Impact of Spot 6 and 7 Data in the Constitution and Update of Spatial Data Infrastructures over Africa

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Abstract. New capabilities provided by *Spot 6 and 7* for large spatial data infrastructures projects are illustrated with exemples from Spot 6 early operational life. The improvement in tasking large coverage is demonstrated through a complete coverage of Mali (1.240 000 km²) in four months. The improvement in feature extraction capabilities is demonstrated through tests over Senegal and Mali. And the absolute horizontal accuracy allows the use of *Spot 6* data for the most complex SDI requirements in Africa.

Keywords: *Spot 6*, Data Continuity, Spatial Data Infrastructure, Africa

1. Introduction

Over the past ten years, Spot 5 has been the cornerstone of large Spatial Data Infrastructures (SDI) all over the world. Its main assets were the very large coverage offered by its 60 km swath and a spatial resolution fitted for 1:50 000 to 1:100 000 projects. Our team has been in charge of choosing imagery for defense and oil & gas cartographic projects over large parts of Africa and Asia and *Spot 5* proved to be very effective for those requirements. *Spot 6 and 7* launches allow maintaining and extending those efforts through the next decade.

This paper presents our first results performed from *Spot 6* data coverages tasked for case studies for SDI requirements in Mali, Senegal and Gabon for Defense, Oil & Gas and Mining operational requirements.

After a presentation of the necessary balance between continuity and innovation in modern SDI requirements, we introduce the capabilities offered by *Spot 6 and 7* and present real life examples gathered in the very early days of *Spot 6* operational life both for creation and update cycles of large spatial data infrastructures.

2. A Stakeholder View – Balancing Continuity and Innovation

2.1. An important asset for socio economic development

An efficient Spatial Data Infrastructure (SDI) is a key for economic and sustainable development in developing and emerging countries. For all parties involved (policy makers, military, private sector, foreign investors, civilian society, international organizations, ...), there are strong expectations for products and services (classical and digital) up to date, reliable, and tailored to operational requirements. And this is true at all levels (local, national, sub-regional or continental).

For years, those SDI's have been created and maintained by western cartographic agencies, the only ones able to have a sustainable effort for decades. Locally, economic operators would create limited SDI for their project (Oil & Gas, Mining, Road & Infrastructure development...) but those data would generally not be shared on the long term with local actors. Most of development decisions still have to rely on ageing cartographic series. In a lot of countries, 1960's or 1970's data are still the only available base layers. The decision for new editions is more often linked to the sales of the previous edition than to any willingness to update the data.

When this willingness exists, obsolescence issues are fairly simple to manage, being linked either to the landscape evolution (new infrastructures, urban growth, change in land cover / land use...), or to available new tools (new sources, new production techniques...). That is why we saw a lot of partial updates based on satellite imagery in the 1980's, just because of source availability. Products being created by legitimate professionals, consensus was easy on obsolescence criterions.

More recently, new projects have flourished, with public and private SDI financed by international projects, both in the civilian and in the military field (The military Multinational Geospatial Coproduction Program is a good exemple), or by economic operators. Those projects are generally based on modern but expensive sources (aerial or satellite coverages + ground work). Hence those infrastructures have a fairly high cost.

Classical criterions for obsolescence evaluation still apply, but stakeholders face new criterions:

- First landscape evolution has accelerated. In Africa, cartographers are faced with urban growth at speeds rarely seen in Europe (De Meulder B., 2010). But those evolutions happen also in rural areas. For instance, asphalted road network in Chad has grown from 300 to 2000 km in less than 4 years (Rousselin T., 2011).
- New sources and techniques also appear faster and this makes difficult an efficient and stable updating program over 10 to 20 years. This technological effervescence impacts all aspects: data collection, data management and production, data and services distribution (online or offline). In developing countries, it may have a catalytic impact but sometimes it just freezes any effort or financing (Rousselin T., 2010).

