Emerging Satellite Programs in Africa, Asia and the Middle East:

Systems Engineering and Project Management Approaches

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NASA Intern
Innovative Partnerships Office: NASA Headquarters
Innovative Partnerships Program: Goddard Space Flight Center Code 504

Systems Engineering Seminar: July 12, 2011
NASA Goddard Space Flight Center
Presentation Overview

• Speaker Background & Career Path

• Overview of New Satellite Activity

• Motivations and Strategic Decisions for New National Satellite Programs

• Emerging approaches in satellite activity

• Choosing Systems Engineering Approaches to Promote Development

• Conclusions for NASA
Background & Career Path

Technical Growth

Applied *Engineering Systems* approach to socio-technical issues of new satellite programs

Technical focus on *System Engineering* development process for satellites

Strong technical foundation in theories behind *Aerospace Engineering*

Academic Experience

MIT PhD in Engineering Systems

MIT M.S. in Aeronautics & Astronautics

MIT M.S. in Technology & Policy

MIT B.S. in Aeronautics & Astronautics
Background & Career Path

MIT B.S. in Aero & Astro

M.S. in Aero & Astro

M.S. in Tech & Policy

PhD in Eng Sys

MIT Research

NASA Research

International Volunteer Work

2010 NASA Student Innovator Award

National & International Conferences

NASA Student Ambassador

United Nations Internship, Vienna
Background & Career Path

• Current internship at Goddard and NASA Headquarters
  – Goddard’s Innovative Partnership Program (Code 504) under Nona Cheeks
  – NASA’s Office of the Chief Technologist in Innovative Partnership Office under Doug Comstock

• Purpose of internship
  – Find synergy between office work and my research
  – Understand NASA approach to technology transfer and community partnership
  – Look at opportunities to facilitate deployment of NASA spinoffs for benefit of developing countries
Overview of Satellite Activity in Latin America, Africa and Asia

Note: This overview excludes India, China and Japan which are advanced in satellite and launch technology
<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>National Space Agency Or Office</th>
<th>Buy LEO Sat.</th>
<th>Buy GEO Sat.</th>
<th>Build LEO Sat. Locally</th>
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<tbody>
<tr>
<td>Africa</td>
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<td>In process</td>
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<td>NASRDA</td>
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<td>South Africa</td>
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<td>Indonesia</td>
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<td>Pakistan</td>
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<td><strong>Asia</strong></td>
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<td>South Korea</td>
<td>KARI</td>
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<td>Thailand</td>
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<td>Turkey</td>
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<td>United Arab Emirates</td>
<td>EIAST</td>
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</table>
Overview of emerging technology approaches

• As satellite technology matures, new approaches are emerging

• Focus here on small satellites for optical earth observation

• Implications for Manufacturers
  – Pursuing more performance from smaller spacecraft platforms
  – Using commercial-off-the-shelf technology (not designed for space) to build subsystems
  – Build heritage gradually and deliberately
  – Control scope and performance requirements carefully

• Implications for Satellite Buyers
  – Buy satellites in addition to buying data
  – Buy training and spacecraft
  – Share launches with other small satellite buyers
Why are new countries investing in space technology?

There are political (subjective) and technical (objective) motivations
<table>
<thead>
<tr>
<th>Investment Area</th>
<th>Satellite Service: Using satellite services in earth observation, communication, navigation and science</th>
<th>Satellite Hardware: Owning and operating a spacecraft and supporting ground system</th>
<th>Satellite Expertise: Training personnel in satellite engineering</th>
<th>Satellite Infrastructure: Establishing local facilities to fabricate satellites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Term Motivation</td>
<td>• Address time sensitive national needs for information</td>
<td>• Meet temporal frequency, spatial resolution, and spectral coverage requirements for information</td>
<td>• Develop knowledge to be an informed consumer of satellite services</td>
<td>• Increase technical involvement of local personnel in satellite activities</td>
</tr>
<tr>
<td>Long Term Motivation</td>
<td>• Enable informed regional planning • Enhance infrastructure and industry</td>
<td>• Gain operations experience • Decrease dependence on uncertain technology sources • Ensure service continuity</td>
<td>• Enhance education and research opportunities • Build up industrial capability</td>
<td>• Use infrastructure to facilitate long term series of satellite projects</td>
</tr>
</tbody>
</table>
Satellite Services Have Global Impact

