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I. EXECUTIVE SUMMARY

1. The space realm is evolving rapidly, and as it does, new commercial vistas are opening up that will transform the global economy. France has emerged as a leading player in space and is a driving force in Europe's collective quest both to derive benefits from these markets and to shape them. But as the commercial stakes and number of players increase in what is now frequently referred to as "new space", and with the global economy growing ever more dependent on space-based digital and communications systems, there is a rising potential for the space realm to become a domain of strategic and military rivalry.
2. This was a central message that a group of national legislators from the NATO Parliamentary Assembly took away from a three-day trip to Paris and Toulouse on 3-5 October 2018.
3. Jean-Paul Granier, from France's Directorate General for Armaments, told the delegation that the space domain has been a central element of French military doctrine, but Western nations now must update strategies to cope with the "new space phenomenon". He noted, for example, that given countersatellite technology that rival nations are now deploying, satellites increasingly require surveillance and anti-jamming capacity to ensure their own survivability. Situational awareness is not only essential to counter aggressive actions by rival states, but also to cope with the growing problem of space debris generated by human activity in space.
4. Mastering the space domain also brings important terrestrial benefits. Toulouse has become the centre of the French and indeed European space industry, and its economy is booming. Jean-Luc Moudenc, the Mayor of Toulouse and President of the Toulouse Metropole, told the delegation that Toulouse has always played a leading role, as it hosted the country's fledgling aviation sector during World War I. Since then, it has been the engine of France's aviation and space sectors. Today commercial partnerships extend throughout the world, and Toulouse has become a cosmopolitan technology hub of international importance.
5. Toulouse and the region around it host a cluster of aerospace engineering companies and research centres, including Airbus, the Centre national d'études spatiales (CNES) and a university system that partners closely with these industries. This has spawned a virtuous circle, in which basic and applied research are generating insights and technologies with consequential commercial and strategic implications, Mayor Moudenc reported. The space and aviation sectors in the region are growing rapidly, triggering a boom in innovation and economic growth. The region around Toulouse is now generating thousands of jobs due to advances in aviation technologies, satellite production and a host of sectors that support these industries or spin off from them.
6. The delegation consisted of 11 members of the NATO Parliamentary Assembly's Sub-Committee on Trans-Atlantic Economic Relations. It was led by two of its Vice Chairs, Jean-Luc Reitzer, of France and Christian Tybring-Gjedde of Norway. French Senator Jean-Marie Bockel, hosted the delegation and helped organise the visit, which included tours of facilities at Airbus Defence and Space, CNES and Thalès-Alenia-Space in Toulouse, and Arianespace Launch Services in Les Mureaux, outside of Paris.
7. At the time of the visit, Senator Bockel, Rapporteur of the NATO PA's Economics and Security Committee was working on a draft report on the Future of the Space Industry, to be presented at the Assembly's Annual Session in Halifax, Canada, last November. The final report can be found on the [NATO PA website](#).

II. MEETINGS IN THE FRENCH SENATE

8. General Michel Friedling, Commander of Joint Space Command, spoke to the Sub-Committee on the theme of New Space and strategic security. The General noted that after 2010, France recognised space as a key strategic priority. The Command was founded to cover all critical space issues and to exercise command and control of all military-related space equipment. The command must operate within the parameters of existing space law and respect key norms that effectively govern France's use of space. The commander also operates as space advisor to the General Staff and ensures that space is considered in a broad strategic framework. France has made a degree of national autonomy a critical strategic objective, and this strongly conditions its approach to the space domain.

9. General Friedling noted that the space domain is evolving very quickly. New actors are playing an increasingly important role, including corporations and even individuals, such as Jeff Bezos and Elon Musk. Commercial opportunities and activities in space are expanding rapidly as costs fall, and there is a heightened sense of strategic competition. Technology is driving change and the cost of launching satellites into orbit has plummeted, not only due to launch innovation but also due to the digital revolution. Satellites are growing more powerful as their size shrinks. Nanosatellites have become critical to global communications and internet infrastructure, and their importance will only mount in the future. Smaller and more powerful satellites mean that more processing power can be sent into orbit as lower cost. Critical innovations in propulsion systems are also driving down the cost of rocket launches, and the rise of new companies like SpaceX and Blue Origin is driving many of these changes, as they pose competitive challenges to older companies in the business.

