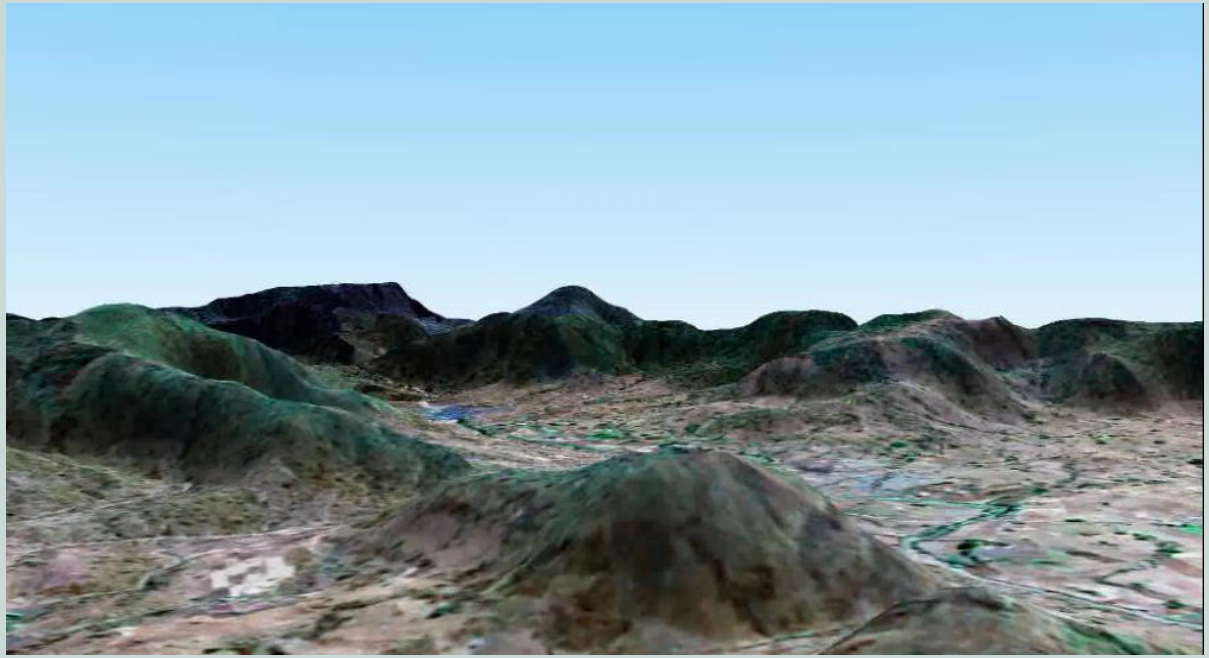
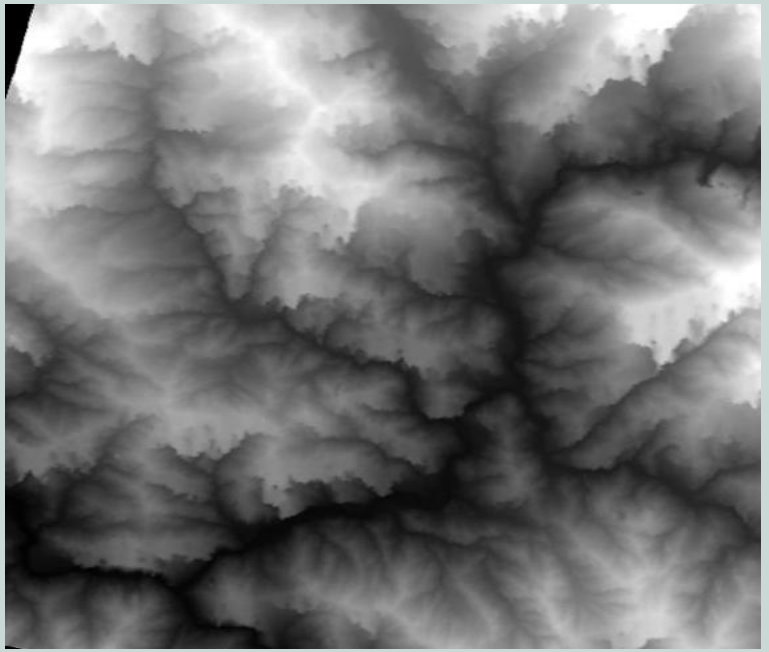
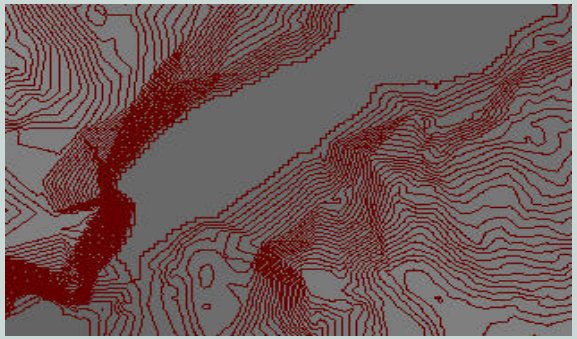
2.5m resolution stereo image from Cartosat-1- DEM draped.



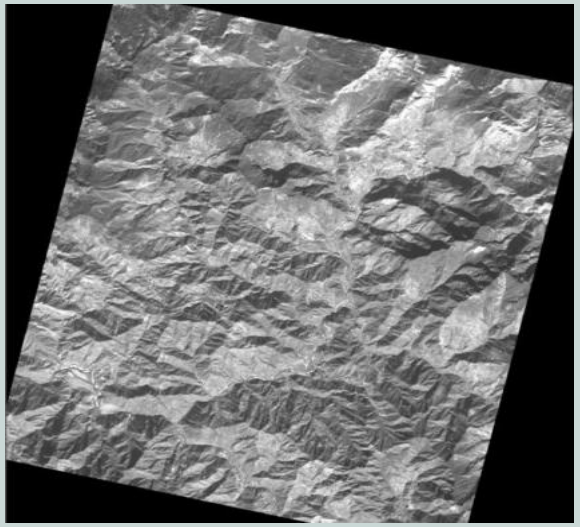
DEM





CONTOUR

ORTHO



Stereo imaging capability

NewSpace is Disruptive

- **NewSpace takes advantage of**:
  - Advances in micro and nanosatellites,
  - Using Commercially-Off-The-Shelf (COTS) components
  - Bulk production processes, and,
  - adopting constellation approach– enhanced throughput
  - Aim at provisioning data or services at revolutionary costs and never before achieved revisits

New Space EO...

