Presentation Overview

• Introduction
• How was/is GIS viewed?
• Future Trends in GIS technology development
• Satellite Data Acquisition for a GIS
• Challenges and opportunities for GI services
• Capacity building in RS and GIS
• Conclusion/Recommendations
1. INTRODUCTION

Dimension Of Poverty And Resource/Environmental Management Challenges In Nigeria

NIGERIA’S SOCIO-ECONOMIC DEVELOPMENT CHALLENGES

- Flooding in the Niger Delta
- Lake Nyos threat
- Gas flaring in Niger Delta
- Gully erosion in south east Nigeria
- Subsistence cultivation of Cassava
- Scarcity of portable water

Potable water crisis persists

WATER
Billion naira investments fail to quench Nigeria’s thirst

12/29/2014 Ron Briggs, UTDallas, GIS Fundamentals
What is Geospatial Technology? (Internet)

- "Geospatial“: 21st century creation; synonymous with GIS which is still largely in use today; except that in geospatial technology, other technologies are added such as RS, GNSS (GPS), UAS, etc.
- Both are related to "spatial" or geographical information such as: natural features (rivers, lakes, forests, etc), infrastructure (roads, cables, pipes, cell towers, hydrants, buildings, etc), administrative boundaries (states, provinces, cities, sales territories, etc), tracking and tracing (cars, trucks, people, bus routes, etc); also include aerial photo, satellite imagery, DTM, etc.
- In criminal justice such as highlighting crime occurrences on maps, compare evolution over time, relate to police beats and precincts, etc.
- In Jobs and projects executions such as:
  - public sector (local and central government) for infrastructure planning, land occupation, cadastre
  - utilities for infrastructure management (pipes, cables; roads etc)
  - retail for geomarketing (store placement, consumer behaviour
- In this digital age where the vast majority of data has a location and time, GIS and Geointelligence (GEOINT) systems provide the means to reference it geographically. Complex dynamics, patterns and relationships can be revealed, analysed and understood in a completely new way.
- Advances in technologies like cloud and 3D modelling, together with increased availability of high-quality, high-accuracy geospatial data especially from space-based remote sensing satellites, are propelling the market for governmental GIS and GEOINT solutions forward into a very exciting future.
Geographic Information Systems (GIS):
(a component of Geoinformatics)

• Art, Science and technology dealing with the acquisition, analysis and management of spatial information, its capture, its classification and qualification, its storage, processing, portrayal/presentation and dissemination including applications for planning and decision support.

• **Include** infrastructure necessary to secure optimal use of geoinformation. **Use geocomputation and geovisualization for analyzing geoinformation.**

• **Connection**: Geography and earth science increasingly rely on digital spatial data acquired from remotely sensed (RS) images analyzed by geographic information systems (GIS) and visualized on paper or the computer screen (Cartography). Modern cartography is largely integrated with GIS.

• **Applications in** sustainable development are diverse: include environmental modeling and analysis, military, transport network planning and management, agriculture, meteorology and climate change, oceanography, engineering, telecommunications, criminology and crime simulation, aviation and maritime,
Benefits of the Use of GIS

• From the straightforward and traditional descriptive mapping, GIS would allow for an advance prescriptive mapping within the systems concept and framework; take note of the S in GIS; i.e. Systems: Technology; Science: concepts and theory; Studies: societal context.
• Once maps have been established in a digital format, then it is a simple task to update them, to change them, or to merge them with other maps in order to create new maps.
• GIS provides a huge range of tools which allow for accuracy of output and thoroughness of decision making.
• The range of potential graphic displays is almost infinite, allowing maps to be customized to suit situations and individuals or tasks, and allowing for visualization experiments to take place.
• GIS contains the prerequisites for modeling scenarios, both from the research aspect and in operational resource management tasks. Multiple scenarios can be rapidly undertaken, and varying hypotheses can be tested.
• GIS allows for the production of one-off maps of a high quality, which would otherwise be non-cost effective.
• GIS allows for the easy and immediate integration of other large data sets, i.e. the technologies of, for instance, GIS and RS, GNSS and field data can be readily combined.
• GIS allows for the display of spatially related data in a way which is easily comprehensible to most people.
• The use of GIS greatly improves human productivity and the speed of working in all maps/data producing operations and associated geostatistical analyses/inferences for decision support
• GIS allows for a regular flow of spatially related information in a standardised format. This might be for a given time series where all maps are produced together, or it might mean that periodically a new version of the same map can be produced.
• GIS allows for high quality cartographic output from people who might have no cartographic skills.
2. HOW WAS/IS GIS VIEWED—

