

**CENTER FOR SPACE
POLICY AND STRATEGY**

APRIL 2019

***WHAT BREXIT MEANS
FOR UK SPACE LEADERSHIP***

**ROBERT S. WILSON AND GINA D. GALASSO
THE AEROSPACE CORPORATION**



ROBERT S. WILSON

Robert Samuel Wilson is a policy analyst in the Center for Space Policy and Strategy. His research covers nuclear and space policy issues, including nuclear command and control, orbital debris mitigation, and space traffic management. Prior to coming to The Aerospace Corporation, he served as a senior defense analyst at the Government Accountability Office, where he focused on nuclear force structure; nuclear command, control, and communications; alliance relationships; and arms control issues. Wilson received his bachelor's degree from the University of Virginia in political theory and his master's degree from the University of Virginia's Batten School in public policy.

GINA D. GALASSO

Gina Galasso serves as the managing director of Vaeros Ltd, The Aerospace Corporation's subsidiary in the UK. She also leads Aerospace's international strategy, bringing the corporate expertise from Department of Defense and civil space programs to the United Nations, intergovernmental organizations, and national governments worldwide. Her past work with the National Oceanic and Atmospheric Administration's (NOAA) Envoy to EUMETSAT gave her valuable experience with the European space community.

ABOUT THE CENTER FOR SPACE POLICY AND STRATEGY

The Center for Space Policy and Strategy is dedicated to shaping the future by providing nonpartisan research and strategic analysis to decisionmakers. The Center is part of The Aerospace Corporation, a nonprofit organization that advises the government on complex space enterprise and systems engineering problems.

The views expressed in this publication are solely those of the author(s), and do not necessarily reflect those of The Aerospace Corporation, its management, or its customers.

Contact us at www.aerospace.org/policy or policy@aero.org



Summary

In the wake of Brexit, UK leadership will face important decisions, including which capabilities to invest in, how much to participate in international space projects, what the role should be for the UK Space Agency, and how much integration should exist between the civil and defense space efforts. Brexit could lead to the United Kingdom ending its participation in EU-funded international space programs, including the global navigation satellite system Galileo (the European Union equivalent to GPS), and pursuing its own global navigation satellites. The potential withdrawal from Galileo and pursuit of an expensive navigation satellite system suggests the UK Space Agency—responsible for strategic decisions on the UK civil space program—may be shifting its focus from investing in international space projects to acquiring national space capabilities. This decision will not just affect where and how much it spends on space but also the fundamental role of British space governance.

Introduction

On June 23, 2016, 51.9 percent of UK voters chose to withdraw from the European Union. Among its implications for society and industry, Brexit will pose sobering options for the growing British space sector. Policymakers face consequential decisions, including which capabilities to invest in, how much to participate in international space projects, what the role should be for the UK Space Agency, and how much integration should exist between the civil and defense space efforts.

Brexit could lead to the United Kingdom no longer participating in EU-funded international space programs, including the global navigation satellite

system Galileo, which the British have been involved in since the program's inception. In turn, the government announced in August 2018 that it was committing £92 million (\$116.90 million) to assess options for pursuing its own global navigation satellite system [1,2].* Its interest in its own navigation satellites suggests that the United Kingdom could be shifting its focus from investing in international projects to buying expensive national capabilities, raising questions about which space systems the United Kingdom should acquire and how much it can afford. This comes at a time of other space-related developments, including the planned release of the nation's defense space

*The UK government has the formal title, "Her Majesty's Government." This paper uses the terms United Kingdom and Britain interchangeably, with no offense intended to Northern Irish subjects. For the conversion of pounds to dollars throughout this paper, we used the average exchange rate from the Department of Treasury on December 31, 2018, of \$1 to £0.787.

strategy this year and pending decisions about the next generation of British-owned military communications satellites. The confluence of these policies and decisions will present British space leadership with important challenges and opportunities.

From January through March 2019, we met with experts on the UK space sector to discuss options available to its space leadership in the wake of Brexit. These experts included current and former officials in the British government—specifically, the UK Space Agency, Ministry of Defense, and Department of International Trade—plus the British space industry, academia, think tanks, the European Union, the European Space Agency, and the U.S. government.

UK Current Participation in International Space Projects

European Space Agency and EU Space Projects

The UK space sector for 2016/2017 generated £14.8 billion (\$18.81 billion) in income, accounted for 5.1 percent of the global space economy, and employed 40,000 people [3].[†] The nation's government and industry set the goal to grow the United Kingdom's global share of the space market to 10 percent by 2030 [4]. Among the sector's highlights—according to a May 2018 trade organization report—are that 40 percent of all small satellites in orbit at that time were British built [5]. The UK Space Agency, a lean organization of about 200 people, oversees the civilian space sector. Begun in 2011, the agency published the United Kingdom's first-ever National Space Policy in December 2015 [6,7]. Experts we met with characterized the agency's primary roles as writing regulations, attracting private investment,

and leveraging international partners, including the European Space Agency, which—from 2013/2014 to 2017/2018—received more than 80 percent of the UK Space Agency's budget [8-12].

