Chapter 10

Technology Issues: Reconnaissance, Surveillance, and Target Acquisition to Support Follow-On Forces Attack

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INTRODUCTION

Attacking follow-on forces requires an ability to collect intelligence about the enemy situation from which enemy strength and intentions may be inferred. This intelligence may be collected by routine efforts (surveillance) or by efforts to obtain more information about a specific area of interest (reconnaissance). FOFA also requires an ability to acquire targets—i.e., to detect and identify enemy forces and to determine or predict their locations with sufficient accuracy to attack them. At present, only fixed targets and vehicles which halt for relatively long times can be acquired reliably. There will be important improvements—especially in timeliness—as systems and procedures for using ASARS-II radar imagery are improved, but shortfalls will still remain, especially in the ability to acquire moving vehicles ("movers") out to about 150 kilometers.

Several programs that could help are at issue now before Congress; these include the Joint Surveillance Target Attack Radar System (Joint STARS) program and various unmanned aerial vehicle (UAV) programs. The Precision Location Strike System (PLSS)–procurement of which has been deferred by the Air Force–could also contribute to FOFA if remaining developmental problems (discussed below) are corrected.[1]

[1]Much information about RSTA systems is classified. U.S. citizens holding SECRET clearances are referred to vol. 2 of this report and to ch. 5 of OTA, Technologies for NATO's Follow-On Forces Attack Concept (U), 10 February 1986. The appendices to this chapter contain extensive additional material.

Reconnaissance, Surveillance, and Target Acquisition (RSTA) Functions

Attacking follow-on forces requires:

1. detecting, recognizing, and roughly locating targets (surveillance or reconnaissance);
2. assessing their value and intent (situation assessment);
3. choosing the targets to be attacked (command decision);
4. identifying opportunities and means to attack them (targeting);
5. planning the attack;
6. tasking attack and reconnaissance platforms to perform the attack;
7. accurately locating the targets to be attacked (target acquisition); and
8. quickly providing target updates to the attack platforms (attack control). If the attack is to be conducted by aircraft, information on enemy air defenses must also be provided.

NATO today has a variety of systems to feed data into this process. Although it is difficult to generalize about a large number of very different systems, we can generally observe that while NATO's current systems are probably capable of supporting the attack of targets that do not move very frequently, they fall far short of providing continuous, broad, deep coverage and of being able to provide targeting data on highly mobile systems-especially those which do not emit radar or radio signals-without undue delays.

Issues

There is concern that the E-8A aircraft proposed as platforms for Joint STARS would not be adequately survivable if operated as close to the FLOT as originally intended, and that if operated farther from the FLOT, their coverage would be inadequate to justify their cost. The Air Force decided not to request fiscal year 1987 funds for procurement of PLSS, which is designed to accurately locate and control attacks against surface-to-air missile (SAM) radars, but did request and receive fiscal year 1987 funds for further development and testing of PLSS avionics. PLSS has almost attained specified emitter location accuracy but has not yet demonstrated specified system reliability (partly because of TR-1 aircraft failures). The Aquila remotely piloted vehicle (RPV) program has suffered cost and schedule overruns, leading some to consider procurement of an existing-possibly foreign-made—RPV which could be modified to have capabilities comparable to those required of Aquila.[2] U.S. procurement of an RPV made by a NATO partner would visibly reinforce U.S. efforts to pave a "two-way street" for intra-alliance arms sales-at the expense of the U.S. trade balance.

RSTA Requirements for FOFA

Ideally, FOFA would be supported by the collection of raw intelligence of several disciplines-communications intelligence (COMINT), electronics intelligence (E LINT), image intelligence[3] (IMINT), and measurement and signature intelligence[4] (MASINT)--across the full breadth and depth of the enemy's rear area under all weather and lighting conditions. Ideally, RSTA systems would be capable of determining and reporting the locations of all targets with accuracy and timeliness adequate to guide attack platforms and weapons to them.

OTA has reviewed a number of analyses which have been performed by or for SHAPE, the Department of Defense, and allied ministries of defense to estimate the RSTA capabilities needed for FOFA (or interdiction). Most provide insight into RSTA capabilities needed for FOFA and the difficulties of estimating them. These analyses and other considerations lead OTA to the following observations:

- Reconnaissance and surveillance needs vary greatly according to the specific operational concepts to be implemented. Current concepts for FOFA require relatively little RSTA support; they seek primarily to delay and disrupt follow-on forces by route attacks intended to create obstacles, and to destroy follow-on forces by attacking them when halted at obstacles. Some new operational concepts—e.g., use of cruise missiles to mine rail lines and destroy key bridges–would likewise require little or no additional procurement of RSTA systems.
- The most ambitious FOFA concepts require some sort of airborne moving-target-indicating (MTI) radar system capable of almost continuous broad coverage to the depth of divisional assembly areas (70 to 100 + kilometers) and near-real-time display, because:
  –Deep, wide-area surveillance is needed for situation assessment. To allow friendly forces time for planning and movement, massing enemy forces must be detected while they are still far (100 to 150 kilometers) from the FLOT. Rapid revisit would facilitate tracking[5] and re-

[2]The House Armed Services Committee recommended, in its markup of the fiscal year 1987 Omnibus Defense Authorization bill, that the Target Acquisition, Designation, and Aerial Reconnaissance System (TADARS) program under which the Aquila RPV is being developed, be terminated. The Senate Armed Services Committee approved fiscal year 1987 appropriations for further development but prohibited expenditures for procurement until the ability of the system to meet all operational requirements has been demonstrated.

[3]Including radar imagery and visible and infrared electro-optical and photographic imagery.

[4]Including, for example, moving-target indication (MTI) provided by radar.

[5]Under conditions likely to be encountered in central Germany, one scan ("revisit' every 30 seconds would be ideal for tracking small formations (10 vehicles), whereas a 60-second revisit interval would suffice for tracking larger formations (50 vehicles). Longer revisit intervals would reduce the probability of successful tracking. See R.K. Little and J.R. Bloomfield, *Trade Stud"es: Tracking With Intermittent* Radar *Coverage* (Minneapolis, MN: Honeywell Systems and Research Center, Aerospace and Defense Group, Technical Report No. TS-01 (Draft), September 1983); n.b. fig. 3 on p. 24.

duce double-counting of enemy units, but is not essential.

