**In test flights, the airborne radar scanned a broad sweep around Cocoa Beach and picked out cars moving along the causeway.**

# The Battle Vision of Joint STARS

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AN exotic radar aircraft now beginning to take shape has rekindled confidence that Air Force technologists will be able to meet one of their most formidable challenges in years.

The team developing the Joint Surveillance Target Attack Radar System is no longer a struggling group plagued by setbacks, as in times past. Joint STARS developers have been staging a comeback for months.

Now, say officers, the technologists seem likely to succeed in producing the plane that Washington wants to provide big-picture radar coverage of a ground war in Europe. The E-8A will be the key sensor in a new plan to locate and attack onrushing Soviet armor. The team run by Electronic Systems Division (ESD) at Hanscom AFB, Mass., overseer of the $6.6 billion program, is strengthened by several factors.

These include breakthroughs in operation of the plane's ultracomplex, steerable, multimode radar; completion of the communications, navigation, and data-link systems; verification of the test vehicle's airworthiness; establishment

of a workable systems architecture; and the first production of vital operations and control software.

No one is complacent, but officers are optimistic they can meet next year's goals of completing development testing and a system-level performance verification of prime contractor Grumman's total product. "We could still fail," says Col. John Colligan, the program director. "But the chances of failure are a lot less than [they were] a year ago."

Washington, too, evidently regards the Joint STARS craft as a going concern. The Pentagon has given USAF authorization to develop an electronic-warfare suite for self-defense, expand force structure from ten to twenty-two airplanes, procure new airframes rather than used Boeing 707s, and provide mission simulators—all expensive propositions.

Effects of recent radar breakthroughs are most evident in the sharp pointing accuracy and precise beam-formation properties that are now being displayed by the first test airplane's ultrasophisticated electronic sensor.

In a series of tests starting last December 22, the 1,700-pound X-band radar slung under the aircraft has shown its capability to focus intently on a single spot on the ground and propagate beams of carefully modulated intensity and shape. The upshot of the tests is summarized by Colonel Colligan:

"Did we prove that a lot of the tough things we wanted to do have now been done? Yep. Sure did. Will we be able to do the job? Yes. From the 'does it work?' standpoint, yes, we can make this radar work."

The side-looking radar, built by Norden Systems, can be operated either in a Doppler mode to detect moving targets or in a synthetic aperture radar mode to see stationary features. Standing off behind the Forward Line of Troops (FLOT), the E-8A radar will be able to scan deep into enemy areas in search of enemy ground activity.

The radar antenna is a large, complex device, steered in two ways. First, mechanical means are used to set the beam's elevation—the point at which it strikes the earth. Secondly, the beam is scanned by electronic means in azimuth. The electronic scanning is carried out by a set of software-controlled phase-shifters in the antenna, and the operation requires complex and precisely timed software instructions. Making sure that the mechanical and electronic operations work together creates an even greater software challenge.

### Meeting the Challenges

The Air Force is now confident that it has met those software challenges. In a six-hour flight of the test aircraft on December 22, ESD verified that the complex digital steering commands do, in fact, focus the beam properly. The phase-shifters swept a beam across the earth and precisely struck a receiving device on the ground.

The December test, program workers note, also showed the integrity of airborne high-power radar transmission elements. The signals exchanged between the Joint STARS aircraft and Grumman's ground-based Integration and Test Facility in Florida confirmed that there was proper formation of the transmit and receive beams.

"We proved that we could put energy, in a controlled sense, through the transmitter, through the antenna, on the ground, to a spot that we could control, in a form of energy that we could control," notes Colonel Colligan.

The radar, unsurprisingly, is not yet working perfectly. Minor glitches crop up. For example, problems with a Joint STARS inertial navigation system in one flight threw the radar off, causing it to mistake one Florida causeway for another nearby. Engineers also found some saturation of the analog-to-digital conversion system.

"But we're not talking about rocket science here," remarks Colonel Colligan. "The important thing is that we understand, and are proving we understand, the radar software. That was the tough part."

In addition to demonstrations of mechanical capabilities, progress in verifying the radar's planned target-detection abilities has been heartening to Air Force officers and their contractors.

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The Joint STARS team in recent months has successfully put together the transmission and receiving functions of the radar. In a test conducted last March 16, Joint STARS technicians beamed energy to the ground and got data back in the form of a target for the first time. The process was repeated days later and has been repeated at regular intervals since.

