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Status of High-Resolution Satellite Imaging

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ABSTRACT

In spite of program delays and two recent failures to deploy satellites in orbit, the era of commercial high-resolution Earth observation satellites is drawing ever nearer. As primary future users of image data from 1 m satellites, the photogrammetric mapping and GIS communities have shown considerable interest in this new technology. There is consequently a broad understanding of the technical characteristics of the sensor systems involved, of the range of image-derived products to be generated, of the opportunities to value-add to these automatically generated products, and of the principal target markets. There remain, however, a number of challenging issues which confront the satellite image providers and the photogrammetric community, which need to be resolved over time if the full commercial potential of high-resolution Earth observation satellites is to be realised. This paper addresses some of these issues, which include data licensing and royalties, availability of camera models, the vagaries of government restrictions, and government's involvement as a major customer for image-derived products.

1. INTRODUCTION

It has now been four years since the 45th Photogrammetric Week, a feature of which was the presentation "Recent Developments for Optical Earth Observation in the United States" by Lawrence Fritz (Fritz, 1995), then Secretary General of the International Society of Photogrammetry and Remote Sensing. This paper laid out the scenario for a new era of high-resolution (1-3 m) Earth observation satellites which would likely revolutionise the entire geospatial information industry. Specifically, the technical characteristics of high-resolution satellite imagery (HRSI) systems were described. The general business strategies of the three commercial companies developing these sytems, EarthWatch, Space Imaging and OrbImage, was also discussed. New geospatial products were being considered, aimed at markets never before contemplated.

All this was of course 'music to the ears' of the photogrammetric mapping & GIS communities, which immediately envisioned a powerful new technology which would potentially render aerial photography obsolescent for mapping scales of 1 : 10 000 and smaller. Expectations were raised, especially given the then imminent launch of the first of these satellite systems, namely *Earlybird* from EarthWatch. By the time of the 46th Photogrammetric Week in 1997, it is fair to say that the initial euphoria over the prospects for 1 m satellite imagery for mapping had subsided a little.

While there was confidence in the technical capabilities of HRSI to produce a new standard of high-quality, high-accuracy image-derived earth information, there was nevertheless some unease in the photogrammetric community about the business strategies being pursued by the companies developing the different satellite systems. On the one hand, there was some annoyance with continuing changes to launch schedules, with published launch dates being perceived, rightly or wrongly, to be decided more by business imperatives to secure investors, partners, affiliates or distributors, than by technical readiness. On the other, there was angst over the stated desires of the HRSI providers to become spatial information companies and not simply distributors of satellite imagery to which the mapping sector would have an unencumbered opportunity to value-add.

From the point of view of the mapping sector there appeared the prospect of a '500 lb gorilla' (actually more than one) trampling over the traditional photogrammetric industry, essentially through the high-volume provision of timely and highly-automated spatial information products. These would centre upon orthorectified imagery with 1 m resolution and a spatial accuracy of a few metres. The view from the HRSI providers, meanwhile, had to retain a focus on the need to achieve a profitable return on investments of several $100 m, and it was always apparent that this would not

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be achieved solely through the sale of basic imagery. These sentiments were expressed in two presentations at the 46th Photogrammetric Week, one on the Space Imaging System (Thurgood, 1997) and one on EarthWatch's *Earlybird* (Gerull, 1997). At the time, both satellites were due for late 1997 launch and the dawning of the new era of HRSI was thus still viewed as 'imminent'.

It was noted in the paper by Dr Jolyon Thurgood that following the then recent acquisition of EOSAT, Space Imaging had become the world's largest, most comprehensive supplier of Earth imagery and derived geographic information products and services. He went on to describe the concept of the globally distributed, digital *CARTERRA* archive which is a central repository of multi-resolution imagery and image-derived products which is readily accessible over the internet. A similar concept is also being employed by EarthWatch in their *Digital Globe* image-product database. Notwithstanding some modest initiatives at that time to provide web-based delivery of aerial orthoimage products, this new business model of multiple-sale, off-the-shelf spatial information products, licensed to rather than sold to customers, represented a significant change to the traditional professional service marketing approach of the photogrammetric mapping industry. This aspect will be further discussed in a following section.

