RECLAMATION
Managing Water in the West

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Bureau of Reclamation

Research Update

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Bottom Line

This research project demonstrated an autonomous unmanned aerial vehicle (UAV) for penstock inspection at Glen Canyon Dam, Arizona.

Better, Faster, Cheaper

Using UAVs to inspect penstocks, tunnels, siphons, and other inaccessible features could be cheaper and safer than traditional manned inspection techniques.

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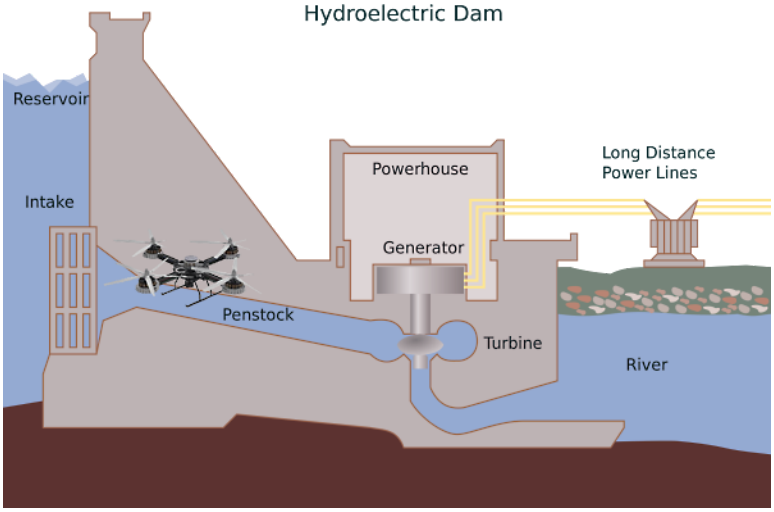
Going Where No Human Can: Inspecting Inaccessible Features at Reclamation's Glen Canyon Dam

Determining the feasibility of using autonomous unmanned aerial vehicles for penstock inspections in inaccessible areas

Problem



Penstocks, siphons, and other full-water conveyance structures need to be dewatered and inspected periodically. However, these spaces are confined and access usually requires permits, specialized training, and safety procedures. Thus, these spaces are termed "inaccessible" and physical inspections are costly and increase risks for inspectors. Tunnels, penstocks, siphons, draft tubes, and other water conveyance structures where the length is much greater than the width are challenging to inspect. While the rounded sides and small amount of water usually collected along the invert make traveling through the tube difficult, the grade oftentimes increases to such a degree that additional support is required, such as ropes. In addition, the spaces are usually classified as "confined space" given the questionable oxygen support and complex entry requirements. Thus, any structural features containing these elements are defined as "inaccessible features."

Solution

Autonomous unmanned aerial vehicle (UAV) technology could be used rather than humans in inaccessible features inspections to improve safety and lower costs. Autonomous navigation allows the UAV to traverse through bends and curves throughout the structure and helps it to avoid obstacles. Three-dimensional (3D) mapping and modeling is used to generate documentation for review and measurement in order that the inspector has quantifiable information to make recommendations. Inspection video is provided in 360 degrees throughout the structure for a visual review of its condition.

The U.S. Army Corps of Engineers (USACE) recognized the potential and has been collaborating with the University of Pennsylvania's Robotics Laboratory to develop a UAV for inaccessible features inspections. The UAV's functions include autonomous navigation, 3D mapping and modeling capabilities, and 360-degree video.

This Reclamation Science and Technology Program research project worked with USACE and the University of Pennsylvania to examine the UAV's effectiveness in inspecting a penstock and to demonstrate its capabilities to Reclamation.

Application and Results

The Unit 2 Penstock at Reclamation's Glen Canyon Dam in Arizona was used for the demonstration. The penstock begins at a fixed wheel gate at the upstream face of the dam and terminates in the generator turbine scrollcase. The penstock is about 400 feet long and features a 285-foot, 60-degree inclined section and a 100-foot-long horizontal section leading to the scrollcase. The inclined section has a 15-foot diameter, which is reduced to 14 feet in the horizontal section. The penstock is steel-lined with portions encased in concrete and others buried in soil. It is coated with a coal tar enamel that has been in service since the mid-1960s. This configuration is representative of many Reclamation and USACE structures.

Autonomous UAV inspection at Glen Canyon Dam, Arizona. The UAV provides the light, illuminating the tunnel.

Only the horizontal section of the penstock was inspected autonomously, as time was limited. A small portion of the inclined section was inspected using manual control. The post-processed video included a stitched panorama from four cameras of the 360-degree circumference of the penstock. A point cloud of the penstock was also generated using two Light Detection and Ranging (LiDAR) sensors. However, the video resolution was too low to accurately identify all potential defects in the penstock coating. In addition, the point cloud was also lower resolution and could not be used to measure loss of coating.

Since this UAV application was entirely indoors, the U.S. Department of the Interior's Office of Aviation Services did not have any National Airspace System (NAS) requirements. Reclamation's Safety, Security, and Law Enforcement required permissions at the regional and local levels, as well as appropriate safety measures. The required safety measures were to ensure that the UAV could not escape into the NAS and that personnel were protected adequately against any potential collisions with the UAV.

Future Plans

Reclamation's Technical Service Center would like to continue to partner with USACE and the University of Pennsylvania to provide additional demonstration sites for testing and to contribute recommendations for future design versions that would thereby provide useful data for inaccessible features inspections.

Autonomous UAV and sensors.

"This research provides promising leads for autonomous inspection of inaccessible features."

Janet White
Manager, Concrete, Geotechnical, and Structural Laboratory
Reclamation's Technical Service Center

Collaborators

- **U.S. Department of the Interior's Office of Aviation Services**
- **U.S. Army Corps of Engineers**
- **University of Pennsylvania's Robotics Laboratory**

More Information

Refer to Reclamation's Science and Technology Program Research Project, "Inaccessible Features Penstock Inspection."

For printable version see: www.usbr.gov/research/docs/updates/2016-19-uav-inaccessiblefeatures.pdf