Laserscan and thermal monitoring – history, present

Ing. Martina Blašková

Air Transport Department, University of Žilina, Slovakia

Abstract — *this paper discusses the detailed history and the present of laserscan and thermal monitoring, the new technologies in these systems and using them "in the air". It describes systems such as laserscan, thermal monitoring and terrain monitoring.*

I. Foundation and first product

Laser-Scan was founded in 1969 by three academics from the Cavendish Laboratories (the Physics department of the University of Cambridge). The academics had built in the laboratory a prototype of a machine called Sweepnik that used a laser beam, moved around by mirrors, to follow lines on photographs. These photos were of bubble chamber experiments to identify the elementary particles (protons, neutrons, electrons, etc.) which are the building blocks of matter. The first Sweepnik shipped to Helsinki in 1972, and was followed by sales to many other countries including France, America, Belgium, India, Japan, Greece, Egypt, etc.

II. Hrd-1 display/plotter

Having successfully shipped the first few Sweepniks, the academics saw an opportunity to build other devices using similar laser-beams and mirrors. The first of these was the HRD-1, which instead of reading images from film, was able to write images onto film. The film could either be postcard-sized diazo for permanent hardcopy, or be a photo chromic film projected onto a screen to give a large display (a meter across).

The HRD-1 lived up to its name as High Resolution Display number 1. Even today, a modern workstation screen is doing well to reach 1000 addressable lines of pixels. The HRD-1 had 140,000 by 100,000 addressable points. Even allowing for the fact that the light spot was 10 times bigger than the addressability, this was still 10,000 lines resolution. The HRD-1 remains to this day one of the very few computer displays in the world on which a complete map can be drawn at scale and remain able to see the detail without zooming in and out.

The HRD-1 was exhibited at graphics shows, and two market areas expressed an interest. One was Digital Mapping, then in its infancy. The other was the security printing industry, including the design and printing of bank notes and bonds. Of the two, the security printing industry wanted to write its own software, and just bought Laser-Scan hardware. It has been said that around a third of the banknotes in the world have been designed using Laser-Scan hardware, including the British notes.

The first digital mapping customer was ‚ECU', the Experimental Cartographic Unit, which was housed in the Royal College of Art in Kensington, just across the road from the Natural History Museum. The founder and boss of ECU was David Bickmore, who was years ahead of his time. I remember a talk he gave to the Auto-Carto conference in London in 1976 on ‚the scale-free database' - an ideal that we are now just managing to achieve with Gothic software and 1999 computer technology!

The HRD-1 used a powerful argon ion laser cooled by running water, and pulling 30 amps on three phase electricity to produce about 300 mill watts of beautiful turquoise light, focused into a spot about 10 microns across. This spot could either draw on photo chromic film to produce the image for the screen, or by swinging a mirror out of the way, could draw on diazo film to produce postcard-sized hardcopy.

The HRD-1 at ECU was serial number 103, but actually the third one built. It was driven by a DEC PDP-9 minicomputer. This was not very mini, as it filled two bays each about 4 meters long by two meters high. The PDP-9 had 16K words of core memory (real magnetic cores - no chips yet) with an 18-bit word length, able to store three 6-bit characters per word. This is in the days before the 8-bit byte had been invented.

Laser-Scan provided no applications software with the HRD-1. The main software that was provided was an interface library called LDLIB which had been written by a researcher at Cambridge University called Peter Woodsford. He had been a member of Cambridge University's CAD Group, where he developed the pioneering GINO graphics package (which is still in widespread use world-wide). Since joining Laser-Scan in 1975, Peter held a series of technical, managerial and directorial positions before becoming Deputy Chairman of the company in 1990.

Laser-Scan at the time operated from very primitive premises behind the CAD Centre on Madingley Road, Cambridge. The pre-delivery trials and training were held there with a party of three researchers from ECU headed by Dr. Les Thorpe, nowadays an independent consultant working at UKHO. His son Martin has worked in his vacations for us in recent years. One of the researchers was a bright young man called David Rhind, which explains an incident many years later when a party of Birbeck students visiting Laser-Scan were very late in arriving and the somewhat harassed Professor of Geography rang in to say the bus was going round and round the Madingley Road site and couldn't find Laser-Scan! They got him better organized when he later became Director-General of the Ordnance Survey.