- Least dependence on governments for financing.
- Reconfiguration of value chain which legacy system find it difficult to adapt.
- Converging into other larger industry and business segments in Information Technology enabled services using the power of Cloud technology, Artificial Intelligence and Machine Learning.
- An ensemble of several innovations that give power to NewSpace.

- New space trend involves not only start-ups but also big web actors with substantial investment capacity.
- Aim to transforming space into a commodity, taking benefit from the convergence between Information technology and EO.
- For Earth observation markets, target is high resolution and high revisit.
- EO Data Buckets in Big Data domain in a significant manner

Remote Sensing Systems (Legacy)

Table 2.1 Characteristics of selected satellite sensors. (Adapted from Rogan and Chen 2004; updated for this publication)

Sensor (mission)	Organization[a]	Operation period	Swath width (km)	Spatial resolution (m)[b]	Temporal resolution	Radiometric resolution	Spectral resolution (μm)	Spectral bands
MSS (Landsat 1–5)	NASA, US	1972–1992	185	80 (MS), 240 (TIR)[c]	16–18 days	8-bit	0.5–1.1, 10.4–12.6[c]	4–5[c]
TM (Landsat 4, 5)	NASA, US	1982–2011	185	30 (MS), 120 (TIR)	16 days	8-bit	0.45–2.35, 10.4–12.5	7
ETM+ (Landsat 7)	NASA, US	1999	185	15 (PAN), 30 (MS), 60 (TIR)	16 days	8-bit	0.52–0.9 (PAN), 0.45–2.35, 10.4–12.5	7+ PAN
OLI (Landsat 8)	NASA, US	2013	185	15 (PAN), 30 (MS)	16 days	12-bit	0.5–0.68 (PAN), 0.433–0.453 (coastal/aerosol), 0.45–2.3, 1.36–1.39 (cirrus)	8+ PAN
TIRS (Landsat 8)	NASA, US	2013	185	100	16 days	12-bit	10.6–11.2, 11.5–12.5	2
MODIS (EOS Terra and Aqua)	NASA, US	1999	2300	250 (PAN), 500 (VNIR), 1000 (SWIR)	1–2 days	12-bit	0.620–2.155, 3.66–14.385	36
ASTER (EOS Terra)	NASA,US; METI, Japan	1999	60	15 (VNIR), 30 (SWIR), 90 (TIR)	4–16 days	8-bit (VNIR/SWIR), 12-bit (TIR)	0.52–0.86, 1.60–2.43, 8.125–11.65	14
Hyperion (EO-1)	NASA, US	2000	7.5	30	16 days	12-bit	0.353–2.577	220
ALI (EO-1)	NASA, US	2000	37	10 (PAN), 30 (MS)	16 days	12-bit	0.48–0.69 (PAN), 0.433–2.35	9+ PAN
OMI (EOS Aura)	NIVR, Netherlands; FMI, Finland; NASA, US	2004	2600	13,000 × 48,000, 13,000 × 24,000[d]	1 day	12-bit	0.27–0.5	740
CALIOP (CALIPSO)	NASA, US; CNES, France	2006	0.1	333	16 days	22-bit[e]	0.532, 1.064	2[f]

Remote Sensing Systems (Legacy)

Table 2.1 (continued)

Sensor (mission)	Organization[a]	Operation period	Swath width (km)	Spatial resolution (m)[b]	Temporal resolution	Radiometric resolution	Spectral resolution (μm)	Spectral bands
VIIRS (Suomi NPP)	NASA, US; NOAA, US	2011	3000	375 or 750 depending on application	12 h	12-bit	0.41–12.5	21 + Day/Night PAN
Aquarius (SAC-D)	NASA, US; CONAE, Argentina	2011	390	150	7 days		3 L-band microwave radiometer beams + radar	N/A
AVHRR (NOAA 6–19; Metop-A, -B)	NOAA, US; EUMETSAT	1978[g]	2700	1100	12 h	10-bit	0.58–12.5	6[h]
I-M Imager (GOES 12–15)	NESDIS, US	1975[i]	8	1000 (VNIR), 4000 (SWIR), 8000 (moisture), 4000 (TIR)	0.25–3 h	10-bit	0.55–12.5	5
HICO (International Space Station)	Office of Naval Research (ONR), US; NASA, US	2009–2014	42 × 192[j]	90	~3 days	14-bit	0.353–1.08 (0.4–0.9)[k]	128 (87)[k]
SAR (RADARSAT-2)	CSA, Canada	2007	20–500[l]	3-100[l]	24 days[m]		C-band radar	N/A
VEGETATION (Proba-V)	ESA	2013	2250	100/350[n]	1–2 days[o]	12-bit	0.438–1.634	4
SAR (Sentinel-1 A)	ESA	2014	20–250[l]	5–40[l]	12 days		C-band radar	N/A
PMC (Gaofen-1)	CNSA, China	2013	69	2 (PAN), 8 (MS)	4 days	10-bit	0.45–0.9 (PAN), 0.45–0.89	4+ PAN
WFI (Gaofen-1)	CNSA, China	2013	830	16	4 days	10-bit	0.45–0.89	4
HROI (Gaofen-2)	CNSA, China	2014	48	0.8 (PAN), 3.2 (MS)	?[p]	?[p]	?[p]	?[p]
MUXCAM (CBERS-4)	CBERS, China/Brazil	2014	120	20	26 days	8-bit	0.45–0.89	4
PANMUX (CBERS-4)	CBERS, China/Brazil	2014	60	5 (PAN), 10 (MS)	52 days	8-bit	0.51–0.73 (PAN), 0.52–0.89	3+ PAN

Remote Sensing Systems (Legacy) ….continued

Table 2.1 (continued)

