The yield from Forecast II is surprising even the optimists. Many of the systems may be ready for demonstration—and some for operation—before the turn of the century.

**Shortcuts to the Future**

*BY JAMES W. CANAN, SENIOR EDITOR*
The Air Force's Project Forecast II is looking a lot less radical than it did at its unveiling early last year. The distant future that the study foreshadowed has turned out to be visible to the naked eye. Evidence is mounting throughout Air Force Systems Command's research and engineering shops that many of the thirty-nine new and nascent technologies identified in Forecast II as essential to Air Force systems of the future are more manageable and more mature than they seemed.

In consequence, many of the thirty-one air and space systems that Forecast II portrayed as representing "the art of the possible" in USAF combat capability beyond the year 2000 are shaping up instead as the art of the probable.

Those systems were billed in Forecast II as having the potential to "revolutionize the way the Air Force carries out its mission in the twenty-first century, guaranteeing continued technological supremacy over any potential adversary."

They were the stuff of science fiction not all that long ago. Among them are aerospace planes, hypersonic aircraft and strategic missiles, engines driven by antiprotons and by other exotic fuels, tactical missiles that see and think for themselves, aircraft with multimode sensors built into their "smart skins," and unjammable, speed-of-light communications.

In the advanced materials and fuels that are prerequisite to much of this, scientists and engineers will rearrange the molecules, atoms, and electrons of nature's own materials and gases. And they know how.

It now seems likely that many of Forecast II's technologies and systems will be ready for demonstration and even for operation before the turn of the century. These include the supercockpit, the National Aerospace Plane (NASP) in the form of its X-30 test-bed aircraft, autonomous missiles, advanced materials, hypersonic strategic missiles, highly energetic rocket propellants, and at least some elements of a battle management and command control communications and intelligence (C^3I) setup using artificial intelligence and photonics.

Rome Air Development Center (RADC) of AFSC's Electronic Systems Division has already built tiny sensing and processing devices that represent the first step—in the form of hardware—toward aircraft smart skins studded with sensors of several descriptions.

In all such examples of the foreshortening of the future as envisioned in Forecast II, history seems to be repeating itself. The same thing happened the last time the Air Force marshaled its technological assets and force-marched them forward.

The First Forecast

Nearly a quarter of a century ago, the Air Force stepped back and surveyed all available technologies, identified those of brightest promise, tagged them as top priority, and pictured the air and space systems to come of them.

The vehicle for this was a 1963–64 study called Project Forecast. Its conclusions turned out to be truer and timelier than anticipated.

Project Forecast paid off handsomely and quickly. The technologies of aerodynamics, propulsion, materials, and sensors that it earmarked for special grooming led to, among other systems, the B-1 bomber, the C-5 transport, the Space Shuttle, and laser-guided and
TV-guided weapons—all of them the products of the following decade.

In some cases, even where Project Forecast was off the mark, it was eventually redeemed. For instance, it set store by advanced materials to be reinforced with boron filaments. Boron never made it as an aircraft body builder—but Project Forecast's emphasis on the need to develop new structural materials in general resulted in the graphite epoxies of wide application in modern airframes.

The Air Force reexamined the Project Forecast report after it was issued and found that "virtually across the board, it had been extremely conservative," says Maj. David Glasgow, chief of AFSC's Project Forecast II program control office. "Much more had happened than the study had predicted would happen—and we perceive the same coming true with Project Forecast II."

"We see terrific synergism between where we are now and where we are going in technologies and in systems concepts. Avenues are already opening up that we never thought of. I believe the results will be revolutionary and that we will be much farther ahead twenty years from now than we thought we would be."

The original Forecast study was somewhat off the mark in one important arena. It did not recommend that the Air Force invest heavily in developing advanced computers and software.

The reason for this was that the Air Force expected the US electronics industry to make sure that its research and development would be in tune with future military requirements for increased speed and computational capability in mainframe computers. This happened, but the industry's companion development of integrated circuits for microprocessors was oriented much more to commercial markets than it was to the military market. This is why the Defense Department eventually had to strongarm it to undertake such vital projects as the one to develop very-high-speed integrated circuitry (VHSIC) for small data and signal processors aboard weapon systems.

