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L5 and L7 Recalibration Procedure

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L5 and L7 Recalibration Procedure

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By

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PROJECT APPROVAL FORM

We certify that we have read this project and that, in our opinion, it is satisfactory in scope and quality as a project for the degree of Master of Science in Information Systems.

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ABSTRACT

The Landsat-5 (L5) satellite was launched on March 01, 1984 with thematic Mapper (TM) and has collected data for 23 years. Over this time, the detectors have aged, and its radiometric characteristics have changed little from the day it launched. The calibration procedures and parameters have also changed with time. Revised radiometric calibrations have improved the radiometric accuracy of recently processed data.

A procedure has been developed to give users the ability to recalibrate their existing Level 1 (L1) products without having to purchase and reprocess data from the U.S. Geological Survey (USGS). The accuracy of the recalibration is dependent on the knowledge of the prior calibration applied to the data. The "Work Order" file, included with standard National Land Archive Production System (NLAPS) data products, gives parameters that define the applied calibration. These are the Internal Calibrator (IC) calibration parameters or the default prelaunch calibration.

DECLARATION

I hereby certify that this project constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions or writings of another.

I declare that the project describes original work that has not previously been presented for the award of any other degree of any institution.

Signed,

Sai Kiran Undrala

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INTRODUCTION

Project Title

Landsat5 and Landsat7 satellite recalibration procedure using LUT07.

Introduction

The aim of this project is to provide the procedure for the accuracy of the data processing from the Landsat satellites which can perform the recalibration of the image processing.

On one hand this helps in the recalibration of the data such that the user get benefited with the ability to reprocessing the Level (L1) products without having to purchase reproduced data from the U.S. Geological Survey (USGS). This method will provide users with a well defined and easy way to process data in simplified manner.

Current Situation

The current processing of the existing images of Landsat satellites use TM (Thematic Mapper) which are processed using the Image loader software IDL and ENVI and the DN digital number are calibrated using the LUT03 and the images are used to calibrate for the scientific, research and more domestic and commercial uses.

Most users order the fully processed (Level 1) data products, to which both radiometric and geometric corrections have been applied to represent the radiometric response or gain of each reflective band as a function of time. The exponential model and coefficients are used to generate a day-specific band-average called Look-up Table (LUT) [3] of detector gains for use in processing. After the application of the LUT gains, the data are rescaled to a fixed radiance range represented by LMIN (radiance corresponding to "zero" DN) and LMAX (radiance corresponding to "255" DN). The thermal band gain is calculated based on the responses to the IC shutter and image data are similarly rescaled to a fixed radiance range. Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+) products are scaled to a LMIN value of "one" DN and the "zero" DN is reserved for the fill data.

Proposed system

This procedure will give user the ability to recalibrate their existing Level(L1) products without having to purchase reproduced data from the Geological survey again and the values has been developed will give The accuracy of the recalibration is dependent on the knowledge of the prior calibration applied to the data. The "Work Order file" it included with parameters that define the applied calibration. These are the Internal Calibrator (IC) calibration parameters or the default prelaunch calibration.

1.1Objective

Provide the procedure for accuracy of the data processing of Landsat satellites.

Provide the recalibration of image processing with the LUT03, LUT 07.

Provide the processing is done such that user get benefited with the ability to reprocessing the level(L1) products without having to purchase reproduced data from U. S. Geological Survey (USGS).

This method will provide users with a well defined and easy way to process data in simplified manner.

1.2 Scope

The Major focus of the project is to provide user with the calibration method to solve the problem related to Level (L1) product but also can maintain consistency and accuracy. New developed method can provide users with a defined and easy to use interface to recalibration of the images of Landsat Satellite images.

1.3 Problem Statement & Limitations

In recent years, processing the satellite images have developed with the new techniques and procedures. It incorporated with advancements in spectral, radiometric, and geometric capabilities relative to the Multispectral Scanner (MSS) flown on previous Landsat images. Onboard are two imaging sensors, the MSS and the TM. L5 TM Bands 1-5 and 7 have 16 detectors with center wavelengths of approximately 0.49, 0.56, 0.66, 0.83, 1.67, and 2.24 μm, respectively. The detectors for Bands 1-4 are located at the Primary Focal Plane (PFP), where the temperature is not controlled, but normally varies between 292 and 300 K. The detectors for Bands 5, 6, and 7 are located at the Cold Focal Plane (CFP). The Internal Calibrator (IC) is an onboard radiometric calibration system for the L5 TM. The calibrator is synchronized with the scan mirror in such a way that it brings the calibration source in view of the detectors during each scan mirror turnaround (when no scene data are being taken). The IC used by the TM (except Band 6) consists of three independent lamps. These lamps were calibrated prior to launch and provide calibration light pulses.

LITERATURE REVIEW

2. The Landsat Program

The Landsat satellite program started about 35 years ago as Earth-observing satellite missions jointly managed by NASA and the Geological Survey. Since 1972, Landsat satellites have collected information about Earth geological resources from space. This science, known as remote sensing, has matured with the Landsat Program.

Landsat satellites are capable of taking specialized digital photographs of Earth's continents and surrounding coastal regions for over three decades, which enable people to study many aspects of our planet Earth and life on the Earth and also to evaluate the dynamic changes caused by both natural reasons and human practices.

Landsat satellites can be classified into three groups.

The first group members were landsat-1,2and 3 which contained the MSS multi-spectral scanner instrument and the return beam vidicon RBV camera. L1/2 instruments acquired data through the 4 spectral band with a ground sampling interval GSI of 80- mts. L3 the last of first generation satellites, included two panchromatic RBV whose GSI was enhanced to 40-mts, its has contained additional set of detectors for thermal infrared band

Second Group members were L4/5 which contains the thematic mapper instruments as well as MSS. In this generation satellites advance remote sensing through the addition of a more sophisticated sensor, the increased transmission of data and high data is processing facility. These could measure data in 6 spectral bands with GSI of 30-mts.

Third group members were L-6/7 which includes the enhanced thematic mapper ETM and due to unfortunate failure of L6 to reach the orbit it got lot of importance in image acquiring.

Bands 1-5 and 7, all have 16 detectors with center wavelengths of approximately 0.49, 0.56, 0.66, 0.83, 1.67 and 2.24 micrometer respectively. Band 6 the thermal emissive band has 4 detectors with center wavelength around 11.5 micrometer. This discrepancy occurs because TM band designations are not in the order of their spectral definition due to design changes that took place late in the development process such that it was not feasible to rename the bands. The need to keep the spectral band within narrow ranges was recognized as being necessary to avoid the atmosphere water absorption regions, while providing better resource classification.

Band -1 blue, Band -2 green, Band –red covers the near infrared, just beyond the visible red bands. Bands -5/7 are in short wavelength infrared SWIR regions. These bands sense the Sun's energy that is reflected from the earth's surface. Band -6 responds primarily to thermal infrared energy emitted from the earth's surface.

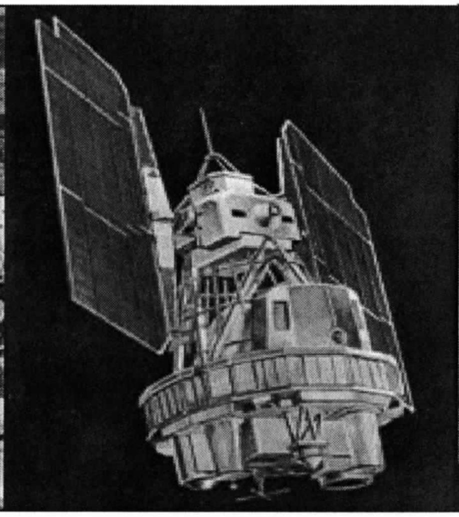
2.1 Few Facts about Landsat Satellites

Landsat 1 is the first satellite which was launched on July 23, 1972; initially at that time the satellite was known as the Earth Resources Technology Satellite (ERTS). It was the first Earth-observing satellite that was launched with the intention of studying and monitoring our planet's landmasses. In Landsat 1 was consisting of two instruments: a) a camera system built by the Radio Corporation of America (RCA) called the Return Beam Vidicon (RBV), and b) the Multispectral Scanner (MSS) built by General Electric.

Landsat 1 was operated until January 1978 acquired over 300,000 images providing repeated coverage of the Earth's land surfaces.

Landsat 2 is second in series of Landsat program which was launched on January 22, 1975. Landsat 2 carried the same sensors as its predecessor Landsat-1 with the Return Beam Vidicon (RBV) and the Multispectral Scanner (MSS). The RBV instrument was primarily used for engineering evaluation purposes while the MSS continued to systematically collect images of Earth. In February of 1982 after seven years of service, Landsat 2 was decommissioned.

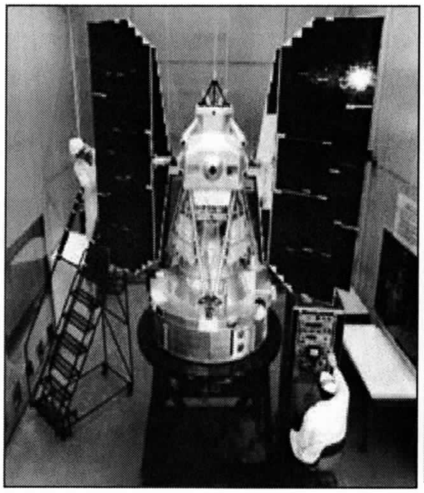
Landsat 1,1972.



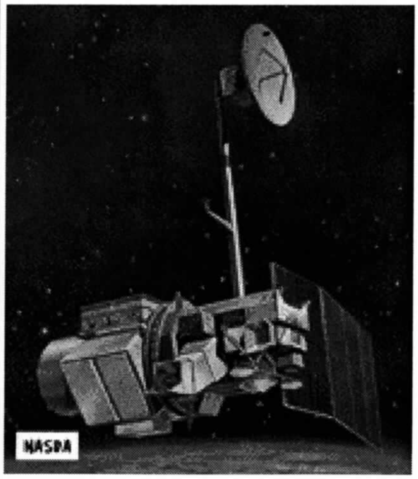
Landsat 1 satellite

Landsat 2

Landsat 3 satellite was launched on March 5. Landsat 3 carried the same sensors as its predecessor: the Return Beam Vidicon (RBV) and the Multispectral Scanner (MSS). The RBV instrument on-board Landsat 3 had an improved 30 m ground resolution and used two RCA cameras which both imaged in one broad spectral band (green to near-infrared; 0.505–0.750 μm) instead of three separate bands (green, red, infrared) like its predecessors. In March of 1983, Landsat 3 was decommissioned.



