The Limits of Tactical Aviation Technology

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For generations, the American military—and the US Air Force in particular—has relied on the technological superiority of its systems to dominate any battlefield. Against conventional enemies, this paradigm has been so successful for so long that it is often taken for granted. Unfortunately, the question of how much longer we can expect that to be the case is very much open to debate. Many people observe that, in terms of technology, we have fallen into something of a lull, especially regarding tactical aviation platforms. This article suggests two actions we can take to start changing that status.

The Present Situation

Our current aviation superiority is largely based on technologies developed and deployed during the last decades of the Cold War.[1] Since the end of that ideological conflict, however, our aviation technology for combat aircraft has reached a plateau. The only major new capabilities have been (1) a limited deployment of F-22s with more advanced stealth airframes capable of supersonic cruise and (2) the beleaguered F-35.[2] Otherwise, much of our effort has concentrated on limited upgrades of existing capabilities as well as the development and deployment of remotely piloted air systems.[3]

The geopolitical environment of the last two decades has made this situation acceptable. During the 1980s, we largely recapitalized our aircraft force with new equipment and have lacked a peer competitor after the collapse of the Soviet Union. We have focused since then on improved command, control, communications, computers, intelligence, surveillance, and reconnaissance, as well as remotely piloted systems that supplanted the development of manned tactical aircraft technology. Unfortunately, this somewhat permissive geopolitical and operational environment is not likely to continue.

At present, we confront a chaotic and increasingly dangerous threat environment around the globe. China, Russia, Iran, North Korea, and radical Islam/terrorism in all its manifestations, along with a host of others, present challenges to our national security. In particular, China's antiaccess/area-denial strategy, intended to defeat our

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ability to project power in the Western Pacific, has made great strides in building the technical base necessary for such a strategy. Furthermore, the Chinese are pursuing what amounts to a staggering list of revolutions in their air and space technology.[4]

When the (potential) opposition is catching up, the obvious counter is—and historically has been—a technological leap forward. Unfortunately, as previously mentioned, manned military aviation technology, especially for manned tactical aircraft, may be reaching a period of little change. Only a small portion of the most recent (2010) Air Force long-range research concept, *Technology Horizons*, dealt with actual aircraft technology. Instead, it concentrated primarily on advanced (and, admittedly, potentially revolutionary) computer applications intended to do what we are already doing—only faster, cheaper, and with less manpower.[5] Most current research on manned tactical aircraft concentrates on what amounts to incremental improvements for and sustainment of existing systems while research on a possible successor generation of such aircraft is only in the preliminary stages. Procurement of manned tactical aircraft for at least the next 20 years effectively will consist of what is presently on the assembly line.[6] The Navy faces a similar situation.[7] Moreover, although we are evidently putting extensive effort into future remotely piloted systems, their ultimate capabilities—especially their survivability on a dynamic, high-threat battlefield—remain to be seen despite the enthusiasm of those systems' proponents.

We must recognize that a central reason for the plateau in manned tactical aviation technology is that we are approaching—if we have not already reached—the limits of what is immediately and affordably available for tactical combat aircraft. Further, it is at least possible that we have reached or nearly reached the limits of what is technically feasible for air-breathing manned combat aircraft. None of the possible upgrades to existing systems are really a breakthrough or a game changer.[8] Beyond these upgrades, there are no readily apparent or available breakthroughs to pursue. At this point, the only evident exceptions are the possibility that active electronically scanned array (AESA) radars can provide us with high-power microwave weapon capability; other exceptions include electromagnetic pulse weapons such as the Counterelectronics High-Powered Microwave Advanced Missile Project (CHAMP) warhead and whatever computer network attack capability we have developed or will develop.[9]

Unfortunately, we are not the only ones with access to such technologies. The rest of the world, especially our rivals, is catching up and is expected to master and deploy these technologies in the near future. In some cases, those rivals are already doing so. Even more ominously, several potential game-changing technologies of the near future, such as very long-range air-to-air missiles (AAM), precision-guided antisurface ballistic missiles, cyber weapons, stealthy cruise missiles, and advanced warheads (such as cluster, electromagnetic pulse, and fuel-air explosive) are as likely, if not more likely, to work against us as for us. This array of technologies obviously has profound implications for the strategic and tactical situations we will encounter around the world. Specifically, we and our allies will not necessarily be able to rely on superior technology and capabilities that served as a force multiplier since the end of the Cold War and compensated for inferior numbers. Meanwhile, our ongoing fiscal and economic situation will make both recapitalizing our aging equipment and pursuing new technology enormously difficult. We should not rely on a cost breakthrough with remotely piloted systems to avoid this situation. Most of those vehicles deployed so far have been relatively inexpensive because their airframes are comparatively simple and cheap. However, costs go up rapidly as airframes and their sensor packages increase in sophistication. So what can we do?

