Florida Wildlife Commission

PORTABLE AERIAL VIDEO SURVEY SYSTEM (PAVSS)

Submitted By:

ADVANCED INTEGRATION

Rockledge Design Group Inc.

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Contents

1 Identification & Significance of the Opportunity

The objective of this proposal is to demonstrate the feasibility of a multi-sensor system for the purpose of capturing, recording, processing and display of high resolution imagery and supporting sensor data. The imaging pipeline is based on latest technology 4K Ultra High Definition (UHD) resolution imaging with the capability to stream the RAW imagery data. Supporting sensor data is time-stamped and incorporated in the imaging data stream on a frame by frame basis. The use of 4K imaging for photographic surveys, production of databases for topography and cartography, and remote sensing has been demonstrated by Thom and Jurvillier (1993), Mostafa and Schwarz (2000), and Kurz et al. (2014). An overview of airborne digital imaging technology has been described by Petrie and Walker (2007).

UHD imagers have evolved into small form factor camera heads capable of streaming RAW full sensor output via 4 x 3 Gigi-bit data links or similar. Additional imager capabilities include global shutter capability to alleviate the rolling shutter effect, control connection, and sync functionality. Access to the RAW video data stream allows for the incorporation of sensor data into the video file wrapper on a frame by frame basis. Appropriate compression can be applied based on record time and available storage. The proposal is to develop a new imaging system based on this latest generation technology, incorporating the multi-sensor data with a robust user interface.

1.1 Deliverable System

The development and final delivery of the multi-sensor system will result in deliverable hardware available for use for aerial surveying via a Cessna type aircraft. The end delivery will include a single imager with optics, attached to a mounting plate that will directing integrate with the rental housing. The imaging package will communicate with a capture system located in a small rack, to be installed interior to the plane via a cable harness. The cable harness will pass through the plane fuselage via available pre-existing access panel. The capture system will interface via a wired link with a touchscreen tablet device, configured with the user interface software. The capture system, portable rack, user interface tablet, and software will all be included as part of the final deliverable. The user interface software shall also be installable on a third party computer for post analysis.

1.2 Future Capability

The design approach will be such to allow the incorporation of future feature requests, as well as a phased approach for technology improvements. Anticipated future work includes additional imager sets operating in parallel, inclusion of new sensors into the data stream, inclusion of 6 Gbps eSata external drives for quick transfer of large data files, and more robust mapping capabilities. Incorporation of new software features, both in terms of data collection and user interface, can be investigated as requirement definitions mature. The incorporation of next generation high dynamic range techniques will also be of future benefit.

2 Background

There is a need for high resolution aerial imaging capability at a reasonable cost. The use of UHD results in a doubling of both vertical and horizontal pixel resolution as compared to high definition video, which is required for accurate identification of the target. Streaming of the RAW imaging data at full bit depth provides increased dynamic range, necessary when imaging regions including both shadows and highlights. The incorporation of sensor data such as range to target, GPS coordinates, as well as camera and optics settings into a RAW UHD data stream has not been widely addressed. There is also a need for a robust user interface providing orientation overlays, display of sensor data, and control functionality.

A challenge to capturing RAW UHD data is the large files sizes generated. An uncompressed (RAW) UHD stream at 60 frames per second and 4:2:2 color space results in an approximate 12.2 Gbit per second video bandwidth. In perspective, this results in approximately 5.5 TB of video data per hour. The use of appropriate video compression will be employed to balance quality versus storage requirements.

3 Technical Objectives

The overall objective of the proposal is to develop the portable aerial video/photo survey system. The specific objectives of the program can be enumerated as follows:

- 4K UHD imager. Future capability to upgrade to multiple imagers.
- RAW UHD data stream for incorporation of sensor data.
- Video compression capability.
- 4K capable optics with iris, focus, and zoom capability.
- Gyroscopic image stabilization.
- Cesna 172 type aircraft mounted housing. Housing initially available on a rental basis with future option to purchase.
- Approximately 10 RU portable rack for recording and processing equipment.
- Touch screen user interface.
    - Tablet type
    - Video and data overlays on same screen
    - Control functions
    - Touch screen
- Video and data recorded with timestamp.
- External device support.
    - Laser rangefinder
    - GPS
    - Imager control
    - Optics control
- User interface display.
    - Field of view overlay with user selectable transact widths
    - GPS data including lat, long, height, date and time

- User interface live control.
    - Imager settings (exposure, white balance, etc.)
    - Record start/stop
- User interface playback control.
    - Playback controls
    - Grab still
    - Mark and grab video segment
    - Grab entire video
- Power interface with line filtering.

