

No US fighter except the F-22 will hold a definite edge on next-generation European fighters.

The Gray Threat

By Mark Lorell, Daniel P. Raymer, Michael Kennedy, and Hugh Levoux

WITH the collapse of the Soviet Union and sharp downward pressure on defense spending, weapon systems conceived during the Cold War are under major political attack. A prime target is the F-22 fighter. This stealthy aircraft, now in the latter stages of development, is slated to replace the F-15C as the Air Force's premier air-superiority fighter.

The F-22 is the Air Force's top-priority system, but the program is vulnerable. Already, budget cuts have pushed back initial operational capability to 2004, and planned production has been slashed by forty percent, from 750 to 442 aircraft. With total cost projected to reach \$71 billion, however, the F-22 is still one of the largest of all programs and continues to be scrutinized.

Opponents argue that, given the evaporation of the Soviet threat and decline in Russia's military aerospace industry, USAF no longer needs such a sophisticated fighter. The Air Force, the Defense Department, and industry officials warn that critics fail to take into account the widespread proliferation of "gray threats"—a new generation of ad-

vanced European fighter aircraft and munitions likely to be widely exported.

The three fighters in question are the multinational EF-2000 Eurofighter, France's Rafale, and Sweden's Gripen. According to the Air Force, these warplanes "will have significant speed, stealth, and maneuverability improvements over current types and . . . are actively being marketed worldwide."

"F-15 Class—Or Better"

Supporters of the F-22 claim that the new European fighters will be significantly more capable in agility, stealth, and other performance parameters, compared to existing US F-16s and F/A-18s and even upgraded versions of these aircraft. One senior Air Force official explicitly stated that the EF-2000 and the Rafale "are in the F-15 class or better." Thus, the supporters argue, without the F-22, US forces could someday have to confront an opponent who, through the purchase of the new European aircraft, possesses major weapon systems equal or superior to USAF counterparts.

How serious are the "gray threats"?

This French-built Rafale going through its paces at a recent air show is one of three advanced technology European fighters with the potential to match or surpass the capabilities of all US counterparts currently in the inventory.



Figure 1: Technical Comparisons

Parameter	EF-2000	Rafale	Gripen	F-16C/40	F-15E
Maximum weight (lbs.)	46,305	47,400	28,000	42,300	81,000
Design weight (lbs.)	33,000	33,500	20,000	27,185	49,000
Empty weight (lbs.)	21,495	19,973	14,800	18,298	32,000
Internal fuel carriage (lbs.)	8,818	9,420	5,000	6,646	13,123
Maximum external load (lbs.)	14,330	17,637	10,000	12,000	24,500
Store stations (number)	13	14	7	9	11+
Length (feet)	52.33	50.17	46.25	49.33	63.75
Span (feet)	35.92	35.75	27.58	31.00	42.83
Wing area (square feet)	538	495	330	300	608
Wing loading (lbs./square foot)	61	68	61	91	81
Maximum thrust (lbs.)	40,460	32,800	18,000	23,770	68,200
Thrust-to-weight ratio	1.23	.98	.90	.87	1.39
G limit	9	9	9	9	9
Maximum angle of attack (degrees)	33+	32	26	26	30+
Takeoff distance (feet)	970	1,290	1,290	1,400	1,400
Landing distance (feet)	1,610	1,290	1,610	2,950	4,250
Maximum speed (Mach number)	2.0	1.8	2.0	2.0+	2.5

Data in this table were compiled by RAND Corp. They come from a variety of unclassified sources, including officials of the European aircraft contractors, government reports, and press accounts. Some figures have been derived by RAND on the basis of other reliable data.

A RAND research team conducted an extensive series of unclassified interviews with key European government and industry officials engaged in development of these fighters, focusing on three basic questions:

- How good are they (and how much better can they get)?
- Will research and development be completed and full-scale production launched?
- Will they be widely exported outside of Europe?