The Way Forward

First, we must water the tree of future research and development and keep it watered—but we can expect results only in the long term. For example, at the moment, the Air Force and the Defense Advanced Research Projects Agency (DARPA) appear to have a reasonably coherent program for hypersonics (flight at or above Mach 5). However, the immediate focus is on tactical missiles, with a larger, reusable remotely piloted hypersonic vehicle expected in the 2030 time frame and a potentially manned hypersonic vehicle for 2040.[10] If we cannot make an immediate or rapid leap ahead in airframes or engines, do other alternatives exist? Might we harvest any low-hanging fruit in the near or intermediate future that could offer new capabilities or at least extend the viability of existing systems, preferably without breaking the bank?

Two areas potentially worth exploring might, if pushed, have an impact as early as the turn of the next decade. Moreover, they would prove especially useful in an environment where we will need to operate at longer ranges against more sophisticated enemies deploying antiaccess/area-denial systems. They include longer-range AAMs and—more ambiguously and much less noticed—improved fuels.

Longer-Range Air-to-Air Missiles

As previously mentioned, we are facing the likely or inevitable proliferation of increasingly long-range AAMs. The Chinese are reportedly deploying these weapons with ranges that at least rival those of currently deployed US AAMs.[11] Consequently, until the widespread deployment of the F-35, the fourth-generation aircraft that the US fighter force and our allies depend on will no longer have a missile-range advantage. The Russians are starting to deploy the R-37/AA-X-13 (reported by some credible sources to have a range in excess of 150 nautical miles [nm]) on their upgraded MiG-31BM.[12] Additionally, the Russians say that variants can also be mounted on other aircraft such as the Su-35 and their T-50 fifth-generation fighter.[13] Even more ominous would be the Russian R-172/K-100, with a reported range of up to 200 or more nm.[14] If produced, it could be mounted on the widely deployed Su-27 family of aircraft.[15] At the very least, such very-long-range systems are likely to pose a major threat to the more vulnerable support aircraft such as tankers and Airborne Warning and Control System aircraft, on which our air operations critically depend.

Aside from the latest version of the advanced medium-range air-to-air missile (AMRAAM), the AIM-120D, which reportedly has a range 50 percent greater than that of earlier AMRAAMs (increasing its range up to a reported 97 nm), the United States has no longer-range AAMs in its inventory or in prospect.[16] The Navy's Phoenix missiles and the F-14s that carried them are long gone. The Next Generation Missile/Joint Dual Role Air Dominance Missile, intended as a replacement for the

AMRAAM (and the AGM-88 high-speed antiradiation missiles), reportedly was cancelled in 2012 for affordability reasons although some sources speculate that classified work has possibly continued.[17] Since one of this missile's major intended characteristics was substantially improved range, its development should be restored as a major priority.[18] At one time, we considered putting a ramjet engine on the AMRAAM to boost its range and capabilities, as is being done on several next-generation missiles such as the British Meteor, reportedly on the Chinese PL-21, and possibly a version of the Russian R-77/AA-12.[19] If doing so will further improve the range and capability of the AIM-120D, we should give serious thought to reviving this development. Finally, Raytheon is developing an extended-range version of the AMRAAM for surface launchers (the AMRAAM-ER) that we should consider modifying for very-long-range air-to-air use.[20] We should also contemplate reviving a version of the Network Centric Airborne Defense Element (NCADE) missile as an alternative very-long-range AAM. The NCADE was intended for boost-phase intercept of ballistic missiles, using an AMRAAM missile frame with an advanced rocket motor and an infrared seeker from an AIM-9X.[21] Early testing was evidently successful, but it does not appear to have been included in the budgets for fiscal year 2013 or later.[22]