But for stakeholders, new "menaces" arise:

- Constant evolution of operational requirements makes it very hard to establish and maintain long term product lines and services. Users focus over a certain area is changing with time and the need to derive products or services from the basic infrastructure is also evolving.
- But the most stressful and distracting aspect is linked with the sudden weight of new actors, from the private sector (like Google or Microsoft) and from the collaborative fields (Easley D., 2010) (Shirky C., 2008) (Howe J., 2008). How to legitimate the slow and costly building of "your" SDI when Google updates its imagery three times faster and federates thousands of free workers to draw vector objects and fill attributes? How to keep the credibility of "your" project when any geotagged picture on Flickr or Panoramio gives instantly "the" proof that this dirt track is in fact now a two lane black top road? How to face criticism on your products based on the fact that as soon as you deliver them, users can check them against crowd sourced photos, videos, GPS tracks, or Open Street Maps productions…?

2.2. Evolving requirements

Due to those requirements, Stakeholders of large cartographic projects obviously need continuity to maintain their SDI performance on the long run. The development of a modern SDI is a lengthy process which requires multiple investments: in capital expenses but also in the building of a complex production ecosystem (with image providers & producers) and in the development of a shared knowledge basis. These investments being done, the capability to offer data continuity for change detection or for updating is a strong requirement.

In terms of imagery sources, it means that new satellites and sensors must maintain continuity on key characteristics not only on sensor and imagery specifications but also on format, interoperability and the protection of the whole value added chain already operational based on the previous sensor.

2.3. Fitted for 2010's SDI

If continuity as aforementioned is a key factor, nevertheless there is a need for evolving requirements. Ten years ago, geospatial expectations in developing countries where linked to the production of base maps. Today large areas are available at 1:50 000. Hence, there is a shift in expectations from base maps to value added geospatial products, performing operational functions, associating geospatial and other data, to provide user with HSEC risks analysis (Health, Security, Environment, human Communities …). To conduct those analyses at a country or regional level, complete, detailed and regular coverage is mandatory.

And stakeholder must satisfy ever-changing customers, comply with new rules (like Inspire in Europe), adjust to new technological frameworks (for instance the compatibility with the new Galileo positioning systems) or user experiences (like the Geoweb).

Imagery providers have to fulfill simultaneously continuity and innovation expectations.

3. Spot 6 new capabilities

3.1. Continuity and innovation on the satellites, sensors and ground segments

Built by Astrium, a member of EADS, the *Spot 6* high-resolution Earth Observation satellite was successfully launched on September 9th 2012 from India. *Spot 6* keeps the 60-km swath that made the success of the SPOT series, while delivering products with a resolution down to 1.5m. Its twin *Spot 7* is scheduled for launch in January 2014. Together with *Pléiades 1A* and *Pléiades 1B*, they will form a complete operating constellation, ensuring continuity of optical Earth Observation services up to 2024. The constellation will allow a twice-daily revisit capability with an ingenious range of resolutions.

A much higher responsiveness of the systems -from acquisition ordering to image delivery- has been made possible thanks to the update of the mission plan every 4 hours, among other improvements, such as the capacity to integrate urgent acquisition requests up to 2 hours before the effective collection. The collection capacity is also increased with a daily coverage of 6 million km² (*Spot 6 and 7* together). Weather forecasts are updated 4 times per day and automatically integrated into the mission planning; this proves very efficient to increase the so-called "success rate", ie the ratio of cloud-free imagery collected by the satellites.

In addition, *Spot 6 and 7* agility allows targeting of any point within a 1500km-wide across track corridor (45° viewing angle). This also opens the way to various acquisition scenarios matching different applications, e.g. the strip mapping mode to collect wide areas in a single pass. When nominal acquisition scheme for the *Spot 6 and 7* satellites is north to south, they may also be tasked to follow linear targets such as communication lines, rivers or coastlines. The *Spot 6 and 7* system also incorporates native tasking modes for stereo or tristereo acquisition, for 3D extraction purposes.

Pansharpened and orthorectified images are standard. The orthorectification process relies on Astrium Services' elevation layer (Reference3D). The registration of *Spot 6 and 7* images on Reference3D enables a perfect overlay for applications implying multi-source or multi-date data in a GIS environment, facilitating change detection processing, map revision, or complex projects.

