SECTION 3. How Does a State Develop Space Capability?

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SECTION 3.

How Does a State Develop Space Capability?

There is no single way to establish foundational space capabilities. The actual method by which any country establishes or expands its capabilities is shaped by the country's history, culture, ideology, and political and environmental realities. That said, a solid first step is to commit to the development of a space program, of any size or budget, to act as a national focal point for space-related affairs. Whether run by a single advisor or by a well-staffed agency, the core function of taking deliberate action to maximize the benefits of existing space infrastructure can be achieved. To that end and beyond, this section provides a framework that enables

- A deliberate, methodical, outcomes-focused planning process;
- Strategic decisions about a space program's intent, goals, organization, and resourcing;
- Inclusion of stakeholders from the government, civil society, private sector, and academia; and
- A demonstratable chain of logic, from intent to action, outcome, and evaluation.

ORIENTATION

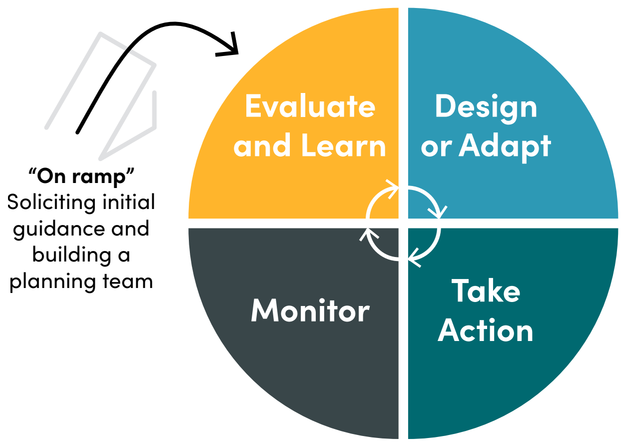
One can think of a national space program as a lever that serves multiple purposes. In addition to providing space-related services to other government offices, it can seed, and then accelerate, the development of a national space ecosystem. Such an ecosystem has various independent parts, or "systems," that can be coordinated, integrated, and aligned to achieve an overall greater national capability than the sum of its parts. A space program can also directly harness space capabilities—such as remote sensing, PNT, and satellite communications—to address specific national priorities.

Building the entirety of a space ecosystem at once would be a herculean task, like suddenly deciding to build a national transportation infrastructure system at once. It is better to start in one area where roads (or a space application) would provide the most good, then grow capability from there, methodically and sustainably in size and complexity. Each expansion in capability and capacity casts the boundaries of space activities outward, tapping new benefits, building domestic and international connections, and strengthening the overall space ecosystem.

Program design and implementation is an iterative process, documented as a strategy, roadmap, or workplan. No plan is perfect, nor perfectly implemented, as understanding of the challenges, needs, and political, budgetary, and other circumstances will naturally change over time. It is useful to envision program design and management as a repeating cycle with sequential phases for evaluation, planning, taking action, monitoring, and again evaluation, learning, and adaption, as illustrated in Figure 3.1. The "on ramp" to the program cycle is first soliciting initial guidance and building a dedicated planning team.

Space programs almost always have a particular built-in challenge thanks to their science fiction roots, and that is demonstrating to policymakers and the public that such programs

FIGURE 3.1 Program cycle



have value in a practical, tangible sense. Section 1 makes the case for "why" foundational space capabilities are important, and Section 2 discusses "what" such a capability may look like. In the program design phase, it is up to program designers and managers to answer "how" space could most concretely benefit national priorities, economic well-being, and the public good, and then methodically pursue those capabilities. The evaluation phase also addresses the first rung in the Space Capability Ladder: Preparation.

SOLICITING INITIAL GUIDANCE AND BUILDING A PLANNING TEAM

National leadership and senior management should start by appointing a space program design team. The selection of the design team's chairperson will be an important determinant of the success of the enterprise. The chairperson will have a principal leadership role, ensuring meetings are well organized, inspiring full participation, protecting teams from diverting or time-wasting activities, and representing the planning team as its Figurehead to the national or more senior leadership. Assuming the first task of a design team is to identify national goals and priorities for space-related activities, the planning team will need one or more sponsor from national executive leadership or senior management. Sponsors' presence initially and during periodic reviews can be an important focusing tool for the team. Such participation also helps to keep senior leadership engaged, but not micromanaging.

Senior leadership may start by providing the team with a vision, or a broad statement of intent. For example, India's vision is, "Harness space technology for national development, while pursuing space science research and planetary exploration." Ideally, however, the chairperson works with the sponsor and other leadership to establish full terms of reference (ToR.). A ToR is a one- or two-page document that establishes the planning team and presents its objectives and brief context. It generally provides initial guidance ("create a space program"), along with a suggested schedule and an appointment of the planning team leadership and supporting offices within the government.

The planning team composition itself should comprise people with experience in program design, management, or both, as well as in national priorities or concerns and in general space capabilities (PNT, remote sensing, and communications). The team's essential objective is to forge a credible consensus on a way forward, built with disparate but respected members. Both the personal qualities and the community or stakeholders they represent are important considerations in selecting members.

Considering all the skills and constituencies involved in developing a space program, a planning team will likely consist of 6 to 10 core members. In European and American cultures, larger groups (of about 10) tend to lead to serial monologues, and the group tends to be overly influenced by dominant speakers. The chairperson, therefore, should take special care to draw out quieter personalities and temper more dominant personalities (Fay, Garrod, and Carletta 2000). It may be valuable to engage a professional facilitator to improve organization, drive focus, and accelerate discussions, consensus, and decision-making (Delaney 2015).

The core team should also identify additional stakeholders from within the government, private sector, civil society, and academia and be prepared to implement a consultation process, using tools such as a document review, calls for input, in-person meetings, online questionnaires, email submissions, focus sessions, and other methods. Low-cost technologies and existing online platforms can help widen the reach of the planning team. If there are skill gaps, such as a lack of space expertise, a government may consider hiring a consultant or reaching out to international bodies, regionally or bilaterally, for support (see "Identifying Funding and Advising Support" later in this section). Regardless, it is rare that everyone supporting the process will have a space systems, design, and policy background, so it is recommended that the group establish a common foundation of knowledge by briefing across areas of expertise. That process of exchange will also highlight when and whom to approach for support to address remaining knowledge gaps.

The planning team will need its own workplan to define roles, activities, and desired outcomes—a miniature version of the space program design effort. Leadership will need to allocate sufficient resources to the planning team to accomplish the task: people with dedicated time, a physical workspace, computers and internet connectivity, leadership support, and authority to communicate across departments, sectors, and stakeholders as necessary. The team's output should be periodic reports to executive leadership or senior management, culminating in a proposal for the space program intent, goals, organization, and estimated costs. In other words, a strategy. This strategy should articulate a clear theory of change, a logical link from intent to implementation to expected outcome, and a plan to evaluate progress. In general, as the team works it is better to provide periodic updates on progress, maybe monthly, rather than to hold recommendations until there is a final proposal. This approach enables leadership input and awareness while reserving necessary independence and flexibility for the planning team during the design process.

EVALUATING CAPABILITY AND EXPLORING POSSIBILITIES

Evaluate and Learn

Once a planning team is assembled and has established its own workplan, timeline, and knowledge foundation, the team should proceed with its first set of *evaluation* questions:

- What space capabilities do we need?
- What space capabilities and capacity do we have now?
- What do we want our space program to do?

There are two ways to determine a space program's goals and to sketch a path toward those goals. The first is using a wide aperture, understanding space capabilities as a type of enabling infrastructure, like roads or power. Such an infrastructure supports critical day-to-day functions as well as development goals and national interests, like security and long-term economic growth. The second, tighter aperture, considers specific national priorities and concerns, and then weighs how space capabilities could be applied specifically to these issues. Combined, a program can incorporate actions that address near-term, high-interest needs for the state, while also investing in the development of a space ecosystem that would benefit a broad set of stakeholders.

Quickly circling back to Section 2, "What?," recall that this Handbook discussed possibilities for the function and structure of a new space program. It also recommended the following "foundational" roles for a space program:

- Protect existing dependencies on space,
- More fully leverage existing space capabilities and applications,
- Encourage the growth of a local data and space ecosystem,

- Attract international and public-private collaboration and investment, and
- Contribute to the development of norms and laws governing space.

To determine if these roles are appropriate, and if there are also short-term, specifically space-related capabilities needed, the planning team should endeavor to understand its government's priorities and concerns. These priorities and concerns are often captured in national (and regional) strategies, policies, and initiatives, in addition to the guiding vision that prompted the program design process itself. Nongovernmental sources, such as the UN and international development banks, usually house functionally oriented documents that provide additional insights and recommendations. The World Bank, for example, codevelops strategies with many low- and middle-income countries that include detailed analysis of "economic constraints" that are slowing growth. Examples of identified bottlenecks may be poor internet connectivity or regulatory shortfalls. Many states have also created strategies to prioritize and implement the UN SDGs, and many philanthropic organizations, like the World Food Programme or Refugees International, work to address persistent challenges and often recommend strategies or specific actions to host countries. The UN Technology Bank recently completed a survey of forty-six least developed countries to support understanding the status of science, technology, and innovation capabilities by measuring the countries' tertiary education, number of research personnel, private sector expenditure on research and development, and other factors. The survey document also provides many recommendations for action that touch on the space and data sectors (United Nations Technology Bank for the Least Developed Countries 2022). Still other multinational groups, like the African Union, have collectively formed space-relevant policies and strategies that articulate collective challenges, intent, and actions to develop and use space capabilities. As a group, these sources document areas of national attention and can therefore inform the purpose, agenda, and role of a space program, as illustrated in Table 3.1. See also Use Case 6 in Annex 3.A.

TABLE 3.1 Examples of sources addressing national priorities and concerns, their recommendations, and possible space applications or space-related activities

EXAMPLE SOURCE	RECOMMENDED ACTION	POSSIBLE SUPPORTING SPACE APPLICATIONS/ACTIVITIES
Information and Communication Technology Agency (ICTA) of Sri Lanka, "National Digital Policy, 2020–2025"	Improve the quality of government service delivery through integrated and efficient processes, to reduce bureaucracy and improve accountability and transparency.	Combine remote sensing and positioning, navigation, and timing (PNT) data with survey data to objectively assess the impact of government program(s). Publish results via a public dashboard or periodic reports.
Inter-American Development Bank, "Bolivia Country Strategy 2021–2025"	To improve the business environment, increase the pace of transactions, and increase the quality and transparency of information, update regulations.	Synchronize and update banking and satellite use regulations to enable/quicken mobile international internet banking.
"Peruvian National Development Strategic Plan that implements the 2030 Agenda"	Increase the participation of provinces in developing emergency response plans. Increase virtual engagement due to the COVID-19 pandemic and restrictions on travel.	Use new lower-cost satellite dishes and subscriptions to connect key remote government offices to 5G internet (and online government mechanisms).

TABLE 3.1 Continued

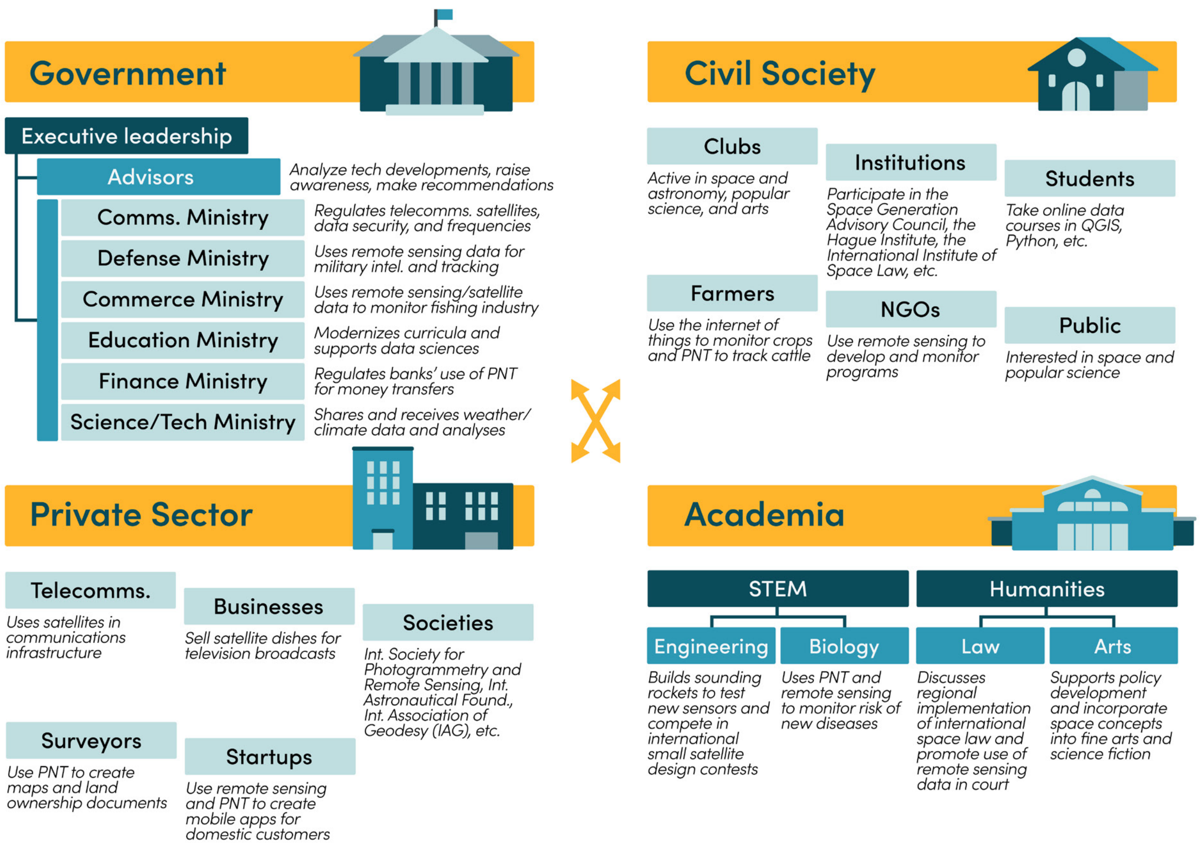
EXAMPLE SOURCE	RECOMMENDED ACTION	POSSIBLE SUPPORTING SPACE APPLICATIONS/ACTIVITIES
World Health Organization (WHO), "Country Cooperation Strategy 2017–2021: Mongolia"	Strengthen programs to improve the provision of safe water and adequate sanitation.	Use remote sensing to monitor current and predict future availability of groundwater to support planning.
NGO Report: "Paths of Assistance: Opportunities for Aid and Protection along the Thailand-Myanmar Border"	The government of Thailand should engage regional partners to press the military junta in Myanmar to end grave human rights abuses.	Use remote sensing data to monitor restricted areas for evidence of serious human rights abuses such as mass graves.
Multinational "Kigali Communique, 2022" on Energy Transition in Africa	Catalyze technology transfer mechanisms to ensure that the entire continent has access to the latest energy innovations, on fair terms. Make modern sustainable energy available to the entire continent.	Reduce the use of gas generators powering remote cell phone towers by integrating satellite-to-cell technology into telecommunications infrastructure. Use PNT data to synchronize traditional and renewable power sources like wind and hydropower, improving system efficiency and reliability.
African Union "Africa Space Strategy, 2019"	Create an enabling environment for small and medium enterprises by supporting their effective participation in the development of the space industry and market.	Include representatives from the business community as a stakeholder in space policy development. Offer contracts to local enterprises to provide geospatial services to government organizations.
"Asia-Pacific Regional Space Agency Forum (APRSAF) Principles, 2013"	"...carry out collaborative activities... identify and undertake measures to contribute to the sustainable socio-economic development in the Asia-Pacific region."	Participate in the "Sentinel Asia" program. Incorporate requests for free remote sensing data and analytical support in cases of natural disaster into national disaster response procedures.
Associations of Southeast Asian Nations (ASEAN) "Plan of Action on Science, Technology and Innovation (APASTI) 2016–2025"	"...establish innovative system and smart partnership with dialogue and other partners to nurture STI [space, technology, and innovation] enterprises to support...enterprises, nurture knowledge creation and space technology... applications to raise competitiveness."	Establish the ASEAN Research and Training Centre for Space Technology and Applications (ARTSA) in Thailand (completed).
"Industrial Policy and Strategic Plan for Mauritius (2020–2025)"	"Develop a digital roadmap for priority manufacturing sectors and ensure digital infrastructure is in place for evolving business models."	Facilitate storage of, access to, and use of remote sensing data to support manufacturing sectors and encourage startups in the localization of value-added services.

