from a centralized location. Also, the augmented reality can be used on-site the structure to enable the engineers and workers to see the output from the embedded sensors in real time. The proposed architecture consists of 4 tiers and they are, Implementation, Data acquisition, Data processing, and Execution.

Example, virsual reality can also be used onsite the actual structure to help engineers read the data streamed from the sensors to the cloud [3].

Imagine that every dam and bridge in America have a virtual reality replica and it's aided by data from sensors and with a system for a machine learning based prediction. The inspection engineers could have an avatar that enables them to fly around and inspect, in real time, these structures from a centralized location.

Image credit imgur.com

Overall Architecture



I Implementation

The solution is tailored for revolutionizing how dams and water delivery system are inspected and maintai--ned, and that's the infrastructure where it can be implemented. However, we are inheriting a very agile approach in developing our futuristic module which enables it to be implemented in other critical infrastr--uctures such as bridges.

II Data Acquisition

Embedded sensor, thermal and radiometric camera on--board drones, 360 degree HD cameras, and water robots are all part of the main technologies that will be used for acquiring the data. These data will consist of images, and signals that will be used for reconstructing the virtual and augmented realities.

In the overall architecture figure, tier II has the following data acquisition tools,

Taking Actions
Technology of Tmowrrow, Now

credit collider.com

1. Strain sensors that are used for monitoring stress on girders.

2. Tilt sensors that are used for monitoring bearings tilt, pier movements and settling, and displacement sensors for monitoring expansion in the infrastructures

3. Thermal and radiometric cameras used for capturing the heat signature and other abnormalities in the structure, including cracks, leaks, and deterioration [15].

4. Waterproof drones used for carrying sensors and taking thermal/radio--metric images [13].(This is our proprietary robot)

5. 360 degree HD cameras used for creating the images required for reconstructing a virtual reality structure [16].

6. Underwater working robots equipped with cameras and sensors for inspecting the submerged parts of the structure [13].(This is our proprietary robot)

III Data Processing

In the data processing Tier III, there is a cloud that runs several services that are required for processing, storing, and reconstructing the data and information. This layer includes more sophisticated techniques for event prediction and classification. It uses data-fusion and a variety of machine learning algorithms to enable classification of the processed data from Tier II into discrete actions in real-time and with high accuracy. This information can be used to make predictions for dam failure and other potential risks. Therefore, the cost of mitigating structural abnormalities will be substantially reduced. The cloud services also processes and stores the captured HD images for creating virtual reality replicas for the centralized inspection center. The cloud in this tier runs four services,

7. Project Tango [5] is used to bring augmented reality to the mobile devices that the engineers will use for inspection. The virtual structure is constructed by using Motion Tracking, Depth Perception, and Area Learning. The inspection engineers can point their mobile devices at any structure within the dam and get an accurate reading of the embedded sensors in real time. By using machine learning, discussed in 10, a prediction of the future state of the inspected area will also be displayed.

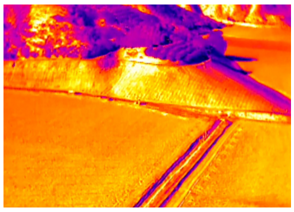


Image credit [15]

