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5.5 MLA IMAGING SYSTEMS*

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MLA is the abbreviation for "Multispectral Linear Array." Within NASA, MLA has evolved to become the generic term for the sensor concept and technology associated with solid-state electronically scanned linear arrays operating in the pushbroom mode for resource observations. The overall program objective is to develop the enabling technology and instrument/mission definition phase for the application of advanced solid-state sensors for future experimental remote sensing missions. The approach being taken is to develop complementary multiyear efforts at GSFC and JPL. GSFC will concentrate upon focal plane development, instrument concept/design development, mission studies, and service requirements; JPL is concentrating on development of an imaging spectrometer technology and a Shuttle sortie mission definition.

There is a heavy emphasis on technology. The technologies that we are developing are the shortwave infrared focal plane technology, primarily mercury-cadmium-teluride, platinum-silicide, visible chips, the optics, passive radiators -- all the critical technology acquired for the implementation of an MLA system. We are also developing instrument concepts and we are doing this through a number of Phase A studies. In addition, we have support activities. Primarily we are trying to define what the requirements are from a science standpoint, and what the user requirements are, and how can we best utilize this technology. We are in the process of forming a science wo ng group. And finally, we are looking into various concepts and scenarios for missions for validation of the technology.

I want to mention the fact that besides the MLA activity there are other complementary technology efforts within NASA. There is the information adaptive system effort which is being funded by OAST. This is an effort to develop and demonstrate a breadboard for on-board signal processing MLA-type data. Specifically, this breadboard process will correct all the MLA data at the 80- to 90-megabyte range, and, in addition, generate all the geometry correction factors such that it can be resampled on the ground. The input will be the ephemeris information, the attitude control information and the thermal data from which the resampling coefficients will be calculated. There are two other activities, one called TIRA (Thermal Infrared Ray)--an effort which has been under way for about two years to develop an 8- to 12,000-micron element linear array. Finally there is another activity -- TIMS (Thermal Infrared Multispectral Scanner): this is an effort to develop a 6-channel imaging spectrometer radiometer for aircraft utilization. I might mention that the scanner will be delivered to JPL for calibration, then in the June-July time frame it will be flown on the Lear 23 Jet out of NSTL.

One of the areas that we're looking at is the possibility of some sort of a Shuttle experiment. Originally, our major interest was in some sort of a free-flyer; however, with the budget uncertainties we felt that a Shuttle-type mission might be a viable and perhaps a more realistic alternative as a precursor for a full-up experimental mission utilizing a free-flyer. What I have summarized here are some of the objectives, technology validation objectives,

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and some research objectives. It turns out that there are some problems utilizing the Shuttle for this type of research. Primarily the Shuttle does not have a very adequate pointing system. The way we think we can circumvent that is to utilize some of the pointing modules which are currently under development with NASA. One of them is the IPS, and I understand there is another pointing module which is being developed by Langley. By tilting the Shuttle about 45° and looking simultaneously at the stars, we think we can both track and get ACS information in addition to imaging on the ground.

Figure 1 provides a comparison between MLA and other Earth observation imaging systems. There are three types of techniques to generate imagery. There is the conventional scanner -- the mechanical scanner -- which scans back and forth across the ground with the spacecraft providing the motion and the scan in the in-track direction. The next level of scanner beyond this, which is strictly mechanical, is the MLA approach which is basically a linear array which provides electronic scan in the cross-track direction and the orbital motion provides the scan in the in-track direction. The key here is the fact that the pushbroom-type scanner provides simultaneous imaging in the cross-track direction -- it maintains perspective in one direction at least. If you go to a conventional framing camera like a 35-mm camera, the perspective is imaged silmultaneously in both directions -- the conventional framer. Again, NASA examples are the return beam videcon and the large format camera -- which is a film camera. What I want to summarize here are some of the pushbroom-type scanners which have been proposed and one which is actually in the hardware stage. The imaging spectrometer (Figure 2) is an approach which JPL is developing and basically is an approach wherein a slit, which corresponds to one line on the ground, is simultaneously imaged in a number of spectral bands. The slit is dispersed by the defraction grading and then reimaged onto the area ray. The advantage is that you have inherent registrations because of the fact that you are imaging only the slit and all the colors simultaneously. The other advantage is the fact that by programming the array you can arbitrarily change both the spectral path and the center frequencies.

