Department of Commerce, Bureau of Industry and Security: Request for Comments in Response to Advanced Notice of Proposed Rulemaking Regarding Review of Controls for Certain Emerging Technologies

Reference: **83 Fed. Reg. 58201 (Nov. 19, 2018); RIN 0694-AH61; Docket # 180712626-8840-01; BIS 2018-0024**

COMMENTS OF THE SMALL UAV COALITION

The undersigned, on behalf of the Small UAV Coalition ("Coalition"),[1] submits these comments in response to the Federal Register notice published on November 19, 2018 (83 Fed. Reg. 58201). The Coalition welcomes this opportunity to provide the Bureau of Industry and Security ("BIS") its comments in response to the Advance Notice of Proposed Rulemaking ("ANPRM") regarding the Review of Controls for Certain Emerging Technologies.

I. EXECUTIVE SUMMARY

The Coalition supports reasonable export controls where necessary to protect U.S. national security. However, it believes controls on emerging technologies must be carefully tailored to address specific, well-defined national security interests, and must balance the need to protect a small number of sensitive technologies against the considerable harm that over-control would cause to impacted U.S. industries. Upon review of the ANPRM, the Coalition has determined that a significant number of the enumerated categories and subcategories of representative emerging technologies under review may cover current and developing drone and other unmanned aircraft system ("UAS") technology. This includes technologies critical to the promotion of safer and more efficient operation of UAS in civil commercial applications.

Imposition of new export controls over emerging UAS technology could have a significant negative impact on the development of such technologies in the United States without being effective at limiting the proliferation of those technologies in foreign countries. Improperly tailored controls relevant to UAS technology could discourage investment, interfere with aviation safety, impede U.S. technological and commercial innovation and compromise U.S. leadership in important sectors of the global economy. Further, they could not only fail to protect essential U.S. national security interests, but could ultimately undermine them in significant ways.

In considering the Coalition's comments, BIS should consider that:

- Mature technologies that are already in production should not be subject to controls as "emerging technologies." The fourteen categories of emerging technologies identified in the ANPRM (the "Emerging Technology Categories") are sufficiently broad to cover many technologies that are no longer "emerging" but rather have matured or have begun to mature. Many technologies within these categories have been in development and production for decades in and outside of the United States. For example, while artificial intelligence technology ("AI") may be applied to new products

[1] A list of the Small UAV Coalition members is available at http://www.smallUAVcoalition.org/members/.

in new ways, the actual technology—the algorithms that make up the AI being deployed—is often identical to algorithms that have been widely available, as open source material or otherwise in the public domain, for years.

- Absent a discrete and well-defined national security interest, subjecting emerging technologies being developed for predominantly civil applications to additional export controls could limit innovation, advancement and adoption, and thus compromise American technological leadership and the objectives of improving safety, efficiency and efficacy. The Emerging Technology Categories include technologies with a broad range of applications, many or most of which are overwhelmingly civil. For example, the same technology behind computer vision is used in self-driving cars to enhance vehicular and pedestrian safety, in UAS to enable safe navigation through the National Airspace System, and in factories and warehouses to improve efficiency and reduce risk. These technologies are basic, undifferentiated tools that can be used in many different applications that raise no cognizable national security concerns meriting imposition of export controls.

- Imposing export controls on UAS-related technologies within the scope of the Emerging Technology Categories would leave us less able to compete for technological leadership, and ultimately less secure. Much innovation in the technologies used in UAS and within the scope of the Emerging Technology Categories is happening outside the United States. These technologies are widely available outside the United States, and in some cases other countries lead the United States in production and development. Without extreme care, attempting to control the spread of these technologies through restrictions that might impact investment, collaboration, hiring of foreign nationals and market access will almost certainly do more harm than good for U.S. national security and technological leadership, as occurred to the U.S. satellite industry. American innovation in UAS-related industries depends on access to a global pool of research, talent and investment. By imposing additional controls on that access, we would be cutting ourselves off from some of the best ideas and most talented experts, and could quickly find ourselves left behind by our global competition.

