FAA Remote-Controlled Crack Monitoring (RCCM) Video System Requirements

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Figure 1: RCCM Software System Splash Screen

Abstract

This document details the requirements for the Federal Aviation Administration’s Remote-Controlled Crack Monitoring (RCCM) Video System Software component, to be used for control and analysis during non-destructive monitoring of fatigue cracking in the unique fuselage panel testing facility at FAA Technical Center near Atlantic City International Airport. These cracks are monitored and recorded using the Remote-Controlled Crack Monitoring (RCCM) system and other Non-Destructive Evaluation methods.
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1 Introduction

The RCCM system is a video data acquisition system consisting of two computer-controlled, high-precision cartesian translation stages, instrumented with a wide-field-of-view camera and a narrow-field-of-view camera. A third "surveillance" camera exits for wide angle views and will not be discussed much, as it is not required for the primary functionality. The combination of the main two cameras allows monitoring the entire panel surface at several levels of magnification, providing a field of view ranging from 0.05" up to 14". Each translation stage has a motion resolution of 0.00039" (1 m), allowing accurate tracking of crack propagation. Measurements and other vital information are recorded concurrently with movement of the system. The system also consists of a scientific event hardware component, which provides information such as cycle counts, applied loads, and other relevant information to the system.

![Photographs of the RCCM system (left) and one of its periscope stages (right)](image)

Figure 2: RCCM System

The general length of each experiment with the current system varies, but they generally range from several hours to several months per full cycle of experiment. The generic work cycle of an operator in the current system involves initializing both the hardware and software, applying test conditions to the fuselage through external controls, using the camera to search for cracks, taking video and photographs of crack propagation and crack formations, using the system to measure the crack formations, manually storing the media, etc. The new system will streamline much of this work cycle.
The new system will also incorporate a third support structure for the entire RCCM system. The new frame will translate in the axial and hoop directions of the fuselage panel via motorized dynamic linear elements that will be controlled by the new computer system. Two linear elements will be incorporated with the new rectangular aluminum frame, which will rest upon the existing vertical steel supports. Attached to the supports are two dynamic linear elements, two roller bearing supports, and two drive motors. Integration of these components with the new computer system will make automated translation of the entire structure possible. For each direction of translation, one dynamic linear element, one roller support bearing, and one drive motor are required. In the hoop direction, the overall translation of the system will be increased by a distance of 12. In the axial direction, translation will be increased by 24.

Figure 3: RCCM System Context Diagram
2 Background

The current computer system consists of two computers, each connected to a camera system as discussed in section 1. The software that controls the cameras gives the user the ability to manually control each camera system. There are controls to move the cameras within a GUI or with an attached joystick. Users can also view a video feed from either the narrow field of vision (NFOV) camera, wide field of vision (WFOV) camera, or the ultra-wide field of vision (UWFOV, or ''surveillance'') camera, as well as take a series of still photos. There are tools to aid in the measuring of a crack, by centering the crosshairs on the camera over one tip, zeroing the measurement, and moving the camera to the other crack tip.

A new system will be designed to not only be up to date with modern technologies, but also add more functionality to make crack measuring quicker and easier, while maintaining accuracy. The system would consist of a single computer, with dual-monitor output: one for the software control center, and one for the video feeds. The operator can arrange these windows to his own preference.

3 Scope

The particular set of requirements will mainly focus on the software aspect of the system and the only briefly the corresponding hardware requirements. Specifically, the computer-based video data-acquisition system used to track, measure, and record multiple crack formation and propagation during loading in real time will be the center of this document. The requirements for this system are partially provided by the FAA Technical Center in the form of abstract prerequisites and feedback regarding the aforementioned system. This document will aim to outline both the prerequisite expectations for the transfer of functionality from the existing system to the new, as well as provide details for the introduction of novel functionality to the existing iteration of the software. The requirements in each section are listed in order of descending priority, and are categorized by the overlying functionality.
4 Functional Requirements

4.1 Camera/Motor Control

Two black and white RS-170 format video cameras operating at 30 frames per second using 768x493 pixel chips are mounted to the software controlled, moveable frame of each RCCM subsystem. The first camera allows a 0.4x to 7.5x magnification of the image. Designated as the "Narrow Field of View Lens", or "NFOV", it detects microscopic defects in the fuselage. The second video provides a view of approximately 2” to 14” and is designated as the "Wide Field of View Lens" or "WFOV". A third camera will rest upon the top of the frame, and act as a "surveillance" view. This third camera will not be discussed in detail as mentioned, as it will only offer one view. There are a total of two translatable RCCM subsystems in the overall structure, which is also translatable.