10. In short, space is becoming a realm of enormous activity and growing strategic and commercial competition. There are currently more than 1,700 active satellites in orbit and this number is slated to rise to 6,000 within several years. These satellites are a critical lynchpin of the digital revolution. Protecting space-based infrastructure now represents a compelling strategic challenge to societies dependent on these services. This transformed commercial and strategic environment is now frequently referred to as "new space" and it is clear that disruptive technological and commercial innovations are central elements of the phenomenon.

11. But greater activity in space introduces new costs and risks. Space debris, for example, are a growing threat to this infrastructure. Strategic planners must also account for the vulnerability of satellite systems to hacking and physical attack. It is hardly surprising that space has also become a field for international strategic competition. The United States is the world's leading space power, and Europe has a very significant presence both in military and commercial terms. But there are other actors who are significantly bolstering their space related activities. China's space programme is progressing very quickly, and it is emerging as a major player in space in both commercial and security terms. Japan, the United Kingdom, Iran, North and South Korea and New Zealand, to varying extents, are all important players as well.

12. The *arsenalisation* of space is underway, even if the deployment of nuclear weapons in space is prohibited under international law. Russia has deployed military satellites that appear to be tracking critical Western satellites. In 2007, China demonstrated its anti-satellite capability by destroying a satellite in high orbit. That demonstration was a success, but the result was the scattering of hundreds of debris at a relatively high orbital range, which ensures that these debris will pose a danger for years to come before they finally return to the atmosphere. The Chinese test left debris that could destroy other satellites in the event of a collision, which would be costly and would create an even larger debris field that could destroy even more satellites. There are justified concerns that the proliferation of debris in orbit could

render parts of space unusable. Such an eventuality would obviously dramatically impinge on global communications architecture. It would also have significant impacts on national militaries given their high level of dependence on space-based communications and intelligence-gathering systems. Efforts are underway to track some of the debris in key orbits, but there are many debris that are not tracked and cannot be fully accounted for.

13. General Friedling said that, because of these developments, efforts are underway to revamp how France and other countries approach space. In July 2018, France announced its own space defence strategy that will include the deployment of Syracuse 4 military communications satellite built by Thales Alenia Space and Airbus Defence and Space. France is also a key player in deploying the Galileo Satellite navigation system, which will have both civilian and military purposes. French defence officials feel that they need to know who is operating in space and what their purpose and capabilities are. It is also essential, in their estimation, to maintain a deterrence capability to deter any hostile acts in space. The French Defence Minister has made this a critical priority. This has an important human resources dimension, as highly trained and talented people are needed to develop and control the space-based systems needed for economic advancement and national security. France leverages its partnerships with its European allies, the United States and other players to maintain its own edge in space.

14. There are also important outstanding questions about the governance of space. The Space Treaty remains the most important source of law governing space, but it is very limited in scope and there are compelling questions about enforcement. The growing use and importance of space suggest that more rules are needed to ensure access and proper stewardship. There is also a rising requirement for space surveillance of satellite manoeuvres and positioning, debris, unfriendly actions, military deployments and unusual behaviour. These are all areas where international cooperation and norm development are essential.

15. Jean-Paul Granier, from France's Directorate General for Armaments, spoke to the delegation on the influence of New Space on the space industry. He reiterated that the French Joint Space Command which was established in 2013 illustrates the degree to which the space domain is now a central element of French military doctrine. France has developed a strategy for dealing with threats in space. It is now updating this to better cope with the developments linked to the phenomenon of new space. The French have launched several space-based military programmes including a new satellite for observation and intelligence. The Syracuse 4 military communications satellites will serve the French armed forces and replace the Syracuse 3A and 3B satellites, which were launched in 2005 and 2006 respectively. These new satellites will enter in service in 2021 and will give France a higher performance system. The Syracuse 4 satellites will be able to counter the most extreme jamming methods due to an active anti-jamming antenna and a digital onboard processor. The two Syracuse 4 satellites will be launched on Ariane 5 ECA rockets between 2020 and 2022. New surveillance capabilities are also under development, and there will be systems in place to enhance the monitoring of objects in low orbit. Some of these programmes are being undertaken in cooperation with key allies like Germany. France is also developing systems to protect its satellites from attack and respond quickly to hostile action. The rules governing military action in space are currently very soft, and there is wide latitude for a range of actors to operate militarily in space. This represents both an opportunity and a risk.