A sample system diagram is included in Figure 1.

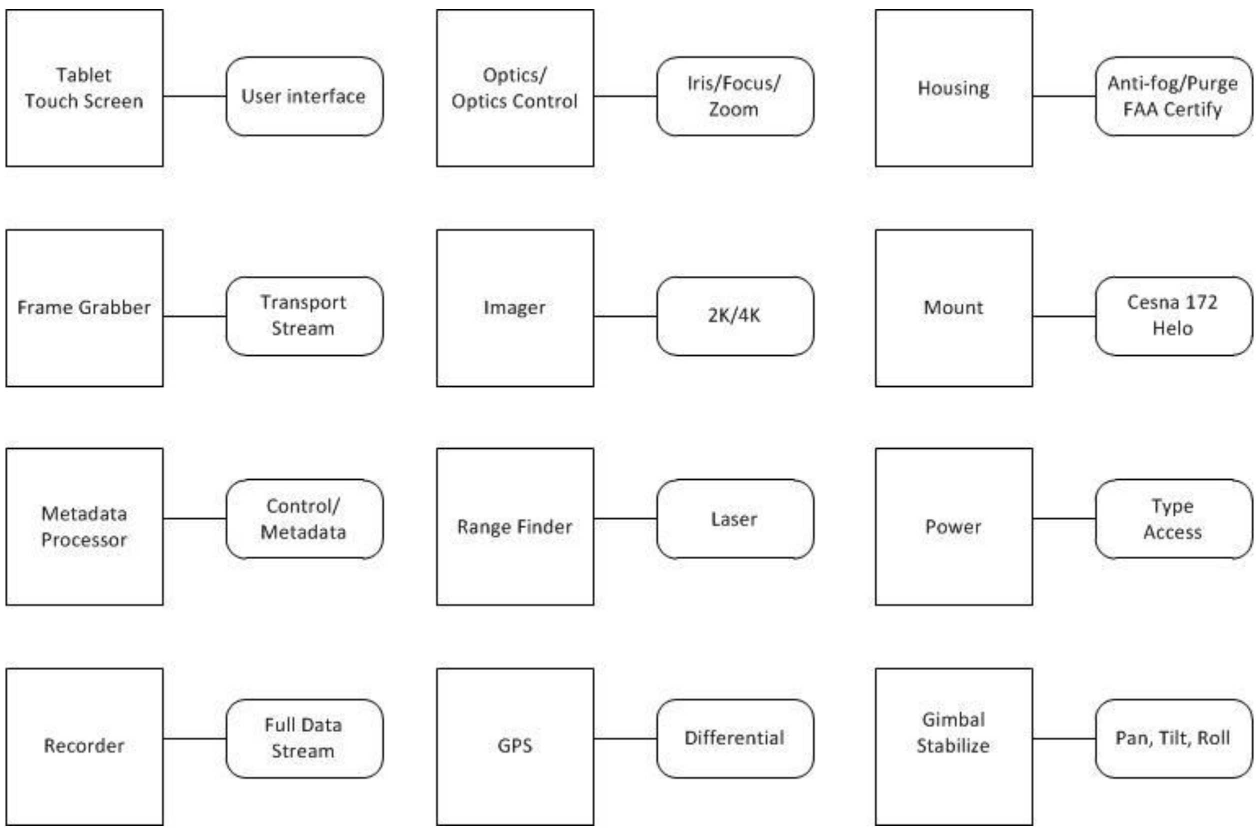

Figure 1 – Sample System Diagram

4 Proof of Concept

The ability to obtain useful images for identification requires the optimization of several imaging factors including at a minimum resolution, sharpness, exposure time, shutter type, and aperture. In order to demonstrate the capabilities of UHD resolution imaging when operating from an aircraft, several tests were conducted. In each test specific imaging factors were isolated and varied to show the effect on the image. The tests are described in the sections below.

