White Paper

# CCTV Health Monitoring

## Past, Present and the Future



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# Abstract


Political instability in the world is demanding extra vigilance, as nations try to improve their resilience to terrorist attack. Part of the response to this need has been an increasing installation rate of CCTV-based monitoring systems. Such large and security-critical CCTV systems have attendant equipment failure rates that need to be managed as effectively as possible. The goal is to maximise the availability and quality of the video for operational, post-incident and intelligence gathering needs. The typical existing approach to CCTV maintenance is a 12 monthly inspection. This White Paper first examines the past and present-day camera maintenance practice of using Reactive and Preventative methods. It then explains the benefits (Business and Security-related) of moving to the highest and emerging methodology of *Predictive maintenance,* which seeks to avoid loss-of-service completely. A TRT designed methodology for low-cost provision of CCTV Health Monitoring is outlined.


# Keywords


CCTV, Equipment Health Monitoring, Camera Health, Camera Servicing, Predictive Maintenance, Image Processing


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# Introduction

## Why we need CCTV Health Monitoring

There are two fundamental reasons for using CCTV Health Monitoring:

- Making security procedures based on CCTV effective and reliable; and
- Providing business benefits to CCTV owners.

## Making CCTV effective

After the London bombings of July 2005, the true value of CCTV became more apparent. It provided the means for rapidly gathering post-event intelligence on the perpetrators, especially from those cameras near to or at the crime scene. However, discovering the identity of the bomber (Hasib Hussain) on the Stagecoach operated Bus number 30, was delayed until his credit cards were found, since the onboard CCTV camera system was not working. CCTV footage of him travelling within London Underground was not found until October.

Actual detections of suspicious activity, either by human CCTV operators, or automatic intelligent surveillance systems remain rare. Cameras can play a role in intelligence gathering and monitoring but are most useful, in the security context, when they are actually working correctly and recording good quality video. The Transport Secretary, Alistair Darling, in a speech to the International Association of Public Transport (IAPT) security conference in November 2005, said that a 'layered approach' to security was needed, and should include simple measures such as 'beefing up' CCTV and ensuring that it is working properly[1].

No products currently exist that cover the range of systems issues needed to ensure that CCTV systems are working reliably and correctly. Thales Research & Technology (UK) has expertise in the right combination of technologies to deliver a solution. Firstly we examine the issues involved in ensuring that CCTV is working correctly.

# Sources of camera failure

CCTV Health Monitoring (CHM) encompasses the whole image delivery chain from the camera itself, through cabling or networking, digitisation and compression, decompression, image storage, and display.

Sources of CCTV failure can be characterised along a continuum ranging from physical/electrical faults, which create loss or degradation of the delivered image, through quality of the image issues as determined by the carrier medium, and finally to higher level issues such as the delivered image's being 'fit for purpose'. The appropriate definition of camera or CCTV system failure at the higher end of the chain depends on the use to which its images are to be put. For example, if the CCTV user's need is to view a specific narrow area for a safety critical function, such as checking a railway platform edge is clear, then unwanted camera movement could be deemed as a failure. In this usage scenario, correct focus and adequate depth of field could also be critical, and changes in these parameters would define a 'failure' of the camera to deliver suitable images for the task in hand.

# Camera Maintenance - Scheduled, Reactive & Predictive

## The Past - Scheduled Maintenance

Until very recently, nearly all camera maintenance was performed as a 6 monthly, or more commonly 12 monthly, maintenance check. An engineer, would visit the camera, clean the exterior housing, check the lens, and measure and possibly adjust the peak-to-peak voltage of the video signal. Camera failures would be recognised by operators and reported to the maintainers. The time to repair would depend on the specifics of the maintenance contract, with 24-48hrs being typical.

### Present Day - Reactive maintenance

Scheduled maintenance is still by far the most prevalent system in use today. However, an increasing number of CCTV end-users are specifying camera maintenance as part of a Service Level Agreement, in which timely detection and repair are required, if the maintainer is to avoid penalty costs. As an example a London Underground camera monitoring specification in 2002, for Driver Only Train platform monitoring, required '*immediate detection*', of camera alignment changes, in order to avoid penalty clauses[2].

Certain CCTV network providers are providing some reactive CCTV Health Monitoring services of which the single most common CCTV system health check offered commercially is 'black frame' detection. This takes the form of detecting a loss of picture or the video sync signal. This is simple and cheap to implement, but only recognises failure after the event.