The European Space Agency has a 2019 budget of about €5.72 billion (\$6.56 billion), the bulk of which comes from its member states, either in mandatory or optional contributions [13].[‡] The member states provide mandatory contributions based on their gross national product and may provide optional contributions to various programs. The mandatory contributions support foundational space science and research; the optional programs cover Earth science, navigation, human space flight, exploration, telecommunications, and space transportation.

Outside of the contributions from the member states, the agency also receives money for specific programs, including from the European Union. Most of this money supports the European flagship initiatives Copernicus—an Earth observation satellite program—and Galileo and its augmentation system, the European Geostationary Navigation Overlay Service [14]. The European Union funds and owns the programs and its executive arm—the European Commission—manages and oversees their implementation. The European Space Agency is responsible for implementing the programs, including their design, development, and procurement. As a member of the European Union and the European Space Agency, the United Kingdom has helped fund these programs and British companies have been involved in their development, including the delivery of satellite components for Galileo and its augmentation system [15].

[†]The UK financial year lasts from April through March; therefore, 2016/2017 reflects April 1, 2016 through March 31, 2017.

[‡]Of the European Space Agency's 2019 budget, about 22 percent comes from the European Union. For the conversion of euros to dollars throughout this paper, we used the average exchange rate from the Department of Treasury on December 31, 2018, of \$1 to €0.872.

For 2021 through 2027, the European Commission also proposed to allocate €500 million (\$573.39 million) to security-related satellite programs [16]. These include secure communications for the public sector and surveillance and tracking of space objects. The United Kingdom has participated in these initiatives [17,18].

Statements from officials and government reports indicate that the United Kingdom will continue to be a member of the European Space Agency.[§] The government department responsible for leaving the Union issued a report in September 2017 that states, “The UK was a founding member of the [European Space Agency] and European collaboration on space has been an important enabler of innovation and technological development in the UK space sector. The UK will continue to play an active role in the [European Space Agency] after it leaves the EU” [19]. Officials from the European Space Agency have also maintained that Britain will remain a member. Said Jan Woerner, its director general, at a press event in January 2019, “We have a clear commitment from the UK to remain [a European Space Agency] member state” [20].

What is less clear is Britain’s continued participation in the European Space Agency’s EU-funded programs. In September 2018, the government issued guidance titled, “Satellite and space programmes if there’s no Brexit deal” [21]. It covered Copernicus, Galileo and its augmentation system, and the space surveillance and tracking program. For each of these programs, the guidance said that without a negotiated agreement, UK-based

companies will be unable to bid for future funding tendered by the European Union and that the government will no longer play any part in their development.

If this were to happen, the United Kingdom would be cut out from a growing share of European space investment. In 2017, the European Commission delegated €1.33 billion (\$1.53 billion) to the European Space Agency for Galileo, its augmentation system, and Copernicus; from 2016 to 2017, the EU-funded programs represented the biggest increase in the European Space Agency’s budget [22]. It and the European Union have also committed to strengthening their relationship: in December 2016, the European Space Agency and the European Commission signed a joint statement on their shared vision and goals for Europe in space, emphasizing their intention to reinforce their cooperation in the future [23]. The European Commission issued a press release in June 2018 that said the European Space Agency will remain a major partner in the technical and operational implementation of the EU space programs [24]. The two organizations also share many of the same member states, as shown in Figure 1 [25-27].**

Galileo and its Public Regulated Service

Much of the debate over the United Kingdom and EU-funded programs centers on Galileo, which culminated in the government’s announcement that it was seeking its own navigation system. Figure 2 shows some of the important events from May through September 2018 in their negotiations.

[§]Agreements over tariffs and freedom of movement, among other issues, could affect the United Kingdom’s relationship with the European Space Agency.

**Related to international space projects, the UK Department for Business, Energy and Industrial Strategy’s Global Challenges Research Fund also pays for the “International Partnership Programme,” a five-year, £152 million (\$195 million) program designed to partner UK space sector expertise with governments and organizations in emerging and developing economies around the world to deliver a sustainable economic or societal benefit.