What is it?

*No easy answer anymore!*

- Geographic/Geospatial Information
  - information about places on the earth’s surface
  - knowledge about “what is where when”
    (Don’t forget time!)

*Internet definitions:*

1. A set of computer tools for analyzing spatial data;
2. A special case of an information system designed for spatial data;
3. An approach to the scientific analysis and use of spatial data;
Geographic Information Technologies

- Global Positioning Systems (GPS)
  - a system of earth-orbiting satellites which can provide precise (100 meter to sub-cm.) location on the earth’s surface (in lat/long coordinates or equiv.)

- Remote Sensing (RS)
  - use of satellites or aircraft to capture information about the earth’s surface
  - Digital ortho images a key product (map accurate digital photos)

- Geographic Information Systems (GISy)
  - Software systems with capability for input, storage, manipulation/analysis and output/display of geographic (spatial) information

*GPS and RS are sources of input data for a GISy. A GISy provides for storing and manipulating GPS and RS data.*
Related Applications

- Medicine
- Epidemiology
- Education
- Archeology
- Law
- Traffic
How was GIS viewed?

- Old GIS:
  - Two dimensional,
  - Static, non-interactive,
  - Very limited scope and interaction between objects,
  - Confusing set of data models,
  - Dominated by the idea of map,
  - Independent application
How is GIS Viewed today?

• Increasing range of views in response to market expansion and range of applications.

• **Current issues**
  • Matching industrial trends,
  • Geobrowser era, and VGI
  • Mobile GIS
  • Cellular phones and location technology
  • New generation of space imaging
  • Interoperability and standards
  • The data fire hose
  • Building the cyber infrastructure
  • Bridging the digital divide
  • The “where” of computing
  • User interfaces: The end of GUIs, WIMP, and the desktop
  • Wireless internet
  • Who owns software
  • Too much data
What can GIS Technology Deliver:

*Efficiency and Effectiveness*

- Cost efficient, quality service to customers: the key to future business success
  - *mapping to manage information* potentially transforms organizations
  - geography is the key to cost efficiency for ranges of business such as pizza delivery and cellular radio towers
- communications with citizens: the key to future public sector success
  - map based information is the key to intuitive information delivery
    - travel directions ([www.mapquest.com](http://www.mapquest.com))
    - natural or social environmental degradation ([http://www.epa.gov/tri/](http://www.epa.gov/tri/))
    - land ownership ([www.dallascad.org](http://www.dallascad.org))
    - General public data ([www.accu-source.com](http://www.accu-source.com), [www.publicdata.com](http://www.publicdata.com), [www.openrecords.org](http://www.openrecords.org))
What can GIS Technology Deliver:

Targeted Communication

Displaying data differently for today’s target constituency:

- governors
- Legislators
- lawyers
- activists
- general public
- 6th grade class

Do-It-Yourself extraction from Societal Databases

- large, networked databases accessible to public at low/no cost
- free browser and training software (e.g. ILWIS, ArcExplorer)
  Content tailored for current location
- The mobile, handheld, interactive GI services revolution
Examples of Applied GIS