As far as the potential advantages of the pushbroom mode of imaging with the MLA, one of the limitations of the mechanical scanner is the question of scanner linearity. With an electronic scanner like the MLA, for all intents and purposes, there is no linearity because of the fact that you are electronically scanning as opposed to mechanically scanning. One of the advantages is that you simultaneously image a line--all the pixels in one line--so that there is less than a jitter problem--because you have literally frozen the line in time and space. There is no high-frequency jitter component variation from pixel to pixel because you don't scan across the line, you simultaneously image it. The other advantage is the fixed geometry, and again that provides the true perspective in cross- ack direction and that potentially will reduce the geometric correction requirements and resampling requirements simply because of the fact that the detector geometry was fixed. The other attribute is the fact that since the scan is electronic, you can change them and program them; for example, if you have orbit anomally, you can presumably change the scan rates dynamically such that you don't have the overlap-underlap problem. Finally, inherent band-to-band registration is possible. One of the reasons why we are insisting on obtaining band-to-band registration and one of the requirements of the definition study is that band-to-band registration be less than 1/10 of a pixel. This requirement is made because, for example, if you have a 15-meter pixel and a misregistration of 1/10 of a pixel, then the best you can do as far as the error in the ratios is of the order of 2%. We are currently involved in an instrument definition study, and we have four contractors studying alternative instrument configurations. One of the things that's come out of the studies is the fact that it's going to be very, very difficult to mechanically register each of the bands to less than 1/10 of an IFOV.

What the Table 1 chart does is compare the results of mounting a Fairchild Loreors and the MLA requirements. As you can see, it looks like it's possible to get to 1/10 of an IFOV, but this is the current state of the art in terms of the physical location and mounting of chips to form a contiguous array.

I just want to quickly touch on two considerations as far as misregistration is concerned. One is the impact of the Earth's rotation (see Figure 3). If you have a displacement of the array in the focal plane -- let's say you have a six-linear array focal plane consisting of six-linear arrays with integrated filters, the physical displacement between band one and band six had to be less than 20 IFOVs. The impact of the rotation of the Earth is shown in Figure 3. There are two ways to compensate for the misregistration and that is to introduce a yaw and a pitch in the direction opposite the westerly rotation of the Earth. The other is to simply change the heading, and reduce the velocity vector associated with the rotation of the Earth. Another consideration -- and this one is equally applicable to scanners and to pushbroom arrays -- is the effect of off nadir viewing and the geometric consideration (Figure 4). As you view off nadir, obviously what happens is that you get panorama effect. You get geometric distortion, but in addition, there's a resolution and a scale change. I might add that the field of views currently being considered for the MLA is $\pm$7-1/2 to 15 degrees. It turns out that the pushbroom array, because of the fact that it simultaneously images, has an advantage. By maintaining perspective, it turns out that there's a slight geometric distortion advantage to the pushbroom over the scanner. But as you can see if you point off nadir, there's a significant change in the perspective which we call the panorama effect. That impacts the problem associated with absolute geolocation and misregistration because any attitude change will result in a considerably larger uncertainty in terms of registration and geolocation off nadir than on nadir. So to summarize some of the issues associated with off nadir viewing, any system we're going to consider in the future will have the capability to point off nadir. The reason we'd like to go to off-nadir pointing is to increase the temporal visitation. For example, with SPOT, their 26-day overpass cycle is reduced to one to five days by a $\pm 26^{\circ}$ off-nadir viewing capability. From the research standpoint, there are additional desirable features of off-nadir pointing. These include the ability to investigate atmospheric effects, adjacency effects, and calibrate the atmosphere. A key issue for the conference to be concerned with as far as off-nadir pointing is the possibility of registering a nadir scene with an off-nadir scene, given the geometric distortions and the other problems associated with off-nadir viewing.