Sensor (mission)	Organization[a]	Operation period	Swath width (km)	Spatial resolution (m)[b]	Temporal resolution	Radiometric resolution	Spectral resolution (μm)	Spectral bands
IRSCAM (CBERS-4)	CBERS, China/ Brazil	2014	120	40 (NIR/SWIR), 80 (TIR)	26 days	8-bit	0.77–12.5	4
WFICAM (CBERS-4)	CBERS, China/ Brazil	2014	866	64	5 days	10-bit	0.45–0.89	4
LISS-IV (RESOURCESAT-2)	ISRO, India	2011	70	5.8	24 days	10-bit	0.52–0.86	3
LISS-III (RESOURCESAT-2)	ISRO, India	2011	141	23.5	24 days	10-bit	0.52–1.70	4
AWiFS (RESOURCESAT-2)	ISRO, India	2011	740	56	24 days	12-bit	0.52–1.70	4
TANSO-FTS (GOSAT/Ibuki)	JAXA, Japan	2009	160[q]	10.5	3 days		0.758–14.3	4
Geoton-L1 (Resurs-P No. 1, No. 2)	Roscosmos, Russia	2013, 2014	32 (PAN), 38 (MS)	1 (PAN), 3–4 (MS)	3 days	10-bit	0.58–0.8 (PAN), 0.45–0.80	5+ PAN
KShMSA-VR/SR (Resurs-P No. 1, No. 2)	Roscosmos, Russia	2013, 2014	97 (VR mode), 440 (SR mode)	VR: 12 (PAN), 24 (MS); SR: 60 (PAN), 120 (MS)	3 days	12-bit	0.43–0.7 (PAN), 0.43–0.9	5+ PAN
GSA (Resurs-P No.1, No.2)	Roscosmos, Russia	2013, 2014	25	30	3 days	14-bit	0.4–1.1 nm band width	130
COSI (KOMPSAT-5)	KARI, South Korea	2013	5-100[l]	1–20[l]	28 days		X-band radar	N/A
AEISS-A (KOMPSAT-3 A)	KARI, South Korea	2015	12	0.55 (PAN), 2.2 (MS)	28 days	14-bit	0.45–0.9 (PAN), 0.45–0.9	4+ PAN
IIS (KOMPSAT-3 A)	KARI, South Korea	2015	12	5.5	28 days	14-bit	3.3–5.2	1
HRVIR (SPOT 4)	Airbus Group, France[r]	1998–2013	60	10 (PAN), 20 (MS)	26 days[s]	8-bit	0.61–0.68 (PAN), 0.50–1.75	4+ PAN

New Space EO system examples

No	Private EO Missions	Observations
1	Planet (US)	300 dove constellation; <20kgs each – 3m and 90 cms; Daily Earth coverage
2	Urthecast (US)	ISS based payloads; Deimos OptiSar (670/1400kg) combination; 1m SAR and optical data; Spot-scan coverage
3	Jilin (China)	60 satellites (~100-200kgs); 72cm imaging and UHD video; aims for all-weather data
4	Satellogic (Arg.)	~300 (when complete) smallsats (~35kgs); 1m XS and 2-hourly revisit
5	AstroDigital (US)	25+ smallsats (~10-20 kgs); 2.5m GSD; Daily coverage of Earth
6	NOVASAR (UK)	SAR satellites (~400kgs); SAR strip; 6m S-Band SAR small strips

Quantum leaps in onboard technologies

- Processor speeds up by million times in 40 years
- Storage capacity up from typical 10 GB (late 1990's) to 8 TB (2010)
- Solar power generators 100$/watt (1970) to 5 $/Watt (2010)---- Inflatable lightweight arrays
- Data transmission..X-band upto 1Gbps;
- With Adaptive Coding and Modulation… 1 TB per day;
- Higher bandwidth through use of 26 GHz band link;
- LEO-GEO- High Altitude Platform- Ground link using optical communications, upto 76 Tb per day possible.

Quantum leaps in onboard technologies

- Advent of Agile satellites for spot imaging

Example: Pleiades Agility for roll or pitch 60 degrees in 25 secs

- Improvement of specific energy densities from 40Wh/Kg (Ni Hydride) to >100 Wh/Kg (Lithium Ion)

- Synthetic Aperture Radar

From 8m resolution (RADARSAT,1995) to 1 m (TerraSAR-X, 2007) and even 25 cm resolution in *staring spot light* mode

Satellite's overall platform technologies

Legacy

Landsat 8

image: usgs.gov

Mass 2071 Kg.
9 Visible + 2 IR bands,
15m & 30m resolution
12 bit radiometry
Global coverage: 16 days
3.14 Tb onboard memory
Cost: 855 mi USD
Down link: 384 Mbps

NewSpace

Planet Lab's Dove

5Kg mass;
3-5m resolution, 3 bands;
29 MP CCD detector;
One Global image set per day with the full constellation deployed,
200Mbps data downlink

India's EO Programme- Sensor Epochs

IRS 1A (1988)	**CCD based 4-band MS camera (3 #), 72m & 36m resolution (LISS 1&2)**
INSAT 2A (1993)	Very High Resolution Radiometer (2.75 km Visible/11km thermal IR)
IRS- 1C (1995)	LISS-3 (23.6m), PAN CAMERA (<6m), WiFS (189m), SWIR band
Oceansat-1 (1999)	Ocean Color Monitor (8 band, 360m) Multi band Scanning Microwave Radiometer (MSMR)
TES (2001)	1 meter resolution , Step and stare imaging
INSAT 3A (2003) Resourcesat 1 (2003)	Improved VHRR (2 km VIS band /8 km W V /8km Ther. IR), CCD Camera LISS 4 (5 m MS) Advanced WiFs
Cartosat-1 (2005)	2.5m Fore & Aft cameras (In track stereo), Global DEM sets
Cartosat 2 (2007, 16)	Operational HR <1m resolution, HR colour, Step & Stare
Oceansat-2 (2009)	Ocean Colour Monitor (OCM), Scatterometer and ROSA payloads
Resourcesat 2 (2011)	LISS 4 (5m MS, 10 bit, 70km swath), AWiFS (12 bits), 200 GB Memory
Megha-tropiques	ISRO-CNES mission - MADRAS microwave radiometer, SAPHIR

Indian High resolution systems

Parameter/ Sensor name	**TES**	**Carto sat-2, 2A, 2B**	**Cartosat-2C, 2D, 2E**		**Cartosat-3, 3A, 3B**		
	PAN	PAN	PAN	MX	PAN	MX	HySI
Spectral range(μ)	0.5 – 0.85	0.5 – 0.85	0.45 – 0.9	0.45 – 0.86	0.45 – 0.9	0.45 – 0.86	0.4 – 2.5
Channels	1	1	1	4	1	4	>200
Resolution (m)	1	0.8	0.65	2	0.25	1	12
Swath(km)	16	10	10	10	16	16	5
Quantization	7	10	11	11	11	11	11