1. All hardware and software specifications for the new system will be matched appropriately against the existing system to ensure compatibility.

2. Compatible controller cards and drivers for translation stages and corresponding video will be acquired and incorporated into the new system. The appropriate manufacturer’s of the existing components will be involved in this process to ensure the latest versions and compatibility.

3. The camera/motor control will allow precise placement of video equipment in three dimensions. The x-y stage will have 24 inches of overall travel. The x and y axes allow the operator to "fly" above the fuselage, while the z axis, or the focus axis, will have 10 inches of travel and provide zoom functionality.

4. The system will allow switching control between all three translatable systems.

5. The system will allow automated movement of the camera, given certain velocity settings that will allow the camera to move in a certain specific direction by itself, at some user supplied speed. The movement settings will encompass all three dimensions, and can be set singly or in multiples.

6. The motion control portion of the software will allow an operator to use either a joystick, computer mouse, keyboard, or pen based device to move the stages and camera. The operator instructions are converted to commands which are translated to the motion control card to provide precise movement of the physical camera system.

7. Multiple operators will be able to use the system concurrently, through separate camera/motor control systems.

8. The system will support realtime viewing of each camera simultaneously, or singularly.

9. The system will optionally also allow manual control of each camera’s focus. This feature is tentative, based on FAA hardware specifications.
10. The camera system will be automatically initialized upon startup, unless the user specifies that they wish to perform manual initialization.

11. The camera system will be allowed to be reset, reinitialized, and docked back to the standard position through the software.

12. The system will store the coordinates of the last camera and system locations between runs. Manual and automatic re-initialization will allow re-calibration.

13. The switching between the different camera systems/motor controls in the system will be able to be done at any point by an operator. The translation controls will then control the currently selected camera/motor.

14. The camera/motor system will have a calibration system that allows a user to initialize certain aspects of the physical camera system that are crucial to measurement and control.

15. The system will support positional awareness in that it will know the exact coordinates and dimensions of each system within the support structure, and the exact coordinates and dimensions of the support structure within the overall RCCM structure. This will provide relative locations of all controls and apparent limits.
Figure 4: RCCM Motor/Camera Cartesian Translation Controls

The bottom left section of the interface shows the translation controls for manipulating the selected motor/camera (top left section of the interface) along the X, Y, and Z axis. The bottom tab displays event data and time stamps received from the event hardware. The bottom right section of the interface illustrates the positional awareness control, showing the relative position of the various controls. Above the positional awareness control, we have buttons to bring up the settings and archive forms. In the top middle section of the interface, we have controls for displaying the various camera views, and configuration relevant to the cameras.
Figure 5: RCCM Motor/Camera Translation Velocity Controls

The bottom left section of the interface shows the translation controls for manipulating the selected motor/camera's (top left section of the interface) velocity along the X, Y, and Z axis. Stop cues for the translating motor are embedded within the relevant translation direction (denoted as the red stop arrow.)
4.2 Data Acquisition - Digital Photos and Video

1. The current system uses analog video sources and VHS recorders to archive all videos. All corresponding video capture cards and adaptors will be retrofitted with the latest technology, retaining compatibility with the existing camera control systems.

2. The new system will provide preferences for various formats of video output, including DivX and Mpeg4. All video will now be digital and captured directly to the operating machine. The listed formats are tentative, based on FAA hardware specifications.

3. All media will support event stamping of cycles counts, applied pressure, date, and other environment events from the corresponding event hardware, that can be dynamically added to media based on user preferences. The display, location, and duration of such information will be determined by the operator.

4. All sound tracks will be removed from the video files, allowing for the optimization of the size and quality of the video captured.

5. Frame information will be configureable, allowing a user to set custom attributes of the video capture, specifically, frames per second, the length of the capture (or allow manual control of start and stop), and the video quality, size, and format.

6. Video sequences may be stored as an actual video file, or as a sequence of images (as supported by the various image formats described in the next points.)

7. All video will be capture-able to disk, and saved in the previous formats listed.

8. All video displays will be scaleable to various sizes in realtime.

9. The various camera displays listed in section 3.1 will have standard playback controls, specifically, rewind, fast forward, play, pause, and step controls. The system will also allow switching back to "live" mode, which provides a live view from each camera.

10. The existing format for photographs taken with the camera system are in Windows bitmap (bmp) format. The new system will provide preferences for various formats, including but not limited to Jpeg, and Gif. The listed formats are tentative, based on FAA hardware specifications.

