The Loudest Voice in the Room

STS Research Paper
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By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

A 1U CubeSat is no larger than a box of tissues, yet it has fundamentally changed the global aerospace and defense industry. This small satellite is not praised, however, because it can do more than other research spacecraft. Rather, it has been so impactful because it can do just as much at a fraction of the cost (Chin et al., 2017). This has pushed the aerospace and defense industry to pursue space research technologies that are low-cost and reliable. With a volume of only 10 cubic centimeters, the CubeSat has proven that large-scale change can be affected by small-scale technological systems.

The CubeSat, though, was not developed arbitrarily. This technology is the product of a need, specifically in the United States, for cheaper space research satellites that were still able to collect reliable data. In 1999, California Polytechnic State University professor Jordi Puig-Suari and Stanford University professor Bob Twiggs designed blueprints for a small satellite to satisfy this need (Chin et al., 2017). Only two years later, the U.S. Air Force's picoSAT 1 & picoSAT 2 were constructed and launched into Low Earth Orbit (LEO) (Swartwout, 2013). Their early successes prompted the immediate construction and launch of six more picoSATs, demonstrating the strength of Puig-Suari and Twigg's blueprints. By 2005, 22 CubeSats had been launched (Swarthwout, 2013; Villela et al, 2019), clearly indicating that the U.S had successfully developed a technological artifact to satisfy the need for cheap, reliable space research.

STS Framework: Social Constructivism

In this way, the development of the CubeSat follows the social constructivist theory developed by Pinch and Bijker (1987), who state that the "sociocultural and political situation of a social group shapes its norms and values, which in turn influence the meaning given to an artifact" (p.130). Once an artifact is introduced to social groups, however, Pinch and Bijker assert that a technology has "interpretive flexibility". That is, they claim that the social meaning given to a technology can vary greatly from group to group until "different interest groups coalesce around a particular design and meaning for [that] technology". It is clear that U.S. stakeholders coalesced around the CubeSat as a viable space research platform. However, meaning given to CubeSat by the social groups of other nations is much less clear.

The global aerospace industry is comprised of stakeholders from many different industrialized nations, each with its own norms and values. Yet, many of the most impactful technologies have been produced by American stakeholders. The CubeSat is only one of dozens of revolutionary aerospace technologies that have allowed American engineers, politicians, and taxpayers to embed their ideas and beliefs into international technological systems. Because of this, the research in this paper explores how the sociopolitical values of American stakeholders in the aerospace industry influence the direction of global aerospace research and development.

The first step in pursuing a more detailed understanding of this large-scale problem, according to Pinch and Bijker (1987), is to understand the fundamental relationships between technological artifacts, social groups, problems, and solutions. Beginning with the least complex of these relationships, the Pinch and Bijker (1987) explain that the links between a technological artifact and the relevant social groups that use this artifact are relatively linear. As depicted by Figure 1.1, once a technological artifact is created, each relevant social group forms a distinct relationship with the technological artifact in question. This linear relationship is clearly demonstrated in the initial stages of development of (what is known today as) the bicycle. Pinch and Bijker highlight the fact that each iteration of the technology highlighted differences between the technical requirements of each relevant social group. Specifically citing the polarity

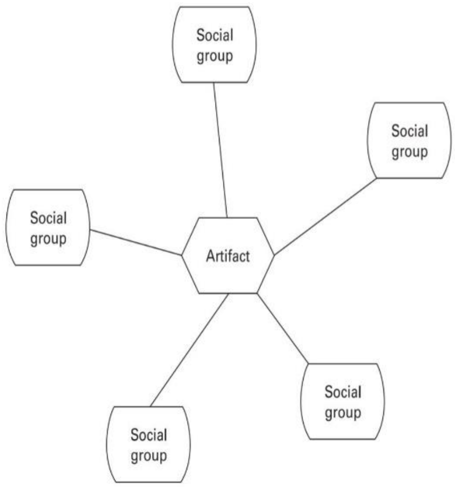

Figure 1.1 – Depiction of the linear relationships that form between relevant social groups and a technological artifact

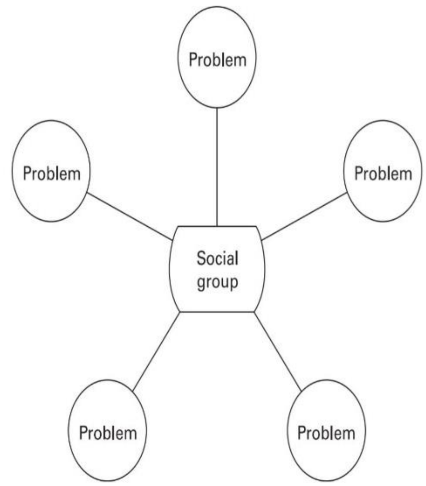

Figure 1.2 – Visual representation of the problems that a social group seeks to solve.

of "the speed requirement and the safety requirement," it is clear that the smaller and safer "low-wheelers" were created to satisfy the former requirement, and that the larger, faster "high-wheelers" were created to satisfy the latter. It is in this way that the bicycle represents a technological artifact with which each relevant social group formed its own, distinct relationship.