Though great uncertainty exists, all available information points to this conclusion: The concern expressed by the Air Force and the Defense Department should be taken seriously. The evidence is that these European aircraft will be highly competitive with existing US fighters and future variants, will be fully developed and procured, and will be sold outside of Europe. The F-22 would be the only US fighter with a clear combat edge.

It appears that, with these three fighters, the Europeans will take a significant step toward closing the performance gap between American fighters and Europe's models. The new fighters are multirole designs featuring cutting-edge technologies, including large, integral, load-bearing composite structures; canard configuration; relaxed stability with fully computerized digital flight controls; some measure of stealth (at least compared to traditional air-

craft); and sophisticated pilot displays and controls.

The EF-2000 will be built by British Aerospace (UK), Deutsche Aerospace (Germany), Alenia (Italy), and CASA (Spain), with the UK and Germany providing technological leadership. Rafale, developed by Dassault, has been created on a purely national basis in France. Far smaller than the first two, Sweden's JAS 39 Gripen has been developed by Saab.

How capable will they be when put to the ultimate test of aerial combat? The question is, of course, extremely difficult to answer. Nonetheless, a rough approximation of combat capability can be achieved by developing basic estimates of air vehicle performance capabilities and by examining in detail several key, high-leverage munitions and subsystems.

Figure 1 presents key design and performance data—obtained from contractors and other open sources—for the three European fighter aircraft and comparable data for two front-line USAF fighters—the Lockheed Martin Block 40 F-16C and the McDonnell Douglas F-15E.

Consistent range data were not available. However, it appears that EF-2000 and Rafale have ranges somewhat greater than the F-16's, while the Gripen's range is somewhat less. The F-15E is probably superior to all because of its massive fuel load.

Impressive Performance

These new European aircraft are impressive in many respects. EF-2000 and Rafale are quite similar in several parameters, including gross weight, payload, stores stations, physical dimensions, speed, and field lengths. EF-2000 has an advantage in thrust-to-weight (T/W) ratio, a key attribute in close-in dogfighting.

Basic performance data relevant to aerial combat suggest that EF-2000 and Rafale will hold clear superiority over the Block 40 F-16C and essential equivalence in important areas with the F-15E. Because it is a much smaller fighter, Gripen is, not surprisingly, outclassed by the F-15 and the other two European fighters. However, the lightweight Swedish entry compares favorably in several respects to the F-16.

The new European fighters show a superior T/W ratio, compared to the F-16, while the EF-2000 is close to the F-15E. Rafale and EF-2000 boast angle-of-attack capabilities superior or roughly comparable to the capabilities of the two US fighters. Gripen's AOA capability is probably about the same as the F-16's.

These data do not reflect important agility advantages that all three European fighters may possess as a result of the static instability of their designs and their canard-delta configurations, combined with their advanced fly-by-wire flight-control systems.

It is difficult, without actually performing a full-scale air-to-air combat simulation analysis, to predict the winner of any future combat between current US fighters and the new European aircraft. However, some insights can be gained through a closer examination of other factors, such as weapons.

European planners intend to develop and equip their new fighters with a variety of high-leverage, advanced subsystems and munitions. Several merit further discussion because of their high potential for enhancing the combat effectiveness of the fighters in ways that cannot be captured in basic performance data.

Subsystems of particular interest include the RBE2 fire-control radar intended for the Rafale, and the integrated electronic warfare systems (IEWS) and infrared search and track (IRST) systems under development

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The JAS 39 Gripen, said to compare favorably with the F-16, is shown here equipped with five different types of next-generation air-to-air missiles—weapons crucial for maximizing the combat power of the new European fighters.