The HRD-1 cost about £130,000, which in today's money would be well over a million pounds. That was without the computer which would have cost about half as much again. It says something for Laser-Scan engineering, that we were still selling HRD-1s into the 1990s, and there are still some operating in various parts of the world.

The ECU HRD-1 acted as a reference site for Laser-Scan, and within two years we had sold another HRD-1 for digital mapping - this time to RWS (the Rijk Waater Staadt) in Holland. They asked us to write map editor software to drive the HRD-1, and that started Laser-Scan on the path to what it is now - a spatial software company. Over time Mapping has become the dominant market for Laser-Scan, and LAMPS software has been used by many of the major national mapping agencies around the world.

III. Fastrak, lasertrak, and vtrak

In 1975, a major military agency in Britain, having seen the Sweepnik following lines and the HRD-1 drawing maps, asked if Laser-Scan could produce a line-following digitiser for maps. Out of this came a product originally called the HRD-1 Digitizing Option, then called FASTRAK, then called Lasertrak. The task of writing the software for map data capture was much harder than envisaged. It is a problem in pattern recognition, which is a task at which humans are very good, and at which computers are notoriously bad!

However, after several false starts, acceptable software was developed, which used very different algorithms to any other automatic digitizing systems since. These line following algorithms have way outlived the original expectations of the developers, and are still in use in Laser-Scan's VTRAK products shipping today.

In 1983 the console of FASTRAK was re-engineered for better ergonomics and appearance, and the software had major new facilities added for Junction Recognition. The resultant new automatic digitizing system was launched in the ACSM show in the USA as the Lasertrak.

The transition from Lasertrak to VTRAK occurred in around 1987, when the costs of raster scanners and computer workstations fell to a level where it was more cost effective to implement the line-following software on commodity hardware than to produce and maintain the expensive and delicate Laser-Scan Lasertrak hardware.

IV. Laserplot and mlp-1

Building on the same laser deflection technology used in the HRD-1 and Lasertrak, Laser-Scan built other kinds of computer output device. The Laserplot in 1985 was a precision plotter drawing on film of nearly A3 size. This could then be photographically enlarged to produce A0 films. The MLP-1 was a similar machine, but drew on 35mm microfilm, and sold particularly to engineering CAD installations.

V. Lamps, lites, and lites2

The first production map editor for the HRD-1 had been written in 1975, and was called SOLADI. It also ran on the FASTRAK and Lasertrak machines, as these were a superset of an HRD-1. Various customers liked it, but wanted to use their Lasertraks just for digitizing, so Laser-Scan was asked to make its map editing software available on commodity hardware. Computer workstations had not yet been invented, but Tektronix had recently produced the Tek4014 storage tube display. So, SOLADI was made available on a workstation based round the Tek display, in a product called IGES (Interactive Graphical Editing System).

In 1979 the Laser-Scan mapping software was moved from the PDP-11 computers to the new DEC VAX range under the VMS operating system. This allowed us to enhance the functionality and the new suite became known as LAMPS (Laser-Scan Automated Map Processing System), with the main editing component called LITES (Laser-Scan InTeractive Editing System).

In 1985, another military contract allowed us to do a major re-implementation of LITES and the plotting and representation components of LAMPS. The new editor was called LITES2, and is still in use at many sites worldwide.

VI. Terrain, tves and teras

As the LAMPS suite grew in facilities, major additions were introduced to handle raster data, terrain modeling, and visualization. Once again, military contracts were major contributors of funding, particular during and just after the Falklands war, and again around the time of the Gulf War.