However, these linear relationships are not as easily identified when examining the connection between social groups and the problems that they need solutions to. When examining Figure 1.2 by itself, it is clear that the social group at the center of the diagram has a multitude of problems that must be solved. However, when considering this figure in the tandem with figure 1.1, the lines of development of a technological artifact become more complicated. For example, if each social group has five unique problems that need to be solved (as is the case in Figure 1.2), then the artifact at the center of Figure 1.1 will potentially be used by each of the five social groups to solve 5 unique problems. That is, a single artifact has the potential to be used in 25 different ways as a solution to each of the 25 unique problems. It is in this way that an artifact's ultimate use becomes less predictable as it travels through the development process.

At this point, the concept of interpretive flexibility becomes rather clear. After examining the figures above, it is reasonable to assert that a technological artifact's intended use (as defined by the creator of that artifact) may differ greatly from how each social group actually uses it. Further adding to this complexity is the final social context in which an artifact operates. An exploration of this context is critical for a balanced application of the social constructivism framework. An analysis of the history of the aerospace industry is beyond the scope of this paper. However, identifying several key demographics in the global aerospace industry will prove useful in understanding the context of this problem from an STS perspective.

Case Context

As previously established, the CubeSat is the product of a need, specifically among U.S. engineers, politicians, and taxpayers, for cheap, reliable space research (Villela et al, 2019). This sociocultural emphasis, though, has not manifested itself solely in the development of the CubeSat. The desire for cheap, reliable aerospace technologies has pushed private groups such as SpaceX to develop innovative technological systems that are rapidly driving down the cost of space launch (Jones, 2018). The SpaceX Falcon Heavy launch system received international praise for its unprecedented reusable rocket boosters. With this significant technological advantage over all other widely used space launch systems, the Falcon Heavy offers a cost reduction of $3,800 per kilogram when compared with NASA's Saturn V system, the next cheapest American launch system (Jones, 2018). In this way, it is clear that the emphasis placed on cheap, reliable space research has permeated more than simply the government research sector.

It follows that the technological advancements made by SpaceX pushed corporations worldwide to develop cheaper, more reliable technologies in order to remain competitive. Returning to the root of this international competition, however, reveals that the United States has a significant influence in the avenues of technological development that are pursued in the global aerospace industry. In general, U.S. engineers, corporate executives, politicians, and taxpayers place social, political, and cultural emphasis on cost reduction without sacrificing the quality of the products in question (Villela et al., 2019). This sociopolitical emphasis, in accordance with the theory of social constructivism, influences the development of new technologies. It is in this way that the United States has considerable sway over the direction of technological development in the global aerospace industry.

Research Question

Specifically, I will use the social constructivism framework to answer the following question: *How do stakeholders in United States influence technological development in the global aerospace and defense industry?* Because technologies are developed based on the values of those persons designing them, understanding how those values manifest themselves as technological systems is a necessary task. If the ideals of only a select few are incorporated into the development of a product that impacts people globally, the implementation of that technology may negatively impact those whose perspectives are not represented. In an industry that is spearheading the colonization of Mars, it is necessary to ensure that aerospace technologies push us towards a bright future for all—not only for those fortunate enough to have a seat at the design table.

Research Methods

A response to the question above was developed using a two-pronged approach. First, a clearer understanding of the demographics of the relevant stakeholders was established using the executive boards of four aerospace and defense corporations. To ensure a representative sampling of the industry, two companies—Bombardier and Aerojet Rocketdyne—were selected at random from Appendix A. The top two aerospace and defense corporations[1]—Boeing and Airbus—were selected given their dominance of the commercial aviation sector.

These corporations all publish the names, roles, and photos of those who make decisions affecting the trajectory of their companies. The race, gender, and nationality breakdowns of these boards was assessed visually, and confirmed with information available online, such as company webpages, yearly fiscal reviews, and video interviews. It should be noted at this point, that this method is not perfect. As with any qualitative assessment of physical characteristics, there are cases where a visual analysis of one's race, in particular, are incorrect. This visual error was mitigated using social media profiles or interviews in which individuals self-report their ethnicity and gender. After a thorough review, it was not clear that any of these visual identifications were incorrect.

These demographics provide the context necessary to explore the initial research question in greater detail. Building on this context, the second portion of the research conducted focused on case studies documenting the importance of diversity[2] on aerospace research and product development. This research was performed to demonstrate why diversity in aerospace is critical.

[1] Rankings based on revenue in 2018 fiscal year. See appendix A for a full ranking list.
[2] Diversity in this context is defined broadly. It includes any difference of race, gender, socioeconomic status, nationality, sexuality, or ideology between members of a group.

That is, it sought to provide an answer to those who ask *"so what"* when confronted with the statement that the aerospace sector, especially in the U.S., is not very diverse at all.