- Satellite Remote Sensing
- Communication
- Positioning & Navigation
- Science
Food Security:

The US government partners with local experts to monitor the health of crops via FEWS NET @ www.fews.net

Goddard teams contribute to FEWSNET data products
Applications of Remote Sensing

**Fire Detection**: South Africa uses satellite data from MODIS on NASA’s Terra and Aqua satellites and Europe’s Meteosat satellites as part of a system to detect fires

http://afis.meraka.org.za/
Land Use Planning:

- South Africa uses satellite data products to track the changes in land use by making inventories of dwellings.

Credit: CSIR Satellite Applications Center, South Africa
Applications of Satellite Remote Sensing

Flood Mapping

The regional remote sensing center in Kenya supports Mozambique by producing a map of 2008 floods.
Applications of Remote Sensing

**Dust Monitoring**: Dubai uses satellites to monitor a dust storm

Danielle Wood

http://www.eiast.ae/default.aspx?options={a93e7034-0baa-4e2b-be21-721a4b6feb8e}&view=Article&layout=Article&itemId=147&id=44
Developing countries face common strategic questions regarding the application of satellite remote sensing data.
How do we access the data we need – affordably and consistently?
Many organizations in Africa receive foreign satellite data

Department of Remote Sensing in Nairobi, Kenya
Many organizations in Africa receive foreign data

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Owner</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat 5</td>
<td>USGS (USA)</td>
<td>Direct ingestion</td>
</tr>
<tr>
<td>Spot 2, 4 &amp; 5</td>
<td>Spotimage (France)</td>
<td>Direct ingestion</td>
</tr>
<tr>
<td>ERS 1 &amp; 2</td>
<td>ESA</td>
<td>Direct ingestion</td>
</tr>
<tr>
<td>Noaa series</td>
<td>NOAA (USA)</td>
<td>Direct ingestion</td>
</tr>
<tr>
<td>Seawifs</td>
<td>NASA (USA)</td>
<td>Direct ingestion</td>
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<tr>
<td>MODIS</td>
<td>NASA (USA)</td>
<td>Direct ingestion</td>
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<tr>
<td>SAC-C</td>
<td>Argentine</td>
<td>Direct ingestion</td>
</tr>
</tbody>
</table>
Government partnerships – such as SERVIR – play an important role

1. What is SERVIR-Africa?

Enabling the use of earth observations and predictive models for timely decision making to benefit society
In times of disaster, data is often shared

http://www.disasterscharter.org/home
How do we ensure that we have professionals in our country who are adequately trained in how to use and apply satellite data?
Regional partnerships play an important role

REGIONAL CENTRE FOR MAPPING OF RESOURCES FOR DEVELOPMENT

Our Vision
To be a premier Centre of excellence in the provision of Geo-Information & Information Technology Applications in Africa & beyond

Our Mission
To provide quality Geo - Information & allied Information Communication Technology products & services in environmental & resource management for sustainable development in our Member countries & beyond
The United Nations Offers Programs To Build Knowledge and Awareness

Every year the United Nations hosts events to spread awareness and provide training on satellite applications.

How do we ensure that the information from satellite data is best organized and applied to social challenges?
NASA Applied Science Approach...

Some countries pursue answers to the previous questions by forming a national satellite program.