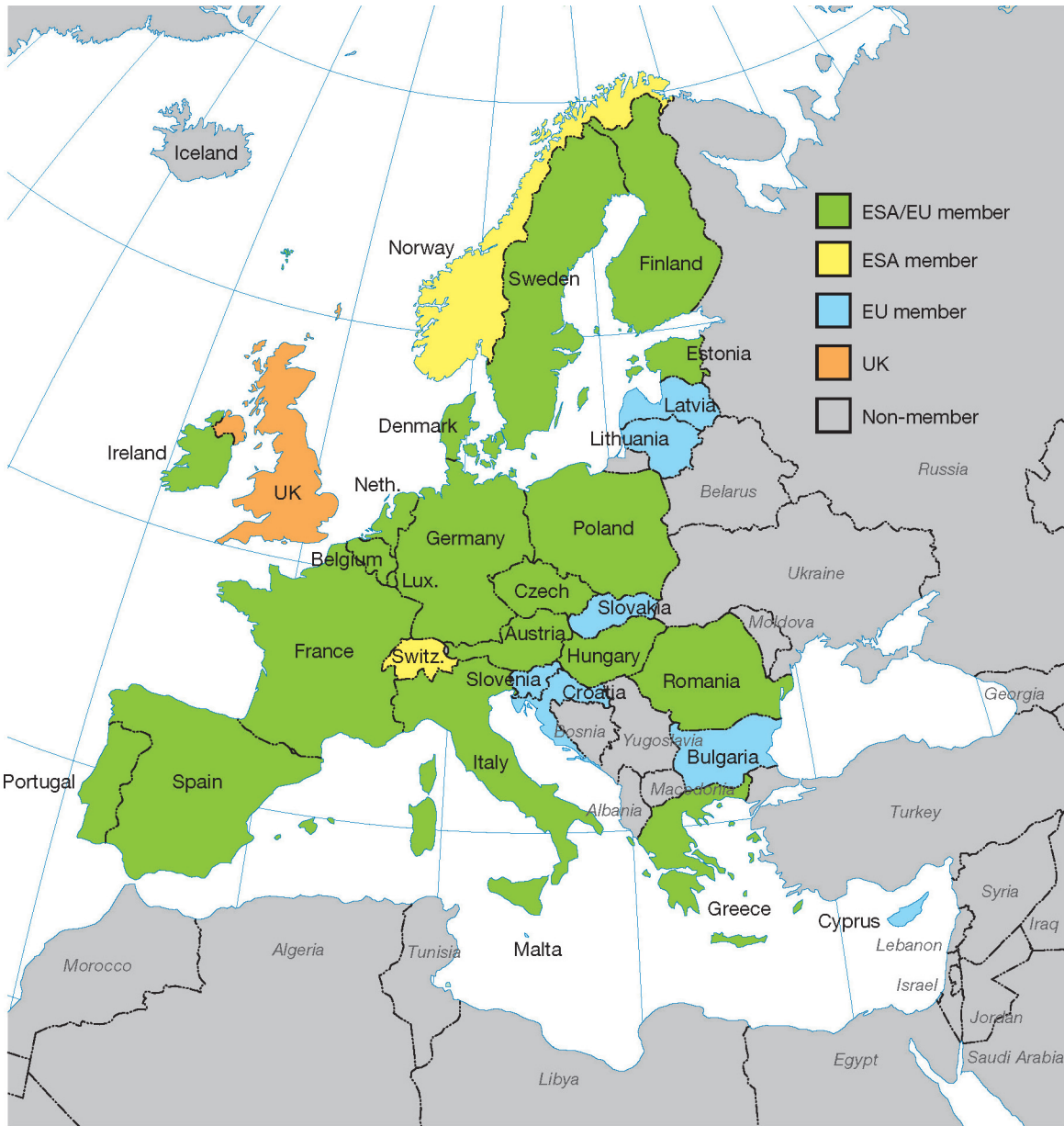


Figure 1. European Union and European Space Agency (ESA) shared member states.

According to the European Commission, Galileo—which began in 1999—will provide global positioning services for citizens, industry, and government users [28, 29].^{††} Galileo will include

two services: encrypted navigation signals called the Public Regulated Service for government authorized users and an open and commercial service. The encrypted service will include anti-

^{††}According to the European Commission, Galileo is expected to be fully operational by 2020.

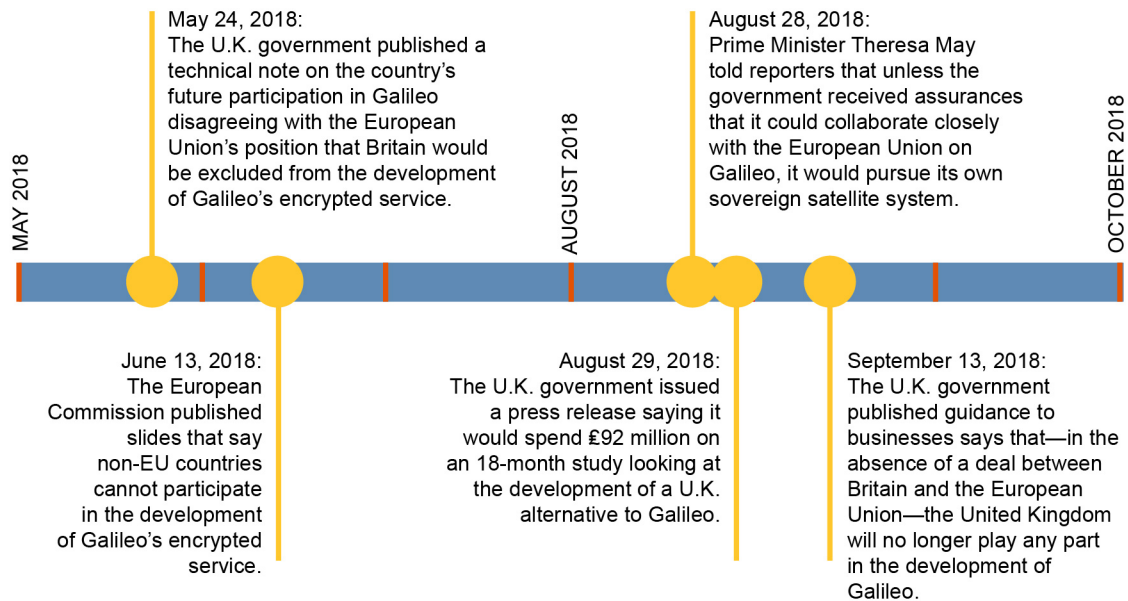


Figure 2. Timeline of important events on EU-UK negotiations on Galileo from May through September 2018.

spoofing and anti-jamming capabilities, which will make the system's signals more difficult to disrupt. When fully developed, Galileo will comprise 30 satellites (24 operational and 6 spares); two control centers; and tracking and control, uplink, and sensor stations.