2. PRESENT STATUS

Regrettably, the first two attempts to deploy HRSI systems in late 1997 (*Earlybird*) and mid 1999 (Space Imaging's *Ikonos-1*) met with failure, and in many respects it could be said that the status of high-resolution Earth observation systems remains at this writing similar to the prevailing situation in both 1995 and 1997, namely that the launch of a working HRSI system is again imminent.

By the time this paper is presented, the *Ikonos-2* satellite from Space Imaging may well be successfully deployed in orbit. Regardless, it is reasonable to assume that by the end of the year 2000, all three of the 1 m HRSI developers will have launched their satellites. In any consideration of the prospects for success of these commercial ventures, the adopted business models of the image providers and the degree to which current projections for a global market in HRSI-derived products are realised will likely have significantly more bearing than technological issues on the final outcome. (1996 estimates of a $US 1.4 billion remote sensing industry by the turn of the century now appear rather optimistic!). To quote from a recent presentation by a senior representative from Earthwatch: "We are dealing with spatial resolution we have never obtained before, with customers we have never met before, for reasons we never had before". Is it any wonder, therefore, that there is currently only a vague idea of the ultimate size of the market for HRSI.

From the photogrammetric community's standpoint, the success of HRSI will be measured in terms of how well it competes, in all respects, with alternative data sources for spatial information, be they aerial photography (digital or analogue) for orthoimage production and feature extraction, or interferometric SAR and airborne laser scanning for DTM extraction, for example. Not only will the mapping industry be shopping around for the best satellite image product at the best price, they will also be seeking out the most productive technology to acquire their spatial information data. Whether current projected pricing for 1 m image-derived products can sustain this competitive pressure is yet to be determined. For example, at an outback mining site in Australia, a price of $US30-50 per square kilometer for a digital orthoimage of 1 m resolution sounds quite attractive, whereas the same price for orthoimage generation over a large city area is not terribly competitive.

In the period between the commencement of active promotion of commercial HRSI (around 1995) and the present time, there has been ample opportunity to speculate upon how the photogrammetric mapping community will need to evolve to best exploit the technological and commercial benefits offered by HRSI. Accompanying these considerations are changing circumstances which present real or potential challenges to both the mapping sector and the commercial satellite image

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providers. These are issues such as licensing rights to data; royalty obligations; the provision of camera model data; the vagaries of government restrictions, both domestic and international; the role of government as the primary HRSI customer; and the question of maintenance of standards when quality oversight by government is potentially absent. The purpose of this paper is to discuss these issues, which generally receive limited exposure in accounts of the current status of HRSI.

3. CHALLENGING ISSUES

3.1. Licenses and Royalties

In any discussion of the business relationship between the HRSI-product providers and the spatial information industry, it is important to highlight a fundamental distinction in the business models prevailing in each case. The traditional mapping industry has long prided itself on being, to a large degree, a specialised professional service. Its basic sales approach has been to obtain customised projects where ownership of the rights to the products generated is sold to the customer. From the point of view of the mapping company, this likely represents a one-time sale, in spite of there being potentially many downstream users of the mapping product. Rarely, for example, would aerial photography specifically flown for one customer be used or on-sold to another.

This approach is in stark contrast to the 'software sales' model that characterises the business strategy of HRSI companies. Under this approach, ownership to the basic imagery or image-derived product is retained by the image provider, and a license to use the product is acquired by the customer. With that license comes restrictions on subsequent distribution, resale and reproduction. Such a model is arguably more suited to multiple sales of the same off-the-shelf image-derived product (e.g. archived orthoimage or DTM). This licensing scheme is not new to the commercial remote sensing sector, but what does seem to be both new and causing angst in the mapping community are limitations on permitted value-adding and distribution activities. It is not that such activities are denied to the mapping contractor, it is more a matter of there being different pricing for value-adders, along with the requirement to pay royalties.