Figure 2: Claimed Combat Simulation Scores

Fighter (Origin)	Effectiveness Score	Inferred Exchange Ratio
F-22 (US)	.91	10:1
EF-2000 (European)	.82	4.5:1
F-15F (US)	.60	1.5:1
Rafale (France)	.50	1:1
F-15C (US)	.43	1:1.3
F/A-18E/F (US)	.25	1:3
F/A-18C (US)	.21	1:3.8
F-16C (US)	.21	1:3.8

Simulation scores registered in this table assume beyond-visual-range aerial combat against threat aircraft possessing the capabilities of the Russian Su-35 fighter equipped with missiles similar to AMRAAM. BAe supplied the effectiveness scores, and RAND translated these into standard exchange ratios. This simulation did not measure the performance of the Swedish Gripen or the US F-15E. The F-15F to which this table refers is a possible upgrade of the USAF F-15 fighter.

for EF-2000 and Rafale. These systems not only exhibit advanced technologies and capabilities but suggest a significant narrowing of the gap between US and European avionics.

The RBE2 is Europe's first phased-array fire-control radar for a fighter. This type can provide major operational advantages over existing radars. No current US fighter is equipped with a phased-array radar. However, an active phased-array system is under development for the F-22.

Historically, European contractors have lagged considerably behind the United States in the development of electronic warfare systems. This situation may be changed by introduction of the Defensive Aids Subsystem (DASS), now under development for the EF-2000, and the IEWS planned for both EF-2000 and the Rafale. Detailed combat-simulation studies conducted by the UK's Defence Research Agency (DRA) and reported to the House of Commons in May 1994 found DASS to be a critical subsystem that adds greatly to the combat effectiveness of EF-2000.

EF-2000 and Rafale will have new-technologyIRST systems, providing a passive option for locating and tracking aerial targets. BecauseIRSTs do not emit energy that can give

away a fighter's location, they increase stealthiness. They also provide a means, under certain circumstances, for tracking fighters with low radar cross section by detecting engine heat and aerodynamic heating of aircraft skin. Simulations conducted by the British DRA show thatIRST adds substantially to EF-2000's aerial prowess.

"Decisive Edge" in Missiles

For maximizing the combat power of the European fighters, nothing is more crucial than the new wave of air-to-air missiles currently planned or under development. Combat simulation studies conducted by RAND and others have suggested that new-generation, high-capability air-to-air missiles can provide a decisive edge in air combat. Most important among these missiles are new "fire-and-forget" weapons that use active, autonomous radar seekers for long range and new-generation, all-aspect imaging-infrared (IIR) seekers for close-in combat. These missiles are capable enough to potentially create favorable combat outcomes with less capable aircraft and crews.

Existing or planned European missiles may even surpass the capabilities of the US-produced AIM-120 Advanced Medium-Range Air-to-Air

Missile (AMRAAM). Rafale is designed to use the Matra-Hachette MICA missile. Unlike AMRAAM, MICA will be built in active radar and IIR-guided variants. The British Procurement Executive and the Royal Air Force are examining options to fulfill a requirement for an FMRAAM—Future Medium-Range Air-to-Air Missile—for EF-2000. British officials are seeking a weapon with longer range, higher speed, and greater agility than AMRAAM.

European contractors and government agencies have conducted numerous computer combat simulations and assessments of their aircraft. These need to be viewed with a great deal of skepticism for obvious reasons. Nonetheless, several clearly were conducted with a high level of professionalism.

In 1993 and 1994, British Aerospace (BAe) and the DRA conducted extensive computer simulations to examine the effectiveness of the various versions of EF-2000 and compare them to future Russian aircraft as well as other fighters. Both studies focused on beyond-visual-range (BVR) air-to-air combat and assumed threat aircraft having the capabilities of an upgraded Russian Su-27 (Su-35) equipped with a missile similar to AMRAAM. BAe's simulations apparently were limited to small engagements of two fighters vs. two fighters, or smaller. DRA's simulations seem to have been more sophisticated; DRA went as high as eight vs. eight engagements.

Both studies used an overall effectiveness outcome scale that ranks fighters from zero to 1.0. The higher the number earned, the greater the probability that the fighter wins in a specific mission. Thus, a score of zero means the fighter will always lose, and a score of 1.0 means it will always win. A score of .5 means a fighter will have a one-to-one exchange ratio. Some of the results of the BAe simulations are shown in Figure 2, along with RAND's own calculations of how the scores translate into more traditional exchange ratios (enemy losses vs. friendly losses).