- **Urban Planning, Management & Policy**
  - Zoning, subdivision planning
  - Land acquisition
  - Economic development
  - Code enforcement
  - Housing renovation programs
  - Emergency response
  - Crime analysis
  - Tax assessment

- **Environmental Sciences**
  - Monitoring environmental risk
  - Modeling stormwater runoff
  - Management of watersheds, floodplains, wetlands, forests, aquifers
  - Environmental Impact Analysis
  - Hazardous or toxic facility siting
  - Groundwater modeling and contamination tracking

- **Political Science**
  - Redistricting
  - Analysis of election results
  - Predictive modeling

- **Civil Engineering/Utility**
  - Locating underground facilities
  - Designing alignment for freeways, transit
  - Coordination of infrastructure maintenance

- **Business**
  - Demographic Analysis
  - Market Penetration/Share Analysis
  - Site Selection

- **Education Administration**
  - Attendance Area Maintenance
  - Enrollment Projections
  - School Bus Routing

- **Real Estate**
  - Neighborhood land prices
  - Traffic Impact Analysis
  - Determination of Highest and Best Use

- **Health Care**
  - Epidemiology
  - Needs Analysis
  - Service Inventory
3. FUTURE TRENDS IN GIS TECHNOLOGY DEVELOPMENT

The general trend of GIS development seems to indicate that it will continue to become:

1. easier to use
2. more intuitive
3. more analytic
4. more embedded within a variety of technologies
5. Applications trend
   - GIS will continue to be used everyday for routine operations (planning, development, navigation, scheduling, etc.).
   - GIS and other areas of science are beginning to merge (graphics, visualization, geomantic, civil engineering, statistics, probability theory, cognitive science, computational geometry, simulation and modeling).
   - Beyond the original decision-support and problem-solving role, GIS are being viewed as tools for generating ideas.

• Cooperation between vendors continues.
• Emphasizing the information and finding new ways for data representation
Future of GIS

• Scientific visualization and computer graphics will be increasingly integrated with GIS
• New capabilities, especially animated and highly interactive maps, will be developed.
• GIS is critical to new scientific trends, especially multidisciplinary research and global systems studies.
• Integration (multiple formats, databases and outputs)
• Accessibility (anytime, anywhere)
• Reliability (no data loss)
• Proper display of data (advanced graphics methods)
Changing Emphases

From Description to Simulation & Modeling

Picture worth a thousand words:

maps & diagrams of how is, or how was

Web portals serve static data sets

Past

Iconic models: scaled down representations of the real thing

Future

Visual simulation & virtual reality:

real time display of how is, and how might be
- forest fire
- freeway traffic flow

Web portals serve continuous sensor-derived data

Symbolic models: based on logical relationships in mathematical or statistical modelling
Changing emphases

GIS Cloud solution

• Fastest and most efficient GIS mapping technology available today access anywhere, anytime on any device
• Application for field data collection in real time, fleet and workforce management, data hosting and sharing
Changing Emphases

_from 2-D description to 4-D interaction_

**Past**
- 2-D flat map displays
  - User as observer

**Future**
- Effective 3-D visualization
  - Via the merger of CAD and GIS?
  - What is the data model?
- 4-D incorporation of time: “The time has come for time.”
  - Via agent-based modeling / cellular automata? Or how?
    - agents (e.g. vehicles, fires or people) interacting over time in a raster (cell)-based environment according to established rules
- 5, 6 and 7-D incorporation of touch (pressure, texture, temperature), sound and smell into modeling/simulation environment
- User as participant
  - Users (researchers, professionals, the public) interact with the model
  - Participatory GIS: the public as the planner
Changing Emphases

Out of this world

Past
- GIS applied to Planet Earth

Future
- GIS as a methodology for the analysis of spheres
  - Other planets—Mars, Jupiter, Comet, International space station, asteroids, interstitial space, etc
  - Spinoff applications
  - The human brain
    - One earth but many brains
    - & visa-a-versa: does the brain use “maps” for organization?