4.1 Pixel Resolution

The pixel resolution test is a test of both imager resolution and optical sharpness as a function of distance. The following data was taken with a decoy of length 15.375 inches. A 24-105mm Canon lens was utilized as the optic on a 4000x2160 resolution Blackmagic 4K camera. The decoy was placed on top of a Kobolt saw case, to add a text reference to the image. A grey colored form board was placed behind the decoy to provide a uniform background, as well as to provide a size guide for cropping.

A summary of the theoretical calculations and measured data for the decoy testing is included in Table 1. Note differences between the theoretical pixels per decoy (column 8) and the actual pixels per decoy (column 9). It is suspected that this variance is primarily a result of actual vs. stated focal length of the 24-105mm optic. There is most likely additional contribution to the variance due to diffraction, aberration, defocus and flare. Manufacturer's generally state optic focal length may be off by as much as +/- 5%. Further verification would be required to determine the actual focal length of this particular optic. Column 10 shows a theoretical exercise to match the actual pixel per decoy numbers, based on a focal length of 97mm, a 7.6% difference as compared to the 105mm. The column 10 exercise does not take into account the other contributing factors mentioned.

The area of interest from sample single frame grabs is shown in Figure 2 – Decoy Testing. The frame grabs were each originally 4000x2160 pixel resolution, and were cropped in a similar manner, using the top and bottom of the background board as the upper and lower limits. The left and right crops were tight to the fore and aft of the perpendicular facing decoy with respect to the camera axis.

Note in the frame grabs that the image at 900 feet appears more out of focus than the data at 1000 ft, using 800ft as a reference. This illustrated the effect of defocus on the measurements.

Table 1 – Pixel Resolution Summary Table for Decoy Testing

1	2	3	4	5	6	7	8	9	10
Range (ft)	FL (mm)	Hfov (ft)	Vfov (ft)	Pixel Resolution (in)	Theor. Pixels per Inch	Pixels Per Foot	Pixels per 15.375" Decoy	Actual Pixels Per Decoy	Pixels per 15.375" Decoy @97mm
100	105	20	11	0.06	16.6	198.9	254.8	235	235.4
200	105	40	23	0.12	8.3	99.4	127.4	117	117.7
300	105	60	34	0.18	5.5	66.3	84.9	79	78.5
400	105	80	45	0.24	4.1	49.7	63.7	58	58.8
500	105	101	57	0.30	3.3	39.8	51.0	48	47.1
600	105	121	68	0.36	2.8	33.1	42.5	39	39.2
700	105	141	79	0.42	2.4	28.4	36.4	33	33.6
800	105	161	91	0.48	2.1	24.9	31.8	30	29.4
900	105	181	102	0.54	1.8	22.1	28.3	27	26.2
1000	105	201	113	0.60	1.7	19.9	25.5	25	23.5

Based on the data collected and human observation of the images, the ideal pixel resolution was determined to be in the range of 300-400 feet, or approximately 70 pixels per 15.375” decoy.