–Rapid revisit would be needed to track deep high-value movers to planned engagement zones or between stops where they could be attacked.

–Wide coverage about once a minute to a depth of about 80 kilometers would be needed to track and target units moving forward out of division assembly areas. Prompt display of target locations would be needed to control attacks against them. A capability to distinguish tracked vehicles from wheeled vehicles would allow armored units to be distinguished from supply convoys, etc.

–More frequent coverage (twice a minute) would be needed to target the more numerous smaller units which would advance from regimental assembly areas closer to the FLOT; shallow coverage (to a depth of about 30 kilometers) would suffice.

Without such capabilities, FOFA would mainly consist of: attacks against halted, long-dwell, high-value, soft targets, such as command posts and SAM batteries,[6] attacks to create obstacles and delay moving units, and some attacks against moving units which might be located accurately and reported quickly by coordinated use of diverse RSTA systems, planned well in advance. Only airborne MTI radar systems can frequently search large areas for vehicles moving in radio silence at night or in adverse weather; they cannot, however, detect targets masked by terrain or vegetation.

- Fusion of intelligence from multiple disciplines facilitates situation assessment and targeting. Hardware, software, and systems now being developed by the Army-Air Force Joint Tactical Fusion Program (JTFP) could be used by USAFE and by U.S. Army corps and divisions in Europe to automate and speed intelligence fusion, analysis, and dissemination. These systems and national systems used now in Europe could interface with the Battlefield Information Collection and Exploitation System (BICES), a NATO-wide intelligence fusion system now being planned. NATO's Tri-Service Group for Communications and Electronic Equipment has established a BICES project group, which is estimating the intelligence requirements of Major NATO Commanders (e.g., SACEUR) and Major Subordinate Commanders (e.g., CINCENT) and considering the designs of interfaces that should be established between their intelligence generation control elements and national systems, as well as interfaces that should be established among the national intelligence systems.[7]
- It will be necessary to destroy mobile SAM batteries which would protect all other follow-on forces from airborne surveillance and air attack.
- It may be necessary to destroy jammers; if so, it would be important that the weapons used be relatively inexpensive.
- Survivability of air bases and command and control facilities is also essential to RSTA. NATO and the U.S. Air Force have programs (outside the scope of this report) intended to reduce the dependence of RSTA on vulnerable facilities.

[6] Individual systems such as the Tactical Reconnaissance System could provide infrequent, broad, deep, all-weather, day/night coverage of fixed targets as well as continuous, broad, deep coverage of emitters to support situation assessment and to cue limited-coverage target-acquisition systems such as UAVs.

[7] See Loren Diedrichsen, "Toward a Functional Model of NATO C'," *Signal*, October 1986, pp. 43-47, and Brigadier A.L. Meier, OBE, "BICES—A Central Region Perspective," *International Defense Review*, October 1986, pp. 1445 ff.

JOINT STARS

Description

The Joint Surveillance Target Attack Radar System (Joint STARS) is an airborne surveillance and attack control system designed to detect and indicate[8] moving ground vehicles and to guide attacking aircraft and missiles to moving or halted formations of enemy vehicles. An outgrowth of the Air Force PAVE MOVER and Army Standoff Target Acquisition System (SOTAS) programs, Joint STARS is to complement the Airborne Warning and Control System (AWACS), which detects aircraft. It will scan a broad, deep coverage area frequently to support situation assessment, attack planning, and real-time control of interdiction attacks by missiles or aircraft. The radar could be operated, and attacks controlled, by operators on board Joint STARS aircraft (E-8 As) or in mobile Ground Station Modules (GSMs) being developed by the Army.

The Joint Surveillance Target Attack Radar System will include both airborne and ground-based segments. The airborne segment includes the radar system, the Operations and Control (O&C) system, a communications system, and the E-8A aircraft-a modified Boeing 707—which carries them. These are being developed and are to be procured and operated by the U.S. Air Force. A Weapon Data Link (WDL) is being developed to provide target updates to in-flight Air Force direct-attack aircraft—F-15Es, F-16Cs, and F-16Ds—and to Army and Air Force missiles equipped with Weapon Interface Units (WIUs).[9] The ground-based segment includes transportable Ground Station Modules–including Down-sized Ground Station Modules (DGSMs)-–which are being developed and are to be procured and operated by the U.S. Army. A Surveillance and Control Data Link (SCDL) is being developed to satisfy Army needs for tactical mobile, in-weather, anti-jamming communications of all radar data to an unlimited number of GSMs. The Joint Tactical Information Distribution System (JTIDS) will provide C^2 communications with Air Force users and threat warning and air track information from AWACS and other air defense elements. The E-8A platform will provide cross-link communications between SCDL and JTIDS users.

Small, transportable ground beacons are also being developed for use by Joint STARS aircraft as radio navigation aids while awaiting full capability of the NAVSTAR Global Positioning System (GPS). Thereafter they could serve as a backup to the GPS. These components are illustrated in figure 10-1.

Status

As of March 1, 1987, Joint STARS aircraft and GSMs were both in full-scale development. A total of $715 million had already been appropriated for RDT&E through fiscal year 1987: $675 million for the Air Force and $240 million for the Army.[10] Two FSD models of Joint STARS E-8A aircraft are being produced for the Air Force by Grumman Melbourne Systems on a $657 million contract, but these have not yet been delivered. Norden Systems is producing the radio-frequency components of the radar subsystems on a subcontract from Grumman. Boeing 707 airframes in commercial use with documented maintenance histories will be purchased for about $10 million each and converted to the EC-18B configuration[11] by the Boeing Military Aircraft Co. under subcontract to Grumman.[12] Grumman will con-

‘Any airborne radar can **detect** moving targets, but in order to **indicate** moving targets as such, an airborne MTI radar must distinguish fixed targets and ground clutter–which are moving relative to the radar-from targets which are moving relative to both the radar and the ground. The signal processing required for airborne MTI radar is more complicated than that required for ground-based air-surveillance radars, which do not move relative to ground clutter.