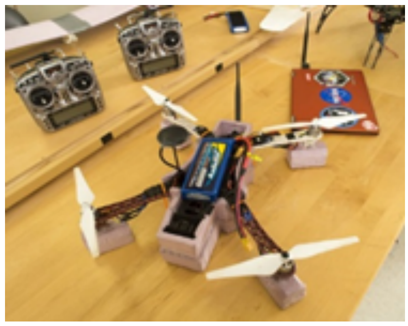
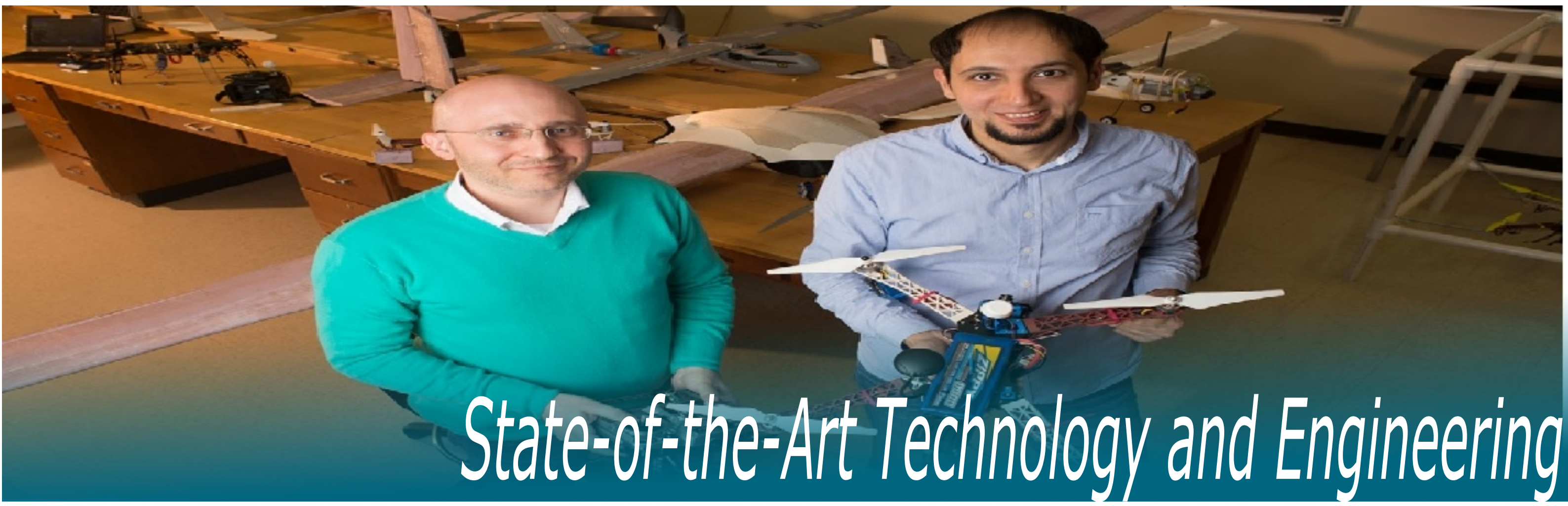


Image credit [16]



State-of-the-Art Technology and Engineering

Credit [5]

8 By enabling a virtual reality engine on the cloud, the HD images that are captured using (5) will be reconstructed. The VOID [3] is one example of many virtual realities that are currently under-development and it could be used for this task. The mapping of the infrastructure can be so precise and accurate because it's aided with sensor readings and machine learning predictions that can reveal issues otherwise won't be observable to the naked eyes.


Credit [3]

9 Components from the Robot Operating System (ROS) [6] will run on the cloud in order to control the robots used for scanning and fixing the dams. These robots are programmed to autonomously accomplish their tasks and charge themselves when they run out of power.

10 The machine learning engines will be responsible for classifying events and making predictions. When important readings from the sensors are missing or when a problem arises the machine learning can help prioritize actions and aid in preparing a response plan. The machine learning agent is interconnected with 7, 8, and 9 and it can drive the robots that are used for scanning or fixing the infrastructure and ROS as the main OS

ROS

Open Source Robotics Foundation

Credit [6]

11 The IBM Watson API [10] will bring deep learning, natural language processing, and machine learning to the proposed system. It will also bring new knowledge, expert knowledge, and make machine intelligence available for the infrastructure engineers in both the augmented and virtual realities. Recently, the IBM Watson was successfully embodied in robots [11],[12].

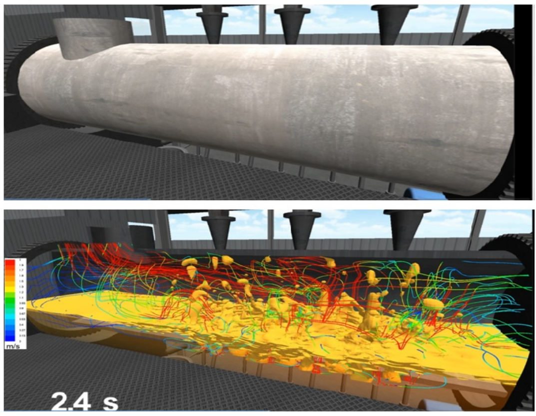
IBM Watson

Credit [10]

IV Execution

In the execution Tier IV, we propose an approach that has four main components. These components are designed to revolutionize infrastructure inspection, servicing, repair, emergency response and planning.