VHSIC is the key to the integration of all avionics aboard USAF's Advanced Tactical Fighter and to the success of a great many Forecast II endeavors in electronics, some of which, such as the supercockpit, may well wind up in the ATF.

**Flagship of the Project**

Computational capability is pervasive in Forecast II technologies and systems concepts and is fundamental to just about everything. The National Aerospace Plane (NASP) program makes the point.

At an Air Force Association symposium on space earlier this year, Brig. Gen. Eric B. Nelson, AFSC's Deputy Chief of Staff for Plans and Operations, described the NASP as "the flagship" of Forecast II and of the entire Air Force science and technology program, which has come to be dominated by Forecast II initiatives.

The NASP program was made possible by the advent of supercomputers for calculating the hypersonic aircraft/spacecraft's extremely complicated fluid dynamics and for designing its airframe and engines accordingly as a thoroughly integrated system. Furthermore, supercomputers with software oriented to artificial intelligence will almost certainly be central to the aerospace plane's avionics.

There is no longer any doubt that supercomputers can be made small enough for carriage aboard aircraft and spacecraft. RADC is fashioning one that will look lilliputian alongside the mainframe supercomputers that are today's standards for size.

The RADC supercomputer will be made up of a stack of superthin silicon wafers in a container the size of a three-pound coffee can. It will be capable of performing more than one trillion computational operations per second and will need only thirty watts of power. Thus, it will be up to 100 times quicker than existing supercomputers and will require only about one eight-thousandth of their power.

RADC began devising the "wafer-stack"—or "3-D"—supercomputer last August after Hughes Aircraft delivered a proof-of-concept model.

"We're developing new architectures for building 3-D computers in a variety of ways," explains Col. Charles E. Franklin, RADC's Com-
Forecast II projects. It plans to compound that ten percent each year through Fiscal Year 1992.

Things are working out even better than anticipated. Impressed by Forecast II, the Air Force leadership granted AFSC an additional $147 million for its science and technology budget for Fiscal Year 1988. Even though that budget took a net cut of $19 million as a result of congressional actions, the Air Force insulated Forecast II programs against harm.

Having taken notice of USAF’s earnest money in support of Forecast II, the US aerospace and electronics industries are demonstrably bullish about their own undertakings attuned to Forecast II projects.

Not long ago, AFSC contacted twenty-four companies with a combined investment of $2 billion in independent research and development (R&D) for the Air Force to find out how much of that investment is being committed to the furtherance of Forecast II projects. The answer: nearly $870 million.

Major examples of programs receiving big industry R&D money are the supercockpit, photonics, knowledge-based systems (AI), battle management/C3I, space-based wide-area surveillance, information processing, ultrareliable software, advanced materials, high-performance turbine engines, autonomously guided (“brilliant”) weapons, hypersonic missiles and aircraft (a family of them, not just the NASP), and advanced VTOL and STOL aircraft for just about every conceivable tactical mission.

The Supercockpit

The supercockpit is a prime example of near-term payoff. Prior to his retirement last July, Gen. Lawrence A. Skantze, who as AFSC’s Commander headed the Forecast II study, had this to say:

“At international air shows, it’s obvious that the performance of other nations’ fighters is approaching ours. The one area where we can leave them in the dust is cockpit battle management. Our distinct lead in computers, avionics, and sensors will culminate in the supercockpit.”

The supercockpit is a melding of the latest technologies of sensors, computers, artificial intelligence, and three-dimensional displays into a system that the Air Force calls the “virtual world.” In this, aircrews will wear helmets that will display virtually everything they need to see inside and outside the cockpit. They will also be able to direct their aircraft and its systems to do certain things simply by means of voice commands and to train their weapons on targets by looking in the direction of the targets.

The purpose of all this is to help aircrews manage their increasingly difficult and demanding work loads without having to look all around their cockpits at an assortment of dials and displays while also looking around the sky and trying to fly and fight.

The Air Force expects to have a full “virtual cockpit” with artificial intelligence around 1996. Vital elements of it will be in existence long before then, however. AFSC’s timetable calls for introduction of a head-aimed fire-control system in 1989 and of an all-aspect head-up display (HUD) in 1991. Both will be built by AFSC’s Human Systems Division into helmets that will actually be lighter than those now in service. Both are also expected to be available for dovetailing with the full-scale development of the ATF.

