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## **NATO Ally Contributions to the Space Domain**



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# Executive Summary

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This paper discusses U.S. North Atlantic Treaty Organization (NATO) ally space capabilities. In November 2019, NATO recognized space as an operational domain, declaring it on par with the air, land, sea, and cyber domains. NATO's designation of outer space as an operational domain is a recognition of the growing role of space in NATO operations. The increased commitment to space by NATO as a whole, and by U.S. NATO allies individually, provides more opportunities for the United States to draw upon the space capabilities of its NATO allies. As the leading NATO space power, the United States is viewed by its NATO allies as an indispensable partner in conducting and expanding space capabilities. Current emphasis by U.S. NATO allies appears to be on improving SDA but as capabilities grow, cooperation involving launch sites and on-orbit capabilities will likely increase. As a result, the emphasis U.S. NATO allies place on space operations presents multiple avenues for the U.S. and its NATO allies to increase and expand capabilities across a range of military space capabilities.

## Introduction

This paper discusses U.S. North Atlantic Treaty Organization (NATO) ally space capabilities. The increased commitment to space by NATO as a whole, and by U.S. NATO allies individually, provides more opportunities for the United States to draw upon the space capabilities of its NATO allies. In providing an overview of the space capabilities of U.S. NATO allies, this paper presents a more detailed discussion of the three U.S. NATO allies with the largest military space programs: France, Germany, and the United Kingdom.

## Background

In November 2019, NATO recognized space as an operational domain, declaring it on par with the air, land, sea, and cyber domains.<sup>1</sup> Space is now recognized as “essential to the Alliance’s defense and deterrence.”<sup>2</sup> This recognition is intended to make it easier for NATO planners to request space capabilities from allies.<sup>3</sup>

NATO’s recognition of space as an operational domain has been described as an evolutionary step.<sup>4</sup> Because NATO will continue to draw upon national capabilities for space support, the U.S. will continue to be the major force driving NATO’s use of space.<sup>5</sup> Moreover, NATO does not intend to deploy space weapons, objects that possess attack capabilities in that domain. Rather, NATO’s approach will focus on increasing interoperability through the use of space and better enabling support from space in the form of communications, positioning, navigation and timing, and remote sensing.<sup>6</sup> NATO will also focus on increasing space domain awareness (SDA). In 2020, NATO announced that it will build a space center at Ramstein Air Base in Germany to gather space surveillance and tracking information.<sup>7</sup> At the 2021 Brussels Summit, NATO recognized that attacks against any of its members to, from, or within space could lead to the invocation of Article 5 of the North Atlantic Treaty that treats an attack on one member as an attack on all members.<sup>8</sup>

NATO’s recognition of space as an operational domain has coincided with an increasing commitment to space by individual NATO members, in particular, France, the U.K., and Germany. To better integrate space into French military operations, in 2019, the French Ministry of Armed Forces renamed its Air Force the Air and Space Force.<sup>9</sup> In 2020, the U.K. Ministry of Defence established a Space Command and appointed its first director of space.<sup>10</sup> That same year, the German Air Force’s Air Operations Center became the Air and Space Operations Center (ASOC) to better integrate space into German military operations.<sup>11</sup>

## **U.S. NATO Allies and Space: An Overview**

NATO activity in space is carried out by individual member states that possess different capabilities and operate according to different space policies. In total, U.S. NATO allies operate 384 satellites. However, only 15 of the 29 U.S. NATO allies operate satellites. Canada, France, Germany, and the U.K. operate the largest number of satellites with 39, 24, 38, and 131, respectively. In comparison, the U.S. has 1,425 satellites in orbit.<sup>12</sup> See Appendix A for a complete list of U.S. NATO ally satellites.

U.S. NATO allies also operate relatively few military satellites when compared with the U.S.— just 42. France, the largest operator of military satellites, those operated or owned by the military or government-affiliated entities, has just 14. The next largest operators of military satellites, Germany and the U.K., have 7 and 6 satellites, respectively. In comparison, the U.S. operates 207 military satellites.<sup>13</sup> Most U.S. NATO allies' satellites skew toward commercial communications satellites, and U.S. NATO allies operate relatively few remote-sensing satellites, with a total of 69. Germany operates the largest number of remote-sensing satellites with 16. U.S. NATO allies may also have their own space policy, which could affect their ability to support U.S. space operations. France, for example, is considered to be more supportive of space weapons than are other U.S. NATO allies. Germany, on the other hand, is opposed to space weapons and has been reluctant to share remote-sensing data with other European countries.<sup>14</sup>

Moreover, certain space capabilities operated by European organizations are not under NATO command. Europe's Galileo satellite navigation system, for example, is operated by the European Union (EU), which includes all European NATO allies and the non-NATO countries Finland, Malta, and Sweden. The EU also operates the Space Surveillance and Tracking Service, which is composed of 8 members and 51 sensors.<sup>15</sup> Another major space actor is the European Space Agency (ESA), which is comprised of most, but not all NATO allies,<sup>16</sup> and non-NATO members Sweden and Switzerland. It mainly conducts scientific missions, but also funds two thirds of the budget of the Guiana Space Centre, owned by France and located in French Guiana.

Table 1. U.S. NATO ally satellites by type

Country	Number of Satellites	Type			
		Military	Government	Civil	Commercial
Belgium	1	0	0	1	0
Bulgaria	1	0	0	0	1
Canada	39	1	12	1	25
Czech Republic	3	0	1	0	2
Denmark	5	1	1	1	1
France	23	14	5	1	3
Germany	38	7	10	10	11
Greece	2	0	0	0	2
Hungary	2	0	0	0	2
Italy	11	8	1	2	0
Latvia	1	0	0	0	1
Lithuania	2	0	0	0	2
Luxembourg	32	0	0	0	32
Multinational	46	0	13	0	33
Netherlands	12	0	1	2	9
Norway	7	0	4	0	3
Spain	21	3	6	1	11
Turkey	7	2	1	1	3
United Kingdom	131	6	4	0	121
<b>Total</b>	<b>384</b>	<b>42</b>	<b>59</b>	<b>20</b>	<b>262</b>

Source: Union of Concerned Scientists Satellite Database.

**Table 2. U.S. NATO ally satellites by purpose**

Country	Number of Satellites	Purpose		
		Earth Observation	Communication	Other
Belgium	1	0	0	1
Bulgaria	1	0	1	0
Canada	39	5	23	11
Czech Republic	3	0	1	2
Denmark	5	2	0	3
France	23	15	4	4
Germany	38	16	4	18
Greece	2	0	2	0
Hungary	2	1	0	1
Italy	11	7	2	2
Latvia	1	0	0	1
Lithuania	2	0	0	2
Luxembourg	32	0	0	32
Multinational	46	7	34	6
Netherlands	12	0	8	4
Norway	7	2	5	0
Spain	21	5	13	3
Turkey	7	3	3	1
United Kingdom	131	6	117	8
<b>Total</b>	<b>384</b>	<b>69</b>	<b>217</b>	<b>99</b>

Source: Union of Concerned Scientists Satellite Database.



## **Space Launch**

Europe's only operational space launch facility is the Guiana Space Centre, located in French Guiana and operated jointly by the French government and ESA (see the France case study for more information). The U.K. and Germany are also planning or building space launch facilities, although these may be for only very small satellites (see the German and U.K. case studies for further information).

## **Space Domain Awareness**

SDA appears to be a focus for many NATO allies and is an important area of cooperation with the U.S. France, Germany, Italy, Poland, Spain, and the U.K. operate a variety of ground-based space surveillance capabilities, including radar, telescopes, and laser range finders. (See Appendix F.)