Major contracts involved the TVES (Terrain Validation and Exploitation System) software, the ‚Al Yamamah' supply of a ground support system to the Saudi Arabian government as part of the sale of Tornado aircraft, and a pilot TERAS (TERrain AnalysiS) system for the British army in Germany.

VII. Laserscan – present

Aerial laser scanning is currently one of the most modern technologies for the acquisition of spatial geographic data. It is used in particular for creating a digital relief model, which represents only natural ground, and a digital surface model, which includes not only the terrain but buildings and vegetation cover as well. Data on the earth´s surface are obtained by using laser beam broadcasts in the form of pulses from the scanner, which is located on the aircraft. Aerial laser scanning has its own source of radiation and is therefore not dependent on sunlight. Reflections from the surface are recorded – including both land and buildings from the earth´s surface. Distance from of the point from carrier is determined by the time that elapses between the sending and reception of the reflection of the beam from the ground or other object back into the scanner. The location of points in the coordinate system is also determined by the position and inclination of the aircraft at the time of transmission of the beam and the known direction of the beam. These values are measured using GPS devices and an inertial navigation system.

The reflection of the laser beam can be a single or multiple. The multiple reflections occur primarily in forests and on edges of buildings. In over forests, part of the energy beam is usually reflected, for example by high vegetation, while the rest penetrates below. A part is again reflected, for example from low vegetation, and the remaining part of the beam gets to the ground and back into the scanner. The data acquired by aerial laser scanning is in the form of a so-called point cloud. These are irregularly spaced point data, which after removal of gross errors represent a digital surface model. With the assistance of automated filtering and classification processes, reflections from buildings, vegetation, solid ground and gross errors are distinguished. The filtered data for solid terrain then serves as the digital relief model.

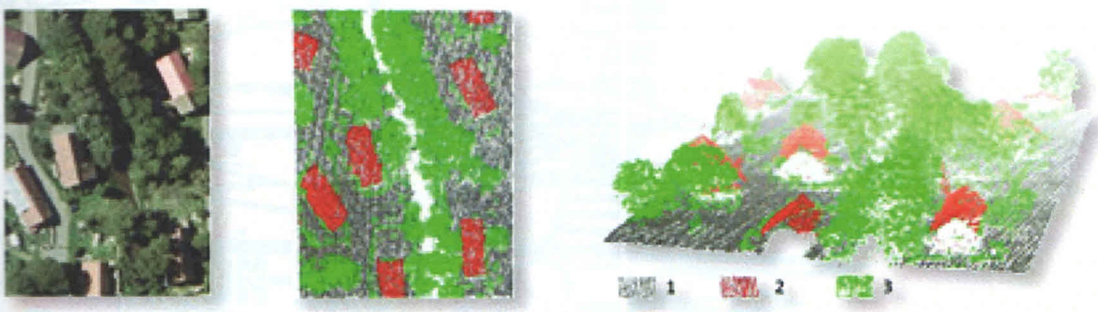

Figure 1: Aerial photo, points from the Aerial laser scanning, 1-terrain, 2-surface of buildings, 3-surface vegetation.

VIII. Aerial thermal imaging

Infrared imaging falling into the category for remote surveying of the ground is contactless measurement of surface temperature of the monitored object with infrared cameras. The infrared camera´s detector measures the electro-magnetic radiation radiated in the infrared spectrum by the object. Camera detected radiation is affected by the emissivity of the body, radiation reflected from the monitored object that was created in the environment and absorption of radiation during movement through the atmosphere. The object may be hiding underground and only affect surface temperature. Infrared photography is strict regarding weather conditions in which the measurement is made. Clouds and their shadows, wind of 3 m/s, high soil moisture - all have negative effects and in some application vegetation or direct sunlight can have a negative effect. The optimum periods for most imaging applications are autumn and winter. Infrared scanning is appropriate to carry out before dawn and with no snow. These conditions greatly limit the use of thermo graphic imaging methods. The number of days suitable for imaging is very narrow. Sometimes it is hard to satisfy all these condition and it my happen that the required imaging cannot be carried out at all. Thermographs can be particularly useful for study of expression of temperature contrasts. The resulting temperature map obtained through thermal scanning is influenced by the properties of the object itself and the characteristics of the environment in which the tracked objet is located.

