Remote Sensing for Archaeological Heritage Management

Edited by David C Cowley

Remote sensing is one of the main foundations of archaeological data, underpinning knowledge and understanding of the historic environment. The volume, arising from a symposium organised by the Europae Archaeologiae Consilium (EAC) and the Aerial Archaeology Research Group (AARG), provides up to date expert statements on the methodologies, achievements and potential of remote sensing with a particular focus on archaeological heritage management. Well-established approaches and techniques are set alongside new technologies and data-sources, with discussion covering relative merits and applicability, and the need for integrated approaches to understanding and managing the landscape. Discussions cover aerial photography, both modern and historic, LiDAR, satellite imagery, multi- and hyper-spectral data, sonar and geophysical survey, addressing both terrestrial and maritime contexts. Case studies drawn from the contrasting landscapes of Europe illustrate best practice and innovative projects.

EAC Occasional Paper No. 5
Occasional Publication of the Aerial Archaeology Research Group No. 3
ISBN 978-963-9911-20-8
Remote Sensing for Archaeological Heritage Management
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Zusammenfassungen
Abstract: Holstebro Museum in western Denmark has secured funding for a four-year aerial archaeology research project. The project is set to run until 2013, comprises nine sub-projects and has a budget of € 650,000. This article deals with the preliminary results of aerial survey and monitoring of scheduled ancient monuments from the air. In 2008 and 2009 the project totalled about 130 flying hours and located some 560 sites. This paper presents an overview of the first 100 fully recorded localities: among other results house sites were found at 33 of the 100 sites and pit-houses provide a good opportunity to obtain an overview of Late Iron Age and Viking Age settlements (20% of the total number of sites date from these periods). Results of the first aerial monitoring of 50 scheduled monuments are also presented. Even these early results allow us to say that there is great potential inherent in both sub-projects.

Introduction

Holstebro Museum in western Denmark has been successful in securing funding for a four-year research project on aerial archaeology entitled An aerial view of the past. The aim of this project is to draw attention to, and to analyse, the potential inherent in aerial archaeology for research, communication and education and in the planning process. The ultimate aim is to obtain a fuller understanding and better protection of the archaeological heritage. Target groups are archaeologists, planners and the general public.

The budget is € 650,000, and the project is funded by the Danish Ministry of Culture, The Heritage Agency of Denmark, Holstebro Municipality, Central Denmark Region, Holstebro Museum, two foundations and, to a lesser degree, the six museums responsible for the areas we survey systematically from the air. The project is, in 2009 and 2010, part of a regional cultural agreement, and it has been designated by the Danish Ministry of Culture as a national assignment. The project is set to run until the middle of 2013.

An aerial view of the past: brief project description

The project comprises nine sub-projects, as outlined briefly below:

1. Basic recording
An overview will be produced of existing historical aerial photograph series covering Denmark, mostly verticals taken for mapping purposes. A description will be produced of where these photos are kept, their accessibility, their state of preservation and an evaluation of their archaeological potential.

2. Basic investigations: aerial photographs and aerial reconnaissance
This sub-project is the most important. Nine areas, each of at least 155km², will be analysed systematically through the historical photo series. The same areas will be systematically surveyed from the air together with other areas (e.g. Figure 23.1). The most informative images will be rectified (from oblique to vertical) and the sites will be mapped digitally and entered into the national Sites and Monuments database. An overview of recorded ancient monuments for the whole of Denmark is freely available on www.dkconline.dk.

3. Archaeological excavations
Minimal, targeted excavations will be carried out at selected sites or structures where an interpretation on the basis of aerial photographs alone proves difficult. Radiocarbon dating may be undertaken. The aim is to clarify the nature of the sites or structures that have been detected.