In addition to building components of the satellites and security systems for Galileo, Britain hosts two Galileo sensor stations [15]. The European Commission had also planned to locate a back-up control center in the United Kingdom; however, because of the Brexit decision, member states voted to relocate the back-up site to Spain because the European Union does not allow non-members to host or manufacture specific security elements of the program [15].

It is this issue of the United Kingdom's involvement in security components of Galileo that has become a pivotal dispute with the European Union. On May 14, 2018, the European Union's chief negotiator, Michel Barnier stated:

Third countries (and their companies) cannot participate in the development of sensitive security matters, such as the manufacturing of [Public Regulated Service]-security modules. Those rules were adopted together by unanimity with the UK as a member, and they have not changed. Those rules do not prevent the UK, as a third country, from using the encrypted signal of Galileo, provided that the relevant agreements between the EU and the UK are in place [30].

Ten days later, the UK government department responsible for leaving the Union published a technical note on its future role with Galileo, stating that its participation was “dependent on its ability to independently assure the integrity of the system so we can rely on it for strategic defence and security uses” [31]. The report lists three requirements: (1) access to the Public Regulated Service and its information, (2) industrial involvement in secure elements, and (3) attendance at security meetings.

An EU official told us that while the United Kingdom could make an agreement with the European Union to access the Public Regulated Service and its information, as a third country it is excluded from industrial involvement in secure elements and attendance at security meetings. In June 2018, the European Commission published a briefing on third-country involvement in EU space programs, including Galileo, which it compared with UK positions [32]. The briefing says that third countries cannot participate in security and Public Regulated Service-related development and third-country businesses cannot manufacture Public Regulated Service security modules.

Two months later, on August 28, 2018, Prime Minister Theresa May told reporters that unless the government received assurances that it could collaborate closely with the European Union on Galileo in the future, the government would “withdraw UK support from Galileo and pursue our own sovereign satellite system” [33]. The next day, the government announced plans to spend £92 million (\$116.90 million) to assess an alternative system to Galileo [34]. The money would fund an 18-month study that would look at the design and development of a British program, led by the UK Space Agency.

Development of a UK Navigation Satellite System

An independent global navigation satellite system may require 24–30 satellites in medium Earth orbit (the same orbit as GPS). Only 18 would be needed for global coverage but satellites experience outages—for example, they drift and need to be repositioned—and more satellites may be necessary for difficult or obscured terrain, such as dense urban environments where there is limited visibility to the sky. Our analysis shows that a system in medium Earth orbit should have 30 satellites for global coverage. Some examples of independent global navigation satellite systems include U.S. GPS (31 satellites in orbit in 2018), Russia’s GLONASS (22

in orbit in 2018), China’s BeiDou (25 in orbit, expected to increase to 35), and Europe’s Galileo system (22 in orbit in 2018) [35-41].

Instead of an independent global navigation satellite system, the United Kingdom could consider acquiring other navigation systems that require fewer satellites. Based on our analysis, an independent regional (non-global) navigation system would require about seven satellites in a higher altitude orbit (such as in geosynchronous or geostationary orbit), which could improve availability and precision for industry, including in transport, aviation, maritime, agriculture, surveying, and timing services. India’s NavIC, which is expected to consist of seven satellites in geosynchronous or geostationary orbit, is an example of an independent regional system.

Rather than an independent system, Britain could also develop a satellite capability that leverages GPS or other global navigation satellites. Similar to the independent systems, these options could offer more availability and higher precision. Galileo’s European Geostationary Navigation Overlay Service, with three satellites over Europe, is an example of such a system. Japan’s Quasi-Zenith Satellite System (four satellites) is another example.

If the United Kingdom pursues its own navigation satellites, the level of investment required could crowd out funding available for international projects. The cost would depend entirely on the option it selected; however, the August 2018 announcement specifies a “British global navigation satellite system” and an “independent satellite system,” which could require 30 satellites. For context, an official from the EU told us that through 2020, Galileo will have cost about €10.3 billion (\$11.81 billion). Given that the UK Space Agency’s annual expenditures in the 2017/2018 fiscal year were about £392.64 million (\$498.91 million)—more than 83 percent of which went to the European

Space Agency—30 navigation satellites would be a tremendous financial commitment [12].

Role of the UK Space Agency

The issue of whether Britain will acquire a navigation satellite system raises questions about the identity of the UK Space Agency. UK officials told us that the government and UK Space Agency will continue to create a business and regulatory framework that attracts private investment, with a focus on leveraging international and commercial partners. The UK Space Agency operates differently than NASA; the agency is more of an enabler, working on national and international space projects in cooperation with industry and academia.

