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Preparing for the space innovations of today and tomorrow

An overview and brief guide on how to maximize your advantage

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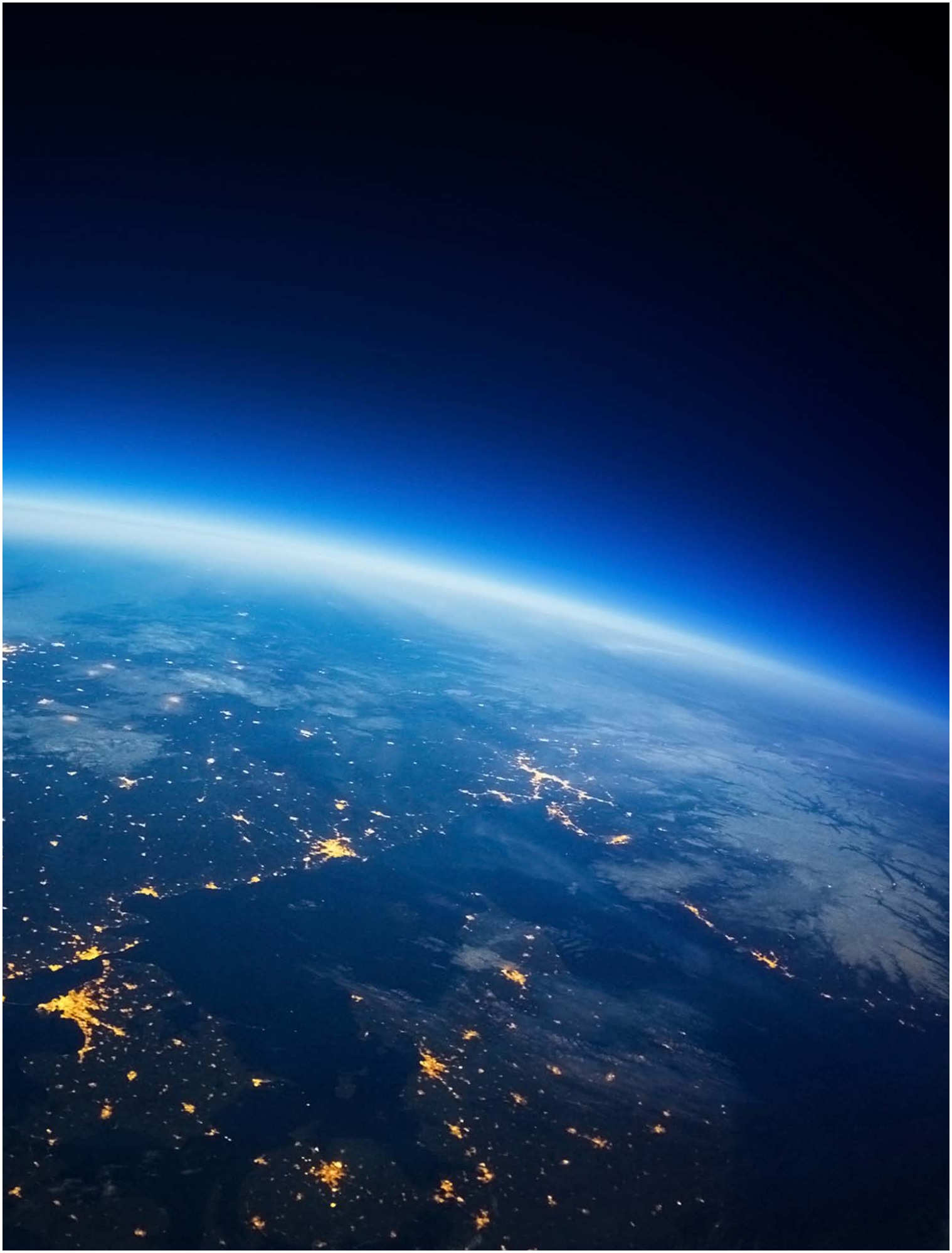

Overview

Innovative technologies are reshaping almost every industry, presenting new business cases and changing our daily lives. These technologies are hyper-connecting the world and offering new ways to interact. Many of these innovations extend to space platforms, in addition to their earth-bound applications; others are space-centric.

Among these new technologies are big data analytics, 3D robotics, geolocation, earth observation and remote sensing, high throughput and advanced satellite systems in multiple spectrum bands and orbits (geostationary orbits (GEO) and low earth orbits (LEO)), asteroid mining, and satellite refueling. More details on these new technologies are presented at the end of this article.

New technologies bring with them many new considerations, many of them quite fundamental. Innovative and disruptive technologies change and improve how we see and interface with the world. They bring great benefits and often a paradigm shift in how people go about their daily lives. Those who succeed become the next "unicorn" success story, usually leaving behind old technologies or business models; those without investment in new technologies and that cannot adapt and reinvent themselves will lose market share and/or fail.

At the same time, these new global space and satellite industry innovations bring many legal, regulatory, and contractual challenges and considerations that need to be kept in mind to support the successful launch of the new business. Along with new business models and new technologies (some fully or partially still on the drawing board), often come new hurdles, paradigms, and new approaches to partnering and capital raising.

The regulatory, commercial, and strategic parameters framing these new technologies present new considerations within (and outside) the framework of existing precedent, and will require the development of new rules and contractual safeguards to address these innovations. Some thoughts on these new parameters are set forth below, including how to turn them into advantages instead of hurdles.

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Regulation + innovation = New puzzles to solve

Innovations in space raise many regulatory questions, not just at the compliance level but at the fundamental nature of the innovation itself. The issues range from whether and how the new technology is to be regulated and whether the regulatory scheme to be applied will support innovation or, conversely, create hurdles that will stand in the way of (or even block) its development.