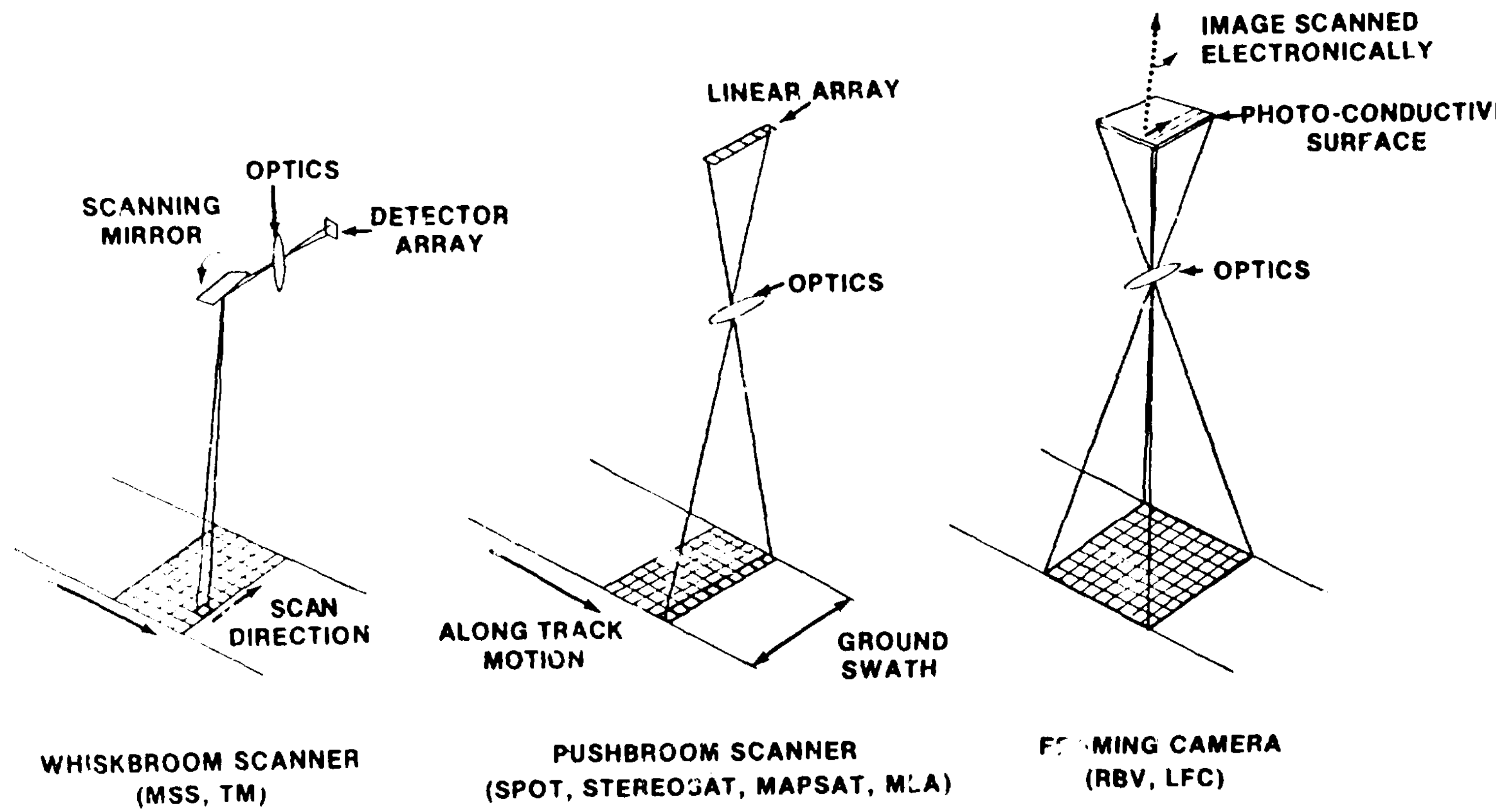
