NEW POTENTIAL AND APPLICATIONS OF ADS

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ABSTRACT

Joint development work by DLR and LH Systems has produced a new camera concept called Airborne Digital Sensor (ADS) which is using forward-, nadir- and backward-looking linear arrays on the focal plane. The camera system provides panchromatic and stereo information using three CCD lines and up to five more lines for multispectral imagery including two NIR channels. Each CCD array for panchromatic measurements has 24000 elements, resulting in a field of view of 64 degrees (across track FOV) by using a focal length of 62.5 mm. The sensitivity covers a dynamic range of 12 bit with a recording interval time of 1.2 ms per line. The performance of the camera allows a 3-dimensional and multispectral image with a ground sample distance of 25 cm for an area of 300 square miles within a flight time shorter than one hour.

1 INTRODUCTION

Increasing world-wide industrialization and population growth make remote sensing very important for investigating and monitoring the ecological system of the Earth. Today almost every country makes use of airborne and satellite remote sensing products for mapping earth resources and land use/land cover and for monitoring such changing phenomena as cultivation, forestry, spring growth and meteorological and hydrological events. We are rapidly moving into an era where remote sensing, combined with geographic information systems technologies and applications-oriented modeling, will produce information about current and future resource potentials. Besides scientific interest their use by government agencies, private companies and individuals is virtually routine. Figure 1 shows a summary of nine important remote sensing areas of application as a function of their needs for spatial and spectral resolution, and Figure 2 illustrates spatial resolutions and revisit times for eight different remote sensing tasks. The very large variation in spatial, spectral and temporal characteristics of objects we wish to measure and record is mostly covered by spaceborne and airborne measurements which are complementary. The preference for airborne observations is when it comes to regional, high spatial resolution (10 cm to a few meters), the necessity of measuring daily or even more frequently, and regions with regular cloud coverage.