Regarding the second question, the difference between what a nation wants to do and what it can currently do is the capability or capacity gap, or both, that a space program should strive to address. A capability gap is the lack of being able to do a task. A capacity gap is the lack of being able to do enough of a task. For example, a small office consisting of three people may have the capability to produce geospatial maps that show likely flood zones in urban areas, but they lack the capacity to produce such maps more often than once a year, or for rural areas of the country.

To find reservoirs of existing space capability, the planning team will need to engage extensively with ministers of government, customary leaders of civil society, CEOs in the private sector, and university chancellors in academia. The leaders may not be fully aware of how their organization uses space capabilities. A good approach may be a combination of informative briefing about the planning team's intent to develop a space program and an overview of space applications in general, followed by surveys or interviews.

Another way to approach understanding the various systems that make up the space "system of systems" is to build a systems map. A "systems map," or "actors map," is a visual representation of the interplay between various actors, organizations, and policies and of the ways in which each connects, affects, and relates to the others. The example in Figure 3.2 illustrates this idea at a national level and shows activity within broad categories of government, civil society, the private sector, and academia. A systems map can also enable planning teams to identify and better understand relationships between specific offices or activities.

FIGURE 3.2 An example systems map showing space capabilities in the government, civil society, private sector, and academia, regardless of a space program



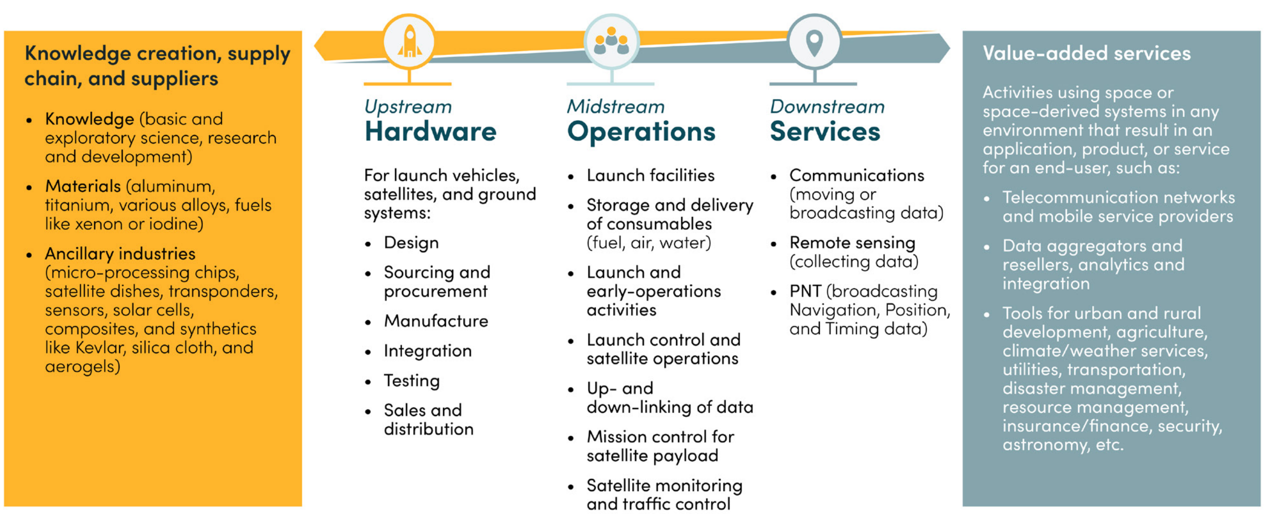
Using a systems map, a planning team should be able to answer the following questions:

- Who are the key stakeholders? Who is, has been, or should be involved in the space ecosystem?
- What are their roles (especially in the context of achieving foundational space capabilities)?
- Where are the greatest connections, activity, or both?
- How are they currently supporting national priorities or addressing national concerns?

It's also useful to consider areas of existing resources, strengths, or growth that can be parlayed into a catalyst for the space ecosystem. The space sector is often discussed in terms of upstream, midstream, or downstream activity. It can also be viewed as a value chain (Figure 3.3) that shows a progression of activities taken by the space industry to deliver a valuable product (i.e., goods, services, or both) to the end user (or customer). Every element, from knowledge development, materials, design, manufacture, services, and operations to a multitude of end user applications, is a link in this chain. These elements are also potential entry points into the global space sector, where a particular country or economy may have a particular comparative advantage.

Another national attribute should also be noted—geography—which can be uniquely leveraged for space-related activity. For example, due to the Earth's rotation on its axis, rocket launch facilities located closest to the equator can take advantage of the momentum of the Earth's easterly spin to launch satellites using less fuel (Figure 3.4). Launch facilities closer to the poles, on the other hand, are better positioned to launch in north-to-south, polar orbits. All launches' flight paths tend to be over water or very sparsely populated areas to avoid possible debris or unused propellent causing collateral damage. It is for this reason that the European Space Agency's primary launch facility (also known as a spaceport) is located on the coast of French Guiana.

FIGURE 3.3 Opportunities in the space sector value chain



Note: The term "value chain" is often used in the private space sector to evaluate all the elements and dependencies involved with creating, selling, and distributing a product. The dividing line between "upstream" and "downstream" activities is not sharply defined, so the term "midstream" generically addresses this area of overlap.

FIGURE 3.4 Examples of advantageous launch facility and Earth station sites

Geography and associated climates can also be advantageous for other space-related activities. Earth stations need to be able to send and receive a signal to a satellite within line-of-sight as it passes from horizon to horizon overhead. Satellite operators have to make careful decisions about where to place their Earth stations so that they are best suited to direct, maintain, and employ their satellite. Space optical communications (free space optical, or FSO) technology, for example, allows greater throughput than typical radio frequency technology, but it is vulnerable to cloud cover. Thus, areas with cloudless skies are advantageous for FSO receiving ground stations (del Portillo et al. 2017). A ground station located at the North Pole will be able to see a satellite in polar low Earth orbit up to fifteen times per day, but a ground station located on the Equator may only see the same satellite three or four times per day. Equatorial stations have other advantages though, like being well positioned to communicate with satellites in—or transiting through—GSO. Generally speaking, satellite operators are interested in having access to more than one Earth station so they are able to communicate with their satellite more frequently as it circles the Earth.

For example, Libreville, Gabon, is located on the Atlantic coast and on the Equator, an ideal location to monitor the launch path from ESA's launch facility in Kourou, French Guiana. From Gabon, ESA launch vehicles remain "visible" during the most critical phases of the mission as a launch vehicle climbs eastward from French Guiana, over the Atlantic Ocean, and into orbit. The ESA tracking and telemetry station network also includes stations in Natal (Brazil), Ascension Island (UK) in the South Atlantic Ocean, and Malindi (Kenya.) This network feeds information back to launch operators about the conditions on board the launcher, its performance, trajectory, and placement of the payload—one or more satellites- into orbit. "Space as a service" companies often build strategically positioned Earth stations and then sell access to them for multiple satellite operators. This is less expensive than building a station for each satellite (Prasad 2020). Geography is a very real "natural" resource worth considering when it comes to space operations.

The above exploration would result in a general inventory of government priorities, current capability and capacity, possible desirable applications, and an understanding of potential entry points within the space value chain and advantageous geography. The planning team may find it useful to document this inventory in an early report. Such hard-won understanding will serve as a starting block for the program that can be built upon, as well as an internal directory of expertise and interest.

Tools to build a policy and strategy

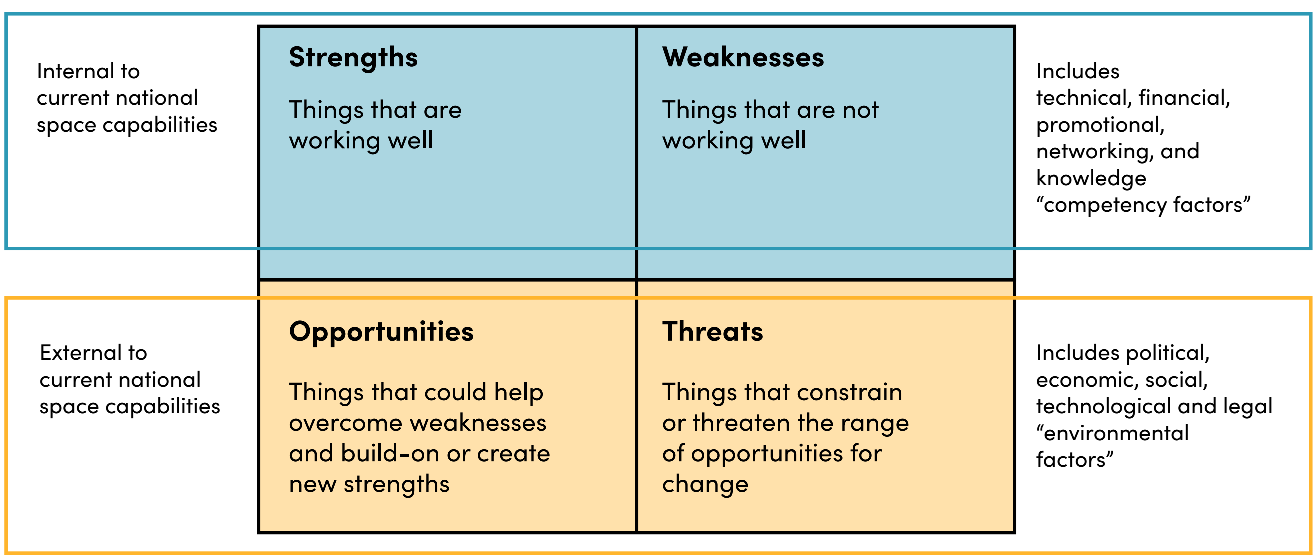
Prepared with an inventory of government priorities, current capability and capacity, possible applications, and familiarity with potential entry points within space value chain and advantageous geography, the planning team should be ready to explore and evaluate options for a space program. A useful tool to explore and organize said options is the popular "strengths, weaknesses, opportunities, and threats" (SWOT) analysis. This tool was originally developed in the 1960s to help an organization assess how it compares with its competitors, but over time it's been adopted by many organizations to facilitate the formation of strategies. The goal in this analysis is to narrow down an impossibly large range of space capabilities relevant to national priorities or concerns, into a set of capabilities that would best take advantage of existing strengths, that would be the most beneficial, or both.

A SWOT matrix consists of a two-by-two square grid, with the top section allotted to listing the strengths and weaknesses of (in this case) current national space capabilities (Figure 3.5). These include technical, financial, promotional, networking, and knowledge "competency factors." The bottom section is allotted to opportunities or threats, external to current national space capabilities. These include political, economic, social, technological, and legal "environmental factors."

When documenting this analysis, the planning team should make significant effort to explicitly use detailed phrases and sentences. Clipped submissions tend to be too vague and open to interpretation as the list develops and is reconsidered over time.

It is best to start the analysis by considering opportunities and threats external to current national space capabilities (the bottom two Boxes). These broad conditions often (but not always) exist not only for the host country, but also for the region, or the world, and can provide useful context for the following strengths and weaknesses sections.

FIGURE 3.5 SWOT matrix



1. The **Opportunities** section is where the team can identify conditions that are positive or helpful, *external* to what a space program can or will do by itself. Examples:

- Space companies and telecommunications companies are increasingly conducting joint ventures to provide affordable, remote internet broadband. This is an opportunity because a new space office could facilitate domestic space and telecommunications company (telco) partnerships.
- Free or low-cost remote sensing data are publicly available (but are not being taken advantage of by most government agencies). This is an opportunity because a space office could support other ministries' use of free or low-cost data.

2. The **Threats** section is where the team can identify conditions that constrain or threaten the range of opportunities for space capabilities. Examples:

- The recent pandemic and other natural disasters have absorbed most unallocated public funding for the next year. This is a threat because it may constrain funding for space-related activity.
- Most policymakers don't understand current reliance on, and the potential usefulness of, space capabilities. This is a threat because it is unlikely a space program will be successful if policymakers don't understand how it benefits the country and people.

3. Next, working the internal **Strengths** section, the team can highlight conditions that are working well, even without a dedicated space program (top left Box). It's more useful to list attributes in a comparative context. For example, a country may have a particularly responsive frequency management office compared to neighboring countries. Examples:

- Frequency managers are active in the ITU and update national regulation every two years or so to align with international standards. They are responsive to space-related frequency requests. This is a strength because clear regulations make it easy for companies to understand how to operate in a given country.
- At least twenty individuals in the maritime forces have been trained in geospatial information systems and can apply remote sensing data to track suspicious ships in our exclusive economic zone. This is a strength because it represents a reservoir of capability and capacity that can be tapped by the space office.

4. Last, addressing the internal **Weaknesses** section, the team can list conditions that are not working well (presumably in part due to the lack of a space program.)

- Acquisition of or contracting for remote sensing data is inefficient. At least three offices paid for the same data separately last year. This is a weakness because the government is wasting funds.
- Risks to current uses of satellites are not well understood, nor mitigated against. No formal guidance exists. No office is responsible for proposing recommendations to improve domestic resiliency in case current space services are interrupted. This is a weakness because the government is unprepared for any interruption of satellite services.

The African Union completed a SWOT analysis in 2019 that ambitiously encompassed the strengths, weaknesses, opportunities, and threats for all fifty-five member states. It provides an excellent reference for considering a wide range of internal and external factors. (See Use Cases 8 and 9.)

5. The last phase in SWOT analysis is to use the sorted data to **Generate Recommendations** for the program. An example template phrase is this:

> "Given the condition of [external factor], our ability to [internal factor] leads to our recommendation that we [recommendation to do something]." (Minsky and Aron 2021)

An example recommendation using SWOT analysis could be, "The availability of free and low-cost remote sensing data and the proven usefulness in applying these data to monitor illicit maritime activity lead to our recommendation that we expand use of remote sensing data to other ministries and national concerns." The goal is to narrow down an unmanageably large range of capability or capacity development possibilities (the "blue sky" wish list) into a set that is most useful, or opportunistic, given environmental realities and national strengths or weaknesses. A good rule of thumb is to use strengths to exploit opportunities and overcome threats, and take mitigation measures where weaknesses and threats combine. Some questions that may assist this discussion include these:

- Where is there growth, energy, and expansion, and where are there gaps, blockages, or constraints?
- Where are areas of broad interest, concern, or excitement?
- Where should relationships be strengthened or forged?