To accomplish this goal, a well-conducted case study on more than 3,500 aerospace patents was obtained using Google Scholar. This paper communicates the importance of international diversity on the efficacy of science and engineering teams, and, given the abundance of data upon which conclusions were made, was assumed to be representative of the majority of aerospace corporations worldwide. Building upon the role of diversity on engineering teams, the research and development processes for Boeing's controversial 737 Max were compared to those of and Airbus's innovative A320 Neo. This comparison utilized papers obtained through Google Scholar, and highlighted clear differences between the norms of each company. After using a social constructivist framework to examine the interplay between these norms, diversity, and technological development, these papers suggest a strong correlation—not causation—between diversity and the success of an engineering team.

Results

Generally, American aerospace corporations are granted a virtually unchecked influence in the global aerospace industry (Pustay, 1992). In many ways, the direction of research and development worldwide is influenced solely by stakeholders in the U.S. Monopolistic as it may be, it begs the question: *is this a negative?* If American stakeholders are making decisions that push the industry towards the future, should other nations bother challenging this influence? Assuming that the leaders of these American corporations consider a diverse array of perspectives when making decisions that affect the lives of millions worldwide, there is no urgent need for another nation to question the status quo. However, the results of this paper suggest that this assumption cannot be applied, for it greatly differs from the realities of technological development within American aerospace corporations. In fact, these results communicate that American stakeholders are *dehumanizing the global aerospace industry.* Because of this, the influence of American stakeholders must be examined with a critical eye.

Central to this examination is an understanding of the function of diversity on a team of engineers. In November of 2019, a team of professors at the Polytechnic University of Bari sought to do just that. Their paper titled *"The role of scientific knowledge within inventing teams and the moderating effects of team internationalization and team experience: Empirical tests into the aerospace sector"* highlights the importance of diversity when forming teams of scientists and engineers. The authors of this source assert that "scientists within inventing teams is negatively related to the development of more general-purpose solutions." That is, they claim that those with a scientific background tend to develop specialized technologies that can only be used by a select few. They go on to say, however, that this problem is mitigated by employing the concept of *internationalization*—building teams with members from a diverse group of nations. When designing aerospace technologies that are to be used by millions of people worldwide, this concept is incredibly important. This importance lies in the fact that diversity prevents a team of inventors from designing a technology that is too specific or biased towards one group of people. (Ardito et. al 2019).

This idea is supported by research performed by University of Australia professor Sabina Nielsen. As interpreted by Ardito et. al (2019), Nielsen asserts that those who work on teams bring with them "national-derived qualities" that influence their beliefs, behaviors, and values (Ardito et. al. 2019, Nielsen 2010). In accordance with the social constructivism framework, such "national-derived qualities" push technology designers to inscribe personal values into the artifacts that they design (Pinch & Bijker, 1987). It is in this way that technologies designed by a homogenous group of stakeholders are more likely to show bias against those with different values systems or beliefs.

With this understanding, it follows that aerospace corporations would seek to create diverse executive leadership teams. To evaluate the validity of this statement, the demographics of four aerospace corporations’ executive councils were examined. These corporations include Bombardier Aerospace, Aerojet Rocketdyne, Airbus Group Inc., and The Boeing Company. As detailed in Appendices B, C, D, and E, the racial, gender, nationality, and salary breakdowns were obtained for each of the aforementioned corporations. Given the research performed by Ardito et. al. (2019) and Nielsen (2010), the nationality breakdowns of these groups are of particular interest. Figure 1 below provides this information and demonstrates the significant differences that exist in the aerospace industry with regard to internationalization. From this

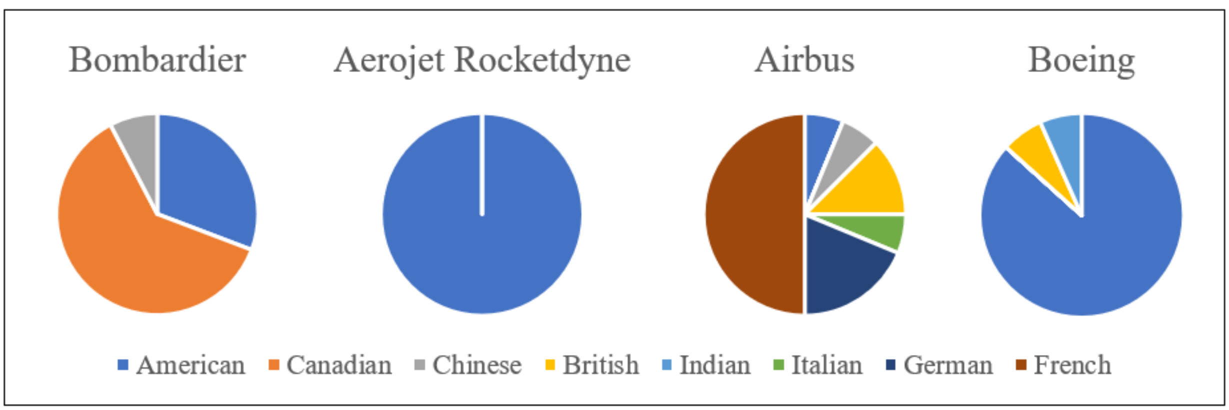

Figure 1: Nationality breakdown of the executive leadership boards of Bombardier Aerospace, Aerojet Rocketdyne, Airbus Group Inc., and The Boeing Company. See Appendices B, C, D, and E for percentages.

