THE UNIVERSITY OF ARIZONA

BE/BAT 485/585

Remote Sensing Data and Methods

Lab - 8

Instructor: Kamel Didan[1,2]

Helpers: Dr. Armando Barreto[1,2]

Mr. Truman Combs[1,2]

[1]BE Dept., University of Arizona,

[2]VIP Lab.

LANDSAT: The Longest Satellite Data Record of the Earth's Land Surface

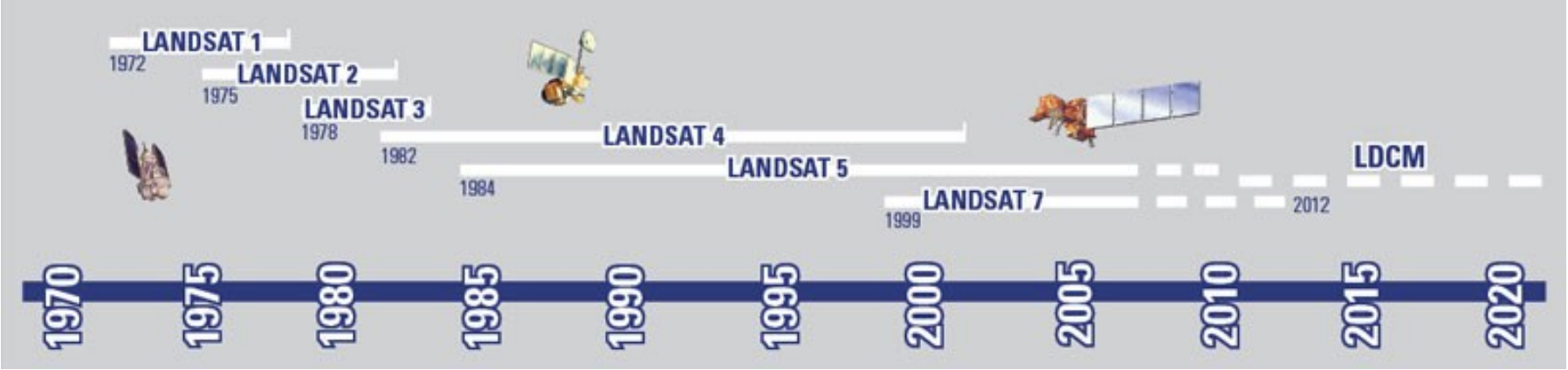
U.S. DEPARTMENT OF THE INTERIOR
INTERNATIONAL TECHNICAL ASSISTANCE PROGRAM

USAID
FROM THE AMERICAN PEOPLE

LANDSAT – 40 years of continuous data

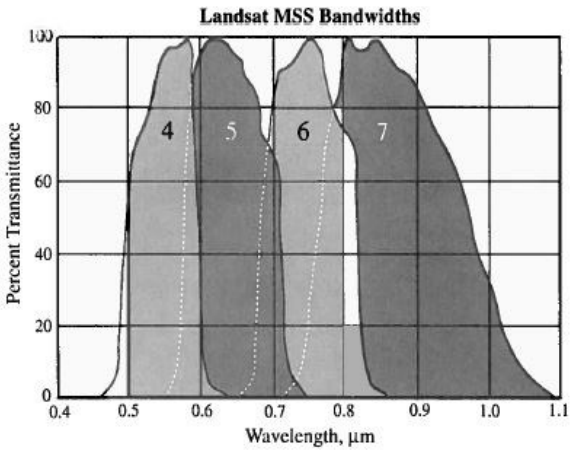
Launch Date:

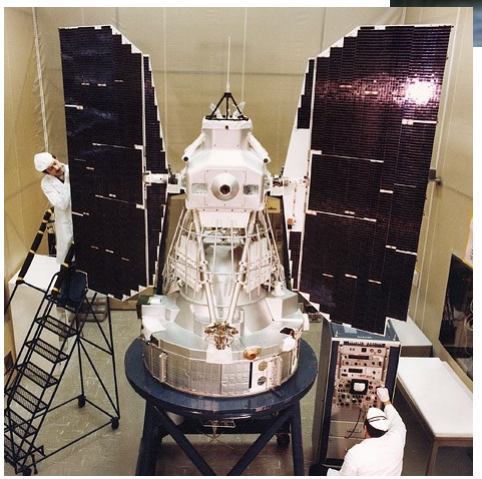
- Landsat 1 - July 23, 1972 (MSS)
- Landsat 2 - January 22, 1975 (MSS)
- Landsat 3 - March 5, 1978 (MSS)
- Landsat 4 - July 16, 1982 (TM)
- Landsat 5 - March 1, 1984 (TM, MSS)
- Landsat 6 - October 5, 1993, but never reached orbit — Failed
- Landsat 7 - April 15, 1999, May 2003 SLC-Off (ETM+) — Failed due to SLC
- Landsat 8 - February 11, 2013 (OLI, TIRS)
- Landsat 9 – Sept. 27, 2021 (OLI, TIRS)



Multi Spectral Scanner (MSS)

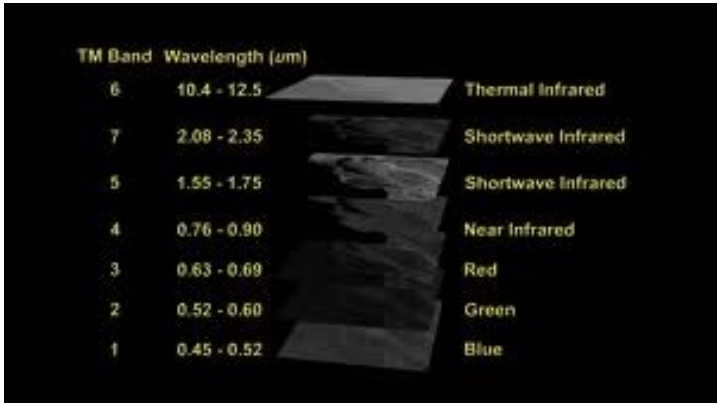
- 4 bands
- Green, red, near infra-red (x2)
- Across-track scanner
- 6 bit data format
- Spatial resolution (Instantaneous Field of View):
  - 79m x 79m





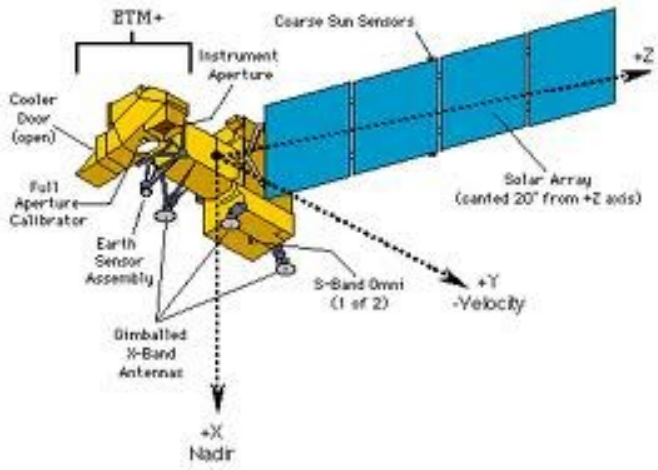
Landsat Thematic Mapper (TM)

- 7 bands
  - Blue, green, red, near-IR, mid-IR (x2), thermal
- Across-track scanner
- 8 bit data format
- Spatial resolution (IFOV):
  - 30m (non-thermal bands)
  - 120m for thermal band (b6)
- Large improvement over MSS. "twice as mu
  information exists in the TM data." – Solon