Some weaknesses of the SWOT brainstorming and sorting analytic method include that it tends to be a snapshot of a specific time and circumstance. It is also subject to the experience and perspective of its current participants (Minsky and Aron 2021). It may be useful, therefore, to run the exercise several times with different "themed" focus groups over time. If the main planning team, for example, sees early-on that increasing use of remote sensing in agriculture would be a likely focus area for the space program, the planning team could bring in stakeholders with a tailored mix of farming, remote sensing, telecommunications, and agriculture-focused development backgrounds to do a deeper analysis of this subset of strengths, weaknesses, opportunities, and threats.

At the end of each round of analysis, the planning team should group the resulting recommendations and action statements into like areas. Some outputs and outcomes will be "quick-wins," where positive results could be expected in a just a year or two. Others will have dependencies that need to be addressed before they can proceed, creating a sort of waterfall programming pattern, as illustrated by Figure 3.18. A small, even notional, space project can also serve by exercising or creating new processes and relationships for space-related activity. It can also help illuminate what policies, directives, contracts, and regulations need to be established or modified to facilitate space activity. Many space actors with large, expensive projects have been significantly delayed due to unforeseen national and international requirements.

The Pareto Principle states that roughly 80 percent of desired outcomes are driven by 20 percent of causes (the vital few actions) (Hugh 2021). Which 20 percent of the planning team's recommendations, or three or four major themes of effort, would potentially result in the best outcomes in addressing national priorities or concerns (outcomes)? Which would (also) advance the establishment of a healthy space ecosystem? It may be useful to again consider the planning teams' interpretation and adoption of the "foundational" roles recommended in Section 1.

At this point, it is important to document the analysis and conclusions the planning team has completed thus far, potentially as the second "in progress" report to leadership. This information provides an important reference point to measure progress and change over time, to make sure future planners have full context for why decisions were made. In general, it is recommended that the chairperson draft such a summary document, because that is the person best situated for synthesizing input from the team and government stakeholders, both informing the following program design phase and posterity. The evaluate phase of program design completes the "Preparation" rung of the Space Capability Ladder.

Now that the *evaluation* phase has provided a good understanding of a nations' current versus desired (and prioritized) capability and capacity, and defined the gaps between the two, the planning team is ready to develop a program.

DESIGNING A SPACE PROGRAM

Design or Adapt

The program *design* phase is the mechanism through which a government can organize itself to refine and act on the evaluation phase's recommendations, while also building overall institutional (or foundational) space capabilities. Quickly recapping, foundational space capabilities include the government's ability to advise, localize, manage, coordinate, and regulate space activity and advance national space interests at regional and world forums. Now that the evaluation phase has provided a good understanding of a nation's current versus desired (and prioritized) capability and capacity, the planning team is ready to develop a program. A program is a set of related projects and activities, managed in a coordinated manner, under a structure that allows for the delivery of outcomes and benefits.

Planning considerations

Essential documentation of this effort includes a space policy, which primarily describes a country's intent for space issued by senior leadership, and a national space strategy, which is a more specific roadmap of who, how, and when gaps will be addressed, to what end. In a perfect world, the planning team would draft a policy first, have it reviewed and adopted by national leadership, and then would develop a more specific, time-bound strategy. Since reality rarely matches the ideal, the planning team may very well need to work on these efforts in parallel or in very quick succession. It is vital, however, that senior leadership approve the planning team's interpretation of leadership's vision or policy, because every follow-on action should be able to coherently explain how it is contributing to that vision.

Another important step in building a space program is establishing a leading office of some sort (an advisor, office, center, institute, agency, or similar) that is focused on foundational space capabilities and is empowered to build, connect, order, and harness the system of systems that enhances a country's access to and use of space. A space office's basic components

TABLE 3.2 Examples of components that contribute to government "foundational space capabilities" and a national space program

POLICY AND REGULATORY FRAMEWORK	SKILLSETS	INSTITUTIONAL SUPPORT
International treaties and commitments	Space-related data utilizers and managers (PNT, geospatial)	Facilities and nondata Infrastructure
Space private sector and operations	Data infrastructure management (hardware, cloud-based)	Data infrastructure
Government activities (such as courts of law, weather, other data for decisions)	Radio frequency and telecommunications	Oversight
Radio-frequency spectrum, telecommunications	Policy advising and program management	Human capital development
	Training, academia, research coordination	Science and technology, research and development
	Interagency and international coordination	Financing/funding
	Civil society and private sector development	Culture, risk acceptance
	Space-related data utilizers and managers (PNT, geospatial)	

include a policy and regulatory framework, a skilled workforce, and institutional support (Table 3.2).

Space program component: Skills

Lack of a domestic skilled workforce is a common shortfall faced by most countries trying to establish a new, complex capability. It takes a skilled workforce to leverage and localize space applications. As discussed in Section 2, a wide range of skills, to include management, research, design, operations, and support to end users, is needed to take advantage of the full range of space-related activity.

Many programs fail because talent development is too focused on short-term needs, without casting a wide enough net for a diverse set of talent and without considering the necessary arch of a career in which a professional can expect to move between different projects and even sectors while increasing capability and responsibility over the course of a lifetime. If there aren't opportunities for professional development and progression, particularly if demand is insufficient to pay a competitive wage, talent often moves on to greener fields, "poached" by a foreign NGO, business, or other opportunities abroad. Gender and diversity should be also considered as part of building human capital for space applications. Such a strategy is important not only because pursuing gender equality in the workplace is a worthwhile goal in itself, but also because increasing diversity leads to better results through the inclusion of new perspectives. A recent study of 6.6 million academic papers in the medical sciences showed that gender-diverse teams produce more novel and higher-impact scientific ideas. In other words, if a space program is working to develop skills for a specific project and build its ecosystem more generally, then it must foster diverse training, an academic pipeline, to steadily develop and progress talent.

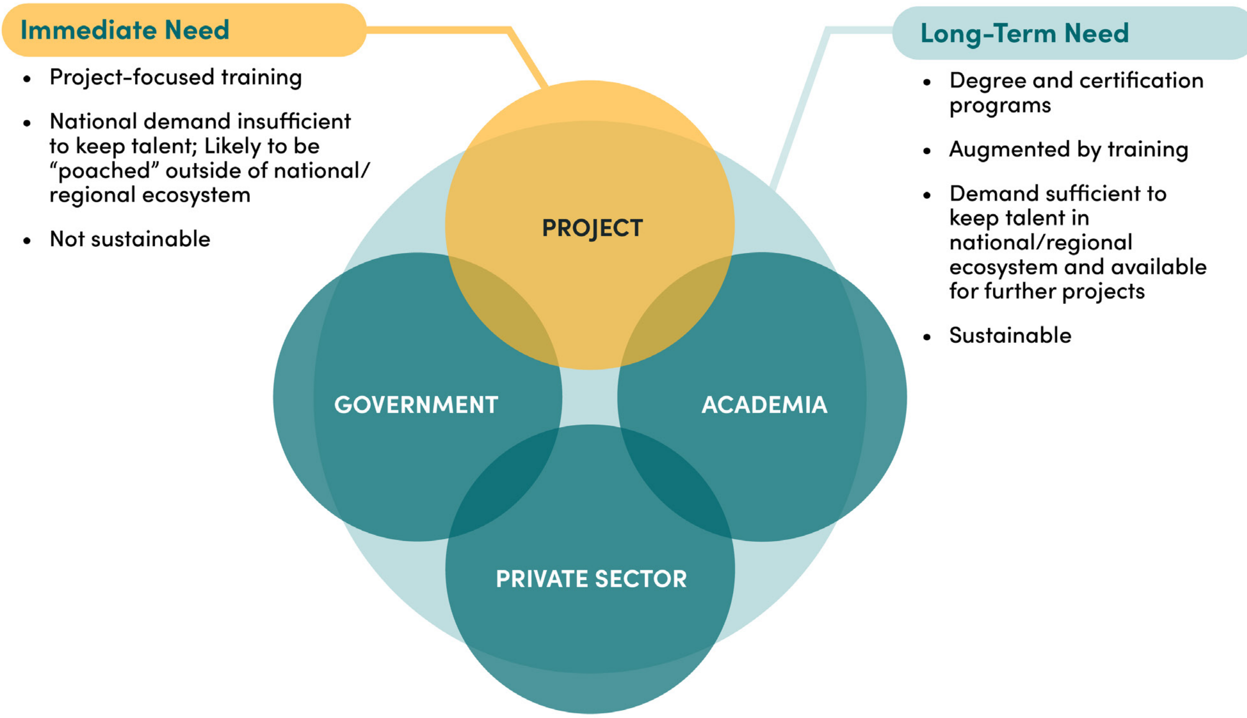
A particular project may need a team of only ten workers for a short term of a few months to years, but the government should consider nurturing and encouraging the growth of the available talent pool that will be needed for long-term sustainability of that project and others that will follow. A multi-week gap between one project and the next, or other appropriate, progressive employment, may force hard-won talent to look abroad for work. A space program should actively support and promote opportunities for skilled talent to transition to new space-related projects of interest to the state, or to other local academic, civil or private sector opportunities.

Reaching out to space and technology professionals that are working abroad is another way to infuse a space program with seasoned professionals. The types of technical skills needed for a space program include familiarity with geospatial information systems and platforms; an understanding of the attributes of various sensors, PNT, and communications satellites; and experience in satellite operations (and radio-frequency spectrum use) in general.

A new space program will also need to plug into a greater human capital development program that enables it to bring new leadership, science, technology, and engineering personnel and to rotate (permanently or temporarily) a multidisciplinary mix of skilled workers who can advance the use of space (Figure 3.6). For example, a lawyer from the Ministry of Justice may be detailed to a space program for a few years to lead the drafting of national laws that determine the rules for using remote sensing data as evidence in a court of law, or aid in establishing contracting standards to normalize government purchase of various space services.

The Vietnam National Space Center (VNSC) found success deliberately growing its human capability and capacity through its "Dragon Roadmap." Starting by working with Japan through an academic connection (first the University of Tokyo and then a consortium of universities), VNSC developed CubeSat in 2013 and SmallSat in 2019. Using these projects, VNSC was able to train and employ about one hundred engineers and scientists. To keep them within the Vietnam space ecosystem, VNSC proceeded to collaborate with the Japanese private sector (a Japanese satellite manufacturer, NEC) to develop progressively more complex satellites (Verspieren et al. 2022). In this case, the agency focused on the development of satellites, but the same pattern could be used to expand any aspect of the space and data ecosystem.

FIGURE 3.6 Advantage of long-term focus on human capacity needs to retain and grow national talent



Space program component: Policy and regulatory framework

International, bilateral, and multilateral treaties and agreements are key mechanisms for countries' integration into the global space sector and contribute to the body of material that is a nation's policy and regulatory framework. *The Handbook for New Actors in Space* (Johnson 2017) provides an overview and discussion of the five main space treaties, starting with the essential "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies," more common signatories as the "Outer Space Treaty" (OST). The UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) monitories the status of signatures and ratifications of the international agreements relating to outer space; UNOOSA posts ongoing updates.[16] It is important to note that OST signatories bear international responsibility for national activities in outer space, whether carried on by governmental agencies or by non-government entities, and require authorization and continuing supervision by the state (Article VI). Additionally, Article VII stipulates that treaty members are internationally liable for damage to other states should its space object damage another members' property in orbit or on Earth. Domestic regulations, therefore, should take care to address launches of satellites from both domestic territory or facilities and those that are procured abroad.

A national space policy, however, codifies domestic goals and priorities for space-related activities and provides a critical reference point, a North Star, for complementary actions at multiple levels of government. A national space policy ideally allocates roles, responsibilities, and resources between various agencies and entities to clear the way for intragovernmental, public, commercial, and international cooperation on specific programs or projects. For example, it assigns responsibility for core space-related functions, such as administrating and licensing radio frequencies used by satellites, or

16 UNOOSA, "Status of International Agreements Relating to Activities in Outer Space," https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/status/index.html.

purchasing, using, and storing remote sensing data. Domestic policies can facilitate growth by lowering barriers to participation. For example, to encourage the private sector, the US government provided liability indemnification as a catalyst; this indemnification reduced insurance costs and requirements to a manageable level for new ventures. Such domestic policy establishes a foundation for international dialogue and formation of international norms and law through such bodies as the UNCOPUOS and ITU. The process of developing a policy itself can also be useful as an organizing (or forcing) function that brings together intra-governmental and other stakeholders to develop a clear rationale and intent that is, in turn, cemented through national leadership approval.

A space strategy traditionally follows a policy, translating national intention into action over a set period of time, often five or ten years. In the case of a new program, an early function of a developing space program may be to support the design of a policy as well as a strategy. A strategy is the key result of systems mapping and SWOT analysis and is where analysis, actions, and plans to monitor and evaluate progress are documented.

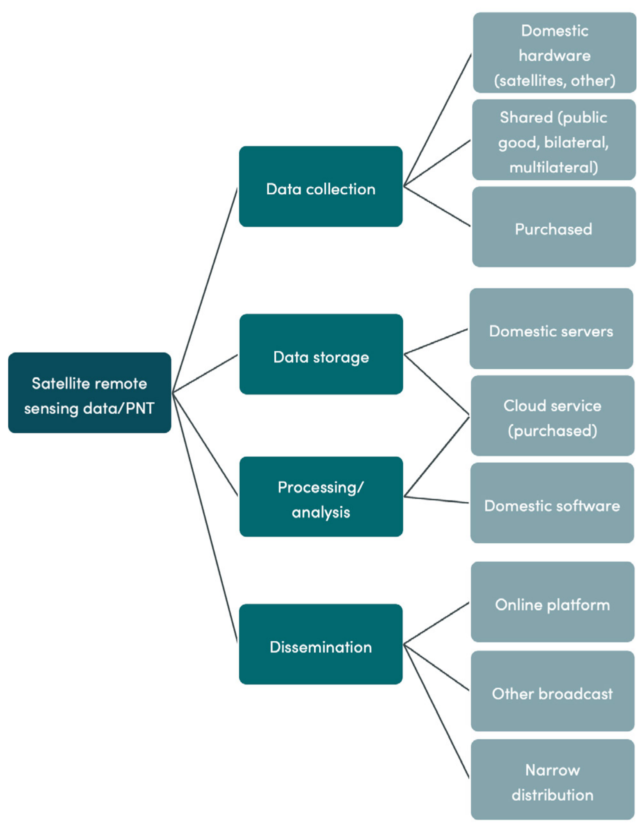
Space program component: Institutional support

A space program and organization, like any government program and organization, will need basic institutional support. This includes facilities, computers, internet, structure, oversight, and financing. The space office must account for how it will integrate into state bureaucracy and be ready to provide inputs to policy and state activity, and to request and manage its allocated resources.