11. Photographs will be taken directly from the camera views indicated in section 3.1.

12. Each photograph and video capture will have metadata associated with it relating to it’s context within the system when it was captured. This will include event data such as cycles counts, applied pressure, date, and other environment events from the event hardware.
The bottom left section of the interface shows the currently selected camera view and RCCM system. To the right of this, we have controls for beginning and ending video and image captures. The right of the capture controls the current position of the video buffer and size are displayed. The bottom right section of the interface shows playback and live view mode selection, as well as video playback controls for the video buffer. The center of the interface shows the actual video feed from the selected camera. The top section of the interface shows various measurement types (top left) and the options for the line/crosshair properties of measurements. Multiple camera views may be up at once on multiple monitors.
4.3 Archiving

This section describes the data which will be stored within the system and its basic structure. An entity-relationship diagram may be supplied at a later time illustrating a more detailed schematic of the data.

1. The system will have an internal catalog with information about stored photos, videos, data, and measurements. All relevant catalog data will be automatically moved to the archive catalog upon instantiation and can be browsed at a later time.

2. The system will be browse-able by categories, such as video, images, and measurements.

3. The system will be searchable, and allow realtime return of items based on the current input.

4. The system will be sortable by the various metadata fields associated with each archive entry.

5. The system will support the display or playback of any media item stored in the catalog.

6. The system will support the display of information relevant to any measurement or data item stored in the catalog.

7. The system will offer support for exporting and importing video and media into the catalog, in the various formats listed in the previous section.

8. The display of metadata in a media entry will be editable, and be able to be shown/hidden at any point.

9. A file hierarchy similar in organization to the catalog will reside on the hard drive, with optional layers of compression.

10. Media items will be able to be added, deleted, or cleared from the catalog, and optionally from the underlying file hierarchy.

11. The system will provide built in archiving solutions for compressing disk space and storing data. This will allow export to CD, DVD, or an external storage device.
The bottom left section of the interface shows the controls for adding, deleting, and clearing archive data. In the bottom right section, we have controls for importing, exporting, and arching the selected data. The center of the interface lists the actual archive data, sortable by the various metadata tabs on the list control. In the top left section of the interface, flags for showing or hiding categories of archive data are shown. In the top right corner, we have a live search or filter for the data.

Figure 7: RCCM Archiving
4.4 Measurement

1. The measurement component of the software will retain compatibility with the previous measuring methodology, where using a crosshair on the image as a reference, accurate measurements of crack length can be obtained through the control of the translation stages through the system described in section 3.1.

2. The system will allow the user to set line settings, including translucency and line color.

3. The system will allow measuring cracks through a point and click interface, where the endpoints of the vector to be measured are used to compute the appropriate measurement information.

4. The system will allow measuring cracks through a multiple point and click interface, where the various points are linearly translated and the summation of the measurements provided. This can be used for more accurate measurements.

5. Image recognition crack guided measurement plotting. This will allow an operator to draw a line along a crack, and realtime image recognition will constrain the line to the crack based on the visual characteristics of such. This will then provide points to the previously listed measurement methodology to provide even better measurement accuracy. This feature is tentative based on FAA requirements.

6. Different measurement methods will be combinable, in that more measurement points may be added to a current measurement with any of the listed measurement methodologies.

7. All of the points generated with any of the measurement methods listed above will be both removable and translatable.

8. Fully automated image recognition for crack measurement, optional to the user. This provides complete automation of the crack measuring process through crack identification algorithms that will gather points and supply them to the measuring methodologies described in the previous items. The feature is tentative based on FAA requirements.
Figure 8: RCCM Camera/Measurement View Fuselage Crack

An illustration of a potential camera view, where a crack needs to be measured. In the top left section of the interface, the point and click measurement method is selected.
Figure 9: RCCM Vector Based Point and Click Measurement

An operator has drawn lines along the crack, representing the measurement vector which will be computed. Each point represents where the operator has clicked, with interpolation of lines between points.
5 Non-Functional Requirements

5.1 Productivity Enhancements

1. The new measurement systems will provide the user with much improved measurement capability, by allowing "pen" type input to the user, where they trace a crack or other course and the camera follows.

2. Measurement and location tracing. There would be restrictive tracing, where the software would aid in tracing a crack by the pixel differentiation through image recognition, and location tracing, where you can trace the location you wish the camera to go, and then let it move on its own. This is the foundation for the tentative features described in section 4.4.

3. The system will be multithreaded, in that it will allow interface manipulation, live video capture and manipulation, and any other task described in the previous sections concurrently.