## **Counterspace**

Only one U.S. NATO ally, France, has stated the intention to develop counterspace weapons. In 2019, French Minister of the Armed Forces Florence Parly stated France's intention to deploy lasers on satellites for defensive purposes.<sup>17</sup>

# Country case studies

## France

### Organization

France's military space operations are commanded by the recently established Space Command (Commandement de l'Espace, CDE). The French Air and Space Force oversees space capabilities and military operations, while the Chief of Staff for the Armed Forces oversees training and force preparation.<sup>18</sup> CDE is staffed by personnel from the Operational Center for Military Surveillance of Space Objects, Satellite Observation Military Center, and Joint Space Command (Commandement Interarmées de l'Espace, CIE).<sup>19</sup> CIE was established in 2010 as France's initial effort to oversee space-related operations and weapon programs. It not only created a single organization for all French military branches to coordinate through, but also facilitated cooperation with other countries.<sup>20</sup> Unlike the CDE, this command is not part of the Air Force but rather falls under the purview of the Chief of the Defense Staff.<sup>21</sup> The Ministry for the Armed Forces also jointly oversees France's national space agency, the National Centre for Space Studies (CNES).<sup>22</sup> The 2019 space defense policy dictates that CNES "establish a closer relationship," suggesting that CNES's mission will focus more on supporting military space operations.<sup>23</sup>

### Space policy

France's space policy, *Space Defense Strategy*, published in July 2019, called space capabilities a "critical factor" for all military operations and a "new front" that must be defended.<sup>24</sup> The strategy called for a revision of doctrine for military space operations based on four functions: space service support, situational awareness, operations support, and active space defense.<sup>25</sup> The strategy called for renaming the French Air Force the Air and Space Force, making greater use of automated mass data processing, increasing weapon connectivity, and developing active and passive means to protect satellites.<sup>26</sup>

### Collaboration with the U.S.

France's space strategy states its willingness and the need to cooperate with the U.S., calling the U.S. "a key ally" for its military space operations.<sup>27</sup> The strategy highlights SDA as an area of cooperation that "must continue."<sup>28</sup> In February 2020, France joined the Combined Space Operations initiative to coordinate space domain awareness efforts. Other countries involved include the United States, Australia, Canada, Germany, New Zealand, and the United Kingdom.<sup>29</sup>

### Space capabilities

#### Satellites

France operates 24 satellites; 13 of which are military. Table 2 lists the military satellites France operates or jointly operates with fellow NATO nations.<sup>30</sup> For a complete list of French satellites, refer to Appendix B.

**Table 3. Military-use satellites operated or co-operated by France**

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
France	Direction Générale de l'Armement (DGA)//Centre National d'Etudes Spatiales (CNES)	Military	Earth Observation (Electronic Intelligence)	4
France	Direction Générale de l'Armement (DGA)	Military	Earth Observation (Multispectral Imaging)	1
France	French Ministry of Defense//Direction Générale de l'Armement (DGA)	Military	Technology Development (Infrared Imaging)	2
France	French Ministry of Defense	Military	Communications	2
France//Italy	French Ministry of Defense//Italian Ministry of Defense	Military	Communications	1
France//Italy//Belgium//Spain//Greece	Centre National d'Etudes Spatiales (CNES)//Direction Générale de l'Armement (DGA)	Military	Earth Observation (Optical Imaging)	2
France//Italy	Centre National d'Etudes Spatiales (CNES)//Agenzia Spaziale Italiana (ASI)	Government //Military	Communications	1

Source: Union of Concerned Scientists Satellite Database.

## **Space launch**

France operates the Guiana Space Centre, in French Guiana, with ESA. ESA, CNES, and the commercial company Arianespace conduct launches from the center's two launch pads. Russia rockets are launched on a third launch pad.<sup>31</sup> The Soyuz launch site, which is run by Arianespace, has been in use since 2011.<sup>32</sup> The Soyuz medium launch vehicle launched there rounds out Arianespace's family of launch vehicles, which had previously consisted of the Ariane 5 heavy launcher and the Vega light launcher.<sup>33</sup> Since it began operations in 1968, the Space Centre has conducted more than 220 launches of Ariane launch vehicles.<sup>34</sup>

## **Space domain awareness**

France plans on bolstering its SDA capabilities, labeling it a "priority" in its space defense policy.<sup>35</sup> This will be accomplished in part by renovating and replacing the GRAVES and SATAM radar systems, both ground-based systems used for observation and tracking satellites in low Earth orbit (LEO).<sup>36</sup> GRAVES, the first such radar system for France to gather tracking data independently,<sup>37</sup> is described as "an essential component of its [France's] space surveillance system."<sup>38</sup> The SATAM radar has the additional capability of tracking space debris. Other SDA capabilities include the Bâtiment d'Essai et de Mesures Monge tracking ship and the Système Probatoire d'Observation du Ciel (SPOC) telescope.<sup>39</sup>

## **Counterspace**

In July 2019, French Minister of the Armed Forces, Florence Parly, unveiled plans to deploy lasers on satellites. According to Parly, "If our satellites are threatened, we intend to blind those of adversaries...We reserve the right and the means to be able to respond."<sup>40</sup> Parly clarified, however, that France was not moving toward an offensive space strategy and that its development of space weapons would be for use "when a hostile act has been detected, characterized and attributed, to be able to respond in an appropriate and proportionate way, in conformity with the principles of international law."<sup>41</sup>

## **Germany**

### **Organization**

Germany's military space operations are under the command of the German Air Force.<sup>42</sup> The air force commands space operations through the Air and Space Operations Center (ASOC) established in 2020.<sup>43</sup> The ASOC expands the former air-centric Air Operations Center composed of the Air Force Operations Center, the National Situation and Command Center for Air Security, and the Air Intelligence Center, to a central, cross-dimensional command and control facility responsible for both air and space. The ASOC is expected to grow from 50 personnel to 150 by 2031.<sup>44</sup> Two other organizations involved in space are the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt e.V., DLR) and the Space Situation Center.

### **German Aerospace Center**

The DLR plans and implements Germany's space program for the government.<sup>45</sup> Its principal client is the civilian Federal Ministry for Economic Affairs and Energy, and it employs more than 8,000 people in research and development. It also trains scientists and advises policymakers.<sup>46</sup>

### **Space Situation Center**

In cooperation with the DLR, the German military also operates the Space Situation Center, which provides space situational awareness (SSA) data, mainly supplied by the U.S. as well as the German military. It serves as the central point of contact for the federal government on space.<sup>47</sup>

### **Space policy**

Both the German government and military recognize the critical importance of space. Germany's space strategy, *Making German's Space Sector Fit for the Future: The Space Strategy of the German Federal Government*, was released by the Federal Ministry of Economics and Technology in 2010. The strategy stated that "military operations, in particular, are now inconceivable without the support of space-based systems."<sup>48</sup> Similarly, the German Air Force stated in 2020 that space is an important component of the German military.<sup>49</sup>

Both the German government and public are regarded as strongly opposed to offensive operations in space. As a consequence, the German government is supportive only of conducting SDA and force enhancement missions, such as space-based communications and remote sensing.<sup>50</sup>

### **Collaboration with the U.S.**

The German military supports collaboration with the U.S. According to the German Air Force's director for space operations, Brigadier General Burkhard Pototzky, "The space situational awareness and space operations are only possible in an international context...It is now important for the Air Force to continue to develop and develop capabilities in the areas of space management and the planning and management of space operations in order to make an active contribution and to remain recognized as an international partner."<sup>51</sup> In 2019, Germany signed the Combined Space Operations Initiative memorandum of understanding with the U.S., the U.K., Canada, Australia, and New Zealand.<sup>52</sup> Focus areas for the initiative include SDA, force support, launch and reentry assessment, and contingency operations.<sup>53</sup>

## Space capabilities

### Satellites

Germany operates 38 satellites, 7 of which are military, mostly for remote sensing (see Table 4). For a complete list of German satellites, refer to Appendix C.

**Table 4. Military-use satellites owned by Germany**

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
Germany	Armed Forces	Military	Communications	2
Germany	Armed Forces	Military	Earth Observation (Radar Imaging)	5

Source: Union of Concerned Scientists Satellite Database.