Some space-specific needs include support for the acquisition, storage, processing and analysis, and dissemination of remote sensing data. A space program must decide how and if it will accomplish these functions, because they require different kinds and levels of institutional support. A space program may just draft guidelines and set standards for the government's use of remote sensing and PNT data, or it may run such a project itself. Regardless, the space office should be the government's repository of expertise on the topic of remote sensing and PNT data.

The space office will need to discover where its activities overlap with other organizations and policies. For example, is there a national data privacy and storage policy? Are there, therefore, restrictions on how domestic data are stored, processed, combined, and shared? A program must consider options for acquiring remote sensing data (Figure 3.7), with decisions such as using sensors on satellites or alternative technology such as pseudo satellites, drones, aircraft, or more traditional techniques (surveys, census, samples, etc.). Remote sensing data can also be acquired through open-source, online data sources (NASA SPIRE, ESA Copernicus, UN-SPIDER, WMO, Digital Earth Africa, etc.), shared through bilateral or multilateral cooperation (BRICS, NATO, etc.) or purchased (Maxar, Planet, among others). As the data market matures, "data marketplaces" like Arlula will likely become more common,

FIGURE 3.7 Decision tree to support use of remote sensing data



making it easier to compare data sets, their unique attributes, and price.[17] For quick reference, one can divide remote sensing data resolution into three rough categories: low resolution, with imaging over 30 meters per pixel; medium resolution, 10–30 meters per pixel; and high to very high resolution, with 30 centimeters to 5 meters per pixel. In general, data are more expensive if recently collected, frequently collected, collected using a higher resolution, or a combination of these.

Data processing occurs when data are collected and translated into usable information. It is notable that remote sensing data storage and processing require significant computing power. For a country that has unstable or costly power and internet access, or that lacks an existing data center, it may be more cost-effective and reliable to use cloud storage and processing than to build, operate, power, temperature control, and generally maintain a local data center. A user just needs an internet connection to gain immediate access to a cloud-based system. The cloud still uses physical servicers to store and process data, which are typically located in large data centers in the US, Europe, India, or China. Some disadvantages to using the cloud include (a) the users' connection can still be interrupted by power and internet outages; (b) it limits national control and flexibility of backend infrastructure and security protocols; and (c) it creates a degree of dependency on a particular vendor (Larkin 2019). Many online commercial GIS services like GoogleEarth Engine, Microsoft Planetary Computer, and software like ArcGIS, will allow users free or inexpensive access to learn and experiment, and then sell annual subscriptions, charge fees for computer processing use, or both.

There are also several nonprofit geospatial platforms that provide processed remote sensing data and tools that can be used to conduct themed analysis (on common interest topics such as agriculture and water availability), such as DE Africa Platform and the US Famine Early Warning Systems Network (FEWS NET). Additionally, a robust community of developers, researchers, and users shares processed data, use cases, and best practices on topics such as soil properties, land cover, oceans and shoreline, hydrology, utilities, weather, and global events. Such communities share information on social media (LinkedIn, Facebook, Reddit), on forums (GIS Stack Exchange, ESRI's GeoNet), at conferences (Global Conference on Space for Emerging Countries, Geospatial World Forum, International Astronautical Federation Conference, NewSpace Africa Conference, etc.), and through professional associations (Institute of Electrical and Electronics Engineers, University Consortium for Geographic Information Science, etc.).

Using a project-specific lens to prioritize

It is difficult and expensive to build all the components needed for a robust space capability at once. One possible way to focus a space program's resources is to build capability around a shorter-term space-related project that also addresses a national priority or concern. This option has two effects. It shortens and prioritizes the requirements for space capabilities and illuminates which capabilities need to be developed first, while also contributing to the overall effort to build greater space capability. For example, having reviewed materials that define and prioritize national needs, completed a systems map, and made initial recommendations based on opportunities and strengths, a country may select "chronic flooding" as the national priority or concern to address. A space program can then focus on using remote sensing data to identify at-risk, low-lying areas, the soil's capacity to absorb water, and the likelihood of severe weather over a set period. A space program can also contribute to use of satellites to support disaster response efforts via satellite-enabled communications and location data.

Designing a short-term project

A good space project can

- Produce an outcome that can be measured and widely understood.
- Expose various government agencies to how space capabilities are useful to their mission.
- Be a catalyst for establishing a domestic workforce's capability to acquire, analyze, and apply remote sensing and PNT data, and/or satellite communications.

17 See, for example, the Arlula Archive Catalog, https://api.arlula.com/catalog.

- Spur the acquisition of appropriate hardware, software, and related skills.
- Provide a context through which a space program can interact with stakeholders (disaster management personnel, leadership of villages at risk, policymakers, concerned NGOs, etc.).
- Produce positive spill-over effects.

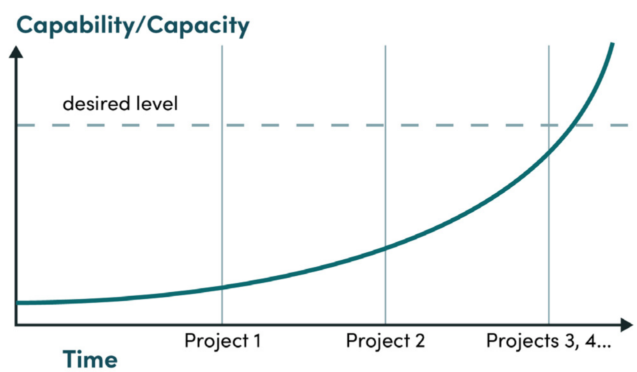
The action of capturing the results of such a project are vital, as they provide a concrete snapshot of a near-term return on a government's investment in space capabilities, especially for a nascent space program. It is harder and takes longer to measure the development of a space ecosystem and its impact. A space program can use these projects as building blocks and continue to establish new projects every year or two, especially as earlier projects are completed or transition to permanent home offices. It can harness the projects' spillover effects, leaving in its wake a more skilled workforce, new cooperative patterns, more knowledgeable and appreciative customers, and so on. A space program can stack projects methodically as a way to sustainably expand its foundational space capabilities and capacity, building toward upstream space activities, if so desired (Figure 3.8). A country could, for example, transfer the (now routine) function of using geospatial data to support emergency planning to its disaster management office (a new geospatial-support office), contract the work to a local small business (thus encouraging the private space sector and overall space ecosystem), or keep it as a function of its national space program.

Determining and prioritizing a space program's activities

In addition to running specific space projects, a space office should act as a catalyst, designed to set or encourage good conditions for the development of a domestic space ecosystem (good regulation, business practices, etc.). A space program can focus space-related inputs (funding, manpower, facilities, data, and so on) and action (provide technical advice, complete a space-related project, award scholarships, expand space-related infrastructure, and so on). These activities will have immediate outputs that are usually quantifiable. The long-term effects, the outcomes, of these activities will be harder to predict or measure since they also depend on other organizations and actions that fall outside a space program's ability to control. A space program can help a government understand how systems work together as they relate to space capabilities. A space program, for example, can advise the telecommunications industry (system) about its use of communication satellites (another system), for a beneficial outcome (broader public access to the internet). This bigger picture supports coordination between systems, and it can highlight potential leverage points to further encourage more positive outcomes in the short, medium, and long term.

In other words, a space program and its strategy ideally analyze, plan, organize, and integrate various systems into a space capability that is greater than its parts. For example, a space program may work with a university to ask why geospatial data aren't being used in research and continue to ask "why" until root causes are identified. These causes could be a lack of awareness, a lack of demand from future employers, lack of geospatial experience in the university system, lack of internet access or sufficient data storage, or other reasons. A "logic model" facilitates the process of breaking down a complex system into manageable pieces to support thinking, planning, and communications about program objectives and actual accomplishments over time.

FIGURE 3.8 A country can use projects to develop its space capabilities and infrastructure, while also providing concrete benefits for stakeholders and the public



Using a logic model

A "logic model" is defined as a graphic showing how a space organization will do its work and identifying the theory and assumptions that underlie the program (Innovation Network 2010). A model helps the planning team connect the program's process (invested resources, specific activities, immediate results) to intended outcomes. It encourages articulation of any related analysis and assumptions, so if these change (and they often do over time), it can prompt a reevaluation of the logical progression from resource to action to outcome.

The first step in using a logic model for program design is to establish a workable problem statement. A problem statement is the problem or challenge (or a subset of this problem) the program will be designed to address. This step leverages the results of the systems map and SWOT analysis and tests the resulting hypothesized recommendations. The following template identifies the national priority or concern to be addressed as well as related analysis or assumptions and external factors. It is read from left to right, so that if certain processes happen, then they will result in certain outcomes. If resources are invested in a space program, then activities will happen with certain outputs. If those outputs occur, then planners can expect certain outcomes in the short, medium, and long term. (Figures 3.9 and 3.10).

A logic model can run "forward" from left to right, from activity to outcomes (Figure 3.11). It can also be run in reverse, from right to left, called a "reverse" logic model (Figure 3.12). A reverse logic model starts with the greatest long-term goal and asks, "but how?" to tease out needed intermediate and short-term outcomes. The model asks again, "but how?" to determine what sort of outputs would be needed, and again, "but how?" to find appropriate activities and resources.

Logic models use a linear process, rooted to a single problem statement at a time. However, multiple logic models can be run to explore and test possible activities. Again, it's useful to circle back to the Pareto principle: Which 20 percent of possible activities or projects would potentially result in the best outcomes? Which would (also) advance the establishment of a healthy space ecosystem?

The planning team will likely need to develop several programmatic lines of effort (also called "thematic groups," "clusters," and "pathways") to best organize its approach to achieving desired outcomes. As an example, in its 2022 Strategy, India defined six distinct "Areas of Capacity Building" (in addition to projects and other activities), each with its own set of activities and results, driving toward greater outcomes of a more developed space ecosystem (ISRO 2022):

- Academia research collaboration
- Infrastructure building
- Industry promotion
- International cooperation
- Human resource development
- Student engagement

TAKING ACTION, OR IMPLEMENTING THE STRATEGY

A critical shift happens during the *taking action phase*. Once program design is complete, the planning team must hand responsibility to the permanent space program office that will be responsible for implementing the strategy. Ideally some of the planning team will transition to the space office as well, to provide continuity and insight into the strategy formation. Others may join an oversight board, or they may return to their primary offices and careers as knowledgeable actors in the overall space ecosystem. Regardless, it's important that the space program office fully understands the analysis done during the evaluation phase and the theory of change underpinning the program design itself. This background provides critical context for the planned activities and sequencing. The space program office will be responsible for acquiring and applying the logic models' inputs, such as leadership, advocacy, funding, administrative support, communication, and expert advice as well for launching the strategy's activities and

FIGURE 3.9 Example of a logic model

Problem Statement: The problem or challenge (or subset of this problem) the program is designed to address.

Analysis/Assumptions: Root cause, or assumed root cause, of the problem or challenge.

(If) Process (...then)					**Outcomes**		
(If) **Inputs**		(If) **Activities**	(If) **Output**		**Short**	**Medium**	**Long**
Resources invested in a program: funding, labor, facilities, supplies, policy development, advocacy...	(then)	• What actions will be taken? • These are the products, tools, advocacy, and other actions that are used to bring about a program's intended changes or results	• Who or what is affected? • These are the direct products of activities, usually quantifiable. Includes the number and type of stakeholders attending events, receiving services, using tools, etc.	(then)	• What will be different within one year of participation? • "Expect to see" • Expect changes in: Awareness, Knowledge, Attitudes, Skills, Opinion, Aspirations, Motivations	• What will be different within 1-5 years of participation? • "Want to see" • Expect changes in: Actions, Behaviors, Practice, Decisions, Policies	• What will be different 5+ years of participation? • "Hope to see" • Expect changes in: Social Economic, Civic, Environment

External Factors: These are conditions in the environment in which the program exists over which one has little control, but they can influence the program's success. For example: the political climate; social, economic, and demographic changes that may affect participation; media coverage; local or national events that may influence public support, changes in laws; changes in organization's or the funding organization's policies and priorities; or, changes in leadership

FIGURE 3.10 Example of a logic model specific to a space program

Problem Statement: There is a lack of capability to use remote sensing data to predict and manage flood zones.

Analysis/Assumptions: There isn't much local awareness of, or demand for, space and data skillsets by government disaster management office. There are no domestic training programs.

Process					**Outcomes**		
(If) **Inputs**		(If) **Activities**	(If) **Output**		**Short**	**Medium**	**Long**
• Advocacy • Funds • Administrative support • Expert advice	(then)	• Offer 12 scholarships per year • Provide 2 short "orientation" events on data & space applications to universities & open to the public/private sector • Sponsor/offer 8 internships per year • Government leader supports in speeches	• 12 students participate, 8+ graduate with space and data relevant degrees, each year • 2 intern at regional disaster management office, 2 at GIS-using businesses, 2 at local telco, 2 in gov space program, per year • 300 students and general public learn about space applications	(then)	• Modest increase of domestic space & data workforce • Government/private sector/civil society experiments with using space applications using "free" interns	• Disaster management office identifies likely flood zones • Government/private sector/civil society normalizes use of space applications, develops demand • Space & data-curricula is updated to meet demand; new research produced • Workforce grows	• Government issues routine and accurate flood warnings. • Space & data-related material incorporated into many disciplines, normalized, increased research output • Businesses/Government/civil society expands use of space applications. Grows demand. • Workforce grows without scholarships or sponsorship

External Factors: These are conditions in the environment in which the program exists over which one has little control, but they can influence the program's success. For example: the political climate; social, economic, and demographic changes that may affect participation; media coverage; local or national events that may influence public support; changes in laws; changes in organization's or the funding organization's policies and priorities; or, changes in leadership