The UAS-related technologies within the scope of the Emerging Technology Categories provide basic tools to enhance safety and unlock the valuable contributions that UAS can make to the American economy. Tapping the full promise of small UAS depends on some of these technologies, including AI; position, navigation and timing ("PNT") technology; data analytics and others. Subjecting these technologies to additional export controls could threaten the development of UAS technologies in the United States and drive even more innovation offshore, thus undermining U.S. efforts to regain technological leadership in UAS.[2]

The best way to promote U.S. national security in relation to emerging technologies is not to subject them to more restrictions and constraints. We can best ensure U.S. technological security and leadership by providing the most attractive climate for intellectual interchange and innovation. The same formula that led to U.S. success in dominating the emergence of internet technologies years ago should apply here: (i)

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[2] Much of this important market has been ceded to China in recent years. Chinese drone maker DJI holds 70 percent of the global commercial and consumer drone market. *See* Reuters, "Chinese drone maker DJI seeking at least $500 million in funds: sources," March 21, 2018, *available at* https://www.reuters.com/article/us-dji-tech-fundraising/chinese-drone-maker-dji-seeking-at-least-500-million-in-funds-sources-idUSKBN1GY0A7. Fostering a more competitive U.S. drone industry to compete with foreign innovators like DJI can best be accomplished not by imposing additional structural disadvantages and impediments on U.S. industry, as would happen if more UAS technologies were subjected to export controls, but by allowing U.S. companies greater access to leading edge know-how from outside the United States.

establish an intelligent national investment strategy; (ii) promote a regulatory environment that attracts talent and investment, and encourages entrepreneurship; (iii) insist on the effective enforcement of internationally-recognized intellectual property rights overseas; and (iv) use targeted regimes such as the Invention Secrecy Act of 1951 to secure the most sensitive technologies.

II. THE SMALL UAV COALITION

The Coalition is a partnership of leading American consumer and commercial technology companies with a demonstrated history and interest in applying UAS technological advancements to benefit consumers, industry and government. We believe a proper regulatory and policy environment can encourage the growth of the UAS industry and benefit the economy by creating jobs and encouraging increased economic activity. As American companies with a global footprint, we believe the United States should lead technological innovation in the industry and set the global benchmark for operational safety. Towards that end, the Coalition strongly encourages development of a regulatory and policy environment that permits the safe operation of UAS within and beyond the line of sight, and with varying degrees of autonomy, for commercial, consumer, recreational and humanitarian purposes.

III. THE MATURING UAS INDUSTRY AND ITS BENEFITS FOR SAFETY, UTILITY AND COMPETITION

The global UAS industry has expanded and evolved dramatically in recent years, with the value of UAS solutions estimated at more than $127 billion. UAS are already being used in the tens of thousands by hobbyists and commercial operators for an array of tasks, including aerial photography and videography, entertainment, site inspection, industrial operations monitoring, pipeline survey, mapping, fishing and fishery management, disaster recovery, search and rescue, and agricultural tasks such as applying fertilizer and monitoring crops. Possibilities for civil UAS applications in the next several years go much further, particularly if they can operate autonomously and beyond line-of-sight.

To that end, innovations in development of safe systems is critical. Autonomous UAS promise significant improvements to safety, capability and cost in a range of civil applications, including humanitarian assistance, firefighting, logistics and package delivery, medical support, weather monitoring, wildlife management and similar applications. In addition, with a flexible and supportive regulatory environment, UAS development can be a significant source of technical innovation and growth opportunity for the U.S. economy, and provide an important advantage for the United States in related technologies, including, for example, telecommunications, mobile robotics and autonomous vehicles.

IV. COMMENTS IN RESPONSE TO THE ANPRM

To properly assist in tailoring the controls under consideration, the Coalition has structured its comments in line with the seven areas of inquiry identified by BIS in the ANPRM.

1. How to define emerging technology to assist identification of such technology in the future.

The Coalition proposes the following definition for "emerging technology":

Emerging technologies are specific technologies that:

a. are "required" for the "development" of items that:

i. provide the United States with a specific and identifiable qualitative military advantage;

ii. are essential to the national security interests of the United States; and

iii. are not identified on the Commerce Control List or the United States Munitions List;

b. are not available in or being produced in foreign countries; and

c. do not include "production" technology or any aspect of "use" technology for items in production.