Figure 23.1: Cropmarks of a characteristic long house with curved side walls of Viking date together with other house sites and pit-houses. Lydum 2 July 2008. © Photo: Lis Helles Olesen.
4. Scheduled ancient monuments
A large number of scheduled ancient monuments in the rural landscape will be experimentally surveyed from the air. The responsibility for the monitoring of scheduled ancient monuments has been shared out between ten museums across the whole country, of which Holstebro Museum is one. We are obliged to visit all the ancient monuments on the ground during the first five-year period (2007–11). The present project will attempt to establish whether it is possible, from the air, to carry out some future monitoring and re-inspection where there has been damage to the monuments.

5. National monuments
Well-known scheduled ancient monuments, such as dolmens and passage graves, Bronze Age barrow groups, tells, war booty sites, ring forts, churches, monasteries, medieval strongholds and castle mounds, as well as non-scheduled special structures such as Iron Age boundaries and Neolithic causewayed enclosures, will be surveyed from the air in order to obtain further information on and understanding of these sites.

6. Underwater archaeology from the air
To a lesser degree, areas of coastal waters will be surveyed from the air in search of shipwrecks, defensive barrages, submerged settlements and so on. The aerial archaeological potential of Danish coastal waters is very poorly understood in contrast to the southern and eastern Baltic Sea where many previously unknown underwater structures have been detected by aerial surveys.

7. Modern technology
The possibilities offered by LiDAR (Light Detection And Ranging, see Doneus & Briese this volume) will be tested on five known archaeological sites. The potential inherent in the national digital terrain model (DK-DEM) will also be investigated in the nine selected areas.

8. National and international collaboration
Measures will be taken to develop national and international collaboration in aerial archaeology. These will include the organisation of meetings, conferences and an international aerial archaeology course in Denmark, and participation in international collaboration and aerial archaeology conferences.

9. Communication and education
An important part of the project is communication of the results with the aim of promoting greater knowledge about the protection and understanding of our hidden cultural heritage. Aerial archaeology provides us with a unique opportunity to display prehistoric sites and monuments which otherwise no-one can see, and so communicate the importance of these otherwise rather unknown remains. We will make active use of the media and the results of some of the sub-projects will be published in articles and pamphlets. At the end of the project a book will be produced. A project website has already been set up: www.aerial-archaeology.dk.

Preliminary results: the first 100 sites
Aerial reconnaissance has proved very effective (Figures 23.2 & 23.3). In 2008 we undertook about 60 flying hours and found about 280 prehistoric and historic sites. In 2009, 70 hours were flown, recording the same number of sites as in 2008. In 2009, we also undertook spring and autumn flights with the aim of investigating traces revealed by soil colour differences in uncultivated fields as well as submerged features, and to test the potential for monitoring scheduled ancient monuments. On these flights we did not find as many new sites.
Find circumstances

All 560 sites have been entered into our database. In order to give an impression of what we have found, an overview is presented here of the first 100 fully recorded sites. A total of 79 of the 100 localities were new discoveries by the project. Of the 21 previously known sites, four were found by St Joseph of Cambridge University in the late 1960s/early 1970s (Eriksen & Olesen 2002, 14). At that time, he surveyed Jutland from the air several times for Moesgård Museum. Nine localities had previously been found by the local museums from the air, while eight localities are long-known sites.

The majority of remains (i.e. 89%) have been recorded as positive cropmarks, revealing the presence of ditches and pits dug in to the ground, providing better growing conditions for the cereal or grass than in the rest of the field. A further 6% are negative cropmarks, which may be produced by buried stone foundations or poorer growing conditions over sub-surface negative features due to them being filled, for example, with shifting sand. Only 1% of the sites have been recorded as variations in soil colour in ploughed fields. This very low percentage is due to us not having flown very much in the spring and autumn when the fields are not covered by crops and may have been ploughed. Furthermore, we have not included in this figure ploughed-down barrows that are already known. The remaining 4% of sites are the remains of slight earthworks surviving on the surface and recorded in raking oblique sunlight as shadows and highlights.