As a result, ESD is convinced that it has produced workable clutter-rejection algorithms to differentiate between actual targets and background. "The guys who know what they're looking at," notes Colonel Colligan, "say, 'Aha! Here's Cocoa Beach, here's Merritt Island, here's the mainland, here's the causeway. See the cars.' "

Producing this kind of capability has been nothing if not difficult. Because of the ground-clutter problem, the job of the Joint STARS radar is more complex than that of the E-3 Airborne Warning and Control System's radar. The magnitude of radar-processing demands can be seen in the fact that the Joint STARS signal processor, several programmable units built by Control Data Corp., perform a staggering 625,000,000 operations per second.

Long months have been spent developing prototype software containing basic algorithms that make the radar look out and spot a moving target on a background of clutter. The code will be written to military specifications later.

### Increased Precision

From today's relatively rudimentary operations, the radar is expected to progress to awesome capabilities. That is made plain by Maj. Gen. Eric Nelson, ESD Vice Commander. In addition to performing broad surveillance, he says, the radar operator will be able to "get a lot more precise, put in a lot more cultural data—road networks, cities, political borders, other reference areas. There will be a zoom capability down to the individual road, very small towns . . . individual vehicles, to tell which way they are moving and at what speeds."

The initial phase of airborne radar testing, completed in April, was limited in scope. It focused on calibrating the Joint STARS radar performance against targets of controlled size and speed—an officer describes them as "a few off-road vehicles and four-wheel drives"—operating in a 100-square-kilometer sector of Florida. While the radar performed well, it was undermatched. The sensor is built to survey areas as large as 30,000 square kilometers.

Demonstrations of wide-area surveillance, which are to focus on the grounds of Eglin AFB, Fla., and a range in southern Alabama, are just now getting under way. By summer's end, the Air Force will be pitting the radar against slow-moving, hard-to-spot targets, such as tanks. "That's the next step in the process," says Colonel Colligan. "That's where you really can see how well you can break into the clutter and bring up a target."

Helping to speed the tests will be full operation, starting in September, of a second Joint STARS test aircraft.

Joint STARS's prospects had gotten a boost from other developmental successes. Airworthiness problems—principally, how to control a craft carrying a large, canoe-shaped radome under its fuselage—were resolved. Voice communications and navigations systems and software were installed and verified.

More significant was ESD's success in fashioning a new surveillance and control data link (SCDL) to transmit Joint STARS information to users on land. The SCDL system, built by Cubic Corp., is pivotal to operational users.

Plans call for on-board Air Force systems to convert radar returns into $C^3I$ information. The Army, needing to supply many users at all levels, will use the SCDL to transmit raw radar returns as well as processed data to the 107 Joint STARS ground stations it is slated to build.

USAF only recently took delivery of the first full set of data-link equipment, but it has been flying test parts since September. ESD officers, Colonel Colligan remarks, have found "very few problems with it. Range, antijam margins, data rate—we're getting what we need."

### Sharing Data

Efforts are under way to ensure that Joint STARS data can be shared with similar NATO battle management systems—France's Orchidée (Observatoire Radar Coherent Héliporte d'Investigation des Éléments Ennemis) and Britain's ASTOR (Airborne Standoff Radar) systems. Cubic's data link will be used in the British demonstrator. France plans to use its own data link. ESD will provide an interface permitting interplay of Joint STARS and Orchidée data.

The ESD program office expresses lack of enthusiasm for Cubic's management of the effort, which brought in the data link twenty-one months behind schedule. As a result, Grumman has opened discussions with three other potential contractors—Harris Corp., General Dynamics, and Unisys—about prospects for modifying an existing data link to do the job. A final decision lies several months ahead.

How far the technology program has come, and has yet to go, is nowhere clearer than in operations and control features—functions for manipulating the radar information into usable data. As ESD officials tell it, Grumman has made steady strides in this difficult area.

The company has established what appears to be a realistic, workable architecture for integrating the various radar functions into a harmonious electronic whole. "There are three kinds of guys working on this program: brilliant, very smart, and smart," comments a program officer. "We've got an architecture that the brilliant guys say will work. The very smart guys are implementing it. We're making progress."

The challenge stems from the unprecedented complexity of Joint STARS's data-processing system. It does not have a central control computer. Instead, the craft will use twenty-seven processors that enable large numbers of computer functions to occur in parallel. The object is to allow processed radar data to be displayed in different forms at the same time at any of the aircraft's ten full-color operator consoles.