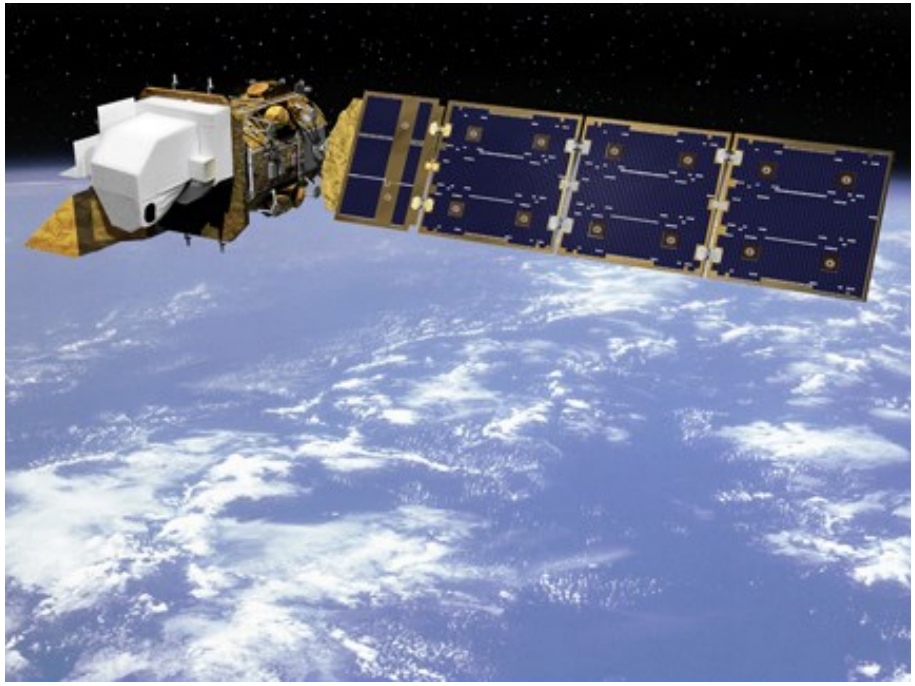
Enhanced Thematic Mapper Plus ETM+

- 8 bands: B, G, R, NIR, MIR (2), thermal, panchromatic
- Across-track scanner
- Spatial resolution (IFOV):
  - 30m for Bands 1 to 7
  - 15m for panchromatic band
  - 60m for thermal band
- Can collect in two gain settings (high or low) for increased radiometric sensitivity and dynamic range
- Vastly improved internal calibration
- 8-bit data format



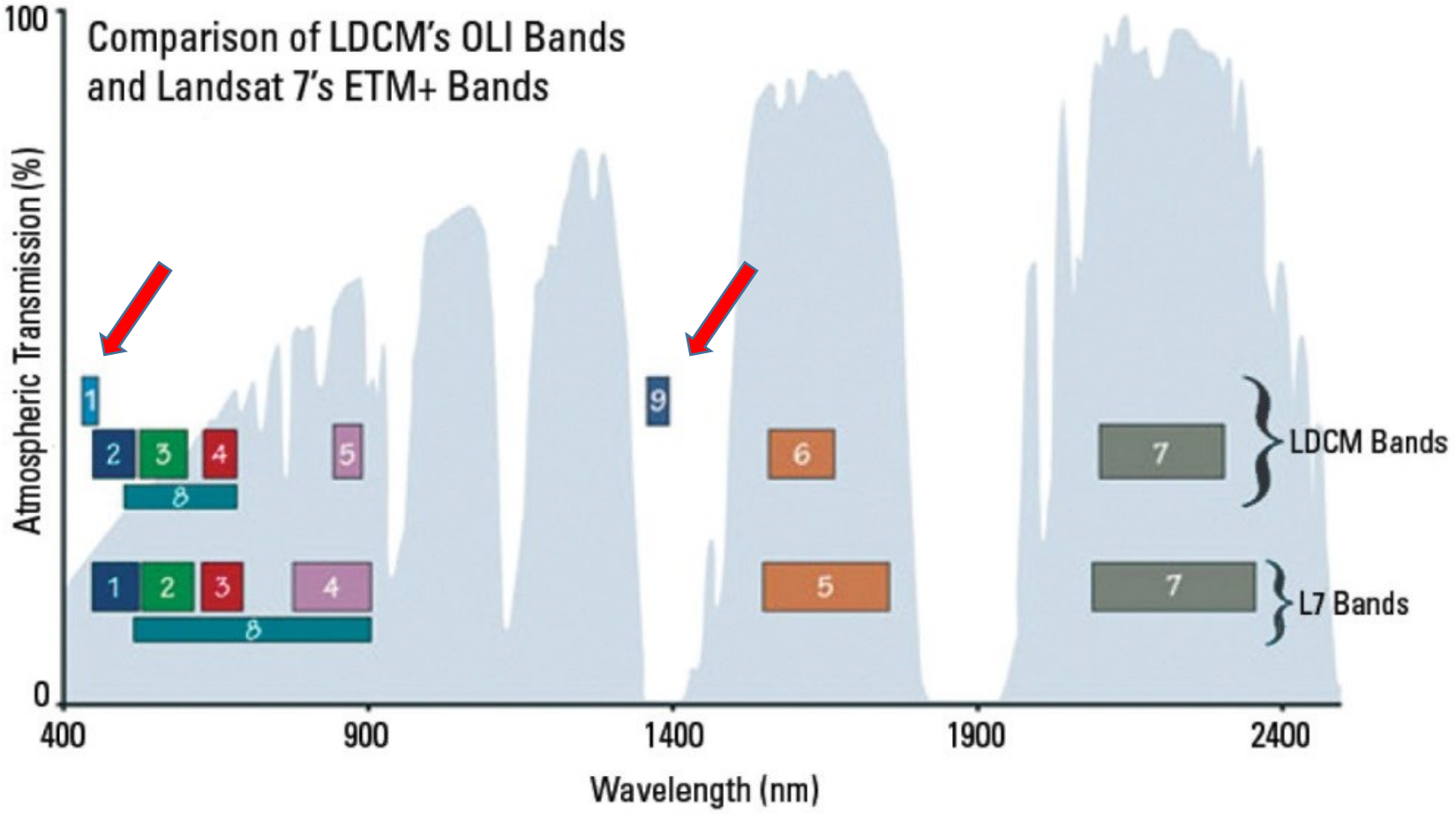
Landsat 8/9: Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)

- Landsat 8/9 both operational
- L5 decommissioned and L7 with scan-line corrector (SLC) issues
- Many enhancements over previous Landsat platforms



Landsat 8/9: Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)

11 bands: coastal aerosol, cirrus cloud and 2nd thermal band added



Landsat 8/9 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)

- Spatial resolution
  - 30m bands 1 to 7 and 9
  - 15m panchromatic
  - 100m for thermal (resampled to 30m)
- Band 1 (ultra-blue) is useful for coastal and aerosol studies.
- Band 9 is useful for cirrus cloud detection and quality control when conducting image analysis studies
- 12-bit data format

Improvements with Landsat 8/9

Landsat-7 Bands			LDCM Band Requirements			
			30 m Coastal/Aerosol	0.433 - 0.453	**(2)**	**Band 1**
Band 1	**30 m Blue**	0.450 - 0.515	**30 m Blue**	0.450 - 0.515		**Band 2**
Band 2	**30 m Green**	0.525 - 0.605	**30 m Green**	0.525 - 0.600		**Band 3**
Band 3	**30 m Red**	0.630 - 0.690	**30 m Red**	0.630 - 0.680		**Band 4**
Band 4	**30 m Near-IR**	0.775 - 0.900	**30 m Near-IR**	0.845 - 0.885	**(3)**	**Band 5**
Band 5	**30 m SWIR-1**	1.550 - 1.750	**30 m SWIR-1**	1.560 - 1.660	**(3)**	**Band 6**
Band 6	**60 m LWIR**	10.00 - 12.50	**120 m Thermal 1**	10.30 – 11.30	**(5)**	**Band 10**
			120 m Thermal 2	11.50 – 12.50	**(5)**	**Band 11**
Band 7	**30 m SWIR-2**	2.090 - 2.350	**30 m SWIR-2**	2.100 - 2.300	**(3)**	**Band 7**
Band 8	**15 m Pan**	0.520 - 0.900	**15 m Pan**	0.500 - 0.680	**(4)**	**Band 8**
			30 m Cirrus	1.360 - 1.390	**(1)**	**Band 9**