<table>
<thead>
<tr>
<th>Type of structure</th>
<th>Number of sites</th>
<th>Number of structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>House site</td>
<td>33</td>
<td>111</td>
</tr>
<tr>
<td>Pit-house (SFB)</td>
<td>19</td>
<td>about 320</td>
</tr>
<tr>
<td>Pit</td>
<td>55</td>
<td>about 600</td>
</tr>
<tr>
<td>Fence/ditch</td>
<td>18</td>
<td>about 60</td>
</tr>
<tr>
<td>Ring ditch</td>
<td>6</td>
<td>about 15</td>
</tr>
<tr>
<td>Postholes (many)</td>
<td>7</td>
<td>many</td>
</tr>
<tr>
<td>Farm site (of recent date)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Castle mound (medieval)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Ancient sunken road</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Ridge and furrow systems</td>
<td>7</td>
<td>many</td>
</tr>
<tr>
<td>Ploughed-down barrow</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Animal pen</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>World War II structure</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Shipwreck</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Unknown structure</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 23.1: Overview of the first 100 fully recorded sites.

Different types of structure

Below is an overview of the first 100 fully recorded sites (Table 23.1). It is apparent from this how many times the various monument types such as house sites, pits and fences occur at the various localities. Account has also been taken of how many examples have been found of each monument type. The fact that the total number of sites does not add up to 100 is due to the potential presence of several different monument types at one individual locality.

Figure 23.3: The red dots show all the sites discovered in 2008 and 2009. Drawing: Esben Schlosser Mauritsen.
Pits

The most common type of structure are pits found at 55 localities with around 600 pits in total. We have attempted, as far as is possible, to exclude modern diggings in the form of, for example, sand-extraction pits. These are, as a rule, quadrangular and often lie in dense clusters on ridges. A few pits in the vicinity of an existing farm are similarly not usually included, illustrating the many choices that must constantly be made in an evaluation of the located traces. Single pits are not deemed as important as house sites, and while the pits cannot be dated without excavation, they may be all that can be seen from the air of a hidden ancient settlement. They are therefore still important.

House sites

It was an exciting discovery that houses could be recorded in so many places, at 33 out of 100 sites, and in such numbers, 111 houses located. In 15 cases, traces of only one house site were found, in nine cases there were between two and four, in seven cases there were five to eight house sites and in two further cases there were 10 and 15 house sites, respectively.

As the development of house types through prehistory is very well understood, a large proportion of the house sites can be dated (Figure 23.4). Not surprisingly, the majority (62) are from the Early Iron Age (500 BC–AD 200) spread across 13 locations. From around 100 BC–200 AD the houses had very large earth-set posts and often a sunken byre at one end as a result of mucking out the animals, factors that make it easier to locate them.
them, they are seen more often as crop marks than house sites (Figures 23.1 & 23.6), and more than 300 pit-houses have turned up on these 19 sites. The aerial perspective clearly has great potential to provide a good overview of the location of Late Iron Age and Viking settlement in the landscape as well as the size of these settlements, specifically on account of these small workshops. For example, after several years of intensive searching in archives, stores/collections and excavation records, we had records of 39 Viking Age settlements in the former Ringkøbing County (4,600km²) by 2007/2008 (Eriksen et al. 2009). Of these settlements, nine were recorded from the air. Subsequently, 11 new localities were found by this project in 2008 and 2009, and a further five sites were found by excavation. So we now know 55 Viking Age settlements in the former Ringkøbing County, of which 20 were discovered from the air (i.e. 36%). To these can be added several possible localities where it could not be ascertained securely whether there were pit-houses or just pits present.

### Dating

The broad dating of house sites is dealt with above. Here, an account will be given of the dating of the 100 sites in general. It is clear that the Iron Age and Viking periods are the best represented, accounting for around 44% of the total number of localities (Table 23.2). It is surprising that around half of these can be assigned to the Late Iron Age and Viking times, when it is taken into consideration that so many of the house sites are from the Early Iron Age. The many dates in the Late Iron Age and Viking times are due primarily to sites with pit-houses.