Landsat 3

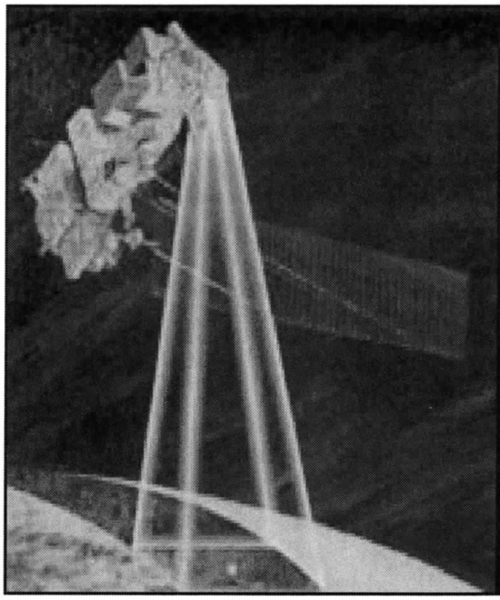


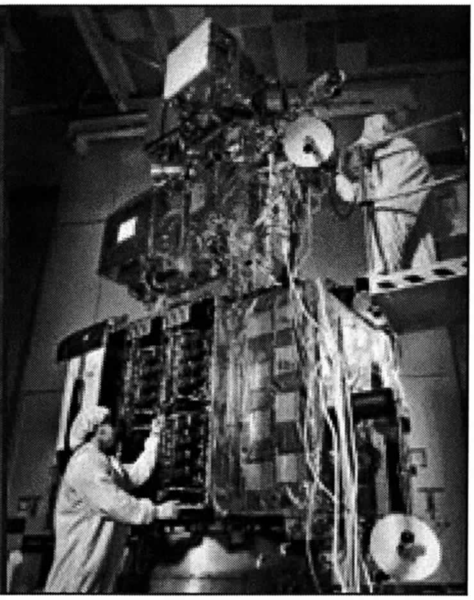
Landsat 4

The Landsat 4 and 5 satellites were launched and placed into lower orbits than the previous Landsat spacecraft and carried improved instrument suites. Landsat 5 L5 was launched on March 1, 1984 with the Thematic Mapper (TM) Earth-imaging sensor onboard.

Landsat 6 was designed and launched to continue the Landsat program. But it unfortunately failed to achieved to reach orbit during launch, and forced the continued operation of the failing Landsat 4 and 5 vehicles

Landsat 7 was successfully launched on year April 15, 1999. Enhanced Thematic Mapper Plus (ETM+) was used in landsat-7which replicates the capabilities of the highly successful Thematic Mapper instruments when compared with Landsat 4 and 5. The ETM+ includes additional features like more versatile and efficient instrument for global change studies, land cover monitoring and assessment, and large area mapping than its design forebears.





Landsat 6 **Landsat-7**

Satellite launching information :-

Satellite	Launch Date	Decommission Date	Sensors
Landsat 1	July 23, 1972	Jan. 6, 1978	MSS - RBV
Landsat 2	Jan. 22, 1975	Feb. 25, 1982	MSS - RBV
Landsat 3	Mar. 5, 1978	Mar. 31, 1983	MSS - RBV
Landsat 4	July 16, 1982	2001	MSS - TM
Landsat 5	Mar. 1, 1984	**	MSS - TM
Landsat 6	Oct. 5, 1993	***	ETM
Landsat 7	Apr. 15, 1999	**	ETM+

Table 1:- Landsat satellites information

MSS – Multi-Spectral Scanner

RBV – Return Beam Vidicon

TM – Thematic Mapper

ETM+ - Enhanced Thematic Mapper Plus

SYSTEM ANALYSIS

3. System Analysis

System Analysis is the first and most important step in the process of the development of a project. It gives the fore most idea about the needs of the end users.

It consists of the functionally dependent equipments and components working together to reach the goal along with process of all possible situations keeping in the mind like boundaries of the system and reports.

System requirements analysis and feasibility analysis are performed at this stage to find out is it worth implementing the project.

System requirements:-

1) **Hardware**

Windows 2000, Windows 2003 Server

1 GB RAM

100 GB Hard Drive

2) **Software**

IDL

ENVI

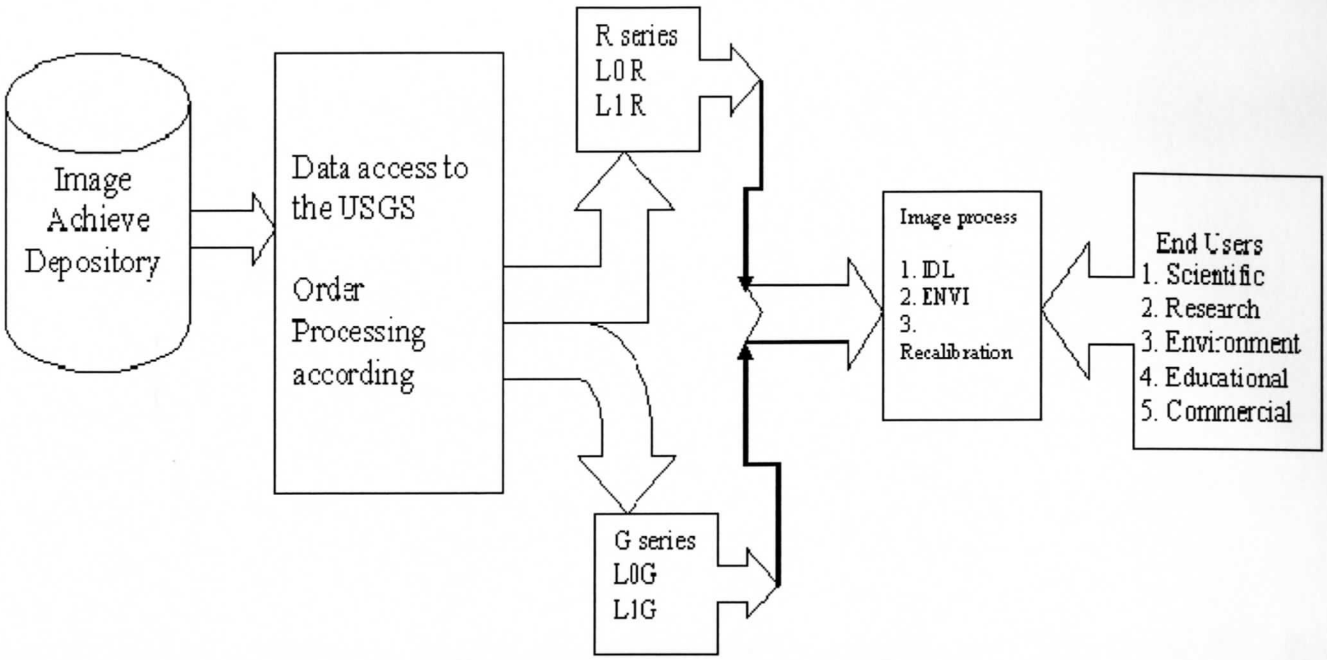
FTP for the image down loading

Humming bird exceed

UNIX for the image validation

Visual Studio .NET

Windows XP Professional, Windows 2000 Professional



Flow (Work Flow)

3.1 Functional requirements.

3.1.1 Management Requirements

1. Authentication

The system should be restricted to specific users, which have their own unique purpose of the using the data. Unauthorized users should not get an access to the data.

2. Inventory

The system should be capable of checking the inventory and record data on selling the image data. A clear demarcation between all sales of existing images like to

a).To the purpose of research,

b).To scientific calculation,

c).Environmental issues and

d).For educational at school level.

3. Tracking orders

Efficient way of retrieving the order status should be possible with the system.

4. Record generation

The system should be capable of generating image work orders in order to track the records of the images.

3.1.2 Consistency

It is necessary for every user to ensure that the data which provided is accurate.

3.1.3 Concurrency

Simultaneous transaction should be avoided for the data consistency and integrity.

3.2 Performance Requirements

3.2.1. Security

The system will be able to support user by means of the facilities in data base systems to back up. It is liable to process the operational aspects to pull the data from the work order through the programs.

3.2.2. Validation

Validation of the data is performed to the scheduled level by the ENVI to ensure conformity between requirements. It will be done by series of different tests. These tests will be carried out according to a verification and validation test plan which contains specific test cases to ensure that all the requirements are satisfied. To validate we can do through the manual calculation on the micro soft excel with the functions.

SYSTEM DESIGN

4. Design

4.1 Existing System

The existing image processing with TM (Thematic Mapper) incorporates an Internal Calibrator (IC) with lamps for the reflective bands with a blackbody source for the thermal band, and a temperature monitored shutter for all the bands. The IC is located behind the primary instrument telescope is synchronized with the scan mirror in such a way that the detectors view the calibration sources during each scan mirror turnaround.

Most users order the fully processed (Level 1) data products, to which both radiometric and geometric corrections have been applied to represent the radiometric response or gain of each reflective band as a function of time. The exponential model and coefficients are used to generate a day-specific band-average called Look-up Table (LUT) [3] of detector gains for use in processing. After the application of the LUT gains, the data are rescaled to a fixed radiance range represented by LMIN (radiance corresponding to "zero" DN) and LMAX (radiance corresponding to "255" DN). The thermal band gain is calculated based on the responses to the IC shutter and image data are similarly rescaled to a fixed radiance range. Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+) products are scaled to a LMIN value of "one" DN and the "zero" DN is reserved for the fill data.

4.2 Proposed system

This procedure will give user the ability to recalibrate their existing Level(L1) products without having to purchase reproduced data from the Geological survey again and the values has been developed will give The accuracy of the recalibration is dependent on the knowledge of the prior calibration applied to the data. The "Work Order file" it included with parameters that define the applied calibration. These are the Internal Calibrator (IC) calibration parameters or the default prelaunch calibration.

Benefits

The repurchasing the data is reduced

The processing method is more users friendly

The output data is more accurate

4.3 System Design

Class diagrams

1. Order request

   In this class order is placed by the user with a (specific purpose like education, research and general commercial)

   ordered , orderDATE , purpose, shippingDATE , payment, shipping charges

Salesorder
orderID:int; orderDATE:int; purpose:char shippingDATE:int; shippingCHARGES:int;

2. Check Achieve (inventory)

   In this class check inventory it has following attributes

   orderID, Description, levelprocessing salesRATE ,Quantity.