What regulations (and how such regulations) will apply to new technologies?

Recent NewSpace innovations raise fundamental questions regarding jurisdiction among federal agencies, and have pushed dated satellite-related regulations to the limit. Much of the technology emerging in today's commercial space industry does not neatly fit within existing regulations. Technology that allows asteroid mining, the proposed launch and operation of large numbers of non-geostationary orbit (NGSO) satellites, optical/laser communications, aircraft borne launches, and mission extension services raise novel questions about the applicability of existing regulations and international treaties.

For example, in the United States, should the Federal Communications Commission (FCC), Federal Aviation Administration (FAA), National Oceanic and Atmospheric Administration (NOAA), or perhaps a new agency, regulate these new and/or hybrid space services?

While agencies stretch existing rules to accommodate NewSpace innovations, they are also pursuing regulatory solutions to better accommodate these new services. The FCC, for example, has proposed changes to its rules applicable to NGSO satellite systems with the goal of better facilitating and coordinating the use of large constellations of NGSO fixed-satellite service systems. The FCC has also stated that it intends to propose new rules to promote the development of smallsat systems. Others are exploring creating new divisions or new licensing regimes to regulate NewSpace technologies, including the grant of mission authority to the FAA, whereby the FAA would authorize all space missions, including "non-traditional" activities, such as asteroid mining, via a process similar to the existing payload review process.

What spectrum will be available to the new technologies and through what processes?

With multiple new space-based platforms currently being proposed, including systems to address new broadband, internet of things (IoT), big data, earth observation, and remote imaging applications (to name a few), spectrum availability, coordination, and sharing have become more important issues than ever. Many of the proposed systems intend to use frequency bands (such as the X, S, and UHF bands) that are shared with existing Federal users, and others are proposing to share frequency bands (such as the Ku, Ka, and V bands) with other commercial satellite operators (each proposing to deploy hundreds if not thousands of satellites) or, in some cases, terrestrial operators. The shared use of valuable and limited spectrum resources often requires parties with conflicting spectrum interests to compromise and reach agreement on a cooperative and coordinated approach to resolving potential interference issues.

In the smallsat community, potential and current satellite operators and incumbent government spectrum users (including the NOAA and the National Aeronautics and Space Administration (NASA)) are already looking for cooperative solutions by voluntarily coming together to participate in the Commercial v Spectrum Management Association (CSSMA). The goal behind CSSMA is simple: By working together to streamline the current frequency pre-coordination process, parties can facilitate commercial access to shared spectrum and minimize interference among all users for the benefit of everyone.

Will national security issues (globally) impact a technology's application, and how?

With new technologies able to collect and process information in ways never before imagined, regulations that limit the application for commercial and/or military uses are inevitable. These may be limited by export control restrictions, government security agreements, and/or other government regulation.

Many of the new space innovations bring with them both commercial and military applications.

Further, in our global economy, many of the new applications are being launched and proposed for global deployment, including potential foreign military applications. Despite the Export Control Reform initiative undertaken by the Obama administration and the removal of most commercial space systems from the U.S. Munitions List, the analysis of the export control requirements applicable to new technologies is often more complex than ever and compliance risks remain significant (with civil penalties imposed on a strict liability basis and both domestic and non-U.S. companies being targeted for enforcement). Because the control lists regularly lag behind innovation, it is often difficult to determine how new technologies are, or will be, classified for export control purposes. For those reasons, it is critical for companies to begin to assess the export control requirements applicable to their innovative technologies as early as possible in the research and development process.

The first step in assessing applicable export control requirements is making the export control "jurisdiction" determination, which is the process of assessing whether the new technology is subject to the export control jurisdiction of the State Department under International Traffic in Arms Regulations (ITAR) or the Department of Commerce under the less restrictive Export Administration Regulations (EAR). To the extent that the company is unable to reach a clear conclusion on its own, it can request a formal Commodity Jurisdiction (CJ) determination from the State Department. Receipt of a favorable CJ determination confirming that the new technology is not subject to ITAR may favorably impact the ease of execution on the business model.

The next step in the process is to determine the export classification of the technology by reviewing relevant entries on the applicable control list (either ITAR's U.S. Munitions List or EAR's Commerce Control List). For technologies subject to EAR, the classification of the technology determines the extent to which export licenses will be required, which can vary significantly.

It is also extremely important to note that even when a particular technology is determined not to be controlled under ITAR, the provision of technical services to military or intelligence customers outside the United States may still be controlled as a defense service under ITAR. Accordingly, contemplated transactions with foreign military and intelligence customers must be reviewed carefully to assess applicable export control restrictions.

How to navigate the international regulatory process

Given the global nature of satellite systems, operators must understand not only U.S. domestic regulations but also the complex regulations of the International Telecommunication Union (ITU) and the rules of non-U.S. jurisdictions in which they intend to have ground stations or otherwise operate. Moreover, administrations are becoming increasingly more competitive in courting prospective satellite operators, with various offerings based on their welcoming, supportive, tax beneficial, politically and economically stable, and other jurisdictional benefits. Examples include the Isle of Man and Luxembourg that have become home to multiple satellite operators (including those with forward looking plans, such as asteroid mining). Operators with geographic flexibility may want to consider, as part of a pre-licensing process, administrations interested in hosting their operations.

How will data protection and privacy issues apply to the new technologies?

New technologies make the ability to see and "listen" to information, data, and people commercially available, in a way previously unavailable except to government intelligence entities. These new technologies can raise novel legal questions of first impression. The current patchwork of laws in the United States and abroad makes it difficult for companies to address data protection and privacy concerns in managing and transmitting data across borders. Satellite companies operating globally will need to keep an eye on these international developments as laws and regulations evolve to keep pace with these new technologies.