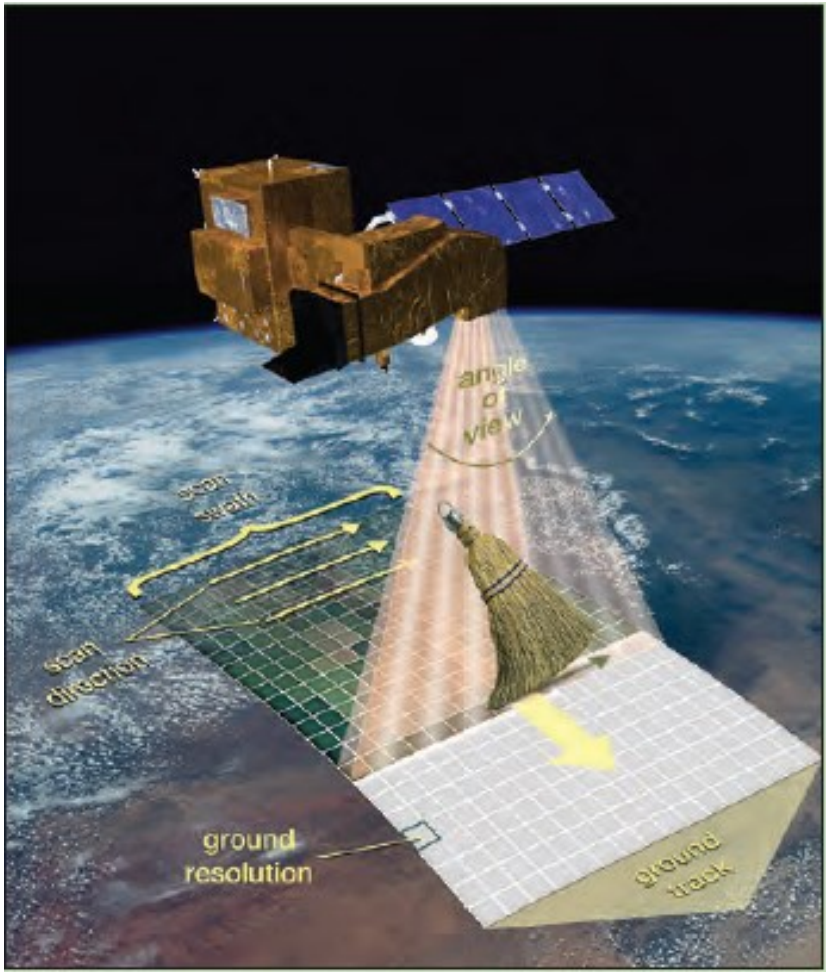
Explanation of Differences

1) Cirrus Band added to detect cirrus contamination in other channels
2) Coastal Band added at request of ocean color investigators requiring higher resolution of coastal waters relative to MODIS and SEAWifs
3) Bandwidth refinements made in all bands to avoid atmospheric absorption features
4) Panchromatic band narrowed to avoid crossing vegetation reflectance transition

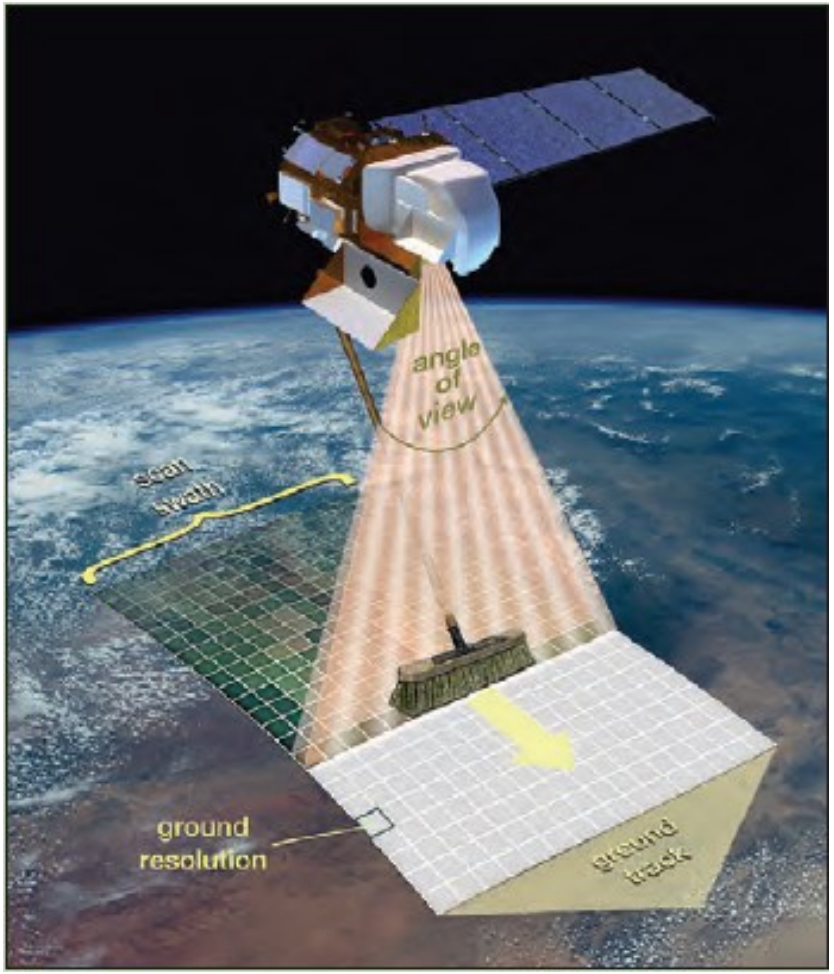
Improvements with Landsat 8/9

- 12 bit vs. 8 bit (4096 potential grey levels vs. 256)
- 5x improvement in signal to noise ratios
- Greater number of detectors
- Push-broom (along-track) vs. whiskbroom (across-track) scanner (no moving mirror)
- Addition of a 2nd thermal infrared channel improves temperature measurements
- Coastal aerosol band enables detection of additional water column constituents