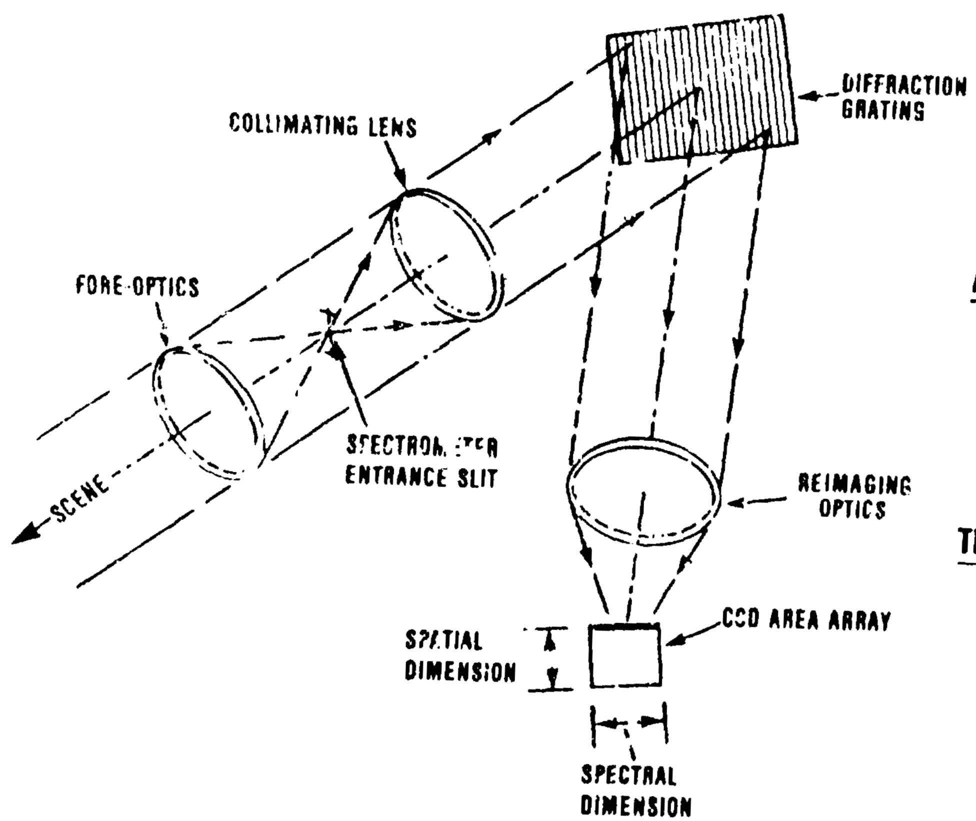