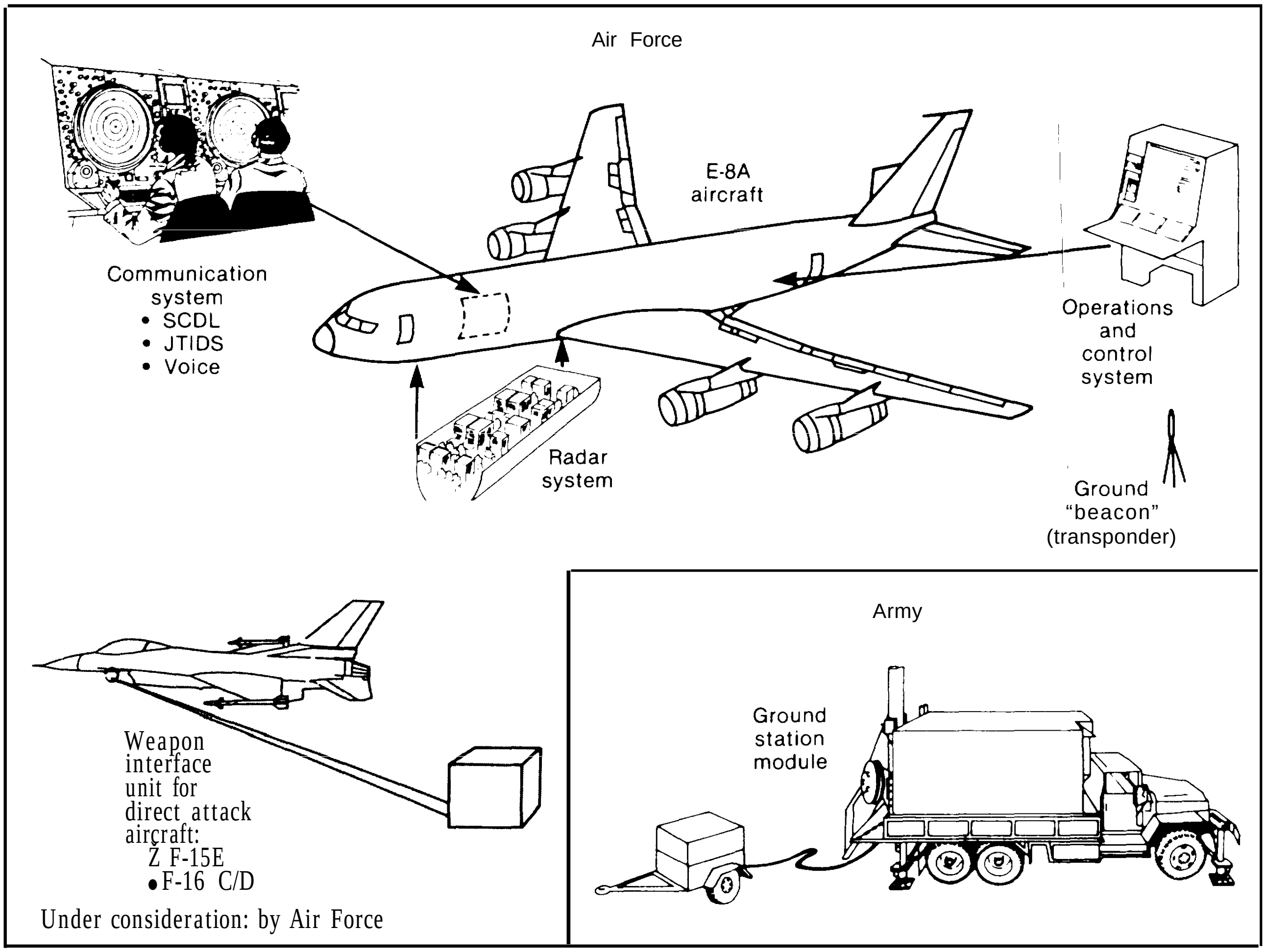
⁹The services have not requested appropriations to procure operational WI US, but prototype units are being developed as part of the full-scale development program to flight test and verify WDL performance.

‘('In current (i.e., “then-year”) dollars.

¹¹Used by Air Force Advanced Range Instrument Aircraft (ARIA).

‘*The last new 707 airframes produced cost about $30 million each. After the last 707 airframes were produced (for AWACS), Boeing closed its 707 production line.

Figure 10-1.—Joint STARS Components



SOURCES U S Army (DAMA CSC ST), U S Air Force (SAF/LLW); and Office of Technology Assessment, 1987

vert these to E-8As by installing the prime mission equipment at its facility at the Melbourne Regional Airport near Melbourne, Florida.

Issues

Although Joint STARS has received broad support within the Army, the Air Force, Allied Command Europe, and the Office of the Secretary of Defense, it has been a matter of contention in Congress. Opponents claim that the C-18 is too vulnerable to attack and must be replaced with a more survivable platform. They also contend that the radar required for the more survivable platform could not be developed from the radar now under development. Therefore, they argue, the program should be canceled and a new one started.

Proponents argue that the E-8A-based Joint STARS will be "survivable but not immortal, " and that when operated in the proper manner, with proper support, it will be capable of doing what is needed. They further argue that more survivable platforms will not, by themselves, satisfy requirements, but that they could usefully complement E-8As as Joint STARS platforms. The Air Force contends that Joint STARS may need to be deployed to areas outside Europe in crises, and that more survivable platforms could not carry all the equipment that E-8As could, nor could they be used to "show the flag' in peacetime without compromising the secrecy of design features on which they would rely for survivability. Proponents also argue that it is important to get something into the field as soon as possible so that the troops can learn how to use this complex capability.

Resolution of these issues will require answering four questions:

1. Why is the capability promised by Joint STARS needed?
2. How serious are the problems of vulnerability to attack and susceptibility to electronic countermeasures (ECM)? Specifically, how would they affect the operational utility of the proposed Joint STARS fleet?
3. What are the alternatives? What are their advantages and drawbacks?
4. If an alternative is desired, could Joint STARS avionics systems developed or procured for E-8As be used by alternative systems? What systems could not be used? Could Joint STARS E-8As themselves complement alternative systems?