However, the agency purchasing a national space capability that could cost many times more than its current annual budget would be a significant departure from this approach.** Will the agency remain primarily focused on regulation or move into large space acquisitions? Should it spend its resources on global space efforts or on a national space program? Experts we met with discussed some considerations for the agency if it determines to spend more on national capabilities.

Prioritize Needed Space Capabilities

A May 2018 report from the UK space industry calls for the government to develop a national space program. It says that, “heightened competition will expose the fundamental weakness of our current approach; i.e. the absence of a robust, joined-up domestic National Space Programme to sit alongside, and amplify the benefits from, our participation in the European space institutions.” Without this, it states, “the sector has had to adopt an ‘ad-hoc’ or reactive rather than strategic approach to future investments” [42]. Some of the experts we met with pointed to Britain’s pursuit of a global navigation satellite system as a reactive

decision that was not strategically driven. These experts told us that, prior to purchasing a national system, the UK Space Agency should strategically prioritize the capabilities or research for government investment. In developing a prioritized list, UK space leadership should consider identifying (1) the space-based capabilities that Britain should completely control, (2) the capabilities Britain should share control of with other countries, and (3) the capabilities Britain could use even if they are controlled by other countries. Moreover, the leadership should determine which of these categories navigation satellites should fit into.

As examples of capabilities the government may consider prioritizing, some experts suggested that the space agency try to take advantage of the industry’s success in small satellites. Dr. Bleddyn Bowen of Leicester University told us that money for a global navigation satellite system could be better spent on “[intelligence, surveillance, and reconnaissance] capabilities or increasing communications satellites, especially when considering new options in small satellites that the UK is world leader in.” He continued, “These would cost a fraction of the entire estimated UK [global navigation satellite system] option and would stimulate a world-leading aspect of the UK space sector whilst also enhancing UK space capability.”

Add Technical Expertise

Most of the experts we met with told us that to develop a national space program, the UK Space Agency should pull in more technical expertise. An organization equipped to write regulations and provide money to international space organizations may have different skills than an organization charged with acquiring massive space assets. Technical expertise is necessary to determine where to invest and how to administer acquisition. While discussing challenges that the UK Space Agency

**In comparison, the U.S. Global Positioning Systems Directorate—the Department of Defense acquisition office for developing and producing GPS satellites, ground systems, and military user equipment—comprises over 500 people.

will have in identifying the right people to assess navigation satellite options, one industry executive told us, “The UK Space Agency does not have the expertise to administer the industry.” Another industry official recommended that the agency develop a “technical arm.” The May 2018 space industry report also noted a need for technical expertise for the sector more broadly, “In order to achieve its growth ambitions UK space needs to recruit and/or train an additional 30,000 employees. This is likely to be a conservative figure. These workers will need to be skilled in mathematics, physical sciences and engineering, at a time when other high-tech sectors will be looking at the same resource pool across the UK” [42].

Future Participation in International Space Projects

As a potential alternative to spending its resources on developing sovereign national capabilities, the United Kingdom could opt to continue investing heavily in international space projects, which UK policy reports and pronouncements consistently characterize as a priority. The National Space Policy outlines as one of its four primary principles an emphasis on international cooperation, including, “collaborating with other nations to deliver maximum benefit from UK investment in space” [4]. A recent House of Commons report says that international collaboration will remain an important element for the space sector due to the high cost and global focus of space projects [43]. Experts we met with proposed options for the UK Space Agency as it considers future international space collaboration. Some predicted that Britain is likely to continue to coordinate significantly with international partners—including with the European Space Agency—in space projects but, in the wake of Brexit, exactly what that cooperation will be is unclear.

Enhance Cooperation with Allies Outside of the European Union

Because of Brexit, experts we interviewed noted that Britain could enhance its civil space relationship with other countries, including UK intelligence partners Australia, Canada, New Zealand, and the United States. Frank A. Rose—currently a senior fellow at The Brookings Institution and formerly the U.S. Assistant Secretary of State for Arms Control, Verification, and Compliance—told us, “For the last 50 years, the UK has worked closely with the European institutions for civil space and worked closely with the United States for defense space. With Brexit, this could fundamentally change. The UK may align more closely with the United States for civil and defense space.” This could be especially true as a result of its potential withdrawal from the Galileo program. If the United Kingdom does pull away from Galileo, Rose told us that their main options will be to develop their own navigation system or enhance their cooperation with the United States, noting that the U.S. GPS system has a military signal called the M-Code—currently reserved for U.S. government users—that offers anti-jamming and anti-spoofing capabilities.

Even if the British acquire their own navigation satellite system, the country may still coordinate more closely with the United States on navigation capabilities. A December 2018 press release from the UK government states that it will not use Galileo for defense or critical infrastructure after Brexit and that a British navigation satellite system must be “compatible with the U.S. GPS system, meaning that if either were subject to malicious attack the other could provide crucial positioning information” [44].

