Project no. AST3-CT-2004 502858_OpTag

OpTag

Improving Airport Efficiency, Security and Passenger Flow by Enhanced Passenger Monitoring

Executive Summary

Instrument type:	**STREP**
Priority name:	**Aeronautics**
Period covered:	**1 Feb 2004 to 31 Jan 2007**
Start date of project	**1 Feb 2004**
Duration:	**3 years**
Project coordinator names:	**Bob Lloyd/Colin Brooks**
Project coordinator organisation:	**Innovision Research & Technology plc**
Revision:	**Rev 1**

OpTag Executive Summary

1. Strategic Objectives Addressed

The OpTag project was devised and proposed to address Thematic priority **AERO-2002-1.4** by contributing to *'an increase in the operational capacity and safety of the air transport system'*.

In particular it addressed key objectives of priority **AERO-2002-1.3.1.4d** by improving airport efficiency through the *'Definition of concepts and technologies to reduce passenger waiting time and to improve the efficiency of land and airside aircraft turn-around from touchdown to take off …'*

2. Project Aims

This project planned to investigate emerging passenger tracking and identification technologies with the objectives of increasing the safety of air travel whilst maximising the utilisation of existing facilities.

Late passengers (or baggage) arriving at a gate cause up to 5% of departure delays. The OpTag system concept was to deliver better knowledge of the position and movements of passengers throughout an airport environment. The aim was to devise a means to locate checked-in passengers who are either missing or late, and thus reduce passenger-induced delays and speed up aircraft turn around.

Such a system might form an essential component of airline passenger identification and threat assessment systems through the automated identification of suspicious passenger movements, or through the closer monitoring of individuals considered to pose a risk to security.

The project involved a network of enhanced Closed Circuit Television (CCTV) systems coupled to local direction-based passenger tracking systems using 'far-field' Radio Frequency Identification (RFID) tags. It was proposed that the OpTag system might provide real-time location of individual passengers within the airport, the analysis of both mass traffic & individual behaviours, and, where appropriate, the semi-automatic control of CCTV based vision systems to observe and record suspicious or unauthorised activity.

Three developments were required to implement the system:

1. A compact, low cost transponder to be carried by passengers.
2. A compact, high resolution, panoramic imaging system together with software to follow a target and confirm the identity of the tagged individual.
3. An ergonomic user interface to facilitate augmented surveillance.

The use of two complementary yet independent systems (one RFID based, one vision based) was intended to ensure an appropriate balance of active and passive tracking, and to enable an operator to track a passenger throughout the facility and to minimise opportunities to evade the system.

It was anticipated that the key benefits of the OpTag system would be:

(i) Passengers (and maybe staff) would be issued with a low cost tracking RFID tags. These tags would have more than 5m range enabling them to be interrogated by beacons comprising RFID readers co-located with high-resolution panoramic CCTV cameras that define regular cells throughout the facility. This would enable the allocation of passengers to these cells and facilitate the determination of the azimuth and altitude of each passenger with respect to the beacon, thus facilitating precise tracking.

(ii) The CCTV system would deliver high-resolution imagery that could be seamlessly directed towards a target location or individual.

(iii) That imagery would have the capability of providing dimension measurement information that could potentially be used for biometrics or speed or other calculations.

(iv) A passenger in camera view could be labelled by their RFID tag and thus linked to other attribute data through Collaborative Decision Support systems.

(v) A passenger could be traced to a fine resolution if they are missing for an imminent flight departure or judged to pose a potential security risk.

(vi) Image data could be linked with vision-based systems to facilitate verification of the target RFID and the characterisation of movement or behaviour.

(vii) The system could have the capability to be upgraded with motion or behaviour analysis software that might be used to spot and flag up unusual or suspicious movements or behaviour.

(viii) It was intended that the OpTag tag could ultimately be of low cost and thus available for many applications.