Source: N N R M S B U L L E T I N - M A R C H 2 0 1 3

Developments in Microwave sensors

Day & Night, all weather imaging/ measurement

Multi-band passive microwave radiometers
Alti meters
Synthetic Aperture Radars
Scatterometers

Laser instruments

LiDARs
Terrain mappers

IMPACT OF “COTS “ APPROACH TO CAMERA

LISS III SENSOR (RESOURCESAT)

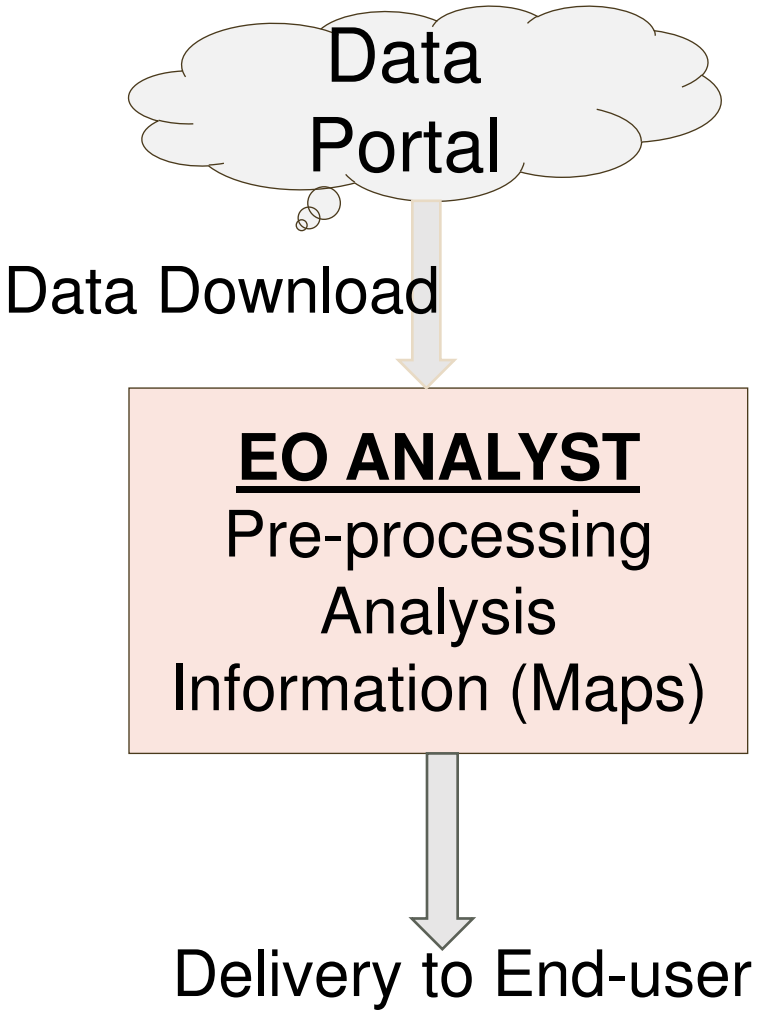
Medium Resolution
4 bands
23 meter spatial res.
70W power
140 km swath
106 Kg

CUBESAT Camera

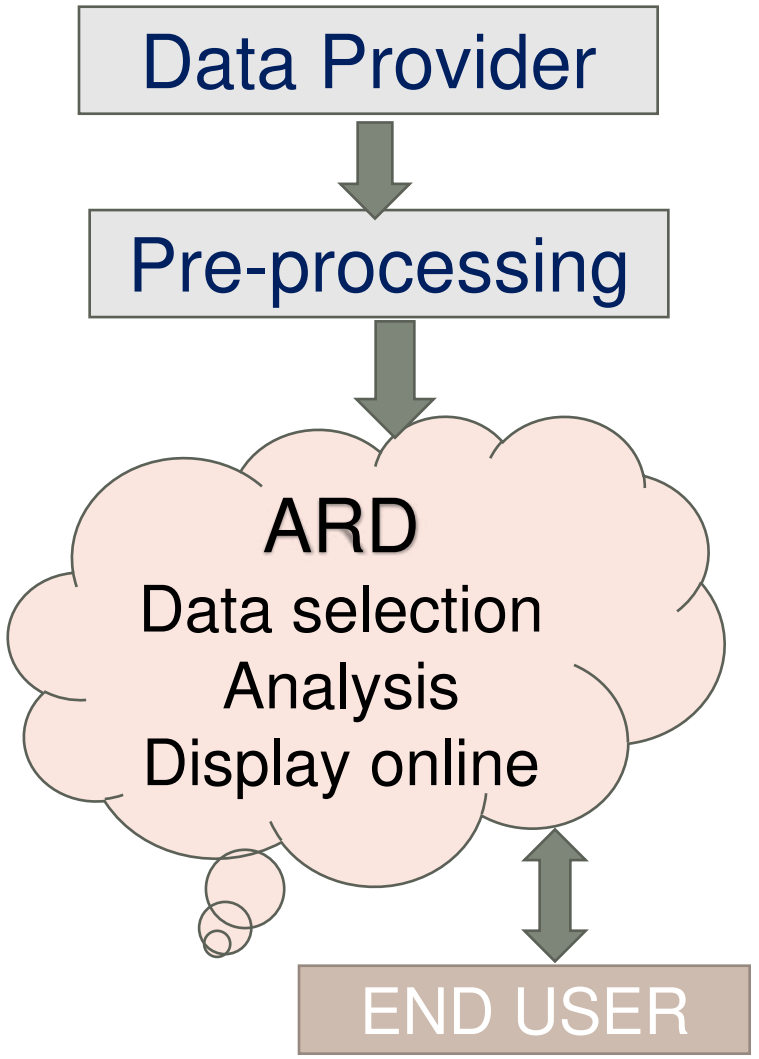
High resolution image & video
5m spatial resolution
3388 x 2712 pixel frame (9MP)
5.1 w power, 398 gram
Model: Imperx B 3412 DX
Mirror

Data access and Data Processing

LEGACY SYSTEMS



NEW DEVELOPMENT



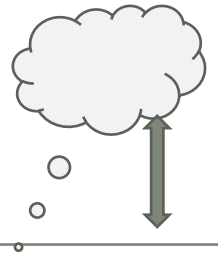
Managed Ground Segments

- Availability of fully managed ground station as a service, as available through AWS ground stations

- facilitate users to undertake tasking, commanding, downlinking and processing of satellite data in cloud and distribute them.