The Coalition believes this definition properly focuses on the national security implications of emerging technology-related export controls, while acknowledging the existing coverage of U.S. export controls, consistent with the policy statements and requirements of the Export Control Reform Act of 2018 ("ECRA"). It does so by:

- Focusing on pre-production technology. The proposed definition provides identifiable standards to demonstrate when technologies are no longer emergent. The temporal focus of the definition (*i.e.*, excluding technology once it is in "production," and thus no longer "emergent") recognizes that the purpose behind the statutory focus on emerging technologies is to identify technologies before they reach the production phase.

  The focus on pre-production technology also limits the possibility that U.S. innovators will be disadvantaged in relation to their overseas competitors. Academic, industry and government researchers around the world often pursue similar technologies at the same time. To limit the possibility that a U.S. innovator could be constrained even though an international competitor already has similar technology in production, the definition excludes from control any technology required for the development of items that have reached the production phase outside the United States.

- Using existing Export Administration Regulations ("EAR") terminology. This proposed definition incorporates existing EAR terms from 15 C.F.R. § 772. These terms are widely understood and applied by the corporate and academic communities.

- Addressing explicit requirements of ECRA. Proposed paragraphs (a)(i) and (a)(ii) are calibrated to ensure that emerging technologies implicated by new controls would be limited to those "essential to the national security of the United States," consistent with the requirement in ECRA § 1758(a)(1)(A) that only this type of technology be singled out for unilateral control by the United States. Similarly, proposed paragraph (a)(iii) addresses the requirement in ECRA § 1758(a)(1)(B) that no technology be subject to emerging technology export controls if it is already described on the U.S. Government's export control lists.[3]

2. Criteria to apply to determine whether there are specific technologies within these general categories that are important to U.S. national security.

ECRA is carefully tailored to limit the imposition of emerging technology export controls to only those needed to protect essential national security interests. Consistent with ECRA, the Coalition believes BIS should apply the following criteria to determine whether specific technologies within the Emerging

[3] Notably, existing controls under the EAR and the International Traffic in Arms Regulations ("ITAR") already impose export limitations of a broad array of UAS-related technologies.

Technology Categories are essential to U.S. national security and should therefore be considered candidates for some level of export control:

A. The emerging technologies subject to export controls should be narrowly defined and technically distinct.

To avoid potentially significant harm to U.S. interests, emerging technologies subjected to export controls should be identified based on specific, well-defined technical parameters. Only such well-defined bounds can avoid an overbroad chilling of innovation and commerce. Patent application standards provide a useful baseline: If the technology cannot be distinguished from other technologies with sufficient clarity to satisfy the U.S. Patent and Trademark Office ("USPTO") tests for distinguishing inventions from prior art, then it cannot be defined as emerging technology.[4]

For the same reason, emerging technologies that present essential national security implications must also be technically distinct from technologies that do not pose such implications. For example, attempting to control an AI algorithm would not be effective because the same algorithm may be used for non-defense and defense applications. The difference cannot simply be what data is presented to the algorithm as part of a learning process, or the tasks performed by the algorithm. There must be fundamental and quantifiable differences between the technology itself and similar technologies that do not present national security implications. In the case of AI technology, for example, the Coalition believes there are few such distinctions as the same algorithm is used across a wide range of applications. For this reason, applying emerging technology controls on any AI would likely be harmful across a swath of applications, many of which would have important civil benefits and no relevance to national security.

B. Emerging technologies should not be subject to export controls unless they have known national security implications.

Imposition of emerging technology export controls should be measured, and focus only on technologies most likely to provide critical military or intelligence advantages. Restricting the export of technologies that provide no military or intelligence-specific functionality provides no discernable national security benefit. In fact, it may weaken U.S. national security by stifling innovation and cost reductions in important technology sectors. Further, it would be futile and commercially destructive to control emerging technologies because an application implicating such national security concerns *may* emerge in the future. Many new technologies could have some theoretical military or intelligence application or implication in the future. However, export controls should only be considered for emerging technologies that provide the United States with a current, specific, identifiable, qualitative and essential military or intelligence advantage.