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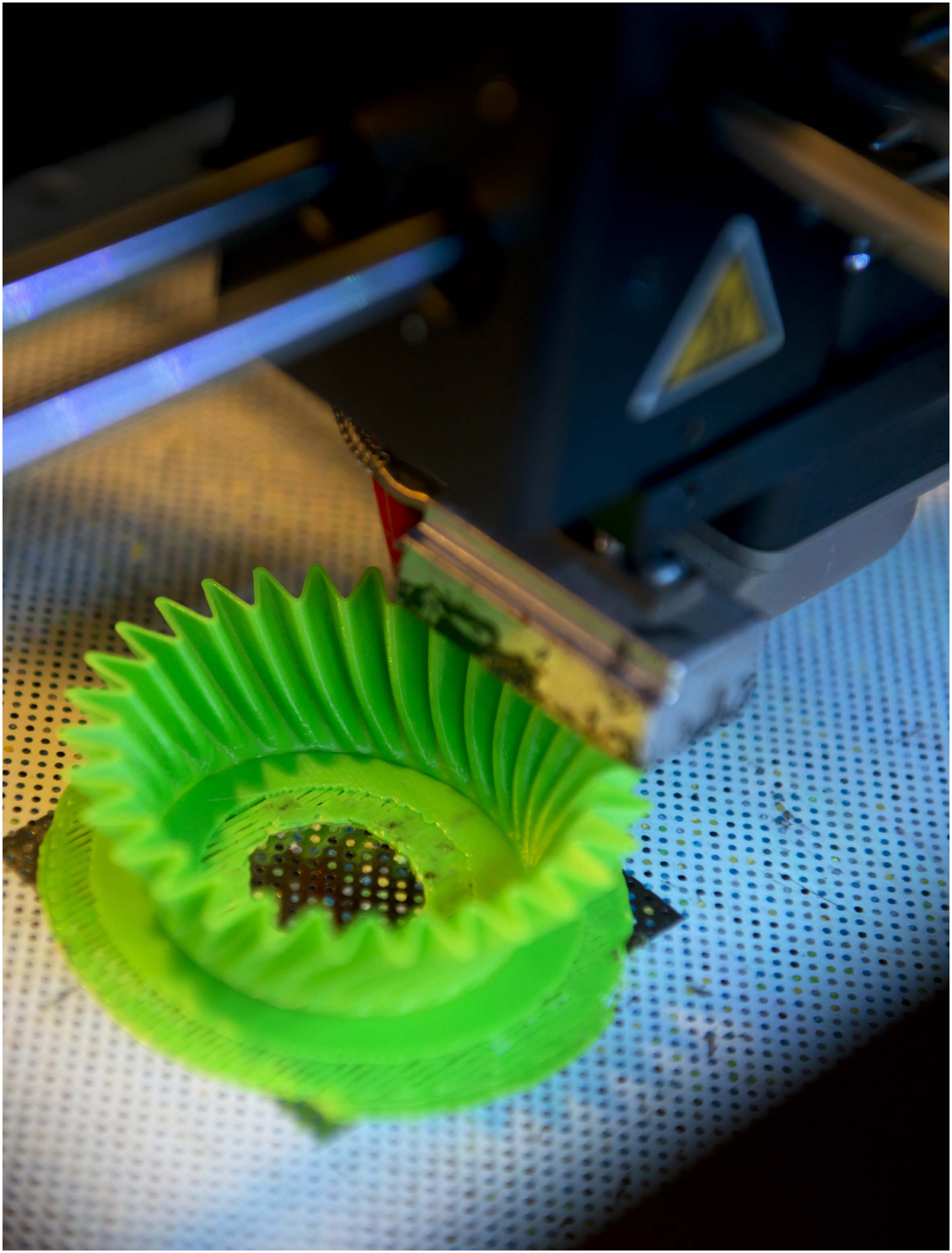


One case study: Legal issues surrounding asteroid mining

In addition to the perennial questions related to global operations for global satellite systems, new issues have arisen as to how to assert and protect rights in outer space. For example, how are rights secured for asteroid mining? Numerous international agreements exist regarding the correlative rights of nations in space, but there are few answers as to how an entity might acquire property rights to an asteroid.

The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (the Outer Space Treaty) may provide some guidance to companies engaged in space activities. But whether the Outer Space Treaty allows private ownership of asteroids or asteroid rights remains an open question. In part due to lobbying efforts by entities seeking clear asteroid mining rights, Congress introduced the Spurring Private Aerospace Competitiveness and Entrepreneurship Act of 2015 (the SPACE Act) to provide private parties property rights in asteroids. However, whether the Outer Space Treaty – particularly its prohibitions on national appropriation and its dedication to the interests of all mankind – forbids private ownership in spite of the SPACE Act has yet to be tested. In fact, U.S. agencies, prior to the enactment of the SPACE Act, have taken the position that ownership of asteroids is precluded by existing law, including the Outer Space Treaty.

If asteroids are susceptible to ownership, the SPACE Act will still require further development to determine exactly how an entity acquires rights of possession and ownership in an asteroid. The SPACE Act provides a right of ownership to an "asteroid resource[…]obtained" by an entity, suggesting that ownership is similar to the rule of capture in the oil industry, where a company acquires an interest in a resource by expending the effort to capture that resource. Future multinational cooperation and commercial custom may ultimately dictate exactly how one gains ownership over asteroid resources.