- Integration of EO data into cloud based services such as AWS enables easy scaling of satellite operations by the user rapidly and cost effectively on the basis of the extent of usage.

Overview of portals for Big Earth data.



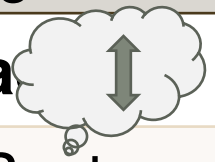
Download, Upload and processing online

Name	Data Structure	Data availability
Google Earth Engine	2D gridded raster bands	Satellite Imagery; Satellite-derived data products (Landsat, MODIS, Sentinel). Programming Env.(IDE)
Amazon Web Services	Image files	Satellite Imagery; Satellite-derived products (Landsat, Copernicus &MODIS, and DEMs)
Earth Server	Data cube	Satellite Imagery; Satellite-derived data products; Model outputs
EODC (water resource monitor)	Image files	Satellite Imagery; Satellite-derived products (EO/GIS users) (Copernicus)
Swiss Data Cube	Data cube	Satellite Imagery; Satellite-derived products
Digital Earth Australia	Data cube	Satellite Imagery
CODE-DE (Germany..)	Image files	Sentinel Imagery -Copernicus services

Data download portals

Name	Data Structure	Data Availability
NSIDC (Snow & Ice data)	Raster, Point, Vector data	In-situ data sets; Model Outputs; Satellite derived data products (soil moisture..)
EUMETSAT	Image Files	Satellite Imagery; Satellite derived data products
Earth Explorer (USGS)	Image files	Satellite Imagery; UAS Imagery, Data products, Digital Maps
Copernicus Open Access Hub	Image files	Satellite Imagery
PEPS (French)	Image files	Satellite Imagery, Copernicus ..

Download & uploa



PANGEA (Environ. Science)	Raster, Point, Vector data	Model Outputs; Satellite derived data products

Other notable user resources

- NASA Sensor Web Suite – software tools for access, process and analysis of data
- For Landsat products—Earth explorer, GloVis and LandsatLook Viewer
- DIAS- Copernicus Data and Information Access Services

REFERENCE ON BIG EARTH DATA MANAGEMENT:
Martin Sudmanns, Dirk Tiede, Stefan Lang, Helena Bergstedt, Georg Trost, Hannah Augustin, Andrea Baraldi & Thomas Blaschke (2019): Big Earth data: disruptive changes in Earth observation data management and analysis?, International Journal of Digital Earth, DOI: 10.1080/17538947.2019.1585976--

Geo spatial services

Bhuvan Geo-portal

- IRS data hosting for visualisation (1m or coarser)
- Free down load of Resourcesat data (more than 2 year old)
- Satellite derived products
- Project / theme specific database information and visualisation
  - Natural Resource Census
  - Agriculture
  - Forestry & environment
  - Rural development
  - Water resources
  - Geo sciences
  - Urban & infrastructure
  - Ocean sciences and atmosphere
  - Disaster Management support
- Mobile applications

Welcome to Bhuvan | ISRO's Geo | Bhuvan Services Objective | NRSC | Welcome to Bhuvan | ISRO's Geo

bhuvan.nrsc.gov.in/bhuvan_links.php#

bhuvan
Indian Geo-Platform of ISRO

National Remote Sensing Centre

NRSC | Search | Bhuvan Store | Bhuvan Collaborators

---------- Visualisation & Free Download ----------

Bhuvan-2D

Bhuvan-3D

Open Data Archive
Free Download

Climate & Environment
EO derived Products

---------- Maps & OGC services ----------

Thematic Services

Disaster Management Support Services

Ocean Services

Create a Map / GIS
My Map | My GIS

Governance/Central Ministries
g-Governance Dashboard

ıment & rest | ENVIS | CRIS | Flycatchers Distribution | Island Information | School Bhuvan | Toll Information | Ground Water

Application Sectors
Collaborative applications - Platform to share your data and create governance applications

Agriculture | Forestry | E-Governance | Water | Tourism | Urban | Rural

Rural
Ground Water | Watersheds | MGNREGA

Special Applications
Data Discovery | Decision Support Dashboard | Hydrological Products | Image Gallery

State Portals/Applications (Click on any State)

State: ANDHRA PRADESH

Andhra Pradesh | Asset Mapping

Visit State Portal of ANDHRA PRADESH

Updates | Download

- Updation of Orthorectified AWiFS and LISS-3 datasets in NOEDA Portal New
- Release of Telangana Forest Portal New
- Release of Punjab Forest Portal New
- Visualization of IMD Weather Products
- Visualization of Weather Climate Environment Modelled Products
- g-Governance: Dashboard

11:32 AM 1/29/2020

APPLICATIONS DRIVERS

Monitoring Agriculture – crop areas, crop health and yield estimates, Advisories
Water resource mapping, ground water targeting, water pollution monitoring, fisheries information

Environmental impact assessments, and environment monitoring, weather observations, cyclone tracking, Forestry applications

Cartography and Mapping applications- digital elevation models,
Asset mapping, and mobile assets tracking, Urban applications,
Land use and land cover changes
Information support for decentralised planning
Monitoring Disasters, warning and assessment of damages

Monitoring infringement of Laws – encroachments of forest lands, illegal mining, infringement of coastal zone regulations etc.