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## Technological Trends Underlying the Transition

### Defense Conversion (and other) spin-offs
- **Location via GPS**
  - Millimeter accuracy
  - Available in every cellphone
  - Super high capacity mass storage
    - Petabyte and *more* systems
- **High resolution (<1m) satellite remote sensing**
  - High resolution: 31 cm now, 10cm soon?
  - Real time Google Earth?
- **The communication revolution**
  - Super high capacity networks (Internet X), even to the home
    - NSF’s 100x100 project: 100 Megabits to 100 million homes
  - Wireless (cellular) communication with anything that moves anywhere on earth

### Information Technology Evolution
- **Interoperability:** easier sharing of data between users, and among vendor products
  - Metadata
  - Spatial Data Transfer Standards
  - OpenGIS
  - Mash-ups
- **Commercially enhanced data**
  - Public data made dramatically more usable/useful
- **Spatial data tools in commercial DBMS* and software dev. environments**
- **ESRI SDE (spatial database engine)**
  - ESRI Map Objects & ArcObjects
- **3-tier computing, separating:**
  - User interface (client workstation)
  - Analysis (applications server)
  - Data (multiple distributed data servers)

*DBMS: data base management systems
**Visual Basic
Operating Environments:

Business & Governments

- customers and citizens take charge
  - requirements for service defined by customer/citizen not the provider
  - demand **more** in shorter **time** at lower **cost** than you ever intended to deliver
  - lower taxes/prices **and** more service
- competition is relentless
  - more people wanting to do what you do
  - private sector assumes (or re-assumes) many gov. tasks.
- change is constant
  - Government evolves from driver to consumer of technology
  - Commercial Off-The-Shelf (COTS) software rather than custom designed
- decentralization to the individual
  - Much new technology is not new: its been around for a while, so what’s new?
    - Computers, video recorders, fax, wireless
  - Dramatic price drops make it as available to individuals as to organizations
Operating Environments:

Computing Technology:

- Desktop loses its dominance
  - Variety of computing appliances: palmtops step up

- Computers act rather than just process
  - Old model: human enters data, computer processes it, human receives and acts
  - New model: data from sensors & transducers, computer processes, computer acts to get job done

- Data and computation become real time
  - Old model: processing archived data to guide future action
  - New Model: processing current data to control current and future actions

- Information and its processing at any and every place
  - Mobile and wireless dominate over fixed and wired services
  - Info access no matter where I am, where data resides, what its format is

Concepts derived from Tennenhous, Director, DARPA, May 1998
Future Generic GIS Internet Enterprise

Browsers

Applications

Web

Web Server

Brokers

Services
(built on .Net, SOAP/XML, Java API)

Databases

Source: Reza Wahadj, CSIG04, with mods.
Geospatial elements of the GRID:

1. GPS takes over

Source: U. Minnesota IVS Lab
Forecast: Wearable GIS

• We will wear our computers, not sit in front of them
Geospatial elements of the future:

1. Portability
Geospatial elements of the future:

2. Sensor webs
New global/spatial grids: QTM
What will the issues be in future

- Computing issues:
  1. Network monitors itself, who sees?
  2. Spyware and security vs Personal privacy
  3. Who pays for services?
  4. Who are the digit police?
  5. Competing solutions and liability
  6. The limits of accuracy
  7. Tractability envelope: New methods
  8. Simulation is everywhere, for everything
    - Vast amounts of scientific, natural, and cultural information to describe and understand the Earth, its systems, and human activities
    - Linking text, maps and imagery: Fusion
    - Making maps and images text searchable
4. Satellite Data Acquisition for A GIS

- **NGA** (National Geospatial-Intelligence Agency) signed *NextView* contracts for development of next generation of commercial satellites, with DOD being given priority access in times of need.

