New models for democratic engagement in the application of space technology for sustainable development

Professor Danielle Wood
Massachusetts Institute of Technology, drwood@media.mit.edu
Session: "Democratic Discontent, Technocratic Agendas, and Emerging Alternatives"

Abstract

The space sector is experiencing what appear to be contradictory trends regarding the role of democratic engagement and the relationship between the state, experts, commercial firms and society. On one hand, the role of the public sector continues to be central to provide funding and innovation that harness satellite technology and space-related research to support public services. Governments around the world currently use space technology to enable public services such as weather forecasting, disaster response, agricultural monitoring and water resource management. Technology from space, including satellite earth observation, communications and positioning services, has the potential support important societal objectives, such as meeting the United Nations Sustainable Development Goals. On the other hand, the role of the private sector in the space sector is changing as satellites and launch technology mature. Firms are experimenting with new business models that depend less on direct government investment to operate large constellations of satellites for earth observation or communication services. In the United States, federal agencies such as NASA and NOAA are exploring new ways to buy data services from commercial firms in additional contracting for the building of full satellite systems owned by the government. Around the world, non-traditional countries are creating new domestic satellite programs. Countries on every continent have invested in government-led projects to buy or build satellites for earth observation and communication. The increase in space-fairing nations leads to new international space policy questions that will help ensure that the orbital environment remains free of debris and safe for all to operate. New democratic models will be needed to ensure that innovation, public services and global access are assured in the space sector. New space-fairing nations are transitioning to increased activity in space. They need to invite democratic participation in setting their national space strategy and policy, but further work is needed to engage these populations. Technology from space has the potential to support democratic engagement by providing communication services to remote areas and by providing objective data about environmental management. Further research is needed to understand whether the increased commercial role in satellite projects and the increase in space-fairing nations is helping citizens access technology benefits and supporting sustainable development.

1) Space Technology is a Symbol of Power and Democratic Engagement

The physical and symbolic components of space activity exist in a paradoxical reality that at once represents centralized and exclusive power while at the same time allowing distributed and inclusive democratic engagement. In the discussion that follows, democratic engagement in the context of space technology is defined as the ability of government agencies, members of the public and commercial companies to access the benefits of space technology that is publicly funded and to participate in creating new innovations based on this technology. Beyond this minimal role, an even higher level of democratic engagement would involve public input to define

future strategic investment in space programs and influence in the international space governance process.

Early in the era of space exploration, starting in the 1950s, space represented the achievements of elite scientists, engineers and government leaders who defied the current understanding of physics to achieve what seemed to be impossible by orbiting spacecraft, satellites and humans around the earth (McDougall 1985). In the context of the Cold War, space achievements were literally used to convince the watching global audience that capitalism or communism could achieve superior historic outcomes (Launius 1997). Even as governments pursued self-serving space programs that were designed with little democratic engagement, the public paradoxically created a role in the space era because of the great interest that new space milestones generated. Millions of people went to watch space launches in person, watched closely the new of early human space flight on the news and celebrated major technological milestones. Through this enthusiasm, the public inserted itself as a figure with power in the progression of international space activity. Organizations such as NASA started to include public outreach and engagement with historians and artists as formal parts of their budgets and programmatic activities (Launius, Ulrich and Glenn 1998) Near Kennedy Space Center, when there are launches, traffic patterns change drastically and the law enforcement system has to respond to thousands of cars parked alongside the road of otherwise rural coastal neighborhoods near Titusville, Florida. The public makes itself felt as a stakeholder in major space achievements pursued by governments. During the early space era, popular culture responded by using space as an analogy for the future that a successful society could create. Notably, Gene Roddenberry's Star Trek, the Original Series, presented a future in which people from a variety of backgrounds worked together as a highly effective team to make scientific discoveries, engage in complex diplomacy and survive existential crises. In addition to aliens from beyond earth, the crew of the Original Series included people in the 24th Century that seemed to descent from the countries of the Soviet Union, Scotland, Kenya and the United States in the 20th Century. Nichelle Nichols made history by being one of the first black women to depict a character with leadership and advanced technical skills as she played Lt. Uhura (Pounds 1999). Through more recent historical research and population interpretations of the *Hidden Figures* movie, it is now clearer that black women such as Katherine Johnson and Dorothy Vaughn were working as computer scientists and advanced mathematicians within NASA when Nichelle Nichols debuted in *Star Trek* (Shetterly 2017). These and other examples show the paradox that space is at once the province of centralized decision making by elites within the government while at the same time being a domain in which public perception and participation is highly influential.