NewSpace companies bold enough to look to space for mineral resources face significant regulatory uncertainty. The Outer Space Treaty, an international treaty ratified by over one hundred countries, and the SPACE Act, an independent U.S. effort to allow for commercialization of asteroids, represent two competing policy objectives; international efforts have thus far sought to engage in cooperative development for the interest of all nations (in the face of certain nations seeking to recognize private rights to asteroid resources). Other international efforts to regulate international commons, such as the United Nations Convention on the Law of the Sea (UNCLOS) may prove informative as asteroid entrepreneurs attempt to anticipate regulation and potential conflict. Multinational efforts to regulate asteroid resources appear likely as the technology for mineral extraction in space moves forward.

NewSpace technology and greater knowledge of asteroids may also spur cooperative industry and intergovernmental efforts, much like the ITU. The ITU, an international cooperation between member states and private and public sector entities developed from a cooperative telegraph union into a specialized agency of the U.N., is now responsible for providing technical standards and coordinating satellite orbits, among other responsibilities. Such cooperative efforts may provide a potential roadmap for public-private coordinated development of asteroid resources.

As sovereigns such as Luxembourg push to be at the forefront of private asteroid mining and as international cooperation and development continues to influence regulation of asteroids, those seeking to engage in asteroid mining activities should be familiar with the array of regulations that may pose challenges to asteroid property rights. Given the upfront cost and inherent risk of engaging in asteroid mining, entities must be well-positioned to understand the regulatory risks presented by asteroid mining (including the potential for evolving standards and cooperative efforts), and must have sound strategies in place to secure asteroid rights.

Contracts + innovation = Build a contract from the ground up, think through the regulatory "what ifs," and allocate the risk of the unexpected

Start with the basic premise that, for contracts involving disruptive technologies in space, you will not achieve a good result by using a boilerplate contract for the main terms and conditions. The contract for a new business model involving disruptive technologies must also be built from the ground up, with a clean sheet of paper architecting the end-to-end system and service expectations, including technology development, technical capabilities, customer experience, financial model, budgeting and handling cost increases, regulatory hurdles and changes, and termination strategy, to name a few. Care must be taken to consider:

— How do I think this new system will operate?

— What flexibility do I need (or can I provide)?

— How do I provide for the unknowns and possible risks?

Most of the boilerplate language that forms a significant part of many standard contracts can be shifted to the back of the document.

Next, you must consider what goes on the clean sheet of paper, as it forms the essence of the business arrangement between or among the parties. We have divided this analysis into three parts, which reflect three different goals in the contracting process:

— First, develop a contract that contains the necessary terms and reflects the company's strategy to obtain what it needs.

— Second, anticipate third-party events that need to be factored in, dealing with the changing regulatory landscape for the new technology and providing for its effects on the parties' deal.

— Third, allocate risks between the parties, as is the case in every contract, but in the case of innovative technologies will likely involve additional twists and turns as the parties try to allocate the risks of the unknown and provide for exit strategies if matters do not develop as anticipated.

It will vary based on the particular business plan, the nature of the contracting parties, the specific business plan risks, relative leverage, and many other factors.

But one common theme is critical to all cases: taking the time to carefully consider a full range of outcomes and possibilities while structuring your contract. Even terms of early stage contracts can have long-lasting impacts on business flexibility, market positioning, and customer commitments. Therefore, getting it "right" from the start is imperative.

Filling up the clean sheet of paper: Design a contractual set of terms that best suits your new technology and business model

Inventory the knowns and unknowns of the technology

Whether you are preparing technology development contracts, financing or teaming arrangements, customer contracts, or other commercial arrangements, first consider the technology knowns and unknowns at the contracting stage. More often than not, the technology that exists today will not be the technology that supports your eventual products and services. The key element in your contractual roadmap may be the ability to identify the functionality that will be needed and where it will come from. The understanding of this roadmap will also help you develop the contractual means by which you can obtain sufficient flexibility to change course based on technology, regulatory, and other developments.

Design an acquisition strategy

The acquisition strategy may be thought of as answers to a series of questions, including how to acquire the relevant rights for what exists today, how to acquire rights to the next stage of the technology (to the extent it is developed by the counterparty), how to price these acquisitions, and how much control and exclusivity is desired. The contractual means by which you can obtain sufficient flexibility to change course are based on technology, regulatory, and other developments.

There are contract forms for acquiring current and future technologies, including an investment or purchase agreement, a technology development agreement, and a commercial license arrangement, amongst others. The one to choose may depend as much on the technology being acquired as other factors, such as the benefits and risks and the potential partnership opportunities presented. With each new technology comes a different business model.

Technologies as diverse as asteroid mining, 3D printing, and data analytics, for example, could require a different approach based on a different business model, different sets of potential customers, differences in the length and type of commitments, dependencies on third-party suppliers, and varying business opportunities to drive the market. In each case you need to consider the business model for implementation and how to interface with suppliers, financing, customers, and other parties.

The approaches for acquisition of future technologies may be the most complex part (as either buyer or seller). Satellite industry innovation is happening at a rate that has never before been seen in the industry, and new innovative technologies can very quickly render existing platforms obsolete (or uneconomic). The pace of innovation may have a negative impact on the willingness of customers to commit to large contract investments (commitments) that may become overpriced or obsolete, unless mechanisms are employed to mitigate this risk.

There are some standard mechanisms that can be included in any technology development agreement to account for possible changes to the obligations of the parties, such as a directed changes clause, where changes can be directed within the general scope of the contract. With a licensing agreement this is more difficult, since the license may only cover the current version. It may be important to have rights to acquire subsequent versions, and the right to create derivative works is often a hotly negotiated point.