An additional feature that we should think about for improving the capability of future missiles involves putting an AESA radar on the AMRAAM, as the Japanese have done with their AAM-4B and as the British may do with the Meteor, if this addition is technically possible. (The AAM-4 is somewhat larger than the AIM-120, allowing it to carry a bigger antenna.)[23] An AESA radar increases the range at which the active radar on the missile can autonomously track a target, reportedly by as much as 40 percent.[24] We may further increase the range of the radar by upgrading it with gallium nitride component technology.[25]

Improved Fuels

An obvious, although little-considered, way of extending the range of aircraft is through fuels with higher energy density per volume, which will yield greater range as long as they do not weigh much more than the fuels they replace. Fragmentary reports indicate that during the Cold War, the Soviets' development and use of a fuel with higher energy density per volume than commonly used Western fuel gave their aircraft considerably longer range than expected, but such reports remain publicly unconfirmed.[26] Recently, the United States has been researching a fuel called JP-900 for two main reasons: as an alternative to fuels produced from petroleum (it comes primarily from coal) and as a fuel having higher heat tolerance than those presently used. (It is called JP-900 for its stability for some specified period at 900 degrees Fahrenheit.) Research has confirmed that JP-900 also has a somewhat higher energy density than present jet fuels but only by several percent.[27] However, higher energy density appears to have been only a secondary consideration in the research. The Department of Defense should make such energy density a primary consideration for such research along with cost considerations (new fuels need to be no more expensive than the current ones) and the ability to immediately substitute for present fuels without modifying aircraft systems.[28]

Conclusions

The days when the United States could take for granted its status as the world's premier air and space technology superpower may not be over, but complacency is clearly not an option. Above all, we need to recognize that we are facing long-term competition and that we must keep our own tree of air and space innovation well watered, especially for tactical systems at a time when, as this analysis has noted, little low-hanging fruit will be harvested in the near future. We should change that prospect for combat aircraft and systems—and soon. It is time to start thinking outside the box.

Aside from applying emerging techniques such as rapid prototyping, we should consider turning to the private sector.[29] Numerous companies are now leading in such fields as cyber and space launch vehicles. For one, SpaceX seems well on the way to revolutionizing the field by providing space-launch-vehicle capability at a cost well under historic norms.[30] Further, the company evidently intends to undertake a further revolution by making such vehicles fully reusable.[31] Of more relevance, civilian companies may be pursuing a similar revolution with high-speed flight. For instance, the Hypermach company is designing the SonicStar, an advanced business jet intended to cruise at over Mach 4.[32] I suggest that DARPA and the Air Force closely monitor its development, and if it actually works, we should explore the feasibility of converting its technology to war-fighting use.[33] ✪

Notes

1. These technologies include the following:
   - Fourth-generation aircraft that were increasingly integrated systems rather than a collection of discrete subsystems: F-15s, F-16s, and F-18s.
   - Stealth aircraft.
   - All-aspect infrared air-to-air missiles (AAM) starting with the AIM-9L Sidewinder.
   - Active radar-guided AAMs: the AIM-120 advanced medium-range air-to-air missile (AMRAAM).
   - Precision-guided air-to-surface munitions.
   - Look-down-shoot-down radars.
   - Precision navigation systems, especially the Global Positioning System.
   - Command, control, communications, computers, intelligence, surveillance, and reconnaissance systems necessary to fight an integrated battle and war.

2. Aside from stealth, many people argue that the F-35A does not provide major improvements over the F-16 and that in some important aspects (maximum speed and maneuverability), it is actually less capable.

3. These upgrades have included improved weapons; more advanced electronics and engines; further integration of sensors both on and between aircraft; improvements of command, control, communications, computers, and intelligence; and maintaining an increasingly aged aircraft fleet while fighting in multiple conflicts simultaneously.

4. The list of revolutions is as follows:
   - In advanced military combat aircraft, including stealth aircraft.
   - In support aircraft.
   - In remotely piloted air systems.
   - In precision-guided long-range missiles, including antiship ballistic missiles.

- In air defense.
- In antisatellite systems.
- In aircraft carriers.
- In manned space systems.

See Lt Col Thomas R. McCabe, *China's Air and Space Revolutions*, Mitchell Paper 10 (Arlington, VA: Mitchell Institute Press, 2013), http://higherlogicdownload.s3.amazonaws.com/AFA/6379b747-7730-4f82-9b45-a1c80d6c8fdb/UploadedImages/Mitchell%20Publications/MP10_China.pdf.