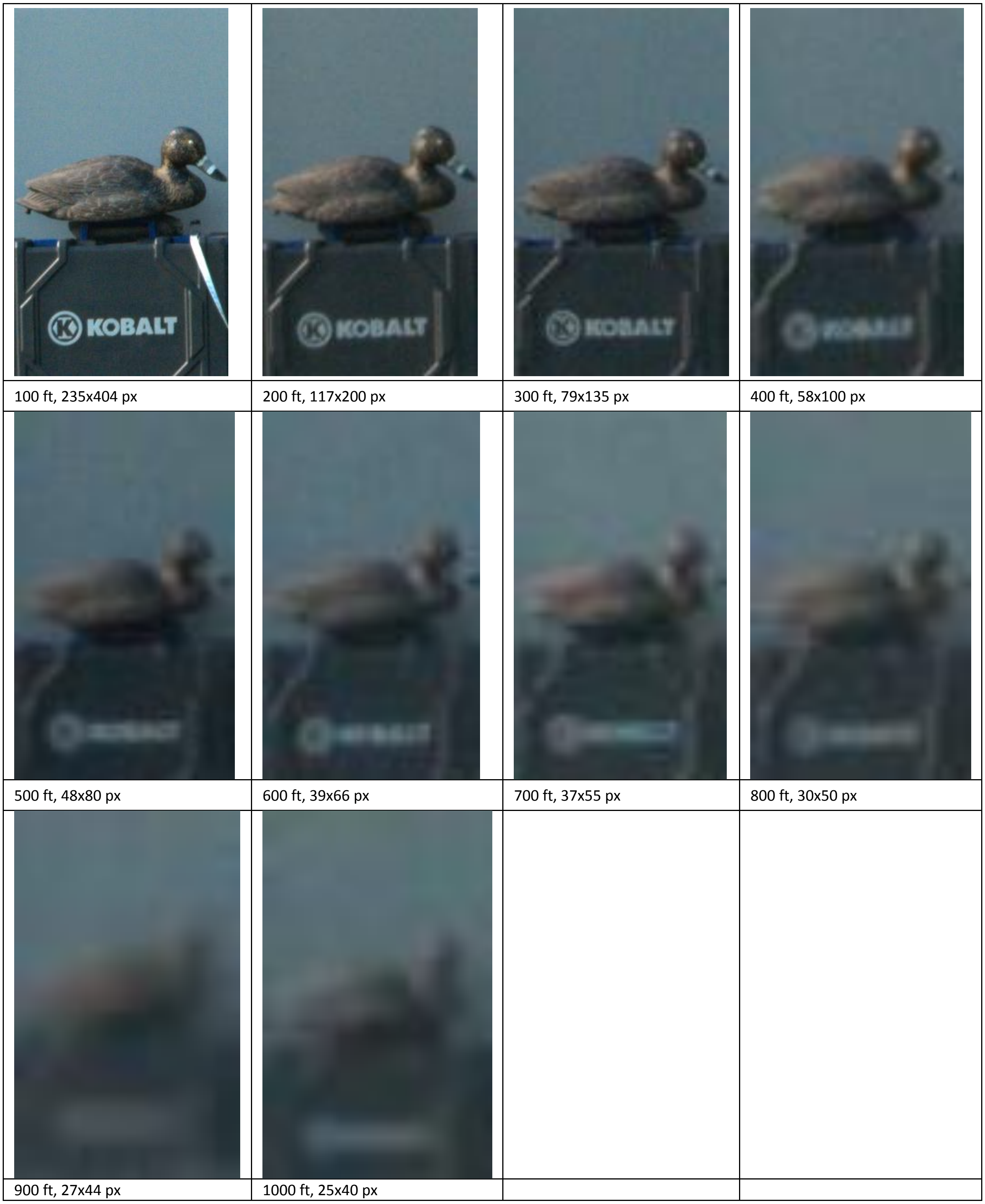

Figure 2 – Decoy Testing

4.2 Exposure Time

The imaging system will be mounted to an aircraft traveling at speeds of approximately 80 to 120 mph. A series of tests were conducted in order to demonstrate how proper exposure timing can be utilized to capture sharp images with motion in the scene. For the purpose of the test, a RED Epic 4K UHD imager was held stationary, with the target decoy in motion mounted to a vehicle. Testing was conducted in an isolated area with a stationary road sign in the background for sharpness reference.

4.2.1 Constant Velocity and Variable Exposure Time

The constant velocity variable exposure time test demonstrates the ability to capture sharp images given a proper exposure time. The effect of a fast, short, exposure can be seen in Figure 3.