Need for Airborne Moving-Target-Indicating Radar Surveillance

As noted above,[13] the most ambitious FOFA concepts require some sort of airborne moving-target-indicating (MTI) radar system capable of frequently "revisiting" (i.e., scanning) broad deep areas. Only an airborne MTI radar system can detect vehicles moving in radio silence at night or in adverse weather and revisit a large area of interest often enough to track such vehicles moving in it. Joint STARS was designed to provide the kind of frequent, deep, wide-area MTI surveillance needed to implement these ambitious FOFA concepts. The MTI capabilities of other operational, developmental, and proposed MTI systems known to OTA fall far short of those needed to support highly effective FOFA:

- The currently operational MTI radar carried by the OV-1D "Mohawk" twin-turboprop aircraft is a side-looking airborne radar (SLAR). Its beam cannot scan and therefore revisits a target only twice per orbit. It would operate within range of multiple types of surface-to-air missiles.[14]
- The British ASTOR-I MTI SLAR system has these inadequacies and others as well: it has no data link and cannot provide moving-target indications until after aircraft recovery when recorded radar echoes can be processed.[15]
- The French ORCHIDEE heliborne MTI radar system, now in development, will also operate close to the FLOT at low altitude and will also have inadequate range and coverage.
- The ASARS-II radar has some MTI capability now and, because its platform (a TR-1) operates at high altitude, it is less affected by terrain and vegetation masking than Joint STARS would be at nominal stand-off range (or at equal stand-off range). However, ASARS-II requires a large ground station to process radar data before it is transmitted to Army and Air Force users. This dependence on a ground station compromises the mobility and survivability of ASARS-II.
- The ASARS-II radar could be enhanced to have even greater MTI capability. It could also be equipped with an SCDL air data terminal, so that its MTI data could be broadcast directly to tactical users. However, the MTI capabilities of an enhanced ASARS-II radar would be inadequate to support highly effective FOFA and inferior to those of Joint STARS. Although it would suffer less masking by terrain and vegetation, it would have several disadvantages:[16]
  - —a minimum detectable velocity about twice that of Joint STARS,

[13] See ch. 5 and the section above on RSTA requirements.

[14] Fixed SAMs could be attacked and others evaded, but evasive maneuvering would interrupt surveillance. In the future, new mobile SAMs are expected to pose a greater threat to Mohawks as well as other aircraft.

[15] The SCDL developed for Joint STARS has been used experimentally to transmit ASTOR-I MTI data to a GSM.

[16] See also the Joint STARS Cost and Operational Effectiveness Analysis being completed by the U.S. Army TRADOC Analysis Center as this report goes to press.

—a detection range two-thirds that of Joint STARS,
—one-fifth the coverage of Joint STARS at a comparable revisit rate,
—inferior moving target location accuracy, and
—vastly inferior electronic countermeasures (in MTI modes).

None of the above-mentioned systems has, or will have, an attack planning and control capability. An integrated surveillance and control capability, such as Joint STARS will provide, would greatly reduce the time between detection of a target and engagement of the target, thereby permitting halted vehicle formations to be engaged and permitting moving columns of vehicles to be attacked by missiles or aircraft.

To engage units on the move with missiles armed with wide-area munitions, the units must be tracked to planned engagement zones, at which time missile launch must be triggered. Last-minute confirmation of a target's approach to an engagement zone is needed just before launch, with minimal delay for maximum effectiveness. Attack aircraft will also need in-flight guidance-which could be provided by voice radio or data link-in order to attack designated moving targets (as distinct from targets of opportunity). Without in-flight guidance, they would be more exposed to observation and fire while searching for designated moving targets and they would suffer higher attrition.

Vulnerability to Attack[17]

Any of several Warsaw Pact SAMs or interceptor aircraft could destroy an unprotected Joint STARS E-8A in a hypothetical one-on-one engagement. In reality, Joint STARS will not operate alone; NATO will provide protection to all such aircraft in NATO airspace. Joint STARS would benefit from general measures such as air defense suppression and offensive counter-air operations using attack aircraft and missiles, and defensive counter-air operations by high-altitude combat air patrol aircraft (e.g., F-15s) and NATO SAMs (e.g., Patriots). It is expected that Warsaw Pact SAMs and interceptors will be increasingly (but not completely) suppressed as a war progresses. When Joint STARS is attacked, it would be forewarned by on-board display of hostile aircraft data from air defense elements (e.g., AWACS) so that it could take evasive action or employ countermeasures. It would also be protected by other Air Force aircraft capable of jamming enemy radars and radios. The addition of on-board threat warning and countermeasure capabilities is being considered to counter Soviet interceptor aircraft and SAM threats.

Even with such protection, Joint STARS would probably be vulnerable to fixed and mobile SAMs and to interceptor aircraft if operated, early in a war, at the setback range originally planned. If operated at a greater range from the FLOT, its vulnerability would decrease, but so would its coverage. Air Force planners may want to hold E-8As back from the FLOT most of the time early in a war and surge them forward, with suitable support, for limited periods of intense activity. It is expected that surge periods could be increased as war progresses and enemy defenses are depleted.

Operating this way, an E-8A could provide good coverage to at least the range of an MLRS rocket, where frequent coverage is most needed. It could provide valuable coverage deeper, but deep targets would be masked more frequently by terrain and foliage and could be masked more easily by jamming. Its deep coverage would still be useful for situation assessment, but its ability to track units would be degraded. The resulting increased likelihood of double-counting units could make situation assessment less certain, and the ability to engage high-value targets deep would be degraded to an extent not yet quantified. OTA is not aware of any thorough analysis of the

[17] In preparing this report, OTA staff were not granted access to "Special Access Required" information about programs and technologies which might be of use in improving the survivability of Joint STARS. It is possible that options not considered by OTA could provide benefits significantly different from those discussed here.