As expected, there are few monuments from the Neolithic and Bronze Age. We could easily increase this total by including all the ploughed-down barrows we see, but for these classes of sites, an examination of earlier national series of aerial photographs and the new national digital terrain model (DK-DEM) is more

<table>
<thead>
<tr>
<th>Period</th>
<th>Number of dates as % of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>General prehistory</td>
<td>11 %</td>
</tr>
<tr>
<td>Neolithic/Bronze Age</td>
<td>4 %</td>
</tr>
<tr>
<td>General Iron Age</td>
<td>4 %</td>
</tr>
<tr>
<td>Early Iron Age</td>
<td>14 %</td>
</tr>
<tr>
<td>Late Roman/Germanic Iron Age</td>
<td>4 %</td>
</tr>
<tr>
<td>Late Iron Age/Viking Age/Early Middle Ages</td>
<td>20 %</td>
</tr>
<tr>
<td>Middle Ages</td>
<td>2 %</td>
</tr>
<tr>
<td>Middle Ages/recent</td>
<td>3 %</td>
</tr>
<tr>
<td>Post-Reformation/recent</td>
<td>10 %</td>
</tr>
<tr>
<td>Undated</td>
<td>28 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100 %</strong></td>
</tr>
</tbody>
</table>

Table 23.2: Dating of the 100 sites.
profitable. This source gives us a truer picture of known and unknown ploughed-down barrows. Traces of house sites from the Stone Age have so far not been detected from the air in Denmark. These house sites have only a single row of post-holes running down through the middle of the house, and, especially when damaged by ploughing they will be difficult to detect. A few house sites have, on the other hand, turned up from the Bronze Age.

The Middle Ages and later centuries are also poorly represented. This is due to the fact that we only include structures that lie within the scope of the project. Thus sand- and clay-extraction pits, recent roads, drainage, cable and pipe trenches, filled-in ponds, grubbed-out shelter belts and water courses and the like are not recorded.

A relatively large number of structures are un-dated. This category covers, among others, sunken roads and many localities with pits, which even though they lie close to a known Iron Age fortification cannot be specifically dated. Many interesting structures that we so far have not been able to classify further are also concealed within this category, for example a large square ditch, measuring about 45 × 45m, at Jersore on Northern Funen (Figure 23.7).

The results from the first 100 sites are not comprehensive as, for example, the Bronze Age house sites have not been included in this overview. Even so, these results give a good impression of the direction that the aerial surveys will take with respect to date, type of structure, find context and so on. Our minor excavations at selected sites and the valuable assistance from metal detectorists supplement our knowledge at a number of the localities (Figure 23.8). These provide an identification of the structure type and a good indication of date so we can minimise the number of unidentified and un-dated structures. While, however, there are discoveries which we cannot immediately identify and date, the majority can be assigned to categories and it will be interesting to see what the development in the number of discoveries in the coming years will be, relative to the first 100 localities dealt with here.

Preliminary results: scheduled ancient monuments

Scheduled ancient monuments reflect special character and value in the landscape, and are also a treasure chest of information about our history. In Denmark, there are about 33,000 scheduled ancient monuments, of which by far the greatest number are barrows. The majority are in arable land and they are often damaged by ploughing. In addition it has always been time consuming and expensive to monitor these ancient monuments adequately. A new law lead, in 2007, to the responsibility for monitoring of scheduled ancient monuments being transferred to ten museums around the country – in the first instance for a five-year period. In our project we thought it was obvious to investigate...
the possibilities of being able to do some of this work from the air, and that new methods are required in order to keep costs down so that monitoring could be carried out at intervals of a maximum of five years.

It should be mentioned, in explanation, that there are two zones around the Danish scheduled ancient monuments that relate to their scheduling. Around the actual monument itself there is a 2m zone within which ploughing, manuring or sowing/planting are not permitted (Figure 23.9). Beyond this is a 100m zone within which no changes may be made in the existing state of the area. For example, it is not permitted to erect fences, plant trees, park caravans and the like.