Emerging national satellite programs face common strategic decisions about their satellite programs.
Societal Needs & Goals

International Context

National Context

Space Program Capabilities:
Facilities and Human Resources

Relationship of Space Program to Domestic Government, Industry and Academia

Relationship of Space Program to Foreign Governments or Companies
Space Technology Ladder

LAUNCH CAPABILITY

- SATELLITE IN GEOSTATIONARY ORBIT
- SATELLITE IN LOW EARTH ORBIT
- NATIONAL SPACE AGENCY
<table>
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<tr>
<th>Level</th>
<th>Description</th>
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<tbody>
<tr>
<td>13</td>
<td>Launch Capability: Satellite to GEO</td>
</tr>
<tr>
<td>12</td>
<td>Launch Capability: Satellite to LEO</td>
</tr>
<tr>
<td>11</td>
<td>GEO Satellite: Build Locally</td>
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<tr>
<td>10</td>
<td>GEO Satellite: Build through Mutual International Collaboration</td>
</tr>
<tr>
<td>9</td>
<td>GEO Satellite: Build Locally with Outside Assistance</td>
</tr>
<tr>
<td>8</td>
<td>GEO Satellite: Procure</td>
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<tr>
<td>7</td>
<td>LEO Satellite: Build Locally</td>
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<td>5</td>
<td>LEO Satellite: Build Locally with Outside Assistance</td>
</tr>
<tr>
<td>4</td>
<td>LEO Satellite: Build with Support in Partner’s Facility</td>
</tr>
<tr>
<td>3</td>
<td>LEO Satellite: Procure with Training Services</td>
</tr>
<tr>
<td>2</td>
<td>Space Agency: Establish Current Agency</td>
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<tr>
<td>1</td>
<td>Space Agency: Establish First National Space Office</td>
</tr>
</tbody>
</table>
Some countries with new satellite programs also invest in local expertise and infrastructure.
Countries progress up capability ladder as they invest in expertise and infrastructure.

Technology
  └── Technological Capability
      └── Technological Learning
          └── Technology Sources
              └── Tacit vs Explicit Knowledge
          └── Individual and Organizational Learning
              └── Absorptive Capacity
Advanced Industrial Countries

Emergence Consolidation Maturity

Product Innov

Process Innov

Developing Countries

Rate of Innovation

Time →

Rate of Innovation

Time →

Process

Product

Adapted from Utterback and Kim
# The Development of South Korea’s Satellite Program

|------------------------------------|---------------|---------------|---------------|----------------|----------------|----------------|

### Increasing Technical Complexity

- **National Space Agency**
  - KITSAT-1 1992: UK + Korean Universities
  - KITSAT-2 1993: Korean University
  - KITSAT-3 1999: Korean University
  - KOMPSAT-1 1999: US Firm + Korean Space Agency
  - KOMPSAT-2 2006: European Firm + Korean Space Agency
  - KOMPSAT-3 2010: European Firm + Korean Space Agency

- **Technical University**
  - KITSAT-1
  - KITSAT-2
  - KITSAT-3

### Spin-Off Firm

- **RazakSat (2009)**: Malaysian Space Agency + Korean Firm
- **DubaiSat (2009)**: Korean Firm + UAE University

Source: SaTReC [http://satrec.kaist.ac.kr/english/SaTReC.html](http://satrec.kaist.ac.kr/english/SaTReC.html)
Examples from African Satellite Programs

AlgeriaSat-1 and NigeriSat-X purchased from same English Firm, SSTL (Source: SSTL)

EgyptSat-1 purchased from Ukraine (Source: Yuzhnoye)

SumbandillaSat built by South African firm, SunSpace (Source: SunSpace)
Many countries pursue collaborative satellite projects with foreign partners.

- Algeria
- Turkey
- Egypt
- UAE
- Malaysia

Photo Credits: SSTL, EADS Astrium, SaTReC-I, Yuzhnoye
Structure of International Training Project

Gov’t Space Agency
- Goals
- Capabilities
- Constraints

Collaborative Satellite Project

Satellite Project Implementation

Foreign Firm
- Goals
- Capabilities
- Constraints

Capability Building
Contribution of Space Activities and Resources to National Development
Development as building technological capability

• Definition of Development from Prof Alice Amsden, political economist:
  – Development is the process of transition from an economy built on primary goods and unskilled labor to an economy built on knowledge-based assets and skilled labor

• Therefore…
  – A country becomes more developed as it makes better use of knowledge and technology for productive activity

Development as measurable improvements to quality of life

• Definition of development from United Nations Human Development Report
  – Development is the process of increasing people’s chances to obtain “a long and healthy life, knowledge and a decent standard of living.”