In some cases, exclusivities, rights of first refusal (ROFRs), and most favored nations (MFN) provisions may be necessary to deal with future technologies and to secure important commitments and/or industry support. In other cases, or in connection with different types of counterparties, those provisions may not be necessary and may put business success at risk.

Always consider, even in cases of exclusivities, ROFRs, or MFNs to carefully limit the scope, time frame, and market segments to which these restrictive provisions apply, to ensure that if the anticipated market benefits are not achieved or delivered by the counterparty, the provisions may be terminated to allow other avenues of business success.

Consideration must be given to pricing models in the midst of technology cost, capacity, market, service, and other unknowns. For development contracts there can be an equitable adjustment to the price, schedule, or other terms. In the commercial licensing arrangement, we have found the standard modest discount on future versions not to be particularly helpful for the buyer/licensee. We have had better result for buyers with an amortization approach: being able to exchange the prior technology for newer versions and obtaining a credit toward the new version based on an amortization schedule for the prior version.

In cases where most of the technology development is expected to happen years down the road, a joint venture or partnership arrangement may be a sturdier vehicle for handling the level of uncertainty. If there is a significant change of operation, business purpose, or cost based on modifications to the law, rather than having economic adjustment provisions to accommodate the legal changes, the parties could employ various rules of governance to alter the business model.

Of course, as with any governance provisions, there are issues about the required level of support, including level of approval (majority, supermajority, or unanimous) and capital contributions to be made by the parties. Again, a combination of decision mechanisms with off-ramps (dissolution provisions, buy-sells, or limits on overall liability) to protect the parties against situations too far from the envisioned business model may be the best alternative.

Creative acquisition arrangements may provide attractive alternatives to use of limited (and often expensive) financing and cash on hand. At the same time, care must be taken to consider whether the creative acquisition arrangements provide technology, intellectual property, customer, and/or other limitations on future diversification, growth, and flexibility that will maximize the business objectives and success in the future.

Maintain flexibility for change where possible

Maintenance of flexibility for change and different business directions should be considered and built into contracts wherever possible. However, we have seen a fair amount of resistance (even in the context of development agreements) to pricing options for future work, products, or services, or rights to shift to different approaches. Although it is a logical model for the party whose business is developing, and in many cases it is possible to mitigate the risks to the party doing the development, we have found few parties who prefer this approach. Also, cost is generally considered a sufficiently material term that certain sections of the agreement could be rendered non-binding if the costs are not readily determinable. Approaches to establishing cost in the future (such as using an industry expert) also have not been popular with either side, being viewed as too uncertain. Therefore, this portion of the contract can be challenging to implement, and creative thinking is at a premium.

There is no “one size fits all” approach, and only a careful consideration of your business situation, aligned with the legal and commercial toolkit of terms, will enable you to determine the likely optimal terms for your new technologies. In all cases, the ability to foresee the future will be imperfect, but careful planning and strategic thinking will help improve the clarity and certainty of reaching the best solution.

Dealing with the changing regulatory landscape

Regulatory conditions precedent or subsequent to having a transaction

Consideration should be given as to timing of the transaction in the face of regulatory uncertainty. Should a transaction be conditioned on regulatory approvals, or should certain off-ramps apply in the event of delay or inability to obtain a desired level of approvals. Consideration should also be given to determine if waiting for regulatory authorization or clarity is a critical conditions precedent to financing or commercialization of the new innovative application.

This may depend on the state of the law, and the risks involved in lack of clarity. For example, the determination of global jurisdictional issues surrounding asteroid mining rights may be key to accelerating investments in the industry. On the other hand, waiting for clarification may put participants behind the rest of the pack in gaining priority rights to new areas of innovation. The parties should consider if the risks presented may be addressed in an acceptable manner through conditions precedent or subsequent, including transactional termination or adjustment provisions relating to receipt of a regulatory authorization or obtaining needed regulatory changes.

Advocacy with regulatory bodies and dealing with unexpected decisions

For companies desiring to deploy innovative solutions, active participation in the process of seeking required authorizations or regulatory interpretations may be required. Contract parties, whether in M&A transactions, investments, joint ventures, or other transactions, are accustomed to contracting around risks that regulatory approvals will not be granted and allocating responsibilities for seeking approval.

Since the applicable regulatory process anticipated may be a lengthy one, specific provisions will be needed to address the roles of the parties in seeking the necessary authorizations and their rights to shape the applications for such authorizations.

This is particularly important where a denial of such an application may be preferred by one or more parties over the grant of an exemption that comes with high compliance costs, and thus obligates the parties to move forward but with different economics than originally anticipated. There are some provisions in the lawyer's bag of tools, such as provisions for payment of break-up fees if conditions attached to approvals are beyond described limits. Fashioning such contractual provisions to handle unknown regulatory risks can be critical for transactions in new areas of innovation, especially since the possible outcomes are not predictable and there is no body of precedent to look to for risk assessment guidance.

Allocating responsibilities for and costs of compliance with future laws

The regulatory landscape will evolve over time to support new innovations. Where the parties are prepared to put a temporary arrangement in place while awaiting broader regulatory action, there may be costs of compliance that exceed those that will apply when the regulations are fully developed. With new innovations, the required approvals and regulatory landscape are not as simple as compliance with other more established legal requirements. Regulatory checklists and time frames should be kept in mind. Ideally, regulatory obligations would be designated as an obligation of a specified party (or parties), failures would be conditions to performance by other parties, and/or costs to maintain regulatory compliance would be factored into the economics of the arrangements.

There is no one best answer as to what goes on the clean sheet of paper.