Space technology, especially satellites that provide public services in the areas of earth observation, communication, positioning and scientific measurement, have a paradoxical, symbolic power to represent both centralized power held by elite governments and access to free services that are used innovatively by the general public and commercial companies. In the context of the United States, for example, the government agencies of NASA and the US Geological Survey operate the long-term series of satellites for earth observation called LandSat. After several experiments of public and private operational models, the current approach for data distribution is that the government provides all LandSat data to the public freely (Borowitz 2017). Through

Google's Earth Engine, these LandSat data set is available on a cloud-based platform that increases ease of use for those who are not familiar with converting satellite-based earth observation data into maps within Geographic Information Systems. As commercial companies such as Planet add new earth observation data to the global marketplace at higher spatial resolution (3 meters) and temporal frequency (daily rather than weekly), they begin by using the LandSat data set as a benchmark that provides the desired frequency bands. Meanwhile, the European Space Agency operates the Sentinel series of satellites which provides free global access to data that is comparable to LandSat as well as higher resolution data in which each pixel is 10 meters. In the area of satellite-positioning, the governments of the United States, the European Union, the Russian Federation and China each operate Global Navigation Satellite Systems. These systems have the potential to be used by individuals from countries around the world to provide information about their location and a precise measurement of time that can be applied in a variety of applications including mapping, transportation, financial transactions and precision agriculture. In most cases, members of the public and private sector organizations can use the signals from these government positioning satellites freely. In the area of satellite communication, countries such as India operate government-owned satellites with the express purpose of providing communication services to support education and medicine in rural areas. The global satellite communication market is dominated mainly by large, multinational companies that achieve profit by providing services to support broadcast television, radio, internet and phone services. While satellite communications greatly increase access to television, radio and internet services, the prices remain high for rural users in Latin America, Africa and Southeast Asia who are typically disconnected. In each of the domains discussed above, there is simultaneously a strong government agency making decisions without a high level of democratic engagement as well as a functional increase in access to important services that contributes to democracy.

Let us view the paradox of space as a source of exclusive power or inclusive democratic participation by viewing examples in through lenses: post-colonial international relationships; theories of national development; and global space governance. In the discussion below, empirical data is derived from previous work by the author (Wood and Weigel 2014; Wood, Polansky and Cho 2015; Wood 2013; Wood and Weigel 2012).

A) Post-Colonial International Relationships

In the space sector, the relationships among countries with historical colonial ties reflect dynamics that bot foster and discourage democratic engagement. Several former colonial nations carry on a form of semi-colonial relationships as part of their ongoing space operations. In three examples, companies and governments from northern countries follow a colonial posture to access land owned by another country that provides advantageous equatorial launch trajectories with reduced power requirements. The European company Arianespace operates a launch facility in French Guiana near the equator. The Italian Space Agency leases land on the coast of Kenya in an equatorial latitude. The site was previously used for launches and currently is used as a site to download data from satellites and provide satellite operations services. The US military operates a military base in the Kwajalein Atoll within the Republic of the Marshal Islands, which also provides access to equatorial launches. Although it is not equatorial, there is a colonial flavor to