• Therefore…
  – A country becomes more developed as it better provides these opportunities to its citizens

The development loop

Development as improved technological capability

Development as improved quality of life for citizens
Five Ways that Space Resources Contribute to National Development

- **Applying Satellite Services**: Using communication, earth observation, navigation

- **Building Technological Capability**: Investing in local space hardware, expertise and infrastructure

- **Enabling Economic Activity**: Founding new space-related businesses

- **Inspiring Technology Applications**: Deploying and facilitating space spinoffs

- **Building Scientific Knowledge**: Harnessing space-based science data, ground-based space science or microgravity research
Emerging satellite technology approaches
As satellite technology matures, new approaches are emerging
Focus here on small satellites for optical earth observation
Since 1980s these approaches have evolved from technology demonstrations to operational missions
There are implications for satellite manufacturers and buyers
  – Manufacturers are pursuing non-traditional engineering approaches
  – New buyers are entering satellite market
Manufacturing small, affordable earth observation satellites

• Systems Engineering Approaches
  – Use Commercial-off-the-Shelf components
  – Design specific subsystems for your organization
  – Build subsystems from component level
  – Flight qualify components or subsystem, then reuse heritage pieces
  – Define standard set of performance options
  – Build small (in mass) missions with focused requirements
Manufacturing small, affordable earth observation satellites

- **Project Management Approaches**
  - Use small, focused teams
  - Balance portfolio between engineering research, technology demonstration with operational missions
  - Work with fixed price contracts
  - Carefully evaluate testing priorities
  - Look for benefits from in-house production versus outsourcing
  - Launch multiple spacecraft simultaneously to save money
  - Accept and manage risk
Choosing Systems Engineering and Project Management approaches that contribute to development

- Design of Satellite Systems
- Design of Satellite Programs
• The engineering approaches will impact the progress of new space countries toward development and policy goals

• Design of Satellite Systems includes choosing…
  – Performance and Functionality Requirements
    • Payload, Pointing Accuracy, Memory, Processing Power, Data Rates, etc
  – Level of Autonomy
    • Satellite; Ground Control System; Data Reception, Archiving and Processing System
  – Manufacturing Approach
  – Materials and Components Sourcing
• The engineering approaches will impact the progress of new space countries toward development and policy goals

• Design of Satellite Programs includes choosing….
  – Team members and leaders
  – Training approach
  – Partners (satellite supplier, consultant, launch provider, trainer, subcontractors, etc)
  – Infrastructure and facilities
  – Team work locations
  – Mentorship approaches
  – Contracts
  – Review process
Choose the program and satellite attributes to contribute to this process

- Development
  - Technology
    - Technological Capability
    - Technological Learning
      - Technology Sources
      - Tacit vs Explicit Knowledge
      - Individual and Organizational Learning
      - Absorptive Capacity
Conclusions

Implications for NASA
Implications for NASA and Partners

- It is valuable for the NASA community to stay aware of these new engineering trends and contribute to world wide satellite engineering dialog

- There may be lessons from NASA projects that can benefit the newly emerging space organizations

- There may be mutually beneficial opportunities for collaboration and partnership in areas such as…
  - Science data and instruments
  - Outreach and education
  - Shared launch opportunities
  - Spinoff Technologies
Implications for NASA and Partners

• There are several organizations that host meetings and discussion on these topics, including…
  – United Nations Program on Space Applications
  – International Astronautical Federation
  – International Academy of Astronautics
  – Committee on Space Research
  – Utah Conference on Small Satellites
Thank you!

Now it’s time for discussion…
Discussion Questions

• How has Goddard innovated in systems engineering methods and approaches?

• How would you compare and contrast the methods discussed here with Goddard’s satellite system engineering or program management approaches?

• What opportunities do you see for Goddard to benefit from new global space activities?

• What technologies advances may enable new satellite applications that could support global development needs?