Sensor Architecture Evolution



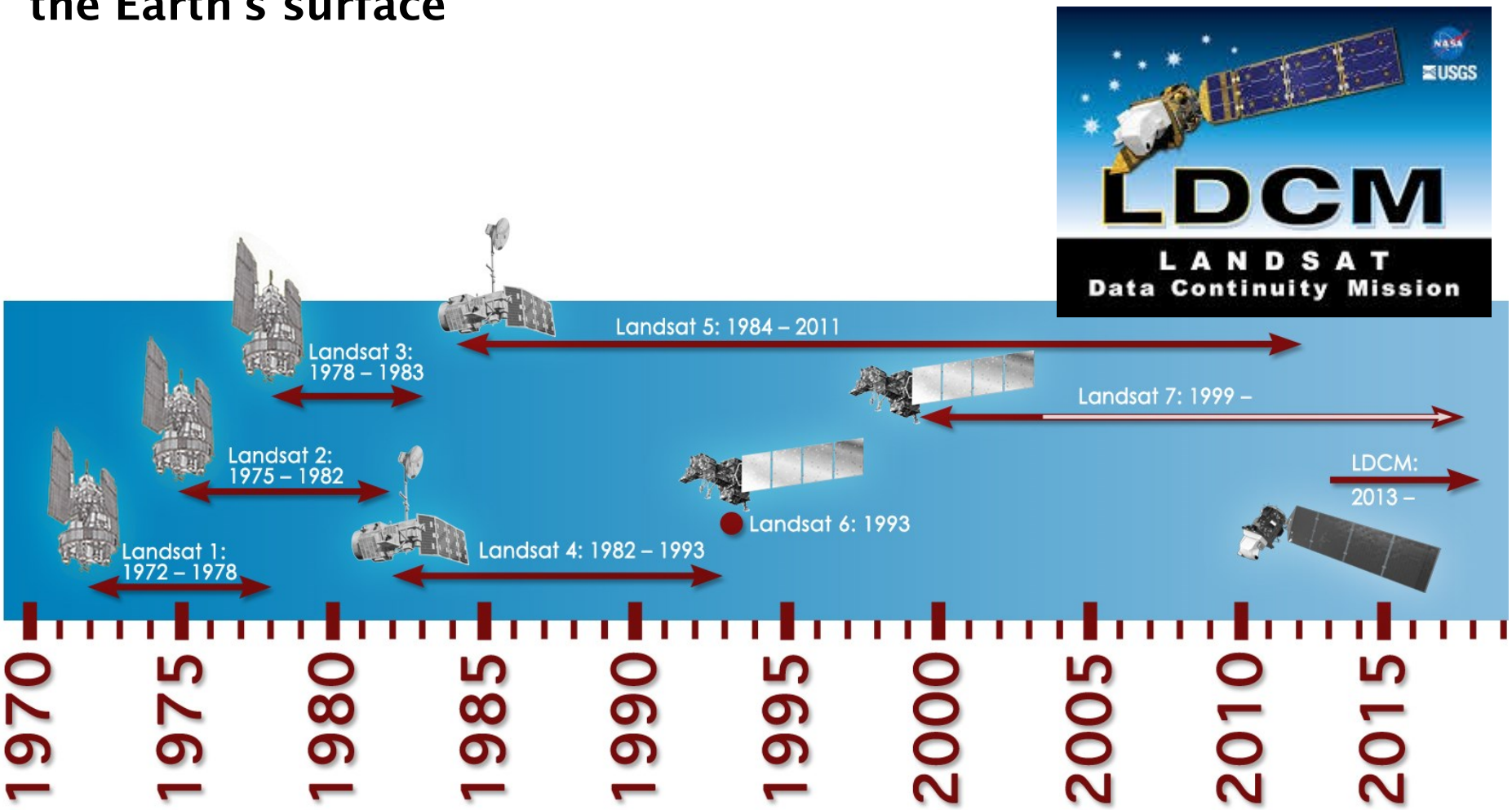
Whisk broom



Push broom

LANDSAT Data Continuity Mission

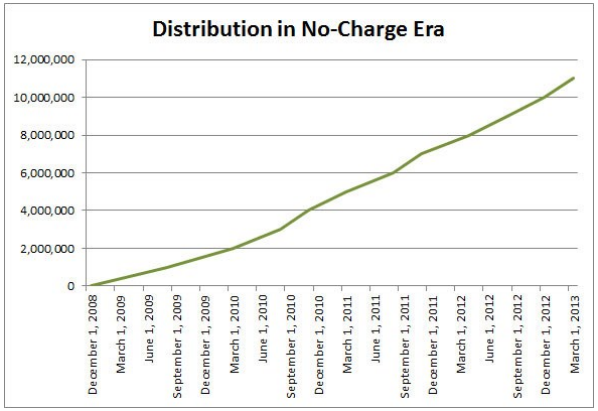
Landsat 8 continues the Landsat mission of collecting data about the Earth's surface



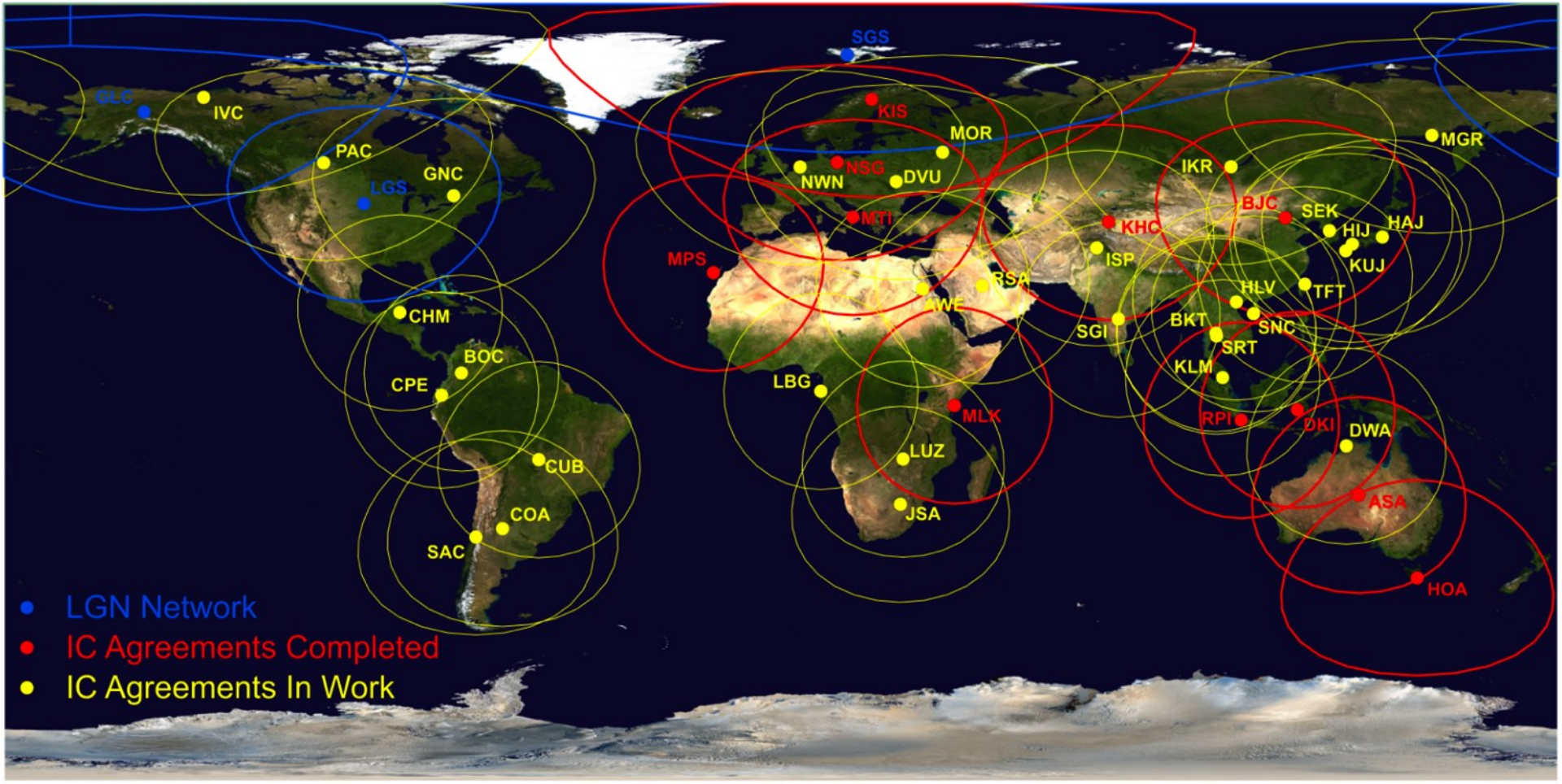
LANDSAT Data Continuity Mission

Landsat has created the longest and most comprehensive record of the Earth's condition ever assembled.