Visual interpretation keys

Tone (colour)
Texture
Shape
Size
Shadow
Pattern
Site
Height
Association

Supervised classification

In supervised classification, the analyst based on prior information on the spectral characteristics of these classes, trains the computer to generate boundaries in the feature space within which each class should lie

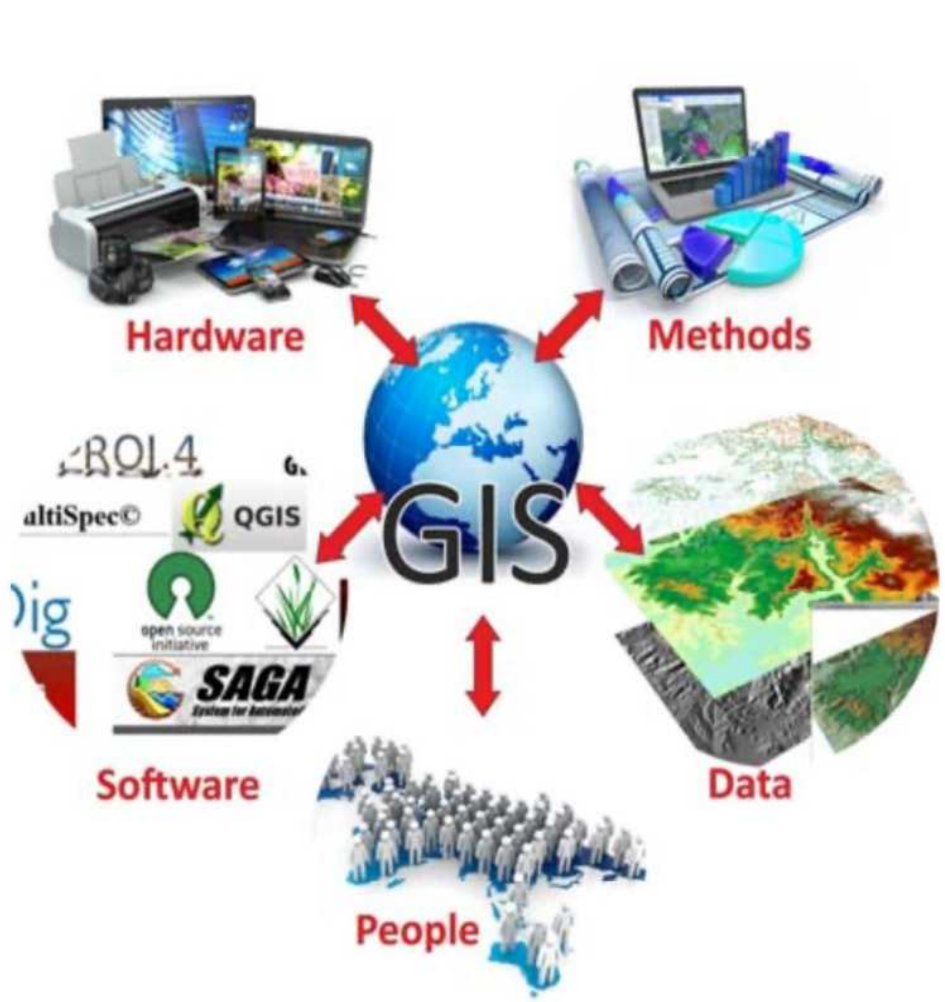
Geographical Information System (GIS)

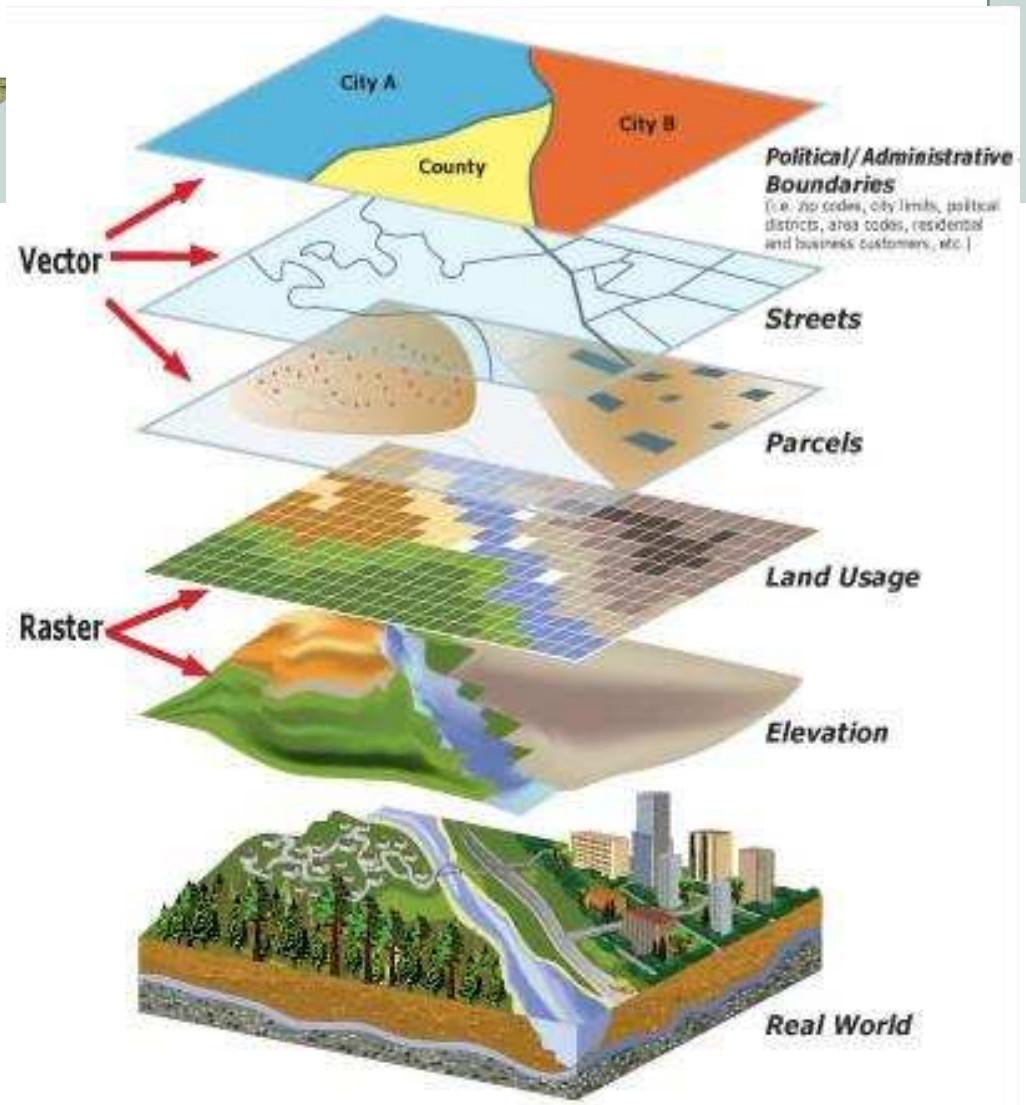
Geographical Information System (GIS) is a system (of hardware /Software /data /applications/policies) that deals with spatially referenced and geographically tagged/linked data.