### The Future - Preventative & Predictive maintenance

Large organisations that manage an extensive infrastructure are beginning to see the value in maintaining their systems and equipment in a way that allows them to prevent failures from actually occurring: that is, moving from Reactive to Preventative maintenance. The key here is to schedule service checks, and defined part replacements frequently enough to detect the warning signs of imminent failure, and then respond quickly and effectively by repair or replacement of worn or faulty parts.

Failure Modes, Effects and Criticality Analysis (FMECA) is one methodology designed to identify potential failure modes for a product or process. The FMECA analysis procedure is effectively a tool that can be used to establish and optimise maintenance plans for repairable systems. It would typically apply reliability data specified in, for example, MIL-HDBK-217F[3]. *However, it is very costly to implement and manage, and requires replacement of parts irrespective of their actual state of wear.*

The ultimate step, advocated in this White Paper, is to adopt the techniques contained in methods of Predictive Failure Analysis. The approach advocated in this White Paper builds on Preventative Failure Analysis by analysing the video carrier signal directly, supplemented by analysis of the image content itself.

The goal is to gather data on a number of equipment performance parameters, and then model these whilst the equipment is in a healthy state. Progressive deviation from specified tolerances can then be detected. A prediction of the time at which intervention is necessary can then be calculated using statistical regression-based techniques. In this way, actual equipment failure-rates can be greatly reduced, and system availability maximised.

## Camera Failure Rates

### MTBF - what it means

Camera manufacturers typically quote Mean Time Between Failure (MTBF) figures for their products. MTBF figures of between 60,000-80,000 hrs are typical. This figure requires some explanation. Most products exhibit a classic 'bathtub' curve: an initial 'infant mortality' phase, in which intrinsic manufacturing/material faults exhibit themselves, followed by a 'Constant failure' phase, and a final 'wear out' phase. MTBF is the inverse of the failure rate, when applied to the constant part of the failure curve. The failure rate for a MTBF of 80,000hrs is around 11% per year, and 60,000hrs gives nearly 15% expected failure per year. There is therefore a significant probability that some cameras will fail in service in any large scale installation.

# Benefits of predictive maintenance

## Business case benefits

### Service Level Agreements

Service Level Agreements (SLA) are being used increasingly in commercial contracts these days. CCTV maintenance can now sometimes effect SLA-penalties incurred. For example, when timely camera failure detection and repair is mandated to provide an agreed level of availability.

A concrete example of how CCTV Health Monitoring could save costs, can be drawn from the maintenance contract for London Underground Ltd's CCTV systems. If SLA penalties are to be avoided, repairs need to be detected and effected within a specified short time period. In order to ensure that a visiting engineer can both diagnose and repair a fault within this time-period, multiple sets of spare parts have to be stored a large number of stations. This avoids the extra service time taken, following fault diagnosis visit, to fetch and return with parts from a centralised warehouse, but greatly increases stock costs. Financial efficiency could be greatly improved both through the CHM system indicating the nature of a fault before the engineer leaves base for a service visit (so they can bring the CHM system's recommended spare parts with them) and by predicting when a camera or CCTV sub-system part is expected to fail, so that efficient service schedules can be generated, lowering travel time and costs.

### Ensuring Operational Value is maximised

A fundamental reason for the installation of CCTV systems on large sites is to facilitate the control of operations. For example, monitoring the safe passage of passengers throughout an airport terminal, or Metro station, checking that critical staff are at their posts, and many other functions. Safety related functions include, for example; ensuring that single-file passage ways are used correctly, assessing the risks associated with crowding levels. Ensuring that the CCTV infra-structure is operational is a prerequisite for these functions. The use of predictive camera maintenance, to ensure that cameras continue to be available, therefore maximises the operational value of CCTV, resulting in improved performance against targets, and savings against contractual penalty clauses.

### Reduced maintenance costs

The *Preventative* maintenance approach demands more frequent service checks than the traditional reactive or simple ‘annual check’ approach, and is therefore typically more costly to implement, but is justified by reduced failure rates, and attendant savings in dealing with secondary effects of failure. Preventative maintenance schedules regular camera/network shutdown, irrespective *of whether repairs are required* and may specify part replacements irrespective of actual failure.

Predictive maintenance, by contrast has a similar initial cost, but determines when the camera/network actually will *require* repair. Equipment is therefore *only repaired/replaced when required* (saving maintenance and parts costs) and most importantly *before it fails* (minimising loss of service).