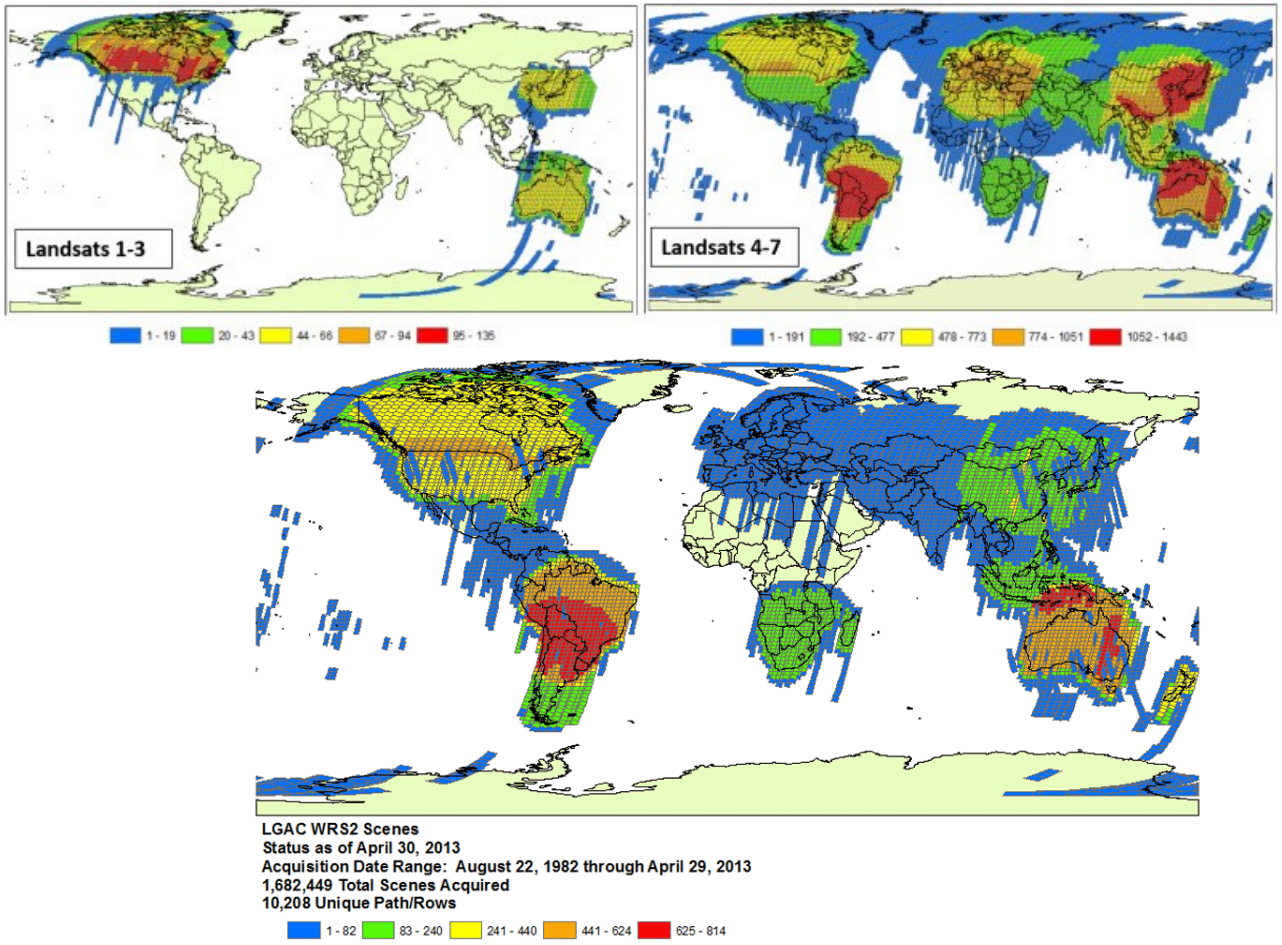
- **In addition to collecting data, dissemination of that data is critical.**
- **USGS began offering all Landsat data free of charge in 2008!**
- **USGS is also working with other countries to "repatriate" historic Landsat imagery.**
  - **This will provide a safe repository for those data and will also continue to improve the data with updated ground processing techniques**



Potential LDCM International Cooperators

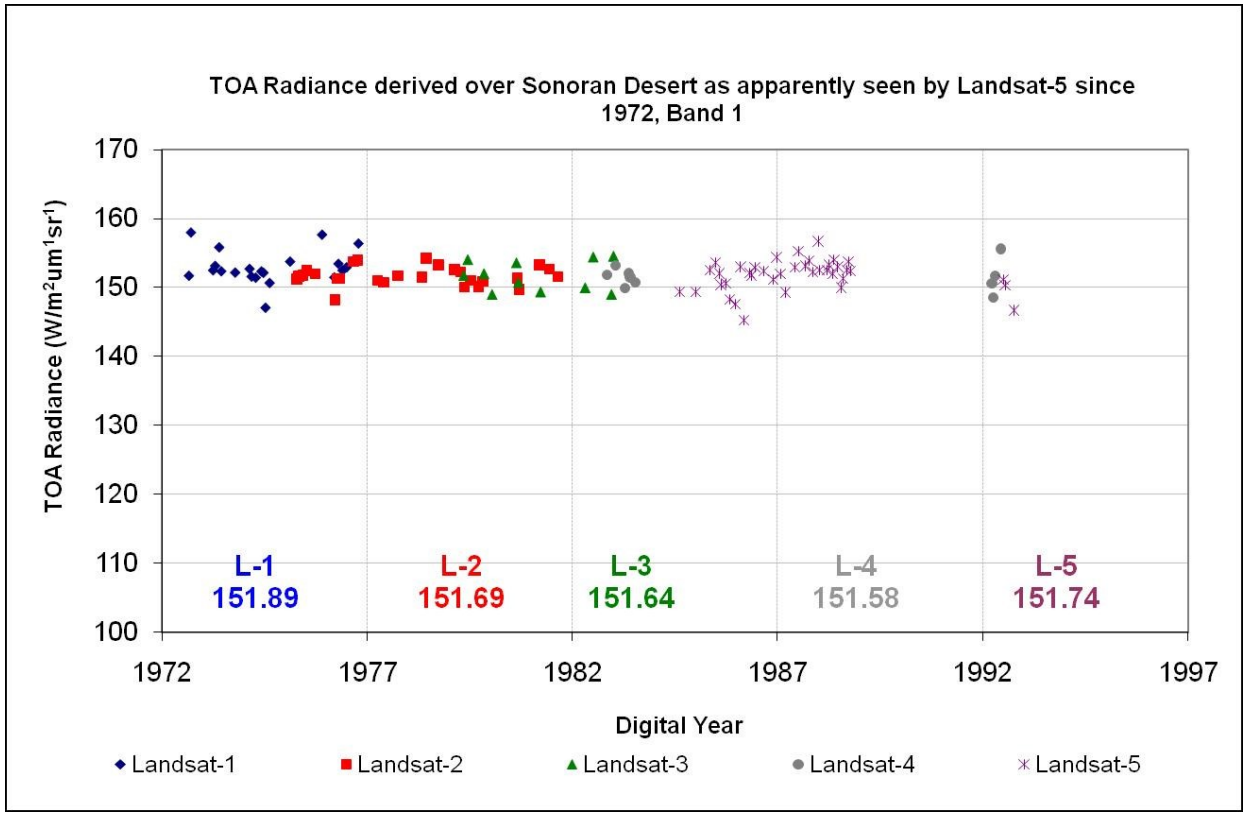


LANDSAT distribution (power of free)



- All Landsat images are available to anyone at no cost.
- Almost 3 million images are distributed to users in over 180 nations and territories each year.

Landsat Data Continuity Mission (LCDM)