GIS allows analysis and integration of various map/image layers and geo-tagged tabular data to determine the spatial distribution, the relationship among various entities and the correlation of the variables in a geographic unit.

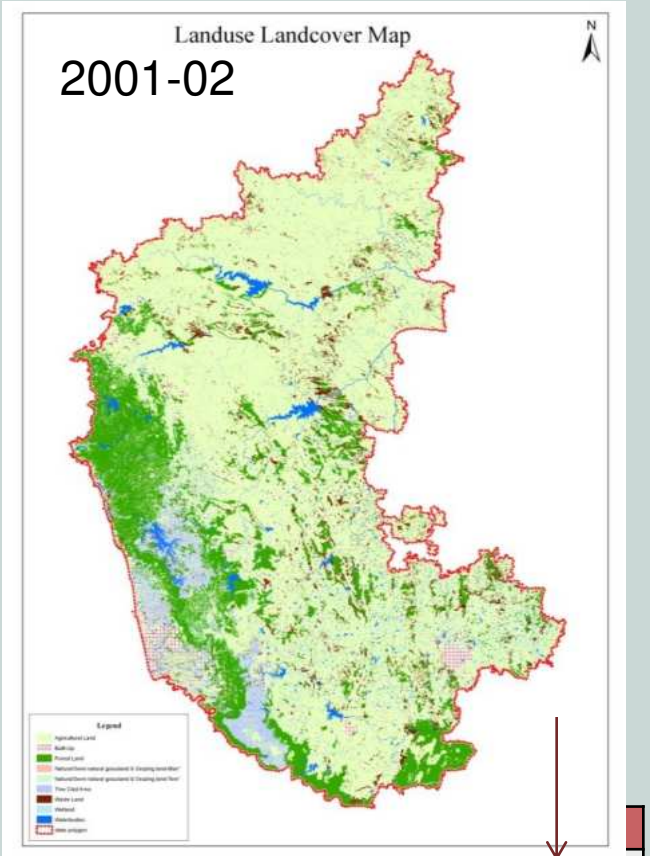
Further, the capability of GIS systems now allows creating map visualization of tabular data and making amenable the spatial or map representation of population data, migration data, consumer data, financial transactions, and beneficiary data and so on.