For the fighters of the next century or even for those of the next decade, Forecast II is providing much additional stimulus in research on autonomous missiles. These will acquire and track targets all by themselves. Requiring no postlaunch communication with their launching aircraft, they will make it possible for those aircraft to stay out of the range of enemy guns and missiles.

In the air-to-air mode, the Advanced Medium-Range Air-to-Air Missile (AMRAAM), now in low-rate production, is the first of such launch-and-leave weapons. It does a good job, but its successors as seen in Forecast II may make it look rather primitive by comparison.

Autonomous missiles of the future are expected to be capable of finding and hitting targets by means of “multispectral sensors,” using, for example, millimeter-wave radar to spot and approach targets and then switching to active or passive infrared sensors to strike them where they stand or move. Such
versatility would confound countermeasures.

The sensors will be teamed aboard the missiles with extremely compact and swift signal processors—possibly photonic, some day—of the supercomputer class in terms of their computational prowess. The prodigious sensing and signal-processing capabilities being worked up for those missiles will also be applicable to the identification, friend or foe (IFF) systems of the future.

The Air Force knows full well that it can make autonomously guided bombs. It has built and successfully tested the seekers needed in them.

Recent tests of such seekers aboard aircraft have shown that they have the ability, for example, to pick out, image, and track halfway down on the left hand side of the third strut of a bridge and to do the same at precisely the point where a runway and a taxiway intersect.

Among near-future milestones scheduled in the development of autonomous missiles are the completion next year of technology work on an advanced seeker-processor for air-to-air weapons and captive flight tests in 1989 of a seeker embodying synthetic aperture radar (SAR).

As is the case with most Forecast II projects, work on autonomous missiles cuts across many AFSC product divisions and laboratories. Armament Division is a big player, of course, but so are Aeronautical Systems Division and Electronic Systems Division.

In the supercockpit program, ASD and Human Systems Division and the Aeromedical Research Laboratory have a great deal of the work. But RADC is in charge of developing the supercockpit’s computerized 3-D visual displays of flight paths together with systems that will enable aircrews to activate aircraft and weapons with voice commands, that will eliminate background noise and interference in air-to-ground voice communications, and that will even translate from one language to another when US crews talk to crews or ground controllers of other nationalities.

RADC is the cynosure of Forecast II’s endeavors in the arenas of battle management/C3I, ultrareliable software, AI, airborne surveillance—in which the development of aircraft smart skins is a high-priority program—and space surveillance, for which highly promising sensors—small, light, and capable of spotting “cold bodies” in space—are already coming to the fore.

**Ultrareliable Software**

Forecast II officials concede that software could be a show-stopper. All modern Air Force systems are now dependent on computer programs and have increasing need of them in greater quantity and complexity. Such software has all too often been troublesome in terms of capability and reliability.

A major thrust of Forecast II’s research on ultrareliable software is the development and standardization of a high-order computer program language for writing the operational software of computers for Air Force systems. Such software-writing software would greatly help—or even replace—human programmers, who tend to perform ingenuously but streakily in their individualistic approaches to programming and who are too few in number in the military software-writing world.

RADC has already demonstrated some of the technologies needed to transfer human operations to computers in software development.

More and more, artificial intelligence will pervade the computer programs to be required for Air Force systems, just as it will be enfolded in the programs of the computers that will write that software.

AI is, for example, essential to the super-sophisticated battle management/C3I systems that Forecast II is fostering. Evidence of success in the development of such systems abounds at RADC, where actual hardware has become the hallmark of Forecast II’s progress.

RADC has modified its command and control laboratory to test and demonstrate its work at building and interlacing sensors and communications—all aimed at making future combat commanders aware of situations at every turn.

Forecast II has captured fancies all over the place. It has engendered several joint programs with the National Aeronautics and Space Administration and the Defense Advanced Research Projects Agency (DARPA). Army and Navy research officials have taken long looks at its initiatives for possible adaptation to their services.

**Boost-Glide Vehicles**

DARPA and NASA have been involved in the NASP program since its inception. Now the Air Force is pursuing a joint program with DARPA to develop hypersonic boost-glide vehicles and build a prototype.