the relationship between Russia and Kazakstan, which hosts the Baikonor Cosmodrome. Russia operates the launch site in Kazakhstan, using land that was previously part of the Soviet Union, but is now within another sovereign nation. In the above example, the nation that is operating the space facility compensates the host nation for the access. One could argue that the host nation benefits from having advanced technology facilities on their territory. This ignores fundamental assumptions, however, about the distribution of benefits from space activity. Prior to the 1950s, it was a colonial way of thinking that assumed it is normal for some countries to control access to space technology and others to be passive observers or beneficiaries. The argument that it is expedient for European and North American countries to pay equatorial countries to take advantage of their geographic endowment assumes that there may be a fundamental worthiness of the northern countries to have whatever technological advantage they can afford. It is also built on concepts that assume equatorial countries or those that have been previously colonized are not prepared or qualified to use the geographic endowments. Such assumptions are counter to the role of space as a source of democratic engagement; they reinforce ideas drawn from racism that assume populations in some geographic locations are naturally less likely to be technologically savvy (Kendi 2017). One might argue that racist intent is not required for a country with space resources to request access to the land of another country. One might take a pragmatic approach and argue that it is useful for the global community to have countries with more experience in space harness the benefits of equatorial launches or satellite tracing facilities. Given this pragmatic argument, however, there would seem to be a limit to the time in which this is the ideal state. Should not we expect that after multiple decades, the host nation would become capable of taking a leadership role in operating the space facility on their sovereign territory? What is the long-term state of this perpetual colonial arrangement in which one country exercises effective sovereignty over land that is not their own? How does this impact the democratic engagement for citizens and organizations in the host country? In the case of Kenya and Italy, the agreement for Italy to lease land on the coast of Kenya was renegotiated recently. As part of the negotiation, Kenya requested that Italy help to build local capability to work on satellite engineering, data analysis and other space related competencies. Through this relationship, representatives from the University of Nairobi collaborated with representatives from the Italian university called La Sapienza to build a small, one unit CubeSat. The building and testing of the satellite was done in Italy with participation of several Kenyan engineers. The satellite was launched by the government of Japan from the Japanese Kibo module on the International Space Station. The Italian-Kenyan satellite was selected as part of a competition hosted by the United Nations. This example continues the paradox. Kenya announced a national space agency in 2017 with a small team and continues to build up institutional capacity. Even as Kenya continues a long process to create domestic capacity to lead the space activity within their country, they commit to a long-term lease with Italy. On the other hand, the model of technology mentoring in the university satellite project identifies a potential approach to foster democratic engagement and eventually transition to Kenyan leadership in their equatorial launch site.

Another way to consider post-colonial relationships that influence space activity is to examine which nations partner with former colonial powers during satellite projects that are designed to build local capability in engineering and management. In previous work, the author has outlined

the experience of multiple nations in Africa, Latin America and Asia that actively sought to start government satellite programs. Their approach was to establish a contract or political agreement with a company or government agency from a nation with experience in satellite programs. These projects are termed Collaborative Satellite Development Projects because the nation that seeks to learn sends engineers to work alongside engineers from the experienced nation to build a satellite together. In some cases, nations choose to work with companies or government agencies from the nation that was their former colonial occupier. For example, Nigeria built their first three earth observation satellites via a contract with a satellite company in the United Kingdom. Some of the members of the Nigerian team also pursued academic study in the United Kingdom via scholarships they could access because they are a member of the British commonwealth. As with the case of Kenya and Italy collaborating, the interpretation is complex. On one hand, both Nigeria and the UK company had other partners. The Surrey Satellite Technology LTD in the UK has performed satellite projects with a focus on technology transfer for customers from many countries, both inside and outside the British Commonwealth. These countries include Turkey, Kazakhstan, Malaysia, Chile and South Korea. For Nigeria, they pursued the earth observation projects with the UK and simultaneously work on projects for satellite communication with China – a choice that counters traditional colonial ties. About 50 Nigerian engineers worked in China during the development of their satellite. The role of China as an active investor, land purchaser and government partner in Africa, however, begs further analysis to determine whether the relationship between Nigeria and China for the satellite development projects is one that promotes democratic engagement for Nigerian organizations and people.

As previously colonized nations adopt space technology as part of national government programs, they face a strategic decision about forming international alliances which may increase or decrease the role of space to foster democratic engagement and effective societal benefit in their nation.

B) Theories of National Development.

The prevailing theories that prescribed how a national government should foster economic development and offer an informative lens to examine whether participation in space activity is viewed as a logical step in national progress or a wasteful investment. Grieve (2004) summarizes helpfully the timeline of popular recommendations that newly independent countries received starting in the post-war period of the 1950s and continuing into the 2000s. Grieve notes that early development scholars encouraged newly independent or newly industrializing countries to seek technical approaches and industries that leveraged high labor and low capital intensive techniques. Such advice assumed that it was not useful for these nations to invest in learning advanced technology or creating domestic capability in research, development and innovation. A later trend, lead by Schumacher, encouraged countries with large rural populations to pursue intermediate technologies that were appropriate to the local materials, knowledge and culture of the region. Grieve notes that this view had some value, but it also contains the narrow-minded assumption that such regions will not benefit from gaining new knowledge in advanced technology. The final stage that Grieve reviews is a realization that every nation will benefit from pursuing a long term effort to create a health National System of Innovation that includes government organizations, universities, schools, large enterprises and entrepreneurial startups. With such an ecosystem, there

can be a balance of labor-intensive, appropriate and advanced technology. A National Innovation Systems builds capability in both technology and management skills. This final phase of Grieve's three part story invites any nation to pursue understanding and local capability in technology areas that they find valuable to national development, including space.