FIGURE 3.11 An example of a "forward" logic model

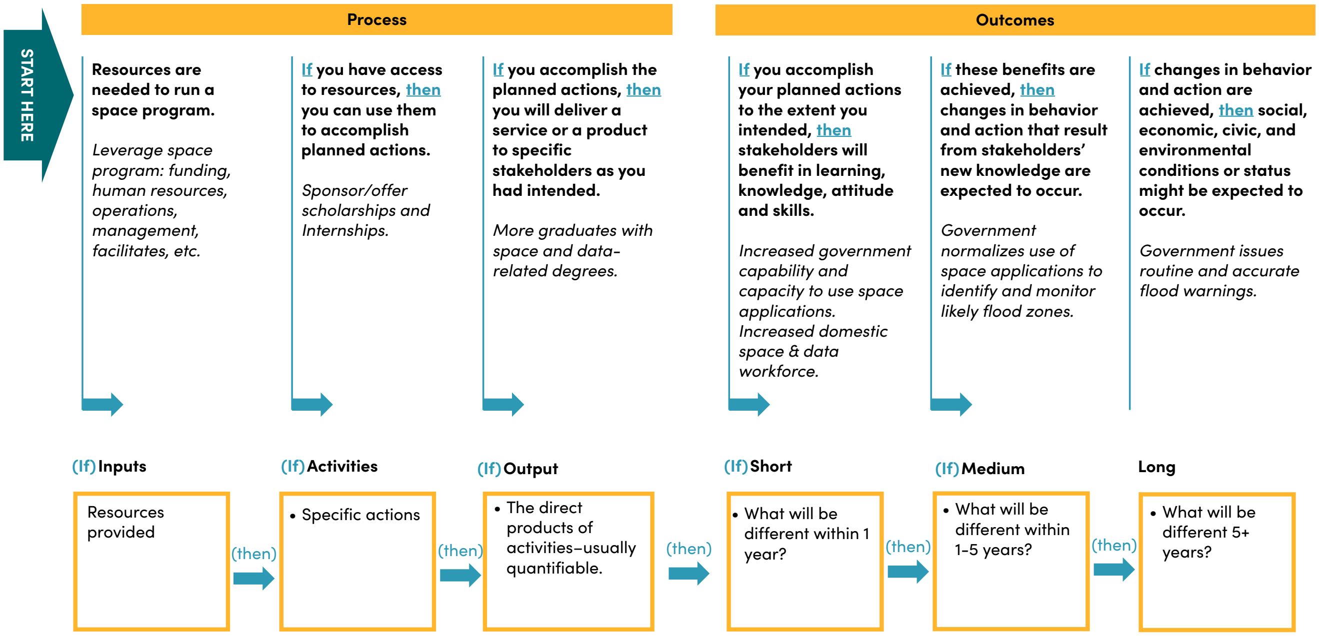
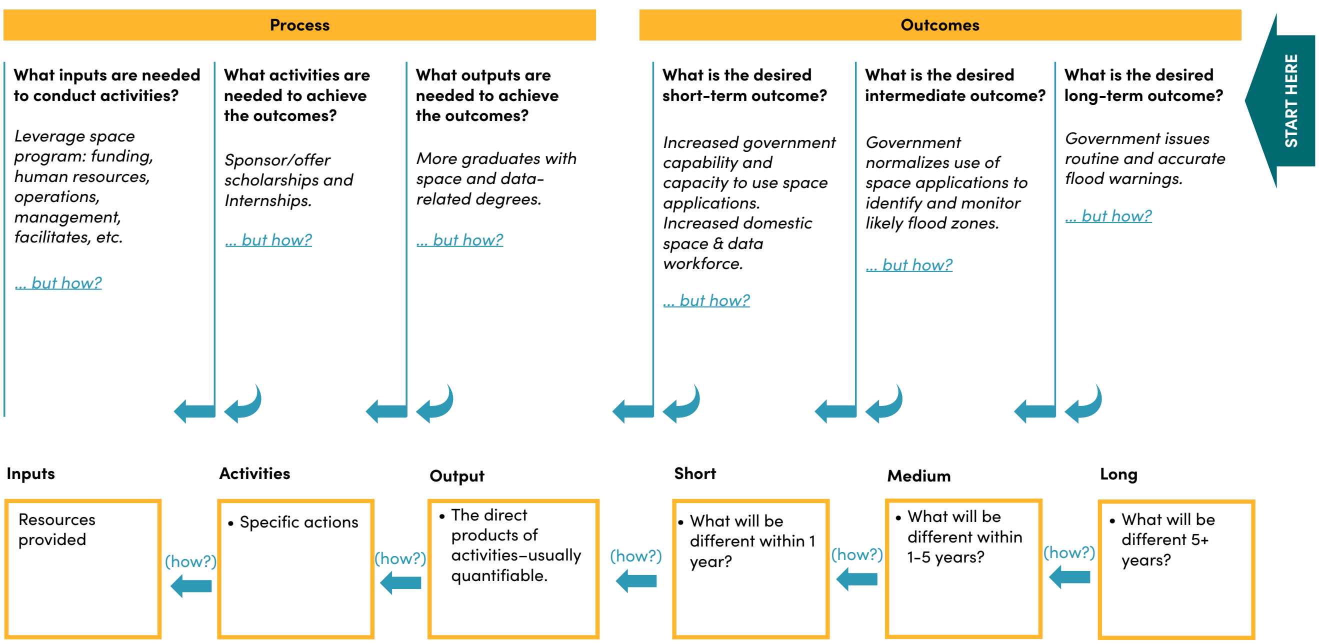


FIGURE 3.12 Example of a "reverse" logic model



projects. While the initial plan to monitor, evaluate, and learn from activities would be drafted by the planning team, the space program office is responsible for partitioning enough internal capacity to successfully complete that monitoring, evaluation, learning, and strategy adaptation as a critical component to overall program success. The space office may break the strategy into more detailed action plans that are bound by a shorter period of time, typically 12 months. An action plan addresses specific initiatives, key objectives, concurrent and supporting activities, specific monitoring and evaluation activities, who will carry them out, and a timeline for doing so.

As discussed in Section 2, there is no one kind of structure required to house a space program. Broadly, however, it should be optimized to execute the established strategy in the short and perhaps medium term. Too large, too fast, and the program may get bogged down in bureaucratic minutiae, or find it difficult to justify the investment in resources before some results can be realized. Early space programs are often more loosely departmentalized, with less specialization, since a small pool of personnel may be called upon to support multiple aspects of foundational space capabilities. As a space program grows, more formalized structures, with stricter parameters for roles, responsibilities, and authority, will become necessary. To determine the necessary size and composition, planners will find that useful questions to ask are "Is the space office organized to provide the necessary inputs, conduct these near- and mid-term planned activities, and monitor outcomes (results)?" "Is it clear who is responsible for each action, and are they, in turn, supported?"

Turning the strategy into action will require frequent communication, both internally and externally. A space program, even a very modest one, should institute reporting structures to make sure the flow of information is effective, efficient, and accessible. A communications plan or protocol is a useful way to document key stakeholders, what data will be communicated and to whom, the frequency of communications, and where information will be posted or stored as well as who holds the internal responsibility to implement the communications plan. Internal communications can manifest as biweekly or monthly meetings, reports, or online dashboards for individuals within the office, among stakeholders, and in collaborating offices. A project status report is a document or tool that records the status of projects and provides general updates on their progress. A more succinct and less frequent executive version should flow to senior leadership to keep them informed and engaged as the space program develops. The communications plan should also account for external reports—those that go to other governments or international organizations and the public at large. This communication, or publicity, can be in the form of newsletters, fact sheets, website updates, speeches, press releases, and social media posts.

MONITORING A PROGRAM

Monitoring and evaluation together help program managers (and national leadership) know if their program is successful. The task consists of a systematic approach to collecting and understanding information about the program's activities and progress toward achieving desired outcomes. No program, anywhere, is perfectly planned or perfectly executed. Monitoring and evaluation, therefore, are key to learning and, most importantly, improving the program's ability to produce desired outcomes. The "NewSpace" private space industry movement especially is characterized by a preference for rapid iteration, which accepts some failure but is also organized to quickly detect problems and adapt to try again (Figure 3.13).

The process of methodically monitoring the results of activities provides information about how well a program activity was performed and measures progress in executing the strategy or derivative plan. Measuring results includes questions like, "Was remote sensing successfully integrated into the university curriculum? Was a Continuously Operating Reference Station (CORS) system installed, and is it operational?"

FIGURE 3.13 Process to monitor, evaluate, and adapt

Monitor Activities ›

- Gather **data** on outputs and outcomes

Evaluate & Learn »

- Are the results and outcomes (thus far) **desirable**?
- **Why** or why not?
- How can we do this **better**?

Adapt Activities & Stategies

Activity:

- Should we change **how** the activity is run?

Strategy or Plan:

- Does the **theory of change** still make sense?
- Should we **add**, **subtract**, or **modify** activities?
- Should we change the **sequence** or **timing** of activities?

Monitoring *outcomes* provides information about the short-, mid-, and long-term impacts of one or many activities. For example, noting the addition of remote sensing coursework into the curriculum and seeking to measure its short-term outcome, a program manager may ask, "How much original research using remote sensing data has the university produced in the past two years?" Noting the new CORS system (combined with other activities and projects, like building new ground control points, or establishing a digital geodetic reference frame), a program analyst seeking to understand outcomes may ask, "What surveying projects referenced the CORS system the past two years, to what effect?"

Development of indicators

An important aspect of monitoring is deciding what, exactly, to monitor. Monitoring specific activities is usually measured immediately or soon after an activity is complete. It asks questions like, "Did the training occur? How many students passed the exit exam?" This provides useful information on how well the program is completing actions. However, the more important (and more difficult) things to measure are the outcomes. Are the program activities resulting in desired short-, medium- and long-term effects? How can one tell? "Indicators" are specific, observable, and measurable trends or facts that shows a level of capability or capacity (Table 3.3). Measuring the same indicator over time illuminates progress made (or not) toward achieving a specific output or outcome in the logic model. A negative or positive result is equally valuable, as each is a signpost indicating where the program needs to focus time and resources in order to make concrete progress.

A worthwhile planning effort is defining a short list (say, one to three indicators) for each output and outcome, and

TABLE 3.3 Indicator types

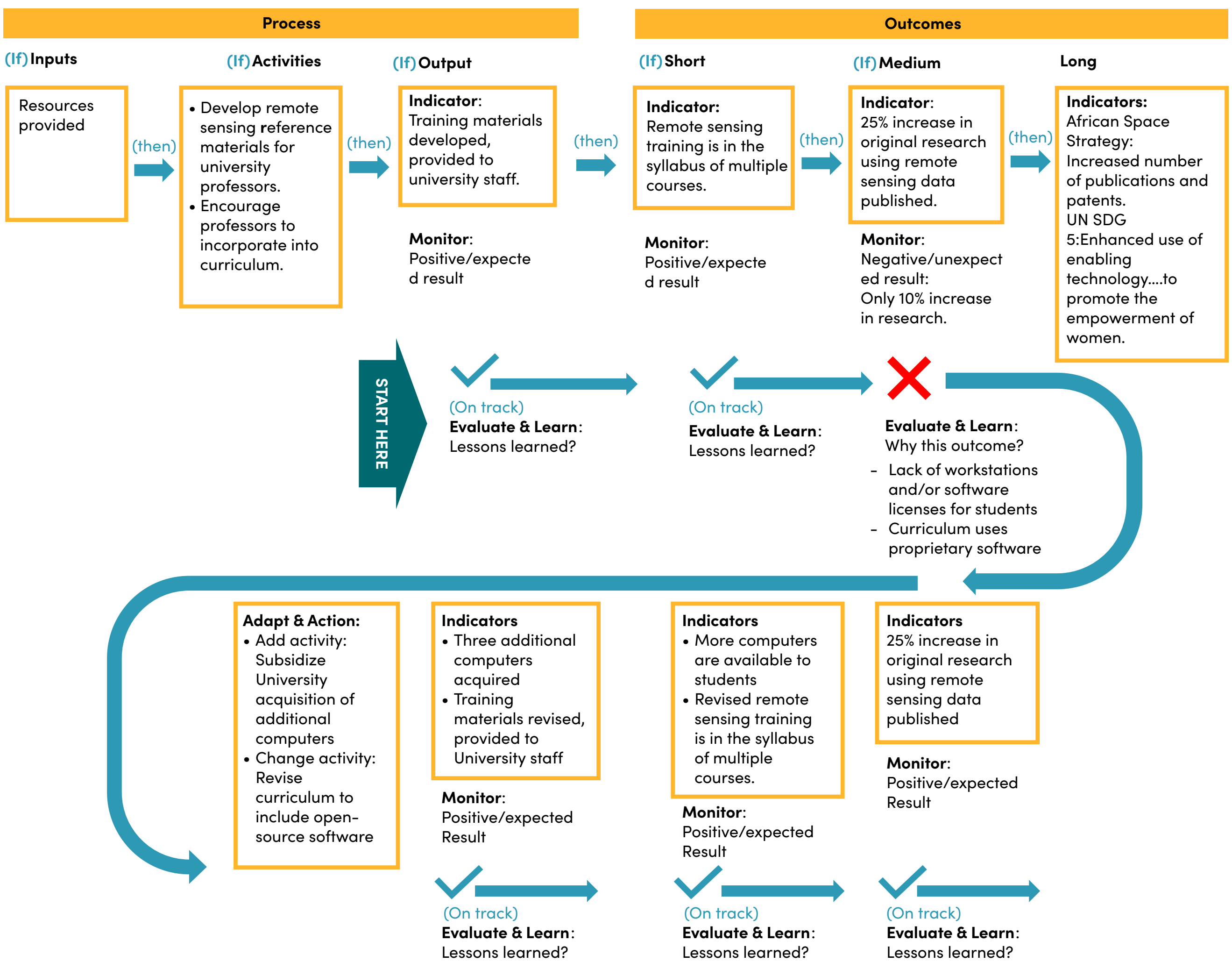
INDICATOR ELEMENTS	DESCRIPTION AND EXAMPLE
Specific	Provides a clear description of what is measured: "Geospatial data training materials have been developed and provided to university staff."
Observable	Focuses on an action or change: "5% of syllabuses include geospatial data familiarization in undergraduate courses at regional universities."
Measurable	Quantified change that is generally reported in numerical terms, such as counts, percentages, proportions, or ratios: "There has been a 25% increase in original research using remote sensing data published since the start of the program."

documenting specifics about who, how, and when these data would be collected for a particular purpose. Choosing too many indicators or indicators that are too difficult to monitor will eat up staff time. Not having enough indicators or relying on nonspecific or untracked indicators leaves the team without enough data to evaluate the program's efforts so far and will lose the team the opportunity to obtain useful, relevant evidence of progress. Of note, the definition of medium- and long-term outcomes may already be defined and monitored by other strategies or programs. For example, the African Space Strategy includes a list of suggested indicators for its objectives, and the World Bank provides standardized indicators by country for the Sustainable Development Goals.[18]

EVALUATING AND LEARNING

Evaluation is making sense of the data collected thus far. Evaluation asks why an action was successful or not, and why it resulted in a desired outcome or not. If the actions have (the intended) positive results and are combining successfully with other actions for desired short-term outcomes, then the program is probably on track. There are still lessons learned or

FIGURE 3.14 Process to monitor, evaluate, and adapt



18 See African Union 2019 and World Bank, "World Development Indicators: Sustainable Development Goals," dashboard, https://datatopics.worldbank.org/sdgs/.

best practices that can be documented and shared (and celebrated). If the actions have negative results (outputs), then the activities themselves may need change.

All new and complex capability development efforts will have setbacks and the need to reassess the approach from time to time. Planners can use the structure of a logic model to unpack a shortfall by asking why and working backwards from the problem. Was the activity (training material) inadequate in some way? Are there new external factors to consider? Perhaps there aren't enough geospatial software licenses or computers available for students to use in their research? If the desired outcomes aren't achieved—or worse, had a negative result—then the program design for that effort may need to be reworked. Perhaps the underlying theory of change needs to be adjusted owing to new external factors. Perhaps the sequence or types of activities need to be changed. Regardless, it is far better to return to the start than to persist in activities that don't contribute to the desired program goals.

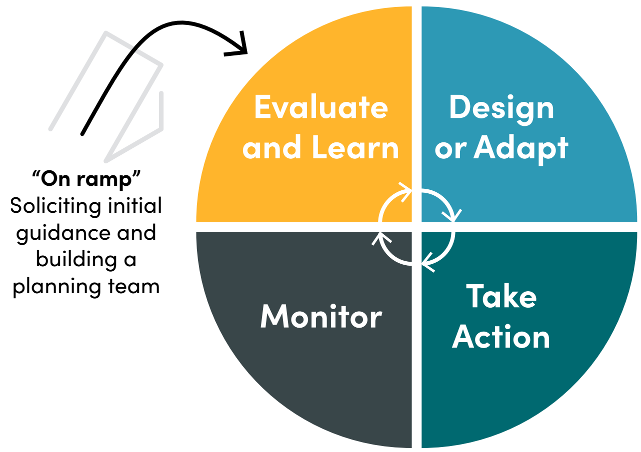
This cyclical monitor-and-iterate approach to program management shows why it is so vital to have a proactive, engaged management team for your space program.