figure, it is clear that Airbus has the most highly internationalized executive board, with Aerojet Rocketdyne’s being the most homogenous. However, Aerojet Rocketdyne produces missiles and rocket technologies—two highly specialized products. Because of this, the negative effects of a lack of nationalization are mitigated by the fact that these executives are not leading the development of a product that will reach an individual consumer.

Boeing, however, does not exclusively produce specialized products. The company competes directly with Airbus in the commercial aviation arena, but has a board representing only 3 nationalities compared to the 6 represented on Airbus's board. Figure 2 above suggests that Boeing, in particular, sought to justify this shortcoming by making their executive leadership team more racially diverse than their European competitor. When considering the racial breakdowns of these companies, it appears that less racially diverse companies tend to be more diverse from a nationality standpoint, and vice versa.

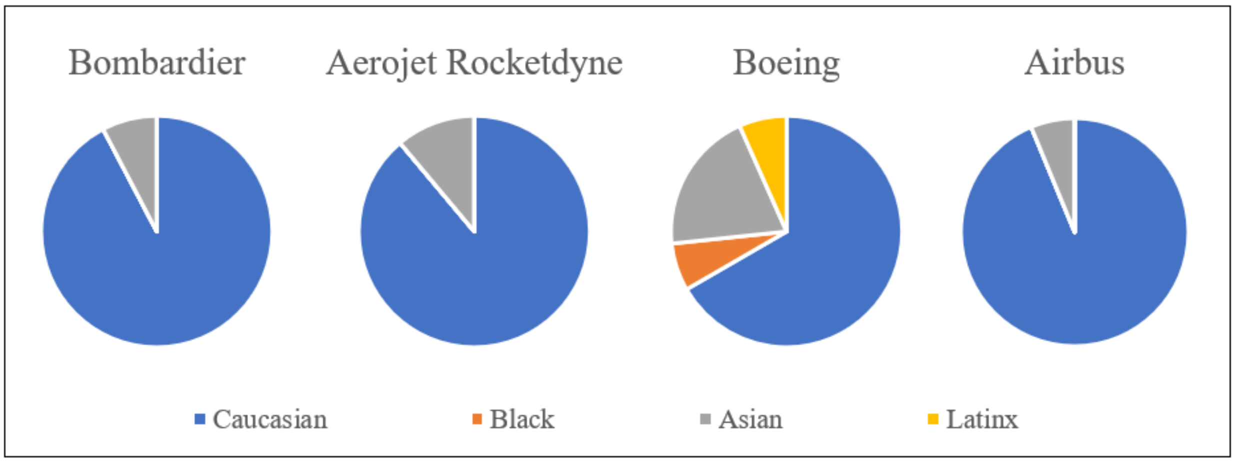

Figure 2: Racial breakdown of the executive leadership boards of Bombardier Aerospace, Aerojet Rocketdyne, Airbus Group Inc., and The Boeing Company. See Appendices B, C, D, and E for percentages.

Boeing's recent Executive Council changes would suggest the company's desire to further broaden their definition of diversity. At the end of the 2019 fiscal year, Boeing's executive council was 25% female and 75% male (Boeing.com), compared to Airbus's Executive Committee of 14% females and 86% males (Airbus.com). In the 2020 fiscal year, however, Boeing appointed Wendy Livingston to be the next Senior Vice President of Human Resources (Boeing.com), thus increasing the percentage of women on the committee from 25% to 36%, as depicted in Figure 3. It is clear that the company has a significantly greater diversity

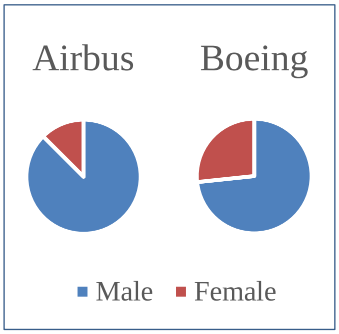

Figure 3: Gender breakdown of the executive leadership teams of Airbus and Boeing in the 2020 fiscal year.

of race and gender than Airbus does. However, are racial and gender diversity enough to justify a lack of internationalization? The controversial development and production of the Boeing 737 Max would suggest not.