At this stage it is helpful to step back from established assumptions and question what underlies the changing attitudes outlined by Grieve. Why do scholars consider it acceptable to debate the type of technology that is "appropriate" for a particular type of country to pursue? Is it not presumptuous and a deterrent to democratic engagement that an outsider feels the right to dictate which technology areas are allowable for members of another nation? People sometimes ask whether it is ethically right for a country with low Gross Domestic Product or high poverty to invest in technology projects related to space. While every government investment should be judged according to the benefit it brings the population, there is no reason to assume that a satellite which provides information about the health of crops in an agricultural country is a waste of money. The concept that certain countries are not ready to participate in advanced technology is built on traditions of racist and colonial thinking. Going further, the concept that national development is epitomized by adoption of advanced technology such as satellites is also fraught with narrow-minded assumptions. When scholars argue that countries from any region should pursue building capability in advanced technology, they are highlighting the means instead of the desired outcomes. The standard for technology priorities can be based on the benefits it brings to the population rather than on the level or type of technology. There are assumptions built into modern society that can be traced to the Enlightenment and later the Industrial Age. Dominant western thought in the North American and European context often assumes that nations are inherently more worthy of commendation if they use advanced technology, rather than evaluating national development or status on the basis of the quality of life of the people. As a counter perspective, consider the mentality of Native American tribes in the United States that place high value on traditional sources of knowledge about the environment and traditional practices for managing forests, wildlife and human health. Many of these tribes are open to applying practices such as prayer to foster environmental soundness but they also harness drones and satellites to collect scientific data. In this context, there is no inherent hierarchy between knowledge based on the application of physics and engineer versus knowledge based on many years of experience within the community. Such a perspective counters the common tendency to give more respect to countries based on their achievements in areas such as satellite technology. Such a tendency ignores the more salient measure of progress, which is the wellbeing of people using measures such as the Sustainable Development Goals. Experience has shown that well design application of technologies such as satellites can contribute to the wellbeing of people, but it is the social outcomes not technology that should be celebrated. In the same way, countries that have experience colonization and exploitation may not have yet built the institutional capacity of their National Innovation System. This is seen to impede their ability to create an environment that supports the wellbeing of the population but it does not imply that there is anything inherent in the members of the society that limits their ability to harness technology or achieve improved societal outcomes. Rather, it implies that they are responding to both internally and externally inflicted actions that damaged the social and technological infrastructure of the nation.

As we view the historical progression of global space activity, the patterns that determine which countries played an active role in space technology development intersect to some extent with other patterns driven by prevailing economic theories of national development. During the 1940s, 1950s and 1960s many countries within Africa and Asia were gaining independence from former colonial powers. At the same time, global institutions such as the World Bank and scholars of economic development often advised formerly colonized countries to build a national economy focused on exporting in their areas of competitive advantage, especially raw materials and items that could be manufactured with low-labor costs. These countries were also counseled to invite foreign direct investment to guide the implementation of new industrial activity. Each of these strategies runs counter to the concept of a newly independent country investing in its own knowledge-based assets, protecting local fledgling industries and identifying specific technological areas in which the country seeks to build national technological capabilities. Many countries followed the dominant prescription and did not invest in technologies at the national level that were considered advanced such as satellites during the 1960s through the 1980s. Instead they worked through a series of commonly accepted steps such as manufacturing low complexity products such as textiles and gradually transitioning to more complex projects such as electronics and later heavy industry products or chemicals. In this way, the dominant economic advice may have reduced democratic engagement with space technology by making it appear out of reach of newly independent countries. This was coupled with the reality that large upfront investments have traditionally been required to start work on satellite engineering and set up testing and manufacturing facilities. India is an example of a country that started soon after independence to counter international advice and follow protectionist practices to support the development of local industries. India also established a space program starting early in the space era with an explicit focus on serving the needs of the rural poor to access communication services and environmental monitoring. In Latin America, countries such as Argentina and Brazil also started national research programs in space early in the 1960s. These fledgling space research programs grew up in the context of the Cold War and the salient reality of nuclear weapons. Several newly independent countries in regions around the world created national institutions focused on nuclear energy, space or both. These topics emerged as salient to the major transitions occurring in the world during the 1960s as all governments realized that more conflict could occur with nuclear assets.