ESTABLISHING A PROGRAM CYCLE

It may be helpful to hold an annual review at which space program members and key stakeholders reunite to evaluate the data gathered through monitoring designated indicators throughout the year. These data can be used to understand if the completed activities have indeed resulted in the desired outputs and outcomes. If so, why did an activity work? If not, why not? Are there lessons learned in resourcing, the execution of the activities themselves, in the process of monitoring? Are there new opportunities or threats that need to be considered and worked into the program? Do the original program design theory of change and logic models still hold true?

A program manager may want to link the phases of this cycle (Figure 3.15) to the greater national annual rhythm so that, for example, an annual report of space-related activity and

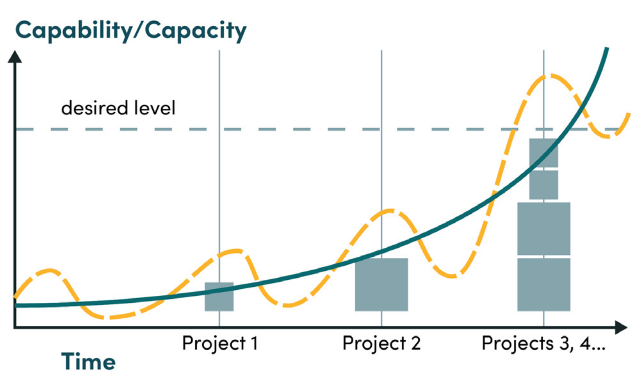
FIGURE 3.15 Program cycle



outcomes, demonstrating a return on investment, is ready for policymakers and the public just as future budget allocations are being planned.

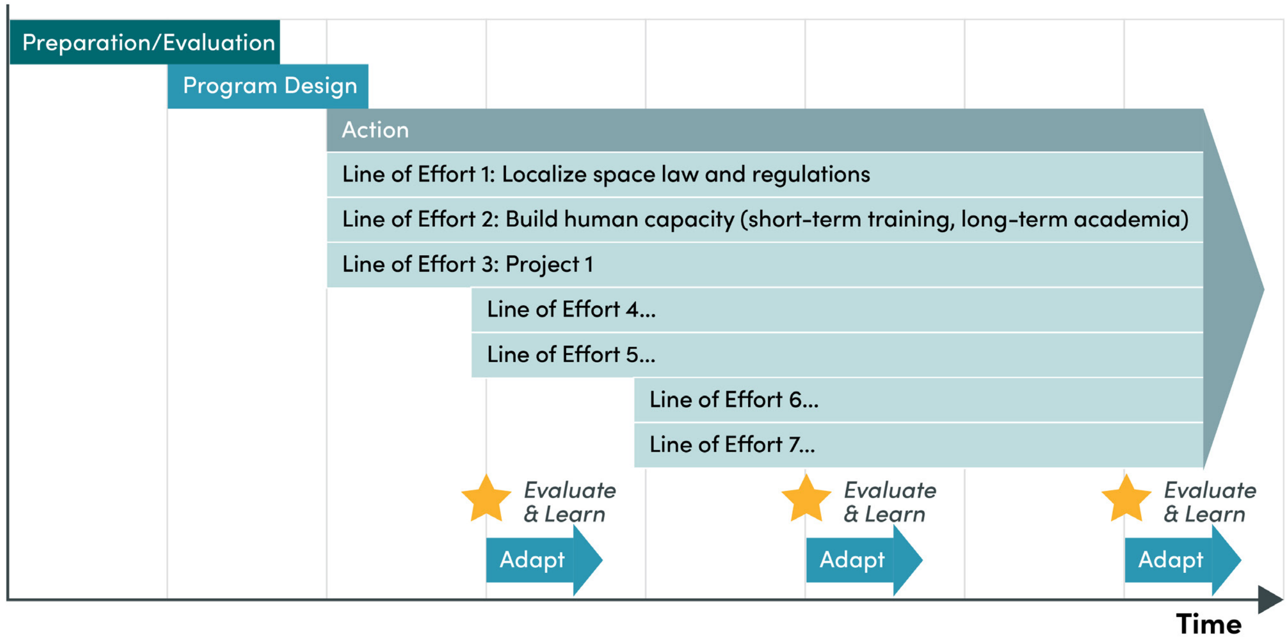
Space capabilities and the space and data ecosystem itself will build over time, but progress will not manifest in a straight line. Activities and projects can serve as a fulcrum, as a forcing function, to develop the components of space capabilities. As these activities change or are completed, and as personnel change over and hardware and software are reassigned or redesigned, it is normal for capability and capacity to fluctuate (Figure 3.16). Over the long run, however, the space program should see a steady improvement. This is again why it is so useful to establish some early, key indicators to help managers measure real change over time (Figure 3.17).

FIGURE 3.16 Capability and capacity progress



Note: The dotted line symbolizes realistic progress toward a desired level of space capabilities versus the "planned" progression in green.

FIGURE 3.17 Program timeline with multiple lines of effort of focus areas, showing increasing activity over time and accounting for "Design/Adapt, Action, Monitor, and Evaluate & Learn" program phases



IDENTIFYING FUNDING AND ADVISING SUPPORT

There are two major approaches to thinking about funding and support for foundational space capability development. The first is the space program and office itself, to include its personnel, facilities, management, internet connection, computers, and so on. It is rare that foreign, private, or philanthropic funding will defray these overhead costs, so a government-sponsored space program will need a funding line in a national or ministerial budget. The proactive engagement of government bureaucracy—building understanding and support with policymakers and the public, submitting and championing a budget request and supporting laws, and maneuvering through many country-unique requirements—all demand considerable skill and persistence. It took Indonesia ten years to go from its an academic draft to signing its first national space act (Verspieren et al. 2022). A successful space program will include a mix of personnel with good management, political savvy, and strong communication skills, in addition to science and technology credentials, between them. The suggested approach of incorporating shorter-term projects into the overall program arc provides regular opportunities to show policymakers and the public a concrete return on their investment, thereby building support for the less tangible, but equally important, longer-term development of the space and data ecosystem.

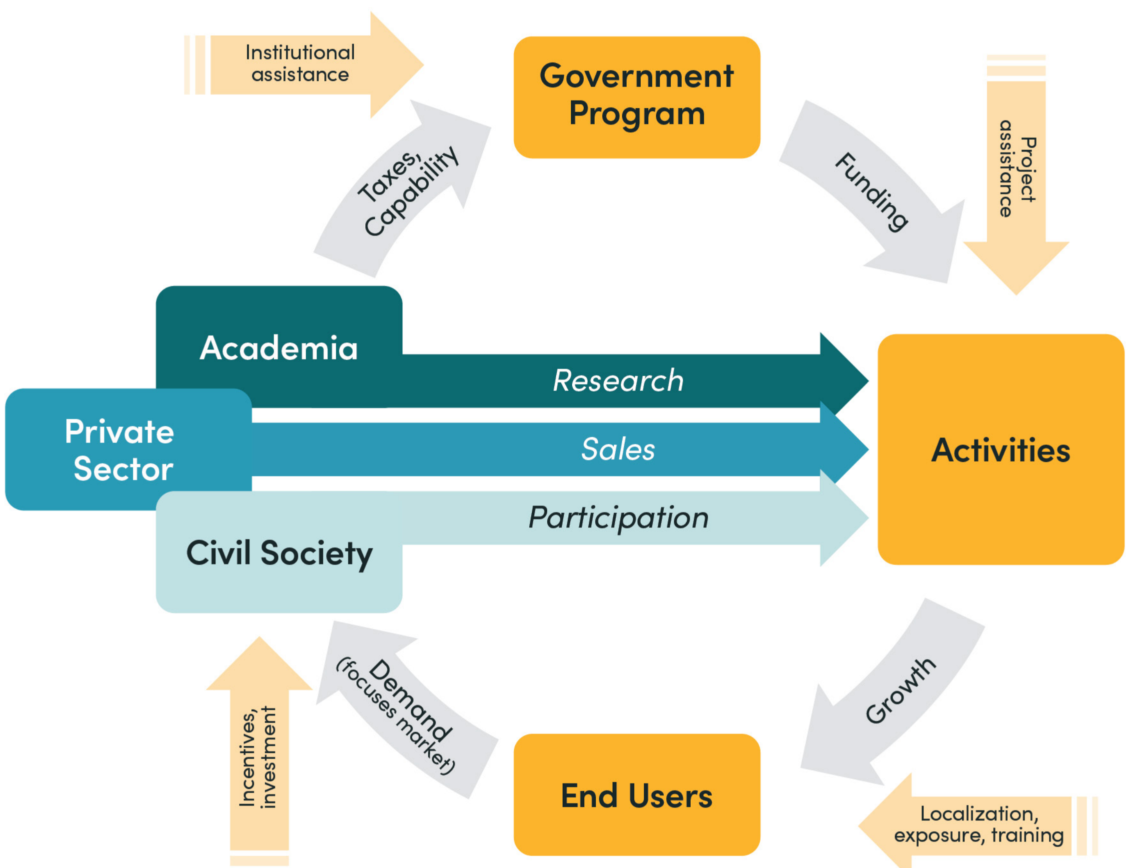
The second approach is funding and support for space-enabled functions, the use of remote sensing, and PNT and satellite communications as enabling components of other state activities. The systems map (see Figure 3.2) shows an example of where space activities may overlap with other programs' activities. Space capabilities should be considered and, if appropriate, woven into other programs (and their funding). For example, if a local government decides to build a new tax cadastre (perhaps aided or funded by an NGO or the UN), and it determines that a cost-effective approach is to use remote sensing data to assess property values, then that capability should be included in the project plan, skills transfer plan, and budget. As an example, a geospatial budget may include a technical advisor, three local geospatial analysts' salary for six months, two computers, a geospatial software license, commercial remote sensing data, data storage on the cloud, a 5G internet connection, and project management and oversight. The space office's role would be to support the teasing-out of space-related needs, support the development of space-related activities (using remote sensing data to survey an area over time), facilitate access to existing capabilities and infrastructure (flag the national spatial reference system and connect "reservoirs" of expertise in the government, private sector, academia, and civil society) and costing (leverage standardized or pre-arranged contracts to acquire data, advise on type of computers needed with sufficient processing power, help define the skills and software required to accomplish the task).

Domestic tools

A state can broadly offer incentives, reduce barriers, and encourage sustainability in the space ecosystem or act as a direct catalyst.

Acting directly, a state may initiate a project that provides a localized service, thus growing awareness and demand for further space-related services and capabilities. For example, a government initiates an e-governance insurance program that tracks drought damage to crops using remote sensing data and then facilitates aid delivery via digital finance (e-finance) to remote farmers by using satellite broadband internet. This naturally captures the interest of farmers, who potentially had never before considered the use of space applications in daily life. They may now proactively look for ways to leverage localized space applications for other areas, such as health, education, and market access. This type of end-user demand should trigger new activity from the private sector (services), academia (projects, research, curriculum development), and the civil sector (participation, use). This growth in research, sales, and participation in turn enhances the space and data ecosystem, making more capability and capacity and (ideally) tax revenue available to the government, which enables improved support to the space sector and other users of space infrastructure. In short, a positive feedback loop is formed (Figure 3.18).

FIGURE 3.18 Ways in which financing and advising support can be used to spur the space ecosystem



To reduce barriers, a state should foster well-coordinated policies on topics that affect the use of satellite applications like satellite broadband, such as those regulating the use of the radio spectrum. In general, many low-income countries tend to have policies that sell access to national spectrum to maximize state revenue, but this tends to dampen the growth of affordable services and private sector network investment. Policies that provide competitive, predictable, and transparent access to sufficient radio spectrum are an important component of thriving space and data ecosystems (Agnoletto, Butler, and Castelis 2022).

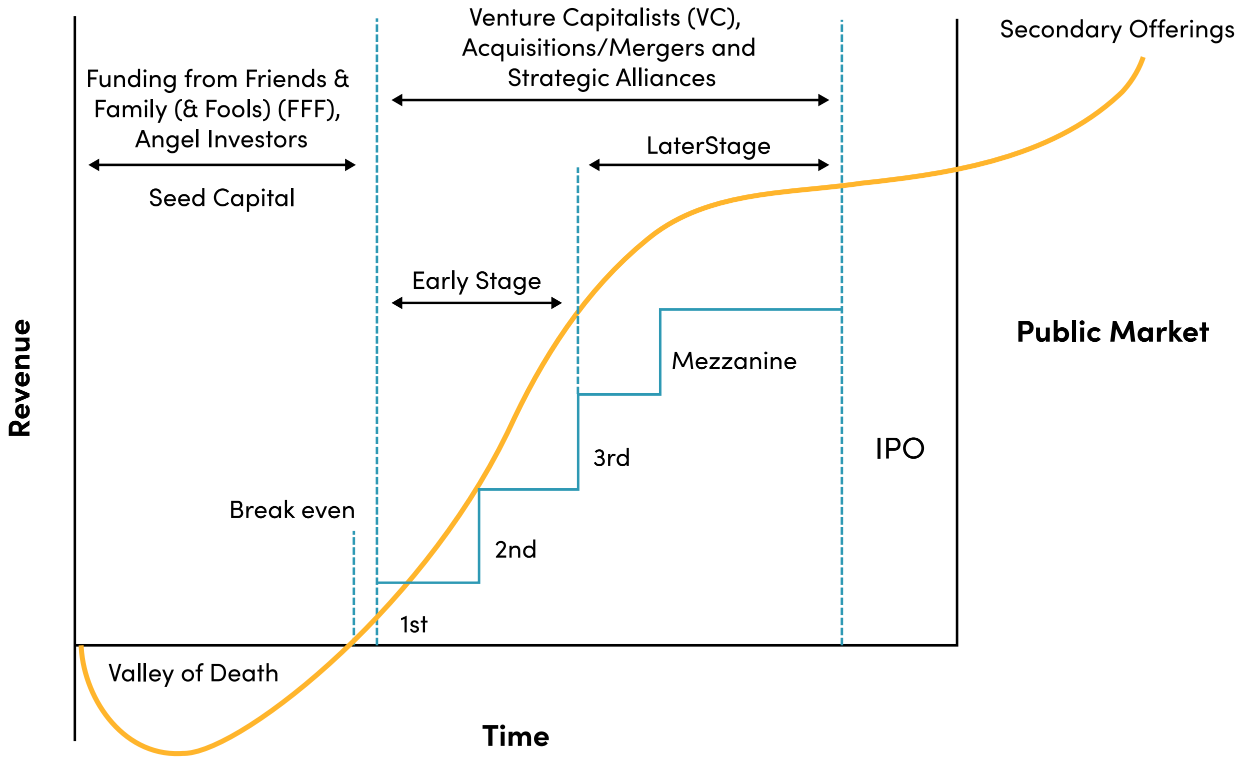
A state can also support its domestic space ecosystem through tax incentives, subsidies, public-private partnerships, prizes, and contracts. Specifically, governments can contract for the delivery of goods to include data, space-related services, and advising. Common contracting types include "fixed-price" contracts and "time and materials" contracts. Prizes can be used to accelerate the pace of innovation and localization. Prizes can do this by offering an award (cash, access to greater support like mentorship and technical assistance), a chance to establish credibility, and free publicity. In turn, prize sponsors have the potential to gain low-risk and low-cost technology development, localization, procurement, or a combination of these with no payment required until the technology is successfully demonstrated. In turn, a space program is able to entice new companies, individuals, and ideas into the space ecosystem and encourage new connections and partnerships ("densifying" the space ecosystem). Prizes also often capture the public's imagination, encourage excitement, and increase awareness of science, technology, and space, thus spurring support for space programs and stimulating greater interest in science and engineering. Prizes do have their limits; that is, solutions are not guaranteed and there is risk for those who compete but do not win. Wealthier competitors may have a greater advantage over those who need to spend time and resources to recruit investors or work without guaranteed pay. Peter Diamandis, chairman of the X–Prize Foundation, recommended incorporating the following: (a) a prize purse and contest time that are well matched to the degree of difficulty, (b) clear and simple rules, (c) an exciting objective, and (d) a potential follow-on market (Culver et al. 2007). A recent example of a prize program designed to "drive entrepreneurial activity in the African space industry and promote awareness of the value of earth observation" is the 2022 Africa Earth Observation Challenge, sponsored jointly by the South African Space Agency, Rwanda Space Agency, and Kenya Space Agency, among others.[19]