Boeing is well known in the commercial aviation field—a sector that caters to a diverse, global population. However, according to the information provided on Boeing.com, the executive council for the Boeing corporation is very homogeneous from a nationality standpoint. That is, of the 14 members of the council, 12 of them are American men and women. Given that they decide the research and development paths that Boeing will take, these 14 men and women effectively determine the values and norms of the entire company. Using a social constructivist lens, it follows that Boeing's products and technologies are embedded with a value commonly held by U.S. business executives—doing more for less. In a manner similar to the development of the CubeSat, Boing's recent major changes to their 737 Max are indicative of their desire to increase the efficiency of the airplane without spending the money necessary for a completely redesigned system. In essence, Boeing—led by their mostly American executive council—retrofitted the 737 Max airframe with engines that sat dangerously close to the ground and implemented a flight software program without properly training pilots on how to use it (Leehamnews.com). With the entirety of the 737 Max fleet currently restricted from flying, the company is feeling the negative effects of prioritizing profit over the safety of their customers.

Airbus's development of the A320 Neo, however, suggests that Boeing's current hardships could have been prevented if the company had more stakeholders from a diverse group of nations. Their Executive Committee, as presented in Figure 1 above, is comprised of stakeholders that represent Germany, France, Great Britain, Italy, China, and the United States. In accordance with the concept of internationalization, this group of executives has historically taken longer to make major decisions than Boeing (Leehamnews.com) given that they have to incorporate the perspectives of stakeholders from three very different nations. The initial phases of development of the Airbus A320 Neo (the direct competitor of the Boeing 737 Max), is evidence of this extended decision-making process given that it took almost twice as long to develop as the 737 Max (Leehamnews.com). However, once the board was certain that the plane would be designed with safety remaining paramount, the airframe was successfully introduced to the world.

In summary, Boeing's 737 Max was heavily influenced by of a group of stakeholders that introduced a "new plane" in order to remain more profitable than Airbus, rather than design a plane that was safe and revolutionary. These stakeholders lacked voices outside of their experience that might have helped the company avoid the disaster that is the 737 Max. Using a social constructivist lens, it is clear that these executives' emphasis on profit over safety resulted a product with this value inscribed into it. This single-minded, profit-driven design process has resulted in Boeing's loss of $60 million dollars per day, the deaths of 368 people, and the loss of the trust of millions more (Cruz, 2020).

Discussion

The commercial aviation sector of the aerospace industry is reasonable for producing planes that are used by billions of people around the globe. These people are incredibly diverse with respect to their nationalities, races, genders, and ideologies. It is critical, therefore, that the airframes they will fly on are designed by those who consider this diversity throughout the design process. The results of this paper demonstrate the dangers of homogeneity on a team responsible for designing a general-use technology. Because the values of a design team are inscribed in the technological systems that the team produces, diversity is critical when designing a commercial aerospace technology.

Given the importance of a diversity, how have Boeing and other American aerospace corporations influenced research and product development in the global aerospace industry? Understanding that technological development follows the theory of social constructivism, it follows that American stakeholders are pushing the aerospace industry towards prioritizing profit over safety. In short, *American stakeholders are dehumanizing the aerospace industry* by pursuing product design processes centered on maximizing capital gains rather than processes centered primarily around safety and inclusivity.

Given the scope of this research, I was not able to include a significant amount of information on the membership of other top executive boards. In the future, I would like to explore trends between other direct competitors such as the Canadian-owned Bombardier and American-owned Gulfstream private jet manufacturers. I would also like to examine the executive boards of the smallest aerospace corporations in order to more definitively speak to whether a lack of internationalization is specific to large American corporations or not.

This research is particularly impactful for me given my status as an aerospace engineer. While I will be a member of the United States Air Force upon graduation (and will be following orders for my first four years in the service), I know that it is important for me to consider safety of those using the technological systems I am designing above all else. I learned that the "less is more" ideal is useful until it starts to jeopardize the safety of the social groups that use the technology. In my view, this research underscored the fact that no amount of money is worth jeopardizing innocent lives. With the understanding that I will subconsciously design technological systems that incorporate my own biases, I know that I must work to identify those biases and embrace international collaboration in order to mitigate their impacts.

Conclusion

The American domination of the aerospace sector is undoubtedly dangerous given the fact that U.S. stakeholders embed cultural norms in the technologies they design. When considering the broader significance of this research, it is clear that American aerospace companies essentially have the freedom to make significant mistakes without much global backlash. This only reinforces the notion that it is acceptable to design aerospace technologies with the goal of saving money at the expense of consumer safety. While most business models seek to drive down costs while increasing profits, it is crucial not to let this model cloud the fact that, as aerospace engineers, we design technologies that have the potential to kill people. While it is almost certain that American capitalist norms will continue to be inscribed in future technological systems, it is essential that the next generation of aerospace engineers understand how to mitigate the negative effects of this inscription.