At the recent 1999 Annual Conference of the American Society of Photogrammetry and Remote Sensing in Portland, Oregon, this proved in more than one panel discussion to be a contentious issue. An example taken from Space Imaging's Catalogue of Products and Services can be used to illustrate why royalty payments on non-traceable, value-added HRSI-derived products might become a 'complicated' matter. The example is given of a "Value Added Reseller" who wishes to extract street centerlines from 1 m panchromatic imagery and then place the centerlines on their website to sell. A special agreement (read extra-license fee) is required to resell such a derived product. This seems straightforward, so far.

Now, consider the more likely scenario where the customer already has centerline data for sale on his/her website and wishes to utilise the powerful new technology of HRSI to update that data. How extensive is the update? This will not be known until the image is acquired. It may turn out that only a modest amount of new road network information is extracted; the rest remains unchanged. Given the metadata structure for the centerline information, it may not be clear just which data was image-derived and which was existing. Moreover, what if the original dataset emanated from a government agency which had stipulated that while commercialisation of their road data was permissible, there was an onus on the reseller to feed back any updates, free of charge, to the agency providing the data.

The aim in presenting such a scenario is not to question the licensing model in any way, but more to highlight the fact that negotiation of royalties for the on-selling of non-traceable image-derived products is potentially a difficult issue, which may well be in need of simplification over time. There seems to be a consensus in the HRSI industry that image providers should at first concentrate primarily on a small range of high-volume, basic image products rather than myriad, low-volume

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specialised offerings. The notion, therefore, of myriad case-by-case licensing agreements covering hundreds of specialised products offered by hundreds of companies is difficult to contemplate.

3.2. The Camera Model

The photogrammetric mapping community has, by its very name, a singular interest in the 'metric' quality of the 3D object space information extracted from image data. Central to the provision of high metric quality is the issue of sensor calibration and provision of calibration data, which the HRSI companies refer to as 'the camera model'. The question of whether there should be full, partial or non release of the camera model to the mapping community, to support the generation of value-added products of high metric quality, is certainly one that attracts much attention, as well as a range of answers.

Within the industry there is a universal desire to gain access to the essential information that will allow optimal metric exploitation – and optimal commercial exploitation - of HRSI. Hence, the chagrin when HRSI companies announce that the camera model will not be released. From the perspective of the imagery providers there may well be the view, on the other hand, that by providing this essential sensor calibration to the reseller market, they give up the very proprietary information that allows them a competitive edge in the high-end of the metric product market. There is a balancing act required here: on the one hand the mapping community who buy basic image products for value-adding needs to be given the means to do just that (e.g. straightforward stereo restitution), whereas on the other the HRSI companies who are also competing in the value-added market need to retain the competitive edge that their substantial capital investment should have given them. One company, OrbImage, has taken the position that rather than withhold the camera model they intend to 'cooperate more closely' with the value-add reseller sector, which implies more open access to sensor calibration data. Moreover, it is EarthWatch's policy to release the camera model as a commitment to the provision of 'open systems'.

Emerging onto the scene, as a possible interim solution, are the much talked about 'rational functions'. These polynomial-based, empirical models, which generally comprise terms to third order, express image coordinates as a direct function of object space coordinates, in much the same way as do collinearity equations (as modified for satellite line scanner imagery). However, whereas the latter specifically require exterior orientation parameters and a camera model, the former contain coefficients that defy geometric interpretation, although these coefficients can be developed in a straightforward manner using a knowledge of the existing exterior orientation. It is said that apart from the benefits rational functions bring to handling geographic coordinates in real time, one reason they became popular for military imaging satellites was that the satellite orbital elements and also the exterior orientation could not be derived directly from the rational function coefficients.

The rational function model has gone some way to placating the concerns of the mapping sector since this approach offers a means to metrically exploit HRSI without recourse to the camera model. Moreover, developers of digital photogrammetric workstations can now provide necessary restitution software, also without the need for a comprehensive sensor calibration.