The infrared camera is located in the plane in the gyro suspension because of the narrow camera angle and minimizing the impact of turbulence on the captured ground. A gyroscopic suspension offsets the negative effects of flying and maintains the axis of infrared cameras in an upright position. As a result of wind effect, the survey aircraft is not always moving parallel to the flight path and the aircraft can drift up to 15 degrees. To eliminate the adverse impact on the outcome of drift, compensation is necessary.

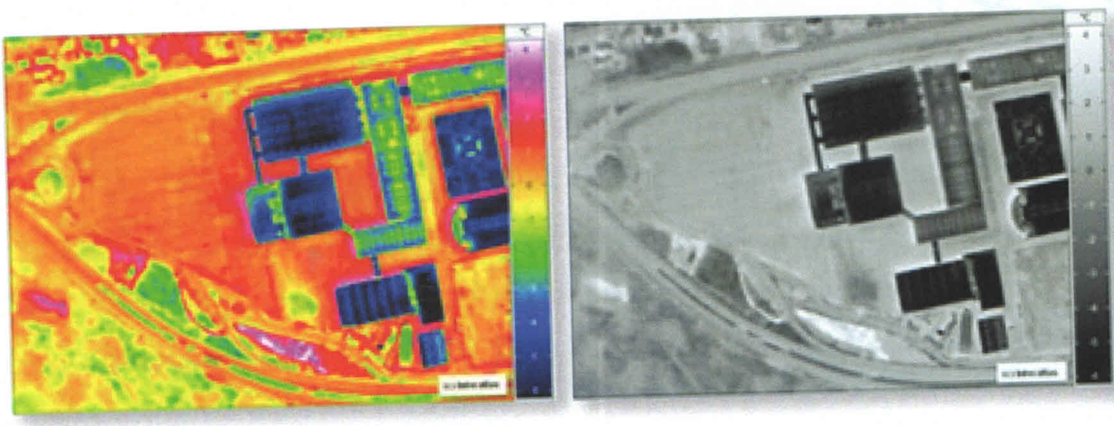

Figure 2: Sample images with different color palette

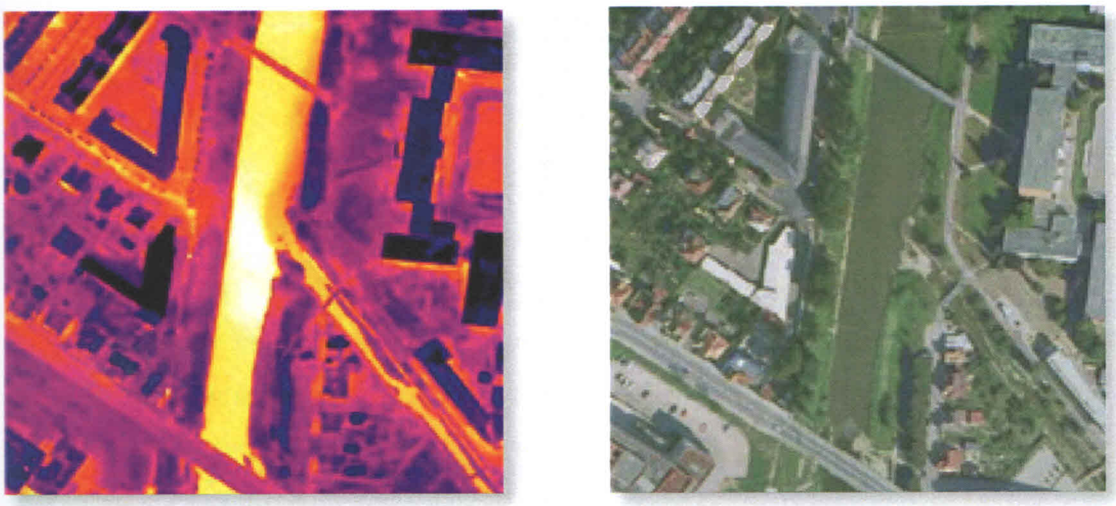

Figure 3: Inflows into waterways

Figure 4: Example of digital thermal camera (Modular sensor system)