We have initiated the first trials involving aerial survey of scheduled ancient monuments. The very preliminary results from this trial are included here, comprising one survey in which we surveyed 50 scheduled barrows in less than 1½ hours. We chose an area where we had monitored the state of the monuments from the ground 1½ years ago.

There were two aims of the aerial survey:
- to investigate whether it was possible to record monument condition with the criteria required for traditional monitoring on the ground,
- to investigate whether there have been changes in the state of the monuments since the monitoring carried out on the ground in 2008.

Of the 50 sites, 45 could be seen from the air, while four others lay in woodland/garden, and one barrow in arable land was so heavily overgrown as not to be visible. Thus for the 45 barrows condition and potential damage could be evaluated both within the 100m cordon and within 2m (actually visible in 46 cases).

The evaluation of the aerial photographs of the barrows demonstrated that although there were no infringements of the monuments within a 0.5–1m cordon, there were 11 infringements within 1–1.5m and 17 infringements within 1.5–2m. These three infringement categories originate in the recording required when monitoring at ground level. The reason that no damage was recorded within 0.5–1m could be that it is difficult to judge these distances precisely from the air. For example, in judging distance from the aerial photographs we can make use of tractor wheel tracks, which are 2m apart, and the distance between rows of maize stubble, which is 70–80cm, and possibly other features that occur in the vicinity of the monument, so it can clearly not be completely accurate. In some instances it is also difficult to judge the exact position of the barrow edge, but this may also be the case ground during a ground visit.

The need for management, for example felling of trees, could be established in 42 cases, and in seven the tree-cover was too dense to even estimate how many trees or shrubs should be removed. On one of the barrows, the trees were so slender and without leaves that they were difficult to see, but use of a longer telephoto lens would solve this problem. At five mounds the evaluation from the aerial photographs was judged unsatisfactory.

**Assessment of changes in monument condition**

It proved possible to compare change in monument condition between the recent survey and that in 2008 for 47 barrows (three lay in dense woodland and were therefore not visible in detail from the air). For 31 cases the situation appeared to be unchanged, although five barrows lack data from the earlier survey. However, for 11 barrows (23%) of the total the situation had changed.

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*Figure 23.9: Many farmers do not respect the 2m cultivation-free zone around barrows. © Photo: Lis Helles Olesen.*
At five barrows the infringements had become worse, although in four cases there had been an improvement. In two cases, the barrows lay fallow in February 2008, at one there was now an infringement and at the other the situation was unchanged. The result obtained, with changes in the state of 23% of the ancient monuments over a period of less than two years, shows that it is important to follow up the survey quickly by making contact with the owner when it has been established that there has been an infringement. The damage was reported to The Heritage Agency of Denmark, which, unfortunately, has not followed this up with contact to the landowners.

Time expenditure
The time expended in this first ‘monitoring survey’ of 50 ancient monuments was 41 hours split between two people broken down into eight hours preparation, two hours travel, three hours flying and 28 hours examining photographs. Time expenditure will be much reduced in the next monitoring surveys as we streamlined procedures and agreed on which map formats and database to use. Thus, it should be realistic to survey a greater number of monuments in one operation – at least 100.

In general, on the basis of this first trial, there appears to be great potential for monitoring scheduled ancient monuments in rural arable areas from the air, as in about 80% of cases it was possible to obtain the relevant information. We will continue these flights in the coming years.

Conclusion
After a little more than a year several parts of the project are now well under way. Two relatively dry summers have ensured good results from aerial survey. The examination of vertical photos from 1954 and the digital terrain model (DK-DEM) in all nine study areas have also provided a large number of new monuments and a greater understanding of past landscapes and settlement patterns. We believe we are already in a position to say with certainty that there is great potential for aerial archaeology in Denmark.

References