12 The first component is a centralized virtual reality center that is used to reconstruct the scanned infrastructure and display the sensors' data in a visual format in both the virtual and augmented realities. This method is expected to lower the cost of inspection by 70%, and will also provide major improvements in emergency response and other areas that will emerge after implementing this component.

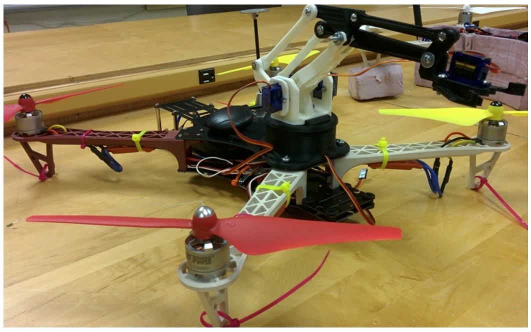


VR is bringing a new era for engineering [17].

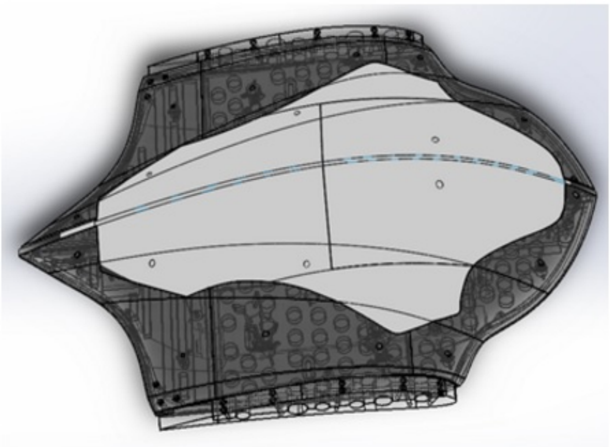
A prototype of a multirotor drone designed by Team UAH [14].

13 Augmented reality on the other hand can be implemented on the inspection site. This component will enable the engineers to see visible cues from the reconstructed graphics on their personal devices. It will change how the on-site inspection is managed and will also reduce both the time required for inspection and the human errors in reading and collecting data.

14 The sensors data and the thermal/radiometric images can be reconstructed as a 3D model using the project Tango agent. This model can be used to give the robots the data that they need to navigate inside the infrastructure even in a GPS deprived area. Also, it gives the inspection engineers a third eye into what is hidden inside the walls and could be detected by the sensors. This component is vital for the infrastructure repair and maintenance for the deployed robots and it has been implemented recently by Boston Dynamics [8].



A 3D printable robotic arm drone prototyped by Team UAH .



A 3D printable submarine robot drone designed by Team UAH .

15 The submarine robotic drones that we are developing are designed for two main tasks, to scan the dam and to report issues found in areas that are hard to reach for humans.It also executes tasks such as remote fixing and service. We designed the robot to enable it to live on the sea floor, and carryout cleaning and keeping check on undersea equipment.
Also, it can float on the surface of the water and autonomously scans the dam and the water pipes and drop sensors in hard to reach areas [13].