Figure 1. Comparison of Scanning Systems for Earth Observations



CONCEPT

- SPECTRAL DISPERSION OF LINE IMAGE VIA DIFFRACTION GRATING
- LINE IMAGE SCANNED IN ORTHOGONAL DIRECTION IN "PUSHBROOM" MODE BY SPACECRAFT MOTION

ADVANTAGES

- INHERENT REGISTRATION OF ALL SPECTRAL CHANNELS
- ELECTRONICALLY PROGRAMMABLE SPECTRAL AND SPATIAL RESOLUTION

TECHNOLOGY DRIVERS

- AREA ARRAY DETECTORS—SWIR
- FOCAL PLANE
- WIDE FIELD OPTICS
- ON-BOARD DATA PROCESSING
- FOCAL PLANE COOLING

Figure 2. Imaging Spectrometer

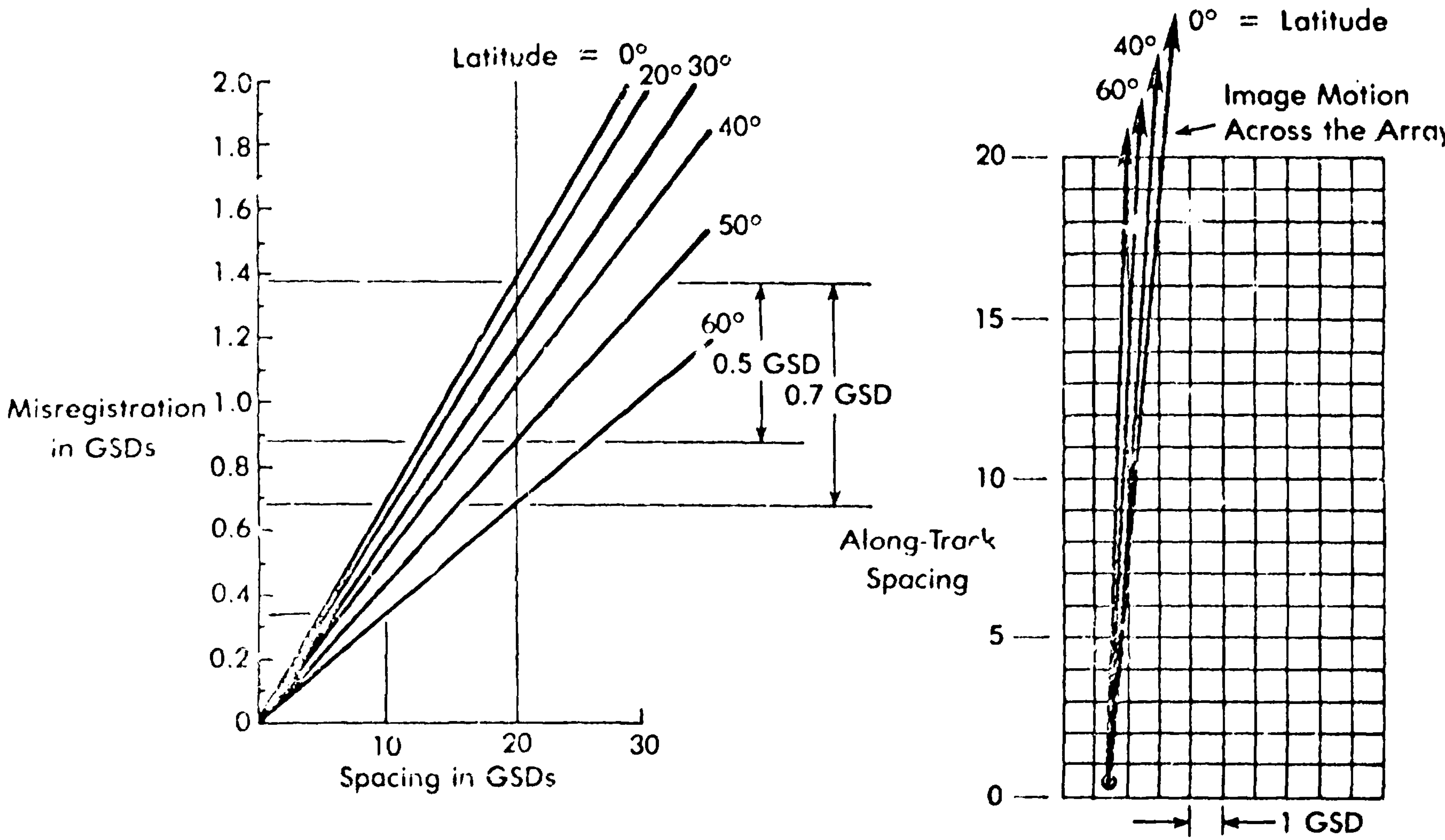
Table 1. COMPARISON OF LOREARS FOCAL PLANE MOUNTING RESULTS WITH MLA REQUIREMENTS

PARAMETER	LOREORS	MLA
LINEAR X	± 2μ (1)	± 1.3μ
ROTATION θ (ONE CHIP)	± 4μ/20.48 MM (2)	± 1.3μ/26.62 MM
STRAIGHTNESS (FOUR CHIPS)	± 8μ/82 MM (3)	± 1.3/106 MM