### Space domain awareness

One of the primary ways in which Germany intends to work with its NATO allies is in the area of SDA.<sup>54</sup> Germany's SDA capabilities have grown recently. In 2019, Germany successfully tested its German Experimental Space Surveillance and Tracking (GESTRA) radar, which was described as bringing in "a new era in space observation" for the country.<sup>55</sup> In addition to GESTRA, Germany also operates the Tracking and Imaging Radar (TIRA) system.<sup>56</sup>

The DLR conducts numerous space-related projects related to SDA.<sup>57</sup> Its SSA Research Group focuses on monitoring space debris and processing sensor data to protect space assets.<sup>58</sup> The DLR also cooperates with U.S. Strategic Command to obtain LEO and geostationary orbit data.<sup>59</sup> According to a 2018 Institute for Defense Analyses report on SSA, the DLR was looking at developing "lasers for detecting orbital debris."<sup>60</sup> The report added that the DLR was "working on a software framework for distributed computing for the Backbone Catalog of Relational Debris Information project."<sup>61</sup>

### Space launch

Germany may build a mobile launch pad in the North Sea that could be opened to the militaries of the U.S. and other NATO allies. The Federation of German Industries (Bundesverband der Deutschen Industrie e.V., BDI) submitted a "public-private partnership" proposal to the government for a launch pad that could accommodate "micro-launchers" capable of lifting several hundred kilograms into orbit.<sup>62</sup> While the pad proposal has yet to be approved, DLR along with the Federal Ministry for Economic Affairs and Energy and the European Space Agency, started a micro-launcher competition in 2020 that will culminate in a launch demonstration in 2022-2023.<sup>63</sup>

## **United Kingdom**

### **Organization**

The U.K.'s Ministry of Defence announced the establishment of a Space Command in November 2020 to lead the U.K. military's space forces.<sup>64</sup> It is unclear how Space Command will operate with the two commands that previously oversaw space operations: Strategic Command (formerly known as Joint Forces Command) and the Royal Air Force (RAF) Air Command.<sup>65</sup> Strategic Command focuses on five domains, one of which is space, and is responsible for satellite communications and intelligence, surveillance, and reconnaissance capabilities.<sup>66</sup> RAF Air Command is responsible for SDA and space control capabilities.<sup>67</sup>

The establishment of a Space Command continues an increasing focus on space by the U.K. Starting in 2018, the Ministry of Defence initiated a 100-person staff increase in the defense space sector, and in 2019 the National Space Council was established to provide strategic leadership for space across the government.<sup>68</sup> In 2020 alone, the Ministry of Defence appointed its first director of space,<sup>69</sup> established a Space Operations Centre, and set up a Commercial Integration Cell to share data between the RAF and the commercial space company UKspace.<sup>70</sup>

### **Space policy**

The U.K.'s growing commitment to space is also reflected in its space policy. In 2017, the Ministry of Defence issued the second edition of its joint doctrine on air and space power. The doctrine emphasized the importance of space capabilities, laid out the country's military and civilian space capabilities, and stressed the need to cooperate with other European nations and the U.S. It notes that space capabilities are essential for the "vast majority of military operations."<sup>71</sup>

In 2018, the U.K. announced its first military space strategy.<sup>72</sup> A two-page strategy overview described space as "vital to modern life" and noted the "growing investment by other states in capabilities that threaten the use of space by the U.K. and its allies." The strategy states the ministry's intent "to secure freedom of action in space" by "fully exploiting its military and civil potential." It also highlighted the following objectives: enhancing space resilience and operational effectiveness, optimizing support to operations, and better supporting government activities.<sup>73</sup>

### **Collaboration with the U.S.**

The Ministry of Defence calls collaboration in space with allies and partners essential.<sup>74</sup> Relations with the U.S., in particular, are described as "critical to assure access to a host of space services."<sup>75</sup> According to one analysis, the U.K. cannot afford to "wean itself off its military dependencies on the United States."<sup>76</sup>

The U.S. and the U.K. conduct a number of cooperative space activities. These include information sharing via the U.K. missile defense warning facility at RAF Fylingdales and the U.S. Space Based Infrared System.<sup>77</sup> In 2019, the U.K. joined the U.S.-led Operation Olympic Defender coalition, which looks at bolstering and synchronizing space capabilities from detection to deterrence.<sup>78</sup> In 2020, the Ministry of Defence and the U.S. Space Force tested the compatibility of the new Protected Tactical Waveform with Skynet, which shares information with NATO allies.<sup>79</sup> The U.K. is also one of the founding members of the Combined Space Operations initiative, an effort to coordinate space domain awareness capabilities, along with the U.S., Australia, Canada, and New Zealand.<sup>80</sup>

# Space capabilities

## Satellites

The U.K. operates 133 satellites. Of these, 6 are military, 122 are commercial, and the rest are either operated or co-operated by the government. The U.K. military only operates communication satellites. The majority of the commercial satellites belong to OneWeb Satellites (74 in total), a joint venture between OneWeb and Airbus.<sup>81</sup> The U.K. military is described as still requiring external support for space capabilities.<sup>82</sup> For a complete list of U.K. satellites, refer to Appendix D.

**Table 5. Military-use satellites owned by the United Kingdom**

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
United Kingdom	Ministry of Defence	Military	Communications	1
United Kingdom	Intelsat//Paradigm Secure Communications (wholly owned by EADS Astrium)	Military	Communications	1
United Kingdom	Ministry of Defence//Paradigm Secure Communications (wholly owned by EADS Astrium)	Military	Communications	4

Source: Union of Concerned Scientists Satellite Database.

## Space launch

The U.K. only recently began building space launch capabilities. In October 2020, construction began on a government-owned spaceport in Cornwall, located in southwestern England, which is to be completed by 2021.<sup>83</sup> Northern Scotland will also host multiple launch sites. The commercially-owned Space Hub Sutherland is planned to launch satellites by 2022, and a vertical launch site, supported by the private sector and a defense contractor, is planned for North Uist.<sup>84</sup> In addition, Lockheed Martin is planning a site at the Shetland Space Centre with the first launch expected in 2022.<sup>85</sup>

## Space domain awareness

The primary U.K. SDA capability is a solid-state phased array radar based at RAF Fylingdales.<sup>86</sup> This facility is tasked primarily with ballistic missile defense, however, which limits its SDA capacity.<sup>87</sup>



## **Conclusion**

NATO's designation of outer space as an operational domain is a recognition of the growing role of space in NATO operations. The increased commitment to space by NATO as a whole, and by U.S. NATO allies individually, provides more opportunities for the United States to draw upon the space capabilities of its NATO allies. As the leading NATO space power, the United States is viewed by its NATO allies as an indispensable partner in conducting and expanding space capabilities. Current emphasis by U.S. NATO allies appears to be on improving SDA but as capabilities grow, cooperation involving launch sites and on-orbit capabilities will likely increase. As a result, the emphasis U.S. NATO allies place on space operations presents multiple avenues for the U.S. and its NATO allies to increase and expand capabilities across a range of military space capabilities.

# Appendix A: U.S. NATO Ally Satellites

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
Belgium	Von Karman Institute (VKI)	Civil	Space Science	1
Bulgaria	Bulsatcom	Commercial	Communications	1
Canada	Aprize Satellite	Commercial	Communications (Automatic Identification System (AIS))	2
Canada	Canadian Space Agency	Government	Earth Observation (Radar Imaging)	3
Canada	Canadian Space Agency	Government	Earth Science	1
Canada	Canadian Space Agency	Government	Space Observation	1
Canada	Canadian Space Agency	Government	Space Science	2
Canada	Ciel Satellite Group	Commercial	Communications	1
Canada	Defence Research and Development Canada (DRDC)//Canadian Space Agency	Government	Earth Observation (Automatic Identification System (AIS))	1
Canada	Department of National Defense	Military	Space Observation	1
Canada	Echostar Corporation (entire payload leased from Telesat Canada Ltd.)	Commercial	Communications	1
Canada	exactEarth	Commercial	Communications (Automatic Identification System (AIS))	3
Canada	exactEarth	Commercial	Communications// Maritime Tracking (Automatic Identification System (AIS))	1
Canada	GHGSat, Inc.	Commercial	Earth Science	1
Canada	Kepler Communications	Commercial	Communications	1
Canada	MDA Corporation	Commercial	Earth Observation (Radar Imaging)	1
Canada	Telesat Canada Ltd. (BCE, Inc.)	Commercial	Communications	5

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
Canada	Telesat Canada Ltd. (BCE, Inc.)	Commercial	Communications Meteorology, Automatic Identification System (AIS))	1
Canada	Telesat Canada Ltd. (BCE, Inc.)	Commercial	Communications	7
Canada	Telesat Canada Ltd. (BCE, Inc.)//APT Satellite Holdings Ltd.	Commercial	Communications	1
Canada	University of Toronto, Institute for Aerospace Studies	Civil	Space Science	1
Canada	University of Toronto, Institute for Aerospace Studies	Government//Civil	Technology Development	4
Canada//India	exactEarth//Indian Space Research Organization (ISRO)	Government	Earth Observation (Optical Imaging)	1
Czech Republic	Czech Aerospace Research Center (VZLU)	Government	Technology Development	1
Czech Republic	iSky Technology	Commercial	Communications (ADS-B Receiver)	1
Czech Republic	SkyFox Labs	Commercial	Technology Development	1
Denmark	Aarhus University	Civil	Technology Development// Education	1
Denmark	GomSpace ApS	Commercial	Technology Development	1
Denmark	GomSpace ApS	Government	Technology Development	1
Denmark	GomSpace ApS	Military	Earth Observation	1
Denmark	University of Aalborg	Civil	Earth Observation (Automatic Identification System)	1
ESA//U.S.	European Space Agency (ESA)//NASA	Government	Space Science	1
ESA//U.S.//Russia	European Space Operations Centre (ESOC)//NASA//Russia	Government	Space Science	1
European Space Agency (ESA)	Airbus	Commercial	Communications	1
European Space Agency (ESA)	Centre National d'Etudes Spatiales	Government	Communications	1