Figure 3 – Constant Velocity Variable Exposure Time

4.2.2 Constant Exposure Time and Variable Velocity

The constant exposure time variable velocity test demonstrates the ability to capture sharp images ,given a proper exposure time, at various velocities of interest. Based on the results of the testing summarized in Figure 3, an exposure time of 517 uS was selected for the variable velocity test. The velocity of the test vehicle and decoy was varied from 80 to 140 mph. The effect of a fast, short, exposure at different velocities can be seen in Figure 4. Only small differences in sharpness were observed. Based on the available light in the scene, a faster exposure time can be implemented resulting in increased sharpness.

			
517 uS, 80 mph	517 uS, 90 mph	517 uS, 100 mph	517 uS, 110 mph
			

Figure 4 – Constant Exposure Time Variable Velocity

5 Reporting

In addition to week-to-week informal contacts with the program monitor, monthly technical progress reports will be submitted.

6 Related Work

The Principal Investigator has been involved in the development of advance imaging systems for the past six years. At his previous place of employment he spent 10 years as the responsible engineer for the conceptual design, development, and testing of several commercial measurement devices used in the medical oncology field. He is currently pursuing a PhD in Imaging with the University of Warwick UK in the Visualization Group under Professor Alan Chalmers and Dr. Kurt Debattista.

He is currently preparing to publish a chapter on Applications of HDR Imaging for the book "High Dynamic Range Video: Acquisition, Display, and Applications" to be published in the latter part of 2015. He also had a paper on the "Calibrated Measurement on Imager Dynamic Range" in review for publication.

7 Intellectual Property

Rockledge Design Group Inc. will remain the owner of all Intellectual Property (IP) developed as a result of this proposal. This includes hardware designs, embedded software, user interface software, and mechanical designs. FWC will be provided 1 complimentary set of software licenses, to include 1 license for installation on the touchpad mobile device, and 2 licenses for installation on post analysis computers. In addition, FWC will be entitled to free, non-expiring, software updates for the single complementary set of licenses, as the initial supporter of the proposal. The software updates will be transferrable within users of this initial system within FWC.

8 Key Personnel

Brian A. Karr

President & Principal Researcher

EDUCATION

Ph.D., Electrical Engineering, University of Warwick, UK, In Progress.

M.S., Electrical Engineering, University of Central Florida, FL, 1997.

B.S., Electrical Engineering, Rochester Institute of Technology, NY, 1993.

CURRENT POSITION AND RESEARCH

Brian A. Karr is the President and Principal Researcher with Rockledge Design Group Inc.

He has more than 20 years of experience involving research, design, development, and testing of advanced products and systems.

9 Relevant Experience

Prior to working as a consultant with Rockledge Design Group Inc., Brian A. Karr was the Principal Lead Engineering of NASA's Advanced Imaging Lab at Kennedy Space Center, FL. There he was responsible for research on image collection, processing, and analysis techniques for photogrammetry, infrared, stereoscopic, high speed, and high dynamic range imaging. (Karr et al., 2014, Clements et al., 2010a, Clements et al., 2010b).

While at KSC he also lead two large scale projects, an 11 million dollar procurement of a replacement Doppler Radar Wind Profiler (DRWP), and the procurement, installation, and testing of a Coastal Radar and Video Surveillance System (CRVSS) utilized to monitor and protect the Space Shuttle along the KSC shoreline.

Prior to his work for NASA, he was the project and design lead of a 64 channel mixed signal custom ASIC for use in radiation oncology at Sun Nuclear Corp in Suntree, FL. He also designed hardware and wrote HC12 family microprocessor routines for commercial Radon Monitor units including user interface, temperature and pressure sensors, radon detection circuitry, and low power operation.

He wrote a successful FAA/Homeland Security research grant and conducted research efforts in the design and development of an Ion Mobility Spectrometry based handheld explosives detector while at Sun Nuclear Corp. Efforts included the design and creation of PCBs for working explosive detector prototype units including low power supply, communication board, and high sampling rate differential integrator measurement board.

10 Prior, Current, or Pending Support

Rockledge Design Group Inc. has no prior, current or pending support for a similar proposal.

11 Cost Proposal

See attached.

12 References

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