The pattern of countries avoiding investments in space is broken by the reality that many nations in Africa, Latin America and Asia did participate since the 1970s in learning about and applying satellite applications, including earth observation, positioning and communication. The United Nations Office of Outer Space Affairs has hosted a Programme on Space Applications since 1971 that fostered awareness and capability building to ensure that all nations had access to satellite applications. The Programme on Space Applications pursued this primarily by hosting regular workshops and training events. Many analysts of satellite data from Africa and Latin America were trained in North American or European universities during the 1970s, 1980s and 1990s. This led to a pattern in which remote sensing data analysts and satellite telecommunication engineers could start to train their others in their countries rather than always relying on external sources of training. During the 1990s, a new opening started as universities and governments proposed new

ways to build satellites with smaller size and less arduous engineering technique. These small satellites are designed to achieve less reliable performance than traditional satellites, but they can be operated in groups and achieve useful missions in satellite earth observation, communication and scientific research. Since the 1990s many countries have started national satellite programs with an emphasis on small satellites. The United Nations Office of Outer Space Affairs created a Basic Space Technology Initiative for the purpose of spreading awareness and training about opportunities for emerging space nations to develop domestic small satellite programs.

C) Global Space Governance

Another lens through which to note that space is both a medium for centralized power and inclusive democratic engagement is global space governance; this refers to the international policy and diplomatic process that sets the norms and agreements for managing the global commons of space. One view can argue with evidence that nations with large space budgets and multinational companies dominate global space governance by setting precedents with their actions. The United States Air Force performs the de facto role to provide global space traffic coordination because it is the institution with high quality technology to achieve the task. The work includes monitoring all objects orbiting the earth and performing mathematical calculations to determine whether two objects are likely to collide. Currently the US Air Force provides the free service to contact satellite owners when there is a risk that they will collide with another space object. They also host a free website through which satellite owners can submit information about their satellite to make it easier for the US Air Force to track. This is both an source of democratic engagement, because it is voluntary information sharing in exchange for service, and a source of centralized power in the hands of one government. In other examples it may be true that in the next few years, companies will set de facto precedent for what behavior is allowed when harvesting resources from asteroids or flying large constellations of satellites. There is a global space policy regime to address these issues and there is open access to nations of all backgrounds to contribute to these policy tools such as treaties. The United Nations Office of Outer Space Affairs it the secretariat of the Committee on the Peaceful Use of Outer Space. This committee has lead the development of five key space treaties that have been ratified by many countries. Countries from every region and economic background are members of the committee which makes decisions via consensus. Thus, there is an opportunity for democratic engagement in shaping the future of international space law.

2) Space Technology as a Practical Tool to Support Democratic Program via Sustainable Development

Space technology has the potential to be highly relevant to socioeconomic advancement for countries and communities that have faced the most harm due to colonialism and racism – such as countries in Africa and native American communities in the US. One way to show this is to outline the role of space technology to support the sustainable development goals. The Sustainable Development Goals (SDGs) provide the high-priority challenges for our generation in areas such as access to clean water, food security, poverty alleviation, health care, environmental sustainability and urban development. Each goal includes a set of Targets countries are working to achieve by 2030. Each Target includes a set of indicators that define the quantitative

measurement for the Targets. A key element of pursuing the SDGs is for nations to work with the UN to develop methods to measure progress toward the Targets on each indicator. Many of the indicators and targets relate to environmental factors, human infrastructure or investment in research and education. In each of these areas, space technology such as satellites can play a role as part of national strategies to both monitor progress toward the SDGs and to work toward achieving the Targets. The proposed research agenda harnesses the definition of Sustainable Development provided by the 2030 Agenda for Sustainable Development and the 17 Sustainable Development Goals (United Nations 2018c). In many cases, achieving a Sustainable Development Goal requires the establishment or improvement of a complex sociotechnical system. For example, Goal 6 discusses "Clean Water and Sanitation" while requiring "universal and equitable access to safe and affordable drinking water for all (United Nations 2018d)." The systems that will provide access to safe drinking water for those who remain underserved will be complex due to limited resources, historical community disenfranchisement and hampered physical infrastructure. The sociotechnical design process that addresses these challenges accounts for the social, cultural and historical factors that created the lack of safe drinking water while respecting the autonomy of community-based leaders that are working to improve the situation. An added layer of complexity is present because the 17 Sustainable Development Goals influence each other. The goals may at times appear to be in tension, such as ensuring the people have access to decent work and economic growth while preserving life on land, including protecting endangered species. When these apparent tensions emerge, there is a need for additional innovation and insights that allow for environmental and economic progress simultaneously.

