Expanding Space Accessibility via Capability Building and Innovation

Danielle Wood, PhD
Assistant Professor, Massachusetts Institute of Technology
Director, Space Enabled Research Group

“The exploration and use of outer space should be carried on for the benefit of all peoples irrespective of the degree of their economic or scientific development…”

Outer Space Treaty, 1967
Space-enabled activities contribute to sustainable development...

1. Earth Observation
2. Satellite Communication
3. Satellite Positioning & Timing
4. Human Space Flight and Microgravity research
5. Inspiration (including education, outreach)
6. Space Spinoffs
7. Scientific Research (earth science, astrophysics, space weather, astrobiology, etc)
Universities can contribute to the Global Space Partnership for SDGs

- **Users Needs**
  - Consult on methods to define and assess user needs
  - Document case studies and evaluations illustrating impact of space for SDGs
- **Space Systems Capacity Coordination**
  - Propose methods to use software-base modeling to inform design of coordination of space systems
- **Access to Space Assets**
  - Perform studies and assessments identifying barriers to access and examples of effective projects; Perform pilot projects demonstrating best practices
- **Capacity Building**
  - Host capability building programs, international research collaboration and personnel exchange
  - Study and evaluate capacity building outcomes
Research Group at the MIT Media Lab:

Advancing justice in Earth's complex systems using designs enabled by space
The Space Enabled Research Group uses four types of methodology:

1) Research social and historical aspects of space initiatives
2) Using software to model space-enabled systems
3) Creating novel approaches to spacecraft engineering
4) Designing and evaluating space-enabled applications for development
Universities can contribute to the Global Space Partnership for SDGs

- **Users Needs**
  - Consult on methods to define and assess user needs
  - Document case studies and evaluations illustrating impact of space for SDGs
- **Space Systems Capacity Coordination**
  - Propose methods to use software-base modeling to inform design of coordination of space systems
- **Access to Space Assets**
  - Perform studies and assessments identifying barriers to access and examples of effective projects; Perform pilot projects demonstrating best practices
- **Capacity Building**
  - Host capability building programs, international research collaboration and personnel exchange
  - Study and evaluate capacity building outcomes
Users Needs

• Consult on methods to define and assess user needs
• Document case studies and evaluations illustrating impact of space for SDGs
**Program Stakeholders**
Individuals, organizations or groups that affect or are affected by the system; Primary stakeholders have direct decision making authority or system impact; Stakeholders have needs that lead to Program Objectives

**Program Objectives**
High level goals of the primary stakeholders that define what the system should achieve

**Program Forms**
(Nouns) Organizations, people, physical or virtual objects, programs and methods that execute program activities

**Program Functions**
(Verbs) Program activities that produce desired outcomes

**Inputs**

**Outputs**

**Context**

**Program Boundary**

**Constraints or Opportunities**

**Emergent Properties**
<table>
<thead>
<tr>
<th>Contextual Sectors</th>
<th>Narrow Contextual Levels</th>
<th>Broad Contextual Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>What is your organization’s technological capability?</td>
<td>What is the state of the art of the technology?</td>
</tr>
<tr>
<td></td>
<td>What are your innovative technologies?</td>
<td>What technology is available on the international market?</td>
</tr>
<tr>
<td></td>
<td>What relevant technologies are you missing?</td>
<td>What opportunities to collaborate with international partners on technology development?</td>
</tr>
<tr>
<td>Organization</td>
<td>What experiences does the implementing organization have with space activities?</td>
<td>What is the operating model for each organization contributing to the satellite program?</td>
</tr>
<tr>
<td>Facilities</td>
<td>What facilities exist in the organization to support the space activity?</td>
<td>What facilities are available among partner organizations to support the program?</td>
</tr>
<tr>
<td>Regulation and Legislation</td>
<td>What regulation and laws within the country impact the execution of the space activity?</td>
<td>What international law, agreements and norms impact the execution of the program—especially in the areas of spectrum management, export control and liability?</td>
</tr>
</tbody>
</table>
For each level, consider factors regarding Technology, Policy, Collaboration and Economics.
Analyze Stakeholders

Identify Stakeholders and Relationships

Categorize Stakeholders

Identify Stakeholder Needs and Desired Outcomes

Stakeholder Categories

- Primary Stakeholders: Making decisions to shape the system
- Secondary Stakeholders: Influencing decisions of Primary Stakeholders
- Tertiary Stakeholders: Beneficiaries of the System