GIS components and concept

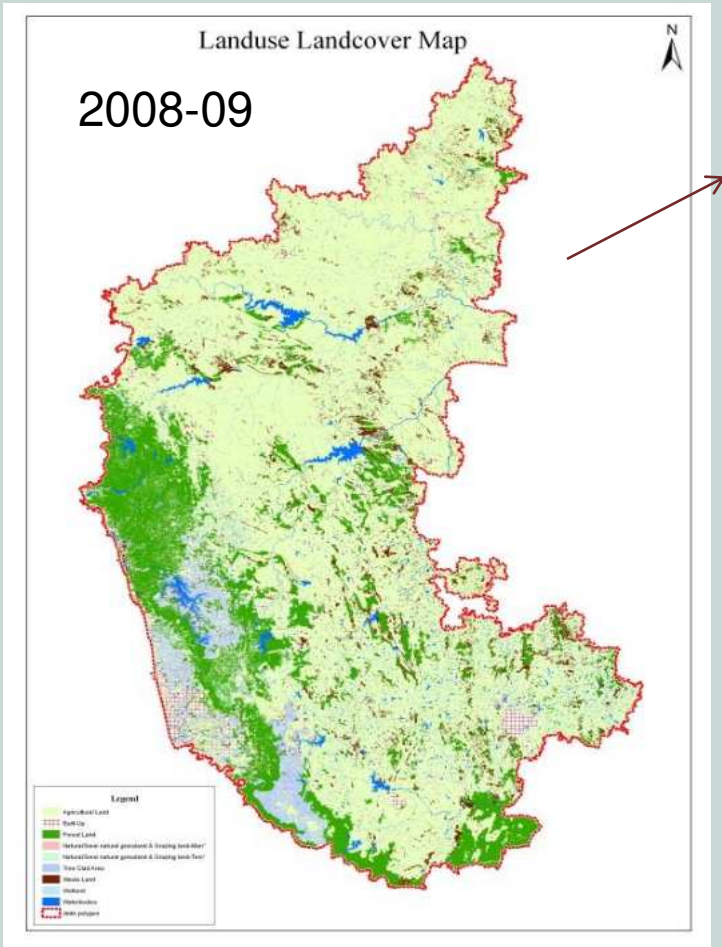




Example of GIS use: Land Use Status



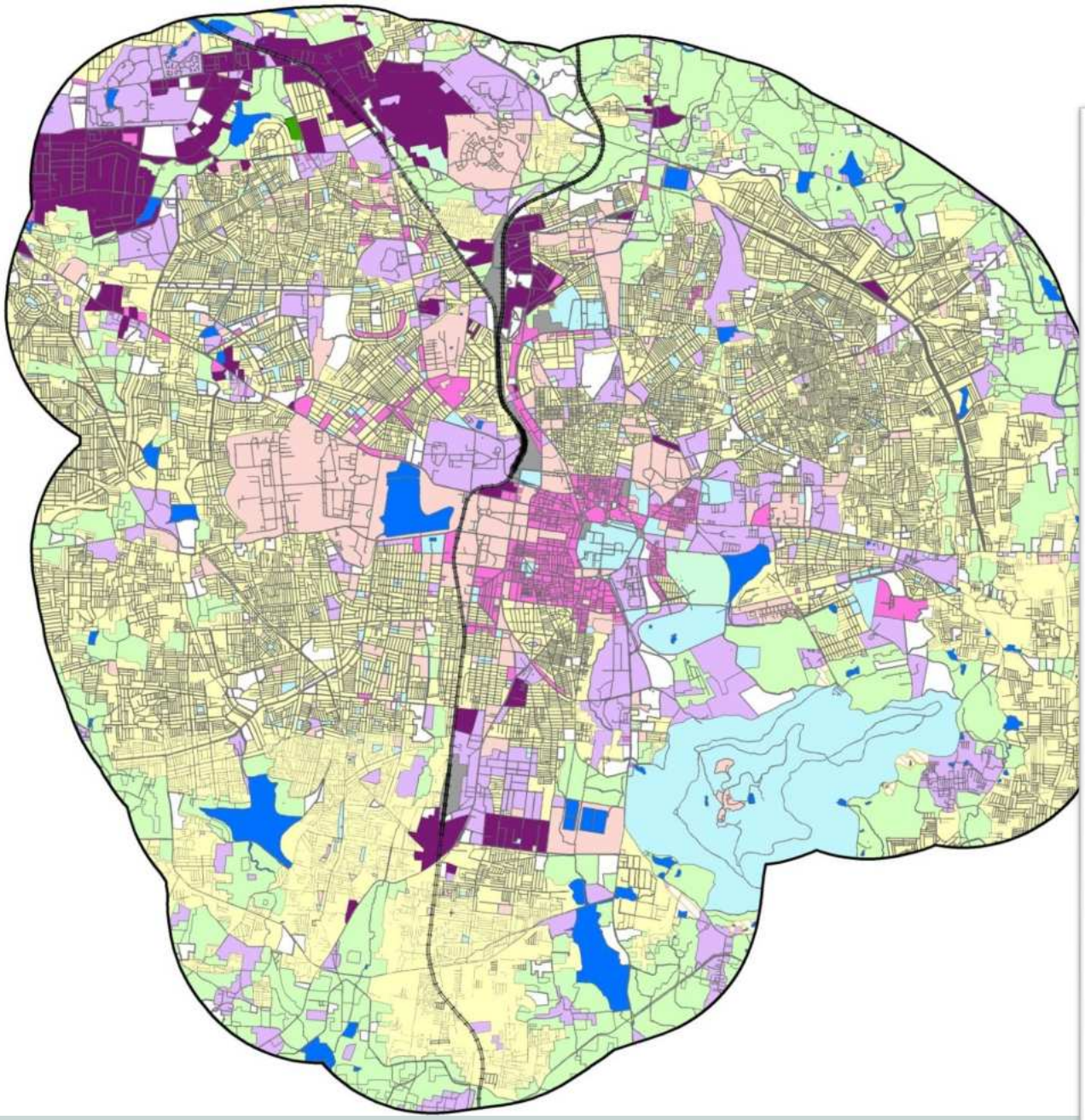
Agricultural land	130264.82
Built-up land	3480.32
Forest Cover	27391.95
Grassland / Grazing land	781.73
Others	10851.94
Wastelands	11831.66
Water Bodies	7154.62
Wetlands	35.84



Sl No	Description	Area in Sqkm
1	Agricultural Land	133191.42
2	Built-Up	5449.41
3	Forest Cover	29248.17
4	Natural/Semi natural grassland & Grazing land	636.55
5	Tree Clad Area	7413.86
6	Waste Land	8529.93
7	Waterbodies	7232.80
8	Wetland	86.12

Courtesy: K-GIS WORKSHOP-JANUARY 23, 2013

CITY-GIS FOR MASTER PLANNING



- Agriculture_Land
- Commercial
- Education_Institute
- Education_Institutes
- Educational_Institues
- Educational_Institutes
- Field_Check
- Forest_Area
- Government_Office
- Ground
- Hotel
- Industry
- Open_Land
- Park
- Power_Plant
- Private_Property
- Public and Semi Public
- Public and Semi-Public
- Public and Semi_Public
- Query
- Recreational
- Residencial
- Residential
- Rocky_Area
- Scrub_Area
- Scrub_Land
- Slum
- Transportation
- Waste_Land
- Water_Bodies

Courtesy KSRSAC
K-GIS WORKSHOP-
JANUARY 23, 2013

SATELLITE IMAGE FOR UPDATING

Spatial data quality

Spatial data---data about positions, attributes and relationships in space

Cartographer's traditional approach– produce best possible accurate maps

Advances in database and digital technologies- multiple sources, greater content, linkages and higher speeds and greater visualisation

Multiplicity/ remoteness of players in creation and use of spatial data

TWO ISSUES:

- **Quality information is essential for user – to choose the data set**
- **Computer rendering shows high accuracies- need for data quality information included in the data set.**

Spatial data quality

Foundation step: Adoption of ISO9000 international standard (ISO 1987)

Tenet: Give no more quality or less quality than the customer requires

- Definition of elements of spatial data quality
- Specification of spatial data quality
- Presenting known data quality in visualisations

Spatial Data Quality

Definition of spatial data quality- efforts in different parts of globe

USA- National Committee on Digital Cartographic Data

Standards(NCDCDS) - Draft 1987

User to decide fitness for purpose of use

Reporting data quality

Lineage,
positional accuracy,
attribute accuracy,
logical consistency, and
completeness.

Europe- *Comite Europeen de Normalisation Technical committee 287*

(CEN/TC287) 1992

Commission on Sp. Data Quality of Intl. Cartographic Assoc.

Addition of 2 more elements– Semantic and Temporal (1995)

Spatial Data Quality

- 1997 ISO's establishing TC211
  - CEN/TC287 work taken into account in the development of global ISO stds.
  - Continuity of ideas (US NIST, ICA and CEN/TC287)
- TC211 Working Group 3:
  - Item 13 --geographic information-quality
  - Item 14 – geographic information-quality evaluation
  - Item 15 – geographic information-meta data
  - Item 4 – geographic information-terminology
- ISO2001

ISO/TC211/WG3/NO13 quality principles *Quantitative elements*Plan for product launch

Thematic accuracy	Completeness	Logical Consistency	Positional accuracy
• Feature accuracy value • Classification accuracy • Misclassification	• Commission • Omission • User defined	• Domain consistency • Format Consistency • Topological consistency • Use defined	• Absolute or external accuracy • Gridded data positional accuracy • Positional stability • Relative Positional stability • Relative of internal accuracy • Shape fidelity • User defined

ISO/TC211/WG3/NO13 quality principles (continued)

Temporal Accuracy	Lineage	Usage	Purpose
• Accuracy • Temporal consistency • Temporal validity • User defined	• History of data set from collection and acquisition through compilation and derivation to its current form	• Application description	• Intended use and rationale for creation of data set

Thank you