Checkinventory
OrderID:int;
Description:string;
Levelprocessing:char
SalesRATE:int;
Quantity:int;

3. Order Processing

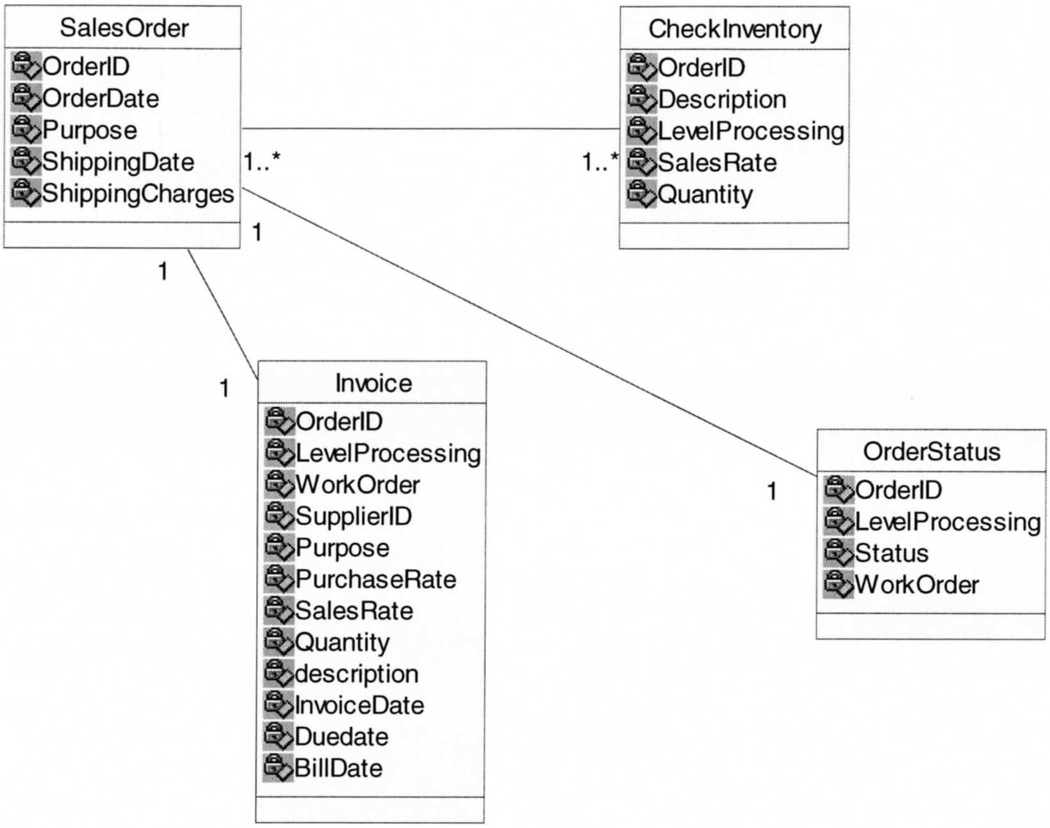
Orderstatus
OrderID:int;
Levelprocessing:char
Status:char;
Workorder:Char

4. Invoice

Invoice
OrderID:int;
Levelprocessing:char
Workorder:char
supplierID:int;
Purpose:char
purchaseRATE:int;
salesRATE:int;
Quantity:int;
Description:string;
invoiceDATE:int;

dueDATE:int;

billDATE:int;



Class Diagram

SYSTEM IMPLEMENTATION

5. Implementing system

After analyzing we will now bring our idea into actual implementation.

While implementing, we significantly focus towards fulfilling the following requirements.

After the processes of image all orders will be given images repository preparation the user will get them in form of the work orders in different levels of processing.

This work orders from the satellite imagery will have all spectral information collected from a scene in form of registered as DN values.

The real light content, namely the radiance and ground reflectance of the scene is offset and scaled during the process. Radiometric calibration plays the rule of recovering all the light information from the digital pixel numbers.

Calibration is the process of converting a sensor's digital counts (DN) or voltage to radiance units. We can calculate radiance from this procedure.

5.1 Software used in image processing

ENVI 'Environment for Visualizing Images' is advanced remote sensing software which transfers the images into the readable data. It boasts a fully accessible software language IDL 'Interactive Data language', it expands ENVI's features and create perfect image processing for the own data

ENVI is like a seamless architecture which can be handled data from all the leading providers of images like Landsat, Spot (Australia), NASA, NOAA, EROS Data Centre and is ready to accommodate data from other sensors.

IDL is ideal software for the data analysis, visualization and cross platform application development. IDL combines all the tools for interactive analysis and display to large scale commercial programming projects.

IDL supports wide range of data sources, file formats, data types and sizes, with a range from byte to string to double precision complex. Variables in IDL can be scalars, arrays of up eight dimensions, aggregate structures pointers, and objects. It is precision to high level languages, it also supports wide variety of common file formats, ranging from TIFF and JPEG to DICOM and DXF. It also reads TCP/IP sockets to import remote data directly via protocols such HTTP and FTP.

Before getting any scene the important thing is site selection

Selection of sites

Earth surfaces with suitable characteristics are called test sites to verify the post-launch radiometric calibration performance of satellite instruments.

1. The site should have high spatial uniformity along with little relative to the pixel size, to minimize the effects of scaling radiometric data to the size of the entire test site.
2. The site should have a surface reflectance greater than 0.3 in order to provide higher signal-to-noise ratio (SNR) and also to reduce uncertainties due to the atmospheric path radiance.
3. The surface of the site should have flat spectral reflectance.

4. The surface of the site should be horizontal and have nearly reflectance to Minimize uncertainties due to differences in solar illumination and observation geometries.

5. The site should be located at high altitude, far from the ocean (to minimize the influence of atmospheric water vapor), and far from urban and industrial areas (to minimize anthropogenic aerosols).

6. The site should be in an arid region to minimize the probability of cloudy weather and precipitation that could change the soil moisture.

Some of the best sites

Scientists like to choose some sites where it will be easy to do the analysis such as a) Railroad Valley Playa's spatial variability is estimated to be within 0.5 % in the specific calibration. b) The La Crau test site in France has spatial uniformities within 2 % in the visible bands and within 4 % in the near-infrared band. c) The large sites of 100 km by 100 km in the Saharan and Arabian Deserts were selected on the basis of having less than 3 % spatial variability.

The main operations of the satellite and its ground processing system is get the images and process them in Digital Numbers. The data from the USGS and National Land Archive Production System (NLAPS) will process the digital images in level 1 data products. To which both radiometric and geometric correction applied to represent gain of each radiometric correction.

Look-up Table (LUT)

Due to the periodic build up of ice during out gassing cycles there is slightly an additional ± 3-5 percent uncertainty in bands 5 and 7 in any given TM product. The developed thin-film model corrects for most of this effect. The oscillatory nature of this model is such that the $G_{new}(t)$ for bands 5 and 7 will be better specified in terms of day-specific LUTs. Hence, for consistency, LUTs was used for $G_{new}(t)$ for all six solar reflective bands.

The final lifetime gain model for L5 TM that has been scaled to the cross-calibration estimates with the L7 ETM+. These gains are generated over the lifetime of the Mission and stored in day-specific LUTs. In the same sense, the gains calculated using IC responses are referred to as IC gains.

The exponential model and coefficients are used to generate a day-specific band-average Look-up Table (LUT) [3] of detector gains for use in processing. After the application of the LUT gains, the data are rescaled to a fixed radiance range (referred to as the post calibration dynamic range) represented by LMIN (radiance corresponding to "zero" DN) and LMAX (radiance corresponding to "255" DN).

The gains and biases calculated using the existing procedure have become less reliable with time. Earlier studies have shown that the constancy of the biases within a TM scene is a poor assumption for bands 1 – 4.

These analyses, gave a new formulation models with the gain on each band as a time-dependent equation. The model initially consisted of the sum of two terms representing an initial exponential decrease in response were based on a calibration lamp [010] with a continuous output. For bands 5 and 7, before generating the model equations, detector responses were corrected for variation due to the buildup of an ice film on the cold focal

plane window [6]. Tme-dependent calibration look-up tables (LUT) were generated from the lifetime gain model equations for all bands.
The biases are now applied line-by-line based on the dark shutter responses acquired from each scan line and the regression based offset will be discarded. This approach will be similar to the current calibration method of the L7 ETM+.

5.2 Procedure for Radiometric Calibration

5.2.1Internal Calibrator

The response of the detectors' on the IC lamps while scene-by-scene basis for radiometric calibration. In such a way that radiance of each lamp state reflective band detector was determined by detector's response so that internal lamp to its response to an external calibrated source. The gain is represented with the slope, while the intercept represents the bias

5.2.1 Lifetime Gain Model

The calibration procedure in the processing system was revised to remove reliance on the lamp radiances by Lookup Table (LUT) procedure for the reflective bands (1-5, 7) which is based on a lifetime radiometric calibration curve for the instrument derived from early lifetime IC responses, cross-calibration with the Enhanced Thematic Mapper Plus (ETM+).

This procedure came up with an improved and more consistent calibration with removing the calibration changes that were clearly due to the lamps and not the detectors.

The new LUT gain model is used to generate the band average gain over the lifetime of the mission and is stored in a day- specific LUT. These numbers are referred to as LUT gains. In the same sense, the gains calculated using IC responses are referred to as IC gains. The LUT gains are available on the USGS Landsat Project Web Site [3]. In conjunction with this, the post-calibration scaling factors were updated to make full use of the dynamic range of the instrument.

A new version of the LUT, with a significantly improved gain model for the first eight years of the mission (1984-1991), was released in April 2007 [4].

5.2.2 Recalibration Formulation

Recalibration procedure gives users ability to improve the absolute calibration accuracy of its products. The formulation and derivation of recalibration equations has resulted of using the recalibration procedure on L5 TM IC data to improve the calibration accuracy and to be consistent with L5 TM LUT and L7 ETM+ data.
The key to recalibration is known by the calibration coefficients that were used to generate the product. This information is available in the NLAPS Work Order Report file delivered with the product. If the Work Order file is available, the recalibration procedure can reproduce the current calibration to within a few percent.

(1)Qcal is the quantized calibrated pixel value for L1 product in Digital Number (DN). Where αref and βref are the scene-specific radiometric processing coefficients which were originally applied during product generation. The coefficients (αref and βref) were nominally based on scene statistics from the IC pulse data recorded during the original processing. In the Work Order report, these numbers are called destriping coefficients and they are listed for 16 detectors in each reflective band. The average of gain coefficients for all 16 detectors gives the αref, and similarly, the average of bias coefficients gives the βref. Gnew is the date-specific LUT gain coefficients for the given band derived using the lifetime gain model. The L5 TM LUT Release Version

Description Document (VDD) describes the file content, structure, and changes associated with each version of the LUT [3].

5.2.3 Data Processing System

This analysis used three image-pairs acquired near-simultaneously by L5 and L7 in June 1999: Railroad Valley Playa in Nevada (Path 40, Row 33), Niobrara in Nebraska (Path 31, Row 30), and Washington DC (Path 15, Row 33). All scenes were processed to Level 1R (applied radiometric, but no geometric correction). L5 TM scenes were processed using two

different calibration procedures through the National Land Archive Production System (NLAPS). The first calibration procedure used the IC, and the second approach used the LUT. The IC-generated product was then "recalibrated" using Equation to enable a check on the recalibration procedure.

5.2.4 Regions of Interest

The analysis approach made use of image statistics based on large common areas between the image pairs. These large areas were carefully selected using distinct features. Common Regions of Interest (ROI) between 5 and 50 km2 were selected within each ETM+ and TM scene, excluding clouds and cloud shadows. From defined regions, mean-calibrated DNs were computed and converted to corresponding at-sensor radiances.

Data continuity requires consistency in the interpretation of image data acquired by different sensors. Calculation of radiance is the fundamental step in putting data from multiple sensors and platforms onto a common radiometric scale. The following is a partial list of variables used for radiometric calibration.

Q Raw quantized voltage or response [DN].

G Detector gain or reponsivity [DN/(W/(m2 · sr · μm)].

B Detector bias or background response [DN].

$L\lambda$ Spectral radiance at the sensor's aperture [W/(m2 · sr · μm)].