Source: Wood and Wolf in Alonso Perez and Qedar, 2014
Identify Stakeholder Needs, Desired Outcomes and Objectives for the System

- **Stakeholder Need**: What problems or desires are stakeholders facing?
- **Desired Outcomes**: What do stakeholders want the world to be like in the future?
- **System Objectives**: What activities will a system do to contribute to the desired outcomes?
| **Need** | **What problem are stakeholders facing?**  
Approx. 200 million malaria cases and 580,000 deaths in 2013, especially impacting less developed countries |
| **Desired Outcomes** | **What do stakeholders want the world to be like in the future?**  
Reduce malaria deaths to near zero; reduce global malaria cases by 75% of 2000 levels |
| **Objectives** | **What activities will a program do to contribute to the desired outcomes?**  
Apply data from satellites and other sources to inform malaria control strategies; create Malaria Early Warning System |
One of the targets of SDG 3 is to eliminate epidemics of malaria and other vector-bourne diseases.
Malaria Early Warning System Objectives

Acquire and Manage Data
- Access census and health information
- Access weather and climate data from satellite, airborne and ground-based sensors
- Access environmental information from satellite, airborne and ground-based sensors
- Maintain historical malaria prevalence data
- Monitor current malaria statistics

Develop Value-Added Products
- Derive hazard model from environmental and weather data
- Produce vulnerability model from census data and health information
- Run transmission model based on the life-cycle of malaria parasite and vector
- Forecast which regions will be most vulnerable to a malaria outbreak based on model above

Respond to Threat
- Treat malaria-infected patients
- Coordinate response
- Notify regional and local leaders
- Move supplies to local health facilities
- Educate local population
- Execute indoor residual spraying campaign
- Distribute bed nets
- Identify and document malaria cases
- Manage migration of people from high transmission areas
Space Systems Capacity Coordination

Propose methods to use software-base modeling to inform design of coordination of space systems
Tools for design and engineering of space systems can be used to inform coordination of space systems for development.
Access to Space Assets

• Perform studies and assessments identifying barriers to access and examples of effective projects
• Perform pilot projects demonstrating best practices
Satellite-enabled Activity in Africa uses domestic and international satellite technology (79 Case Studies)

Domestic satellite technology adoption

Accessing international satellite technology

Every country in Africa is represented in these case studies
1. Earth Observation (EO) System Design and Implementation
2. EO System Operation, Data Retrieval, Calibration & Validation
3. EO Data Correction and Processing
4. Earth Science Modeling and Assimilation of Earth Observations
5. EO Data Discovery & Visualization: Providing interface to find and explore data
6. EO Data Transformation: Creating data interface based on user needs
7. Knowledge Integration: Combining physical, social, economic and other data
8. Decision Support: Providing recommendations for action
<table>
<thead>
<tr>
<th><strong>Satellite Engineering</strong></th>
<th>Traditional satellite engineering builds large, highly reliable, long-lasting satellites</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Satellite Earth Observation</strong></td>
<td>Overwhelming amounts of free data are available, difficult to find and apply</td>
</tr>
<tr>
<td><strong>Satellite Communication</strong></td>
<td>Traditional business models lead to high prices that exclude low-income users</td>
</tr>
<tr>
<td><strong>Space Launch</strong></td>
<td>Launch opportunities have traditionally been expensive and limited to certain orbits</td>
</tr>
<tr>
<td><strong>Microgravity Research</strong></td>
<td>Access has been expensive; research has focused on low maturity technology</td>
</tr>
<tr>
<td><strong>Space Spinoffs</strong></td>
<td>Spinoff opportunities are found through unplanned connections</td>
</tr>
</tbody>
</table>
### Future opportunities for application of space-enabled technology for SDGs

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite Engineering</td>
<td>New satellite engineering methods will reduce debris, reduce cost and provide new operational models</td>
</tr>
<tr>
<td>Earth Observation</td>
<td>Commercial market will form to apply machine learning, cloud computing and visualization to infuse satellite earth observation data into decision support systems</td>
</tr>
<tr>
<td>Satellite Communication</td>
<td>New communication constellations propose to reduce price and target low-income market</td>
</tr>
<tr>
<td>Space Launch</td>
<td>Launch prices are decreasing, new commercial launch players are emerging and new launch vehicles will focus on small satellites</td>
</tr>
<tr>
<td>Microgravity Research</td>
<td>Private and government entities will offer routine access to earth orbit and other microgravity environment</td>
</tr>
<tr>
<td>Space Spinoffs</td>
<td>Spinoffs will increase as the space industry engages more with other industries</td>
</tr>
</tbody>
</table>
Capacity Building