[4] For example, the USPTO requires that in patent applications: "the invention must be explained along with the process of making and using the invention in full, clear, concise, and exact terms. This section should distinguish the invention from other inventions and from what is old. It should also describe completely the process, machine, manufacture, composition of matter, or improvement invented. In the case of an improvement, the description should be confined to the specific improvement and to the parts that necessarily cooperate with it or that are necessary to completely understand the invention." USPTO, Nonprovisional (Utility) Patent Application Filing Guide (January 2014), *available at* https://www.uspto.gov/patents-getting-started/patent-basics/types-patent-applications/nonprovisional-utility-patent#heading-17.

C. Emerging technologies should not be subject to export controls if they have predominant civil applications.

Emerging technologies should only be subject to export controls if they do not have predominantly civil applications. Applying a new level of export controls on technologies when their uses are primarily civil in nature could well undermine U.S. national security by constricting investment and innovation in the United States and encouraging its movement overseas. For example, the U.S. commercial satellite industry's history illustrates how crippling export control restrictions can be for civil industries. U.S. satellite manufacturers held approximately 75 percent of the global commercial communications satellite industry in 1998 when Congress shifted satellites to the United States Munitions List ("USML"). Over the next decade, U.S. manufacturers dropped to 30 percent of the industry, lost an estimated $21 billion in revenue to their European and Asian competitors, and shed approximately 9,000 jobs. While there were many contributing factors, participants in the U.S. commercial satellite industry have indicated that overly broad export control restrictions contributed to this significant opportunity loss for the United States.

ECRA recognizes the risk of over-regulation by expressly advising in its Statement of Policy that "[t]he national security of the United States requires that the United States maintain its leadership in the science, technology, engineering and manufacturing sectors, including foundational technology that is essential to innovation. Such leadership requires that United States persons are competitive in global markets." ECRA § 1752(3). This admonition, paired with ECRA's focus on controlling only those emerging technologies "essential to the national security of the United States," weighs heavily in favor of excluding from new export controls emerging technologies that are predominantly civil in nature and focusing instead on technologies with current, specific, identifiable, qualitative and essential military or intelligence capabilities.

D. Mature and maturing technologies should not be subject to emerging technology export controls.

As detailed further below, several of the UAS-related technologies within scope of the Emerging Technology Categories have already reached high levels of maturity. Such technologies are no longer "emerging," and BIS should not impose controls on them, or the building blocks from which they are made, under ECRA. This is especially true for the general-purpose tools that provide the technology for AI. While most of these tools are open source and thus publicly available, even controls on non-public AI tools and building blocks would be damaging. If these tools or the technologies they enabled were subject to export controls, we can expect engineers in other countries to develop their own and innovate in a more flexible environment that fosters collaboration within a global development community. Even if only controlled for export to certain countries, developers in countries not subject to U.S. controls will be reluctant to innovate and advance technology in an environment limited by export restrictions. The United States would largely forfeit its ability to tap into global talent and resources, limiting development of new products and services created with these mature and well-established technologies.

E. Emerging technologies widely available outside the United States should not be subject to export controls.

Any export controls imposed on emerging technologies must be effective at limiting proliferation of covered technologies in foreign countries. As noted in ECRA's Statement of Policy, "[e]xport controls applied unilaterally to items widely available from foreign sources generally are less effective in preventing end-users from acquiring those items. Application of unilateral export controls should be limited for purposes of protecting specific United States national security and foreign policy interests." ECRA § 1752(6). Accordingly, in the case of emerging technology

export controls, ECRA requires that BIS account for "(i) the development of emerging and foundational technologies in foreign countries; (ii) the effect export controls . . . may have on the development of such technologies in the United States; and (iii) the effectiveness of export controls . . . on limiting the proliferation of emerging and foundational technologies to foreign countries." ECRA § 1758(2)(B)(i) – (iii).

As discussed in more detail in Part IV(5), below, in the case of UAS-related technologies, imposition of emerging technology export controls would be highly unlikely to be effective at limiting the proliferation of those technologies in foreign countries. Not only are UAS manufacturers and developers in other countries actively advancing many of these technologies, but much of the underlying technology is open source in nature, originated outside the United States, is being actively developed inside and outside the United States, or is otherwise already widely available outside the United States.