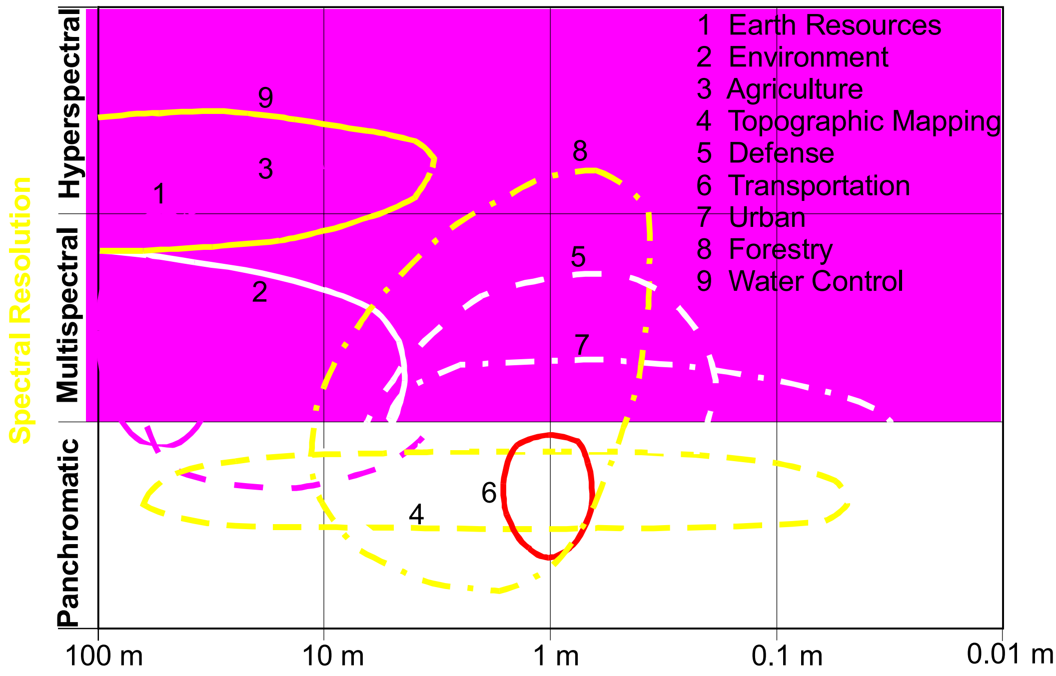
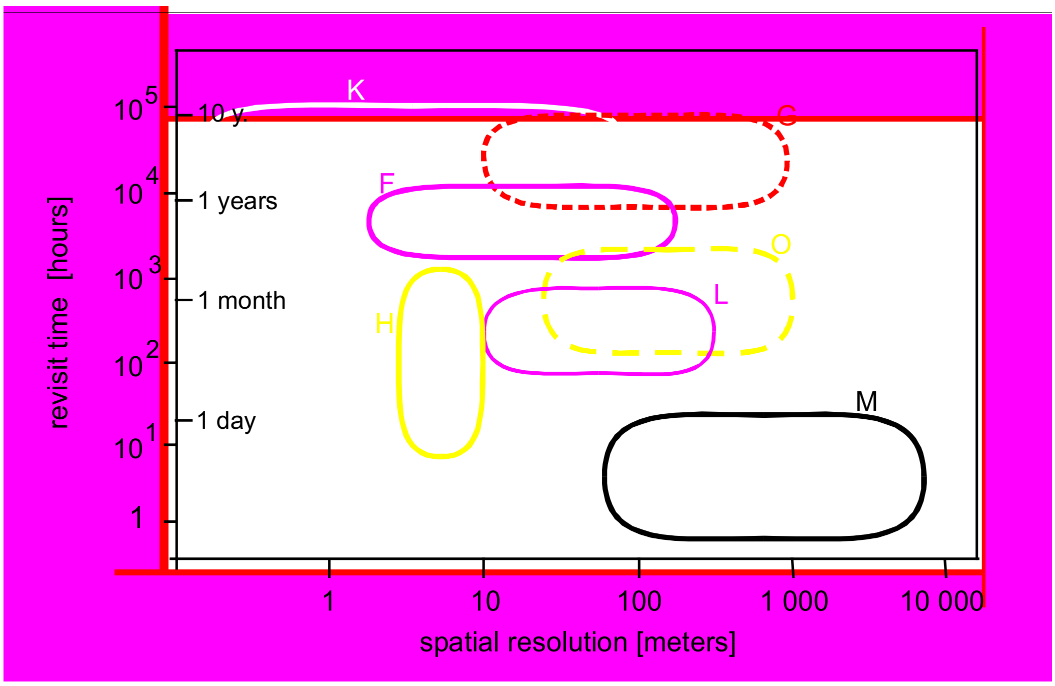


Figure 1: Remote sensing



H - hydrology, M - meteorology, O - oceanography, marine pollution
F - forestry, - cartography, G - geology, - natural hazards,
L - agriculture

Figure 2: Spatial resolution and revisit time for different remote sensing tasks

2 AIRBORNE DIGITAL CAMERA REQUIREMENTS

Up to now film aerial cameras with traditional techniques have normally been used for high precision photogrammetric mapping followed by digital scanning for image processing including stereo visualization. By using different films these cameras can also be used for remote sensing to some extent. Figure 3 illustrates the typical workflow for the film-based process. Extensive research and industrial developments within the last 10 years in CCD technology, computer performance and data storage capacity offer the opportunity to replace the film aerial camera for many applications and also to improve the quality of the photogrammetric and remote sensing products.