These would be quite different from the runway-takeoff aircraft/spacecraft that the NASP program is expected to bring about. The boost-glide vehicles would be unmanned weapons and breathtaking ones at that.

They would almost certainly revolutionize strategic warfare. The Air Force sees them as capable of reaching speeds up to fifteen times that of sound, of ranging farther than ballistic missiles, and of approaching targets at relatively low altitudes.

It is possible that a prototype could be built and test-launched by the early 1990s. Initial plans involve launching the prototype atop a Minuteman ICBM booster, now in storage, for a test flight from Vandenberg AFB, Calif., to the Kwajalein Missile Range in the Pacific Ocean.

The hypersonic vehicles would not go into space. They would level off in the upper atmosphere and head toward their targets oceans and continents away. They are being designed to be so maneuverable on their approaches that they would be difficult to bring down—even if it were possible to detect and track them in the first place.

There is a passing similarity between the boost-glide vehicle and the X-20 Dyna-Soar, which was conceived by AFSC in the late 1950s as a manned, winged craft to be launched into space by a Titan booster and then to glide back through the atmosphere. That project was dropped in the early 1960s, but the work done on it led to the development of the Space Shuttle in the 1970s, most especially with regard to advanced materials for absorbing the heat of reentry.

The concept of the hypersonic boost-glide vehicles was promoted by Forecast II and is an outstanding example of how research in materials, propulsion, electronics, and...
The Air Force's V/STOL transport aircraft of the future may well resemble these products of an artist's imagination. Given the rapid progress and high promise of propulsion and aerodynamics technologies fostered by Project Forecast II, it now seems likely that such aircraft will be built for a wide range of missions in the next century, maybe sooner, and will transform the way the Air Force fights.

—Artist's concept for USAF by Keith Ferris

Optics has progressed to the point where the Air Force can pull it all together to begin developing—with confidence—a full-blown system for testing.

Materials for Tomorrow

On the wings of Forecast II, research on advanced materials is flying high. In the offing are lightweight, highly ductile, superstrong materials of supreme resistance to heat. New processes have been introduced in rapid solidification rate (RSR) powder metallurgy for producing awesome alloys. Extremely strong and heat-resistant "intermetallics"—for example, titanium aluminum—are coming forth, as are advanced carbon/carbon materials and ceramic composites.

ASD's Materials Laboratory is learning how to rearrange the molecules and atoms of a broad range of materials to endow them with properties that greatly improve upon those offered by nature itself. Forecast II calls these "ultrastructured materials." Some are already in existence.

Whatever their compositions, these highly advanced materials are destined for optical computers and switches and for high-performance turbine engines.

Capable of holding up under terrific heat, those engines will not need the complex cooling techniques required by today's turbine engines and, in consequence, will be far smaller, lighter, more powerful, and more reliable.

It is increasingly likely that such advanced engines will come to pass by or around the turn of the century, thanks to Forecast II's having underscored their research.

They are expected to double—at least—the thrust in relation to the weight of the ATF's advanced engines. This would be a startling—even revolutionary—advancement.

The ATF's engines will improve upon the performance of powerplants in modern fighters in many ways, particularly by providing the capability for supersonic speed and persistence without using afterburners. But in terms of thrust to weight, the ATF's engines will be only about twenty percent—one-fifth—superior to the best of the currently operational fighter turbine engines.

With the exceptionally high thrust-to-weight engines in Forecast II's future, the Air Force will be able to build Mach 4 aircraft and—by converting thrust into lift—V/STOL aircraft for a wide variety of missions.

Most likely, the ATF will have entered production—in the mid-1990s, if all goes well—before the turbine engines foreseen in Forecast II are ready to be flown. However, the ATF will undoubtedly evolve into increasingly capable variants as it goes along, so it is possible that those engines will become available for it as its production approaches or crosses the cusps of the centuries.

Smaller Boosters, Bigger Loads

Rocket engines are also in for a big shot of change as a result of research rallied by Forecast II. Such research is generating a new class of fuels—"high-energy-density propellants"—that are expected to double the thrust of existing solid and liquid propellants in space boosters.