Negotiate an Agreement for Galileo

Another option for the United Kingdom would be to negotiate an agreement with the European Union to ensure its companies can continue to compete for contracts for EU-funded programs, such as for manufacturing components of Galileo. An EU official told us that this is an option for the British. The official told us that UK companies are still eligible to apply for manufacturing contracts for the Galileo system, apart from some applications related to the essential security interest of the European Union and its member states, such as the control center moved from the United Kingdom to Spain.

Some experts told us that the United Kingdom should try to continue to participate in Galileo, even if that does not include an ability to manufacture certain security elements and join in decision making over the program. The costs to industry of leaving Galileo could be substantial. The Chief Financial Officer for Surrey Satellites Technology Limited (headquartered in Guildford, UK)—which has manufactured satellites and components of satellites for Galileo—told us that the company receives 50 percent of its revenue from the program and after Brexit it will no longer be able to secure any future work from it. However, an EU official told us that Surrey Satellites would be eligible for subsequent Galileo satellites because the satellites are not a security feature of the program; therefore, non-EU businesses would not be excluded.

The United Kingdom could also negotiate an agreement to access the Public Regulated Service’s encrypted signals. An EU official noted that the United States and Norway are currently in negotiations with the European Union for gaining such access. However, UK leadership has indicated the government will not rely on a system used for security and defense when it is not involved in the decisions on the system. In discussing this position, Frank Rose told us that the European Union should have allowed the United Kingdom an ability to

participate in the security meetings. He said, “The UK is a natural security partner for the EU and should be able to help shape what the Public Regulated Service looks like. Consequently, I expect that the UK will align more closely with the United States on security matters for space.”

Relationship Between the UK Space Agency and Ministry of Defence

Integrate More Between Civil and Defense Space

The past year was momentous for the UK defense space sector. The Ministry of Defence issued a report in December 2018 on defense modernization that officially identified space as an operational domain to go with cyberspace, land, sea, and air [45]. In May 2018, Defence Secretary Gavin Williamson announced the launch of a UK defense space strategy, which is expected for release this year, and an increase in the number of defense space personnel from 500 to over 600 [46]. Also in May 2018, the defense ministry launched the Carbonite-2 demonstrator satellite that offered full-motion color video from space [47].

Similar to civilian space, UK defense space leadership faces serious decisions over what to invest in and how much it can afford. The Ministry of Defence will need to replace the UK’s SkyNet system of five military communications satellites, some of which are due to go out of service in the early 2020s. The ministry procured one new geostationary satellite, SkyNet 6A, to fill the potential gap in capability before it purchases a new group of satellites [48]. The ministry could also play a role in the procurement of a British global navigation satellite system, as indicated in the announcement of the 18-month study that the Ministry of Defence would support the UK Space Agency. In the launch of the defense space strategy, Secretary Williamson said, “Britain is a world leader in the space industry and our defence scientists and military personnel have played a central role in the development of the EU’s Galileo

satellite programme alongside British companies, so it is important we also review our contribution and how we plan for alternative systems in this crucial area” [46].

Some experts told us that while the UK Space Agency and Ministry of Defence are coordinating more on space than in the past, the organizations should further integrate to create a more cohesive government space strategy where they can leverage technical expertise and prioritize investments in global and national space efforts. For example, Professor Christopher Newman from Northumbria University told us, “Moving forward, there should be a more holistic approach to UK space interests, recognizing that, as civilian capacity grows, it makes sense to integrate the military provision where possible.” He added, “There seems little to suggest an integrated space strategy fusing military and civilian interests is likely to emerge in the near future.” While the near-term prospect of a civil-defense space strategy is unclear, UK leadership has noted the importance of the organizations working together on space. For example, General Sir Chris Deverell, the commander of the Joint Forces Command, said in November 2018, “Cooperation with the UK Space Agency and industry is vital” [49].

Looking Ahead

The world’s spotlight is on the United Kingdom as it maneuvers through Brexit. The change in its relationship with the European Union could be an inflection point for the UK space sector. The country has many opportunities available and can follow lessons learned from other nations’ space efforts to determine what course it wants to take. One expert told us that Brexit has helped force the nation’s leadership to think strategically about space. The potential withdrawal from Galileo and pursuit of a navigation satellite system raises not just questions about where and how much to invest but also about the fundamental role of British space governance. Prior to the establishment of the UK

Space Agency—and long before Brexit—the House of Commons issued a report in 2010 that looked at what balance should exist between investment in the European Space Agency and a national program and what should be the UK Space Agency’s role, priorities, and relationship with the Ministry of Defence [50]. The United Kingdom’s space leadership should continue to consider these issues. The decision about whether to transition from spending the vast majority of its resources on international space projects to acquiring large national space systems has serious consequences for the sector. It should be made deliberately and strategically.

Acknowledgments

We thank the experts we met with—some of whom are already mentioned. We also thank Paul Anderson, Dave Eccles, Ranwa Haddad, Joseph Hidalgo, Nina Isaia, Josef Koller, Julia Kopischke, Craig Lindsay, Jamie Morin, Jim Vedda, and Jamie Wilson. In particular, we thank Kristi Bradford, Michael Gleason, and Colleen Stover, who provided invaluable insight and contributions to the paper.