Data consistency is important across platforms

L8 calibrated to L7 for consistency in long-term analyses

- **Performed 2 day underflight of L7 and L8 to calibrate**

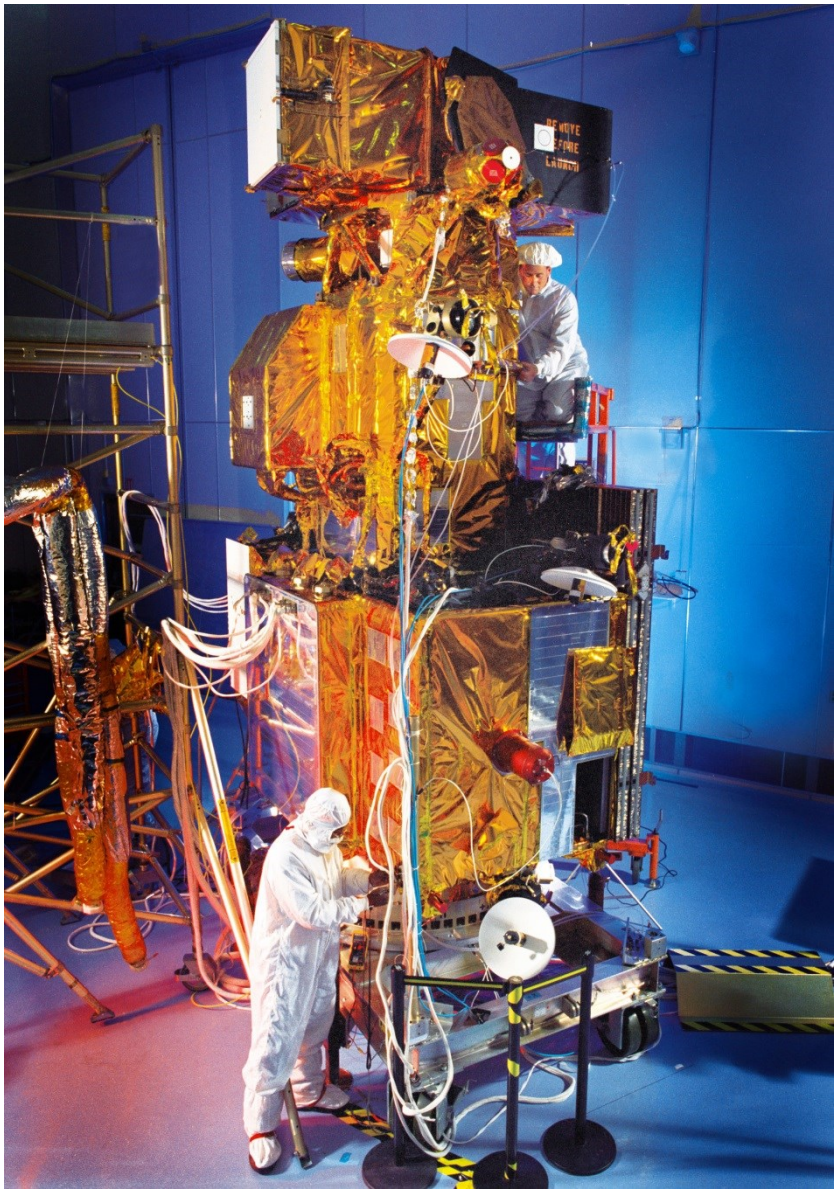
Landsat Data Continuity Mission (LCDM)

- All images reprocessed using updated methodology
- Using more standardized format for all products:

Pixel size:	**15m/30m/30m**
Media type:	**FTP**
Product type:	**Level-1T (precision, terrain correction)**
Output format:	**GeoTIFF**
Map projection:	**UTM (Polar Stereographic for Antarctica)**
Datum:	**WGS84**
Orientation:	**North up**
Resampling:	**Cubic convolution**
Accuracy:	**OLI 12m circular error, 90% confidence**
	TIRS 41m circular error, 90% confidence

Landsat Global Archive Consolidation

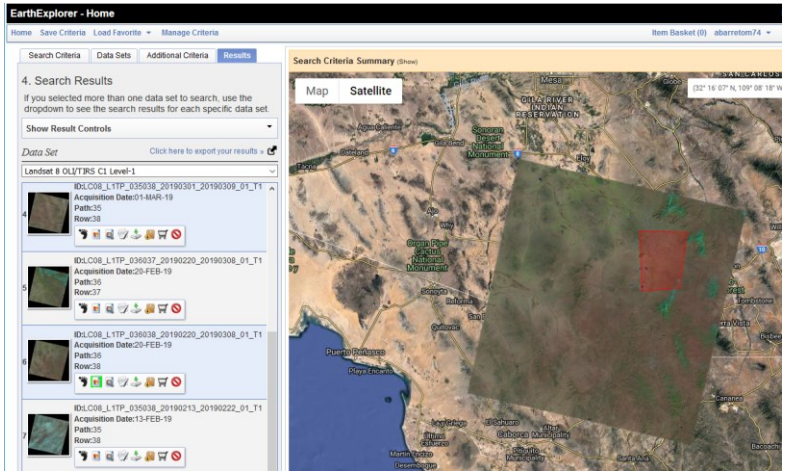
- All imagery housed at Earth Resources Observation and Science (EROS) Data Center in South Dakota, USA
  - With offsite backup
- Imagery processed upon request
- New OLI acquisitions should be available within one day
- As repatriated data are successfully ingested, the Landsat scenes will become immediately available for download at no charge from EarthExplorer (http://earthexplorer.usgs.gov) or GloVis (http://glovis.usgs.gov).



Landsat data

Data from: https://earthexplorer.usgs.gov/

Landsat data comes compressed as **tar.gz** files : Ex: LC08_L1TP_036038_20190220_20190308_01_T1.tar.gz



After extraction (individual tif files for each band):

```
LC08_L1TP_036038_20190220_20190308_01_T1_B1.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_B2.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_B3.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_B4.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_B5.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_B6.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_B7.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_B8.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_B9.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_B10.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_B11.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_BQA.TIF
LC08_L1TP_036038_20190220_20190308_01_T1_ANG.txt
LC08_L1TP_036038_20190220_20190308_01_T1_MTL.txt
```

Metadata text file

```
GROUP = L1_METADATA_FILE
  GROUP = METADATA_FILE_INFO
    ORIGIN = "Image courtesy of the U.S. Geological Survey"
    REQUEST_ID = "0701903089133_00019"
    LANDSAT_SCENE_ID = "LC80360382019051LGN00"
    LANDSAT_PRODUCT_ID = "LC08_L1TP_036038_20190220_20190308_01_T1"
    COLLECTION_NUMBER = 01
    FILE_DATE = 2019-03-08T15:13:43Z
    STATION_ID = "LGN"
    PROCESSING_SOFTWARE_VERSION = "LPGS_13.1.0"
  END_GROUP = METADATA_FILE_INFO
  GROUP = PRODUCT_METADATA
    DATA_TYPE = "L1TP"
    COLLECTION_CATEGORY = "T1"
    ELEVATION_SOURCE = "GLS2000"
    OUTPUT_FORMAT = "GEOTIFF"
    SPACECRAFT_ID = "LANDSAT_8"
    SENSOR_ID = "OLI_TIRS"
    WRS_PATH = 36
    WRS_ROW = 38
    NADIR_OFFNADIR = "NADIR"
    TARGET_WRS_PATH = 36
    TARGET_WRS_ROW = 38
    DATE_ACQUIRED = 2019-02-20
    SCENE_CENTER_TIME = "17:57:57.0958719Z"
```

```
ROLL_ANGLE = -0.001
SUN_AZIMUTH = 146.19954259
SUN_ELEVATION = 41.01501145
EARTH_SUN_DISTANCE = 0.9887457
```

```
GROUP = RADIOMETRIC_RESCALING
  RADIANCE_MULT_BAND_1 = 1.2843E-02
  RADIANCE_MULT_BAND_2 = 1.3152E-02
  RADIANCE_MULT_BAND_3 = 1.2119E-02
  RADIANCE_MULT_BAND_4 = 1.0220E-02
  RADIANCE_MULT_BAND_5 = 6.2538E-03
  RADIANCE_MULT_BAND_6 = 1.5553E-03
  RADIANCE_MULT_BAND_7 = 5.2421E-04
  RADIANCE_MULT_BAND_8 = 1.1566E-02
  RADIANCE_MULT_BAND_9 = 2.4441E-03
  RADIANCE_MULT_BAND_10 = 3.3420E-04
  RADIANCE_MULT_BAND_11 = 3.3420E-04
  RADIANCE_ADD_BAND_1 = -64.21606
  RADIANCE_ADD_BAND_2 = -65.75803
  RADIANCE_ADD_BAND_3 = -60.59546
  RADIANCE_ADD_BAND_4 = -51.09750
  RADIANCE_ADD_BAND_5 = -31.26912
  RADIANCE_ADD_BAND_6 = -7.77635
  RADIANCE_ADD_BAND_7 = -2.62105
  RADIANCE_ADD_BAND_8 = -57.82831
  RADIANCE_ADD_BAND_9 = -12.22068
  RADIANCE_ADD_BAND_10 = 0.10000
  RADIANCE_ADD_BAND_11 = 0.10000
```

```
REFLECTANCE_MULT_BAND_1 = 2.0000E-05
REFLECTANCE_MULT_BAND_2 = 2.0000E-05
REFLECTANCE_MULT_BAND_3 = 2.0000E-05
REFLECTANCE_MULT_BAND_4 = 2.0000E-05
REFLECTANCE_MULT_BAND_5 = 2.0000E-05
REFLECTANCE_MULT_BAND_6 = 2.0000E-05
REFLECTANCE_MULT_BAND_7 = 2.0000E-05
REFLECTANCE_MULT_BAND_8 = 2.0000E-05
REFLECTANCE_MULT_BAND_9 = 2.0000E-05
REFLECTANCE_ADD_BAND_1 = -0.100000
REFLECTANCE_ADD_BAND_2 = -0.100000
REFLECTANCE_ADD_BAND_3 = -0.100000
REFLECTANCE_ADD_BAND_4 = -0.100000
REFLECTANCE_ADD_BAND_5 = -0.100000
REFLECTANCE_ADD_BAND_6 = -0.100000
REFLECTANCE_ADD_BAND_7 = -0.100000
REFLECTANCE_ADD_BAND_8 = -0.100000
REFLECTANCE_ADD_BAND_9 = -0.100000
```