Specifically, this airborne thermal camera system is for professional digital aerial thermograpgy. With a thermal resolution of 0.00ťK, the standard temperature range is -40°C to 120°C. The uncooled micro bolometer FPA-detector with 640x480 pixels delivers brilliant thermal images in high quality. Using a graphical user interface with real time preview, no additional video system is required. This system is a complete solution for an extremely rapid and workflow for the generation of directly georeferenced thermal images.

IX. Applications

- Capture loss of heat in populated areas, industrial plants, pipelines and power lines
- Flow measurement of streams and rivers
- Forrest fire warning system
- Monitoring volcanoes
- Animal tracking
- Search and rescue operations

X. Terrain mapping system

System serves to terrain mapping for 3D topographic surveys with fixed-wing aircraft and for 3D corridor mapping with helicopters. The system is designed to provide highly accurate measurements for DTM and DSM creation. It is compact, lightweight and can be installed easily on small survey aircraft or different helicopter models.

Laser scanners sample the surface in parallel lines with regular point spacing both in and across flight direction to provide the most accurate surface representation. The scan speed can be varied in a range to provide very point spacing within each scan.

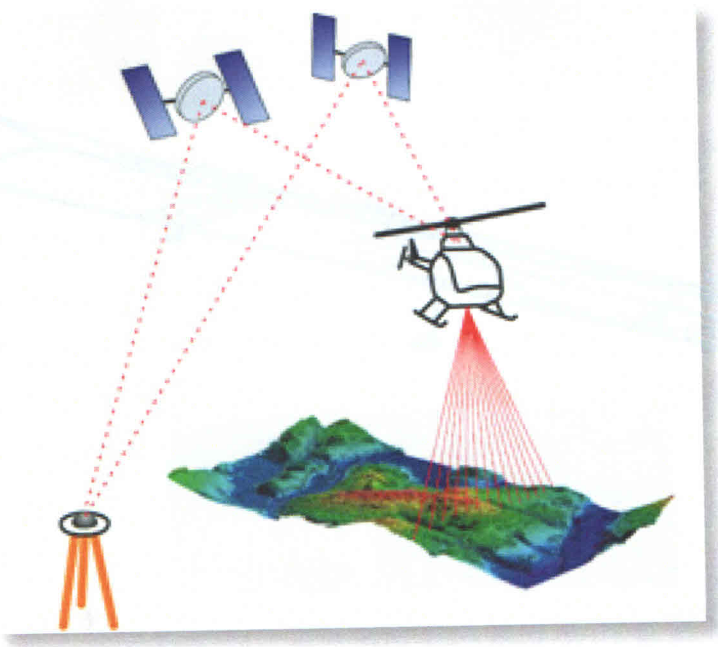

Figure 5: Operation of the terrain mapping system installed on helicopter.

XI. Applications

- Corridor mapping - highway, railway, pipeline, power line, airports
- Flood mapping -shoreline protection, Flood visualization
- City modeling - urban planning, waste management, route planning (emergency, traffic), noise protection, cadastral registration (trees, buildings), tourism
- Forestry - canopy height, single tree segmentation, classification, derive a bare earth DTM under the trees
- Opencast pits, archeology, applied research

Figure 6: Mapping system installed on a helicopter.

XII. Conclusion

Currently, monitoring systems offer many options for monitoring and evaluation from the air, whether it is form the airplane or helicopter. Aerial laser scanning and thermal imaging is currently expensive method, of obtaining the source data, but an initial investment is paid back many times over. These systems weight about 40 kilograms, so installation on the helicopter is not a problem. For example, Robinson R44 has payload about 400 kilograms, with two pilots (75kg one) and these systems, it can easily perform measurements and monitoring.

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