F. Emerging technologies that are already controlled should not be subject to additional export controls.

Consistent with ECRA and the definition of "emerging technology" proposed above, BIS should not apply emerging technology export controls to technologies that are already subject to control via listing on the USML, the Commerce Control List ("CCL") or under other U.S. export control designations. Any product that has already been considered and subjected to control should by definition not be considered an emerging technology.

3. Sources to identify such technologies.

The Coalition believes the use of Technical Advisory Committees ("TACs"), the national security investment review process managed by the Committee on Foreign Investment in the United States ("CFIUS"), relevant professional bodies and national security-related investments by U.S. government agencies provide useful resources for identifying specific emerging technologies. As a general matter, BIS should also establish and encourage confidential channels for entities to provide information on cutting edge technologies without compromising the commercial viability of those technologies.

A. Technical Advisory Committees, including the Emerging Technology TAC

TACs provide one of the best resources for identifying emerging technologies that may have essential national security implications, and for properly defining those technologies to minimize the potential harm to other U.S. interests including commercial success, innovation and global leadership. Given the fast pace of emerging technology development, it is critical that government and industry work together to enhance an understanding of specific technologies.[5]

B. Professional Bodies

Many of the technologies identified in the Emerging Technology Categories have dedicated professional organizations serving as standard setters, fora for technical dialogue and repositories of knowledge. For example, the Institute of Electrical and Electronics Engineers ("IEEE") provides a range of publications, technical councils and communities that could be consulted as part of the

[5] The Coalition understands that the Emerging Technologies TAC intends to provide comments in response to the ANPRM.

process of identifying emerging technologies and their applications. Numerous other professional bodies serve elements of the fourteen Emerging Technology Categories.

C. Information from CFIUS Process

The Coalition recognizes that with the recent changes to the CFIUS process, particularly the Critical Technologies Pilot Program, the U.S. government will gain greater insight into foreign investment flows and the technologies being developed both inside and outside the United States. Under this criterion, the lessons learned from the CFIUS process should be proactively applied to better identify specific emerging technologies with national security applications. For example, CFIUS reviews could specifically request information about technologies under development as part of the review process for acquisitions in those industries implicated by the ANPRM.

D. U.S. Government National Security Investment Vehicles

Finally, BIS may be able to use the Defense Advanced Research Projects Agency ("DARPA"), In-Q-Tel and similar government national security investment sponsors to identify specific technologies that qualify as emerging technologies potentially meriting export controls. Such agencies are in the business of identifying, promoting and protecting specific technologies that may have national security applications, and could presumably offer insight into what pre-production technologies may be essential to the national security of the United States.

4. Other general technology categories that warrant review to identify emerging technology that are important to U.S. national security.

The Coalition has no comment on this question.

5. The status of development of these technologies in the United States and other countries.

The Coalition is aware of several instances where UAS-relevant technologies within the scope of the Emerging Technology Categories are being developed and commercialized inside and/or outside the United States. Broadly speaking, global UAS development is focused on several maturing technology areas that cut across the categories of technologies identified by BIS. These include the detection of objects and people in image and videos using machine learning, including using multiple cameras of different types; building three dimensional representations of the world by analyzing images and video; and planning actions and routes using constraints to achieve particular goals. More detailed examples of how these maturing technologies are being developed within a few of the Emerging Technology Categories are provided below. However, none of them would qualify as "emerging technologies" per the Coalition's proposed definition, both because they are already in wide production and use for civil applications, and because any potential military or intelligence applications appear to be technologically indistinguishable from their civil applications.

A. AI – Computer Vision (*e.g.*, object recognition, image understanding)

As a maturing technology, AI has been widely developed and is widely available in and outside the United States. Access to the global community advancing this technology is critical to the United States' continued safe development of UAS. Imposing export restrictions on this technology would do nothing to preserve national security interests. Rather, it would halt the development of safe UAS in the United States and clear the way for competitors across the globe to take advantage. As just a few examples of relevant technologies:

i. Small UAS can now utilize multiple computer vision technologies to detect and understand the environment in which the UAS is operating to avoid collisions or safety hazards, and to plan actions to achieve a specific goal, such as landing in a certain location.