Exercise #1

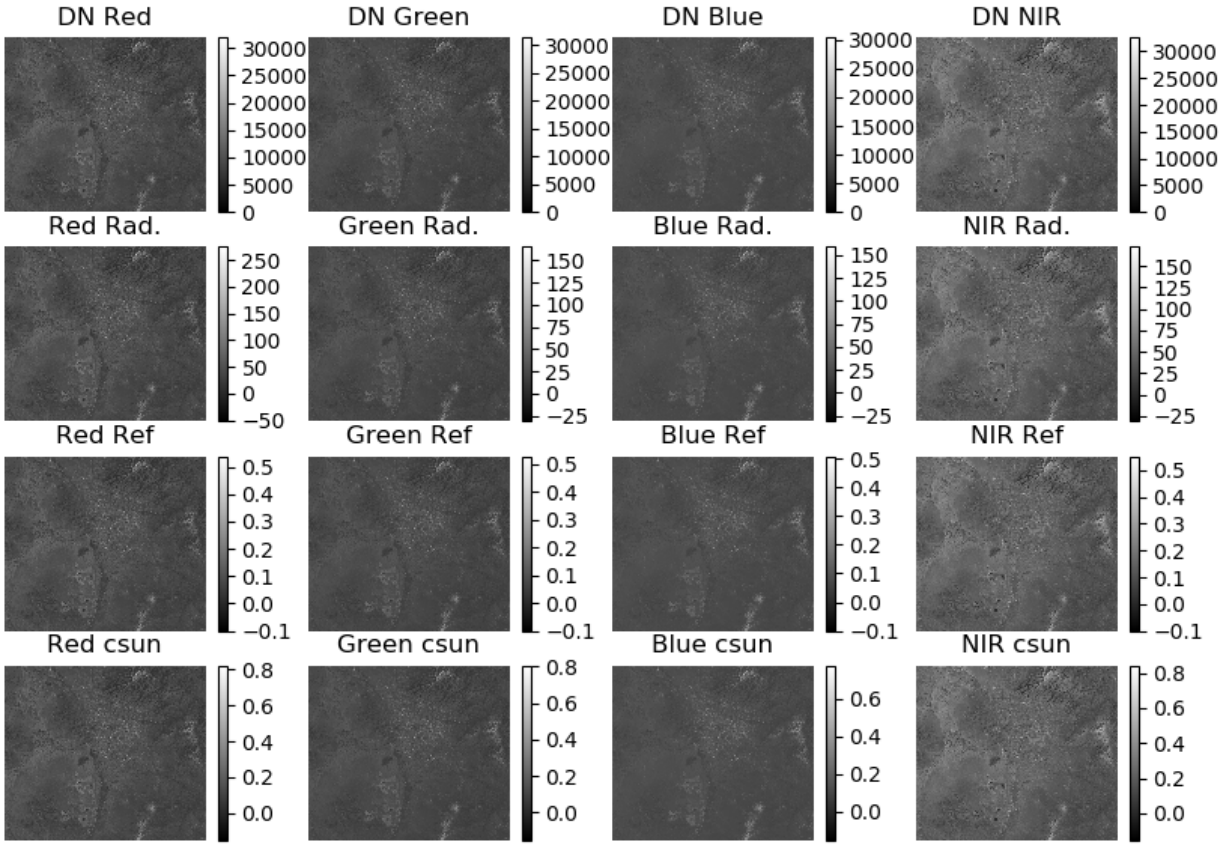
- **Read a Landsat 8/OLI BSQ File**
  - This is your usual BSQ file format
  - Red, Green, Blue, NIR, MIR bands
- **Image calibration pipeline**
  - **(1) DN → (2) Radiance → (3) Surface reflectance → (4) Surface reflectance corrected for sun angle**
  - Save calibrated images to a new BSQ file
- **Homework**
  - The notebook example shows calibration for two bands (Red + NIR)
    - Complete the calibration for all other bands
    - Create images of all bands after each processing stage (**DN → Radiance → Surface reflectance → Surf Refl Corr for sun angle)**
    - Create true color images after each processing stage
  - You should recall this from earlier lab work
    - Extract spectral signatures for two or more features from all stages
      - Be thorough and creative and label the images properly (like we did before & in the exam)
    - Extract a transect (a line in any direction) from each stage and plot them on the same plot for each band separately
      - Be creative also and consider using a scale so plots show properly

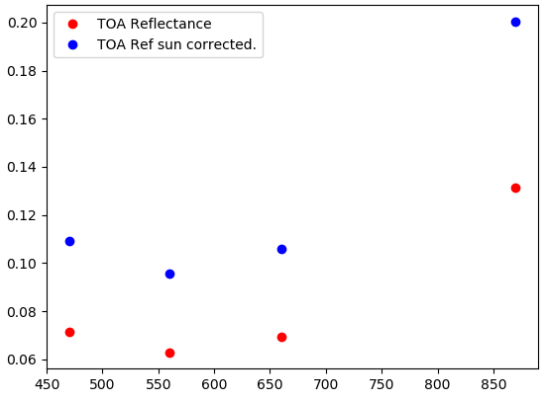
Instructions:

- From D2L : Download files:
  - HDF file: LANDSAT8.A2020006.DN.Tucson.bsq
  - Metadata file: LC08_L1TP_036038_20190220_20190308_01_T1.MLT
  - Python Notebook: BE485_Lab8_Ex2.ipynb (you will be modifying and adding to this)

Calibration Results

LANDSAT
Bands calibration



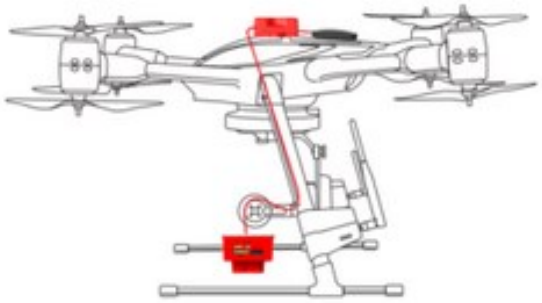


Spectral signature

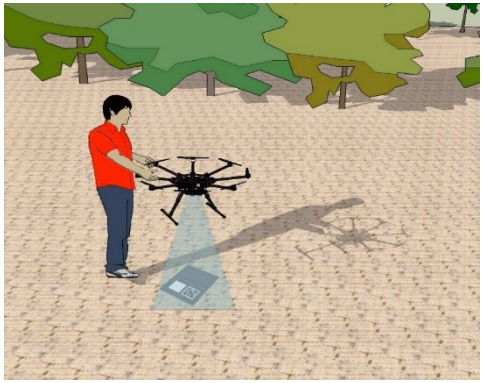
```
Reading BSQ  LANDSAT8.A2019051.DN.Tucson.bsq
Applying LANDSATcorrections:
Displaying calculation for pixel row=20, col=20 RED band...
DN pixel= 8791
TOA Radiance pixel= 37.86902
TOA Reflectance pixel= 0.07582
TOA Ref corrected pixel= 0.11553405154098675
saving  RED
saving  NIR
program ended.
```

Multispectral Imaging with UAS/Drones

Micasense RedEdge camera
Green, Red, NIR, Rededge bands

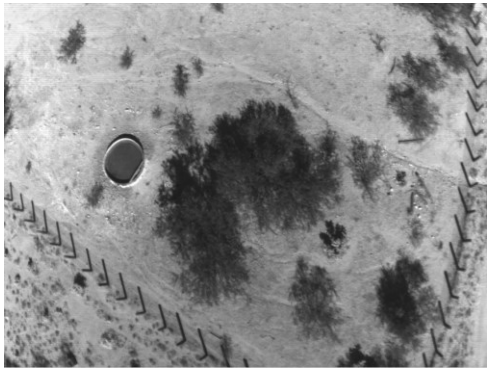


Compact/small multispectral cameras mounted on drones can be used to collect multispectral observations of fields at sub-cm resolution. Most cameras will save a separated image per band in a “tif” format. Each pixel is a Digital Number (DN) recorded by the optical sensor. The DN values must be converted to reflectance during post-processing to be useful.
Calibration plates are one way to standardize & radiometrically calibrate the images. The calibration (plate) target enables the generation of an absolute (traceable) reference value, which allows the generation of absolute reflectance values and hence makes it possible to compare data coming from different cameras, flights, or times.