The OpTag project aimed to deliver a prototype, integrated system of tags, readers and panoramic cameras for evaluation of this concept within a simple airport environment.

3. Project Participants

The OpTag project consortium consisted of the following participants:

OpTag Project Participants				
Role	**Number**	**Participant name**	**Participant short name**	**Country**
CO	1	Innovision Research & Technology plc	IRT	UK
CR	2	University College London	UCL	UK
CR	3	Longdin & Browning	L&B	UK
CR	4	Photonic Science Ltd	PSL	France
CR	5	Telecommunication Systems Institute at Technical University of Crete	TSI	Greece
CR	6	Debrecen Airport	Debrecen	HU
CR	7	Europus Ltd	Europus	UK
CR	8	SLOT Consulting	SLOT	HU

4. Project Work-packages

The project work was split into 6 work-packages as follows:

- WP1: Project Management Control & Reporting
- WP2: Exploitation & Dissemination
- WP3: System Specification; Tag & Reader Development
- WP4: Camera Hardware Development
- WP5: Camera Communications, Intelligence Development and Testing
- WP6: System Integration and Field Tests

4.1 WP1: Project Management

Innovision Research & Technology plc (IRT) were the project coordinators. The initial project start-up review was held in Brussels with the Project Officer, and subsequently at UCL for more detailed planning and setting up of ground rules and communication links. The coordinator ensured that everyone was clear on objectives, timescales and deliverables, and also acted as the link to Brussels for information.

In the early stages of the project, the consortium members were visited at least once for project reviews, etc. In the final stages of the project most of the meetings were held at UCL, London were the OpTag equipment had been set up for development and testing purposes prior to the trial at Debrecen Airport.

4.2 WP2: Exploitation & Dissemination

Initially this work consisted of a combination of investigating the existing IP situation on the key system components; tags, panoramic cameras, and their applications in passenger tracking. In addition, meetings were held with various airports, airlines and passenger bodies to clarify the requirements of the OpTag system.

Detailed patent searches were undertaken, and an inventor's note has been prepared covering aspects of the OpTag project concept.

Slot Consulting investigated how the OpTag system might look, and how it might fit within an airport environment. Slot also prepared an initial cost-benefit analysis document to consider appropriate target costs for the various components of the system.

In addition to speaking at conferences on subjects related to OpTag, the team set up a special project website (see details below). A number of academic papers have been published on the technical aspects of the system.

More recently, in 2007, the European Commission produced and circulated a DVD entitled "SMEs" and this included a highly informative 5 minute video of the OpTag project. (Refer to: http://sme.cordis.lu for further information.)

4.3 WP3: System Specification; Tag & Reader Development

The results of initial airport meetings and technical reviews were collated to clarify a specification for the individual elements and overall system for OpTag.

UCL Department of Electronic Engineering (UCL EE) developed the RFID tag and reader specification in more detail. This work began with the selection of a suitable frequency standard, consideration of tag operating range, and methods of anti-clash operation. After modelling the tag design, UCL EE developed three variants of the tag, the final version being based on a synthesiser approach. UCL EE also performed propagation modelling of the tag in a range of indoor environments.

Finally, three prototype RFID readers and a number of model RFID tags were manufactured and taken to Debrecen Airport for evaluation purposes.

4.4 WP4: Camera Hardware Development

Research into the required camera resolution was undertaken, including a meeting with the UK Police Scientific Development Branch who have expertise in camera systems. The camera hardware specification was developed and agreed, and a suitable image sensor was selected to meet this requirement.

Photonic Science Ltd (PSL) and UCL Department of Geomatic Engineering (UCL GE) worked closely together to develop a suitable panoramic camera featuring a 360 degree viewing angle. The mounting of the camera sensors was considered very carefully to optimise the panoramic view from a practical camera height, and to ensure that the image stitching was possible.

Three prototype camera clusters were manufactured, each comprising an assembly of 8 individual camera units into a modular cluster that facilitated both real-time 360 degree viewing, and zoomed high definition imaging of specified regions of interest. These camera clusters were used in the Debrecen Airport trial.