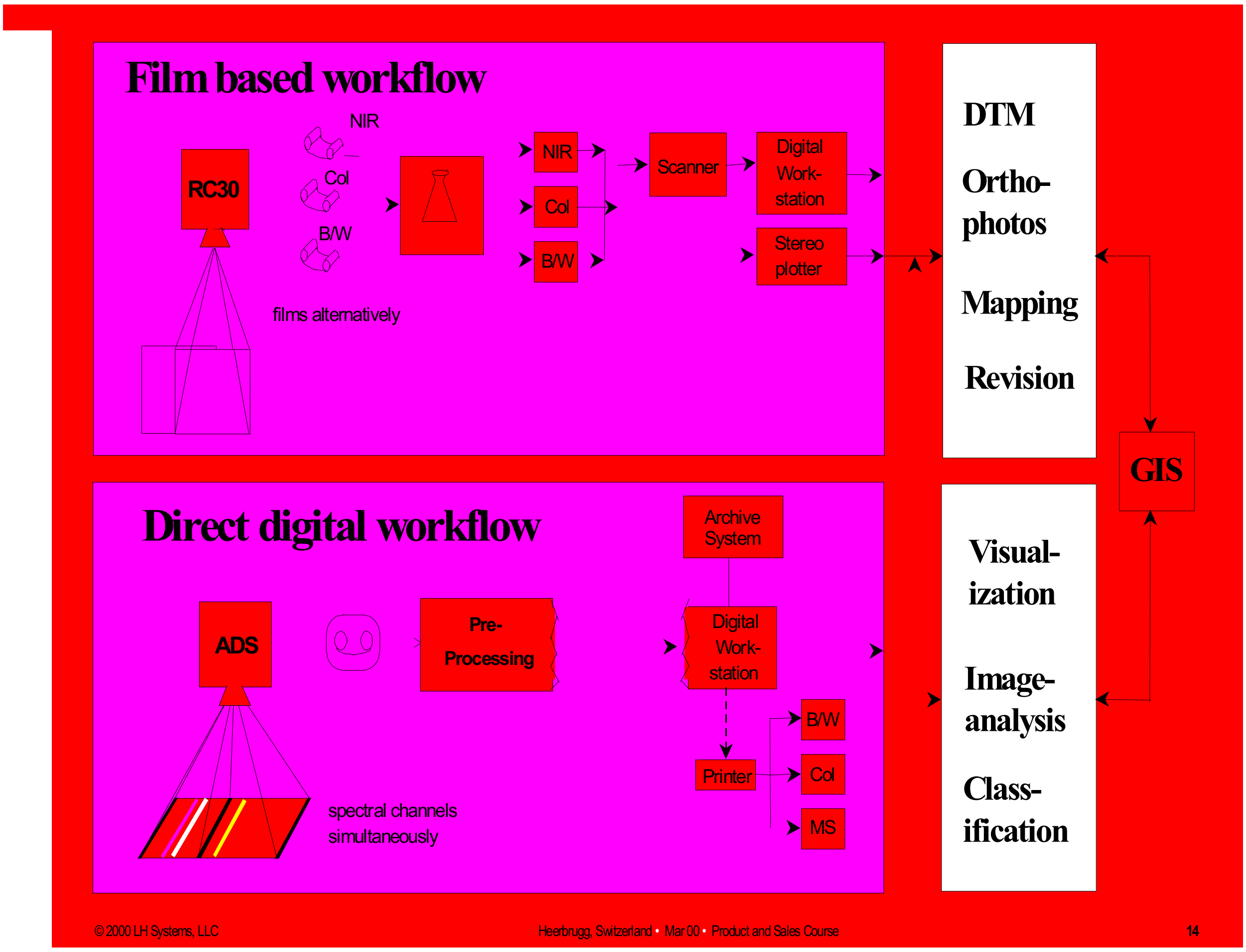


Figure 3: Film based and direct digital workflow

To have any chance of an effective impact in a market place governed for decades by high performance film cameras, an airborne digital sensor (ADS) must ideally fulfill all the following requirements.

- Provide a large field of view along and across the flight direction to reduce flight time and cost
- The detector system should have a high sensitivity and a linear response characteristic with high dynamic range
- The size of the CCD elements must enable high spatial resolution
- For multispectral imagery several wavelength channels with suitable bandwidths, including NIR, must be available
- The sensor system should operate with short exposure time and high repetition rates
- Provide a radiometric calibration procedure to guarantee stability of the sensor sensitivity
- Provide stereo capability in flight with one camera only
- Near real time availability of the data on the ground.