References

1. Bureau of the Federal Service, "Treasury Reporting Rates of Exchange as of December 31, 2018," 2019. <https://fiscal.treasury.gov/reports-statements/treasury-reporting-rates-exchange/current.html>.
2. Ministry of Defence, UK Space Agency, and Department for Business, Energy & Industrial Strategy, "Space sector to benefit from multi-million pound work on UK alternative to Galileo," 29 August 2018. <https://www.gov.uk/government/news/space-sector-to-benefit-from-multi-million-pound-work-on-uk-alternative-to-galileo>.
3. London Economics, "Infographic: Size & Health of the UK Space Industry 2018," 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/774818/LE-SHUKSI_2018-INFOGRAPHIC-FINAL-Issue1-S2C090119sw.pdf.
4. UK Space Agency, "National Space Policy," 13 December 2015. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/484865/NSP_-_Final.pdf, p. 4.
5. ADS, "2018 Industry Facts & Figures: A Guide to the UK's Aerospace, Defence, Security & Space Sectors," 1 May 2018. <https://www.adsgroup.org.uk/facts/facts-figures-2018/> (p. 22).
6. UK Space Agency <https://www.gov.uk/government/organisations/uk-space-agency>.
7. UK Space Agency, "National Space Policy," 13 December 2015. <https://www.gov.uk/government/publications/national-space-policy>.
8. UK Space Agency, Annual Report and Accounts 2013-2014. <https://www.gov.uk/government/publications/uk-space-agency-annual-report-and-accounts-2013-to-2014>, p. 6.
9. UK Space Agency, Annual Report and Accounts 2014-2015. <https://www.gov.uk/government/publications/uk-space-agency-annual-report-and-accounts-2014-to-2015>, p. 76.
10. UK Space Agency, Annual Report and Accounts 2015-2016. <https://www.gov.uk/government/publications/uk-space-agency-annual-report-and-accounts-2015-to-2016>, p. 72.
11. UK Space Agency, Annual Report and Accounts 2016-2017. <https://www.gov.uk/government/publications/uk-space-agency-annual-report-and-accounts-2016-to-2017>, p. 84.
12. UK Space Agency, Annual Report and Accounts 2017-2018. <https://www.gov.uk/government/publications/uk-space-agency-annual-report-and-accounts-2017-to-2018>, p. 86.
13. European Space Agency. "ESA budget by domain for 2019." https://www.esa.int/About_Us/Welcome_to_ESA/Funding.
14. Space Foundation, "The Space Report 2018: The Authoritative Guide to Global Space Activity," 2018, https://www.thespacereport.org/system/files/premium_downloads/The_Space_Report_2018.pdf, p. 10-12.
15. House of Lords, "Galileo Satellite System," Library Briefing, 13 November 2018. <https://researchbriefings.parliament.uk/ResearchBriefing/Summary/LLN-2018-0120#fullreport>, p. 1-2.
16. European Commission, "EU Budget for the Future: The EU Space Programme," 6 June 2018. https://ec.europa.eu/commission/sites/beta-political/files/budget-june2018-space-policy_en_0.pdf.
17. European Defence Agency, "Governmental Satellite Communications (GovSatCom)," <https://www.eda.europa.eu/what-we-do/activities/activities-search/governmental-satellite-communications-govsatcom>. As of March 13, 2019, the United Kingdom is listed as one of the participating countries.
18. EUSST, "What is EUSST?" <https://www.eusst.eu/>. As of March 13, 2019, the United Kingdom is listed as one of the EU member states that formed the initiative.
19. Department for Exiting the European Union, "Foreign policy, defence and development: A Future Partnership Paper," 12 September 2017. <https://www.gov.uk/government/publications/foreign-policy-defence-and-development-a-future-partnership-paper>, p. 14.
20. Megan Gannon, "European Space Agency leaders expect a challenging year ahead," Space News, 17 January 2019. <https://spacenews.com/european-space-agency-leaders-expect-a-challenging-year-ahead/>.

