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Expeditionary Logistics: A low-cost, large-scale, unmanned, deployable sensor network to support of Airfield Damage Assessment

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EXPEDITIONARY LOGISTICS: A LOW-COST, LARGE-SCALE, UNMANNED, DEPLOYABLE SENSOR NETWORK TO SUPPORT OF AIRFIELD DAMAGE ASSESSMENT

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EXECUTIVE SUMMARY

Project Summary
Airfield Damage Repair (ADR) is among the most important expeditionary activities for our military. The goal of ADR is to restore a damaged airfield to operational status as quickly as possible. Before the process of ADR can begin, however, the damage to the airfield needs to be assessed. As a result, Airfield Damage Assessment (ADA) has received considerable attention. Often in a damaged airfield, there is an expectation of unexploded ordinances, which makes ADA a slow, difficult, and dangerous process. For this reason, it is best to make ADA completely unmanned and automated. Additionally, ADA needs to be executed as quickly as possible so that ADR can begin and the airfield restored to a usable condition. Among other modalities, tower-based monitoring and remote sensor systems are often used for ADA. There is now an opportunity to investigate the use of commercial-off-the-shelf, low-cost, automated sensor systems for automated damage detection. By developing a combination of ground-based and unmanned aerial systems (UAS) sensor systems, we demonstrate ADA to be completed more swiftly and in a safe, efficient, and cost-effective manner.
Keywords: *Airfield Damage Assessment (ADA), sensor systems, unmanned aerial vehicles (UAVs)*

Background
Critical to the success of all the branches of the Department of Defense (DOD) is the ability to conduct air operations. Air operations do not only focus on air-to-air combat but also support ground and sea operations. Air power includes a variety of roles and responsibilities including air interdiction, intelligence collection, and battlefield management, etc. In addition, the use of air power is not limited to times of war. Heavy use of aircraft is seen outside of war environments such as moving personnel and equipment during peace keeping, humanitarian assistance, disaster relief, and training operations. Regardless of the objective, all aircraft have a basic need for a functional airfield. In a war time environment, not only is this need exceptionally increased, but so is the likelihood that enemy forces will damage our airfields.
Current Navy ADA and ADR processes are dangerous, slow, iterative, and human-in-the-loop dependent. The emergence of cheap, readily available, and accurate technology offers a way to increase the efficiency and accuracy of the ADA process, assist the repair decision making process, and help expedite airfield readiness for take-off and landing operations.

Findings and Conclusions
The goal of this thesis was to develop and test a system architecture and define the data flow to conduct a fast and accurate ADA using a combination of commercial-off-the-shelf (COTS) sensors and equipment. The system we designed and tested utilized a camera-equipped UAV combined with multiple image analysis and processing techniques to assist the Emergency Operations Center (EOC) in Minimum Operating Strip (MOS) determination and planning of repair operations. We divided the system into two distinct components: initial and secondary runway scans.

The initial runway scan consists of multiple sub components including the UAV flight over the damaged runway, automated damage detection, damage localization, and mosaic creation. The goal of the initial runway scan is to collect and forward the most critical information to the EOC as fast as possible in order to quickly make a determination if the runway is damaged, worth repairing, assist in MOS selection, and visualize, identify, and classify damage to the extent possible. This is accomplished by using survey mapping techniques built into Pix4Dcapture, a Phantom 4 Pro UAV and an iPad/flight controller to take a series of overlapping images across the runway. A trained TensorFlow neural network is then used to automatically identify and classify the damage. This information is both logged for direct output and also visualized onto the image itself. Finally, the images are stitched together and grid lines are placed onto the resulting mosaic using Python's OpenCV library.

The second runway scan takes place after the initial runway scan is finished and an MOS is selected. Once the area that has been repaired has been identified, the UAV can be sent back to previously logged damaged locations and use survey mapping techniques in Pix4Dcapture in order to collect more images of the area of interest. These images can then be used to create 3D models in programs such as WebODM and Agisoft PhotoScan. Finally, the 3D models can be incorporated into existing modeling software such as GeoExPT/AutoCAD in order to estimate required repair materials.

Our system offers a cost-effective and low-training-requirement design that is capable of assisting the EOC in conducting ADA. We divided the system into multiple sub elements including data collection, mosaic creation, automatic damage detection, 3D model creation, and further repair planning analysis. We identified a set of tools and software and tested them resulting in a data flow that produces a mosaic of an airfield, overlays grid lines onto the mosaic, automatically identifies and logs the position of spalls and craters, and generates 3D models for further analysis. These products can have an immediate and direct positive impact on the EOC's ability to conduct ADA by increasing the accuracy and decreasing the time to conduct the assessment. In addition, our system lays the groundwork for continued development and integration with multiple sensors and pieces of technology to create an even more capable solution for automated ADA.

Recommendations for Further Research

Many of the individual components of the presented system design may benefit from further testing, evaluation, and fine-tuning. Regarding placement of the grid lines after the mosaic is created, detailed analysis could be conducted on how accurate the grid lines are based on separate GPS reading of the testing site. In addition, the system would benefit from software based error correction and handing if the mosaic is tilted in order to maximize grid line accuracy. Further experimentation on the optimal drone speed while taking images could have a large effect on the speed of the data collection. Instead of stopping at each waypoint to take an image, it may be possible to orient the camera angle and modify the camera parameters based on the seed of the UAV so that data could be collected faster without sacrificing accuracy or creating distorted images. During mosaic creation, different image stitching techniques could be tested in order to both maximize speed of the image stitch and also determine optimum image percent overlap decreasing time required for data collection. Vast amounts of testing could be done on the TensorFlow neural network including using different models, varying the training data set, and modifying training parameters in order to maximize detection capabilities. In addition, incorporation of unexploded ordinance (UXO) and camouflet detection are a much needed requirement. Testing and evaluation on the effects of detection at different altitudes and lighting, and the accuracy of both UAV GPS and detected damage locations remains an area for improvement. Finally, with the continued advancement of COTS UAVs, conducting real time damage detection on board the UAV may decrease overall evaluation time.

Acronyms

ADA – Airfield Damage Assessment
ADR – Airfield Damage Repair
COTS – commercial off-the-shelf
DOD – Department of Defense
EOC – Emergency Operations Center
MOS – Minimum Operating Strip
UAV – unmanned aerial vehicle
UAS - unmanned aerial systems
UXO – unexploded ordinance