5. Office of the United States Air Force Chief Scientist, *Technology Horizons: A Vision for Air Force Science and Technology, 2010–30*, vol. 1, AF/ST-TR-10-01-PR (Washington, DC: Office of the United States Air Force Chief Scientist, September 2011), http://www.defenseinnovationmarketplace.mil/resources/AF_TechnologyHorizons2010-2030.pdf. More recent studies, such as *Global Horizons*, also show a lack of concentration on aeronautics. See Office of the United States Air Force Chief Scientist, *Global Horizons Final Report: United States Air Force Global Science and Technology Vision*, AF/ST TR 13-01 (Washington, DC: Office of the United States Air Force Chief Scientist, 21 June 2013), http://www.defenseinnovationmarketplace.mil/resources/GlobalHorizonsFINALREPORT6-26-13.pdf. Intriguingly, a briefing on the subject by Dr. Mark Maybury mentioned modularity and speed (not mentioned in the text) as air game changers but gave no specifics regarding efforts to pursue them. Briefing, Dr. Mark Maybury, subject: Air Force Global Horizons, 24 April 2013, http://www.dtic.mil/ndia/2013ST/Maybury.pdf. See also House, *Dr. David E. Walker, Fiscal Year 2014 Air Force Science and Technology, Presentation to the House Armed Services Committee, Subcommittee on Intelligence, Emerging Threats and Capabilities,* 113th Cong., 1st sess., 16 April 2013, http://www.defenseinnovationmarketplace.mil/resources/FY14_AF_ST-Testimony.pdf. In 2014 *America's Air Force: A Call to the Future* did not mention superior aircraft as a priority. See Deborah Lee James [secretary of the Air Force], *America's Air Force: A Call to the Future* (Washington, DC: Headquarters US Air Force, July 2014), http://airman.dodlive.mil/files/2014/07/AF_30_Year_Strategy_2.pdf. Finally, in early 2015, the Air Force's Scientific Advisory Board was concentrating on studies on quantum systems, cyber vulnerabilities, and remotely piloted systems. See Aaron Mehta, "US Air Force Launches Trio of Tech Studies," *DefenseNews*, 31 January 2015, http://www.defensenews.com/story/defense/air-space/air-force/2015/01/31/usaf-launches-study-trio-sab/22524543/. Analysis of future air warfare, both by the Air Force and the Defense Advanced Research Projects Agency (DARPA), also evidently does not expect much in the way of improved aircraft performance and capability. See Marc Schanz, "Rethinking Air Dominance," *Air Force Magazine* 96, no. 7 (July 2013): 36–39; and Graham Warwick, "No Silver Bullet," *Aviation Week* 175, no. 16 (20 May 2013): 52.

6. With the possible (but unlikely) exception of the Long-Range Strike Bomber, none of the Air Force's top modernization priorities (the F-35, KC-46 tanker, Long-Range Strike Bomber, E-8 Joint Surveillance Target Attack Radar System replacement, and the T-X trainer) extend the envelope on aircraft performance. See June L. Kim, "The Top Modernization Priorities Developing Airmen," *Air Force Magazine* 97, no. 11 (November 2014): 39–40.

7. The Navy claims to have three times as many airplane projects in production or on the drawing boards as the Air Force. However, an examination of the actual programs (three variants of the F/A-18, two variants of the F-35, the P-8 patrol aircraft [a redesigned Boeing 737], the V-22 tilt-rotor in production, a new-start advanced fighter, and a stealthy unmanned combat air vehicle in design) shows that the same pattern applies. See John A. Tirpak, "Navy Offers Airplane-Building Advice," *Air Force Magazine* 96, no. 8 (August 2013): 14.

8. These include active electronically scanned array (AESA) radars, which provide improved radar range, greater reliability and survivability, and some degree of detection capability against small targets like stealth platforms and cruise missiles; improved engines that might give aircraft somewhat longer operating ranges and somewhat better speed; improvements to stealth that are likely to concentrate on increasing the range of radar frequencies protected against and improving the ease of production and maintainability; and more capable, better integrated sensors and better computers that may, to a degree, help cope with the fog of battle, data overload, jamming, and hostile stealth.