To summarize its strengths, *Spot 6 and 7* maintain key characteristics (both in terms of satellite performances and service) which guarantee the continuity of a High Resolution (HR) offer fitted for medium scale cartographic projects. But new distribution services like streaming are suited to a new way to monitor change, assess the SDI obsolescence and give stakeholder objective elements to decide on the need for update (where, when and how?).

3.2. A new Multisensor constellation

Spot 6 and 7 is part in a satellite constellation which also includes *Pleiades 1A* and *1B*. The phased orbit and synergies (same operator and provider, coherent tasking system) are essential for data access and collection optimization. For multiscale projects optimizing (technically and financially) HR and VHR data, there is a clear benefit from an integrated solution, using the same geometric reference and provided in the same format.

4. Tasking capabilities in complex situations

4.1. Features

In order to optimize the quality of future ortho products and subsequent feature extraction, it is mandatory to avoid, right from the image collection phase, any disturbing effect linked with annual, seasonal, angular heterogeneities. For instance an efficient data collection process over the Niger River needs to adjust to the seasonal flooding of surrounding areas, progressively moving downstream. To achieve these requirements, imagery has to be collected in the shortest and most homogenous time period.

Spot 6 and 7 ground and space segments were designed for improving the performances of the previous SPOT missions. They propose multiple improvements which potentially overcome some traditional collection and production bottlenecks.

The new agility of the two satellites allows a much easier collection, especially over large surfaces. Furthermore, this coverage capacity is reinforced by an efficient tasking system, based upon six tasking plans per day and finer weather forecast. This increases both reactivity and quality of acquisitions in terms of cloud coverage.

And in areas with important annual cloud cover, climatology optimization and use of fine weather forecasts should improve imaging plans almost to the last minutes and hence, significantly improve the number of good and useful images.

The high agility of both satellites provides impressive collection capabilities particularly suitable to serve those cartographic needs. *Spot 6 and 7* standard collection modes are illustrated below:

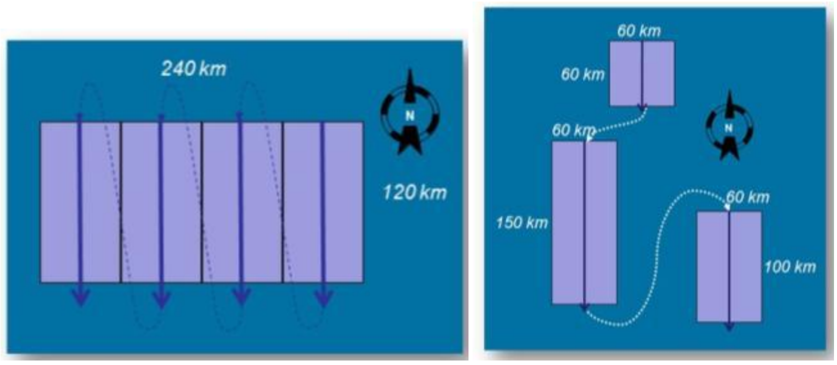

Figure 1: Multi strip and single strip mode

The above standard modes are a key to achieve homogenous coverage of large areas within a short period of time.

4.2. Large monoscopic coverage: the Mali example

On October 24th 2012, shortly after its launch, *Spot 6* was tasked to image the full territory of Mali, i.e. 1,240,000 km². The coverage was performed with no particular priority in November and December 2012. Priority was increased in January and on March 12th 2013. The whole cloud free collection (**Figure 2**) was achieved after only 20 weeks.

Figure 3 illustrates the importance of *Spot 6* agility to achieve cloud-free coverage of large areas.