Allocating risks for technology failures, liability, and losses

Allocating known and unknown risks

With regulatory uncertainty (and the unknown time frame and costs to implement compliance), comes unknown impacts to the business case. The upside potential to innovation is virtually unlimited, but the possibility of increased costs, liabilities, and losses is also potentially significant. Clearly there is a potential advantage to being first, but there are also downside risks and costs. If large investments or commitments are at stake, careful consideration needs to be paid to how to ameliorate the downside risks, while at the same time gaining the advantage.

Particular attention must be paid to contractual provisions that envision the allocation of risk and outcomes to accommodate the timing, incremental costs, requirements, uncertainties, and limitations of technologies that are changing quickly. This includes specific provisions on risk and cost allocation, dealing with risks of significant delay or reduced functionality, and off-ramps of various kinds, including termination provisions.

To keep risks at manageable levels, the parties may need to implement adjustment mechanisms to maintain the basic economic deal. Where it is difficult to accurately assess the business risk presented, there may need to be a series of risk allocation and adjustment provisions, coupled with termination rights, buy-sells, or other off-ramps to cap maximum exposure.

Thinking these issues through is critical, and it may be to your advantage to seek agreement at the onset to set cost and liabilities expectations, rather than leaving the implications of changes to later negotiations. All reasonable scenarios should be contemplated when drafting agreements to ensure that all compliance, approval, cost, indemnification, termination, insurance, and financing provisions support the desired business outcome.

Indemnification and other remedies

Once there is agreement on the allocation of liabilities and risks, the parties need to support that agreement with appropriate indemnification provisions. These clauses, often considered boilerplate in more routine arrangements, may take on greater importance because there are so many uncertainties with respect to which indemnification provisions may be called upon to address risk allocations. It is also vital to build into the transaction the remedies that result in the most equitable outcomes, since standard contract remedies may not match to all the parties' exposures and potential benefits. If the transaction counterparty is a start-up or under-funded entity, tailored contractual protections may be needed since indemnity provisions prove to be of little practical benefit.

Schedule for determining if there is a deal

Many innovative projects will be time-and sweat equity-dependent. Parties entering into a commercial transaction are often willing to invest a substantial amount of time, recognizing that a solution provided by innovative technology requires this type of commitment, but still need some way to exit if the arrangement is not working. Parties should consider having firm backstops to the development or implementation timeline, and consider the remedies if that timeline is not met.

Government and strategic interest + innovation = New opportunities for partnership

What private/public partnerships will develop in NewSpace, and how to anticipate and take advantage of them

U.S. government interest in commercial platforms is higher than ever, given the new opportunities presented by these innovative systems as well as the potential cost savings. For example, rapidly refreshing geo-imaging systems will support the ability to observe floods, forest fires, refugee crises, war zones, and other hotspots with improved accuracy and timeliness. Improved earth observation and imaging significantly increase our ability to predict the weather. Operators are implementing space-based aircraft tracking to complement the FAA's ongoing Automatic Dependent Surveillance-Broadcast (ADS-B) program. All of these new technologies become significantly more useful with advances in data analytics and artificial intelligence.

The government is trying to nurture these new technologies with a combination of ceding the field to commercial players, and entering into development contracts under which companies are paid to reach the next technological level, even if the commercial application is not entirely clear. As a result, there are new opportunities and complexities surrounding the receipt of new licenses to pursue the next generation of innovations – innovations the government would have pursued, but has decided to leave to the private sector.

A key example is weather data. NOAA is pursuing a combination of partial replacement of aging satellites, new licenses for private companies to launch and operate weather prediction systems, and contracting with these companies to use the weather data gathered through their earth observation satellites.

Other examples include new contracts entered into by NASA and DARPA (the U.S. Defense Advanced Research Projects Agency) to develop new launch vehicles. These programs have a number of complexities and requirements designed to ensure forward progress by the lucky awardees. However, with the recent example of Firefly, NASA has shown that it will allow private companies with such contracts to fail if they cannot maintain course.

Many new companies have inherited technologies developed by the U.S. government through the prior generation, but which are now being given to the private sector for further development. This is often done by license. These new companies can benefit from legal advice and business guidance in how broad a license to seek, as well as maintaining a good relationship with the issuing agency in order to clarify the licensing scope issues that inevitably will arise.

Sometimes there is controversy over the government's approach. For example, DARPA has been funding preliminary work by one satellite manufacturer to service satellites in GEO, while NASA has a separate program for LEO. Issues have been raised with this approach as DARPA's funding of a government program in direct competition with a commercial venture is not consistent with U.S. national space policy against the government competing with the private sector.

Funding the start-up phase

Complex issues arise for investors supporting companies with untested commercial technologies, particularly with uncertain and shifting regulatory hurdles. These investors may seek to add additional layers of contingencies to funding innovative-related programs, such as terms and conditions with time frames for development, delivery, and implementation. Investors' requests need to be carefully considered and addressed early in the process to limit surprises or delays and to leave enough room for the inevitable changes that occur as the technologies evolve.

Partnering with "Old Space" companies

The innovative developments are attracting strong interest from strategic investors, and opportunities are arising for creative teaming arrangements as an accelerant to growth. See our recent article *Creative teaming arrangements to jump-start early-stage companies*.

A deeper dive into specific areas of new innovation

Big data analytics

Big data may be a new buzzword, but the concept of turning large data sets into useful information is nothing new. What has changed is the dramatic increase in processing power, as well as the unfathomable expansion of the sources of data. Space is a major source of increasingly bigger data sets for both civilian and military use. Especially with the emergence of small satellite constellations, the future looks bright for space-generated data. However, this will come with its own technical challenges, especially relating to timely access to the data from Earth, where big data analytics currently are processed. Can data throughput keep up? Will we be doing more big data analytics in space, so that we only need to transmit the results, saving on data transfer overhead? Will there be a constellation similar to Amazon Web Services that provides such analytics services to satellite owners? What are the technical, practical, regulatory, and legal implications?