4. The ability to script the camera control to perform certain "patterns" of control. This will allow the automation of redundant tasks, such as scanning the initial fuselage for a crack count. This feature is tentative based on FAA requirements.

5. The system will incorporate the use of preferences to remember default settings.

6. The system will display a splash screen to the user indicating status of the system.

Figure 10: RCCM Settings

A subset of the RCCM system settings, showing various selections for input device, image, and video settings.
5.2 Ease of Use

1. The system will greatly increase upon ease of use and general usability over the existing system.

2. The system will provide for user interface functionality that has become standard since the inception of the previous system. This includes dynamic resizing of windows, multi window interfaces, isolated preferences, and simplified controls overall.

3. The systems interface will be greatly simplified over the current system. This includes navigational interfaces for saved media and measurements, more intuitive and custom controls, and modern GUI design.

Figure 11: RCCM Input Device Selection

Simple interface for selecting the current input device. This input device will then map to the relevant controls for translation of the selected camera or motor.

5.3 User Feedback

1. The system will have the ability to know approximately where the camera system is in stage space. The system will also provide the ability to reset the camera back to it’s initial position.

2. The system will display a limit switch status. It will show when ”end of travel” has been reached when manipulating the camera by some cue.
### Interface Form | Component | Location | Opens
---|---|---|---
Camera/Motor Cartesian | Archive | Top Right | Archive
Camera/Motor Cartesian | Settings | Top Right | Settings
Camera/Motor Cartesian | Camera Switching | Top Middle | Selected Camera View
Camera/Motor Cartesian | Camera Config | Top Middle | Camera Configuration
Camera/Motor Cartesian | Input | Middle Left | Input Device Selection
Camera/Motor Cartesian | Velocity Switch | Middle Left | Velocity Control (IP)
Camera/Motor Velocity | Cartesian Switch | Middle Left | Cartesian Control (IP)
Camera View | Color Selection | Top Right | Color Dialog
Camera View | Playback | Bottom Right | Video Buffer & Controls (IP)
Camera View | Live View | Bottom Right | Live View & Status (IP)
Camera View | Crosshair | Top Right | Zero Based Meas (IP)
Camera View | Pan Add | Top Right | Point & Click Meas (IP)
Camera View | Pan Draw | Top Right | Aided Measurement (IP)
Archive | Import | Bottom Right | Import File Dialog
Archive | Export | Bottom Right | Export File Dialog
Archive | Archive | Bottom Right | External Device Dialog
Settings | Input Device | Top Middle | Input Device Selection
Settings | Image Format | Middle Left | Image Format Selection
Settings | Image Size | Middle | Image Size Selection
Settings | Video Format | Bottom Left | Video Format Selection
Settings | Video Size | Bottom Middle | Video Size Selection
Settings | Frames Per Sec | Bottom Right | Video FPS Selection

Figure 12: RCCM Interface Relationships

This figure provides a list of each component in the interface that opens or instantiates another interface form or component. The "IP" designation is used to denote when a component is opened "In Place," meaning it will replace some form of the existing control or component.
6 Constraints

There is a considerable amount of new functionality that could be added to the new software; however, restrictions exist on what we will be able to implement. The most critical restraint is time. The system must be installed in the FAA tech center by May 2007 and be fully operational. The budget and corresponding requirements designated by the FAA may also act as a restraint.

7 Methods

The new computer system will be a Windows XP-based, single computer system with two monitors. One monitor will display the video feeds, the other will display the control panel. The software will be written with the .NET 2.0 framework. Our new software will utilize all proper software engineering techniques, and make use of all proper design patterns. As this software interacts directly with hardware, we will make use of interfaces to decouple the hardware from the main application. This is advantageous because it allows the software to be upgradeable. If, in the future, new controller cards, motors, or cameras are used, the implementation of the interface is all that needs to be changed, and the main application can remain untouched. We will also be providing the FAA with all source code, accompanied by very clear and comprehensive documentation. Almost all software projects are living, in that even after delivery, requirements change and features are added, modified. By providing the source code and documentation, it will allow the FAA to simply upgrade the current system, rather than completely redesigning new software.

8 Alternatives

The logic behind our decision to use a single computer system, over the current dual-computer setup, is that the new software will be much quicker in terms of measuring cracks, so it will no longer be necessary to have two people operating the system at once. Also, having a single computer substantially reduces the cost of the computer system. However, if for some reason the single monitor solution becomes unviable or the FAA requests that the system support dual operators, it may be necessary to use two computers like the current system.