The costs of a polynomial restitution approach are well known in terms of the provision of extra ground control and tie points in a multi-image scene. These inconveniences may be avoided, however, if the rational functions are obtained from the HRSI vendor along with the imagery, and not derived by the customer. The metric impact of this empirical modelling approach is yet to be fully quantified, though it is unlikely that the majority of end users will be too concerned about questions of minor accuracy differences. The remote sensing and photogrammetric communities have, after all, long been achieving accuracies with polynomial models for satellite line scanner imagery that can reach the one pixel level in favourable situations.

It is not inconceivable that shortly after HRSI becomes available, photogrammetic research groups will achieve a self-calibration of the imaging sensors and publish their own camera models. In the

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meantime, however, all parties in the mapping industry, the image providers, the photogrammetric system developers and companies performing stereo-based value adding, will be able to proceed with product generation. The niche, very high-accuracy end of the market will likely remain the domain of these with access to the camera model, namely the HRSI companies themselves.

3.3. Government Restrictions

At the very time this paper is being written (June, 1999), it has been reported that OrbImage will appeal US government-imposed conditions on its license to sell hyperspectral imagery from the *OrbView-4* satellite. OrbImage has found itself in the unenviable position of providing a capability specifically sought by the military, and intended also for commercial exploitation, which is now being restricted. Whereas 8 m hyperspectral imagery was seen to have significant application in natural resource exploration and management, it is apparently also quite an effective means to see through camouflage. Pentagon officials are thus insisting that commercial users of this imagery will have a 24 m limit on spatial resolution.
How many more restrictions from both the US and other national governments might we encounter once the full capability of 1 m satellite imagery is realised? How many more examples such as the restriction of imagery of Israeli territory to 2 m resolution might we expect? In some countries in South East Asia it is forbidden to capture aerial imagery without special licensing. Will this be extended to high-resolution satellite imagery? In other countries it is forbidden to sell independently produced (read non-government authorised) earth imagery. What might be the impact of importing such imagery from an overseas supplier? There are many such questions which need to be answered as the HRSI market gains momentum. Although licensing by the US government for the private HRSI industry came with very few restrictions, there can be no assurance that issues such as national security concerns and international competitiveness will not induce authorities to impose future commercial restrictions. One can only hope that HRSI becomes as ubiquitous as GPS, such that the political clout of the commercial satellite imagery market becomes a force to be reckoned with, as has the commercial GPS sector.

3.4. Government's Involvement as a Customer

Although there has been considerable marketing hype attached to the prospects of HRSI in commercial markets such as agriculture, real estate, the news media and the insurance industry, there is a growing consensus that, at the outset at least, the major customers will be governments. The timely delivery of highly automated image-derived products is an appealing prospect for military mapping and defence intelligence. Moreover, the systematic coverage of large areas (e.g. 4000 km^2 in 40 seconds from *Quickbird* and two 10 000 km^2 areas in a single 10 minute pass of *Ikonos*) should be very beneficial for topographic mapping and database revision/updating projects.
Such mapping programs in many countries remain the domain of federal and state governments. A number of potentially contentious issues arise out of this situation, commencing, for example, with the royalty question referred to earlier. How might the distribution of government spatial information be impacted upon by royalty obligations based on the inclusion of commercial image products in what has traditionally been viewed as a public asset? What if governments were to make available to the public image-derived products which directly overlap with data contained in global archives such as *Carterra* or the *Digital Globe*? How will pricing be handled in an arena where these public assets have traditionally been made available to users at heavily subsidies costs? Such assets can be viewed as components of essential state infrastructure, and yet commercial realities demand proper pricing by the HRSI providers?

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The impact of substantial involvement by governments becomes even more uncertain in countries where government HRSI systems are being developed, such as in India and France. The pricing models for image derived products from such systems could well undermine the viability of purely commercial providers. There will of course be strong incentives to price as competitively as possible. One can almost foresee a situation where the US government considers punitive tariffs on foreign HRSI companies to counter "dumping" of 'below cost' image products into the US market. But given the fact that the information products in question might come either over the internet or on a CD-ROM, how would the volume of such trade be quantified?