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
European Space Agency (ESA)	Centre National d'Etudes Spatiales (CNES)//European Space Agency (ESA)	Government	Earth Observation (Earth Science)	1
European Space Agency (ESA)	Centre National d'Etudes Spatiales (CNES)	Government	Space Science	1
European Space Agency (ESA)	European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)	Government	Earth Observation (Earth Science)	7
European Space Agency (ESA)	European Space Agency	Government	Space Science	1
European Space Agency (ESA)	European Space Agency	Government	Technology Development	1
European Space Agency (ESA)	European Space Agency	Government	Earth Observation (Earth Science)	2
European Space Agency (ESA)	European Space Agency	Government	Earth Observation (Radar Imaging)	1
European Space Agency (ESA)	European Space Agency	Government	Earth Observation	3
European Space Agency (ESA)	European Space Agency	Government	Technology Demonstration	2
European Space Agency (ESA)	European Space Agency (ESA) (and 250 international scientific investigators)	Government	Space Science	4
European Space Agency (ESA)	European Space Operations Centre (ESOC)	Government	Space Science	1
European Space Agency (ESA)	European University Network	Civil	Earth Observation//Earth Science	1
European Space Agency (ESA)	European Space Agency	Commercial	Navigation//Global Positioning	26
France	Defense Ministry	Military	Communications	2
France	Direction Générale de l'Armement (DGA)//Centre National d'Etudes Spatiales (CNES)	Military	Earth Observation (Electronic Intelligence)	4
France	Direction Générale de l'Armement (DGA)	Military	Earth Observation (Multispectral Imaging)	1

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
France	Ministry of Defense//Centre National d'Etudes Spatiales (CNES) - cooperation with Austria, Belgium, Spain, Sweden	Government	Earth Observation (Optical Imaging)	1
France	Ministry of Defense//Direction Générale de l'Armement (DGA)	Military	Technology Development (Infrared Imaging)	2
France	University of Montpellier	Civil	Earth Science	1
France	UnseenLabs	Commercial	Earth Observation (Maritime Surveillance)	1
France//Belgium//Sweden	Spot Image	Commercial	Earth Observation (Optical Imaging)	2
France//India	Centre National d'Etudes Spatiales (CNES)//Indian Space Research Organization (ISRO)	Government	Earth Observation (Earth Science)	2
France//Italy	Centre National d'Etudes Spatiales (CNES)//Agenzia Spaziale Italiana (ASI)	Government//Military	Communications	1
France//Italy Ministry//French Defense Ministry	Italian Defense	Military	Communications	1
France//Italy	Ministry of Defense//Centre National d'Etudes Spatiales (CNES) - cooperation with Austria, Belgium, Spain, Sweden	Government	Earth Observation (Optical Imaging)	1
France//Italy//Belgium//Spain//Greece	Centre National d'Etudes Spatiales (CNES)//Délégation Générale de l'Armement (DGA)	Military	Earth Observation (Optical Imaging)	2
France//U.S.	Centre National d'Etudes Spatiales (CNES)//NASA	Government	Earth Science	1
France//China	ThrustMe//Spacey Aerospace Co.	Commercial	Technology Development	1
Germany	Armed Forces	Military	Communications	2

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
Germany	Armed Forces	Military	Earth Observation (Radar Imaging)	5
Germany	German Aerospace Center (DLR)	Government	Earth Science	1
Germany	FH Aachen Development	Government//Civil	Technology	1
Germany	German Aerospace Center (DLR)	Commercial	Technology Development	1
Germany	German Aerospace Center (DLR)	Government	Communications (Automatic Identification System (AIS))	1
Germany	German Aerospace Center (DLR)	Government	Earth Observation (Optical Imaging)	1
Germany	German Aerospace Center (DLR)	Government	Technology Development	1
Germany	German Aerospace Center (DLR)//Astrium	Government	Earth Observation	1
Germany	German Aerospace Center (DLR)//Infoterra	Government//Commercial	Earth Observation	1
Germany	German Orbital Systems	Commercial	Technology Development	3
Germany	Institute of Space Sensor Technology and Planetary Exploration	Government//Civil	Earth Observation//Technology Development (Optical Imaging)	1
Germany	RapidEye AG	Commercial	Earth Observation (Optical Imaging)	5
Germany	Technical University Berlin	Civil	Technology Demonstration	1
Germany	Technical University Berlin	Civil	Technology Development	2
Germany	Technical University of Munich	Government//Civil	Technology Development	2
Germany	University of Stuttgart	Civil	Earth Observation//Space Science Automatic Identification System	1
Germany	University of Würzburg	Civil	Technology Development	2
Germany	University of Würzburg	Civil	Communications (Optical Imaging)	1
Greece	Hellas-Sat Consortium	Commercial	Communications	1

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
Germany//Morocco	Institut für Luft-und Raumfahrttechnik (Berlin)//CTRS Morocco	Government	Technology Development	1
Germany//China	unnamed German firm//Innovation Academy for Microsatellites, Chinese Academy of Sciences	Commercial	Technology Development	2
Hungary	ATL (Advanced Technology of Laser)	Commercial	Technology Development	1
Hungary	Budapest University of Technology and Economics	Civil	Earth Observation (Earth Science)	1
Italy	Italian Defense Ministry	Military	Communications	1
Italy	Italian Defense Ministry	Military	Earth Observation (Optical Imaging)	1
Italy	Italian Defense Ministry//Telespazio	Military//Commercial	Communications	1
Italy	Italian Space Agency	Government	Earth Observation (Hyperspectral Imaging)	1
Italy	Italian Space Agency//Ministry of Defense	Military//Civil	Earth Observation (Radar Imaging)	1
Italy	Italian Space Agency//Ministry of Defense	Military//Government	Earth Observation (Radar Imaging)	4
Italy	Max Valier school Bolzano, Italy, Oskar von Miller school, Merano, Italy	Civil	Space Science//Technology Development	1
Italy	OHB Italia	Commercial	Earth Observation (Automatic Identification System (AIS))	1
Italy	University of Rome	Civil	Earth Science	1
Italy//China	Italian Institute for Nuclear Physics//China Earthquake Administration	Government	Earth Science	1
Latvia	Ventspils University College	Civil	Technology Development	1
Luxembourg	LuxGovSat	Government//Military	Communications	1
Luxembourg	SES S.A.	Commercial	Communications	30

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
Luxembourg	SES S.A./EchoStar Satellite Services, LLC	Commercial	Communications	1
Multinational	ESA//EUMETSAT (European Organization for the Exploitation of Meteorological Satellites)	Government//Civil	Earth Observation (Earth Science// Meteorology)	3
Multinational	EUMETSAT (European Organization for the Exploitation of Meteorological Satellites)	Government//Civil	Earth Observation (Earth Science// Meteorology)	4
Multinational	EUTELSAT Americas	Commercial	Communications	3
Multinational	EUTELSAT S.A.	Commercial	Communications	26
Multinational	EUTELSAT S.A. - leased from Loral Skynet Satellite Services (Loral Global Alliance)	Commercial	Communications (Radar Imaging)	1
Multinational	EUTELSAT S.A./Es'hailSat	Commercial	Communications	1
Multinational	EUTELSAT S.A./Nilesat	Commercial	Communications	2
Multinational	Institute of Space and Astronautical Science (ISAS)//NASA	Government	Space Science	1
Multinational	Institute of Space and Astronautical Science (ISAS)//NASA//ESA	Government	Space Science	1
Multinational	NASA//Multinational	Government	Space Science	1
Multinational	NASA//University of California, Berkeley (in partnership with Germany, France, Austria, Canada)	Government//Civil	Space Science	3
Netherlands	AMSAT-UK	Civil	Communications	1
Netherlands	Hiber Global Development	Commercial	Technology	2
Netherlands	Netherlands Organization for Applied Scientific Research (NTO) consortium	Government	Technology Development	1
Netherlands	SES S.A.	Commercial	Communications	7
Netherlands	Technical University, Delft	Civil	Technology Development	1



Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
Norway	Norwegian Coastal Administration	Government	Communications (Automatic Identification System)	2
Norway	Norwegian Space Center	Government	Earth Observation (Automatic Identification System)	1
Norway	Norwegian Space Center	Government	Earth Science//Earth Observation	1
Norway	Telenor Satellite Broadcasting	Commercial	Communications (Optical Imaging)	2
Norway	Telenor Satellite	Commercial	Communications Broadcasting	1
Poland	SatRevolution	Commercial	Earth Observation	1
Poland	Warsaw University of Technology	Civil	Technology Development	1
Spain	AISTech	Commercial	Earth Observation Automatic Identification System	2
Spain	Deimos Imaging//DMC International Imaging	Government	Earth Observation (Optical Imaging) (DMCII)	2
Spain	Fossa Systems Development	Commercial	Technology	1
Spain	Hisdesat	Military//Commercial	Earth Observation (Radar Imaging)	1
Spain	Hisdesat//Ministry of Defense	Military	Communications	1
Spain	Hispamar (subsidiary of Hispasat - Spain)	Commercial	Communications	4
Spain	Hispasat	Commercial	Communications	4
Spain	Instituto Nacional de Técnica Aeroespacial (INTA)	Government	Communications	1
Spain	Instituto Nacional de Técnica Aeroespacial (INTA)	Government	Communications//Technology Development	1
Spain	Ministry of Defense//XTAR	Military//Government	Communications	1
Spain	Spanish Space Agency Development	Government	Technology	1
Spain	Universitat Politècnica de Catalunya	Civil	Technology Development	1
Spain	University of Vigo//Alén Space	Commercial//Civil	Communications	1

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
Turkey	ITU Space Systems Design & Test	Civil	Technology Development	1
Laboratory				
Turkey	Space Technologies Research Institute	Government	Earth Observation (Optical Imaging)	1
Turkey	Turkish Ministry of National Defense	Military	Earth Observation (Optical Imaging)	2
Turkey	Turksat	Commercial	Communications	3
United Kingdom	Avanti Communications, PLC	Commercial	Communications	3
United Kingdom	Earthi//Surrey Satellite Technology Ltd.	Commercial	Technology Development	1
United Kingdom	INMARSAT, Ltd.	Commercial	Communications	12
United Kingdom	Intelsat//Paradigm Secure Communications (wholly owned by EADS Astrium)	Military	Communications	1
United Kingdom	Kepler Communications Internet of Things	Commercial	Communications	1
United Kingdom	Ministry of Defense	Military	Communications	1
United Kingdom	O3b Networks Ltd.	Commercial	Communications	20
United Kingdom	OneWeb Satellites	Commercial	Communications	74
United Kingdom	Sky and Space Global, UK	Commercial	Technology Development	3
United Kingdom	Surrey Satellite Technology Ltd.	Commercial	Earth Observation (Optical Imaging)	4
United Kingdom	Surrey Satellite Technology Ltd.	Commercial	Technology Development	2
United Kingdom	Surrey Space Center Development .	Commercial	Technology	1
United Kingdom	UK Government//Surrey Satellite Technologies	Government// Commercial	Earth Observation (Radar Imaging)	1
United Kingdom	UK Space Agency Development	Government	Technology	1
United Kingdom	UK//DMC International Imaging (DMCII)	Government	Earth Observation (Earth Science)	1
United Kingdom//ESA	INMARSAT, Ltd.//ESA	Government// Commercial	Communications// Technology Development	1

Source: Union of Concerned Scientists Satellite Database.

# Appendix B: French Satellites

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
France	Direction Générale de l'Armement (DGA)//Centre National d'Etudes Spatiales (CNES)	Military	Earth Observation (Electronic Intelligence)	4
France	Direction Générale de l'Armement (DGA)	Military	Earth Observation (Multispectral Imaging)	1
France	French Ministry of Defense//Direction Générale de l'Armement (DGA)	Military	Technology Development (Infrared Imaging)	2
France	French Ministry of Defense	Military	Communications	2
France//Italy	French Ministry of Defense//Italian Ministry of Defense	Military	Communications	1
France//Italy//Belgium//Spain//Greece	Centre National d'Etudes Spatiales (CNES)//Direction Générale de l'Armement (DGA)	Military	Earth Observation (Optical Imaging)	2
France//Italy	Centre National d'Etudes Spatiales (CNES)//Agenzia Spaziale Italiana (ASI)	Government//Military	Communications	1
France	French Ministry of Defense//Centre National d'Etudes Spatiales (CNES) - cooperation with Austria, Belgium, Spain, Sweden	Government	Earth Observation (Optical Imaging)	1
France//Israel	Centre National d'Etudes Spatiales (CNES)//Israel Space Agency	Government	Earth Observation (Optical Imaging)	1

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
France//Italy	French Ministry of Defense//Centre National d'Etudes Spatiales (CNES) - cooperation with Austria, Belgium, Spain, Sweden	Government	Earth Observation (Optical Imaging)	1
France//U.S.	Centre National d'Etudes Spatiales (CNES)//NASA	Government	Earth Science	1
India//France	Indian Space Research Organization (ISRO)//Centre National d'Etudes Spatiales (CNES)	Government	Earth Observation (Earth Science)	2
U.S.//France	NASA//Centre National d'Etudes Spatiales (CNES)//NOAA//EUMETSAT	Government	Earth Observation (Earth Science)	1
France	UnseenLabs	Commercial	Earth Observation (Maritime Surveillance)	1
France//Belgium//Sweden	Spot Image	Commercial	Earth Observation (Optical Imaging)	2
France	University of Montpellier	Civil	Earth Science	1
			<b>TOTAL</b>	<b>24</b>

Source: Union of Concerned Scientists Satellite Database.

# Appendix C: German Satellites

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
Germany	Armed Forces	Military	Communications	2
Germany	Armed Forces	Military	Earth Observation (Radar Imaging)	5
Germany	German Aerospace Center (DLR)	Government	Communications Automatic Identification System	1
Germany	German Aerospace Center (DLR)	Government	Earth Observation (Optical Imaging)	1
Germany	German Aerospace Center (DLR)//Astrium	Government	Earth Observation	1
Germany	German Aerospace Center (DLR)	Government	Earth Science	1
Germany	German Aerospace Center (DLR)	Government	Technology Development	1
Morocco// Germany	CTRS Morocco//Institut für Luft- und Raumfahrttechnik (Berlin)	Government	Technology Development	1
U.S.// Germany	NASA//German Research Centre for Geosciences (GFZ)	Government	Earth Observation (Earth Science)	2
Germany	German Aerospace Center (DLR)//Infoterra	Government// Commercial	Earth Observation	1
Germany	Institute of Space Sensor Technology and Planetary Exploration	Government//Civil	Earth Observation// Technology Development	1
Germany	FH Aachen	Government//Civil	Technology Development	1
Germany	Technical University of Munich	Government//Civil	Technology Development	2
Germany	RapidEye AG	Commercial	Earth Observation (Optical Imaging)	5
Germany	ACME AtronOmatic (MyRadar)	Commercial	Technology Development	1
Germany	German Aerospace Center (DLR)	Commercial	Technology Development	1

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
Germany	German Orbital Systems	Commercial	Technology Development	3
Germany	University of Würzburg	Civil	Communications (Optical Imaging)	1
Germany	University of Würzburg	Civil	Technology Development	2
Germany	University of Stuttgart	Civil	Earth Observation//Space Science (Automatic Identification System)	1
Germany	Technical University Berlin	Civil	Technology Demonstration	6
			<b>TOTAL</b>	<b>40</b>

Source: Union of Concerned Scientists Satellite Database.