(1) ACTUAL "X" ALIGNMENT ACHIEVED FOR LOREORS
2 BUTTS - NO DETECTABLE ERROR
2 BUTTS - 2μ APART
1 BUTT - 4μ APART (DEEMED ADEQUATE - REMOVAL AND REALIGNMENT NOT WARRANTED

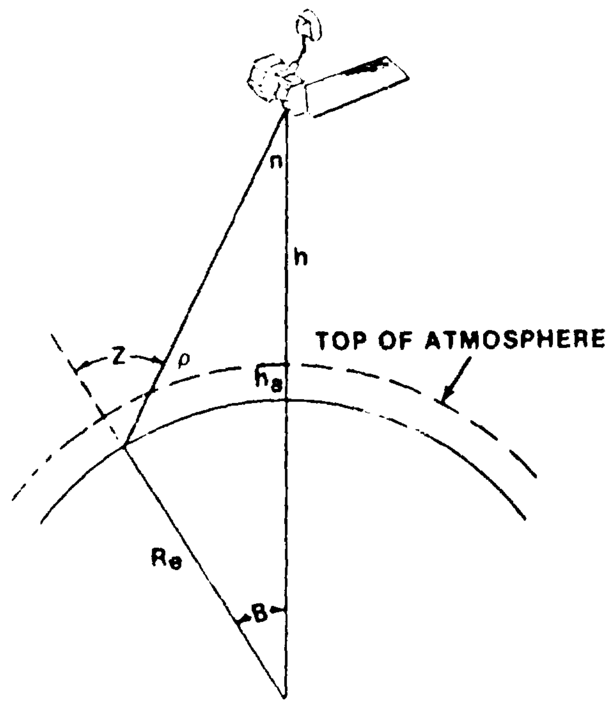
(2) WITHIN ± 3μ

(3) WITHIN ± 3μ

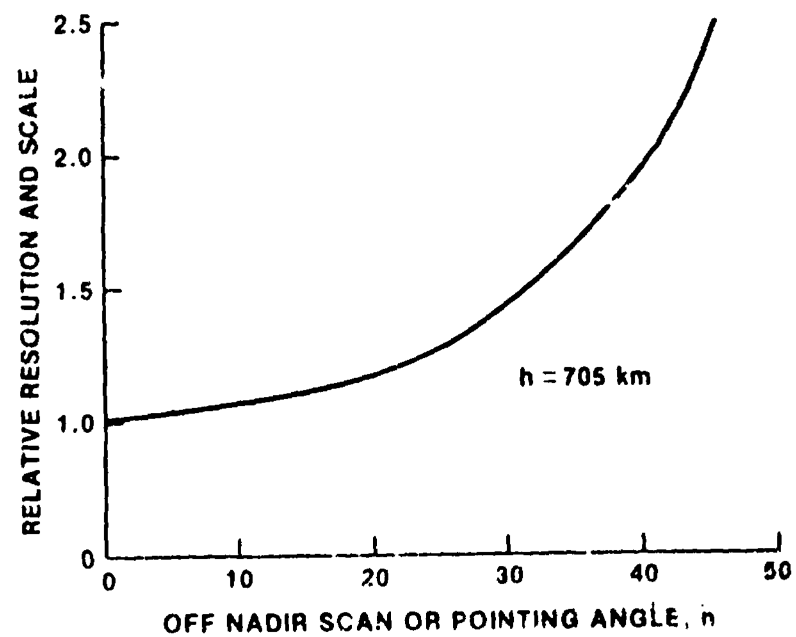


Array Normal to Ground Track Direction Error in Cross Track Direction Only $X \leq 1.4$ GSD

Figure 3. Misregistration Due to Earth Rotation



SATELLITE VIEWING GEOMETRY



- CHANGE IN RESOLUTION/SCALE
- INCREASED ATTITUDE, EPHEMERIS SENSITIVITY
- RADIOMETRIC CHANGE

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Figure 4. Off Nadir Viewing Geometric Considerations

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