3 ADS CAMERA CHARACTERISTICS

LH Systems, like its predecessor Leica, is an expert in the development and worldwide use of film aerial cameras (www.lhs). In view of the new digital technologies, the company decided a few years ago to develop an airborne digital sensor jointly with the German Aerospace Center (DLR) in Berlin, which has research activities and a long tradition in the development of digital cameras including stereo and multispectral capability for different space missions (Albertz96, Sandau96, www.dlr). The development has been completed, test flights have been done, first with an engineering and later on with a prototype model, and the production version is scheduled for the market in mid-2000.
The first step in the development was the decision to use the three line scanner approach instead of CCD matrix arrays. The reasons for that are manifold: larger swath width, multispectral performance with well-defined wavelength bands for each CCD line, and cost. But using a line scanner has also a disadvantage given by the fact that aircraft tilts cause the linear arrays to image widely varying strips of terrain which has to be corrected as shown in Figure 4.
The ADS camera has eight parallel sensor lines, three panchromatic lines (forward, nadir, backward), three lines used as Red, Green and Blue channels and two different NIR channels. They are all placed on one focal plane of a single lens system with a focal length of 62.5 mm. The panchromatic lines with different angles (Sandau2000) provide the stereo capability. Each panchromatic line consists of two linear arrays, each with 12000 pixels but staggered by a 0.5 pixel shift. The color sensor lines RGB, also with 12000 pixels, are optically superimposed during the flight. This is accomplished with dichroitic mirrors, which divide the incoming light beam into three color components followed by a narrow filter band.