16. Although the UN is the leading institution on space governance, it does not conduct threat analysis. Allied countries need to invest resources to develop these capabilities. France also wants to ensure that it has a place at the table whenever rules governing space are hammered out. It clearly does not want a single dominant space player setting all the rules. But it needs to enhance its technology and presence in space to ensure that its voice is heard. US efforts to control the export of its technology also poses potential problems to countries like France. This is one reason the French are so keen on developing their own technologies, over

which they can exercise full control. But technology development unfolds in an international rather than a strictly national setting. With the advent of reusable launchers in the United States, for example, Europe confronts a new set of competitive challenges that will doubtless drive technological development.

17. Like the United States, France is working on space-related technologies with dual use potential, such as nanosatellites, which can be used for surveillance purposes but also have commercial applications and might, for example, expand the potential for the so-called internet of things. The commercialisation of technologies originally developed for military purposes and vice versa can help build scale into the system and drive down unit costs in a field that is growing increasingly competitive. The New Space paradigm makes competition a central feature of technology development. The emergence of SpaceX and Blue Origin have compelled the European launching sector to drive down costs and develop new and competitive technologies, products and service. But innovation is taking place across the board and this has triggered a paradigmatic shift in the space business and how states conceive of space policy.

18. The European and US space markets are very different. The United States have a different capital structure and seems more comfortable with risk. This has made it easier for start-ups in the United States to tap into the finance needed to innovate in the space economy. There are start-ups in Europe as well, but they face more challenges given the structure of European capital markets and risk preferences, which are also culturally and historically informed. The United States enjoys a large consolidated budget for space-related military research which no European country can match. The US Defense Advanced Research Projects Agency (DARPA) can afford to undertake risky research projects, whereas French agencies feel more compelled to target their research on projects with a higher probability of yielding practical outcomes. At the same time, France recognises that in the new space order, the state cannot act alone and start-ups will become an increasingly important pillar of space development.

19. The EU historically was left out of defence market deliberations, but it is increasingly playing a role, particularly as technology spins in from the commercial sector to the military sector. Still there are limits to the EU's role and national governments continue to take a proprietary view on the development of some military technologies, including those with space applications. The need for a degree of defence autonomy is clearly an aspect of France's approach to the issue, and the whole question of US export controls has made this issue more apparent. In short, allies and partners are also competitors, and this makes the space-industrial-military nexus complex and evolving.

20. Eloi Petros, a PhD Student at the Université Paris-Sud and ArianeGroup, addressed the delegation on law and space and the French example. Mr Petros noted that although there is some international law and a range of norms and standards shaping activity in space, these are not highly developed and there is thus a high degree of legal ambiguity surrounding space operations. Different institutions also operate within their own structure. The European Space Agency, for example, operates with its own set of rules as well as those agreed upon internationally. These are essentially linked to the peaceful use of space. There are also questions about private law and the law of contracts. Mr Petros mentioned five treaties of direct relevance to space law, including the 1967 Outer Space Treaty (OST) which provides the essential guidelines governing the use of space. There is also the Agreement Governing the Activities of States on the Moon and Other celestial bodies that turns jurisdiction of all celestial bodies over to the international community. But this law has been ratified by only 18 states and by no state that engages in self-launched manned space exploration or states that plan to do so, including the United States, most members of the European Space Agency, Russia, China and Japan.

21. Most of what passes for governance takes the form of non-legally binding norms as well as UN resolutions and government regulations and practices. Because space law is so limited, national laws assume a degree of importance, particularly when considering the laws of major actors in space. Interestingly, there are no binding international laws on debris and debris generation, but an *ad hoc* group has been formed to draft technical regulations to limit debris. This group has no legal standing as such, but many countries have adopted these standards as well as other non-binding agreements. This kind of practice helps impose a degree of uniformity to national rules governing activities in space. It also points to the degree to which rule making for operations in space has become a bottom up rather than a top down process. It is also worth noting that article 189 of the EU's Lisbon Treaty creates a shared competence on some space-related matters. The European Space Agency is also providing EU members with a set of shared norms, even if they are not elevated to the level of law.