For much of the project, Telecommunications Systems Institute Crete (TSI) had one of the camera clusters for software development, and PSL and UCL GE used the remaining two camera clusters for hardware and system development purposes. Several hardware revisions of the camera design were necessary in order to increase the frame rate and improve reliability.

4.5 WP5: Camera Communications, Intelligence Development and Testing

Significant effort was applied to the development of the OpTag network operation. The networking solution had to be capable of carrying adequate image data to be able to be processed by multiple users, and yet provide sufficient resolution to be able to aid in passenger identification and tracking.

TSI and UCL GE worked together and separately on the various components of the OpTag camera sub-system. For example, TSI developed the software responsible for the processing of the camera images. This included correction of the distorted image coordinates on the 2D plane, panorama stitching, compression and communication of the MJPEG images on the network. UCL GE delivered updated software parameters following recalibration of the cameras. These included an extended calibration model to take into account small sensor rotations that appeared to vary each time a camera cluster was re-assembled. They also improved the resulting panoramic image with the inclusion of cylindrical projection.

4.6 WP6: System Integration and Field Tests

The objective of this package was to integrate the camera and networking hardware and software with the RFID tag and reader system to make a prototype OpTag system that could be operated in a real airport environment.

Initially this work concentrated on the development of the user interface to allow useful information on the tag ID and passenger position to be viewed and plotted. Simulations of the user views were built and reviewed within the team and with potential users.

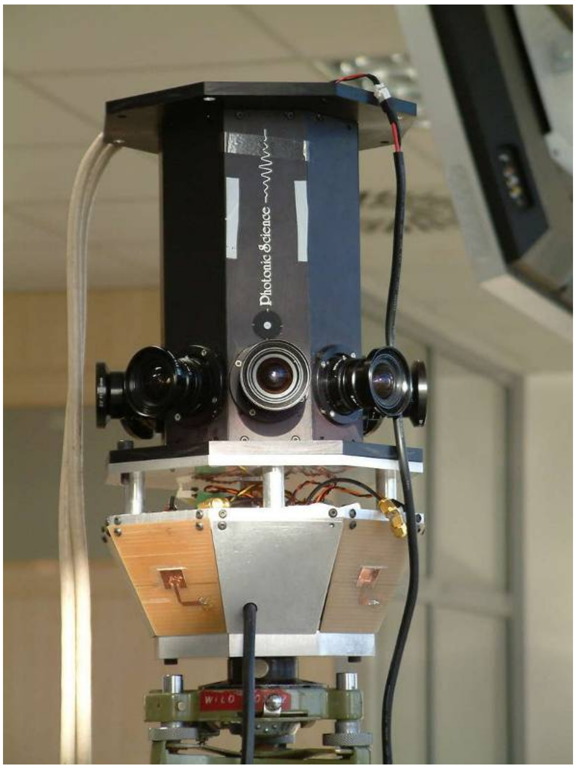
With the late delivery of the camera hardware, RFID tags and readers, effort was concentrated on establishing algorithms and software to compute and display the 3D geometry including the relationship between each camera, tag and person location as these were the essential functional building blocks of the OpTag system.

In the weeks leading up to the Debrecen Airport trial, the majority of the equipment required to demonstrate the OpTag system was assembled, set-up and tested in the Foster Court Laboratory at UCL GE. The equipment could be left permanently set-up in this laboratory during the final stages of development for experimental trials, and this was extremely helpful.

5. The Debrecen Airport Trial

The OpTag equipment was shipped from London during the w/c 1st January 2007, and arrived at Debrecen Airport by 11-Jan-07, in good time for the start of the trial during w/c 15th January 2007. The airport has two similar departure lounges on the ground and first floors of the terminal building. Only one of these lounges was required to cope with the expected air traffic during this period, which meant that the OpTag consortium had uninterrupted access to the ground floor departure lounge during the whole trial week.