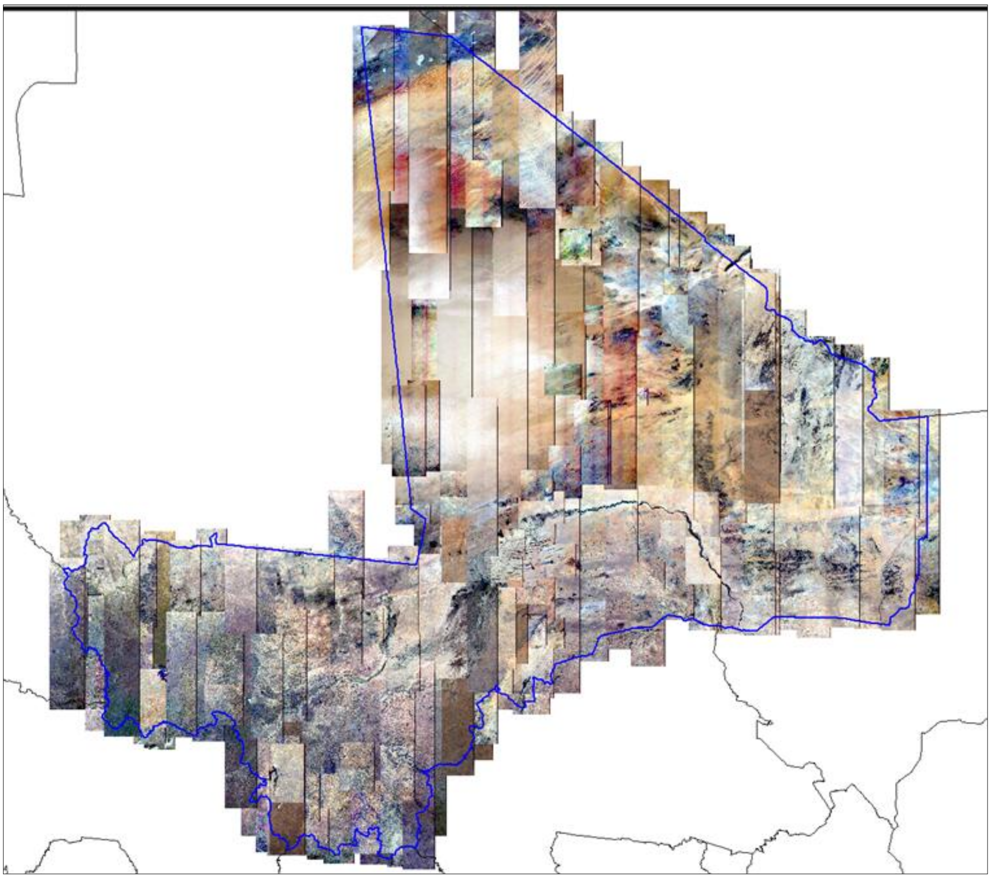

Figure 2: *Spot-6* monoscopic cloud-free coverage of Mali (Oct-March 2012/13)