Resources

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Appendix A
PriceWaterhouseCoopers Aerospace & Defense Top 100 Companies

		Revenue (US$ millions)			Operating Profit (US$ millions)		
#	Company	2018	2017	Change	2018	2017	Change
1	Boeing	101,127	94,005	8%	11,987	10,344	16%
2	Airbus	75,126	66,541	13%	5,953	3,005	98%
3	Lockheed Martin	53,762	49,960	8%	7,334	6,744	9%
4	General Dynamics	36,193	30,973	17%	4,457	4,236	5%
5	United Technologies (P&W and Collins Aero)	36,031	30,851	17%	3,572	3,491	2%
6	GE Aviation	30,566	27,013	13%	6,466	5,370	20%
7	Northrop Grumman	30,095	26,004	16%	3,780	3,218	17%
8	Raytheon	27,058	25,348	7%	4,538	4,231	7%
9	Safran	24,794	18,462	34%	2,553	2,737	-7%
10	BAE Systems	22,428	22,167	1%	2,140	1,826	17%
11	Rolls Royce	20,972	18,979	10%	(1,548)	471	-429%
12	Thales	18,697	17,168	9%	1,987	1,539	29%
13	Honeywell Aerospace	15,493	14,779	5%	3,503	3,288	7%
14	Leonardo	14,434	13,229	9%	1,321	1,214	9%
15	L-3 Technologies	10,244	9,573	7%	1,106	1,031	7%
16	Leidos	10,194	10,170	0%	749	559	34%
17	Textron	9,681	9,843	-2%	1,026	857	20%
18	Bombardier Aerospace	8,703	8,866	-2%	(179)	86	-308%
19	Rockwell Collins	8,665	6,822	27%	1,354	1,102	23%
20	Huntington Ingalls	8,176	7,441	10%	951	881	8%
21	Spirit AeroSystems	7,222	6,983	3%	843	532	58%
22	Mitsubishi Aircraft, Defense and Space	6,446	6,272	3%	(135)	8	-1778%
23	Babcock International Group	6,213	5,852	6%	494	463	7%
24	Harris Corp	6,182	5,900	5%	1,122	1,073	5%
25	Booz Allen Hamilton	6,172	5,804	6%	520	484	7%
26	Dassault Aviation	6,037	5,525	9%	835	246	240%
27	MTU Aero Engines	5,386	4,393	23%	791	646	22%
28	AVIC Aircraft Company	5,310	4,829	10%	386	385	0%
29	Embraer	5,071	5,859	-13%	35	342	-90%
30	Singapore Technologies	4,965	4,725	5%	423	393	7%
31	CACI	4,468	4,355	3%	341	297	15%
32	SAIC	4,454	4,442	0%	256	263	-3%
33	IHI Aero Engines and Space Operations	4,199	4,209	0%	544	473	15%
34	TransDigm Group	3,811	3,504	9%	1,655	1,480	12%
35	Saab	3,810	3,708	3%	260	263	-1%
36	Rheinmetall Defence	3,798	3,423	11%	300	196	53%
37	Serco UK Central Government and Americas	3,783	3,798	0%	108	27	300%
38	Elbit Systems	3,684	3,378	9%	293	324	-10%
39	Israel Aerospace Industries	3,682	3,520	5%	12	121	-90%
40	Melrose / GKN Aerospace	3,305	4,682	-29%	(59)	364	-116%
41	Triumph Group	3,199	3,533	-9%	(362)	57	-735%
42	Trimble	3,108	2,647	17%	321	236	36%
43	Kawasaki Aerospace	3,007	2,956	2%	189	223	-15%
44	BBA Aviation	2,881	2,409	20%	262	237	11%
45	Hindustan Aeronautics Limited (HAL)	2,833	3,010	-6%	486	550	-12%
46	Perspecta	2,819	2,732	3%	211	160	32%
47	Meggitt	2,775	2,566	8%	489	454	8%
48	MOOG	2,709	2,498	8%	220	217	1%
49	Cobham	2,484	2,642	-6%	149	134	12%
50	Curtiss-Wright	2,412	2,271	6%	374	325	15%
51	SES	2,370	2,294	3%	461	689	-33%