F-22 Has Advantage, But . . .

The scores from both studies indicate that EF-2000 is superior to all fighters examined, with the exception of the F-22. Furthermore, BAe



Having resolved contentious work-share issues, the nations building the EF-2000 increased the likelihood of full-scale development and production. British, German, Italian, and Spanish aerospace heavyweights are partners in the program.

proudly notes that the F-22 is only about ten percent higher on BAe's effectiveness scale but costs about twice as much as EF-2000. However, when one uses exchange ratios—the traditional way of measuring combat effectiveness—the F-22 comes out much better, with more than double the effectiveness of EF-2000.

BAe and DRA analysts reported that all existing US fighters, with the exception of the F-15, performed relatively poorly. Even the F-15 barely exceeded a one-to-one exchange ratio and placed well below EF-2000. Rafale does not do particularly well, but it is shown to be competitive with the F-15 and superior to other US fighters. Because of limitations in radar range, speed, and acceleration, Gripen does not fare as well as the other European fighters do, but DRA found that it performed about as well as the F/A-18E/F did, the heavily modified and upgraded version of the US Navy Hornet.

French spokesmen insist that, with similar scenario assumptions, tactics, equipment, and munitions, Rafale performs about the same as EF-2000 does, and Sweden claims new-generation BVR missiles used with a ground air defense radar net and combined with Gripen's small signature and rapid turnaround rates make their fighter a highly effective weapon system.

The F-22 would perform effec-

tively against the European fighters in BVR combat because of its stealth, supercruise, and radar capabilities. If a "leaker" ever managed to get close, the F-22 would be at least a match and probably superior.

The F-15 and F-16, however, would confront something close to an even match, especially against EF-2000 and Rafale. This is not to say that current US aircraft would be outclassed, but they may confront rough parity in exchange ratios. Many planners would argue that such an outcome is politically unacceptable.

Will US fighters ever have to face these weapons? RAND found it probable that all three new European fighters will be fully developed and produced in significant numbers.

The Gripen has now entered into full production, and the Swedish Air Force is almost certain to support a substantial production run. Current SAF plans call for production of 110 aircraft, but Gripen supporters hope for a total SAF production run of 300.

The new Chirac-Juppé government recently launched a major review of overall French military spending levels. Reductions and stretchouts in procurement programs are likely.

Yet, Rafale faces little political opposition; the R&D program is now viewed as politically secure. As a key program in the new French five-year military budget law, the new fighter almost certainly will complete development and enter production.

Of the three, EF-2000 is the most uncertain. However, it will most likely be fully developed and produced, though possibly without full participation of all current nations. This argument rests largely on the perception that the UK has an unshakable commitment to the program and that other partner nations recognize that they would pay very high political, economic, and technological costs for pulling out. Indeed, in November 1995, the four partners were finally able to reach an agreement on the contentious work-share issue. This agreement dramatically increases the likelihood of full-scale development and production.

The gray threats can be taken seriously only if the new European fighters are sold outside Europe. RAND found that this is likely to be the case. Despite high prices and constraints on the global market, the three European fighters have a reasonable prospect of winning significant foreign orders.

First, several of the key European governments and contractors in these programs appear more committed than ever to promoting foreign sales and seem determined to do whatever it takes to win export orders. The three aircraft have been actively promoted on the international market. Second, export prices of these fighters will likely be broadly competitive with US fighters available for export. Third, a large potential market outside of Europe exists.

The claims made by some USAF and Defense Department officials that the European fighters represent potential gray threats deserve further serious consideration by defense analysts. The US should carefully evaluate its defense requirements and weapon needs for a possible future environment where the gray threats turn out to be real. ■

Mark Lorell, Daniel P. Raymer, Michael Kennedy, and Hugh Levaux, all RAND Corp. analysts, researched and wrote a longer study, "The Gray Threat: Assessing the Next-Generation European Fighters," from which this article is adapted. That study was published in November 1995.