Qcal Quantized calibrated pixel value [DN].

Qcalmin Minimum quantized calibrated pixel value

(DN = 0) corresponding to LMINλ.

Qcalmax Maximum quantized calibrated pixel value

(DN = 255) corresponding to LMAXλ.

LMINλ Spectral radiance that is scaled to Qcalmin [W/(m2 · sr · μm)].

LMAXλ Spectral radiance that is scaled to Qcalmax[W/(m2 · sr · μm)].

Grescale Band-specific rescaling gain factor [(W/(m2 · sr · μm))/DN].

Brescale Band-specific rescaling bias factor [W/(m2 · sr · μm)].

Conversion to Radiance for L1 Products (Qcal-*to-* $L\lambda$)

The pixel values in the Level 1 (L1) data are represented as Qcal. During the radiometric calibration, pixel values (Q) from L0Rp image data are converted to units of absolute radiance using 32-bit floating-point calculations. The absolute-radiance values are then scaled to 8-bit values representing the calibrated digital numbers (Qcal) before output to the distribution media.

Conversion from Qcal in L1 products back to $L\lambda$ requires knowledge of the original rescaling factors. This process is given by the following relationship:

$L\lambda$ = _LMAXλ − LMINλ

Qcalmax − Qcalmin_(Qcal − Qcalmin) + LMINλ

or

$L\lambda$ = _LMAXλ – LMINλ

255 _Qcal + LMINλ

where

Qcalmax =255

Qcalmin =0 or

$L\lambda$ = Grescale × Qcal + Brescale

L5 TM gain model fitting coefficients (LUT07)			
Band	a_0	a_1	a_2
1	0.2901	0.1399	1.209
2	0.1246	0.1045	0.6305
3	0.0839	0.2386	0.9028
4	0	0	1.082
5	0	0	8.209
7	0	0	14.695

Table 2:- Gain model coefficients

*G*rescale =LMAXλ – LMINλ

*B*rescale =LMINλ.

The LUT gains are used for converting the *Q* in the L0Rp to spectral radiance, while the rescaling gains (*G*rescale) are used to convert the *Q*cal in the L1 data to spectral radiance. The conversion from *Q* to *Q*cal is performed during the L1-product generation; accordingly, users with L1 data do not apply the LUT gains for conversion to radiance.

5.2.5 REVISED RADIOMETRIC CALIBRATION

The validation of current LUT procedure in the NLAPS systems has continued in order to refine the lifetime gain model. These studies have relied primarily on the data acquired over pseudo invariant desert sites but have been hindered by the limited amount of data available over any one site for the 23-year life of the mission.

The time-dependent equations for L5 TM gain

*G*new(*t*), which are applicable to the raw data, take the form

*G*new(*t*) = *ax*0

exp (−*ax*1(*t* − 1984.2082)) + *a*2

Where

Time *t* is in decimal years,

*a*0 is a scaling factor for the exponential decrease,

*a*1 is a time constant of the exponential decrease,

$a2$ is a required offset, and 1984.2082 refers to “time zero,” which is the acquisition date of the first on-orbit L5 TM data available in the U.S. archive (March 16, 1984).

The coefficients $a0$, $a1$, and $a2$ are summarized in Table I. This model is based on the pseudo invariant desert-site data and the cross calibration of L5 TM with the L7 ETM+ from June 1999.

This revised LUT calibration model will be used for all of the L5 data that are processed and model implemented in 2003 (LUT03) will be replaced by a new lifetime radiometric-calibration LUT model (LUT07).

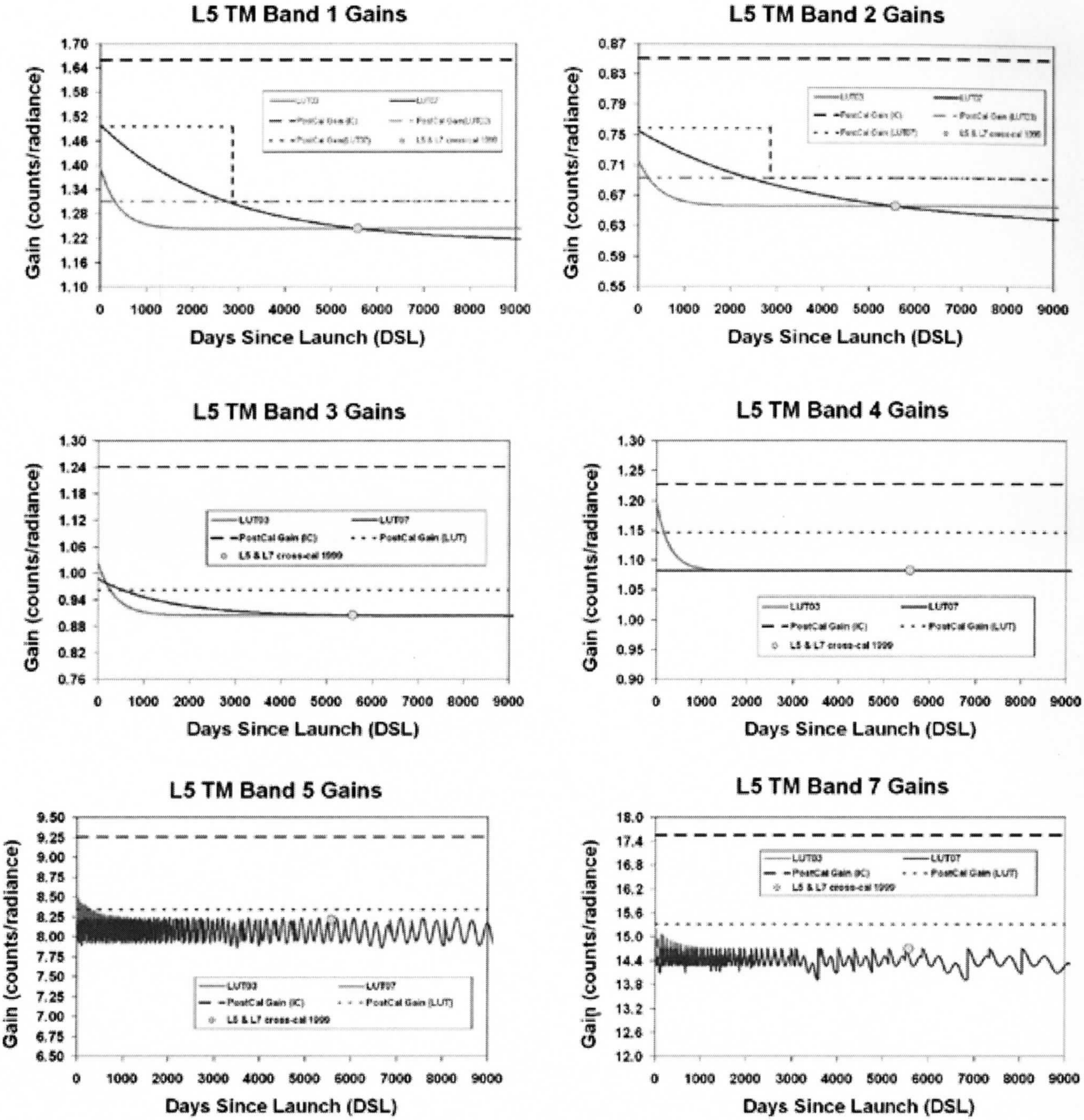


Fig. 1 shows the comparison of the LUT07 versus the LUT03.

CONCLUSIONS

6.1 Conclusions

An improved lifetime gain has been implemented for the absolute radiometric calibration of the L5 TM solar reflective bands based on the instrument's detector response to pseudo invariant desert-site data and cross calibration with the L7 ETM+,

The new lifetime gain model for the reflective bands (1–5, 7) is based on a lifetime radiometric-calibration curve that is derived from the instrument's response to desert sites and cross calibration with the ETM+. In this calibration update, only the LMAXs and the corresponding *G*rescale values for bands 1 and 2 for approximately the first eight years of the mission have been changed. Users will need to apply new post calibration dynamic ranges (*G*rescale and *B*rescale) to convert the newly processed calibrated data products to radiance. The revised post calibration dynamic ranges are only applicable to the data processed after April 2, 2007, with the updated lifetime gain model (LUT07).

- The lifetime gain model that was implemented on May 5, 2003 for the reflective bands (1-5, 7) will be replaced by a new lifetime radiometric calibration curve derived from the instrument's response to pseudo-invariant desert sites and from cross-calibration with the L7 ETM+
- The radiometric scaling coefficients for Bands 1 and 2 for approximately the first eight years of the mission have also been changed
- Users will need to apply these new coefficients to convert the calibrated data product digital numbers to radiance
- The scaling coefficients for the other bands have not changed.

The new LMAXs should not be applied to the data processed using IC gains. The figures and tables validate the data.

Tables

Table 3. This model is used in look up table form (LUT07) to represent the band average gain of the TM bands. Coefficients a_0 and a_2 are in units of DN/ (W/m^2sr □m) and the a_1 coefficients are 1/years

L5 TM gain model fitting coefficients (LUT07)			
Band	**a_0**	**a_1**	**a_2**
1	0.2901	0.1399	1.209
2	0.1246	0.1045	0.6305
3	0.0839	0.2386	0.9028
4	0	0	1.082
5	0	0	8.209
7	0	0	14.695

Table 4. Post-Calibration Dynamic Ranges for L5 TM Data processed to level 1 before April 2, 2007

Spectral Radiances, LMIN and LMAX in W/(m^2.sr.µm)						
Processing Date	**From March 1, 1984 To May 4, 2003**			**From May 5, 2003 To April 1, 2007**		
Band	**LMIN**	**$LMAX_{(IC)}$**	**$PostCal_{(IC)}$**	**LMIN**	**$LMAX_{(LUT03)}$**	**$PostCal_{(LUT03)}$**
1	-1.52	152.10	1.66	-1.52	193.0	1.31
2	-2.84	296.81	0.85	-2.84	365.0	0.69
3	-1.17	204.30	1.24	-1.17	264.0	0.96
4	-1.51	206.20	1.23	-1.51	221.0	1.15
5	-0.37	27.19	9.25	-0.37	30.2	8.34
6	1.2378	15.303	18.13	1.2378	15.303	18.13
7	-0.15	14.38	17.55	-0.15	16.5	15.32

Table 5. Post-Calibration Dynamic Ranges for L5 TM Data processed to level 1 after April 2, 2007

Spectral Radiances, LMIN and LMAX in W/(m^2.sr.µm)				
Processing Date : From April 2, 2007				
Band	**Acquisition Date**	**LMIN**	**$LMAX_{(LUT07)}$**	**$PostCal_{(LUT07)}$**
1	**Mar 1, 1984 - Dec 31, 1991**	**-1.52**	**169.0**	**1.50**
	Jan 1, 1992 - Present	-1.52	193.0	1.31
2	**Mar 1, 1984 - Dec 31, 1991**	**-2.84**	**333.0**	**0.76**
	Jan 1, 1992 - Present	-2.84	365.0	0.69
3	Mar 1, 1984 - Present	-1.17	264.0	0.96
4	Mar 1, 1984 - Present	-1.51	221.0	1.15
5	Mar 1, 1984 - Present	-0.37	30.2	8.34
6	Mar 1, 1984 - Present	1.2378	15.303	18.13
7	Mar 1, 1984 - Present	-0.15	16.5	15.32