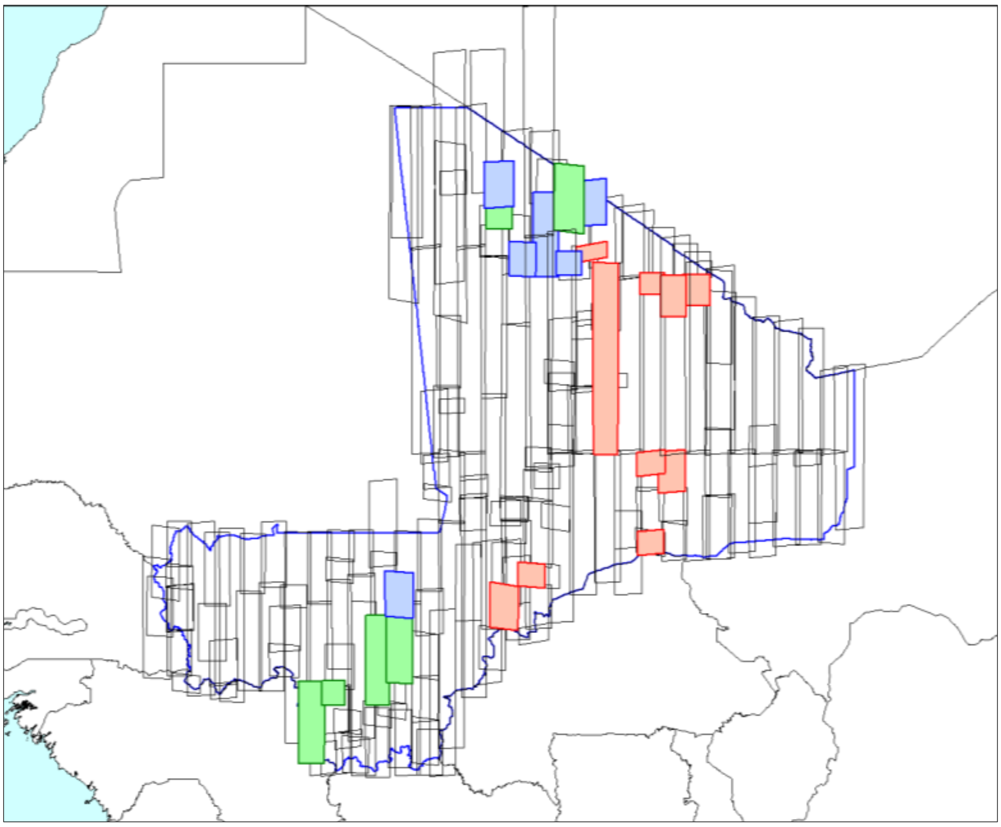

Figure 3: Single-day collections over Mali:
Dec 12 (blue) & 14 (green), Feb 18 (pink)

4.3. Coverage over areas with heavy cloud cover: the Gabon example

Intertropical areas like the Gulf of Guinea have always been very difficult for optical satellites coverage. A first attempt over Gabon even if the coverage is far from complete, gives promising results.

After four months, *Spot 6* has already acquired 40% of the surface acquired by *Spot 5* in seven years (with the same 10% cloud cover constraint) including the two most coveted targets (Libreville and Port Gentil).

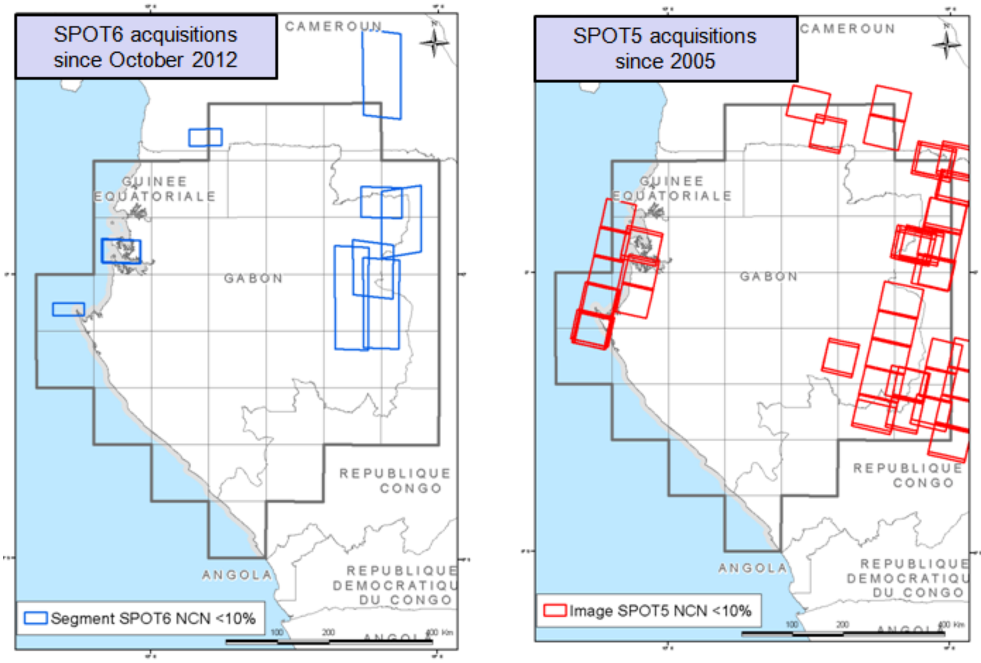

Figure 4: Comparison between 4 months of *Spot 6* acquisitions and 7 years of *Spot 5* acquisitions

5. Feature extraction: *Spot 6* – the missing link?

In terms of resolution, the new 1.5-metre range meets the evolving needs of both state-owned mapping programs and commercial users, allowing better understanding of terrain features and easing the detection capability. The spatial resolution improvement has a decisive impact for the analysis of small to medium cities where *Spot 5* resolution was inadequate and Very High Resolution (VHR) data too expensive.