Technical teams from UCL EE, UCL GE and TSI set up the OpTag equipment whilst Longdin & Browning (L&B) surveyed the airport lounge in order to provide 3D CAD model necessary to calibrate the camera sub-system. Once set-up, the OpTag system was operated for approximately two days for experimental purposes before being packed up again for return to the UK.

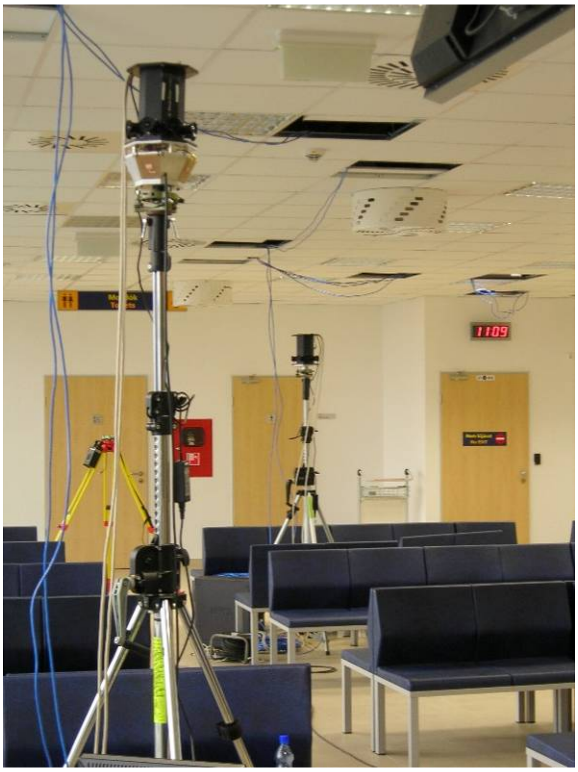


A close-up of an OpTag camera cluster (top) and RFID reader module (bottom)

Three panoramic cameras and RFID reader modules were mounted on tripods around the airport lounge to provide good coverage of the area. Each panoramic camera was linked to a camera server computer, and these were connected by network cabling to two client computers that provided the user interface software to operate the whole system.

As is usually the case with practical trials, there were a number of technical issues that had to be overcome so that the trial could proceed and measurements could be taken. For example, one of the camera servers suffered a major hard disc failure (perhaps related to shipping) that required the disc to be reformatted and all the operating software re-installed. Various problems with the RFID reader modules meant that network connection of these was not possible, and it was necessary to resort to manual measurements.

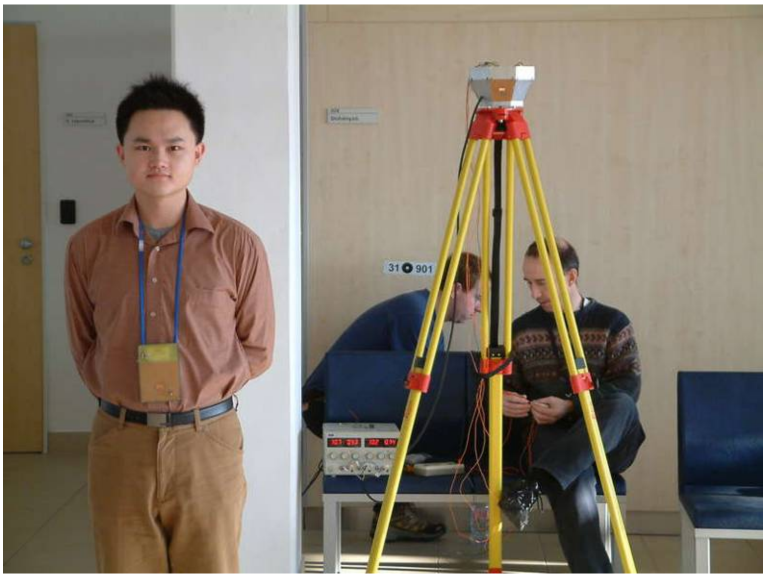
Nevertheless, despite these practical difficulties, the trial continued and a great deal was learnt about the operation of the OpTag system in an airport environment.