- **Digitalglobe** contract in 2003, focused on:
  - Higher resolution
  - Delivery time to customer
    - 3 hours now (Iraq war)
    - Future: 90 minutes standard, 20 minutes “rush jobs”
  - **WorldView-1** launched September 2007
    - .5 m panchromatic
    - 1.7 days revisit
  - **WorldView-2** launch 2008
    - .5 m panchromatic and 1.8 m multispectral (4)
    - 1 day revisit
    - **WorldView-3** launch 2014
      - 0.31m panchromatic
  - **Supplier for Google Earth**

- **Orbimage** contract in 2004
  - OrbView 5 satellite to launch early 2007 (now early 2008)
  - 0.41 m panchromatic, 1.64 m multispectral (4 bands)
  - 3 m. position accuracy
  - 3 day revisit
  - Downlink imagery real time to ground station

Note: the award of this contract to Orbimage resulted in their acquisition of Space Imaging (which failed to get the contract) in January 2006 and renaming of the combined entities as GeoEye. OrbView 5 now called GeoEye-1
Satellite resolution is reducing by the day

<table>
<thead>
<tr>
<th>Feature</th>
<th>IKONOS</th>
<th>QuickBird</th>
<th>WorldView-1</th>
<th>GeoEye-1</th>
<th>WorldView-2</th>
<th>WorldView-3</th>
<th>GeoEye-2 (subject to change)</th>
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<tbody>
<tr>
<td>Spectral characteristics</td>
<td>Pan + 4 MS</td>
<td>Pan + 4 MS</td>
<td>Pan</td>
<td>Pan + 4 MS</td>
<td>Pan + 8 MS</td>
<td>Pan + 8 MS + 8 SWIR</td>
<td>Pan + 4 MS</td>
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<td>Panchromatic resolution (nadir)</td>
<td>0.82 m</td>
<td>0.55 m</td>
<td>0.50 m</td>
<td>0.41 m</td>
<td>0.46 m</td>
<td>0.31 m</td>
<td>0.31 m</td>
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<tr>
<td>Multispectral resolution (nadir)</td>
<td>3.28 m</td>
<td>2.20 m</td>
<td>N/A</td>
<td>1.64 m</td>
<td>1.84 m</td>
<td>1.24 m</td>
<td>1.24 m</td>
</tr>
<tr>
<td>Accuracy specification (nadir)</td>
<td>9 m CE90</td>
<td>23 m CE90</td>
<td>4 m CE90</td>
<td>3 m CE90</td>
<td>3.5 m CE90</td>
<td>3.5 m CE90</td>
<td>3.5 m CE90</td>
</tr>
<tr>
<td>Onboard storage</td>
<td>80 Gbits</td>
<td>128 Gbits</td>
<td>2199 Gbits</td>
<td>1000 Gbits</td>
<td>2199 Gbits</td>
<td>2199 Gbits</td>
<td>3000 Gbits</td>
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<tr>
<td>Collection capacity</td>
<td>150,000 km²/day</td>
<td>160,000 km²/day</td>
<td>1,500,000 km²/day</td>
<td>350,000 km²/day</td>
<td>1,200,000 km²/day</td>
<td>680,000 km²/day</td>
<td>680,000 km²/day</td>
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<tr>
<td>Launch timing</td>
<td>1999</td>
<td>2001</td>
<td>2007</td>
<td>2008</td>
<td>2009</td>
<td>2014</td>
<td>TBD</td>
</tr>
</tbody>
</table>
Status of satellite technology programmes in Africa

- Two groups of space emerging African nations:
  
  **Emerging Space Faring Nations:**
  Nations with well developed space policies and agencies and satellites in space
  - Algeria... Launched EO AlSats-1 & 2A; AlSat-2B in progress
  - Egypt... Launched EO EgyptSat-1 & Comsats: Nilesats, 101, 102 & 201
  - Nigeria... Launched EO NigeriaSats-1, 2 & X and NigcomSat-1R
  - South Africa... Launched EO SumbadilaSat-1 & long history of ground station management of many satellites and highly developed astronomy