5.1. *Spot 5* vs. *Spot 6* comparison at 2.5 m resolution

Tests were performed over Senegal and Mali where a Spot 5 coverage was available and had been used as a source for the production of a 1/50 000 scale military Spatial Data Infrastructure. Tests areas were in coastal areas (Grande Côte from Dakar to Saint Louis ; Petite Côte from Mbour to Joal) and hilly gold mining areas (Sabodala district in Senegal and Loulo district in Mali).

Spot 6 imagery resampled at 2.50m resolution allows one to identify many more objects than its predecessor for an identical resolution. First there is an undeniable ease of interpretation that is not present on *Spot 5* images. Shapes and contrasts are improved as one can see on the airport area in **Figure 5**.

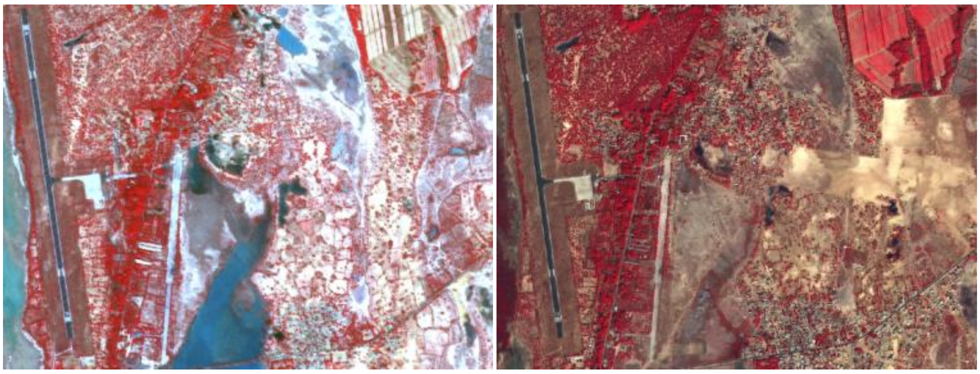

Figure 5: Saint-Louis airport area (Senegal) with *Spot 5* (left) and *Spot 6* (right)

Object detection in **Figure 6** is more obvious, anthropogenic features are better delineated on soil or hard coating. Buildings that could not even be detected on *Spot 5* images are now correctly identified on *Spot 6* images.

Figure 6: Anthropogenic features detection with *Spot 5* (left) and *Spot 6* (right)

Spot 6 resolution image outclasses *Spot 5* and allows one to yearn for an improved use of 2.5m resolution images.

Yet this comparison is tightly linked to the difference in Ground Sampling Distances between *Spot 5* and *Spot 6*.

5.2. Spot 6 vs. VHR comparison

Large spatial data infrastructures rely heavily on multiresolution sources. But very often the economic dimension leads to compromises. If Very High Resolution imagery will be considered mandatory for high profile targets, lower priority targets will have sometimes to settle with the sources selected for surrounding landscapes. Small cities are a good exemple. They are too small to justify the specific tasking of a VHR image but contain too much remarkable buildings for a *Spot 5* HRG image.

Figure 7 : Details of a mining processing plant on *Spot 6* 1.5m resolution (top) and Digital Globe *QuickBird* 0,7m (bottom)

Spot 6 imagery resampled at 1.50m show certainly some weaknesses concerning the discrimination of particular features within intricated industrial sites, like processing plants where VHR imagery contribution stays important (**Figure 7**). But *Spot 6* imagery allows to detect and interpret the overall layout of the mining facility.

And Spot-6 resolution is largely sufficient to detect and identify small objects very well. **Figure 8** puts in evidence the identification of a mosque within a small village.

Figure 8 : Building identification comparison between Spot 6 (left) and VHR Digital Globe imagery

As one can see on **Figure 8** the shapes of buildings are truthful and well delineated. Moreover, in light density areas, smaller objects than buildings can be identified thanks to their shadow (**Figure 9**).

Spot 5 imagery proved to be fitted for extraction at 1:50 000 to 1:25 000 scale. Based on our preliminary african tests, Spot 6 looks promising for 1.25 000 to 1:15 000 scale. It could even prove useful at higher scales if the goal is updating and not creation of the SDI from scratches.