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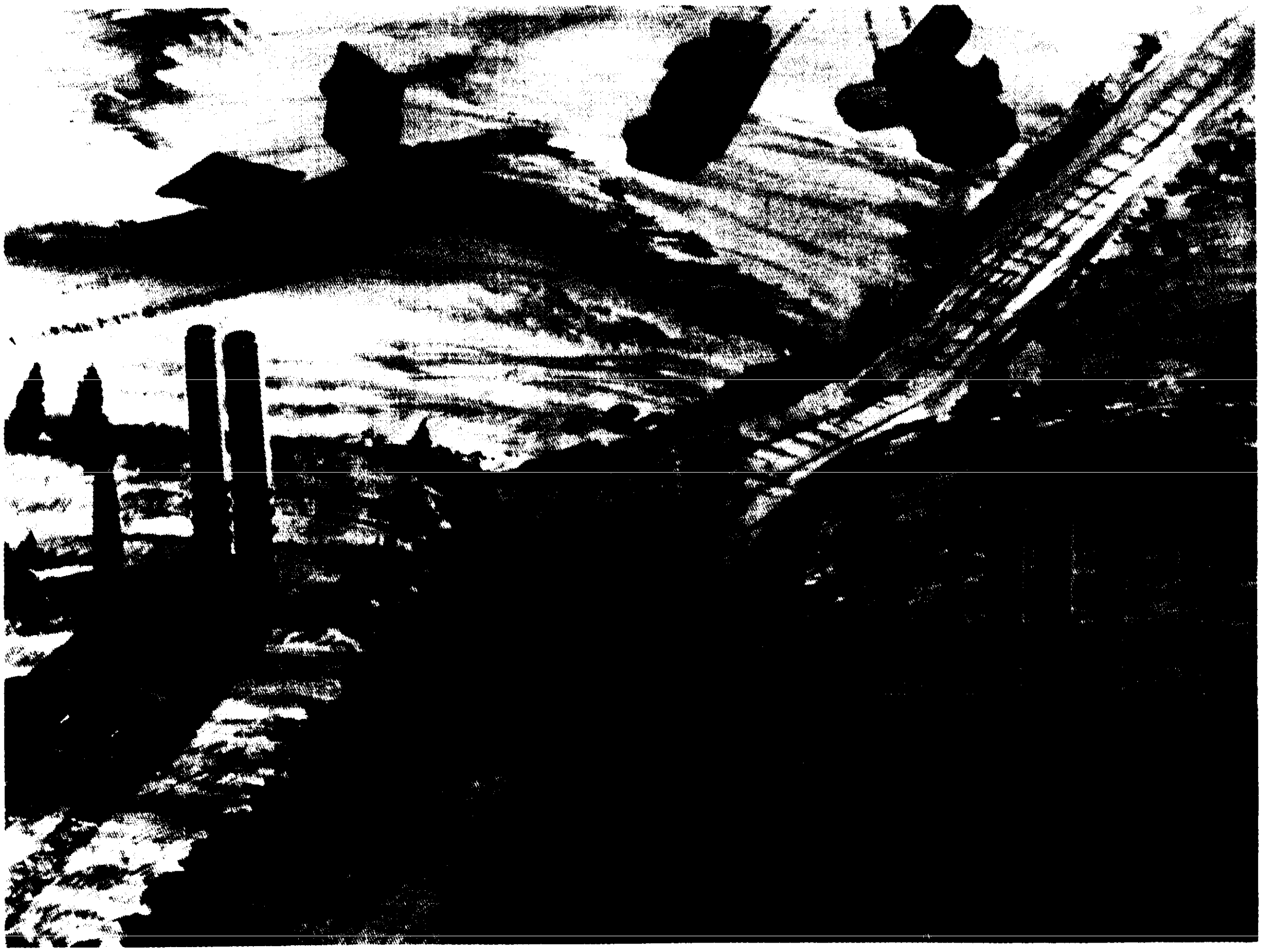


Photo credit: "Soviet Military Power," U.S. Department of Defense

The SA-X-12 air defense system.

utility of Joint STARS as a FOFA system operating in this manner, although a major study coordinated by the Army Training and Doctrine Command's TRADOC Analysis Center is nearing completion. Smaller studies for the Army[18] and Air Force[19] have examined or are now examining the impact of such revised operational concepts on selected operational capabilities.

Susceptibility to Jamming

Joint STARS is designed to have very capable electronic counter-countermeasures, but its performance could be degraded by severe jamming. Two types of jamming might be attempted against Joint STARS: sidelobe jamming and mainlobe jamming. Successful sidelobe jamming would require very powerful or highly directional jammers. The jamming signal must be strong enough so that even if received by the airborne radar when its beam is pointing away from the jammer,[20] it will be powerful enough to mask received radar

[18] E.g., by the BDM Corp.

[19] E.g., by the Rand Corp. for the Directorate of Operational Requirements (AF/RDQ).

[20] I.e., when the airborne radar receiver is relatively insensitive to the jamming signal.

echoes. In principle, the entire area scanned by an airborne surveillance radar could be masked by a single jammer, if sufficiently powerful.[21] Unless highly directional, a sidelobe jammer would have to be immensely powerful and would probably interfere with enemy radar systems.

If necessary, the electronic counter-countermeasures of operational Joint STARS aircraft could be upgraded to counter sidelobe jamming threats more severe than those which the two developmental aircraft are required to counter, Growth capabilities are built into the Full-Scale Development radar to permit such enhancement without modifying the radar's design. Alternatively–or additionally--sidelobe jammers could be attacked. Whether immensely powerful or highly directional, sidelobe jammers would be relatively expensive and hence high-value targets for jammer-suppression attacks using anti-radiation missiles or other weapons.

Successful mainlobe jamming occurs when the beam of an airborne radar is pointing at a jammer; the airborne radar is then most sensitive to the jamming signal, which need not be very powerful. If sufficiently strong relative to the radar echoes from the area near the jammer, the jamming signal will mask those echoes, and the radar will be unable to detect targets near the jammer. However, although successful mainlobe jamming would require relatively little power, a single jammer would mask only a small area. A large number of jammers would be required to intermittently mask the whole coverage area specified for Joint STARS; more would be required to mask the specified coverage area continuously.

If effective mainlobe jammers are developed and proliferated, lethal suppression may be necessary to counter them, although relatively minor upgrades to Joint STARS could provide a significant amount of additional anti-jam margin. If, in the future, an effective mainlobe jamming threat is projected, and if lethal suppression is deemed necessary to counter it, identification of the least-cost means of killing mainlobe jammers will require further study.[22] A comparison of the cost to NATO of killing such jammers with the cost to Warsaw Pact nations of producing and operating them would indicate which alliance would suffer more economically if both were to compete in a jammer/counter-jammer competition; however, other incentives will affect decisions to compete in or refrain from such a competition.