This system accounts for the aircraft's vast software requirements. At present, plans call for Joint STARS to run about two million lines of code, some 600,000 lines of it new and complicated. A large fraction of this total focuses on operations and control. Today, all Grumman software has passed

through preliminary design, half of it through detailed design, and a third of it through code-writing.

Still, experts such as Colonel Colligan regard operations software as the most likely place where Joint STARS may be tripped up. "If you talk to Grumman guys, they'll say they're getting a handle on the radar software," says the colonel. "But we've asked them to do an awful lot of things to make this data have very high utility for the operator. Doing all that simultaneously is going to be a tough job. We've said we want all ten consoles to be completely independent. Each one of these guys ought to be able to act like it's *his* radar."

In the end, some maintain, the Air Force may have to relax or modify some of its ambitious goals. This could have a relatively modest impact. For example, time required to provide a complete replay of the foregoing three hours of radar data, now planned at thirty seconds, may go up to forty-five seconds. Other functions could be affected more seriously or dropped altogether. ESD is consulting with Tactical Air Command to establish priorities.

All signs are that Grumman faces a workable, but tight, development schedule. The contractor will have to complete some ninety-five percent of its software before the start of the demanding, three-month, system-level performance verification tests. That could come as early as next summer, but in any case no later than November 1990, barring a major snag in the program. Officials say Grumman looks to be on schedule. But, one acknowledges, "There's a very tough integration job in front of us."

### New Development Problems

The Pentagon, persuaded that Joint STARS is here to stay, has reshaped and expanded the program. The steps will require new attention from the developers.

Most conspicuous, but by no means most important, is the new technological task caused by Pentagon approval of a different airframe for the E-8A role. Originally, plans called for the use of older, refurbished Boeing 707 commercial aircraft for the Joint STARS fleet. In 1988, the Air Force selected and the Pentagon approved use of new 707-320 frames, the same used by the Navy for its E-6A plane. The changeover, however, will pose no great technological challenge. It will entail installation in the Air Force E-8 of a cargo floor not found in the Navy E-6 and perhaps minor structural alterations.

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Another Pentagon decision—to fit future Joint STARS aircraft with self-defense suites to enhance their survivability—will not be executed so readily. ESD is in the throes of an effort to examine its needs, define the system it wants, and determine the fastest, cheapest, and least disruptive way to install it.

There is little doubt that such a system is needed. From the beginning, experts within and outside the Air Force—particularly the chief of the Pentagon's systems analysis office, Deputy Assistant Secretary David Chu—warned that a large, slow-flying, and extremely valuable aircraft would present a tempting target.

The matter came to a head last year with completion of a new Pentagon analysis. "Basically," says Colonel Colligan, "the conclusion reached was that we're pretty survivable, with the defenses that are in place, at standoff ranges from the FLOT. But there, we couldn't provide as much utility [to Western forces] as we would like. We would not be looking as deep as we would like to look, obviously."

In order to operate closer to the front with security, he adds, Joint STARS requires an EW suite to deal with a "leaker," a single aircraft that gets close enough to take a potentially lethal shot.

ESD has hired a contractor to examine the problems and solutions. Electronic-warfare specialists based at Aeronautical Systems Division are being consulted. Possibilities include installation of a radar warning receiver, approach warning radar, flares, chaff, and a deceptive jammer.

Even if ESD uses existing equipment, as it plans to do, new development costs could reach $200 million. Final decisions are not expected for another year, and first tests will not take place until 1992 when the third test aircraft becomes available.

One aspect of the aircraft, a weapons data link, is in limbo. Part of the initial Joint STARS plan approved in 1985, the link was supposed to permit the radar to broadcast present target positions to a black box resident on an airplane or a missile. Inasmuch as no one has developed the black box, ESD has declined to spend money developing the 15,000 lines of software needed for the link.

If events go as planned, the Grumman system-level performance review will be followed by long-lead funding for the first production aircraft and the start of initial operational tests, which would run through 1991. An Air Force production decision would come in October 1991, with deliveries starting in 1994 and limited operation in 1995.

There is optimism that the timetables will hold. "Basically, we're keeping to the plan that we laid out for the leadership," says Colonel Colligan. "If we can continue to do that, I'm happy." ■