Table6. Rescaling Gains and Biases used for the conversion of L1 calibrated data product digital numbers (Q_{cal}) to spectral radiance (L_λ)

Rescaling Gain ($G_{rescale}$) and Bias ($B_{rescale}$) in W/(m^2.sr.µm)								
Processing Date	**Mar 1, 1984 - May 4, 2003**		**May 5, 2003 - Apr 1, 2007**		**Apr 2, 2007 - Present**			
Acquisition Date	**Mar 1, 1984 - May 4, 2003**		**Mar 1, 1984 - Apr 1, 2007**		**Mar 1, 1984 - Dec 31, 1991**		**Jan 1, 1992 - Present**	
Band	$G_{rescale(IC)}$	$B_{rescale}$	$G_{rescale(LUT03)}$	$B_{rescale}$	$G_{rescale(LUT07)}$	$B_{rescale}$	$G_{rescale(LUT07)}$	$B_{rescale}$
1	0.602431	-1.52	0.762824	-1.52	0.668706	-1.52	0.762824	-1.52
2	1.175100	-2.84	1.442510	-2.84	1.317020	-2.84	1.442510	-2.84
3	0.805765	-1.17	1.039880	-1.17	1.039880	-1.17	1.039880	-1.17
4	0.814549	-1.51	0.872588	-1.51	0.872588	-1.51	0.872588	-1.51
5	0.108078	-0.37	0.119882	-0.37	0.119882	-0.37	0.119882	-0.37
6	0.055158	1.2378	0.055158	1.2378	0.055158	1.2378	0.055158	1.2378
7	0.056980	-0.15	0.065294	-0.15	0.065294	-0.15	0.065294	-0.15

FIGURES

The Landsat images of the processed scenes

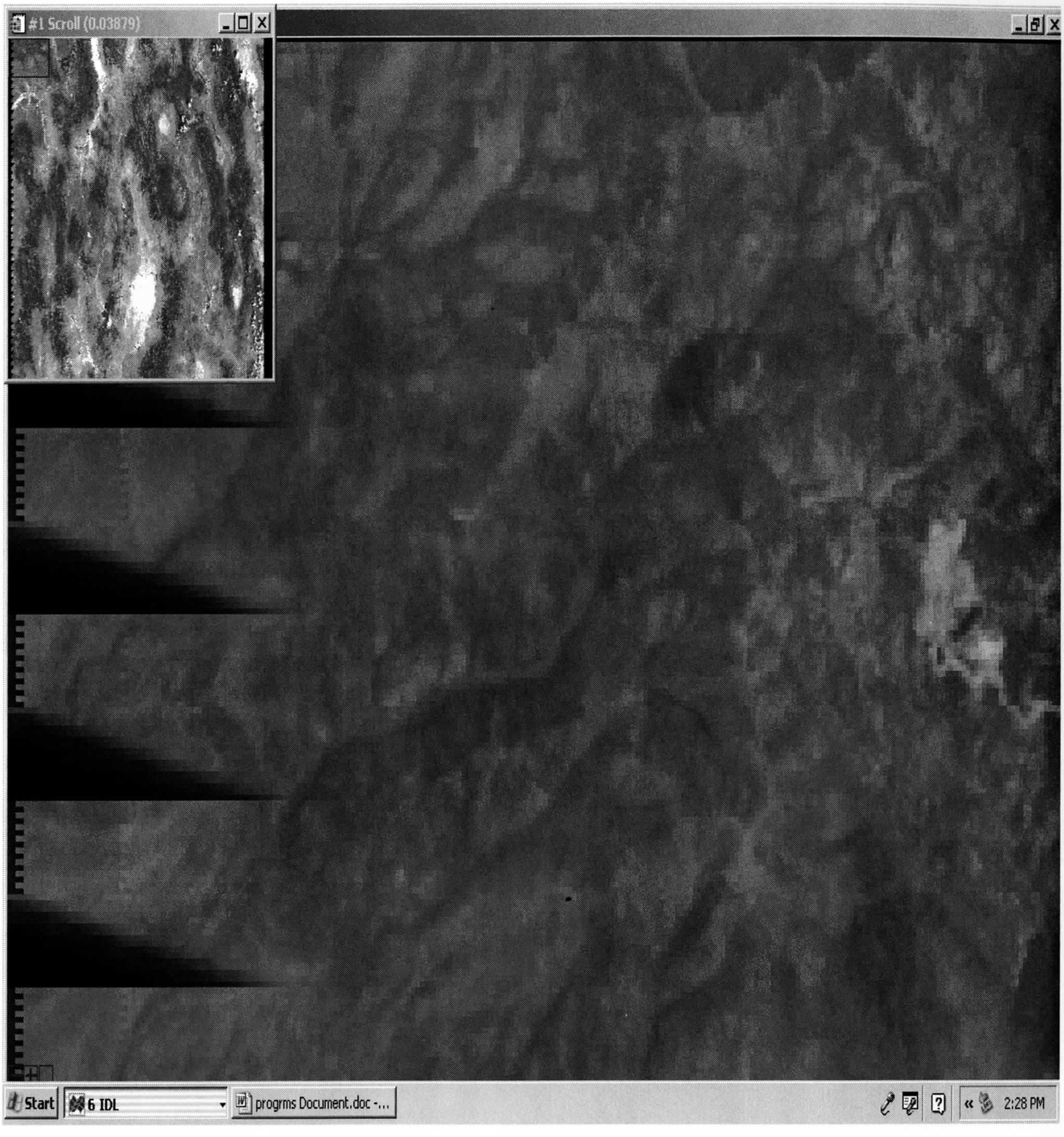
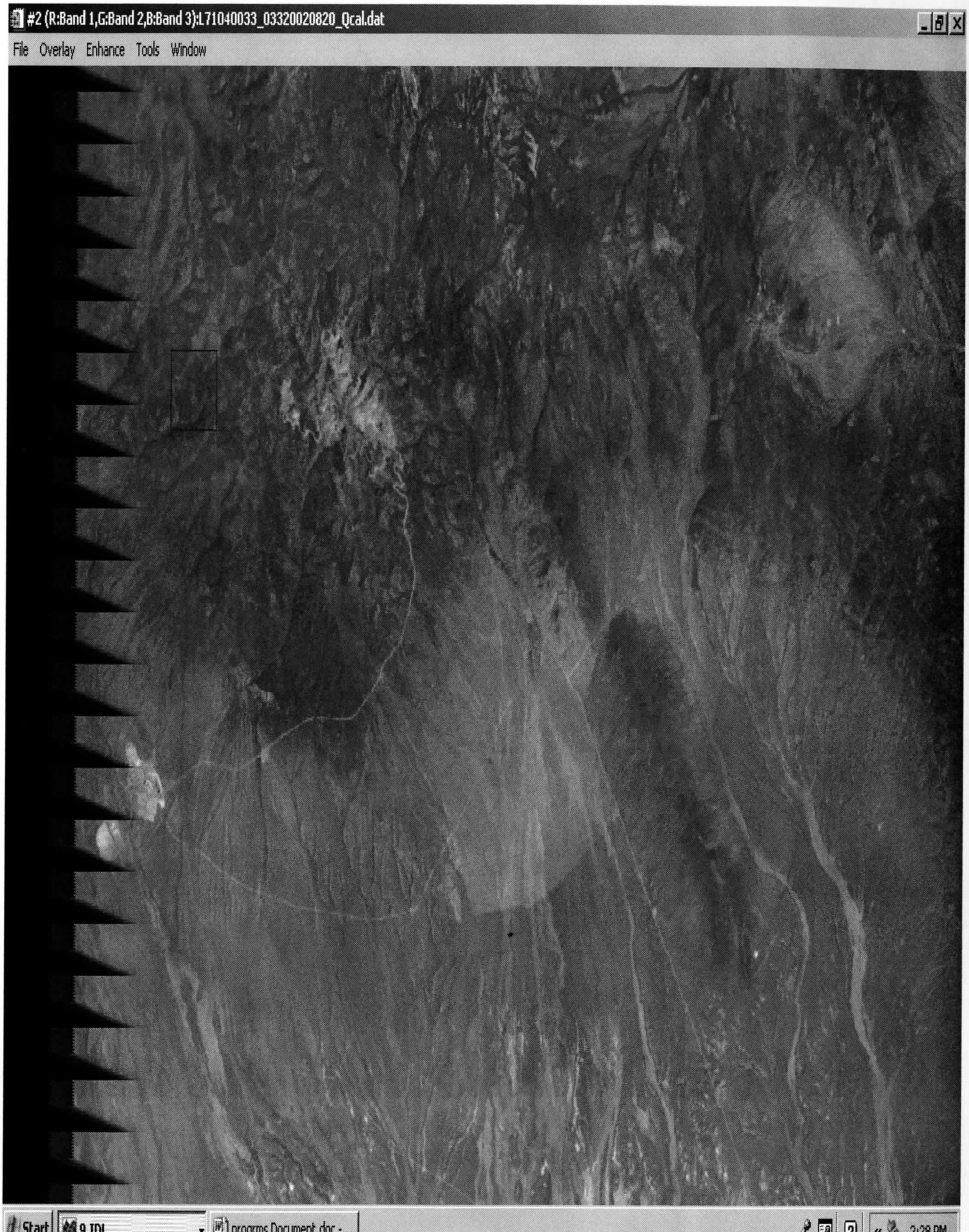


Fig2:- The scene at first region of interest


#2 (R:Band 1,G:Band 2,B:Band 3):L71040033_03320020820_Qcal.dat
File Overlay Enhance Tools Window
Start
9 IDL
progrms Document.doc -...
2:28 PM