Alternatives

There are several alternatives to funding the Army and Air Force Joint STARS programs as proposed, or canceling them. These include:

1. development (if necessary) and procurement of add-on systems to enhance the utility and survivability of Joint STARS E-8 AS;
2. development (if necessary) and procurement of an alternative platform more survivable or protectable than an E-8A; and
3. development (if necessary) and procurement of complementary platforms intended to operate in coordination with E-8As, enabling the E-8As to operate in a more survivable (or protectable) manner.

Add-On Systems

If Joint STARS is procured, its utility and survivability could be enhanced by procuring accessories:

- Non-lethal self-defense suites could be procured for E-8As to enhance their survivability. These could include expendable and non-expendable electronic and infrared countermeasure systems, some of which are already used on other aircraft. Joint STARS E-8As and other platforms could

[21] App. 10-C in vol. 2 of this report discusses OTA's assessment of the susceptibility of Joint STARS to sidelobe jamming by existing and anticipated Soviet jammers.

[22] Jammers and radars could be attacked by manned aircraft (e.g., F-4G Wild Weasels) or by kamikaze drones, such as the air-launched TACIT RAINBOW drone being developed by Northrop for the Air Force and Navy. TACIT RAINBOW is expected to complete full-scale development in fiscal year 1988. During initial operational testing and evaluation, the drones are being launched from B-52, A-7, and A-6E aircraft. [*Aerospace Daily*, Jan. 8, 1987; *Aviation Week and Space Technology*, Apr. 27, 1987, p. 34.

be equipped to tow or dispense expendable decoy emitters[23] which could be developed to draw fire and jamming from the Joint STARS E-8As. The Joint STARS Program Office is now evaluating several self-defense suite concepts and will present its findings to the Joint Requirements and Management Board in March 1987 for a decision on self-defense suite acquisition.

- An air-to-air missile system for last-ditch defense against surface-to-air and air-to-air missiles could also be developed and procured.
- Weapon Interface Units (WIUs) could be procured for ground-attack aircraft. These digital data links could guide ground-attack aircraft to more distant targets more accurately than voice radio or a JTIDS data link could, so the aircraft could find moving columns of armored vehicles with less searching, exposure, and attrition.

Alternative Platforms

Alternatively, a less observable (i. e., "stealthy' high-altitude aircraft could be used as a platform for Joint STARS; it could fly closer to the FLOT with a much lower probability of being detected and attacked, and its susceptibility to sidelobe jamming would also be reduced,[24] as would masking of targets by terrain and vegetation.[25] The Department of Defense has considered proposals to develop a more survivable platform than the E-8A. However, information about the concept or concepts considered by the Department of Defense is highly classified and unavailable to OTA. Some potential benefits and limitations of reducing the observability of the Joint STARS platform, radar, and signal are discussed in volume 2 of this report, which is classified. (Authorized readers interested in this important topic are referred to app. 10-C in vol. 2. However, readers should be aware that there are facts and concepts that OTA is unaware of, and that could conceivably change OTA's observations.)

The use of a stealthy platform would not, by itself, guarantee low-observable operation: the detectability of the radar antenna by a threat radar would have to be reduced, and the detectability of the radar emissions would also have to be reduced. Balanced reduction of the platform and antenna cross-sections" and the radar's signature would be needed: if any one of these were readily observable, the system could be readily detected.

Many things could be done to reduce the detectability of radar emissions; some would not reduce radar performance. However, when all else has been done, further reduction of detectability, if necessary, would require reducing the radar's power, which would require reducing its coverage area or revisit rate, increasing the minimum detectable velocity, or a combination of these trade-offs. It would also increase susceptibility to jamming. Hence, if operated in a stealthy manner, a stealthy Joint STARS would "see" less than an E-8A would. Although it would be able to view some areas which would be hidden from a lower, rearward E-8A by terrain and foliage, its beam could not frequently revisit the broad area near the FLOT–where frequent revisit is most

[23] See Marc Liebman, "Expendable Decoys Counter Missiles With New Technology, " *Defense Electronics*, October 1986, pp. 69 ff.

[24] If enemy radars could not detect **and** track a Joint STARS platform or its antennas, and if enemy direction-finding equipment could not reliably detect **and** recognize Joint STARS radar emissions **and** track their source, jammer beams could not be aimed at the radar. However, operating Joint STARS equipment in a stealthy manner may require operation at reduced power. This would reduce the power of radar echoes and hence the power required for mainlobe jamming.

[25] Masking of targets in central Germany by summer vegetation would be significant: cf. figures 1 and 2 of V.L. Lynn, "Terrain and Foliage Masking for Long-Range Surveillance; A Sample of Measurements in Central Germany" (Lexington, MA: Massachusetts Institute of Technology, Lincoln Laboratory, Project Report TST-35, June 15, 1979), Defense Technical Information Center accession No. AD-B040205 See vol. 2 of this report for further discussion of masking.

[26] An object **radar cross-section** is an index of its observability by radar; it depends on the frequency of the radar signal, the polarizations of the transmitting and receiving antennas, and the directions to these from the target.

needed[27]—without compromising its low observability .

For this reason, some analysts believe that a significantly more survivable Joint STARS would not be able to gather all the information "required" by the Joint Service Operational Requirement for Joint STARS. This does not mean such a system would be useless—it might be very useful—but OTA knows of no analysis of the contribution to FOFA of such a reduced capability. In order to judge the value of a stealthy Joint STARS, a detailed analysis is needed comparing the separate and combined contributions to FOFA capability of an E-8A operated for survivability and a stealthy platform operated near the FLOT.

Rather than reduce power to the extent required to completely avoid detection, deception could be used to make enemy identification, tracking, and engagement of a low-observable Joint STARS platform improbable. Expendable decoy emitters–discussed above–would need less power to mimic a low-power, stealthy Joint STARS than to mimic a high-power E-8A-based Joint STARS.

Complementary Platforms

The surveillance capabilities of E-8As could be increased or supplemented by other aircraft operating in coordination with them; these could include aircraft of three distinct types:

1. stealthy aircraft with comparable radars used to observe deep areas;
z. aircraft with less capable radars, which could observe some targets masked from E-8 As; and
3. stealthy aircraft used primarily to passively observe deep areas "illuminated" by E-8As at greater stand-off range.