Debrecen Airport departure lounge showing two OpTag readers mounted on tripods

5.1 RFID Reader Results

A structured series of tests and measurements were taken with the RFID system involving various members of the consortium.



Manually measuring the RF signal received from a tag facing away from the reader

For example, a consortium member was given a tag to wear and then asked to move around the lounge in a controlled manner so that readings could be taken to determine a bearing. Other members of the consortium were used to surround this person to deliberately block the signal from the tag to see what affect this had.

There were several key conclusions to be drawn from the experimental measurements taken at Debrecen Airport:

1. Location accuracy with a centrally-mounted RFID reader was found to be very variable, typically of the order of 1-3 metres. Radio propagation effects were very significant in this particular reader configuration, as reflections from walls and other objects were often found to exceed the strength of the direct path with misleading results.

2. The results obtained with the RFID reader placed in the corner of the room were much better in terms of direction-finding and hence location accuracy. This is doubtless due to the improved propagation environment with a corner-mounted reader. In addition, this arrangement makes for a more straightforward location algorithm. This configuration is therefore preferable.

3. Obstruction by one or more persons was found to cause a significant reduction in signal strength, around 10 dB, but still provided ample signal.

4. Experiments were also conducted to show the affect of a crowd of people surrounding the tag – this tends to affect the location-estimate accuracy, but not to an unacceptable degree. The presence of more than one person in the direct path makes little difference to the received signal, indicating that at these frequencies (5.8 GHz) a single person causes a large attenuation of the direct path.

5. Tag operating range was found to greatly exceed the required target of 10 metres. The signal was well above the -90 dBm threshold, even to ranges of 25 m and with an intervening wall. This was a very pleasing result, indicating that quite large cell sizes should be possible, with reduced infrastructure requirements.

6. One of the results obtained with corner-mounting showed that the mean error with location bearing was close to zero, indicating that there was no bias in the reader, but there was considerable variation around this mean, dependent on the tag location. The RMS variation in this particular set of results is 16 degrees – equating to 1.4 m of location error at the typical operating range of 5 m.

These findings provide useful guidance for the design of any commercial RFID implementation of the OpTag concept.