Taking an image of calibration plate

The necessary radiometric calibration images can be taken immediately before or after each flight, or during the flight. It is important that the weather and lighting conditions are as similar as possible to the ones during the flight.



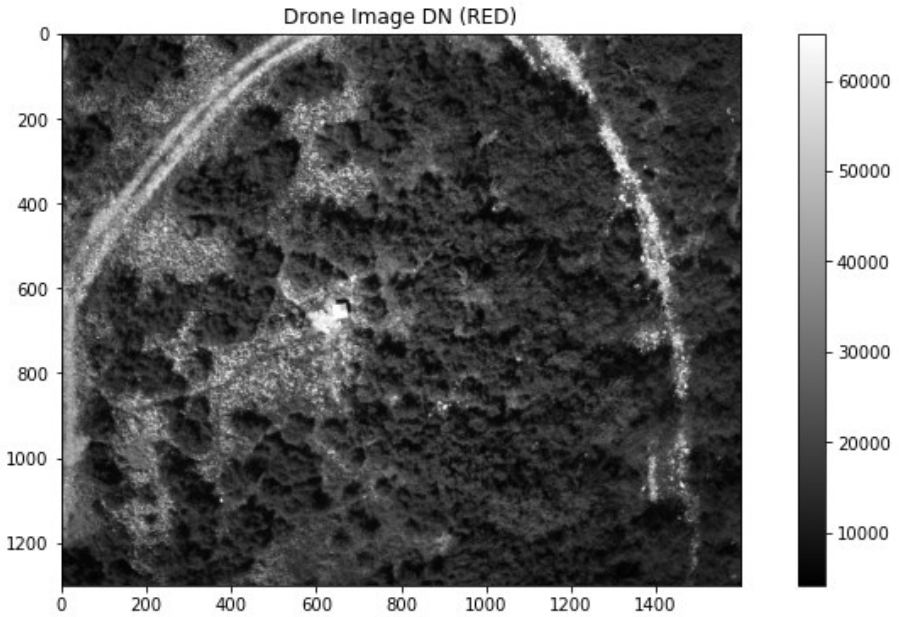
Exercise #2: UAS/Drone Image Calibration

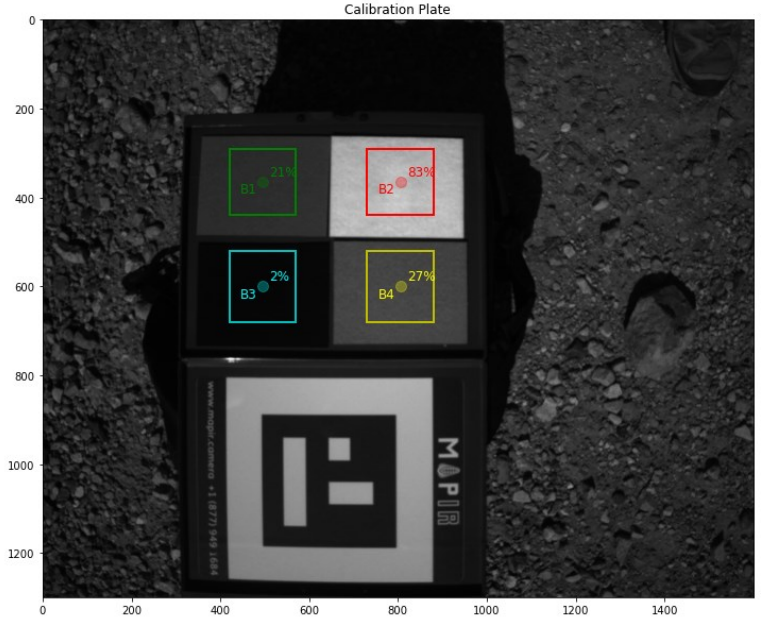
- **Data Input**
  - Multispectral drone images (tif)
    - Red, NIR, Green and RedEdge
    - Regular image
  - Calibration plate images
    - Image used for calibration
- **Processing**
  - Calibration Plate
    - Read, Display, Draw a Region of Interest (ROI) rectangular area on the plate
    - Get average signal for that ROI
    - Calculate the Gain (slope) and Offset (Intercept) parameters for the calibration equation and for each band
  - Drone imagery
    - Read, Display, Calculate the Reflectance
    - Display images of corrected bands (Before and After)
- **Homework**
  - Process the calibration plate and drone images for the other bands
  - Generate histogram of before and after

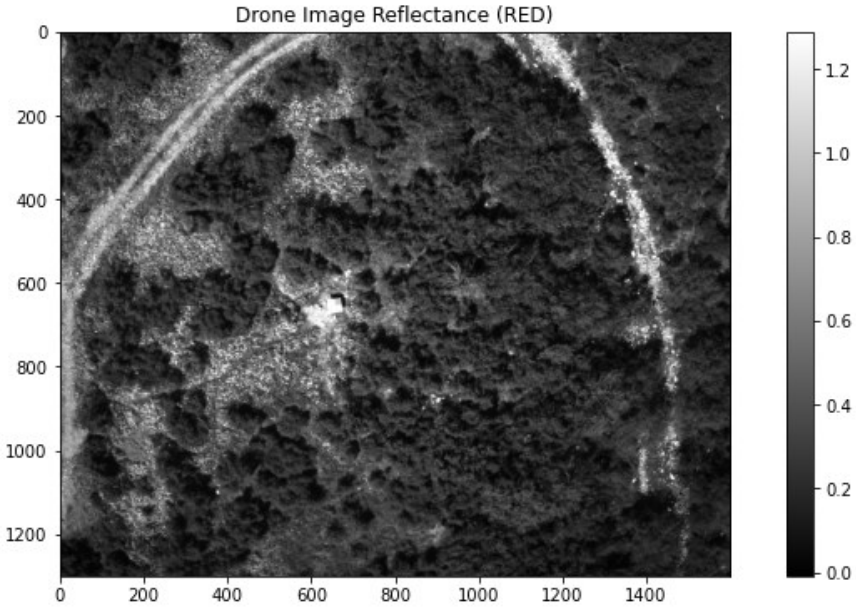
Instructions:

- Download from D2L files:
  - BE485_Lab8_ex2.ipynb

- Calibration plate images:
  - P1_***_0002_090721_102608_G00_H109_A1160_R000_CAL.TIF
  - ***: RED, NIR, BLU, REG, GRE
- Drone images:
  - P1_***_0069_090721_103316_G10_H089_A1230_R071.TIF
  - ***: RED, NIR, BLU, REG, GRE







Mapir	Dark (2%)	DarkGray (21%	LightGray (27%	White (83%)
BLUE	0.01999	0.18548	0.25098	0.79629
GREEN	0.01955	0.19733	0.26648	0.87157
RED	0.01925	0.20229	0.26674	0.87689
REDEDGE	0.01945	0.21728	0.26662	0.8753
NIR	0.02014	0.23223	0.27964	0.86702