PwC   Aerospace and defense 32

#	Company	Revenue (US$ millions) 2018	2017	Change	Operating Profit (US$ millions) 2018	2017	Change
52	Allegheny Technologies High Performance Metals	2,334	2,067	13%	335	246	36%
53	Parker Hannifin Aerospace	2,316	2,285	1%	398	337	18%
54	Hexcel	2,189	1,973	11%	379	351	8%
55	Delta Tucker Holdings / DynCorp International	2,148	2,004	7%	166	103	61%
56	Maxar Technologies	2,141	1,631	31%	(1,125)	(44)	-2657%
57	CAE Aviation Defense and Security	2,092	1,998	5%	348	304	15%
58	RUAG	2,041	1,987	3%	108	121	-10%
59	Esterline Technologies	2,035	2,000	2%	183	183	0%
60	ManTech International	1,959	1,717	14%	113	98	15%
61	Swire Pacific / HAECO	1,899	1,867	2%	145	(12)	-1359%
62	Eaton Aerospace	1,896	1,744	9%	398	332	20%
63	Aerojet Rocketdyne	1,888	1,871	1%	265	178	49%
64	Korea Aerospace Industries	1,882	2,607	-28%	(190)	283	-167%
65	Aselsan	1,858	1,487	25%	459	353	30%
66	Oshkosh Defense	1,829	1,820	0%	223	208	7%
67	BWXT	1,800	1,688	7%	305	292	4%
68	Heico Corporation	1,778	1,525	17%	376	307	22%
69	FLIR Systems	1,776	1,800	-1%	319	290	10%
70	AAR	1,748	1,591	10%	86	82	5%
71	KLX	1,741	1,494	17%	216	129	67%
72	ViaSat	1,595	1,559	2%	(92)	36	-356%
73	Wesco Aircraft Holdings	1,570	1,429	10%	109	(209)	-152%
74	Woodward Aerospace	1,558	1,342	16%	302	257	18%
75	Bharat Electronics	1,484	1,366	9%	287	304	-6%
76	Austal	1,392	1,310	6%	57	40	43%
77	Subaru Aerospace (formerly Fuji)	1,288	1,237	4%	111	81	37%
78	Vectrus	1,279	1,115	15%	48	41	17%
79	Cubic Corporation	1,203	1,107	9%	24	2	1100%
80	Ball Aerospace	1,196	991	21%	113	98	15%
81	OHB Technology	1,152	931	24%	57	50	14%
82	Larson Toubro	1,118	1,048	7%	100	90	11%
83	Qinetiq	1,111	1,008	10%	188	171	10%
84	SIA Engineering	1,095	1,104	-1%	76	72	6%
85	Smiths Detection	1,057	884	20%	124	90	38%
86	Ultra Electronics	1,023	997	3%	87	80	9%
87	Senior Aerospace	1,013	915	11%	96	88	10%
88	FACC	886	796	11%	75	28	168%
89	Astronics	803	624	29%	64	32	100%
90	Latecoere	777	741	5%	6	47	-88%
91	Kongsberg Gruppen Defense and Aerospace	750	742	1%	76	48	59%
92	Magellan Aerospace Corp	745	736	1%	91	102	-11%
93	Crane Aerospace & Electronics	743	691	8%	164	160	2%
94	Kaman Aerospace	736	725	2%	94	118	-20%
95	Jamco Corp	704	730	-3%	40	19	113%
96	VSE Corporation	697	760	-8%	54	54	0%
97	Teledyne Aerospace & Defense Electronics	697	646	8%	135	116	16%
98	Indra Security & Defense	672	672	0%	89	78	14%
99	Ducommun	629	558	13%	24	16	50%
100	Kratos Defense & Security Solutions	618	603	2%	31	(12)	-358%
	Total	759,974	697,438	9.0%	81,013	74,131	9.3%

Appendix B

Boeing Executive Council

David L. Calhoun, President & Chief Executive Officer

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: 28 million (2020)

Bertrand-Marc Allen, President—Embraer Partnership & Group Ops

- Ethnicity: Latinx
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Michael Arthur, President—Boeing International

- Ethnicity: Caucasian
- Nationality: British
- Gender: Male
- Total compensation: Unknown

Leanne Caret, President & CEO—Boeing Defense, Space & Security

- Ethnicity: Caucasian
- Nationality: American
- Gender: Female
- Total compensation: Unknown

Ted Colbert, President & CEO—Boeing Global Services

- Ethnicity: African American
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Stanley A. Deal, President & CEO—Boeing Commercial Airplanes

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Brett C. Gerry, Executive VP—General Counsel

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Niel Golighty, Senior VP--Communications

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Greg Hyslop, Chief Engineer & Senior VP

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Timothy Keating, Executive VP—Government Operations

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Wendy Livingston, Senior VP—Human Resources

- Ethnicity: Caucasian
- Nationality: American
- Gender: Female
- Total compensation: Unknown

Jenette E. Ramos, Senior VP—Manufacturing, Supply Chain & Ops.

- Ethnicity: Asian
- Nationality: American
- Gender: Female
- Total compensation: Unknown

Diana L. Sands, Senior VP—Office of Internal Governance & Admin.

- Ethnicity: Asian
- Nationality: American
- Gender: Female
- Total compensation: Unknown

Greg Smith, Chief Financial Officer & Executive VP

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Vishwajeet Uddanwadiker, Chief Information Officer & Senior VP

- Ethnicity: Asian
- Nationality: Indian
- Gender: Male
- Total compensation: Unknown

Appendix C
Airbus Executive Committee

Guillaume Faury, Chief Executive Officer

- Ethnicity: Caucasian
- Nationality: French
- Gender: Male
- Base salary: $1.47 million (2019)

Dominik Asam, Chief Financial Officer

- Ethnicity: Caucasian
- Nationality: German
- Gender: Male
- Base salary: Unknown

Thierry Baril, Chief Human Resources Officer

- Ethnicity: Caucasian
- Nationality: French
- Gender: Male
- Base salary: Unknown

Jean-Brice Dumont, Executive VP—Engineering

- Ethnicity: Caucasian
- Nationality: French
- Gender: Male
- Base salary: Unknown

Bruno Even, Chief Executive Officer—Helicopters

- Ethnicity: Caucasian
- Nationality: French
- Gender: Male
- Base salary: Unknown