22. Luxemburg has been the first European country to implement legislation extending private operators' assurances regarding the ownership of the resources that they extract in space. This law secures the right of private operators working in the space sector to resources that they have extracted in space. It also regulates the approval and surveillance of missions to explore and use space resources. This legal framework is one of the main pillars of the strategy adopted by the government as part of a space resources initiative to develop the space exploration sector and the use of space resources. The law creates a licensing and supervisory regime in Luxemburg addressing the ownership of resources acquired in space. The law is similar to the US Commercial Space Launch and Competitiveness Act and states that commercial companies operating within its regulatory framework may legally appropriate resources acquired in space from celestial bodies known as Near Earth Objects (NEO). Space law does not apply to satellite communications, orbital positions or the use of frequency bands. The Luxemburg law creates a modicum of legal certainty for commercial projects in the space sector. The Outer Space Treaty of 1967, signed by 107 countries, established principles for the peaceful and free exploration of space by nation states. However, the OST does not address the ownership by private organisations of the resources harvested from NEOs through processes such as asteroid mining. The Luxemburg law potentially provides a framework for the future mining of celestial objects. The law, which obviously builds on existing space law, is generally considered a major advance in space law and is likely to influence other national legislative packages.

23. Liability rules are also key drivers of how states operate in the space field. States from which rockets are launched, for example, are generally considered responsible for any damage stemming from that launch. France has rigorously upheld these kinds of rules and elaborated norms for the various phases of launch. It demands guarantees for damages and liabilities. This, however, is a financial guarantee and not insurance as such, but it plays a similar function.

24. The delegation visited Arianespace Launch Services in Les Mureaux outside of Paris to meet with corporate leaders and advisors, and to visit facilities in which the Arian 5 Launchers are assembled prior to shipment to launch facilities in French Guiana, the European Space Agency's primary space launch centre. A joint company owned by Airbus and Safran, the Ariane Group is 50% French and 50% German owned but its mission is to accord all of Europe access to space. It has 9,000 employees in France and Germany. It is very focused on the space launch sector and works on related equipment and service markets while serving both the military and civilian sectors. While the civilian sector is European, the military side of the company is French, and this requires proper separation of research and production facilities as well as all data systems. The view of management is that these two sectors reinforce each other and provide scale to the company's production. At the time of the meeting, the company had just marked the 100th launch of the Arian 5 Rocket, which can launch two satellites at once and has helped drive down costs in that sector.

25. The Ariane launch programme involves over 60 companies, and many of these are now involved in the development of the next generation Ariane 6 launch vehicle. This programme is very focused on further driving down costs and has acutely felt competitive pressures from new players like SpaceX. There is also intense competition from China, Russia and India, and this competition has helped drive down costs while creating new opportunities in the space market. Currently, 23% of the Ariane Group work force is female and there is a concerted effort to increase the number of women working in the company and the field.

26. The Ariane 6 launcher can deploy either two or four boosters depending on payload and target orbits, and the Vinci Engine will be reignitable, is set to be the largest monolithic booster in the world. Ariane 6 will not feature reusable boosters, in part because the economics do not work out given the number of planned launches. The company is, however, conducting research on the technology. The programme has helped spawn important advances in a number of technologies aiming to lighten the aircraft and drive down costs. This is a significant technological and economic undertaking and it has spawned commercial spin off industries, some of which have nothing to do with space as such. The company is also developing launch pad technology and advanced testing systems. Although it is serving commercial markets, Ariane is also fully conscious that its success can further enhance European autonomy in space. And while its military function supports French deterrence, it is very conscious of the need for interoperability across the Alliance and the commercial field and has sought to incorporate considerations of this need into its relevant space programmes.

27. Driving down cost is a central priority of management and there is commercial imperative to do so in order to remain competitive. This requires management and engineers to constantly challenge existing assumptions, to closely collaborate with customers and to innovate relentlessly.

28. On the defence side, the company is working to enhance situational awareness for the military and to play a part in the development of Ballistic Missile Defence. It is critical to understand how BMD advances are shaping future requirements for delivery systems. Arian has worked with the NATO theatre BMD programme and on territorial defence and has helped develop an array of interceptors and early warning systems that detect infrared plume signatures. It is also working on NATO command and control systems as well as on an array of optical surveillance satellites.

29. The company is acutely aware of the changes underway in the space sector and needs to respond to the mounting competition posed by new players including new state entrants into the space sector as well as non-state actors and corporations. This has resulted in the democratisation of access to space, which is fundamentally altering the market and driving rapid technological change with implications for many different commercial and military endeavours.