Development of stealthy platforms to complement (not replace) E-8As would avoid several shortcomings of a force consisting solely of stealthy platforms. E-8As could be used before complementary platforms are operational. Thereafter:

- In peacetime, E-8As could be used in Europe to provide indications of Pact mobilization and warning of attack. Stealthy platforms should not be used routinely because their routine use would risk compromising their security and survivability.
- In crises, E-8As could be deployed from Europe to other theaters where it would be difficult to deploy GSMs quickly. Stealthy platforms, if small, would be unable to carry much operations and control equipment. Joint STARS E-8 As, like AWACS E-3 A/B/Cs, could be used to "show the flag"; stealthy platforms, if observed, might be more easily countered later.
- In wartime, the stealthy platforms of a "mixed" force could view selected deep areas frequently, or broad deep areas infrequently, with little terrain masking, whereas E-8As normally at a greater distance from the FLOT could revisit the close battle area frequently with their powerful radar beams. The E-8As could approach the FLOT more closely when provided extra defense support or after enemy air defenses have been degraded; they could also serve as operations and control centers, complementing GSMs.

Less capable airborne radars could observe some targets masked from E-8 As; these include ASARS-II, enhanced ASARS-II, Mohawk, ASTOR-I, and ORCHIDEE, which were mentioned above,[28] as well as radars on unmanned aerial vehicles, which are discussed later in this chapter. These could not replace E-8As but could complement them; for example, a short-range MTI radar being developed for the Army's Intelligence and Electronic

[27] In experiments using simulated imagery, the success rate of operators tasked to track company-size formations (10 vehicles) for 24 minutes decreased from about two-thirds to about one-half when the revisit interval was increased from 30 to 60 seconds. Their success rate tracking battalion-size formations (50 vehicles) decreased similarly when the revisit interval was increased from 60 to 120 seconds. See Little and Bloomfield, op. cit., p. 24, fig. 3. Masking of targets by vegetation was simulated in these experiments, and a stationary radar location was assumed.

[28] See *also* ch. *8*, above, and the section below, in this chapter, on "The Two-Way Street, " where the NATO Airborne Radar Demonstrator System (ARDS) program is discussed.

Warfare Unmanned Aerial Vehicle could be used to monitor targets in areas masked from E-8As by hills.

In the more distant future, it might be possible to build a bistatic ("two-station") MTI radar system employing a powerful transmitter on an airplane or satellite at a presumably safe distance to irradiate the coverage area while an airplane closer to the coverage area receives and processes the radar echoes .[29] The receiver platform would not divulge its location by beaming radar pulses into enemy territory and, if sufficiently stealthy, might therefore escape attack and sidelobe jamming even if very close to enemy territory. It would still be susceptible to mainlobe jamming, although potentially less so than a low-power radar. Its advantage over baseline or low-power systems is that it could scan close and deep areas at a high revisit rate. The platform location determination and signal synchronization and processing required for such a system would be very challenging. However, if and when it is feasible, Joint STARS E-8As might be used to irradiate the coverage area from a safe distance, while a complementary airplane, possibly using most of the avionics components developed for E-8 As, collected and processed radar echoes and transmitted MTI data rearward to E-8 As, which could downlink it to Army ground station modules and other users and service their requests for radar tasking and attack control.

[29]George W. Stimson, *Introduction to Airborne Radar* (El Segundo, CA: Hughes Aircraft Co., Radar Systems Group, 1983); pp. 576-577.

Potential Commonality of Joint STARS Prime Mission Equipment for E-8As and Other Platforms

If a decision were made to develop a low-observable platform for Joint STARS, it appears that all the radar components developed for the E-8A except the antenna could be used on such a platform without major changes, if that system were to operate in the same frequency band. Operations and control consoles developed for the E-8A would not be usable on a small platform, but could be used, if desired, on other aircraft or in ground-based facilities.

THE PRECISION LOCATION STRIKE SYSTEM (PLSS)

The Precision Location Strike System (PLSS: pronounced "pens") is a developmental surveillance and control system designed to detect, identify, and accurately locate modern mobile jammers and electronically agile[30] radars in near real time.[31] Such emitters would accompany and protect follow-on forces. An ability to attack these emitters soon after they are detected in a new location would be very valuable for protecting allied aircraft that detect and attack follow-on forces. PLSS has demonstrated a capability to locate and report more such emitters per hour with greater accuracy and timeliness than can all other U.S. systems now reporting to Europe combined. However, development of PLSS has been delayed by several problems, and the Air Force decided last year not to begin procurement of PLSS in fiscal year 1987. This year, the Air Force reconsidered procurement of PLSS after an operational utility evaluation of PLSS was completed in April, and recommended cancellation of the program.

PLSS would use electronic equipment carried aloft by three TR-1 aircraft operating together, each communicating by means of an Interoperable Data Link (IDL) with a Central Processing Subsystem (CPS), which could be transportable or based in a hardened PLSS Ground Station (PGS: see figure 10-2).

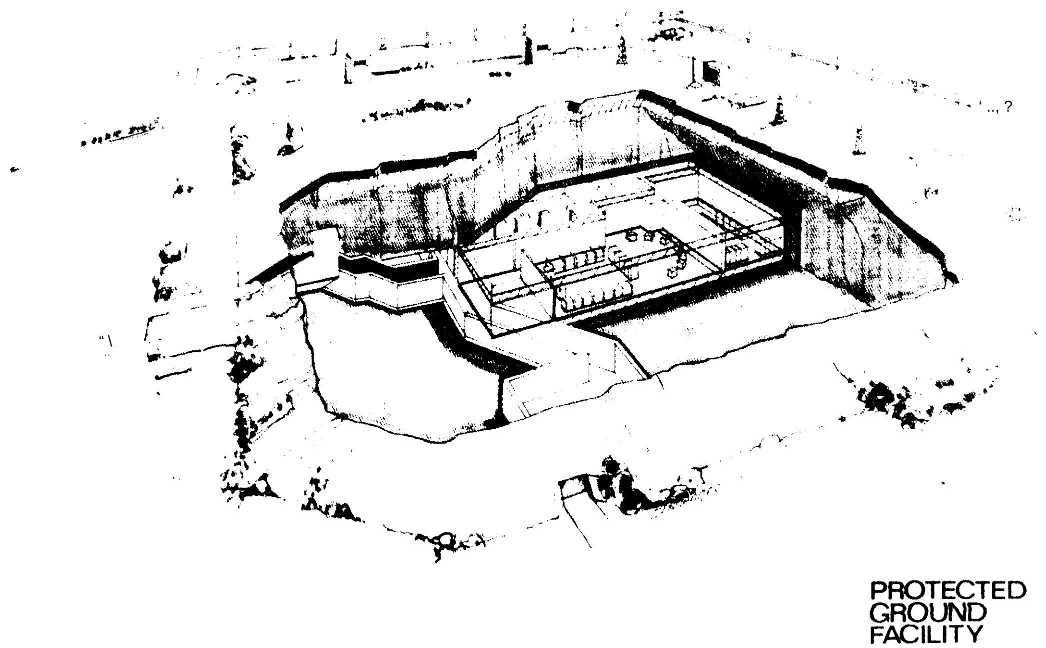
To locate emitters both accurately and quickly, PLSS uses a combination of distance-measuring equipment (DME), time difference of arrival (TDOA), and direction of arrival