  **Space Aspiring Nations:**
  Nations with space programmes, aspiring to develop space policies and agencies, but have various platforms of space programmes for cooperation
  - Ethiopia
  - Ghana
  - Kenya
  - Libya
  - Morocco
  - Tunisia

- Production of space policy towards the establishment of African Space Agency.
Unmanned Aerial System (or vehicle)

Unmanned Aerial Systems (UAS) provide a better surveillance picture than satellite images, which are the current standard for mapping and monitoring environmental changes.
Typical Examples of RS and GIS applications (in smart governance)

(i) Agriculture and Food Security: GIS maps showing the extent of fadama land in Nigeria and its potential yield for rice cultivation

1. crop type classification
2. crop condition assessment
3. crop yield estimation
4. mapping of soil characteristics
5. mapping of soil management practices
6. compliance monitoring (farming practices)
7. Precision agriculture
(ii) Road, rail and waterway transportation

- Aids selection of possible transportation corridors to arrive at the best and most economical corridor/route
- Aids in the creation of a national road database or a digital atlas for road transportation network, road maintenance and traffic monitoring/management.

NASRDA provided GIS maps & information derived from NigeriaSat-1, such as settlements, roads, drainage system and water bodies, existing rail routes, etc, to the contractors developing the railway networks for Nigeria to enhance their study for the expansion and standardization of...
1. Market Prospects: 353 Earth observation (EO) satellites are expected to be launched over the next decade (2014 - 2023) compared to 162 over 2004-2013.
2. This will result in $36 billion in manufacturing revenues over the period, an 85% increase over the previous decade.
3. Organizations from 41 countries are expected to launch EO satellite capacity by 2023, compared to 33 over the previous decade.

• Government supply continues to grow strongly as more countries expand their portfolios of EO satellites to meet various policy needs.

• New entrants such will launch their first satellites, and others, particularly in the domain of commercial meteorology and environment monitoring solutions, could follow suit in the next decade.
5. CHALLENGES AND OPPORTUNITIES FOR GI SERVICES

- Services now the 4th “S” in GIS
- location based services

  *for organization*  
  - Map facilities
  - Geocode customers
  - Route deliveries
  - Analyze the market

  *for individual*  
  - where I am
  - where I want to go
  - how I get there
  - what is there

- Content tailored for current location, not the desktop
  - Mobile
  - Handheld
  - Interactive

- Evolution involves
  
<table>
<thead>
<tr>
<th>Past</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Few applications</td>
<td>many and varied</td>
</tr>
<tr>
<td>Few users</td>
<td>many</td>
</tr>
<tr>
<td>Standalone</td>
<td>web, cloud</td>
</tr>
<tr>
<td>Fixed</td>
<td>mobile</td>
</tr>
</tbody>
</table>
Challenges for GI Specialists
(the fifth “S” for GIS?)

Geospatial information scientists, specialists (or students)
– appreciative of the broad ranging, integrative role geospatial data can play
  • location is the most common denominator for all data
– highly knowledgeable with respect to the unique challenges of geospatial data
  • Challenges posed by a spherical earth (datums, projections, etc.)
  • Complexity of spatial data representation in 3-D and beyond
  • Challenges of spatial statistics and modeling
– fully conversant with mainstream information technology
  • and how to store and program spatial objects
– sufficient expertise in an application area (geology, local government, marketing, etc.) to make a contribution.
Challenges for GI Intake

Data is still at the heart

• Dominant IT (Information technology) issues:
  – Hardware in the 1970s and 1980s
  – Software in the 1980s and 1990s
  – Data in the 2000s
• No more an issue of acquiring data, but of management
• Will either be short of it, or drowning in it?
• Will its availability be
  – plentiful and cheap?
  – in infinite detail, if you can afford it?
  – severely curtailed by legal controls to ensure personal privacy?
Challenges for Nigeria and Africa Region