## Security-related benefits

One of the outcomes of the London July 2005 bombings was the increased realisation of the extraordinary post-incident analysis and intelligence gathering value of the CCTV video recorded around London. Cameras that are not working properly do not record usable video. And, as stated in the introduction, the UK government sees relatively simple measures, such



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as ensuring cameras are working properly, as an important part of the state's counter-terrorism measures[1].

### Ensuring Image Quality & availability

In addition to checking that a camera is transmitting a video stream, it is essential to ensure that video quality is fit-for-purpose, that is, sufficient for;

- operational use
- post-incident analysis
- and is of evidential quality.

In October 2005, The British Security Industry Association (BSIA) released a Code of Practice for digital recording systems to be used as evidence[4]. In the section on ensuring image quality, *transmission medium* and *system maintenance* are identified as some of the key factors.

In February 2005, The Home Office Scientific Development Branch (HOSDB) & Association of Chief Police Officers, released a pamphlet summarising the police requirements for digital CCTV Systems[5]. This document states, '*To ensure continued quality of recording it is essential that regular maintenance of all aspects of the system be conducted - especially camera focus, cleaning of lenses, housings, etc.', p.2*.

In addition to physical maintenance, an associated aspect of SLAs is the increasing use of Quality of Service (QoS) monitoring to validate that SLA levels are being met. QoS monitoring is almost exclusively associated with digital transmission networks. Video QoS (VQoS) at the application layer in digital systems is still in its infancy, partly because research into finding objective measures of quality that match subjective tests, is proving difficult. Many commercial systems exist to provide the monitoring services, but these are almost all related to transport layer monitoring, and whilst JPEG, JPEG2000, H.262 (MPEG2) and H.264 (MPEG4) are in increasing use in surveillance, they are still the minority installed video formats, compared to analogue.

Most importantly, VQoS measures are generally unsuitable for monitoring camera image quality, as they depend on the 'double-stimulus' standard, which requires transmission of a test image or sequence and its comparison to a standard.

Another approach is therefore needed in building a general purpose CCTV Health Monitoring system. It needs to be capable of handling the standard PAL/NTSC/SECAM based image transmission mediums, as well as those of IP-enabled systems.

# The Way Forward

We first distinguish between fault detection (electrical and physical) and fault prediction.

## Fault detection & 'fit-for-purpose' checking

The 'bottom-line' metrics on whether a CCTV system is currently working satisfactorily are that: all cameras views are available; the image streams delivered to the user, are of acceptable quality; and that images are 'fit-for-purpose', as defined in the previous section.

IP-cameras (which produce a digital output) tend to be reliable (with marginally fewer components than analogues), but which can still drift in terms of picture quality, or can

[1] Security improvements, additional to the protection against loss of service afforded by Predictive maintenance approach, may be added by building in redundancy to the physical transport medium, and automatic re-routing in IP-enabled networks. If survival of the CCTV network after a major incident crisis is required, we would recommend physical bomb-proofing of cameras in conjunction with the use of *Ad-Hoc* wireless networks, which will automatically reconfigure, should one or more camera nodes go down. This allows the CCTV network to still support crisis management operations, in the critical short-term aftermath.

sometimes fail catastrophically. At this point in time however, the majority of CCTV systems, use analogue cameras providing images distributed using analogue transmission systems.

TRT proposes a low-cost approach, designed to cope with CHM of systems containing all categories of cameras by combining analogue signal analysis which applies to analogue cameras only, with analysis of image content (which applies to both analogue and IP-cameras).

Testing the image content directly, gives a great deal of information on camera and CCTV system health, at minimal cost in terms of modification to existing infrastructure. Image content analysis, can be hosted on a single PC-platform, using a digital feed via IP-addressing for IP-cameras and a split-signal from the CCTV system MUX, output to a standard low-cost digitiser PCI-card, or similar, for analogue cameras.

### Signal analysis

Analysis of the (PAL/NTSC) image carrier signal can also provide a powerful set of fault detection tests. The industry standard test equipment is the Tektronics VM700. This equipment can perform a host of tests, but is very costly, and provides many features redundant to CHM. The TRT solution is to use a low implementation cost high-speed Digital to Analogue Converter, in a PCI-card format. The signal recorded can then be analysed in software. Timing specifications for the PAL video signal and tolerances are specified in ITU-R BT.470 for analogue encoders, and ITU-R BT.601 for digital encoders. An additional possible analysis method, is to use the video insertion test signal which many cameras already output (ITU-R BT.473) which may be used to test several PAL parameters (similar NTSC standards exist), and gives an excellent measure of the transmission systems health. In addition to this option several other approaches look promising, as now discussed.