A third matter here concerns the traditional provision by government of spatial information products at nominal cost for 'public-good' programs. Whereas sound public policy might dictate the dissemination of certain image-based information to environmental groups, land-care groups, researchers and indeed the general public, one can appreciate that the commercial HRSI sector will be less amenable to this prospect than is government. Should the commercial providers be compelled to make such information available at greatly subsidised cost, and if so how much information and to whom? Or, should government be expected to acquire the data/information at commercial rates and then continue to dispense it at very low cost, as previously?

Current political pressures for 'smaller government' do not augur well for the latter option, yet few would argue about the merits of public-good programs. It is unfortunately likely that public-good initiatives, be they via university research or NGO activities, will not receive the increased levels of funding needed to enable acquisition of HRSI products at full commercial rates. One can be optimistic here and acknowledge that in their roles as both good corporate citizens and businesses wishing to expand their markets, HRSI companies will have a tangible interest in supporting research and public-good initiatives. But, the extent to which this occurs, and whether such initiatives are largely confined to the US, is an important unresolved issue.

3.5. Other Issues

As has been reported, again by Larry Fritz (Fritz, 1999), there are other important issues that will arise as the commercial HRSI industry evolves. These include the possible devolution of the development and maintenance of standards and specifications from government to the geo-information industry. This is no trivial matter. There have been a number of recent publications extolling the benefits of HRSI for cadastral mapping. Yet in many countries the integrity of the cadastre is guaranteed by government, which would suggest that there should be a powerful incentive in such instances for government to remain involved.

Other issues involve the possible need for legislation to regulate unlawful use of HRSI-derived information; and technological questions related to how the user community will accommodate the vast amount and diversity of satellite image products, and who will subsidise the necessary growth and education of this industry sector.

4. CONCLUDING REMARKS

In the compiling of this paper an attempt has been made to touch upon some of the less well canvassed issues that accompany a discussion of the status of HRSI. It is apparent that in most cases these issues have not been resolved as yet since they impact on how HRSI-derived products are created, distributed, managed, regulated and ultimately used. Since, at this writing, we are still to witness a successful deployment in orbit of a 1 m resolution commercial remote sensing satellite, it is not too surprising that these issues have received less priority than the development of the necessary technology to bring HRSI to fruition. While none of the issues raised present intractable problems, some are 'thorny', and will no doubt take time to resolve to the full satisfaction of the HRSI providers, the value-add community, end-users and governments.

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As an important participant in the value-add sector, the photogrammetric mapping industry has a lot to gain from the commercial opportunities offered by HRSI. Yet in order to optimise the potential of 1 m resolution remote sensing satellite systems in the geospatial information sector there will need to be a mutually beneficial working relationship between the mapping industry and the satellite imaging companies. It behoves both to dedicate some attention and effort to resolving outstanding issues which could impede the progress of this new technology. It is clear that the '500 lb gorilla' model is unsustainable, especially internationally, and it is also clear that the professional service oriented photogrammetric community is going to have to change in order to live with the new and substantial competition emanating from the HRSI providers, who see themselves more as full service spatial information companies.

One significant benefit enjoyed by the present photogrammetric industry is its extensive experience in image-derived mapping products and its established customer base. With the global coverage of HRSI and unrestricted access to imagery, there is nothing to preclude active participation in the international market by companies which have hitherto maintained only a regional or national focus. Moreover, HRSI will provide a unique opportunity for mapping/GIS companies to both increase and enhance their business without significant capital investment.

As someone who has a tangible professional interest in commercial high-resolution satellite imaging, the author is very confident about both the viability of HRSI and the opportunities this technology offers for the photogrammetric mapping and GIS industries. He is also confident that, over time, a mutually beneficial working relationship will evolve between the HRSI providers and the value-add community. Such a relationship is, after all, a necessity rather than a luxury if, indeed, "digital remote sensing from space has matured and the opportunities it offers to address activities on Earth may provide impacts upon society which are potentially awesome" (Fritz, 1999).

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