- Nigeria is a big market for satellite products.
- There are over 170M people living in Nigeria;
- Mobile penetration in Nigeria stands at 71.8% or 127m active mobile subscribers (Jan '14);
- Nigeria: 8th largest mobile market in the world and the largest mobile market in Africa
- PC penetration is very low
- Nigeria can only access its own share of global satellite market with:
  (i) a focus on human capacity development.
  (ii) International cooperation- From BRICS to BRINCS: (N: Nigeria)

  BRICS economies have performed exceptionally well, offering exciting markets and exceptional opportunities for satellite telecom
Opportunities

- It has been empirically proven that every 10% increase in broadband penetration in developing countries results in a commensurate increase of 1.3% in GDP.
- By 2020, Nigeria has the potential to become one of the top twenty economies in the world, with a principal growth target of no less than $900 billion in GDP and a per capita income of no less than $4000 per annum.
- If Government continues to drive the transformation of the country into a knowledge-based economy, it will attract investments by multinational companies.
- Drive Pervasive broadband access which is a critical requirement for Nigeria to achieve this vision.
- Installation of fibre-optic cables to connect the country to rest of the world.
**Challenges: Need for Critical space enabled ICT infrastructure**

- Creates opportunity for geo-information acquisition for sustainable socio-economic development
- Reduces economic dependence on oil and imports,
- Increases competitiveness of local industries by reducing production costs
- Reduces overdependence of the private sector on government patronage and contracts for quick, immense wealth
- Increases teledensity especially in the rural areas and enables knowledge-based society
- Reduces internet costs and increases broadband penetration
- Increases ICT penetration in the informal sector
  - Facilitates globally competitive private sector needed for accessing new markets
  - Attracts investment, promoting innovation, employment and economic opportunities
Technological catch-up using SST poses challenges and enormous opportunities for institutions in the developing countries to leapfrog development.

The (ICT) convergence on the information superhighway has greatly influenced the economy, culture and politics of countries all around the world.

The dynamic nature in technological convergence coupled with the rapid growth of the space entreprise requires appropriate policy frameworks, in tune with the changing technologies, markets and services.

Leapfrogging development stage cannot survive under the existing often decades-old political and institutional structures in Africa.
Critical Need for Geospatial data Infrastructure

- **Social Infrastructure**
  - Population
  - Land Use
  - Cadastre etc.

- **Urban Infrastructure**
  - Police and Fire
  - Cable and Pipeline
  - Transportations

- **GIS (NGDI) Information Infrastructure**

- **Environmental Infrastructure**
  - Natural Resources
  - Pollution
  - Disaster etc.

- **Economic Infrastructure**
  - Marketing
  - Banking
  - Car Navigations etc.

- **Educational Infrastructure**
  - Basic knowledge
  - Computer assisted education

Pictorial illustration of some economic indices in a GIS (NGDI) infrastructure network development (Agbaje and Akinyede, 2006).
Promotion of the use of GIS in Nigeria has led to the formulation of a national geoinformation policy and the establishment of a National Geospatial Data Infrastructure (NGDI) to facilitate:

1. Production, ownership/custodianship, archiving and maintenance of fundamental and thematic geospatial datasets.

2. Standardization of data production, transfer and exchange and of hardware and software.

3. Provision, standardization and maintenance of metadata for every geospatial data holding in the national Geospatial Data Infrastructures.

4. Executing legal issues related to ownership/custodian of datasets, copyright/intellectual property, confidentiality, privacy and liability.