3D robotics and artificial intelligence

Our everyday lives and businesses are being transformed through the use and implementation of robotics and artificial intelligence (AI) as a way of increasing efficiencies and reducing costs. Bringing technology to regular business functions - such as manufacturing, delivery of goods, inspections, and transport - helps streamline our ability to be more productive. Even at home, robotic and AI technologies are being developed to provide home care to seniors, manage heating and cooling systems, clean homes, and fold laundry. While we continue to see advances in robotics and AI in everyday use, space discovery has long used these technologies to automate and implement many functions for exploration that otherwise could not be achieved. Many years ago, the robotic Mars Rover was developed to reach areas of the universe not fit for human travel. Much continued effort is focused on roboticizing many other areas to develop broader capabilities in space exploration. We have seen the penetration of AI-enabled uses increase exponentially over the past few years, further enabled by the advanced integration of software in the real world.

This in turn has led to continued growth in investment and application of robotics and AI in NewSpace. Given the vastness of space, AI will help astronauts (and robots) make quick decisions, and provide opportunities for tremendous cost savings and streamlined use of resources. Robotics and AI also provide significant new business cases for space-based satellite recovery, analysis, and repair efforts that otherwise would not be possible.

Spectrum and spectrum alternatives

Spectrum is the bedrock resource for all satellite operations. As more operators seek to enter the industry, spectrum will become more scarce and operators will face challenges in negotiating coordination agreements. Satellites also increasingly compete with terrestrial services for the use of spectrum.

As an alternative to spectrum, some entities are testing and designing systems with optical/laser communications. This offers many potential benefits, including decreased spacecraft cost and mass, power savings, increased mission life, and potentially fewer interference issues. Such communications systems would also offer much higher bandwidth capability, which is ideal for data hungry applications and technologies. Equally important, optical communications are currently unregulated, so operators are unconstrained by regulatory allocations or other spectrum limitations. However, regulatory agencies may be rethinking this status in the face of this rapidly advancing technology. Prospective operators should be mindful of this potential shift.

Geolocation, earth observation, and remote sensing

NewSpace technologies, especially smallsats, are transforming the way we view and monitor the Earth. Already, smallsat systems are capable of imaging the Earth on a daily basis. New operators are proposing to deploy systems that will significantly increase imaging capabilities. Other smallsat operators are using radio occultation technology to predict weather and offer a lost-cost alternative to expensive government-funded weather satellites. Still other smallsat operators are improving geo-location services with innovative space-based applications for AIS (automatic identification system) and ADS-B signals. Public and private sector entities alike are already exploring the possibilities for leveraging all these capabilities.

Satellite refueling and mission extension services

NewSpace technologies include services intended to prolong the useful life of assets in orbit. A number of companies have proposed, and are building, spacecraft designed to dock with an in-orbit satellite and assume maneuvering responsibilities or provide refueling services. Such new capabilities offer opportunities for satellite operators to prolong and protect revenues of existing space assets, and provide greater flexibility in managing in-orbit fleets.

Launch innovations: Reusable and multiple-payload launches

Motivated by the significant developments in both traditional and NewSpace, launch operators are exploring new models for launch logistics. Today, spaceflight service companies can loft over 100 spacecraft on a single rocket, expediting satellite deployment and delivering cost savings to operators. Other providers are offering opportunities for sharing and reusability through split and customized payloads, access to orbital slots, delivery in-orbit, and shared architecture. Operators seeking launch solutions now face the challenge of choosing the best offering/model for their unique technology, constellation, and timeline.

High throughput satellites

Both traditional and new satellite operators are deploying, or hope to deploy, high throughput satellites all over the globe that support high-speed broadband access. These systems have the potential to bridge the digital divide by providing broadband service where it is not physically and/or financially feasible to deploy terrestrial systems. New satellite operators are contemplating deploying innovative LEO systems, comprised of thousands of satellites. How these systems will complement, or compete with, existing satellite systems, and what marketplace changes to expect, will be issues to watch going forward.

On-orbit manufacturing

NASA and commercial companies continue to invest in space-based 3D printing, or "on-orbit manufacturing." The benefits of on-orbit manufacturing could be significant. Engineers could design satellites, for example, without the need to withstand the Earth's gravity or to accommodate the environmental pressures of launch. Because satellites manufactured on-orbit would not need to be launched inside a space faring, they could be several times larger than what is possible today.

NASA uses a number of methods to support commercial entities' research into on-orbit manufacturing. One such method is public-private partnerships, such as the Tipping Point program, through which NASA partners with private businesses to develop a range of promising new technologies and to qualify them for market. Public information for one Tipping Point participant indicates the company received a two-year contract and US$20 million in funding. NASA also continues to directly support research conducted by small businesses, including start-ups, through its Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. A company that successfully completes each phase of the SBIR/STTR program could receive US$875,000 over a 30-36 month period.