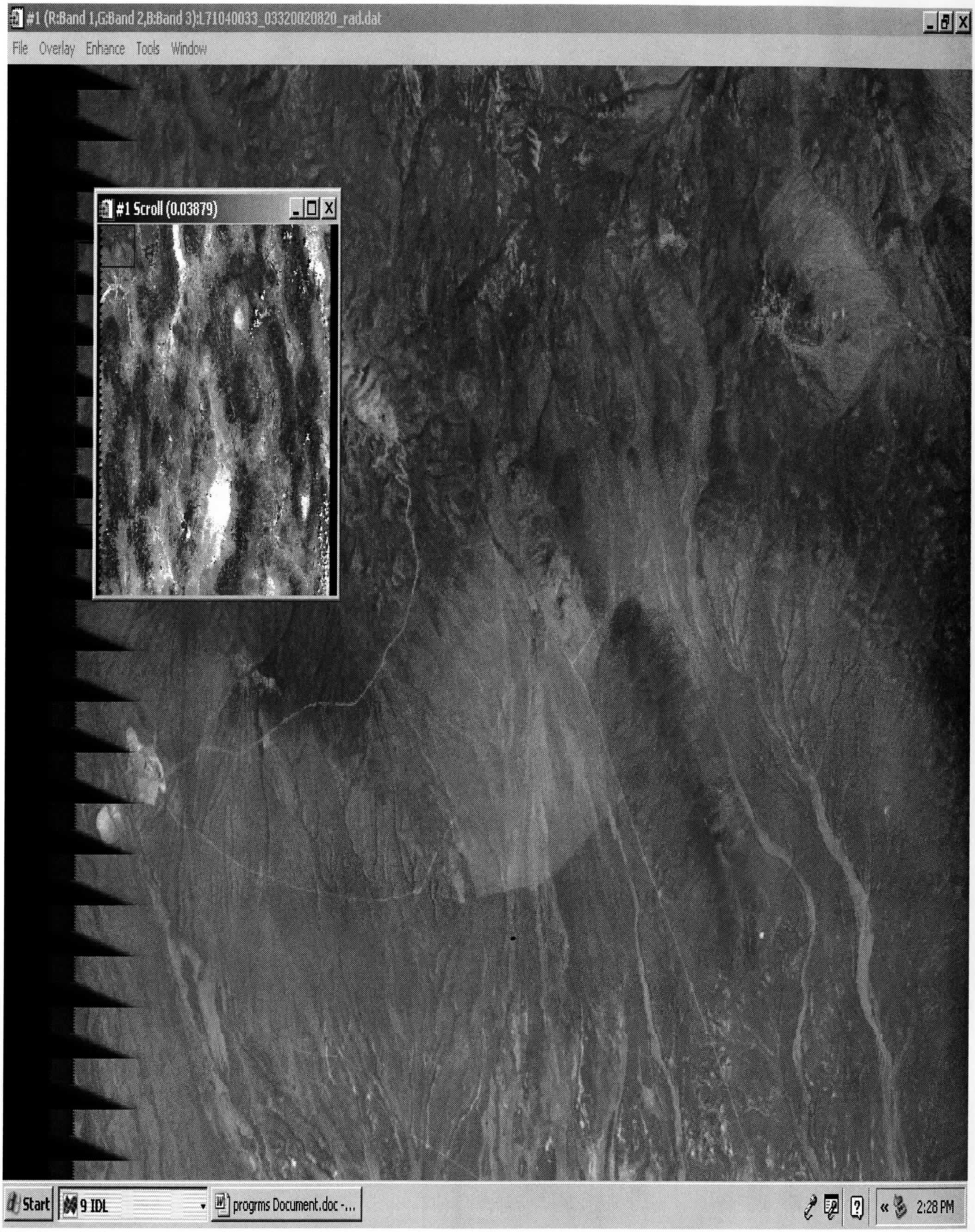


Fig3 and Fig4 are the railroad playa.

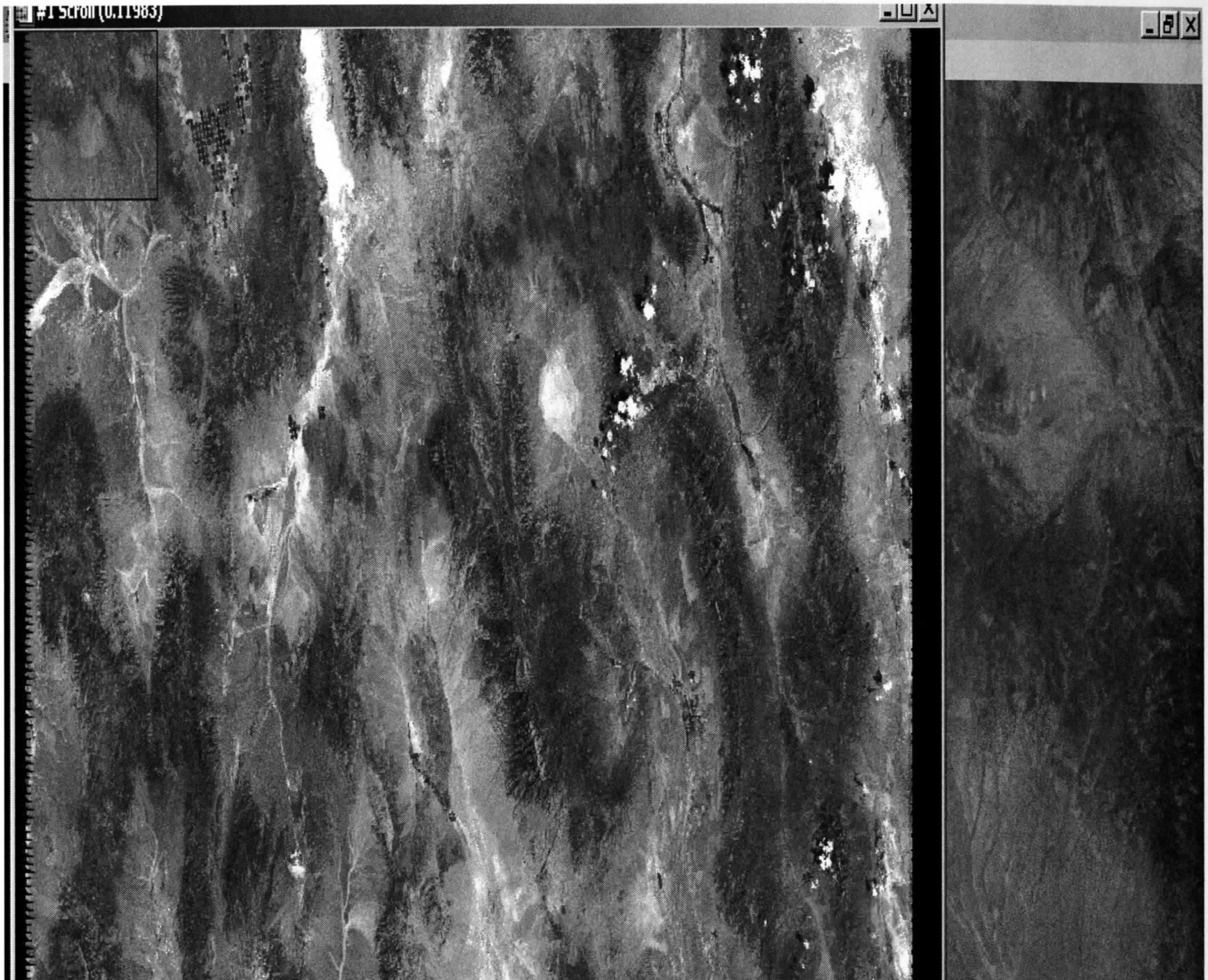


Fig5:- the scene where the region of interest has a cloud.