Figure 1: 2030 Agenda for Sustainable Development defines 17 Sustainable Development Goals

As noted above, six technologies from the space sector are already being used to support the monitoring and achievement of the Sustainable Development Goals. These technologies include satellite earth observation, satellite communication, satellite positioning, microgravity research, technology transfer and the inspiration drawn from research and education. Despite many examples of progress, barriers continue to limit the application of these technologies as part of development strategies. Ongoing research by the author works to reduce barriers for development leaders to use them.

3) What are the implications for democracy of these pressing trends within the space domain?

What is the synthesis of the tension between forces that propel space as a venue of exclusive power and space as a venue of democratic engagement? Consider a few reflections.

- New space programs in developing countries inherently advance democracy by challenging traditional colonial mentalities that called for countries in the equatorial regions to focus on natural resource production and low-value added products rather than pursuing work related to knowledge-based assets. It is necessary to debunk such myths to support the long-term development of democracy in countries that have traditionally been technology consumers rather than technology producers based on historical patterns. Drawing on the tradition of the Science, Technology and Society literature, we learn to not praise technology as an outcome in itself, but rather to ask how technology or other sources of knowledge influence the human condition and environmental sustainability.
- Space activity can provide functional democracy by bringing information to individuals, communities and local leaders. This is evident when organizations access freely provided data from government operated earth observation satellites. New companies are experimenting with business models to achieve sustainable operations of satellites for profit. Some of these companies are motived to support human wellbeing while pursuing a profit-based business model.
- New space activity in emerging countries is not necessarily increasing democracy from the point of view of members of the public feeling a part of the program direction; we see a mix. In some countries there is high level, top down decision making; in other countries there is bottom up participation. The example of the United Arab Emirates, Malaysia, and Kenya have some positive examples of public participation and involvement of university students via government programs.
- The new level of global space activity requires participation by all countries in global space policy dialog such as via the United Nations Committee on the Peace Uses of Outer Space. Every country will be adversely impacted if we do not maintain the long term sustainability of space.

References

Borowitz, Mariel. *Open Space: The Global Effort for Open Access to Environmental Satellite Data*. MIT Press, 2017.

Grieve, Roy H. "Appropriate technology in a globalizing world." International Journal of Technology Management & Sustainable Development 3.3 (2004): 173-188.

Kendi, Ibram. Stamped from the beginning: The definitive history of racist ideas in America. Random House, 2017.

Launius, Roger D., and Howard E. McCurdy, eds. *Spaceflight and the myth of presidential leadership*. University of Illinois Press, 1997.

Launius, Roger D., Bertram Ulrich, and John Glenn. *NASA & the Exploration of Space: With Works from the NASA Art Collection*. Stewart, Tabori & Chang, 1998.

McDougall, Walter A. "Heavens and the earth: a political history of the space age." (1985).

Pounds, Micheal C. *Race in space: The representation of ethnicity in Star Trek and Star Trek, the Next Generation*. Scarecrow Press, 1999.

Shetterly, Margot Lee. *Hidden figures*. HarperCollins Nordic, 2017.

Wood, D. & A. Weigel, "Architectures of Small Satellite Programs in Developing Countries," *Acta Astronautica*, Vol 97, April – May 2014, pp 109-121. https://doi.org/10.1016/j.actaastro.2013.12.015

Wood, D., Polansky, J., Cho, M., "University Partnerships As A Model For Capability Building In Emerging Space Nations," *International Astronautical Congress*, Jerusalem, Israel, October 2015.

Wood, D., "Analysis of Technology Transfer within Satellite Programs in Developing Countries using Systems Architecture," *American Institute of Aeronautics and Astronautics Space 2013 Conference, September 9-11, 2013.*

Wood, Danielle, and Annalisa Weigel. "Building technological capability within satellite programs in developing countries." *Acta Astronautica* 69.11-12 (2011): 1110-1122.