## Appendix D: U.K. Satellites

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
United Kingdom	Ministry of Defense	Military	Communications	1
United Kingdom	Intelsat//Paradigm Secure Communications (wholly owned by EADS Astrium)	Military	Communications	1
United Kingdom	Ministry of Defense//Paradigm Secure Communications (wholly owned by EADS Astrium)	Military	Communications	4
United Kingdom	UK//DMC International Imaging (DMCII)	Government	Earth Observation (Earth Science)	1
United Kingdom	UK Space Agency	Government	Technology Development	1
United Kingdom	UK Government//Surrey Satellite Technologies	Government//Commercial	Earth Observation (Radar Imaging)	1
United Kingdom//ESA	INMARSAT, Ltd.//ESA	Government//Commercial	Communications//Technology Development	1
U.S.//United Kingdom//Italy	Goddard Space Flight Center//Penn State University	Government//Civil	Space Science	1
United Kingdom	Avanti Communications, PLC	Commercial	Communications	3
United Kingdom	INMARSAT, Ltd.	Commercial	Communications	13
United Kingdom	Kepler Communications	Commercial	Communications (Internet of Things)	1
United Kingdom	O3b Networks Ltd.	Commercial	Communications	20
United Kingdom	OneWeb Satellites	Commercial	Communications	74

Country of Operator/Owner	Operator/Owner	Users	Purpose	Number of Satellites
United Kingdom	Surrey Satellite Technology Ltd.	Commercial	Earth Observation (Optical Imaging)	4
United Kingdom	Earthi//Surrey Satellite Technology Ltd.	Commercial	Technology Development	1
United Kingdom	Sky and Space Global, UK	Commercial	Technology Development	3
United Kingdom	Surrey Satellite Technology Ltd.	Commercial	Technology Development	2
United Kingdom	Surrey Space Center	Commercial	Technology Development	1
			<b>TOTAL</b>	<b>133</b>

Source: Union of Concerned Scientists Satellite Database.



# Appendix E: U.S. NATO Ally Space Domain Awareness Capabilities<sup>88</sup>

Country	System	Description	Capability	Comments
France	SATAM	C-Band Radar		Three radars located at Suippes and Captieux, plus a mobile radar
France	GRAVES	VHF bi-static surveillance radar	400-1,000 km range	
France	Monge tracking ship	Radar		Space tracking secondary mission
France	SPOC (Système Probatoire d'Observation du Ciel) telescope	Telescope	Wide-optical sensor for initial orbit determinations	
France	TAROT	Telescope		Two 25 cm telescopes in France and Chile
France	SATAM	C-Band Radar		Three radars located at Suippes and Captieux, plus a mobile radar
Germany	Tracking and Imaging Radar (TIRA)	Radar	Tracks 2 cm targets at altitude of 1,000 km	Uses L-band for tracking and Ku band for ISAR imaging
Germany	German Experimental Space Surveillance and Tracking (GESTRA)	Phased array radar	Track objects in LEO	(Semi) mobile system with separate receiver and transmitter units
Italy	RAT-31	L-band, solid state, phased array radar		Primarily intended for air defense
Italy	BIRALES (Bistatic Radar for LEO Survey)	A bistatic UHF radar for surveillance located in Sardinia (transmitter) and near Bologna (receiver)		

Country	System	Description	Capability	Comments
Italy	BIRALET (Bistatic Radar for LEO Tracking)	Bistatic radar		
Italy	PdM-MITE telescope	Telescope		350-mm fast telescope that uses separate CCDs for surveillance and tracking purposes
Italy	VdV-CAS telescope			Similar to the PdM-MITE
Italy	Matera Laser Ranging Observatory (MLRO)	Laser		Dedicated to the measurement of the exact orbital parameters of cooperative artificial satellites, i.e. those fitted with laser reflectors
Poland	Borowiec Satellite Laser Ranging Station	Laser		
Poland		Telescope		19 telescopes located in Poland, Argentina, Australia, Chile, Italy, Spain, RSA, and U.S.
Spain	Monostatic Space Surveillance Radar (MSSR)	L-band radar		Owned by ESA
Spain	S3T Surveillance Radar (S3TSR)	Phased array, L-band radar		
Spain	Centu-1	Telescope		Wide-field telescope for searching debris on GEO and MEO regimes

# Endnotes

- <sup>1</sup> “Foreign Ministers Take Decisions to Adapt NATO, Recognize Space as an Operational Domain,” NATO, Nov. 20, 2019, [https://www.nato.int/cps/en/natohq/news\\_171028.htm](https://www.nato.int/cps/en/natohq/news_171028.htm).
- <sup>2</sup> “Press Conference by NATO Secretary General Jens Stoltenberg Ahead of the Meetings of NATO Ministers of Foreign Affairs,” Nov. 19, 2019, [https://www.nato.int/cps/en/natohq/opinions\\_170972.htm](https://www.nato.int/cps/en/natohq/opinions_170972.htm).
- <sup>3</sup> “Foreign Ministers Take Decisions to Adapt NATO, Recognize Space as an Operational Domain.”
- <sup>4</sup> Kestutis Palauskas, “Space: NATO’s Latest Frontier,” Mar. 13, 2020, <https://www.nato.int/docu/review/articles/2020/03/13/space-natos-latest-frontier/index.html>.
- <sup>5</sup> Ibid.
- <sup>6</sup> “NATO Defence Ministers Approve New Space Policy, Discuss Readiness and Mission in Afghanistan,” NATO, Jun. 27, 2019, [https://www.nato.int/cps/en/natohq/news\\_167181.htm](https://www.nato.int/cps/en/natohq/news_167181.htm).
- <sup>7</sup> “NATO Plans New Space Center in Ramstein, Germany,” *DeutscheWelle*, Oct. 19, 2020, <https://www.dw.com/en/nato-plans-new-space-center-in-ramstein-germany/a-55319344>.
- <sup>8</sup> “NATO’s Approach to Space,” NATO, June 17, 2021, [https://www.nato.int/cps/en/natohq/topics\\_175419.htm](https://www.nato.int/cps/en/natohq/topics_175419.htm).
- <sup>9</sup> French Ministry of Armed Forces, *Space Defence Strategy*, 2019, p. 40.
- <sup>10</sup> Andrew Chuter, “Former Fighter Pilot Picked to Lead British Military’s Space Command,” *Defense News*, Jan. 15, 2020, <https://www.defensenews.com/global/europe/2020/01/15/former-fighter-pilotpicked-to-lead-british-militarys-space-command/>.
- <sup>11</sup> Dominic Vogel, “Germany Armed Forces Approaching Outer Space: The Air and Space Operations Centre As a Gateway to Multi-domain Operations,” *SWP Comment* No. 49 (October 2020,): p. 1, <https://www.swp-berlin.org/10.18449/2020C49/>.
- <sup>12</sup> Union of Concerned Scientists Satellite Database, <https://www.ucsusa.org/resources/satellitedatabase>.
- <sup>13</sup> Ibid.
- <sup>14</sup> Hitchens, Theresa. “Raymond Urges NATO Space Ops; Europeans Fear Offensive Missions,” *Breaking Defense*, November 18, 2019, <https://breakingdefense.com/2019/11/raymond-urges-nato-space-opseuropeans-fear-offensive-missions/>.
- <sup>15</sup> “EU Space Surveillance and Tracking Service Portfolio Service Portfolio,” European Commission, [www.eusst.eu](http://www.eusst.eu).
- <sup>16</sup> NATO member countries not part of the ESA are as follows: Albania, Bulgaria, Croatia, Iceland, Lithuania, Montenegro, North Macedonia, Slovakia, Turkey, and the U.S. Canada, Latvia, and Slovenia “qualify to full participate” but are not members of the ESA. “ESA Member States, Canada, Latvia and Slovenia,” ESA website, [https://www.esa.int/Education/ESA\\_Member\\_States\\_Canada\\_Latvia\\_and\\_Slovenia](https://www.esa.int/Education/ESA_Member_States_Canada_Latvia_and_Slovenia); “Member Countries,” NATO website, Sept. 24, 2020, [https://www.nato.int/cps/en/natolive/topics\\_52044.htm](https://www.nato.int/cps/en/natolive/topics_52044.htm).
- <sup>17</sup> Brian Weeden and Victoria Samson (eds.), *Global Counterspace Capabilities: An Open Source Assessment*, Secure World Foundation, Apr. 2020, p. 4-2.
- <sup>18</sup> Christina Mackenzie, “French Air Force Changes Name as it Looks to the Stars,” *Defense News*, Sept. 15, 2020, <https://www.defensenews.com/global/europe/2020/09/15/french-air-force-changes-nameas-it-looks-to-the-stars/>.
- <sup>19</sup> “Communiqué\_Florence Parly Confirms the Creation of the Space Command Within the Air Force (Communiqué\_Florence Parly acte la création du Commandement de l’espace au sein de l’Armée de l’air),” French Ministry of Armed Forces, Sept. 1, 2020, [https://www.defense.gouv.fr/salle-depresse/communiqués/communiqué\\_florence-parly-acte-la-creation-du-commandement-de-l-espaceau-sein-de-l-armee-de-l-air](https://www.defense.gouv.fr/salle-depresse/communiqués/communiqué_florence-parly-acte-la-creation-du-commandement-de-l-espaceau-sein-de-l-armee-de-l-air); “Interactive Flowchart of the Air and Space Force (Organigramme interactif de L’Armée de l’Air et de l’Espace),” Air and Space Force (Armée de l’Air et de l’Espace), accessed Dec. 9, 2020, <https://air-actualites.com/OrganigrammeArmeeAirEspace/>.
- <sup>20</sup> French Ministry of Armed Forces, *Space Defence Strategy*, p. 40.
- <sup>21</sup> Ibid. “The Missions of the Joint Space Command (Les missions du Commandement interarmées de l’espace),” French Ministry of Armed Forces, Mar. 26, 2012, <https://www.defense.gouv.fr/portail/dossiers/l-espace-au-profit-des-operations-militaires/lecommandement-interarmees-de-l-espace-cie-et-le-cloud-spatial/les-missions-du-commandementinterarmees-de-l-espace>.
- <sup>22</sup> French Ministry of Armed Forces, *Space Defence Strategy*, p. 41.
- <sup>23</sup> Ibid., p. 42.