5. Setting modalities for data access/sharing and data security

6. Setting modalities for organizational structure and arrangement of the NGDI with reference to recognizing the importance of management of datasets being close to source and posing no threat to the mandate of the stakeholders.
### Fundamental Datasets in Nigeria, Africa and Europe (Kufoniyi, 2010)

<table>
<thead>
<tr>
<th>SN</th>
<th>Dataset 1</th>
<th>Dataset 2</th>
<th>Dataset 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Geodetic Control</td>
<td>Geodetic Control</td>
<td>Geodetic reference. data</td>
</tr>
<tr>
<td>2</td>
<td>Administrative Boundaries</td>
<td>Administrative Boundaries</td>
<td>Units of Administration</td>
</tr>
<tr>
<td>3</td>
<td>Cadastral data</td>
<td>Land management units</td>
<td>Units of property (parcels, buildings)</td>
</tr>
<tr>
<td>4</td>
<td>Topographic data</td>
<td>Hypsography (contours, DEM, spot heights, etc.)</td>
<td>Selected Topographic themes (hydrography, Settlements, transportation, etc)</td>
</tr>
<tr>
<td>5</td>
<td>Digital Imagery and Image Maps</td>
<td>Remotely sensed imagery (e.g. aerial photos and satellite images)</td>
<td>Ortho-imagery</td>
</tr>
<tr>
<td>6</td>
<td>Land Use/ Land Cover</td>
<td>Natural Environment</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>7</td>
<td>Transportation</td>
<td>Transportation</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>8</td>
<td>Hydrography</td>
<td>Hydrography</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>9</td>
<td>Geology</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>10</td>
<td>Demography</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>11</td>
<td>Not applicable</td>
<td>Geographic Names</td>
<td>Geographic Names</td>
</tr>
<tr>
<td>12</td>
<td>Not applicable</td>
<td>Not Applicable</td>
<td>Addresses</td>
</tr>
<tr>
<td>13</td>
<td>Not applicable</td>
<td>Utilities and services</td>
<td>Not applicable</td>
</tr>
<tr>
<td>10</td>
<td>10 datasets</td>
<td>10 datasets</td>
<td>7 datasets</td>
</tr>
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6. CAPACITY BUILDING AND INTERNATIONAL COOPERATION

Capacity Building Institutions for RS and GIS in Nigeria and Africa

- Regional Centre for Training in Aerospace Surveys (RECTAS), Ile-Ife, Nigeria and Regional Centre for Management of Resource for Development (RCMRD), Nairobi, Kenya (established in 1972)

- Introduction of courses and laboratory for RS (& GIS) training in departments of many tertiary institutions in Nigeria and Africa

- National Center for Remote Sensing, Jos, Nigeria established in 1996

- African Regional Centre for Space Science and Technology Education in English (ARCSSTE-E) and French (CRASTE-LF) in Nigeria and Morocco, established in 1998

- National Space Research & Development Agency (NASRDA) established in 1999

- Establishment of Center for Space Research and Applications and Department of RS and GIS at the Federal University of Technology, Akure
Capacity Building and International Cooperation

• ARCSSTEE runs a 9 months PGD programme in RS & GIS, Basic Space Science (BSS), Satellite Communication (SatCom), Satellite Meteorology (SatMet), GNSS and Space Law

• ARCSSTEE=E commenced MTech. degree programme in collaboration with Federal University of Technology, Akure (FUTA) in Jan, 2014. Courses: RS/GIS, SatCom, SatMet, BSS and GNSS

• Students of the programme will have the opportunity to proceed to a PhD degree level in collaboration with FUTA
7. CONCLUSION/RECOMMENDATIONS

1. Critical need for Visionary and forward-looking leadership to drive S & T initiatives
2. Government to encourage agriculture and its markets for sustainable infrastructural development
3. Formulate and implement policy on GI intake through NGDI and promote geospatial governance
4. Restructuring of existing institutions/political structures
5. Encourage private sector participation in the space enterprise.
6. More investment in capacity building in Universities
7. Revision of school curriculum with focus on STEM
8. More interactions with all stakeholders both in the public and private sector, including academia and industry
9. Strenthening of ICT- and space/GIS-related institutions
10. Increase investment in S & T with innovative management of resources
11. Encourage innovations and free markets for satellite products