ii. Small UAS can now build a three-dimensional digital representation of the world environment by analyzing images and video. Stereo camera imagery is analyzed by block-matching algorithms to create a depth map of surrounding objects and terrain. Digital world representations are also built using single-camera algorithms and motion analysis. Implementations of these algorithms are available in OpenCV, a BSD-licensed open source library that is in the public domain.[6]

iii. Objects within small UAS operating environments are now perceived from images using machine learning techniques. Convolutional neural networks ("CNNs") are a widely-used algorithm that process structured visual datasets to extract common characteristics about images in the dataset. Once the algorithm is trained with the dataset's characteristics, it can be applied to recognize objects, humans or animals.[7] In its application to small UAS, CNNs trained with environmental and object-specific datasets are used to detect aerial hazards such as trees, birds and other aircraft, and to detect safety hazards on the ground such as humans, animals, vehicles and furniture. CNN implementations and training datasets are available in a wide variety of open source packages.

Notably, computer vision and machine learning algorithms from open source distributions are critically important for safety and life-saving applications in various industries, including UAS, self-driving cars, safety improvements for human-driven cars such as automatic braking systems, and medical devices for disease detection (*e.g.*, pathological analysis of samples). Computer vision and machine learning algorithms are also included in consumer devices as varied as mobile phones (facial recognition) and home robotic vacuum cleaners (navigation and safety).

This technology is being developed and produced widely across the globe thanks to a global regulatory environment that enables cross-border collaboration. Companies such as Mobileye (Israel), Adasky (Israel), Subaru (Japan) and DJI (China), among others, are involved with its development and commercial deployment.[8] In the context of small UAS, combining computer

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[6] There are several algorithms that are relied on in the context of commercial drones including matching algorithms similar to OpenCV block matcher. References for block matching can be found at https://docs.opencv.org/3.0-beta/modules/cudastereo/doc/stereo.html.

[7] Two CNN algorithms are commonly used for machine learning-based object detection on computationally-limited embedded systems, which includes UAS: (i) "You Only Look Once (YOLO)" and (ii) "single-shot detector." Both of these algorithms may be found in general literature. An example of an extensively testing YOLO implementation from ETH in Switzerland can be found at https://github.com/leggedrobotics/darknet_ros. References for the YOLO algorithm can be found at https://pjreddie.com/darknet/yolo/. References for single-shot detector may be found at https://leonardoaraujosantos.gitbooks.io/artificial-inteligence/content/single-shot-detectors.html.

[8] For example, DJI, headquartered in Shenzhen, PRC (known as the "Silicon Valley" of China) is the largest consumer drone-maker specializing in UAVs. DJI benefits from direct access to a competitive global work force and supply chain. DJI "focus[es] on transforming complex technology into easy-to-use devices," and creates UAV "products that combine advanced technology with dynamic designs." It is known within the industry for obstacle avoidance technology. DJI crowd sources updates to its products from its vast global user community. Updates prompted by users include swarming technology, 3D mapping and the potential for facial recognition. See related information at https://www.dji.com/company; https://www.economist.com/business/2015/04/11/up and https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=270064016.

vision with other onboard sensing technologies such as sonar, lidar and radar is important in enhancing safety and meeting FAA requirements for exercising vigilance in avoiding other objects.[9] This allows the introduction of safe automation that meets or exceeds current levels of human performance with regards to aircraft and obstacle avoidance.

B. Position, Navigation and Timing ("PNT") Technology

PNT technology is another maturing technology that is being widely developed and made available in and outside the United States. Accordingly, restriction of PNT technology exports would serve no cognizable national security interest. At the same time, the United States needs access to global talent and resources advancing this technology to develop safe UAS in the United States on par with or ahead of global competitors.

The core algorithms that underpin PNT technologies are available in many textbooks and open source repositories.[10] As this and related technology are used in any drone system that follows waypoints, it has been and continues to be developed both inside and outside the United States, for example by Parrot (France) and DJI (China). Furthermore, international organizations and academic institutions dedicated to understanding and advancing PNT technology are critical sources for continued development. [11] Once again, this technology has important safety

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AdaSky uses LWIR and advanced machine vision algorithms for human detection as products for cars. According to the company, "AdaSky's image processing and computer vision algorithms process the signals collected by the camera to provide accurate object detection and scene analysis, giving the vehicle a new layer of information." See this and other information at http://www.adasky.com/.