- <sup>24</sup> AFP, “France to Develop Anti-Satellite Laser Weapons: Defence Minister,” *France24*, Jul. 25, 2019, <https://www.france24.com/en/20190725-france-develop-anti-satellite-laser-weapons-defenceminister>.
- <sup>25</sup> French Ministry of Armed Forces, *Space Defence Strategy*, p. 40.
- <sup>26</sup> *Ibid.*, p. 11.
- <sup>27</sup> French Ministry of Armed Forces, *Space Defence Strategy*, p. 34.
- <sup>28</sup> *Ibid.*
- <sup>29</sup> “Combined Space Operations initiative welcomes France and Germany,” U.S. Space Command, February 13, 2020, <https://www.spacecom.mil/MEDIA/NEWS-ARTICLES/Article/2083368/combined-space-operations-initiative-welcomes-france-and-germany/>.
- <sup>30</sup> Union of Concerned Scientists, *Satellite database*, Apr. 1, 2020.
- <sup>31</sup> “The Spaceport,” Arianespace, <https://www.arianespace.com/spaceport-facility>.
- <sup>32</sup> “Soyuz Launch Site Ready for First Flight,” European Space Agency, Apr. 1, 2011, [http://www.esa.int/Enabling\\_Support/Space\\_Transportation/Soyuz\\_launch\\_site\\_ready\\_for\\_first\\_flight](http://www.esa.int/Enabling_Support/Space_Transportation/Soyuz_launch_site_ready_for_first_flight).
- <sup>33</sup> “Arianespace Takes Official Delivery from ESA of the Soyuz Launch Complex at the Guiana Space Center,” Arianespace, May 7, 2011, <https://web.archive.org/web/20110707161921/http://www.arianespace.com/news-pressrelease/2011/5-7-2011.asp>. “Soyuz,” Arianespace, <https://www.arianespace.com/vehicle/soyuz/>.
- <sup>34</sup> “The Spaceport.”
- <sup>35</sup> French Ministry of Armed Forces, *Space Defence Strategy*, p. 40.
- <sup>36</sup> *Ibid.*, p. 46.; ONERA, “GRAVES, the 1st European Space Surveillance System,” Jun. 17, 2019, <https://www.onera.fr/en/news/graves-the-1st-european-space-surveillance-system>.
- <sup>37</sup> ONERA, “GRAVES, the 1st European Space Surveillance System.”
- <sup>38</sup> French Ministry of Armed Forces, *Space Defence Strategy*, p. 45-46.
- <sup>39</sup> Brian Weeden and Victoria Samson (eds.), *Global Counterspace Capabilities: An Open Source Assessment*, p. 4-2.
- <sup>40</sup> *Ibid.*, p. 4-2.
- <sup>41</sup> Theresa Hitchens, “Space Lasers for Satellite Defense Top New French Space Strategy,” *Breaking Defense*, Jul. 26, 2019, <https://breakingdefense.com/2019/07/france-envisions-on-orbit-lasers-forsatellite-defense/>.
- <sup>42</sup> Vogel, “Germany Armed Forces Approaching Outer Space: The Air and Space Operations Centre As a Gateway to Multi-domain Operations,” p. 1.
- <sup>43</sup> *Ibid.*
- <sup>44</sup> “German Military Launches Space Junk Tracking System.”
- <sup>45</sup> “DLR Space Administration,” DLR website, [https://www.dlr.de/rd/en/desktopdefault.aspx/tabid2099/3053\\_read-4706/](https://www.dlr.de/rd/en/desktopdefault.aspx/tabid2099/3053_read-4706/).
- <sup>46</sup> “Aerospace Policy,” Federal Ministry for Economic Affairs and Energy, <https://www.bmwi.de/Redaktion/EN/Dossier/aerospace-policy.html>.
- <sup>47</sup> Air Force Command, “Multinational Partnership for the use of Space (Multinationale Partnerschaft für die Nutzung des Weltraums),” German Armed Forces website, Aug. 6, 2020, <https://www.bundeswehr.de/de/organisation/luftwaffe/aktuelles/multinationale-partnerschaftfuer-die-nutzung-des-weltraums-171128>.
- <sup>48</sup> Federal Ministry of Economics and Technology, *Making Germany's Space Sector Fit for the Future: The Space Strategy of the German Federal Government*, Federal Ministry of Economics and Technology, Nov. 2010., p. 8.
- <sup>49</sup> “Deshalb ist es eine Dauereinsatzaufgabe der Bundeswehr, den Weltraum zu nutzen. Sowohl für den Grundbetrieb als auch für den Einsatz ist er schon lange unverzichtbar. Dadurch wird der militärische Beitrag zur Weltraumsicherheit zu einem wichtigen Baustein der gesamtstaatlichen Sicherheitsvorsorge für den Weltraum.” Silo translation, modified by authors. Air Force Command, “Multinational Partnership for the use of Space (Multinationale Partnerschaft für die Nutzung des Weltraums).”
- <sup>50</sup> Hitchens, Theresa. “Raymond Urges NATO Space Ops; Europeans Fear Offensive Missions,” *Breaking Defense*, November 18, 2019, <https://breakingdefense.com/2019/11/raymond-urges-nato-space-opseuropeans-fear-offensive-missions/>.
- <sup>51</sup> “Multinational Partnership For the Use of Space,” Bundeswehr, <https://www.bundeswehr.de/de/organisation/luftwaffe/aktuelles/multinationale-partnerschaftfuer-die-nutzung-des-weltraums-171128>.
- <sup>52</sup> *Ibid.*