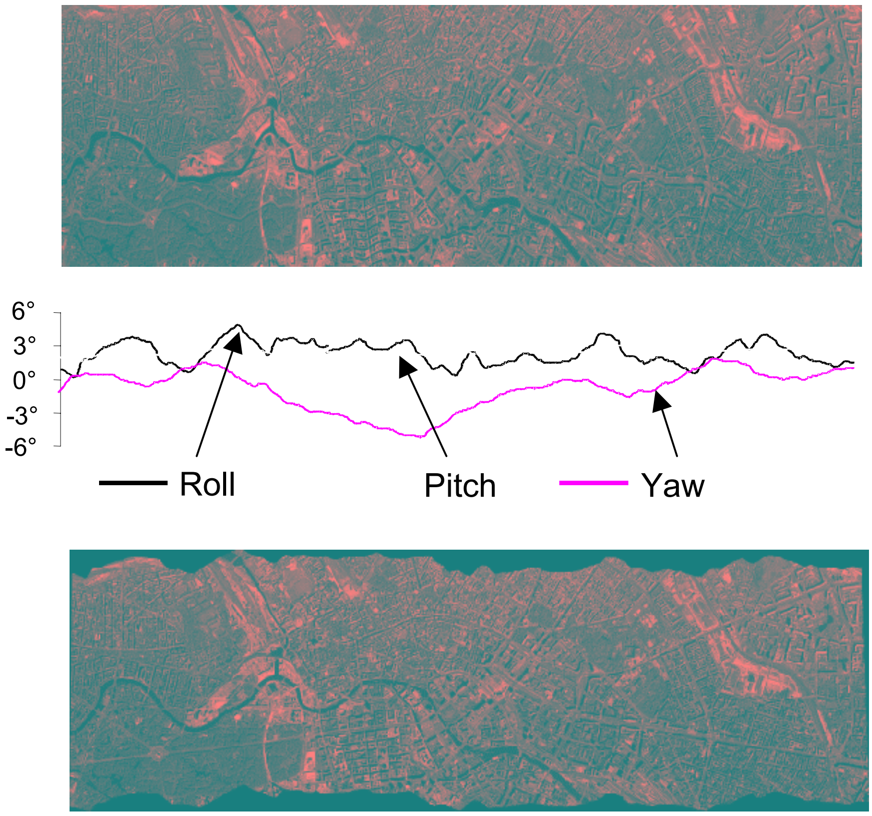


Figure 4: Imagery over Berlin with a 3 line scanner

The well-defined separation of the different wavelength bands is important to make ADS, combined with an appropriate post processing, a powerful tool for remote sensing. The lines of the NIR channels – one of them is optional - have 12000 pixels each and are slightly offset to the RGB triplet. The dynamic range of the CCD is 12 bit with a radiometric resolution of 8 bit. This is very much higher than the best film material available. The read out frequency of each line can be adapted to the flight velocity and altitude of the aircraft in the range from 200 to 800 Hz. The selection of the spectral channels is a compromise, taking into account the most frequent tasks which have to be fulfilled depending on the surface reflectance and minimizing the atmospheric distortion. A focal length of 62.5 mm in combination with a staggered 2 x 12000 pixel CCD array results in a field of view across the track of 64 degrees. Assuming a flight altitude

of 3000 m, the ground sample distance is 16 cm with a total swath width of 3,75 km. Because of the high data rate during flight the airborne camera system is available with an in-flight storage capacity of between 200 and 500 GByte. The camera has temperature stabilization and compensation for the CCD lines. In addition special care has been taken to avoid condensation on critical components.
Figure 3 illustrates schematically the direct digital workflow of ADS in comparison to the film based workflow.

4 LINE SCANNER IMAGE PROCESSING

The push-broom type of this geometric CCD line configuration simultaneously acquires the multispectral and panchromatic images by a high frequency sampling of the different sensor lines. As already mentioned, the raw images contain distortions due to roll, pitch and yaw movements of the aircraft. Figure 4 shows this effect and its correction on a flight over Berlin. The top image is raw. The bottom image has been rectified and looks like a conventional aerial photo. Note the correspondence between the edges of the rectified image and the roll of the aircraft. Tilts have been compensated by adjusting each individual CCD line image for the attitude of the aircraft, using Global Positioning System (GPS) and Inertial Measurement Unit (IMU) data. These have been collected during the flight and been written together, with the acquired image data, into a Mass Memory System (MMS). A synchronized clock times the events of IMU, GPS and sensor line recording in order to achieve a high quality imagery, in particular in the case of stereo images (Tempelmann2000). After the flight a ground processing system archives all the data, followed by post processing to convert the data into different levels of image products (image rectification, Digital Terrain Model (DTM), orthophoto, mosaic production, etc.).

5 APPLICATION POTENTIAL

Provided that the new digital airborne camera system fulfills all the listed requirements, it will certainly revolutionize photogrammetry and remote sensing in quality and fast availability of the data. In principle the image data can be transferred from the aircraft directly to the user’s ground-/workstation. In particular the simultaneous imagery with many spectral bands, including two NIR channels definitely has a strong advantage over the film camera. But for the highest spatial resolution with ground pixel sizes of 50 mm and below the film camera will still be the instrument of choice.
The very large swath width combined with a high spatial resolution and multispectral channels makes ADS very cost and time effective which can be demonstrated by the following examples:

- Greater San Diego, with an area of about 500 km^2, could be 3-dimensionally mapped with a resolution of 25 cm within a one hour flight time producing a panchromatic data volume of about 120 Gbyte.
- To map the Ohio river with the same ground resolution and a swath width of 5 km it would take about 5 hours with a data volume of about 500 Gbyte, which still fits the storage capacity.