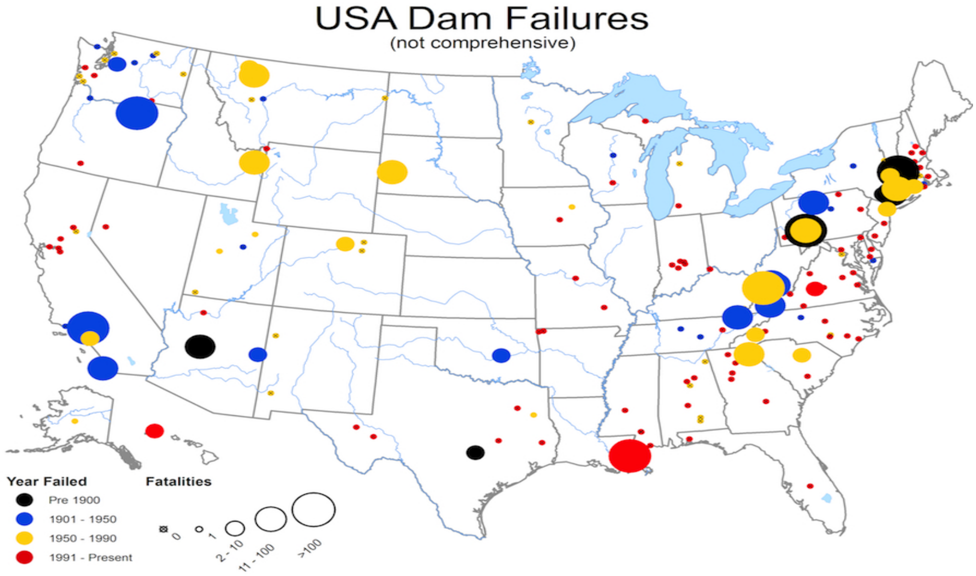
Overall Metrics

Safety

Cost

Reliability

Environmental sustainability



Map prepared by James S. Halgren, Office of Hydrologic Development, National Weather Service, National Oceanic and Atmospheric Administration, based on data complied by the Association of Dam Safety Officials.

Our proposed solution is technology focused and forward-looking and It must meet four over-arching goals: Safety, reliability, cost and environ--mental sustainability. It must be measurable and accountable.
We will have succeeded, when we meet and exceed these goals,

Credit cbc.ca

Safety, increase the safety of the U.S. infrastructures and reduce the fatalities and eliminate failure or collapse due to lack of maintenance and structural flaws.

Reliability, the system must be reliable in reporting data and in providing the engineers with a robust tool. The machine learning, predicting and the autonomous robots involved in maintaining the infrastructure must have zero error otherwise human lives will be lost.

Cost, we determined our goal of reducing the inspection cost by 70% and the maintenance cost by %30 after the second year of implementing the system.

Environmental Safety, the infrastructure of the future must coexist with nature instead of working against it. Furthermore, the U.S. has 900 [18] mining dams that were built to block hazardous materials from mining and human activity. The collapse of these dams could have catastrophic impact on the environment. Our goal will be achieved if we were able to prevent the collapse of these dams.

Credit Pixabay, public domain

The Public Library (center right) Ground Transportation Center, (left) and the Cedar Rapids Science Station (bottom left) in downtown Cedar Rapids (Perry Walton/P&N Air)

In Alabama

Provide the required inspection data for Alabama's dams to make the state eligible for federal funding. Lack of data is blocking Alabama from receiving these funds.

Have all High Hazard dams, including privately owned ones, in Alabama equipped with the technology that we are proposing to address potential collapse and protect people living in the dam break inundation zone. Alabama lacks statistics on the numbers of people who live in dam failure inundation zones, but those people are completely unaware of the potential hazard lurking upstream.

Enable the engineers to inspect and fix the vulnerable dams remotely without allocating huge resources for logistics that the state may not be able to afford.

In the U.S.

The solution that we are proposing is expected to have the highest impact on these four areas

Population, in the U.S. millions live downstream from dam failures. An advanced inspection and warning system is vital for this population, especially to minorities, elderly people, and depressed communities that are incapable of escaping the area within the needed time frame.

State facilities, all state facilities in the dam failure inundation zone are vulnerable to damage

Critical facilities, all critical facilities, Utilities such as overhead power lines, cable and phone lines, and transportation infrastructures in the dam failure inundation zone are vulnerable to damage.

Economy, Damage to buildings, farms, properties can impact a community's economy and tax base, water and food supply, and affect all aspects of life.

Impact

Population

State Facilities

Critical Facilities

Economy

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Team UAH in the Media

http://www.waaytv.com/videos?autoStart=true&topVideoCatNo=default&clipId=12401274

http://www.waaytv.com/tech_alabama/uah-students-look-to-address-alabama-s-lack-of-dam/article_07411e8a-0e37-11e6-a045-0ff67bd4e60c.html

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Disclosure

In the proposed solution, there are components that rely on third party development kits and software, which is either, 1) open source, e.g., ROS, or 2) offered for integration and development with an SDK or an API, e.g., IBM Watson and project Tango, and 3) proprietary e.g., The VOID. The latter is presented as an example and the authors were given credits and cited in the references.