Screen shorts in The IDL Environment:-

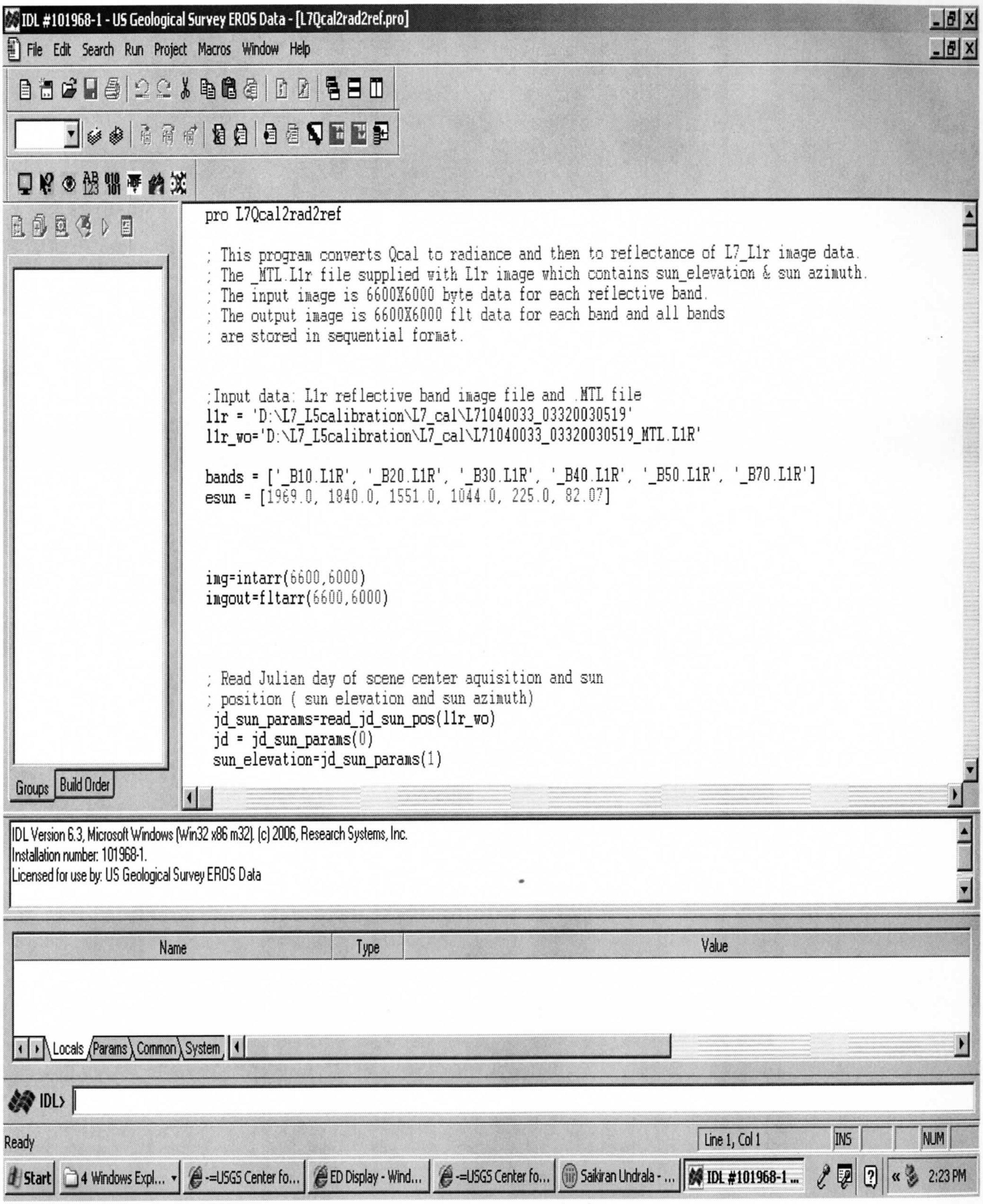


Fig6:- The IDL environment which executing the Qcal2radref.pro

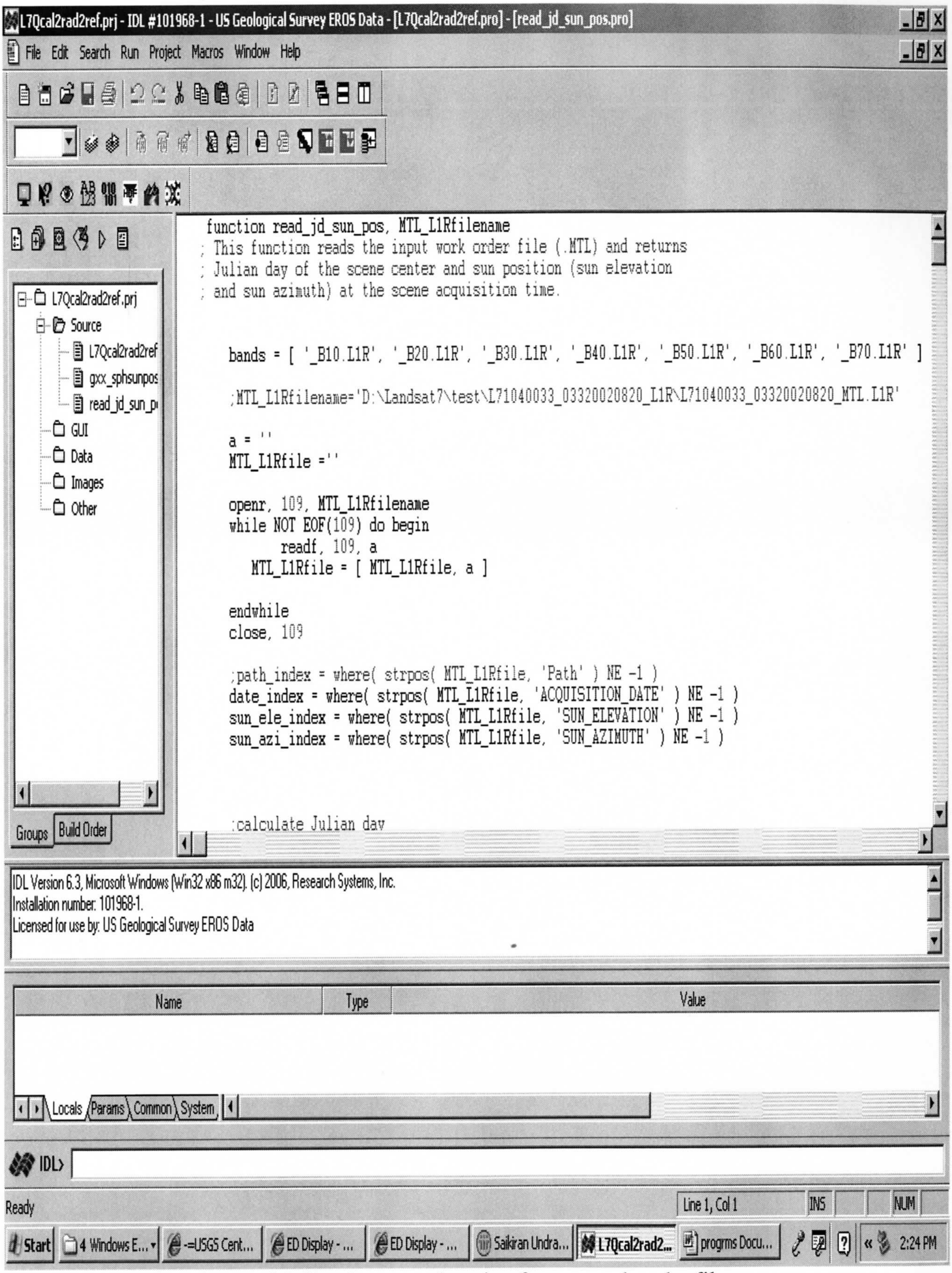


Fig7:- Program function read Julian day, sun elevation from a work order file

Fig8:- gxx_sphsunposted_c.pro this a project included file we can observe in the left side box the details of the associated programs running with the project.

Appendix

Script Code

****

ymd2dn.pro

****

```
/* This code is to process the day , month and year of the image */
;;+
; NAME:
;     YMD2DN
; PURPOSE:
;     Convert from year, month, day to day number of year.
; CATEGORY:
; CALLING SEQUENCE:
;     dy = ymd2dn(yr,m,d)
; INPUTS:
;     yr = year (like 1988).               in
;     m = month number (like 11 = Nov).    in
;     d = day of month (like 5).           in
; KEYWORD PARAMETERS:
; OUTPUTS:
;     dy = day number in year (like 310).  out
; COMMON BLOCKS:
; NOTES:
; MODIFICATION HISTORY:
;     Written by R. Sterner, 20 June, 1985.
;     Johns Hopkins University Applied Physics Laboratory.
;     RES 18 Sep, 1989 --- converted to SUN
;     R. Sterner, 1997 Feb 3 --- Made work for arrays.
;
;-
;-------------------------------------------------------------------------------------------------

        function ymd2dn,yr,m,d, help=hlp

        if (n_params(0) lt 3) or keyword_set(hlp) then begin
          print,' Convert from year, month, day to day number of year.'
          print,' dy = ymd2dn(yr,m,d)'
          print,'   yr = year (like 1988).               in'
          print,'   m = month number (like 11 = Nov).    in'
          print,'   d = day of month (like 5).           in'
          print,'   dy = day number in year (like 310).  out'
          return, -1
        endif
```

```
        ;----  Days before start of each month (non-leap year)  -----
idays = [0,31,59,90,120,151,181,212,243,273,304,334,366]

;----  Correct for leap year if month ge 3  -------------
lpyr = (((yr mod 4) eq 0) and ((yr mod 100) ne 0)) $
or ((yr mod 400) eq 0) and (m ge 3)

dy = d + idays(m-1) + lpyr
return, dy

end
```

****

stichTM_Hist.pro

****

```
/* This code is to have the histogram to stich from the work order files*/

l0r = 'D:\data\QC\LT5040033009915210.'

bands = ['I1', 'I2', 'I3', 'I4', 'I5', 'I7', 'CF']

img=bytarr(6300,5985)
imgb=bytarr(6300,5985,7)

for i=0,n_elements(bands)-1 do begin
l0rb=l0r + bands(i)
print,  l0rb
openr,1,l0rb
readu,1,img
imgb(*,*,i)=img
free_lun, 1

endfor

openw,1,'D:\data\QC\L5.img'
writeu,1,imgb
close,1

Window,1,xsize=900,ysize=900
!p.multi=[0,2,3]

plot,histogram(imgb(*,*,0)),background=clu(255, 255,
255),color=0,charthick=1.5,xrange=[0,250],xtitle='Pixel DN',ytitle='Number of
pixels',xcharsize=1.5,ycharsize=1.5,xthick=2,ythick=2
xyouts,150,900000,'Band-1',color=0,charsize=1.0
plot,histogram(imgb(*,*,1)),background=clu(255, 255,
255),color=0,charthick=1.5,xrange=[0,250],xtitle='Pixel DN',ytitle='Number of
pixels',xcharsize=1.5,ycharsize=1.5,xthick=2,ythick=2
```

```
xyouts,150,900000,'Band-2',color=0,charsize=1.0
plot,histogram(imgb(*,*,2)),background=clu(255, 255,
255),color=0,charthick=1.5,xrange=[0,250],xtitle='Pixel DN',ytitle='Number of
pixels',xcharsize=1.5,ycharsize=1.5,xthick=2,ythick=2
xyouts,150,900000,'Band-3',color=0,charsize=1.0
plot,histogram(imgb(*,*,3)),background=clu(255, 255,
255),color=0,charthick=1.5,xrange=[0,250],xtitle='Pixel DN',ytitle='Number of
pixels',xcharsize=1.5,ycharsize=1.5,xthick=2,ythick=2
xyouts,150,900000,'Band-4',color=0,charsize=1.0
plot,histogram(imgb(*,*,4)),background=clu(255, 255,
255),color=0,charthick=1.5,xrange=[0,250],xtitle='Pixel DN',ytitle='Number of
pixels',xcharsize=1.5,ycharsize=1.5,xthick=2,ythick=2
xyouts,150,600000,'Band-5',color=0,charsize=1.0
plot,histogram(imgb(*,*,5)),background=clu(255, 255,
255),color=0,charthick=1.5,xrange=[0,250],xtitle='Pixel DN',ytitle='Number of
pixels',xcharsize=1.5,ycharsize=1.5,xthick=2,ythick=2
xyouts,150,900000,'Band-7',color=0,charsize=1.0

write_jpeg, 'Histogram.jpg', tvrd(/TRUE), /TRUE

end
```

****

Pro read _wo

****

```
/* Thiscode is for the read a work order file */

--------------------------------------pro read_wo-----------------------------------------------------

        bands = [ '1', '2', '3', '4', '5', '6', '7' ]
        lut_col = [ 3, 4, 5, 6, 9, -1, 10 ]
        n_dets = 16

        a = ''
        wo_file = ''

        filename = dialog_pickfile( )
        openr, 109, filename
        while NOT EOF(109) do begin
                readf, 109, a
                wo_file = [ wo_file, a ]
        endwhile
        close, 109

        path_index = where( strpos( wo_file, 'Path' ) NE -1 )
        date_index = where( strpos( wo_file, 'Scene center date:' ) NE -1 )
        ;calculate some sort of date
        date_split = strsplit( wo_file(date_index), /extract )
        time_split = strsplit( date_split(9), ':', /extract )
```

```
	date_julday = julday( date_split(4), date_split(5), date_split(3), time_split(0), time_split(1),
time_split(2) )
	launch_julday = julday( 3, 1, 1984 )
	year = date_split(3)
	years = ( date_julday - launch_julday ) / 365.25 + 1984.1667;need to check with Chander and
Esad on this calculation!!

doy = ymd2dn( date_split(3), date_split(4), date_split(5) )


;B1 rescaling coeffs start at rescale_coeff_start_index+3
rescale_coeff_start_index = where( strpos( wo_file, 'DN to Radiance' ) NE -1 )

band_start_index = where( strpos( wo_file, 'gain      offset      gain      offset' ) NE -1 )

;read LUT
lut_filename = 'D:\data\QC\lut07\L5gain9a.txt'
lut = read_ascii( lut_filename )
lut = lut.(0)

lut_index = where( fix(lut(1,*)) EQ year AND lut(2,*) EQ doy )

;find index for day's gains
;year_diff = abs( lut(1,*) - years )
;lut_index = where( year_diff EQ min(year_diff) )

openw, 109, filename + '.txt'
printf, 109, filename
printf, 109, 'Comparing to ', lut_filename
printf, 109, wo_file(date_index)
printf, 109, wo_file(path_index)
printf, 109, 'JAB date: ', years, format='(A,F12.5)'
printf, 109, 'LUT date: ', lut(1,lut_index), format='(A,F12.5)'
printf, 109
printf, 109, 'Band   WO_gain     LUT_gain'

for i = 0, n_elements(bands)-1 do begin

	if bands(i) NE '6' then begin

		;retrieve the rescaling coeffs
		rescale_string = strsplit( wo_file(rescale_coeff_start_index+3 + i ), /extract )
		rescale_gain = float( rescale_string(3) )
		rescale_bias = float( rescale_string(4) )

		;average the processing gains/offsets
		proc_string = wo_file(band_start_index(i)+2:band_start_index(i)+2+n_dets-1)

		proc_gain_forward = total( float( strmid( proc_string, 10, 9 ) ) ) / n_dets
```

```
            proc_offset_forward = total( float( strmid( proc_string, 19, 11 ) ) ) / n_dets
            proc_gain_reverse = total( float( strmid( proc_string, 30, 12 ) ) ) / n_dets
            proc_offset_reverse = total( float( strmid( proc_string, 42, 11 ) ) ) / n_dets

            alpha = ( proc_gain_forward + proc_gain_reverse ) / 2.0
            Gold = alpha / rescale_gain

            printf, 109, bands(i), gold, lut(lut_col(i),lut_index)
        endif ; not band 6

endfor  ; i n_bands

close, 109


stop
end
```