30. The delegation had the opportunity to visit the campus of Thalès-Alenia-Space to learn about the satellite, antenna and radar systems and programmes on which it is working, a number of which extend beyond the realm of specifically space-oriented products. The company has facilities in France, Italy, Belgium, Germany, the United Kingdom, Switzerland and Poland and is very European in scope. It ranks among the world leaders in telecommunications satellites and military satellites and has pioneered a number of communications innovations which now help link up the global communications system. Moreover, it is a key player in the Galileo programme. The company designs and manufactures satellites for navigation, Earth observation and meteorology, as well as intelligence and surveillance systems including the Syracuse satellites used by the French military. It has recently produced a prototype of a high atmosphere balloon, the Stratobus, that can be placed in a stationary deployment for a year in the stratosphere (20,000 meters) and functions as an observation and communications satellite. This high atmosphere balloon has

both military and commercial communications applications and has attracted great interest among potential clients. Thalès-Alenia-Space also works in the realm of space exploration and has produced roughly half of the modules on the international space station. It is also working on projects related to Mars exploration.

31. The delegation visited the Toulouse campus of the French Space Programme Agency (CNES - *Centre national d'études spatiales*), which supports and conducts much of the critical research for France's commercial and military space programmes. The centre has a budget of roughly EUR 2.4 billion to support this effort, which has helped make France the world's second most important player in space. The work of the Centre is varied and touches the entire cycle of space systems from basic research, satellite engineering, command and control of satellites and ground station designs, to data generation and management and earth observation. The Centre works very closely with the universities and diverse array of space and aeronautic firms working in the region. It has conducted pioneering work on nanosatellites, which have helped drive down costs in the telecommunications business. CNES has sought to support start-up companies with potentially important technologies and it underwrites basic scientific research in areas as diverse as the origins of the universe and climate change. It also supports international programmes aiming to carry out a mission to Mars. Moreover, it engages in long-range forecasting in order to shape the research and investment agenda.

32. CNES is a leader on coping with the problem of space debris. It has supported efforts to track 23,000 objects, many of which are in low orbit. Only a small percentage of these are satellites. Every time a collision occurs, more debris are created and the problem worsens. CNES is working with the European Space Agency, the Japanese Space Agency and NASA to avoid collisions in critical orbits—a process which can involve the frequent repositioning of satellites. The effort requires CNES to manage 7,000 messages a day regarding potential collisions in space. The case of China's anti-satellite test is instructive in this regard. That single event in 2007 created an estimated 20,000 pieces of debris in an orbit that ensured that these debris would pose problems for decades. The problem is that such events can render critical orbit areas unusable. This poses a serious potential threat to global communications systems and to the digital economy. CNES is also supporting research on how this problem can be addressed. Clearly, the best approach would be to minimise debris generation in the future. This is an area where greater international cooperation and the establishment of respected norms would be welcome.

33. Earth observation and optical research have been another research priority. The delegation was shown three dimensional images of Earth taken from satellites—a technology with myriad commercial, scientific, environmental and military applications. It also visited a control centre through which CNES scientists and engineers interact with US colleagues in Pasadena, California operating the Mars Rover. Coordinating the Rover is a complex task which engages 200 specialists on a daily basis.

34. Finally, the delegation visited the headquarters of Airbus Defence & Space in Toulouse. The delegation learned about the Airbus OneWeb satellite programme, which aims to launch 900 microsatellites to provide affordable internet access to the entire world. The first satellites are being deployed in 2018. This is an ambitious project that has also demanded rapid satellite manufacturing. The delegation toured a production line that has revolutionised and streamlined satellite manufacturing, making it both less worker intensive and dramatically quicker.

35. 40% of the revenues of Airbus are now generated in its space programmes. The company is thoroughly European and is the second largest global player in global aviation markets after Boeing. The company is also a global leader in the production of satellites with military, surveillance, telecommunications, commercial, scientific, Earth observation, radar, imaging, and meteorological applications. It has recently developed a High-Altitude Pseudo-Satellite (HAPS) that fills a capability gap between satellites and unmanned aerial vehicle

(UAV). The Zephyr is a solar-electric, stratospheric UAV and the first unmanned aircraft of its kind to fly in the stratosphere. It runs exclusively on solar power, above the weather and conventional air traffic and is able to fly for months at a time, combining the persistence of a satellite with the flexibility of a UAV. It has military, scientific and commercial applications and is yet another example of how innovation is revolutionising the space domain.