9. James Drew, "USAF Nominates JASSM Missile to Host New Computer-Killing Weapon," Flightglobal, 14 May 2015, http://www.flightglobal.com/news/articles/usaf-nominates-jassm-missile-to-host-new-computer-killing-412348/. Note the "Suter" airborne network attack system reportedly used by the Israelis in their raid on the Syrian reactor site in the October 2007 CHAMP. See John Antal, "Ray

Guns and War," *Military Technology* 36, no. 8 (2012): 43; and David A. Fulghum and Douglas Barrie, "Israel Used Electronic Attack in Air Strike against Syrian Mystery Target," Aviation Week.com, 8 October 2007, http://abcnews.go.com/Technology/story?id=3702807&page=1.

10. John A. Tirpak, "Getting All Hyper," *Air Force Magazine* 98, no. 3 (March 2015): 18. For details on the tactical missiles, see Kris Osborn, "AF Chief Scientist: Air Force Working on New Hypersonic Air Vehicle," Defensetech, 1 June 2015, http://defensetech.org/2015/06/01/af-chief-scientist-air-force-working-on-new-hypersonic-air-vehicle/.

11. Wendell Minnick, "China Reveals New AMRAAM," *DefenseNews*, 23 May 2011, http://minnickarticles.blogspot.com/2011/05/china-reveals-new-amraam.html; and Richard Fisher Jr., "China's Emerging 5th Generation Air-to-Air Missiles," International Assessment and Strategy Center, 2 February 2008, http://www.strategycenter.net/research/pubID.181/pub_detail.asp.

12. Dr. Carlo Kopp, *The Russian Philosophy of Beyond Visual Range Air Combat*, Technical Report APA-TR-2008-0301, Air Power Australia, updated April 2012, http://www.ausairpower.net/APA-Rus-BVR-AAM.html; and "Russian Air Force Tests New Air-to-Air Missile," *Sputnik International*, 24 January 2012, http://en.rian.ru/russia/20120124/170929008.html.

13. "In the News: Missiles and Radars," *Beyond Defence* (blog), 11 September 2013, https://beyonddefence.wordpress.com/tag/rvv-bd/; and Bill Sweetman, "Cloak and Dagger," *Aviation Week* 175, no. 30 (2 September 2103): 29.

14. Kopp, *Russian Philosophy.*

15. Ibid.

16. Mike Hoffman, "Lockheed Test Pilot Calls for Longer Range AIM-120," Defensetech, 18 February 2014, http://defensetech.org/2014/02/18/test-pilot-calls-for-longer-range-aim-120/. It must be noted that the reported range for the AIM-120 varies widely and may depend on a variety of factors such as altitude of launch and speed of the launch aircraft.

17. Zach Rosenberg, "USAF Cancels AMRAAM Replacement," Flightglobal, 14 February 2012, http://www.flightglobal.com/news/articles/usaf-cancels-amraam-replacement-368249; Dave Majumdar, "AF Looks to Trim Procurement, R&D in 2013," *Air Force Times*, 13 February 2012, http://www.airforcetimes.com/article/20120213/NEWS/202130341/; and Amy Butler, "Next-Generation Fighter, Directed Energy Weapons May Converge," *Aviation Week*, 5 August 2014, http://aviationweek.com/defense/next-generation-fighter-directed-energy-weapons-may-converge.

18. Stephen Trimble, "In Focus: USAF Committed to Replace AMRAAM and HARM with New Missile," Flightglobal, 6 December 2011, http://www.flightglobal.com/news/articles/in-focus-usaf-committed-to-replace-amraam-and-harm-with-new-365333.

19. Douglas Barrie, "British Court Germany and France on FMRAAM Project," Flightglobal, 14 June 1995, http://www.flightglobal.com/news/articles/british-court-germany-and-france-on-fmraam-project-25672/; Dr. Gareth Evans, "Air-to-Air Missiles—Expanding the No-Escape Zone," airforce-technology.com, 11 April 2012, http://www.airforce-technology.com/features/featureair-to-air-missiles-expanding-the-no-escape-zone/; Wendell Minnick, "China Developing Counterstealth Weapons," *DefenseNews*, 31 January 2011, http://www.defensenews.com/article/20110131/DEFFEAT04/101310315/China-Developing-Counterstealth-Weapons; and Douglas Barrie, "Vympel Launches R-77 Ramjet from Su-27," Flightglobal, 5 July 1995, http://www.flightglobal.com/news/articles/vympel-launches-r-77-ramjet-from-su-27-21749/.

20. Richard Tomkins, "Raytheon Developing Extended Range AMRAAM," UPI, 24 February 2015, http://www.upi.com/Business_News/Security-Industry/2015/02/24/Raytheon-developing-extended-range-AMRAAM/5641424782276/.