States can also provide favorable loans through their national development bank or equivalent institution. A government can sponsor grants for scholarships, research and development, technology accelerators, and incubators. Of note, accelerators and incubator programs are typically competitive and can be sponsored by the government as well as by investors or other companies, or they can be sponsored by an independent for-profit or nonprofit organization. Accelerator programs usually have a set timeframe, generally several months, during which startups work with a group of mentors to build out their business, culminating in a pitch competition or demo day with potential investors, which provide funding often in exchange for a small amount of equity in the future business. For incubator programs, a new company pays an open-ended, month-to-month lease for shared workspace, where it will obtain mentoring, refine its ideas, network, build out a business plan, and work on its product (Kenan Institute of Private Enterprise 2020).

Private sector companies, both domestic and international, can seek seed funding, support from friends and family, crowdfunding, small business loans, and "blended" financing (Figure 3.19). "Blended financing" includes various instruments to "crowd in" commercial investment for development, and includes collective investment or pooled vehicles, such as facilities and funds. More developed space sectors have access to larger for-profit funding, like angel funding, venture capital, or an initial public offering (IPO). Nongovernmental and philanthropic organizations, like the Space Foundation, Secure World Foundation, and the International Astronautical Federation, often convene, share information, and sometimes

19 See "What Is the Africa Earth Observation Challenge?," https://eochallenge.africa/about/.

FIGURE 3.19 Startup financing cycle



Source: Kmuehmel 2009.

support domestic civil society space organizations. Many non-space-focused civil organizations use space applications as a matter of course and thus also represent a significant resource. Examples include organizations focused on geography, cartography, climate, weather, and general science. Some large private companies with a social mission build community and training into their business models. A few examples of such public-benefit corporations include ESRI, Planet, and Google Earth Engine (Legal Information Institute 2020).

Regardless of the types of tools a state decides to use, they aren't useful if people do not know they exist. Good communication is key. Space agencies, like NASA, ESA, and ISRO, routinely post calls for proposals for research, collaboration, goods and services, and host guidance, tutorials, and standards to support the general development of their space ecosystem.

Regional or local governments interested in growing their tech and space industry often do the same. For example, the city of Shenzhen, China, published a list of available subsidies and support measures for companies developing satellite-related technology, which included support for reaching international certification, subsidies for internal market access, and subsidies for joint ventures with foreign companies in related industries.[20] The US state of Virginia hosts a website for its spaceport, lauding its tax incentives to locate and headquarter space flight launch and training business operations in Virginia, its liability law, and trade zone status.[21]

Ideally, as the nongovernment elements in the space and data ecosystem grow, more services and benefits will flow to activities and end users that are not specifically driven by a government space program.

20 "A Rising Chinese Space Sector: Expectations vs Reality | Satellite Markets & Research." file:///C:/Users/rose/Zotero/storage/6Z36VE9D/rising-chinese-space-sector-expectations-vs-reality.html

21 "Virginia Space and the Mid-Atlantic Regional Spaceport." https://visitesva.com/things-to-do/listings/virginia-space-and-the-mid-atlantic-regional-spaceport/

For startup companies, the early "valley of death" is the period when a business startup is doing research for and development of its product and has not yet started to generate revenue. As a business matures and is able to prove the viability of and demand for its product, it can attract larger investments as well as depend on increasing revenue.

Additional tools

Although the government must manage its own program overhead costs, it can leverage or support access to significant funding, technical advising support, or both, that are available through development finance institutions (DFIs), international cooperation, access to bilateral and multilateral forums and organizations, and the United Nations. These organizations tend to sit on a spectrum somewhere between "advising" and "financing" poles. It is useful to investigate their past activity and various programs to understand what mix of assistance or financing they are likely to provide. These organizations can support the development of the space office itself, the program's activities, or the development of the greater space and data ecosystem. This support may include but is not limited to loans, grants, technical advising, training, networking, acquisition of equipment, data infrastructure, and diverse forms of cooperation. International links can also make the space program itself more politically robust, as commitment to an outside organization tends to solidify domestic political commitment as well.

The foundational space capabilities of consulting, advising, and localization are a critical balancing factor when weighing possible collaboration or support. Every country has its strengths and ability to contribute, be it geographic attributes, its networks and geopolitical relationships, its technology, industry, or people.

Philanthropic organizations, civil sector organizations

There are many nonprofit organizations that can provide useful networking, reference material, training, advising, and, occasionally, funding. Some are explicitly space focused, like the International Astronautical Federation (established in 1951) and Space Frontier Foundation (founded in 1988), among others. These organizations excel in their ability to convene diverse elements of the space community and support networking and mentoring. The Space Generation Advisory Council (SGAC) is associated with the UN and has numerous national, regional, and international chapters that run workshops on all sorts of space topics but excels at developing youth leadership in the space sector. Non-space-focused philanthropic organizations frequently support efforts that include space applications and capability and capacity building. A land-reform-focused NGO could, for example, support the implementation of using remote sensing data in the development of property registers for the process of titling and registering land. Education-focused NGOs incorporate support for youth engagement with digital public goods, science, and technology, which connects to or can lead to the space ecosystem and helps build human capacity in the long term. If a country is clear about the tools it would like to consider for addressing its developmental goals, many development-oriented philanthropic organizations will take space applications more seriously when negotiating possible collaboration and support.

There are also many nonprofit organizations that focus on bridging space capabilities to development-related actions. OpenGeoHub (funded by the European Union) "aims to accelerate the uptake of key environmental data…[for use] in the field of research, decision-making, and practitioners, including landholders and citizens, in support of effective and impactful actions on the ground."[22] The Geo4Dev initiative is a collaboration between a private company (New Technologies Inc.) and two nonprofits (Center for Global Action and 3IE) and operates from the University of California, Berkeley, to "inspire novel research collaborations, share knowledge, and build capacity to utilize geospatial data, tools and approaches."[23] OpenStreetMaps, Ushahidi, and others provide user-friendly geospatial platforms. Nonprofit, license-free software, like QGIS, can be a useful way to remove cost barriers to accessing

22 "Open-Earth-Monitor Cyberinfrastructure," https://opengeohub.org.
23 "About Geo4Dev," https://www.geo4.dev/about.

and using remote sensing data. GSMA Mobile for Development (a charitable section within the GSMA trade association) and the Internet Society, among others, focus on closing the digital divide, to include the space segment of telecommunications infrastructure.

Academia and research community

Universities and research or education-oriented networks are another way to foster domestic, regional, and international cooperation to build foundational space capabilities. Partnerships can include a variety of activities such as (but not limited to) joint research, training, curriculum development, scholarships, and faculty and student exchanges. International partnerships can be structured to include applied field and laboratory work, research, publication, and internships to expose young professionals to a range of skills and material on science and technology subjects as well as humanities subjects such as leadership, commerce, management, and governance. High-quality, open-access, peer-reviewed journals like *Remote Sensing, Geosciences, International Journal of Geo-Information (IJGI)*, and *IEEE Communications Surveys and Tutorials*, among many others, are accessible via the internet.

Stepping back further, it is useful to recognize that a government has a primary role in preparing the country's population to participate in the space and data ecosystems starting in primary and secondary schools. Strong foundations in math, science, critical and problem-solving skills, creativity and innovation, research, communication, cooperation, interpersonal management, life skills, and lifelong learning are essential. A state can maximize the potential of its population by encouraging children of all backgrounds, races, ethnicities, genders, religions, and income levels to join and benefit from this growing and increasingly global knowledge-based economic community.

Development finance institutions

Major DFIs include the World Bank Group (International Bank for Reconstruction and Development, International Development Association, and the International Finance Corporation), African Development Bank, Inter-American Development Bank, European Bank for Reconstruction and Development, Asian Development Bank, (the China-led) Asian Infrastructure Investment Bank, Islamic Development Bank, and New Development Bank (formerly the BRICS Development Bank). These institutions offer policy advice, research and analysis, technical assistance, and financing to varying degrees. The World Bank, for example, often accounts for space applications like remote sensing when partnering with a country to address a state's (non-space) economic constraints. In 2011 the World Bank provided US$4.59 million in grants to improve water resource and agricultural management within Jordan, Tunisia, Morocco, Lebanon, and the Arab Water Council. This support provided hardware, software, and technical assistance needed for the application of various remote sensing and decision-support tools to address water resources and agricultural management (World Bank 2011). Another example is the Climate Risk and Early Warning Systems (CREWS) initiative that funds analytical and advisory services, technical assistance, investments, capacity building, and some operational support for "risk-informed" early-warning systems in least developed countries and small island developing states. This naturally includes leveraging various space applications, from remote communications to remote sensing data. The dividing line between types of assistance and organizations can be blurred—the fund's secretariat is hosted by the WMO, steered by eight member states, managed by the World Bank, and implemented by the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR), UN Office for Disaster Risk Reduction (UNDRR), and the WMO.[24] Explicitly space-focused DFI programs are harder to find but are becoming more common. In 2020, the Asian Development Bank provided US$50 million to Kacific Broadband Satellites International Ltd. to bring affordable and reliable internet to remote communities and island states in Asia and in the Pacific (ADB 2020). The case for leveraging DFIs to grow foundational space capabilities will strengthen as access to and use of space are increasingly recognized as important national infrastructure and a component of national development. Having policy and strategy that connect to broader national

24 See CREWS website, https://www.crews-initiative.org/en.

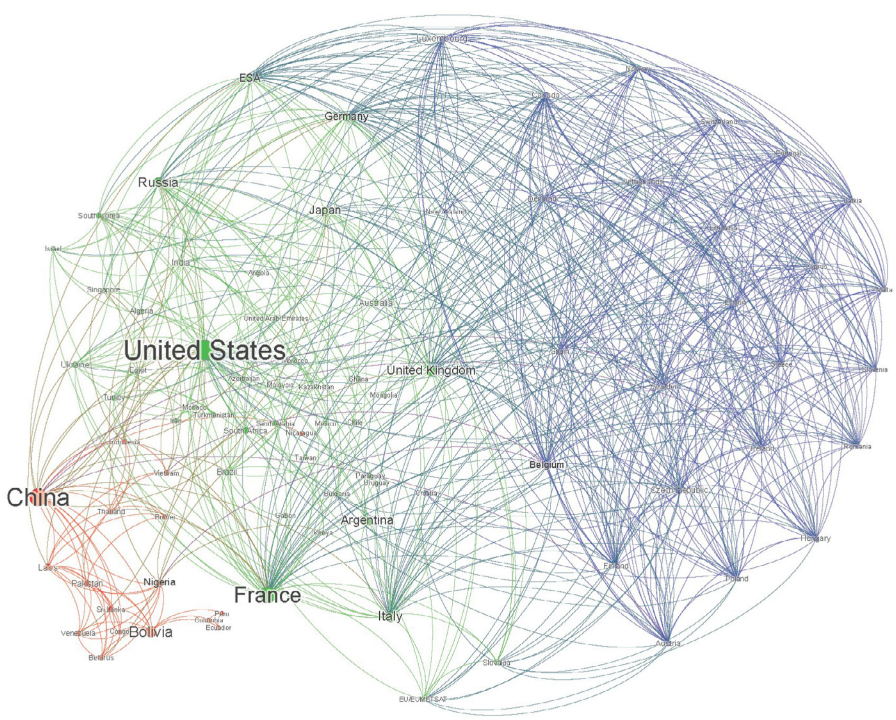
priorities for development as well as shovel-ready activities and projects in mind will greatly improve the likelihood of gaining DFI support.

Bilateral and multilateral cooperation and assistance

Space actors with long-standing, developed programs, such as the United States, the European Union, Russia, and China, have a history of rich international cooperation. Such partnerships can provide rapid access to significant capability and a robust commercial space sector, as well as diplomatic prestige (space cooperation as a signifier of a strong relationship). Such a bilateral relationship tends to be asymmetrical, however, and geopolitics are an ever-present backdrop. When China built a satellite tracking and control center in Argentina in 2017, the US expressed concern that China was using it to spy on geostationary communication satellites that serve the US East Coast. In 2020, when countries began signing the US-sponsored Artemis Accords (a common set of principles to govern the civil exploration and use of outer space), China characterized the accords as an attempt to stymie Chinese space ambitions (Ji, Cerny, and Piliero 2020). However, these and other major space actors provide many core services, such as sharing PNT and weather data, without requiring any formal cooperation agreement (Figure 3.20). Looking forward, as the global space economy matures, space activity will probably gain increasing independence from state-driven strategic objectives and agendas (Lal et al. 2015).