For several remote sensing tasks with multispectral applications the large field of view (FOV) perpendicular to the flight direction requires a correction of the data with respect to the viewing angles. A Bi-directional Reflectance Distribution Function (BRDF) catalogue for many typical land/vegetation surfaces will be available (Demircan2000).
Using the new generation digital airborne camera aerosense companies will not only increase their annual acquired data volume by orders of magnitude but also the simultaneous acquired multichannel data will provide all kinds of applications illustrated in Figure 1 and 2. The combination of high resolution stereo images with 5 different wavelength channels in the VIS to NIR range having mathematically well known filter curves will certainly offer new airborne remote sensing applications. Because of the absolute calibration for the sensor system atmospheric corrections are possible which enable measurements of time-varying parameters even when these are small. In addition data fusion with satellite data will be very effective and will therefore improve the quality of the data products for the customers.
Figure 5 demonstrates that many of the applications in forestry, urban areas, water control, agriculture and vegetation can be covered in terms of swath width and spatial resolution on the ground because of the optical and geometrical parameters of ADS. Figure 6 shows the ground sample distance as a function of flight altitude for the staggered 2 x 12000 CCD array. The ADS performance is characterized by the focal length of 62.5 mm.

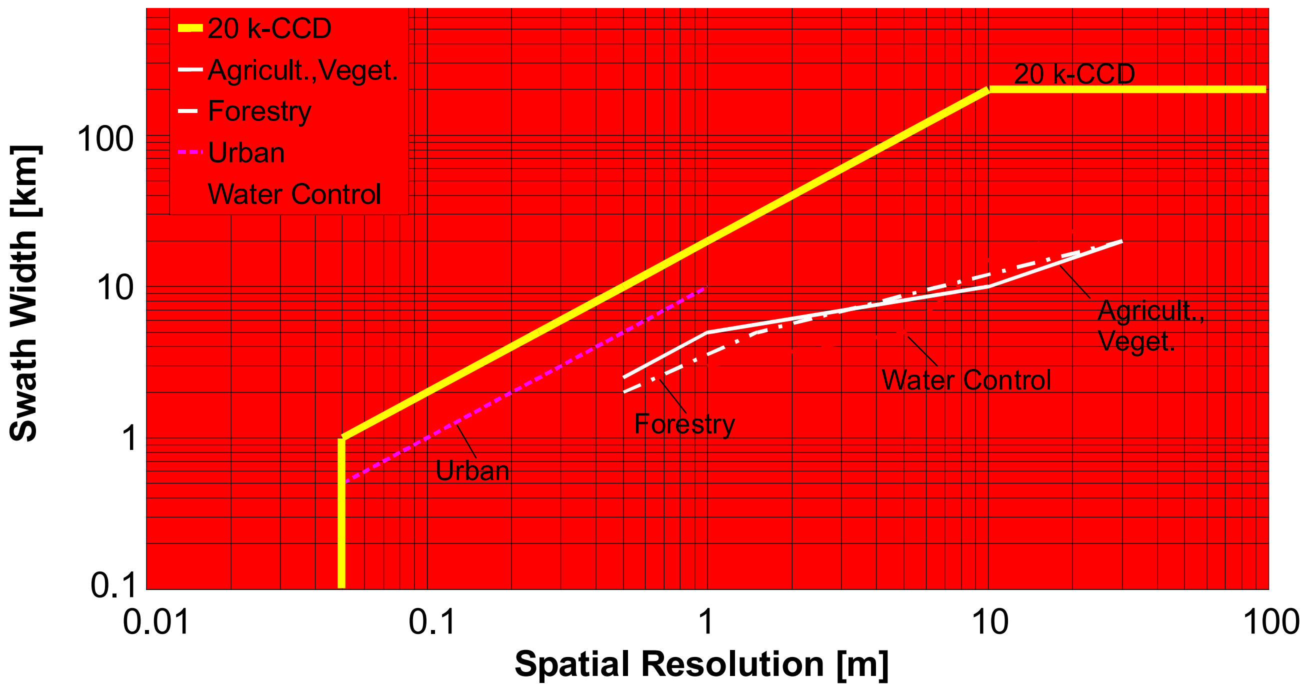


Figure 5: Potential of a 20 k CCD line for different applications

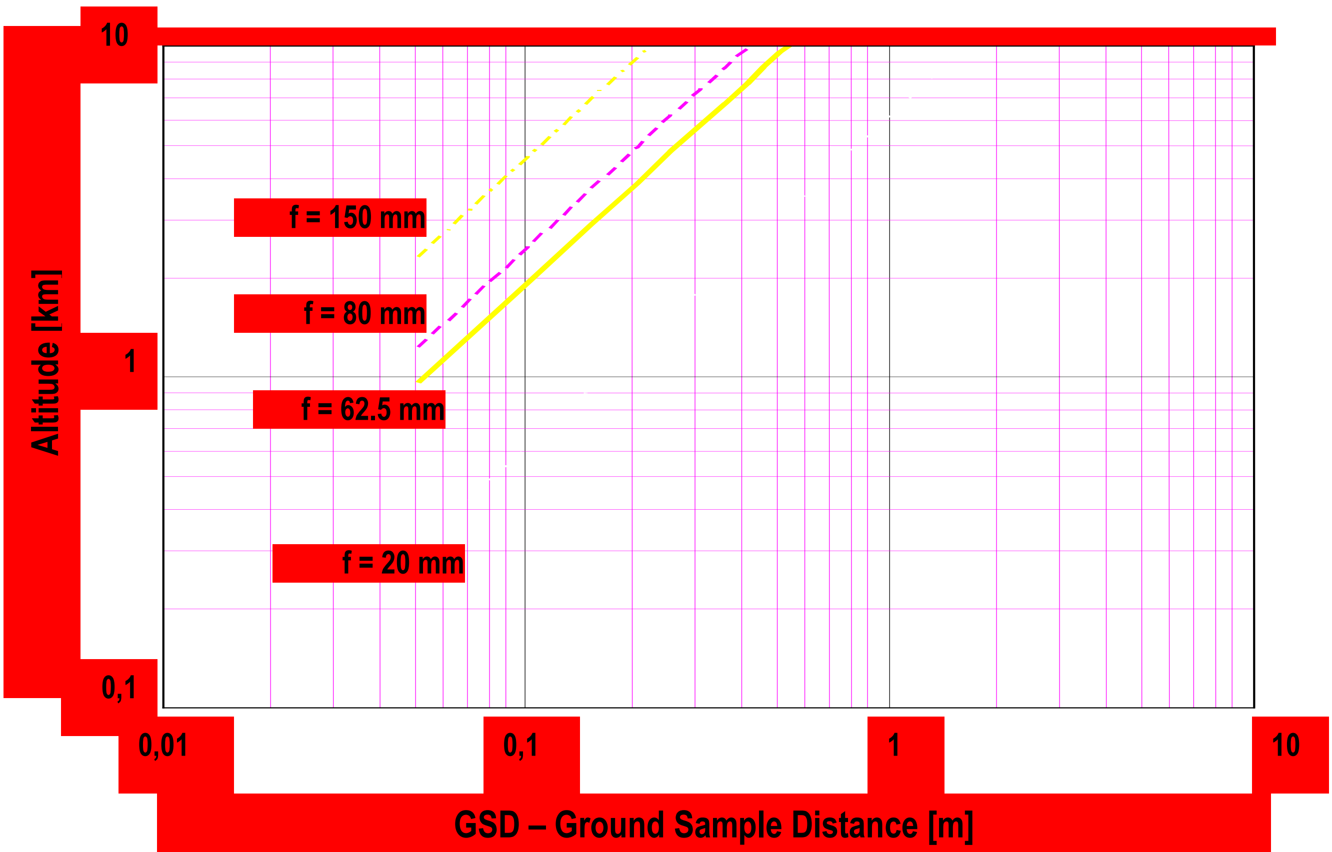


Figure 6: Ground sample distance as a function of flight altitude combined with different optical lengths. The curve for ADS is f = 62.5 mm.

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