Their energy density—thrust per unit of mass—may be ten times or more that of current propellants. This will make them amenable to containment in boosters of dwarfish dimensions and of puny poundage in comparison with the boosters that now loom like skyscrapers on planetary launchpads.

The implications for the US space program are profound. It has always been plagued by the extraordinarily high cost of boosting payloads into orbit. Smaller boosters capable of carrying larger and more numerous payloads at the same total system weight will translate into far greater cost-effectiveness, capability, and versatility for the US space program, which is currently short on all such attributes.

Forecast II sees the advanced fuels as powering the heavy-lift launch vehicles of the future. USAF has a crying need for such lifters. The Space Shuttle fleet has a limited and uncertain future, and the Strategic Defense Initiative program, the Space Station program, and others to involve outsize payloads will make strong demands on US space-
Forecast II places considerable emphasis on developing battle management/command control communications and intelligence (C3I) systems that will make combat leaders acutely aware of all situations at all times. This artist’s concept captures the light-speed communications and visual-display vistas that will be fundamental to such systems.

launch capabilities in the 1990s and beyond.

The first of the heavy lifters—the Advanced Launch System (ALS)—is being developed and will be operational well before Forecast II’s futuristic propellants come on the scene—but maybe not all that long before.

The Air Force plans to demonstrate the technologies of such fuels by 1990. Experiments on them began this year, and researchers believe that the technologies will be under control in relatively short order.

Such work stands as yet another example of going nature one better in Forecast II research. It involves exciting the outer-shell electrons of such inherently stable chemical elements as argon and krypton to make them unstable. Once this state is reached, the agitated electrons are “bound” in ionic or covalent compounds that expend enormous, pent-up energy upon combustion.

Air Force Astronautics Laboratory (formerly Rocket Propulsion Laboratory) and AFOSR have awarded twelve contracts to universities to master the chemistry and the “excited-state physics” involved in producing the powerful propellants.

Forecast II officials are confident that such mastery is well within reach. Supercomputer calculations have told them so.

To the Stars and Back

They are also increasingly upbeat about the prospect of developing an antiproton space-drive system in the twenty-first century, perhaps much closer to the beginning of it than they once believed possible. In such a system, negatively charged particles called antiprotons and protons—positively charged particles in the nuclei of atoms—would annihilate one another in mixture and release enough energy to make a hydrogen bomb blush—and do it, moreover, with no sound, no radiation, and hardly noticeable heat.

This mutual destruction would release one hundred times more energy than that of a fusion reaction and one hundred million times more than that of current chemical propellants.

Forecast II officials estimate that it may take until the year 2015 to generate antiprotons at the rate of one gram a year—but that the single gram should be enough to power all the space missions that the US anticipates undertaking.

If the research on antiprotons lives up to its promise, such missions may be downright galactic. Antiproton drive could take spaceships through the solar system in no time flat, as gauged by today’s standards for spaceflight, and out to the stars and back before their crews had aged much at all.

The European Center for Nuclear Research (CERN) in Geneva, Switzerland, is now catching antiprotons in “collector rings” and storing them for experimentation. At CERN, a University of Washington research team has now demonstrated that it can capture the elusive particles in a football-size container—not in the huge collector rings—and can hold them there for minutes on end.

The team is confident that it will be able to store antiprotons indefinitely. Its work has revolutionary implications for future spaceflight.

The Soviet Union is building a facility that Air Force officials expect to be capable of collecting far more antiprotons per year than the CERN facility can now collect. Now, the US science establishment, with the Air Force involved, is planning to modify a major research center—possibly Los Alamos National Laboratory or the Fermi Laboratories—for the same purpose.

Air Force researchers see “no significant technological hurdles” in developing antiproton propulsion and “should be able to begin working on practical applications in the foreseeable future,” AFSC’s Major Glasgow says.

Not all Forecast II projects are hurtling ahead. For example, the Air Force has struck a measured pace in developing its concept of relatively small surveillance satellites that would carry interrnetting “distributed sparse arrays” of sensors and would function altogether—just as effectively as, but less vulnerably than, today’s few relatively large, multisensor satellites.

Many Forecast II projects are “black,” and a goodly number of these have to do with low observables—stealth—technologies and future systems.