Figure 9 : Water tower identification on a *Spot 6* image (left) and a VHR Digital Globe image (right)

5.3. Performance under steep incidence angles

With high agility come big constraints, but the quality of the extraction is not spoiled by high angles even in hilly areas.

Figure 10 is an illustration of Spot6 capacity in a vegetated area with relief and an angle of incidence around 30°.

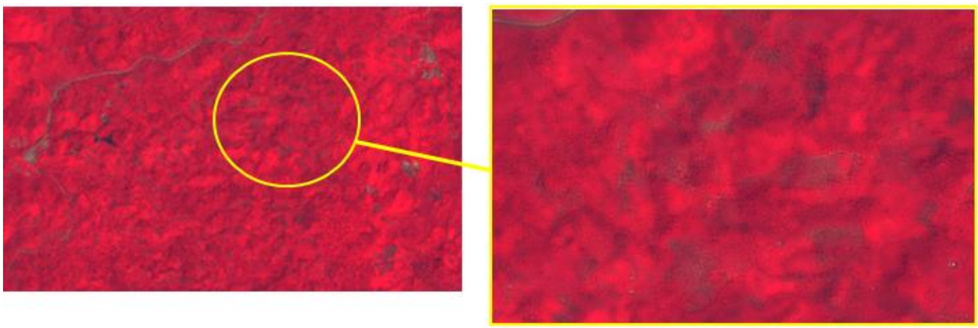

Figure 10 : Spot 6 tracks and village extraction in a complicated area

Spot-6 capabilities are such that one can hardly see the difference between a subvertical image and an angular image in a dense urban environment (exemple over Mbour, Senegal in **Figure 11**).

Figure 11 : Angle of incidence impact on Spot-6 1,5 m images in a dense urban area (subvertical image on the left and high angle of incidence image on the right)

6. Geometric Accuracy

First results of *Spot 6* geometric tests are very impressive.

Rigorous Geometric Model accuracy without GCP (Spot 6 products location with on-board data only) which was specified at 50mCE90@30° has been measured at 20mCE90@30°. Rigorous Geometric Model accuracy reset on (perfect) GCP and DEM was specified at 1 pixelCE90. It was measured on the french Aix Sainte Victoire test site against 199 horizontal GCPs and was assessed to 1.20m CE90. Tests done over Mali (a 5 images spatiotriangulation block based on reference3D) included long segments, different incidence angles and various land covers (Niger delta, desert, arid areas, hills…). Results show RMS values under 5 meters and absolute values under 10 m (**Table 1**).

ID	NB	PCCN rel	PCCN abs	DXY MIN	DXY MAX	DXY MEAN	DXY STD	DXY RMS	BIAS
SEN_SPOT6_20130104_101256300_000	982	7,1	**9,3**	0,2	18,3	3,9	2,5	**4,6**	1,5
SEN_SPOT6_20121106_101613500_000	990	6,7	**9,0**	0,1	19,4	3,7	2,4	**4,4**	1,2
SEN_SPOT6_20121228_101645100_000	988	7,4	**9,5**	0,1	18,9	4,0	2,7	**4,8**	1,7
SEN_SPOT6_20121221_102010900_000	990	6,4	**8,8**	0,2	19,5	3,5	2,3	**4,2**	0,8
SEN_SPOT6_20121221_101907900_000	981	6,9	**9,2**	0,0	19,8	3,7	2,6	**4,5**	1,6

Table 1: Assessment of the geometric absolute accuracy of a block of five *Spot 6* images over Mali

7. Conclusion

With only four months of *Spot 6* imagery collection and two months of data exploitation, results have to be preliminary.

But they look very promising. Collection capabilities already proved to be beyond expectations over significant areas (Complete coverages of Mali and Senegal used for those tests) and weather and collection planning optimization gave first results over difficult areas like Gabon.

Vector extraction tests are very positive on Spot-6 technical ability to replace Spot-5, with an obvious improvement on buildings and a very low impact of the incidence angle.

Spot-6 cannot replace VHR resolution imagery on intricated targets but could be sufficient on less complex or secondary features.

Geometric results are also beyond specification and unique for an HR sensor.

Other features like the blue spectral band will have to be evaluated to enhance product relevance and interpretation over shorelines, and enable the production (and screen display) of really true colors.

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