- Host capability building programs, international research collaboration and personnel exchange
- Study and evaluate capacity building outcomes
<table>
<thead>
<tr>
<th>Learning</th>
<th>Individual</th>
<th>Group</th>
<th>Institutional</th>
<th>Programmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short Term</strong></td>
<td>Individuals learning new knowledge and skills</td>
<td>Individuals converting tacit knowledge to explicit knowledge</td>
<td>Achieving new institutional milestones</td>
<td>Observing progress toward goals; making changes to ensure progress</td>
</tr>
<tr>
<td><strong>Long Term</strong></td>
<td>Individuals increasing autonomy in executing tasks</td>
<td>Individuals learning to leverage the contributions of group members</td>
<td>Communicating knowledge across organizational units</td>
<td>Observing both goals and progress toward goals; changing goals as needed</td>
</tr>
</tbody>
</table>
Space Activity Learning Lifecycle

- Exploratory or Demonstration Phase
- Building Technology Literacy Phase
- Technology or Service-Oriented Phase
- Innovation Adaptation Diffusion Phase
Nigeria
Algeria
Egypt
UAE
Malaysia
Turkey
Chile
Nigeria
South Africa
Thailand
Nigeria
Ground Station, Satellite Control Room and Model for DubaiSat Program

Emirates Advanced Institute for Science and Technology

United Arab Emirates
“Service-Oriented” Program

Gov’t Overseer → Promise Info → Foreign Supplier → Imple-menter → Gov’t Overseer

“Technology-Oriented” Program

Gov’t Overseer → Promise Info → Foreign Supplier → Imple-menter → Gov’t Overseer

<table>
<thead>
<tr>
<th>Functions</th>
<th>Service Oriented Attributes</th>
<th>Technology Oriented Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundraising</td>
<td>Seek funding support formally through providing service</td>
<td>Seek funding support formally through providing new technology achievement</td>
</tr>
<tr>
<td>Supplier</td>
<td>Selected based on formal process that is acceptable to funders</td>
<td>Selected based on trust and common objectives</td>
</tr>
<tr>
<td>Satellite</td>
<td>High complexity and performance</td>
<td>New feature or performance</td>
</tr>
<tr>
<td>Training</td>
<td>Emphasizes theory and formal mentoring</td>
<td>Emphasizes on the job responsibility and mentoring as needed for the project goals</td>
</tr>
</tbody>
</table>
Defining capability building

Capability Building can happen when an individual or organization experiences a new topic, a new level of autonomy or a new level of complexity.
Evaluating Technical Achievements of Space Capability

Building

- Independently
- With Mutual Partner
- Locally with assistance
- With support externally
- During training

Satellite System Operation
Satellite System Manufacture, Assembly, Test
Satellite Project Business Development
Satellite Project Definition
Satellite System Design
Product Invention
Product Innovation
### What Individual Capabilities Do We Want to Build?

#### Satellite Engineering Skills

**Overall Project Skills:**
- Project Definition
- Requirements Management
- Software Tools
- Overall Design skills
- Procurement, Manufacture, Assembly, Integration & Testing
- Management & Documentation
- Launch & Operations
- Space Systems Engineering

**Subsystem Specialties:**
- Mission Orbit Design
- Ground Station Design
- Communication systems
- Structural and thermal
- Attitude control and determination systems
- Electrical power system
- On-board computer

#### Academic Research Skills

- Identify Topic and Motivation
- Identify Literature Gap
- Define Research Question
- Define Research Methodology
- Define Data Sources and Analysis Method
- Collect Data; Develop Simulation or Model
- Analyze Data
- Interpret Findings
- Answer Research Question
- Present Research
Capability Building Evaluation: Technical Learning Outcomes in Academic Research Project

Technical Learning Outcomes in Academic Research (Bachelors, Masters and PhD)

- Identify Topic
- Review Literature
- Define Question
- Define Plan
- Define Methods
- Collect Data; Simulate
- Analyze Data
- Interpret Findings
- Answer Research Question
- Present Conclusions

Independent Implementation
Supervised On the Job Experience
Practical Training
Related Practical Experience
Theoretical Training
Related Theoretical Training

• The MIT Media Lab stands ready to collaborate with UNOOSA and the Global Space Partnership for SDGs to support application of space for sustainable development.
• The MIT Media Lab is eager to join and play a leadership role in a network of universities supporting capability building, accessibility and innovation.