21. Department for Business, Energy & Industrial Strategy, "Satellites and space programmes if there's no Brexit deal," 13 September 2018. <https://www.gov.uk/government/publications/satellites-and-space-programmes-if-theres-no-brexit-deal>.
22. Space Foundation, "The Space Report 2018: The Authoritative Guide to Global Space Activity," 2018, https://www.thespacereport.org/system/files/premium_downloads/The_Space_Report_2018.pdf, p. 11.
23. European Space Agency, "ESA and the EU," 2017. http://www.esa.int/About_Us/Welcome_to_ESA/ESA_and_the_EU2.
24. European Commission, "EU budget: A 16 billion Space programme to boost EU space leadership beyond 2020, 6 June 2018. https://ec.europa.eu/growth/content/eu-budget-%E2%82%AC16-billion-space-programme-boost-eu-space-leadership-beyond-2020_en.
25. European Space Agency, "Welcome to ESA," http://www.esa.int/About_Us/Welcome_to_ESA/New_Member_States.
26. European Union, "About the EU," https://europa.eu/european-union/about-eu/countries_en.
27. UK Space Agency, "International Partnership Programme," 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/746241/IPP_Brochure_online_final_copy_02-10-18.pdf, p. 6.
28. European Commission, "Galileo & Egnos: The EU Satellite Navigation Programmes Explained," 2017. https://www.gsa.europa.eu/sites/default/files/galileo-egnoss_brochure_2017_web_1.pdf, p. 7, 10, 12-13.
29. European Global Navigation Satellite System Agency, "PRS," 2018. <https://www.gsa.europa.eu/security/prs>.
30. European Commission, "Speech by Michel Barnier at the EU Institute for Security Studies conference, 14 May 2018. http://europa.eu/rapid/press-release_SPEECH-18-3785_en.html.
31. Department for Exiting the European Union, "Technical Note: UK Participation in Galileo," 24 May 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/710790/FINAL_GALILEO.pdf, p. 4.
32. European Commission, "Involvement in the EU's space related activities (slides)," Task Force for the Preparation and Conduct of the Negotiations with the United Kingdom Under Article 50 TEU, 13 June 2018. https://ec.europa.eu/commission/sites/beta-political/files/slides_on_the_eus_space-related_activities.pdf, p. 3-10.
33. Dan Sabbagh. "Theresa May pledges Galileo alternative if UK locked out of satnav system," Guardian, 28 August 2018. <https://www.theguardian.com/politics/2018/aug/28/theresa-may-pledges-galileo-alternative-if-uk-locked-out-of-satnav-system>.
34. GOV.UK, "Space sector to benefit from multi-million pound work on UK alternative to Galileo," 29 August 2018. <https://www.gov.uk/government/news/space-sector-to-benefit-from-multi-million-pound-work-on-uk-alternative-to-galileo>.
35. Space Foundation, "2017-GPS." <https://www.thespacereport.org/advanced-search?keys=GPS>.
36. Space Foundation, "2017-GLONASS." <https://www.thespacereport.org/resources/infrastructure/positioning-navigation-timing-pnt-satellites/russian-pnt-satellites-glonass/2017-glonass>.
37. Space Foundation, "2017-Beidou." <https://www.thespacereport.org/resources/infrastructure/positioning-navigation-timing-pnt-satellites/chinese-pnt-satellites-beidou/2017-beidou>.
38. Space Foundation, "2017-Galileo." <https://www.thespacereport.org/resources/infrastructure/positioning-navigation-timing-pnt-satellites/european-pnt-satellites-galileo/2017-galileo>.
39. Space Foundation, "2017-NavIC." <https://www.thespacereport.org/resources/infrastructure/positioning-navigation-timing-pnt-satellites/indian-pnt-satellites-navic/2017-navic>.
40. Space Foundation, "2017-QZSS." <https://www.thespacereport.org/resources/infrastructure/positioning-navigation-timing-pnt-satellites/japanese-pnt-satellites-qzss/2017-qzss>.
41. For the details on the number of satellites for each navigation satellite system, we also spoke with experts at The Aerospace Corporation and used internal tools to track satellites in orbit in 2018.

42. Space Growth Partnership, "Prosperity from Space: A Partnership Strategy for the UK," 11 May 2018. http://www.ukspace.org/wp-content/uploads/2018/05/Prosperity-from-Space-strategy_2May2018.pdf, p. 8.
43. House of Commons, "Space Sector Report," Exiting the European Union Committee. <https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Sectoral%20Analyses/34-Space-Report.pdf>, p. 15.
44. Prime Minister's Office, "UK to tell EU it will no longer seek access to secure aspects of Galileo," 1 December 2018. <https://www.gov.uk/government/news/uk-to-tell-eu-it-will-no-longer-seek-access-to-secure-aspects-of-galileo>.
45. Ministry of Defence, "Mobilising, Modernising & Transforming Defence: A report on the Modernising Defence Programme," 18 December 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/765879/ModernisingDefenceProgramme_report_2018_FINAL.pdf, p. 4.
46. Ministry of Defence, "UK poised for take-off on ambitious Defence Space Strategy with personnel boost," 21 May 2018. <https://www.gov.uk/government/news/uk-poised-for-take-off-on-ambitious-defence-space-strategy-with-personnel-boost>.
47. Ministry of Defence, UK Space Agency, and Defence Science and Technology Laboratory, "Lift-off: Satellite launched into space on RAF mission," 1 March 2018. <https://www.gov.uk/government/news/lift-off-satellite-launched-into-space-on-raf-mission>.
48. David Bond and Sylvia Pfeifer, "Delay to MoD's military space strategy causes concern," *Financial Times*, 3 February 2019. <https://www.ft.com/content/e2fd0f9a-2006-11e9-b2f7-97e4dbd3580d>.
49. Sandra Erwin, "As satellites become targets, UK military seeks closer ties with space industry," *Spacenews*, 6 November 2018. <https://spacenews.com/as-satellites-become-targets-u-k-military-seeks-closer-ties-with-space-industry/>.
50. House of Commons, Science and Technology Committee, "The UK Space Agency," 8 September 2010. <https://publications.parliament.uk/pa/cm201011/cmselect/cmsctech/445/445-i.pdf>.