****

L7 Qal Rad Ref

****

```
/* This code is to convert the Qal to radiance of landsat satellites */

function read_jd_sun_pos, MTL_L1Rfilename
; This function reads the input work order file (.MTL) and returns
; Julian day of the scene center and sun position (sun elevation
; and sun azimuth) at the scene acquisition time.


  bands = [ '_B10.L1R', '_B20.L1R', '_B30.L1R', '_B40.L1R', '_B50.L1R', '_B60.L1R', '_B70.L1R' ]


;MTL_L1Rfilename='D:\Landsat7\test\L71040033_03320020820_L1R\L71040033_03320020820_MT
L.L1R'

  a = ''
  MTL_L1Rfile =''

  openr, 109, MTL_L1Rfilename
  while NOT EOF(109) do begin
       readf, 109, a
    MTL_L1Rfile = [ MTL_L1Rfile, a ]

  endwhile
  close, 109
```

```
;path_index = where( strpos( MTL_L1Rfile, 'Path' ) NE -1 )
date_index = where( strpos( MTL_L1Rfile, 'ACQUISITION_DATE' ) NE -1 )
sun_ele_index = where( strpos( MTL_L1Rfile, 'SUN_ELEVATION' ) NE -1 )
sun_azi_index = where( strpos( MTL_L1Rfile, 'SUN_AZIMUTH' ) NE -1 )



;calculate Julian day
date_split = strsplit( MTL_L1Rfile(date_index), /extract )
date_split1=strsplit(date_split(2))
date_split1=strsplit(date_split(2),'-', /extract)
date_julday = julday( date_split1(1), date_split1(2), date_split1(0))


; Retrive Sun position
sun_split1 = strsplit( MTL_L1Rfile(sun_ele_index), /extract )
sun_split2 = strsplit(MTL_L1Rfile(sun_azi_index), /extract )
SUN_ELEVATION = sun_split1(2)
SUN_AZIMUTH = sun_split2(2)

close, 109

 data = [date_julday,  SUN_ELEVATION,  SUN_AZIMUTH]

return, [data]

end
```

****

gxx_sphsunpostod.c

****

```
/
;
; NAME:                gxx_sphsunpostod.c
;
; PURPOSE:
;     To compute equatorial spherical coordinates of Sun referred to
;     the mean equator and equinox of date.
;
; REFERENCES:
;     Bretagnon, P. and Simon, J.L. (1986).  Planetary Programs and
;       Tables from -4000 to + 2800. (Richmond, VA: Willmann-Bell).
;
;
;  NOTES:
```

```
;      1. Quoted accuracy is 2.0 + 0.03 * T^2 arcsec, where T is
;      measured in units of 1000 years from J2000.0.  See reference.
;
;
;
*******************************************************************************
;                   Landsat 7 Image Assessment System (IAS) Software

*******************************************************************************
/

;pro gxx_sphsunpostod, jd

function gxx_sphsunpostod, jd

sun_con_l = [  403406.0,      195207.0,      119433.0,      112392.0, $
          3891.0,        2819.0,        1721.0,          0.0,  $
          660.0,         350.0,         334.0,         314.0,   $
          268.0,         242.0,         234.0,         158.0,   $
          132.0,         129.0,         114.0,          99.0,   $
          93.0,          86.0,          78.0,          72.0,    $
          68.0,          64.0,          46.0,          38.0,    $
          37.0,          32.0,          29.0,          28.0,    $
          27.0,          27.0,          25.0,          24.0,    $
          21.0,          21.0,          20.0,          18.0,    $
          17.0,          14.0,          13.0,          13.0,    $
          13.0,          12.0,          10.0,          10.0,    $
          10.0,          10.0 ]

sun_con_r = [     0.0, -97597.0, -59715.0, -56188.0,  -1556.0, -1126.0,   -861.0,   $
          941.0,  -264.0,  -163.0,     0.0,   309.0,  -158.0,     0.0,  $
          -54.0,     0.0,   -93.0,   -20.0,     0.0,   -47.0,     0.0,  $
          0.0,   -33.0,   -32.0,     0.0,   -10.0,   -16.0,     0.0,    $
          0.0,   -24.0,   -13.0,     0.0,    -9.0,     0.0,   -17.0,  $
          -11.0,     0.0,    31.0,   -10.0,     0.0,   -12.0,     0.0, $
          -5.0,     0.0,     0.0,     0.0,     0.0,     0.0,     0.0,  $
          -9.0 ]

sun_con_alpha = [ 4.721964, 5.937458, 1.115589, 5.781616, 5.5474  , 1.5120  , 4.1897  , $
            1.163   , 5.415   , 4.315   , 4.553   , 5.198   , 5.989   , 2.911   , $
            1.423   , 0.061   , 2.317   , 3.193   , 2.828   , 0.52    , 4.65    , $
            4.35    , 2.75    , 4.50    , 3.23    , 1.22    , 0.14    , 3.44    , $
            4.37    , 1.14    , 2.84    , 5.96    , 5.09    , 1.72    , 2.56    , $
            1.92    , 0.09    , 5.98    , 4.03    , 4.27    , 0.79    , 4.24    , $
            2.01    , 2.65    , 4.98    , 0.93    , 2.21    , 3.59    , 1.50    , $
            2.55 ]
sun_con_nu = [    1.621043, 62830.348067, 62830.821524, 62829.634302, 125660.5691 , 125660.9845
, $
            62832.4766 ,     0.813  , 125659.310  , 57533.850  ,    -33.931  , 777137.715  , $
            78604.191  ,     5.412  , 39302.098  ,    -34.861  , 115067.698  , 15774.337  , $
```

```
          5296.670 , 58849.27  , 5296.11  , -3980.70  , 52237.69 , 55076.47  ,  $
          261.08  , 15773.85  , 188491.03 , -7756.55 ,  264.89 , 117906.27 , $
          55075.75 ,  -7961.39 , 188489.81 ,  2132.19 , 109771.03 ,  54868.56 , $
          25443.93 , -55731.43 ,  60697.74 ,  2132.79 , 109771.63 ,  -7752.82 , $
          188491.91 ,   207.81 ,  29424.63 ,   -7.99 ,  46941.14 ,   -68.29 , $
          21463.25 , 157208.40 ]

EPOCH_2000 =     2451545.0
SECS2RADS = 206264.806247096355
r2d = 180.0 / !pi
d2r = !pi / 180.0
factor = 1.0e-07;
au = 1.4959965e+11;
hrs2rad = 15.0 * d2r

twopi = !pi * 2.0

; Define the time unit 'u', measured in units of 10000 Julian years from
; J2000.0.

u = (jd - EPOCH_2000) / 3652500.0

; Compute longitude and distance terms from the series.

sum_lon = 0.0
sum_r = 0.0
for i=0,49 do begin
   arg = sun_con_alpha[i] + sun_con_nu[i] * u
   sum_lon = sum_lon + sun_con_l[i] * sin (arg)
   sum_r = sum_r + sun_con_r[i] * cos (arg)
endfor

; Compute longitude and distance referred to mean equinox
; and ecliptic of date.

lon = 4.9353929 + 62833.1961680 * u + factor * sum_lon

lon = lon MOD twopi
if (lon lt 0.0) then lon = lon + twopi

dis = 1.0001026 + factor * sum_r

; Compute mean obliquity of the ecliptic.

t = u * 100.0
t2 = t * t
emean = (0.001813*t2*t - 0.00059*t2 - 46.8150*t + 84381.448)/SECS2RADS

; Compute equatorial spherical coordinates referred to the mean equator
```

```
    ; and equinox of date.

    sin_lon = sin (lon)
    ra = atan ((cos (emean) * sin_lon), cos (lon))
    ra = ra MOD twopi
    if (ra < 0.0) then ra = ra + twopi
    ra = ra * r2d / 15.0

    dec = asin (sin (emean) * sin_lon)

    ;print, dec, hrs2rad * ra, dis, dis*au

    return, dis
end

function read_jd_sun_pos, MTL_L1Rfilename
; This function reads the input work order file (.MTL) and returns
; Julian day of the scene center and sun position (sun elevation
; and sun azimuth) at the scene acquisition time.


    bands = [ '_B10.L1R', '_B20.L1R', '_B30.L1R', '_B40.L1R', '_B50.L1R', '_B60.L1R', '_B70.L1R' ]


;MTL_L1Rfilename='D:\Landsat7\test\L71040033_03320020820_L1R\L71040033_03320020820_MT
L.L1R'

    a = ''
    MTL_L1Rfile =''

    openr, 109, MTL_L1Rfilename
    while NOT EOF(109) do begin
        readf, 109, a
      MTL_L1Rfile = [ MTL_L1Rfile, a ]

    endwhile
    close, 109

    ;path_index = where( strpos( MTL_L1Rfile, 'Path' ) NE -1 )
    date_index = where( strpos( MTL_L1Rfile, 'ACQUISITION_DATE' ) NE -1 )
    sun_ele_index = where( strpos( MTL_L1Rfile, 'SUN_ELEVATION' ) NE -1 )
    sun_azi_index = where( strpos( MTL_L1Rfile, 'SUN_AZIMUTH' ) NE -1 )



    ;calculate Julian day
    date_split = strsplit( MTL_L1Rfile(date_index), /extract )
    date_split1=strsplit(date_split(2))
    date_split1=strsplit(date_split(2),'-', /extract)
```

```
    date_julday = julday( date_split1(1), date_split1(2), date_split1(0))


    ; Retrive Sun position
    sun_split1 = strsplit( MTL_L1Rfile(sun_ele_index), /extract )
    sun_split2 = strsplit(MTL_L1Rfile(sun_azi_index), /extract )
    SUN_ELEVATION = sun_split1(2)
    SUN_AZIMUTH = sun_split2(2)

    close, 109

     data = [date_julday,  SUN_ELEVATION,  SUN_AZIMUTH]
    return, [data]
end
```

Reference

1. Revised Landsat 5 TM Radiometric Calibration Procedures and Post-Calibration Dynamic Ranges By Chander USGS , Brian L. Markham

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3. Revised Landsat 5 Thematic Mapper Radiometric Calibration
   By Gyanesh Chander, Brian L. Markham and Julia A. Barsi

4. Improvement in absolute calibration accuracy of Landsat-5 TM with Landsat-7 ETM+ data Gyanesh Chander, Brian L. Markham, Esad Micijevic, Philippe M. Teillet, Dennis L. Helder