21. See "NCADE: An ABM AMRAAM—Or Something More?," *Defense Industry Daily*, 20 November 2008, http://www.defenseindustrydaily.com/ncade-an-abm-amraam-03305/. See also "Exhibit R-2, RDT&E Budget Item Justification: PB 2013 Air Force" (U), February 2012, http://www.globalsecurity.org/military/library/budget/fy2013/usaf-peds/0604330f.pdf.

22. Baker Spring, "President Obama's Missile Defense Program Falls behind the Threat," Backgrounder no. 2686, Heritage Foundation, 3 May 2012, http://thf_media.s3.amazonaws.com/2012/pdf/bg2686.pdf; and Spring, "Congress Must Stop Obama's Downward Spiral of Missile Defense," Issue Brief, Heritage Foundation, 20 May 2013, http://www.heritage.org/research/reports/2013/05/congress-must-stop-obamas-downward-spiral-of-missile-defense. Neither have I been able to find any references to testing in the budget for fiscal year 2015.

23. Bradley Perrett, "Japanese Guidance," *Aviation Week* 176, no. 26 (28 July 2014): 27; and Perrett, "Japan Upgrading 60 F-2s with AAM-4, J/APG-2," *Aviation Week*, 27 February 2012, http://www.aviationweek.com/Article.aspx?id=/article-xml/AW_02_27_2012_p27-428848.xml.

24. Perrett, "Japan Upgrading."

25. See Amy Butler and Graham Warwick, "Power Circuit," *Aviation Week* 176, no. 5 (17 February 2014): 45; and Sydney J. Freedberg Jr., "The Biggest Thing since Silicon: Raytheon's Gallium Nitride Breakthrough," Breaking Defense, 20 February 2015, http://breakingdefense.com/2015/02/the-biggest-thing-since-silicon-raytheons-gallium-nitride-breakthrough/.

26. George C. Larson, "Cool Fuel," *Air and Space* 19, no. 3 (August/September 2004): 12. Some sources refer to a Russian T-6 fuel that is heavier than Russia's usual jet fuels, but no specifics are available as to its performance. Lori M. Balster et al, "Development of an Advanced, Thermally Stable, Coal-Based Jet Fuel," *Fuel Processing Technology* 89, no. 4 (April 2008): 366, http://www.sciencedirect.com/science/article/pii/S037838200700238X.

27. The author's estimate, confirmed by a pilot coworker, is that JP-900 has an improved energy density of about 6 percent. However, this improvement comes at the cost of slightly lower fuel performance and somewhat higher weight. Based on Balster, "Development," fig. 1.

28. Some sources report that JP-900 is too dense to be used in unmodified fuel systems. See ibid., 366.

29. Aaron Mehta, "Rapid Prototyping the New Model: Sikorsky's New Norm Saves Money, Time," *DefenseNews*, 31 October 2013, http://www.defensenews.com/article/20131031/DEFREG02/310310025/Rapid-Prototyping-New-Model.

30. See Andrew Chaikin, "Is SpaceX Changing the Rocket Equation?," *Air & Space*, January 2012, http://www.airspacemag.com/space/is-spacex-changing-the-rocket-equation-132285884/.

31. Ibid. Meanwhile, the British are attempting to leapfrog this development with their Skylon single-stage-to-orbit vehicle.

32. Chad Trautvetter, "HyperMach Reconfigures SSBJ Design, Aiming for Mach 4.5," *AIN Online,* 6 December 2012, http://www.ainonline.com/aviation-news/2012-12-06/hypermach-reconfigures-ssbj-design-aiming-mach-45.

33. Admittedly, this is a big "if." Ambitious plans from a decade ago for supersonic business jets have so far come to nothing. See Stuart F. Brown, "Mine's Faster Than Yours," *Fortune*, 28 June 2004, http://archive.fortune.com/magazines/fortune/fortune_archive/2004/06/28/374394/index.htm. Evidently, such supersonic aircraft are not expected to reach the market until at least 2021. See Grant Martin, "The World's First Supersonic Business Jet Will Reach the Market in 2021," *Forbes*, 31 October 2013, http://www.forbes.com/sites/grantmartin/2013/10/31/the-worlds-first-supersonic-business-jet-will-fly-in-2021/.

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