9 *See* 14 CFR § 91.113 (Right-of-way rules: Except water operations).

10 Examples of open source technology include ETHZ MSF (https://github.com/ethz-asl/ethzasl_msf); Kalman.sourceforge.net and TinyEKF (https://github.com/simondlevy/TinyEKF). Examples of textbooks on the subject include:

- *Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Second Edition (GNSS Technology and Applications)*, Groves, Paul D. (2013). This book provides a "current and comprehensive understanding of satellite navigation, inertial navigation, terrestrial radio navigation, dead reckoning, and environmental feature matching. It provides both an introduction to navigation systems and an in-depth treatment of INS/GNSS and multisensor integration. The second edition offers a wealth of added and updated material, including a brand new chapter on the principles of radio positioning and a chapter devoted to important applications in the field. Other updates include expanded treatments of map matching, image-based navigation, attitude determination, acoustic positioning, pedestrian navigation, advanced GNSS techniques, and several terrestrial and short-range radio positioning technologies."
- *Fundamentals of High Accuracy Inertial Navigation (Progress in Astronautics & Aeronautics)*; Chatfield, A., (1997). "The primary focus of Fundamentals of High Accuracy Inertial Navigation is on the physical and mathematical principles forming the basis for inertial navigation. The material in the book is directly applicable to the inertial navigation of all types of vehicles whether on land, in or on the ocean, in the atmosphere, or in space in the vicinity of the Earth."
- *Applied Mathematics in Integrated Navigation Systems, Third Edition (AIAA Education)*; Rogers, Robert M. (3rd ed., 2007). "The subject of integrated navigation systems covered in this book is designed for those directly involved with the design, integration, and test and evaluation of navigation systems. It is assumed that the reader has a background in mathematics, including calculus. Integrated navigation systems are the combination of an onboard navigation solution (position, velocity, and attitude) and independent navigation data (aids to navigation) to update or correct navigation solutions. In this book, this combination is accomplished with Kalman filter algorithms."

11 ION is "a not-for-profit professional organization dedicated to advancing Positioning, Navigation and Timing (PNT). ION's international membership is drawn from many sources including professional navigators,

applications for small UAS operation. Accurate estimates of air vehicle position, orientation, velocity and other parameters enable airspace integration with other aircraft, better ability to keep the vehicle in the intended position and preserve safe separation margins, and better responses to off-nominal events. Each of these decrease the chance the UAS may collide with another vehicle, structure, person or object.

C. Data Analytics Technology – Visualization and Automated Analysis Algorithms

Data analytics is another maturing technology that, if subject to export controls, would disadvantage the United States in developing safe and competitive UAS, without serving any cognizable national security interest. Data analytics technologies are widely used across the world in many scientific and industrial projects, and are widely available as open source.[12] Much like the commercial airline world has accomplished, advanced data analytics technology provides the UAS industry opportunities to identify and mitigate risk factors and identify precursors to hazards. For example, visual technology of this type helps Coalition members better understand performance and safety issues (*e.g.*, a graph motor or battery temperatures) to ensure safe operations.

All of these technologies—and others—are important for the advancement of UAS in the United States. Access to global sources and talent that are developing these technologies today is critical to this advancement. Restricting the development and application of these technologies by subjecting them to emerging technology export controls would conflict with industry and government safety efforts and further disadvantage the U.S. UAS industry in relation to its overseas competitors.

6. The impact specific emerging technology controls would have on U.S. technological leadership.

The Coalition believes additional export restrictions on the UAS-related emerging technologies identified in the ANPRM would undermine U.S. innovation and technological leadership, and do more harm than good for U.S. national security. By further isolating U.S. companies from the global marketplace for ideas and talent, such restrictions would push innovation offshore and advantage our adversaries while harming our own industries.