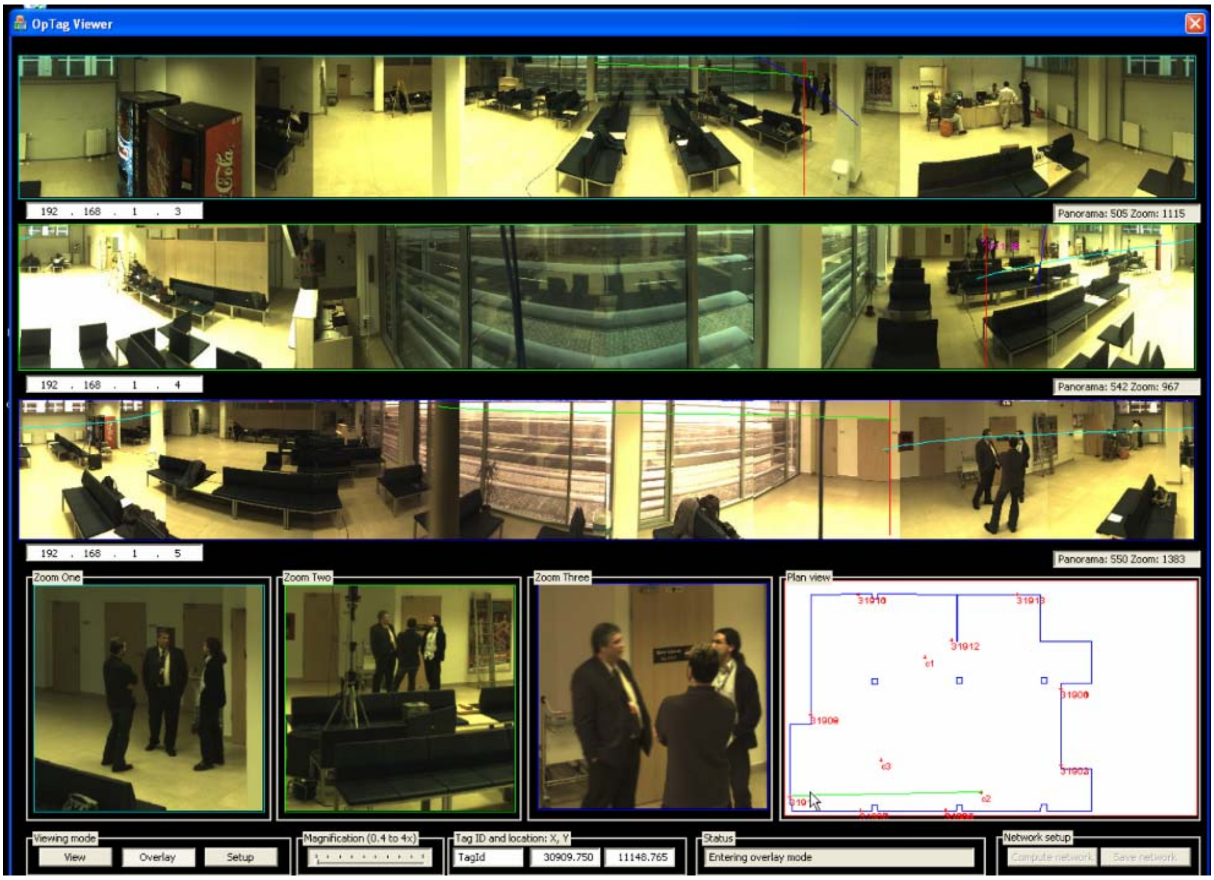
5.2 Camera System Results

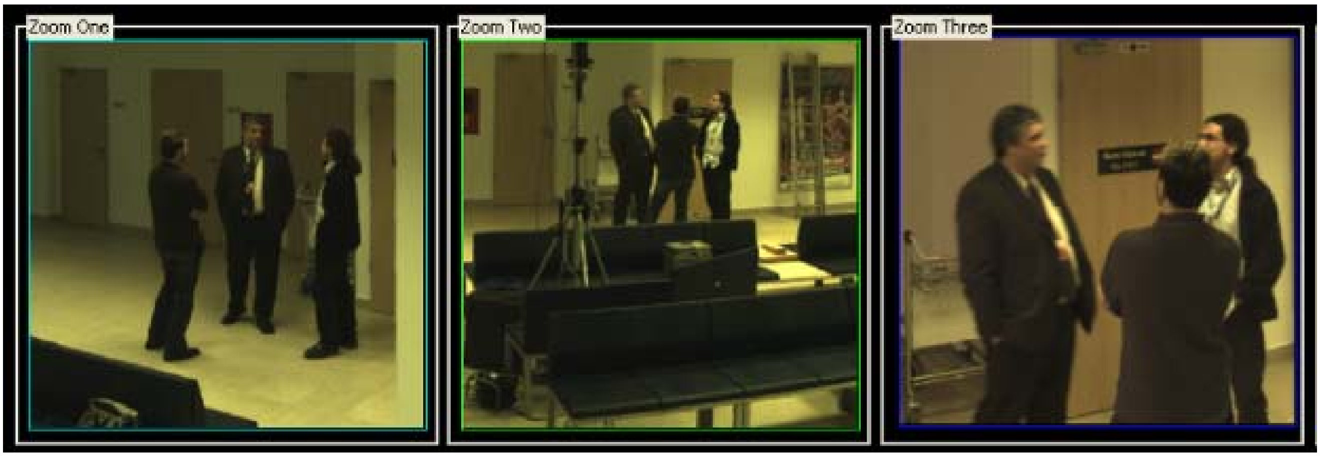
The network of three panoramic cameras and two client computers was assembled in the test area in such a way as to provide good coverage throughout the airport lounge floor space. Whilst there were some system failures, all of which were recovered from during the trial period, all components of the camera sub-system performed sufficiently well to provide a strong demonstration of the technology. Refer to the screen images shown overleaf for an example of the system operation.