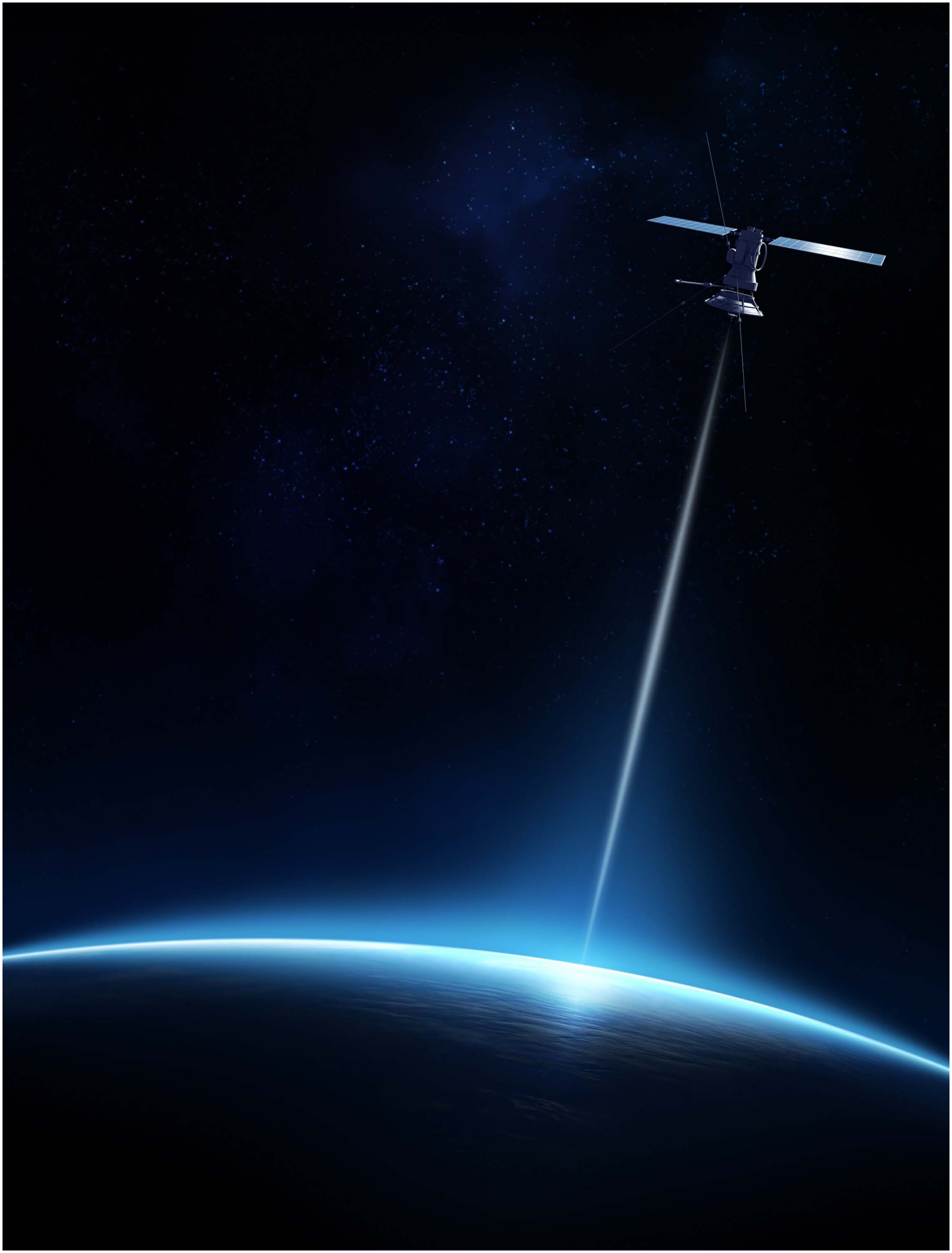
Asteroid mining

The world's population is growing steadily, and as a result there is an ever increasing demand for mineral resources. In addition to meeting basic human needs, these minerals are used to improve the quality of life for the world's inhabitants. There are, for example, more cell phones than people in the world. Nonetheless, mining projects are often controversial, and mining companies must navigate a complex series of laws, regulations, financial requirements, and social and political hurdles to start a mine. Asteroid mining might be able to serve humanity's need for minerals, while bypassing some of these issues.

Asteroids may contain rich deposits of important resources such as platinum, iron, and nickel. Others may store great amounts of water, methane, and volatile compounds that can provide fuel and resources for life support systems for passing space vessels. See the discussion of the mineral potential of asteroids at asterank.com.

Experts differ on when the technology to make asteroid mining feasible will be commercially available. Spacecraft have already successfully orbited and landed on asteroids. One craft even demonstrated the ability to land on an asteroid and return sample particles to earth (though that vessel overcame extreme challenges and only just managed to extract samples from the asteroid). Other spacecraft are currently en route to explore and sample other asteroids and return minerals to Earth. More ambitious proposals to sample asteroids for scientific study, including one involving a plan to redirect an asteroid in orbit around the moon, are also being formulated. While the technical challenge is currently being met, the ability to exploit the mineral potential of asteroid resources on a commercially profitable basis could still be decades away.

The law often lags behind technology, but not for space mining, and not in Luxembourg. On 14 July 2017, Luxembourg enacted the first law in the European Union for the exploration and use of space resources. The law allows a company organized and administered in Luxembourg to secure an authorization from the Luxembourg ministers of economy and space activities for a resource development mission in space. The requirements for this authorization are fairly general – the operator will need to present a "robust scheme" for its operation, including demonstrating financial, technical and statutory capabilities. The operator can then pursue it mission, subject to the payment of a fee, submitting to auditing, and a risk assessment. With the advent of this legal structure, Luxembourg has positioned itself to be the preferred corporate venue for companies seeking to develop resources in space.



Conclusions

We are working in an era where disruptive technologies are changing the way we do business, as well as how we live and work, with continual changes to the business, legal, regulatory, and strategic landscape. This is nowhere more the case than in the global space industry. While much of this requires starting with a clean sheet of paper for preparing your commercial agreements, there are many precedents on which to draw from the introduction of prior technologies. It is critical to consider the "what ifs" and the art of the possible in structuring commercial arrangements of all kinds in these new space ventures.

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