John Harrison, General Counsel

- Ethnicity: Caucasian
- Nationality: British
- Gender: Male
- Base salary: Unknown

Dirk Hoke, Chief Executive Officer—Defense and Space

- Ethnicity: Caucasian
- Nationality: German
- Gender: Male
- Base salary: Unknown

Julie Kitcher, Executive VP—Communications & Corporate Affairs

- Ethnicity: Caucasian
- Nationality: British
- Gender: Female
- Base salary: Unknown

Phillipe Mhun, Executive VP—Programmes & Services

- Ethnicity: Caucasian
- Nationality: French
- Gender: Male
- Base salary: Unknown

Christian Scherer, Chief Commercial Officer

- Ethnicity: Caucasian
- Nationality: French
- Gender: Male
- Base salary: Unknown

Michael Schoellhorn, Chief Operating Officer

- Ethnicity: Caucasian
- Nationality: German
- Gender: Male
- Base salary: Unknown

Grazia Vittadini, Chief Technology Officer

- Ethnicity: Caucasian
- Nationality: Italian
- Gender: Female
- Base salary: Unknown

Antoine Bouvier, Head of Strategy, Mergers & Acquisitions

- Ethnicity: Caucasian
- Nationality: French
- Gender: Male
- Base salary: Unknown

Marc Fontaine, Digital Transformation Officer

- Ethnicity: Caucasian
- Nationality: French
- Gender: Male
- Base salary: Unknown

C. Jeffrey Knittel, Chairman & CEO—Airbus Americas

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Base salary: Unknown

George Xu, Chief Executive Officer—Airbus China

- Ethnicity: Asian
- Nationality: Chinese
- Gender: Male
- Base salary: Unknown

Appendix D

Aerojet Rocketdyne Executive Leadership Team

Eileen Drake, Chief Executive Officer

- Ethnicity: Caucasian
- Nationality: American
- Gender: Female
- Total compensation: $5.53 million (salary.com, 2018)

Mark Tucker, Chief Operating Officer

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: $2.47 million (salary.com, 2018)

Paul Lundstrom, VP Finance & Chief Financial Officer

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: $2.05 million (salary.com, 2018)

John Schumacher, Senior VP—Washington Ops. & Comms.

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: $1.30 million (salary.com, 2018)

Arjun Kampani, VP—General Counsel & Secretary

- Ethnicity: Asian
- Nationality: American
- Gender: Male
- Total compensation: $1.25 million (salary.com, 2018)

Jim Maser, Senior VP—Space

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Tyler Evans, Senior VP—Defense

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Greg Jones, Senior VP—Strategy & Business Development

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Andreas Wagner, Chief Human Resources Officer

- Ethnicity: Caucasian
- Nationality: German
- Gender: Male
- Total compensation: Unknown

Appendix E

Bombardier Aerospace Executive Management Team

Éric Martel, President & Chief Executive Officer

- Ethnicity: Caucasian
- Nationality: Canadian
- Gender: Male
- Total compensation: Unknown—Martel joined Bombardier in 2020)

David Coleal, President—Business Aircraft

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: ~$3.81 million (2018, Bombardier.com)

Fred Cromer, President—Commercial Aircraft

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: ~$3.88 million (2018, Bombardier.com)

Danny Di Perna, President—Transportation

- Ethnicity: Caucasian
- Nationality: Canadian
- Gender: Male
- Total compensation: ~$3.60 million (2018, Bombardier.com, based on predecessor's compensation)

John Di Bert, Senior Vice President & Chief Financial Officer

- Ethnicity: Caucasian
- Nationality: Canadian
- Gender: Male
- Total compensation: ~$3.21 million (2018, Bombardier.com)

Daniel Brennan, Senior Vice President—Human Resources

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: Unknown

François Caza, Chief Technology Officer

- Ethnicity: Caucasian
- Nationality: Canadian
- Gender: Male
- Total compensation: Unknown

Mtre Daniel Desjardins, Senior Vice President—General Counsel

- Ethnicity: Caucasian
- Nationality: Canadian
- Gender: Male
- Total compensation: Unknown

Mike Nadolski, Vice President—Communications & Public Affairs

- Ethnicity: Caucasian
- Nationality: American
- Gender: Male
- Total compensation: Unknown

Steeve Robitaille, Vice President—General Counsel

- Ethnicity: Caucasian
- Nationality: Canadian
- Gender: Male
- Total compensation: Unknown

Paul Sislian, Chief Operation Officer—Bombardier Aviation

- Ethnicity: Caucasian
- Nationality: Canadian
- Gender: Male
- Total compensation: Unknown

Jim Vounassis, Chief Operation Officer—Bombardier Transportation

- Ethnicity: Caucasian
- Nationality: Canadian
- Gender: Male
- Total compensation: Unknown

Jianwei Zhang, Chairman & President—Bombardier China

- Ethnicity: Asian
- Nationality: Chinese
- Gender: Male
- Total compensation: Unknown