A number of limitations were identified which would need to be addressed should the system be taken to further towards a commercially viable product. The problems experienced included excessive latency between target motion and image display, along with further latency between panoramas and zoom windows. This caused particularly difficulty when attempting to track individuals, as a predictive approach had to be applied. The network periodically slowed the image update rate and eventually locked up for indeterminate periods.

Cameras occasionally developed a cyan colour cast consistent with a change in order of colour pixels delivered to the frame-grabber. On such occasions the camera and/or network had to be reset. The camera AGC was unable to cope with the extremes of lighting variation both at fixed times during the day, and the variation between night and day i.e from natural to artificial lighting. This meant that the apertures of the cameras needed to be adjusted as the lighting conditions changed, imposing another level of complexity when setting up the system for a particular test scenario.

In general the problems identified above did not prevent the trial from exposing its capabilities as an alternative to the established pan and tilt surveillance system along with the advantages set out in the initial project proposal. In this respect the trial in Debrecen has been extremely informative and has resulted in a successful demonstration of the OpTag system.





(Top) Example client view showing three common views of one of the OpTag team members that had been selected by the operator.
(Bottom) Enlarged views of the selected zoom windows.

6. Conclusions

The OpTag project ran for three years from 1st February 2004 and successfully concluded with an experimental trial of the prototype OpTag system at Debrecen Airport in Hungary during January 2007.

The project aimed to investigate emerging passenger tracking and identification technologies with the objectives of increasing the safety of air travel whilst maximising the utilisation of existing facilities. It involved a network of enhanced Closed Circuit Television (CCTV) systems coupled to local direction-based passenger tracking systems using ‘far-field’ Radio Frequency Identification (RFID) tags.

Despite technical problems during the system development and actually during the trial itself, it was possible to demonstrate the original project concept and many useful results and practical experience were obtained.

However, the current prototype OpTag system would require further engineering development work in order to produce a viable commercial implementation. The current tag, reader and camera designs are still very prototype in nature. They would need to be re-designed for commercial production in order to improve performance, make them easier to manufacture, and to reduce cost. In particular, a very low tag cost is probably critical to the commercial viability of any system like this one.

There is another important point to consider. During the latter stages of this project, there has been considerable commercial and media interest in the OpTag concept for a variety of reasons. There appears to be a genuine commercial interest in the concept of using a real-time location system in conjunction with video images – and being able to link and operate these two systems in a straightforward manner. Equally, it should be recognised that some of the media interest in OpTag has been fairly negative. This reflects an understandable concern to see adequate protection of individual privacy and freedoms, whilst balancing these issues against the need for improved security in certain environments. It would be important to address this topic openly as part of any future commercial development of the OpTag concept.

7. Project Website

The OpTag project website can be found at:

<http://www.optag-consortium.com/

This website includes some general presentations and articles written about OpTag, details of the consortium membership, and controlled access to the OpTag User Club for more detailed information about the project.

8. Project Co-ordinator

The OpTag project was co-ordinated by:

Bob Lloyd (from February 2004 – June 2006)
Colin Brooks (from July 2006 onwards)

Innovision Research & Technology plc.
33 Sheep Street
Cirencester
Gloucester
GL7 1RQ

Tel + 44 1285 888 200

Email: colinb@innovision-group.com
Web: www.innovision-group.com