First, research and development with respect to UAS in the United States depends heavily on the employment of non-U.S. scientists and engineers, who contribute to algorithms and other technologies to

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engineers, physicists, mathematicians, astronomers, cartographers, photogrametrists, meteorologists, educators, geodesists, surveyors, general aviation and airline pilots. Corporate members include corporations, civil and military government agencies, private scientific and technical institutions, universities and training academies, and consulting firms." ION sponsors technical meetings that provide the "opportunity to exchange technological information on the various navigation and positioning systems," including:

- ION GNSS+ Meeting (Sponsored by the ION Satellite Division)
- Joint Navigation Conference (Sponsored by the ION Military Division)
- Pacific PNT (involves policy and technical leaders from Japan, Singapore, China, South Korea, Australia, and the United States)
- IEEE/ION Position Location and Navigation Symposium ("PLANS")
- Precise Time and Time Interval Meeting ("PTTI")

See Institute of Navigation (https://www.ion.org/).

[12] The Jupyter and Matplotlib projects are examples that are in heavy use in academia at dozens of institutions. Jupyter (https://jupyter.org/) is an open source project designed to support interactive data science and scientific computing across all programming languages. Matplotlib (https://matplotlib.org/) is an open source library project for the Python programming language to produce 2D plots.

strengthen American efforts. For example, many AI development teams in the United States are staffed fifty percent or more by non-U.S. engineers. Universities in the United States do not provide enough skilled engineers to fill all the roles required to maintain U.S. leadership in these areas. Imposing additional export controls on hiring of non-U.S. engineers would seriously constrain the ability of U.S. companies and research organizations to appropriately staff their teams, and could benefit America's adversaries by closing the U.S. market to much of the world's best talent in these fields.

Second, innovation and leadership are fundamentally dependent on international collaboration in those categories of greatest relevance to the Coalition. The United States is an important but not dominant player in AI, PNT and data analytics. Its companies and universities rely heavily on the ability to share concepts, applications and code with overseas partners. For example, the power of AI research in computer vision is largely in open source, where companies, researchers, government labs and others can share enhancements and build on one another's work. Many industry and academic teams developing computer vision and other AI technologies are international in scope, with well-developed resources in Israel, Asia, Europe and North America collaborating to develop the fundamental technologies behind computer vision and its deployment in small UAS. Overly restrictive or poorly-defined controls could limit Coalition member companies and other U.S. researchers' ability to contribute to and benefit from these powerful platforms for innovation, and thus inhibit their opportunities to develop and deploy cutting edge computer vision and other AI tools in UAS and other applications.

Finally, the United States is not alone in developing many of these technologies, including in the small UAS sector. If burdensome export controls are placed on that development, the rest of the world will continue to innovate in these areas, with the United States increasingly cut off from cutting edge technology. This would leave us less well-off and less secure than we are now.

7. Any other approaches to the issue of identifying emerging technologies important to U.S. national security, including the stage of development or maturity level of an emerging technology that would warrant consideration for export control.

As emphasized above, the Coalition believes that when defining emerging technologies and imposing related export controls, it is critical to focus on:

- Truly "emerging" technologies. The purpose behind ECRA's inclusion of emerging technologies is to identify and assess for control those technologies in development that are too new to have been reviewed as part of the normal multilateral process for controlling relevant technologies.

- Controlling specific technologies, not applications. Emerging technologies should be identified based on specific technical parameters. The underlying technologies used in many of the Emerging Technology Categories are quite similar between those with national security-related applications and those with only civil uses. Employing vague definitions for controlled emerging technologies could inflict significant collateral harm on important civil technologies, with potentially disastrous results for the U.S. economy.

- Only controlling discrete technologies that provide the United States with a current, specific, identifiable, qualitative military or intelligence advantage. It is not appropriate to the purposes of ECRA to impose export controls when emerging technologies could have a theoretical national security application in the future, but rather when they currently present a specific and essential military or intelligence advantage.

- Only controlling emerging technologies that do not have important civil applications. Applying a new level of export controls on emerging technologies with important civil applications could well

undermine U.S. national security by constricting investment and innovation, and encouraging proliferation within America's adversaries.

V. CONCLUSION

The Emerging Technology Categories identified in the ANPRM hold great transformative potential, including in enhancing the safety and performance of small UAS. The most effective way to further U.S. national security in this area is to ensure that any additional controls on these technologies are targeted at technologies still in development that have discrete applications with essential national security implications. The Coalition strongly encourages BIS to refrain from creating more structural impediments to the commercial potential of UAS in the United States. Instead, the U.S. Government should promote U.S. national security by fostering U.S. innovation through investment, regulatory reform and enforcement of existing international IP obligations.

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