Numerous problems can result from *inaccurate timing*. Errors in pulse widths can cause picture break-up. Edges that are too sharp can cause ringing artefacts. A number of measurements related to camera health and picture quality are possible. Problems in *frequency response* can cause; flicker, brightness inaccuracies, horizontal streaking and smearing or fuzzy vertical edges. Problems from *noise* can cause snowy or grainy images and colour sparkles to appear. *Luma non-linearity* in colour images is particularly noticeable, since colour saturation is effected which the eye is particularly sensitive to. *Cross-modulation* of the Chroma-Luma signals (cross-talk) can cause variations in brightness caused by colour saturation inaccuracies, which may appear as what is commonly known as 'dot-crawls'.

EMI, is a common problem in many CCTV installation sites. For example, new power cabling, or plant is installed, and inadequate shielding results in visually salient detectable noise artefacts. Such interference patterns are highly amenable to detection using image content and carrier signal analysis methods. Another source of signal quality disruption, is from poor termination, and bad connections (which are notoriously progressive as corrosion builds on contact surfaces). These faults are also highly amenable to detection through signal analysis.

### Image analysis (image quality & Fit-for-purpose checking)

Using image analysis techniques, it is possible to detect many faults at an early stage in their development. It is also possible to provide a diagnosis of the most likely cause of the fault and therefore schedule the necessary corrective action. Most fit-for-purpose issues relate to physical changes in the camera's setup. For example, focus change and camera movement (detectable through comparison of current and reference images in the frequency and spatial domains). Examples of other detectable faults or movements out of specification, include: changes at the camera lens, image noise that appears suddenly or progressively & 'ghosting' from internal cable reflections. For example, consistent over or under exposure could indicate a faulty auto-iris system or possibly a faulty digitiser. Such changes may also be progressive, and therefore amenable to failure prediction analysis. TRT has already established the feasibility of these approaches.

### Fault Prediction

The signal and image measures discussed above would be monitored in a software application using trend analysis, and time-to-failure prediction methods used by predictive maintenance. In essence such techniques rely on time-based variants of regression analysis. In this way gradual changes are detected and the time at which they could be expected to exceed tolerance values would be predicted. This information is then embodied in a software maintenance application that automatically generates a prioritised maintenance schedule for the user and provides an interactive and visual health status report on the CCTV system, using, for example, colour coding to indicate each cameras health.

## Conclusions

Thales Research and Technology (UK) has the right expertise to deliver a solution for CCTV Health Monitoring based on predictive maintenance principles. TRT (UK)'s possesses a strong image processing background, including: conducting the research & development of a world leader in ANPR technology (Talon); technical/project management, and system design of a £2.8M part EC-funded advanced intelligent CCTV system (ADVISOR), designed to recognise suspicious behaviour of Metro passengers; and development of the image quality and compression standards in use by London Underground to monitor Image quality against SLA's on the CONNECT SDH/ATM system, which currently transmits video and other data modalities across two-thirds of London.

TRT also possesses a vast experience in design, test and development of world-class signal-processing applications based applications in radio, video, radar and navigation.

Thales Security Systems is an international supplier of large-scale CCTV-based security solutions, with a complete portfolio from cameras and CBRN sensors, through to large scale CCTV network management and Command & Control systems.

Given the above synergies within TRT and other Thales Group companies, Thales Research and Technology (UK) welcome discussions with interested third-parties on the development of these technologies though to a unique product, fit to service the changing needs of large-scale CCTV system users.

## Glossary

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| ANPR | Automatic Number Plate Recognition |
| ATM | Asynchronous Transfer Mode |
| CBRN | Chemical, Biological, Radiological & Nuclear |
| CHM | CCTV Health Monitoring |
| EMI | Electro-Magnetic Interference |
| MUX | Multiplexer (combines analogue video streams) |
| MTBF | Mean Time Between Failures |
| NTSC | American standard for analogue video |
| PAL | UK Standard for analogue video (with multi-national variants) |
| PCI | A bus used to allow external devices (boards) to communicate with a CPU |
| QoS | Quality of Service |
| SDH | Synchronous Digital Hierarchy |
| SLA | Service Level Agreement |
| TRT | Thales Research & Technology |

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## Further Information

- www.thalesresearch.com
- www.thalesgroup.com