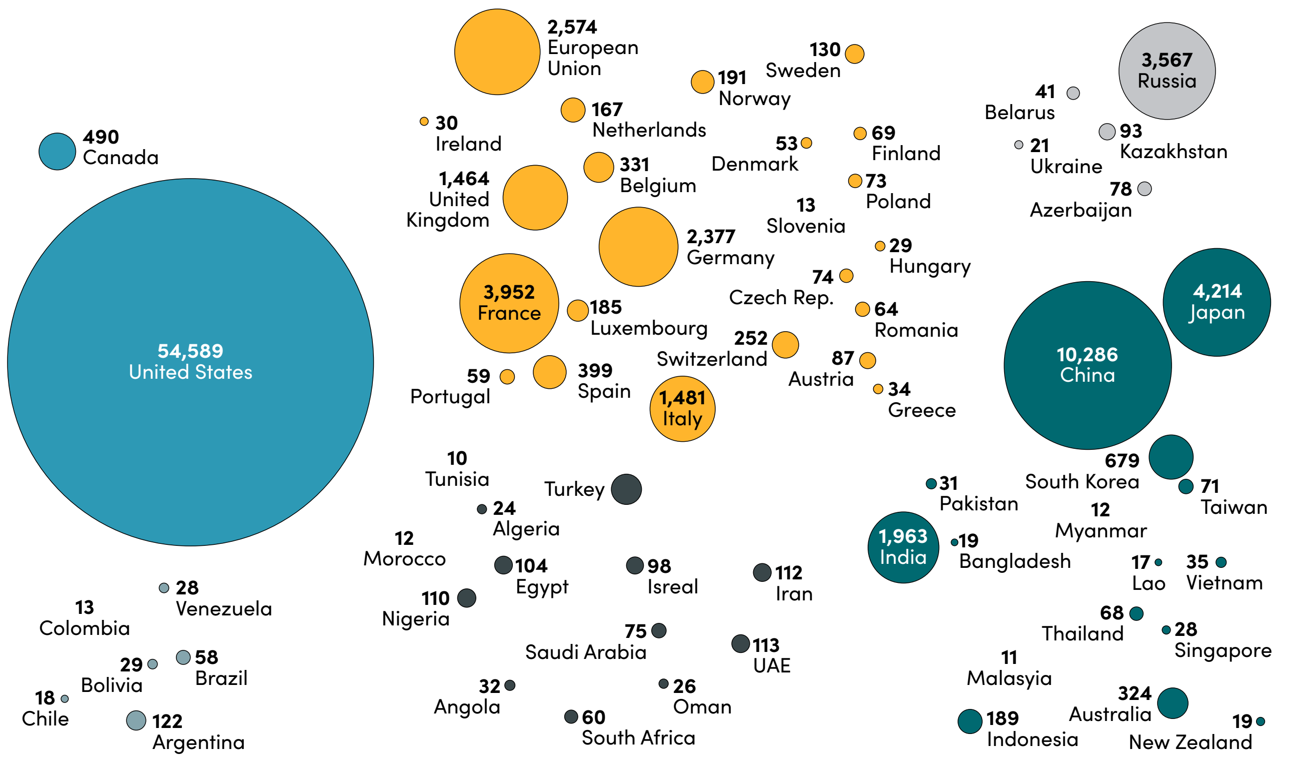
Figure 3.21 shows world government expenditures for space programs with a budget of over US$10 million, highlighting significant space actors such as the UK, France, Germany, Italy, India, Japan, South Korea, and Canada, among others (Berger 2022). These countries can offer other states a relationship with less charged (but not absent) political baggage, if not as much capacity for engagement as the US or China. Italy and Kenya, for example, have a multidecade history of cooperation, which includes exploring models for profit sharing (Space in Africa 2018). Brazil has leveraged its advantageous geography to work with France on stratospheric balloons, since Brazil is well placed for both balloon release and recovery. Japan is particularly adept at cooperating internationally through

FIGURE 3.20 Patterns in country-to-country collaboration



Source: Lal et al. 2015, 4–5. Reproduced with permission.

FIGURE 3.21 World government expenditures for space programs in 2021



Note: The total was US$92.4 billion. Budgets indicated for European countries include their contributions to the European Space Agency (ESA) and European Organisation for the Exploitation of Meteorological Satellites (Eumetsat). Only countries with a budget of at least US$10 million appear on the map.
Source: Berger 2022, from Euroconsult, Government Space Programs, 22nd edition, 2022.

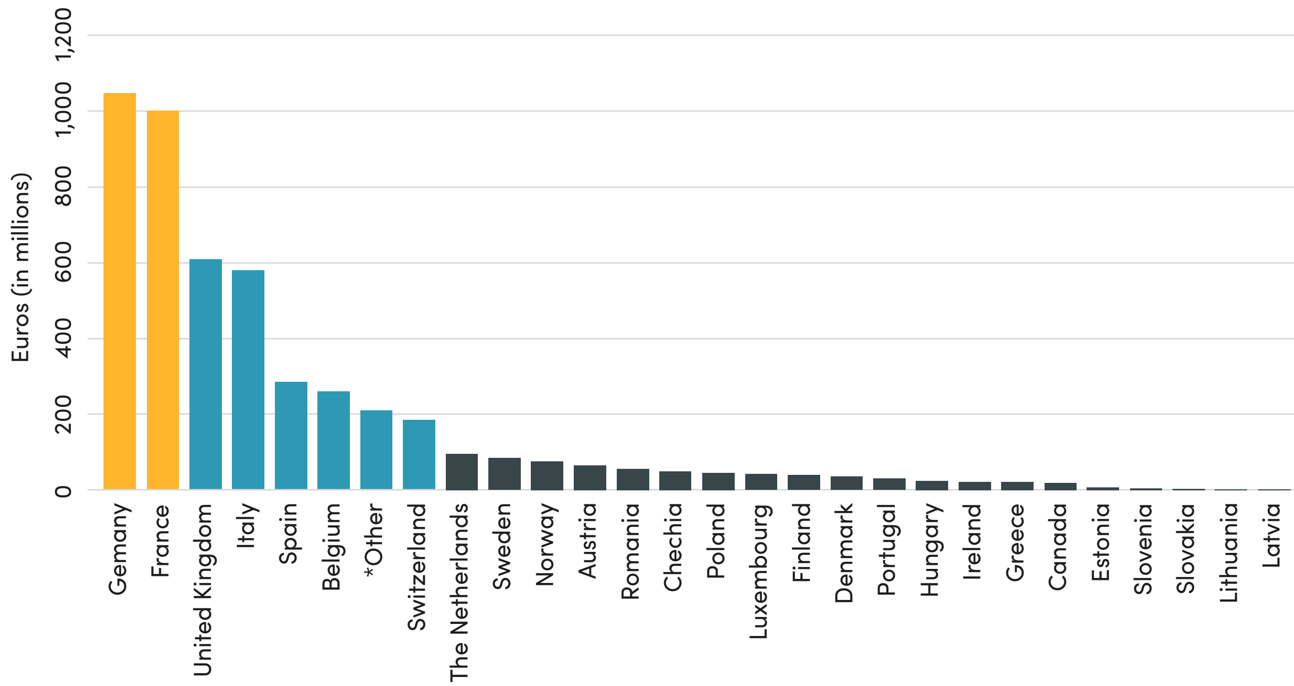
its academic institutions. As part of a collaboration program between two universities, for example, the Philippines' first two satellites, DIWATA-1 and DIWAT-2, were developed and manufactured by Filipinos and then produced in Japan. Further, there is no requirement that a state work with only one partner. Vietnam initiated its program with the Soviet Union focused on space science and then moved on to work with France and Japan on satellite development and applications (Verspieren et al. 2022). India credits its early success to ongoing cooperation with the US, Russia, and France combined with engaging the Indian diaspora and a systemic indigenous effort (Guruprasad 2018). Today, India has space cooperation agreements established with sixty countries and five multinational organizations (Sidharth 2022).

Regional space agencies

Regional space agencies offer countries the ability to pool resources and risk, though these efforts do require constant negotiation and compromise. The European Space Agency (ESA) has done this to great effect, building a twenty-two-member organization into one of the largest and most sophisticated space programs in the world, while also ensuring access to space technology and data at a sustainable cost for members that have the least resources. All ESA member states make mandatory contributions to certain core programs on a scale based on their gross national product (GNP). Members are free to decide on their level of involvement in other "optional" programs that may be of interest to only a subset of member states (Figure 3.22).[25]

25 "European Space Agency Funding," https://www.esa.int/About_Us/Corporate_news/Funding.

FIGURE 3.22 European Space Agency (ESA) budget 2022, in million euros



Source: "European Space Agency Funding," 2023 https://www.esa.int/About_Us/Corporate_news/Funding.

Other regional space agencies include the Asia-Pacific Space Cooperation Organization (APSCO) and the African Space Agency (AfSA). There is an effort underway to establish a Latin American and Caribbean Space Agency (ALCE) (Government of Mexico 2021). There are also numerous forums where nations can share information and best practices, collaborate on various themes, and participate in capacity building programs. The Asia-Pacific Regional Space Agency Forum (APRSAF) includes space agencies, governmental bodies, international organizations, private companies, and research institutions.[26]

United Nations

The United Nations Office for Outer Space Affairs (UNOOSA) is probably the largest and oldest platform for international space cooperation and capability building. UNOOSA was established in 1958 to support governments in building legal, technical, and political infrastructure to support global space activities. UNOOSA provides capacity building through training, workshops, conferences and knowledge-sharing portals, fellowships, and competitive programs for interested countries. In addition to capacity-building programs, UNOOSA provides advisory missions and emergency support to countries. Work is divided between various committees:

- Committee on the Peaceful Uses of Outer Space (UNCOPUOS) governs the exploration and use of space for the benefit of all humanity: for peace, security, and development. The committee is tasked with reviewing international cooperation in peaceful uses of outer space, studying space-related activities that could be undertaken by the UN, encouraging space research programs, and studying legal problems arising from the exploration of outer space. UNCOPUOS led the codification and entry into force of five "core" UN treaties related to outer space activities, as well as other international agreements and mechanisms vital to cooperation in space. Meeting annually in Vienna, Austria, UNCOPUOS is the primary forum whereby its (currently) one hundred member

26 "About APRSAF," Asia-Pacific Regional Space Agency Forum, https://www.aprsaf.org/about/.

states discuss issues including the regulation of space debris, safe (sustainable) space operations, "common good" space applications such as climate change mitigation and water management, and threats posed by asteroids, among other areas requiring discussion, consensus, and creation of international law. Most recently, UNCOPUOS negotiated the "Guidelines for the Long-Term Sustainability of Outer Space Activities."[27]

- UNCOPUOS Science and Technical Subcommittee (STSC) addresses scientific and technical aspects of outer space activity and international space cooperation, diving deep into topics such as space weather, orbital debris, and the long-term sustainability of outer space activity.
- UNCOPUOS Legal Subcommittee (LSC) helps countries understand the fundamentals of international space law and increase their capacity to draft or revise national space law and policy in line with international normative frameworks on space. This is particularly important as more and more actors enter the space arena.
- The International Committee on Global Navigation Satellite Systems (ICG) promotes the compatibility and interoperability of the GNSS and cooperation on matters of mutual interest related to civil satellite-based PNT and value-added services.

Major initiatives include the following:

- United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) Knowledge Portal. This portal offers links to open source (free) datasets of satellite imagery, elevation models, and land use and land cover maps as well as near real-time data products for different hazard types (floods, fires, earthquakes, etc.). Each month, the UN-SPIDER team compiles a list of applications of remote sensing data. Past topics include locust monitoring, soil erosion, and population and settlement data.
- "SPACE4SDGs" is a directory of sorts that matches space capabilities and initiatives (e.g., Space4Water, Space-4Climate Action, Space4Youth) to specific sustainable development goals.[28]
- "Access to Space for All" focuses on technical know-how, engineering processes. and infrastructure in the areas of hypergravity and microgravity, satellite development, and space exploration (UNOOSA 2022).
- "Space4Women" campaigns to increase women's representation in the space sector. In October 2022, UNOOSA launched a mentorship program for women in the aerospace sector.[29]
- "Space Law for New Space Actors" is a UN project to raise awareness of, and adherence to, the existing normative framework governing outer space activities. Upon request, the UN will facilitate a country's effort to draft national space law, policy, or both. This includes e-learning modules, advisory services, and capability building.[30]
- UN Register of Objects Launched into Outer Space. UNCOPUOS manages space object registration as a means of identifying which states bear international responsibility and liability for space objects—that is, satellites and associated debris.[31]

The UN Office for Disarmament Affairs (UNODA) also has a role for space, mainly focused on preventing an arms race in outer space; setting norms, rules, and principles for responsible behavior in space; and reducing the risk of misunderstandings and miscalculations in space.

Specialized agencies

UN International Telecommunications Union (ITU), established in 1865, is the UN's specialized agency for information and communication technologies. Originally organized

27 "Awareness-Raising and Capacity-Building Related to the Implementation of the Guidelines for the Long-Term Sustainability of Outer Space Activities," United Nations, https://spacesustainability.unoosa.org/.
28 "Space4SDGs: How Space Can Be Used in Support of the 2030 Agenda for Sustainable Development," UNOOSA, https://www.unoosa.org/oosa/en/ourwork/space4sdgs/index.html.
29 "Space4Women," https://space4women.unoosa.org/.
30 "Legal Advisory Project: Space Law for New Space Actors," USOOSA, https://www.unoosa.org/oosa/en/ourwork/spacelaw/capacitybuilding/advisory-services/index.html.
31 "United Nations Register of Objects Launched into Outer Space," UNOOSA, last modified December 13, 2022, https://www.unoosa.org/oosa/en/spaceobjectregister/index.html.

to regulate the telegraph industry, the ITU has evolved in step with the telecommunications and, increasingly, space industry. Today, through the implementation of radio regulations and regional agreements, the ITU works to ensure that radio-frequency spectrum and associated satellite orbits are used equitably, efficiently, and economically by states, and it prevents physical and electromagnetic interference in geosynchronous orbit.

The ITU has three technical sectors: T, R, and D. The ITU-Telecommunication Standardization Sector (ITU-T) is responsible for setting international standards (known as "recommendations") on issues such as interoperability and 5G technology. ITU-Radiocommunication (ITU-R) manages satellite ownership and spectrum allocation. ITU-Development (ITU-D) specializes in building human and institutional capacity, providing data and statistics, and promoting digital inclusion.[32] Each sector and region has its own set of study groups and conferences that build up to the ITU's Plenipotentiary Conference, held every four years.

Last, the UN has "DFI-like" components as well. The UN Technology Bank for Least Developed Countries focuses both on low- and middle-income countries. The UN Technology Bank's mandate is to strengthen science, technology, and innovation (STI) capacity in the least developed countries, including the capability to identify, absorb, develop, integrate, and scale up the deployment of technologies and innovations, as well as the capacity to address and manage intellectual property rights issues. The UN's Inclusive Digital Economy programs as well as the Least Developed Country (LDC) Investment Platform, both financed by the United Nations Capital Development Fund, provide flexible grants and loan instruments to least developed countries to finance a wide range of products and services in various sectors, including those that complement development of space and data ecosystems.

As of 2022, 193 states are members of the ITU, and one hundred states are members of UNCOPUOS. States must formally apply for membership in UNCOPOUS to participate. It can be difficult and expensive for countries to send delegates to UN space-related meetings and events, so many leverage their representatives posted to a permanent mission based in Geneva, Switzerland. The ITU convenes in Geneva, but UNOOSA and UNCOPOUS meet about 1,000 kilometers west, in Vienna, Austria. Most representatives will not have a deep background in space-related issues, so it's important that they are supported by a domestic space office. These representatives should be empowered to participate in international coordination, cooperation, norms setting, and so on, through tools such as information papers, white papers, and formal guidance from the member state.

SUMMARY OF SECTION 3

Space program design is essentially the process of writing highly localized instructions—a strategy—for methodically building foundational space capabilities and for setting the best conditions possible for accelerating the growth of a space and data ecosystem. A space office, no matter the size, gives a program an anchor within the government, a focal point capable of bringing together national priorities, organization, and resources—and those of the private sector, academia, and civil society—to achieve better access to and use of space and to engage the global community.

32 "About the ITU-D and the BDT," International Telecommunication Union, https://www.itu.int:443/en/ITU-D/Pages/About.aspx.