- 53 U.S. Space Command Public Affairs Office, “Combined Space Operations Initiative Welcomes France and Germany,” U.S. Space Command, Feb. 13, 2020, <https://www.spacecom.mil/MEDIA/NEWSARTICLES/Article/2083368/combined-space-operations-initiative-welcomes-france-and-germany/>.
- 54 “Multinational Partnership for the Use of Space.”
- 55 “Eine neue Ära in der Weltraumbeobachtung.” Silo translation. Alexander Feja, “GESTRA Space Radar Detects the First Objects (Weltraum-Radar GESTRA entdeckt erste Objekte),” German Armed Forces website, *German Armed Forces website*, Dec. 5, 2019, <https://www.bundeswehr.de/de/organisation/luftwaffe/aktuelles/weltraum-radar-gestra-entdeckterste-objekte-161080>.
- 56 Asha Balakrishnan Bhavya Lal, Becaja M. Caldwell, Reina S. Buenconsejo, and Sara A. Carioscia, *Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM)*, IDA Science & Technology Policy Institute, Apr. 2018, p. 32, <https://www.ida.org/media/feature/publications/g/gl/global-trends-in-space-situational-awareness-ssa-and-spacetraffic-management-stm/d-9074.ashx>.
- 57 *Ibid.*, p. 60.
- 58 German Aerospace Center, “Space Flight Technology,” accessed Nov. 3, 2020, <https://www.dlr.de/rb/en/desktopdefault.aspx/tabid-8126>.
- 59 German Aerospace Center, “Space Situational Awareness (SSA),” accessed 3 Nov. 2020, [https://www.dlr.de/rb/en/desktopdefault.aspx/tabid-10156/17320\\_read-41664/](https://www.dlr.de/rb/en/desktopdefault.aspx/tabid-10156/17320_read-41664/).
- 60 Bhavya Lal, *Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM)*, p. 35.
- 61 *Ibid.*, p. 39.
- 62 “Germany Eyes Space Satellite Launchpad in North Sea,” *BBC*, Sept. 8, 2020, <https://www.bbc.com/news/world-europe-54070759>. “#SpaceWatchGL Interviews: Matthias Wachter Of The Federation Of German Industries (BDI),” Feb., 2020, <https://spacewatch.global/2020/02/spacewatchgl-interviews-matthias-wachter-of-bdi/>.
- 63 “DLR Microlauncher Competition: These Three Teams are one Round Further (DLR-MikrolauncherWettbewerb: Diese drei Teams sind eine Runde weiter),” *DLR website*, Jul. 14, 2020, [https://www.dlr.de/content/de/artikel/news/2020/03/20200714\\_dlr-mikrolauncher-wettbewerb-drei-teams-sind-eine-Runde-weiter.html](https://www.dlr.de/content/de/artikel/news/2020/03/20200714_dlr-mikrolauncher-wettbewerb-drei-teams-sind-eine-Runde-weiter.html).
- 64 “Defence Secures Largest Investment Since the Cold War,” UK Ministry of Defence, Nov. 19, 2020, <https://www.gov.uk/government/news/defence-secures-largest-investment-since-the-cold-war>; Gareth Jennings, “UK to Launch New Space Command,” *Janes*, Nov. 19, 2020, <https://www.janes.com/defence-news/news-detail/uk-to-launch-new-space-command>.
- 65 *The Integrated Operating Concept 2025 (accessible version)*, Sept. 2020, <https://www.gov.uk/government/publications/the-integrated-operating-concept-2025/theintegrated-operating-concept-2025-accessible-version>.
- 66 “Defence Secretary Outlines Ambitious Space Programme,” Jul. 18, 2019, <https://www.gov.uk/government/news/defence-secretary-outlines-ambitious-space-programme>.
- 67 Ministry of Defence, *Towards a Defence Space Strategy: MOD Defence Space Strategy Headlines*, Ministry of Defence, 2018.
- 68 “UK Poised for Take-off on Ambitious Defence Space Strategy with Personnel Boost,” Gov.UK website, May 30, 2018, <https://www.gov.uk/government/news/uk-poised-for-take-off-on-ambitious-defencespace-strategy-with-personnel-boost>; “Leading the New Space Age: Government Backs Ambitious Plans for the UK in Space,” GovUK, Jun. 4, 2019, <https://www.gov.uk/government/news/leading-the-new-space-age-government-backs-ambitious-plans-for-the-uk-in-space>.
- 69 Andrew Chuter, “Former Fighter Pilot Picked to Lead British Military’s Space Command.”; Jennings, “UK to Launch New Space Command.”
- 70 “UKspace and RAF to Establish Commercial Integration Cell for Greater Military and Commercial Space Collaboration,” UKspace website, Jul. 23, 2020, <https://www.ukspace.org/ukspace-raf-establish-cic-for-greater-military-and-commercial-space-collaboration/>.
- 71 Ministry of Defence, *UK Air and Space Power (2nd Edition)*, Development, Concepts and Doctrine Centre, Ministry of Defence, Joint Doctrine Publication 0-30, Dec. 2017, [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/668710/doctrine\\_uk\\_air\\_space\\_power\\_jdp\\_0\\_30.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/668710/doctrine_uk_air_space_power_jdp_0_30.pdf).

- <sup>72</sup> “UK Defence Space Conference,” Royal Air Force website, May 23, 2018, <https://www.raf.mod.uk/news/articles/uk-defence-space-conference/>.
- <sup>73</sup> Ministry of Defence, *Towards a Defence Space Strategy: MOD Defence Space Strategy Headlines*.
- <sup>74</sup> Ministry of Defence, *UK Air and Space Power (2nd Edition)*, p. iii.
- <sup>75</sup> *Ibid.*, p. 84.
- <sup>76</sup> Bleddyn Bowen, *The Integrated Review and UK Spacepower: The Search for Strategy*, Freeman Air & Space Institute, July 2019, p. 9.
- <sup>77</sup> Ministry of Defence, *UK Air and Space Power (2nd Edition)*, p. 114.
- <sup>78</sup> Defence Secretary Penny Mordaunt, “Defence Secretary Keynote Speech at the Air and Space Power Conference 2019,” Jul. 18, 2019, <https://www.gov.uk/government/speeches/defence-secretarykeynote-speech-at-the-air-and-space-power-conference-2019>.; “Defence Secretary Outlines Future Space Programme,” Royal Air Force website, Jul. 18, 2019, <https://www.raf.mod.uk/news/articles/defence-secretary-outlines-future-space-programme/>.; U.S. Space Command Public Affairs Office, “USSPACECOM Releases First Formal Order to Execute Multinational Space Operations,” May 21, 2020, <https://www.spacecom.mil/MEDIA/NEWSARTICLES/Article/2194150/usspacecom-releases-first-formal-order-to-execute-multinational-spaceoperations/>.
- <sup>79</sup> Sandra Erwim, “Space Force Tests Compatibility of U.S. Secure Satcom Network with U.K. Skynet,” *Space News*, Jul. 19, 2020, <https://spacenews.com/space-force-tests-compatibility-of-u-s-securesatcom-network-with-u-k-skynet/>.
- <sup>80</sup> “Combined Space Operations initiative welcomes France and Germany,” U.S. Space Command, February 13, 2020, <https://www.spacecom.mil/MEDIA/NEWS-ARTICLES/Article/2083368/combined-space-operations-initiative-welcomes-france-and-germany/>.
- <sup>81</sup> Union of Concerned Scientists, *Satellite database*.
- <sup>82</sup> Bowen, *The Integrated Review and UK Spacepower: The Search for Strategy*, p. 12.
- <sup>83</sup> Stanley Reed, “Britain is Getting Ready for its Space Race,” *The New York Times*, Oct. 6, 2020, <https://www.nytimes.com/2020/10/06/business/britain-satellites-brexite.html>.; “Why is Scotland a Prime Rocket Launch Site?,” *BBC*, Nov. 19, 2020, <https://www.bbc.com/news/uk-scotland-48119118>.
- <sup>84</sup> George Allison, “New RAF Space Command to Launch Rockets from Scotland,” *UK Defense Journal*, Nov. 19, 2020, <https://ukdefencejournal.org.uk/new-raf-space-command-to-launch-rockets-fromscotland/>.; “Why is Scotland a Prime Rocket Launch Site?.”; “Space Hub Sutherland - FAQs,” Highland and Islands Enterprise website, <https://www.hie.co.uk/our-region/regional-projects/space-hubsutherland/space-hub-sutherland-faqs/>.; Peter Urpeth, “Rocket Launching Plans for the Uists Develop,” *Stornoway Gazette*, Feb. 20, 2020, <https://www.stornowaygazette.co.uk/news/people/rocketlaunching-plans-uists-develop-2008068>.
- <sup>85</sup> “Shetland Space Centre Plans Take Step Nearer Launch,” *BBC*, Oct. 22, 2020, <https://www.bbc.com/news/uk-scotland-north-east-orkney-shetland-54634943>.
- <sup>86</sup> Ministry of Defence, *UK Air and Space Power (2nd Edition)*, p. 93.
- <sup>87</sup> Bowen, *The Integrated Review and UK Spacepower: The Search for Strategy*, p. 13.
- <sup>88</sup> Sources: NATO Joint Air Power Competence Center, Command and Control of a Multinational Space Surveillance and Tracking Network, June 2019, [https://www.japcc.org/wpcontent/uploads/JAPCC\\_C2SST\\_2019\\_screen.pdf](https://www.japcc.org/wpcontent/uploads/JAPCC_C2SST_2019_screen.pdf); European Union Space Surveillance and Tracking, Service Portfolio, 2020, <https://www.satcen.europa.eu/keydocuments/EU%20SST%20ServicePortfolio5f58ae198c7cd800013e8b6c.pdf>; “Poland Has Joined the Space Surveillance and Tracking (SST) Consortium Established to Track Space Debris,” Polish Space Agency, <https://polsa.gov.pl/en/events/events/15-latest/943-poland-has-joined-the-spacesurveillance-and-tracking-sst-consortium-established-to-track-space-debris>.



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