[30]Capable of quickly changing frequency or emitting brief pulses after long, irregular intervals.
[31]HQ TAC, TAF ROC 314-74.

Figure 10-2.—Components of the Precision Location Strike System (PLSS)

The TR-1 high-altitude reconnaissance aircraft.

SOURCE U S Department of Defense



Artist’s conception of a hardened PLSS Ground Station.

SOURCE *Signal* (the official journal of the Armed Forces Communications and Electronics Association) January 1986 Copyright 1986 reprinted by permission

(DOA) techniques: The TR-1 aircraft determine their own locations using DME; TDOA comparisons produce a few very precise candidate locations for each emitter; and DOA sensing determines which of them is the correct one.[32]

The necessity that three airborne receivers simultaneously detect a radar pulse requires that each receiver be very sensitive and use high-gain antennas, because at least two of the three receivers will be in an emitter's sidelobes (or backlobe) when it emits a pulse. To attain the antenna gain required, each airborne receiver uses a phased array of antennas. A high-gain antenna pattern is necessarily directional, so the phased array is designed to form multiple receive beams which collectively cover the specified coverage area without scanning; scanning would risk missing the signal of a "short on-time" emitter.

Emitter locations reported by PLSS, when correlated with intelligence from other disciplines, could be used for situation assessment and targeting. These activities could be performed by the proposed PLSS Intelligence Augmentation Subsystem (PI AS), or in existing intelligence fusion and targeting facilities. Once targets have been selected and attacks planned, near-real-time emitter location reports from PLSS could indicate when missiles should be launched, and could be relayed to attack aircraft using a variety of communications systems. Attacks against emitters could be controlled from the PGS.

Components and Programs

Components used by or related to PLSS are being developed or procured under six separate programs:

1. PLSS
2. TR-1
3. IDL
4. ELS
5. ATDL
6. PIAS

PLSS

Equipment developed by the PLSS program, per se, includes the airborne mission subsystem (AMS) carried by each TR-1 aircraft; the Central Processing Subsystem (CPS), and the Site Navigation Subsystem. AMS consists of an airborne intercept element (AIE: antennas, intercept receiver, and control system), distance-measuring equipment, and government-furnished Interoperable Air Data Link (IADL) equipment for the IDL. The CPS includes government-furnished Interoperable Ground Data Link (IGDL) equipment to communicate with the TR-1s, signal and data processing equipment, and a PLSS Interface Module (PIM) for selecting, formatting, and disseminating PLSS location reports to various users according to their needs. Each Site Navigation Subsystem (SNS) is a transportable DME transponder.[33]

TR-1

PLSS airborne mission subsystems must be carried aloft aboard TR-1 reconnaissance aircraft. Late-model TR-1s can carry either a Tactical Reconnaissance System (TRS) payload[34] or a PLSS AMS, but not both simultaneously. TRS and PLSS payloads can be swapped in about an hour. During development and testing, PLSS airborne mission subsystems have been carried aboard TR-1s flying training missions. PLSS could provide a limited operational capability, if desired, using TR-1s procured for the TRS, training, or other missions. A greater operational PLSS capability, if desired, would require procurement of additional TR-1s.

[32] R. Hale, "Precision Location Strike System, " *Signal*, January 1986, pp. 51 ff.

[33] Ibid.

[34] Consisting of an ASARS-II airborne radar system, etc.

IDL

Interoperable Data Link equipment is in production and will be provided to the prime contractor for PLSS as government-furnished equipment. It includes both IADL equipment for installation on TR-1s and IGDL equipment for use by the PLSS CPS.

ELS

PLSS was designed to locate pulsed radars; the Emitter Location System (ELS) program is developing software and hardware to give PLSS the ability to locate non-pulsed emitters.

ATDL

Until 1986, Adaptive Targeting Data Link (ATDL) equipment was under development for installation in aircraft or weapons. ATDL-equipped aircraft and weapons could be guided to emitter locations determined by PLSS. Starting in fiscal year 1990, Block 30P F-16s were to be equipped with ATDL transponders, which would allow them to receive guidance from controllers in the PGS via relay equipment in the TR-1s. If equipped with ATDL transponders, missiles and other weapons could also be guided to emitter locations by PLSS. Weapons which have been considered (and, in some cases, tested) for this application include the GBU-15 glide bomb,[35] air- and ground-launched versions of the T-16 Patriot and T-22 Lance missiles,[36] the Conventional Stand-off Weapon (CSW) proposed by the Air Force,[37] and the now-defunct JTACMS (Joint Tactical Missile System).[38] Unlike an antiradiation missile (ARM), which can home on a radar antenna only when it is transmitting, an ATDL-equipped missile would attack a radar antenna location and could disable it even when it is not transmitting.

PIAS

To enhance the intelligence value of PLSS by improving analysis, exploitation, and reporting capabilities, a PLSS Intelligence Augmentation Subsystem (PIAS) is being developed under the PLSS Intelligence Augmentation Program (PIAP). Originally, two subsystems were to be developed. One was to be located with the PLSS CPS in a hardened PGS to be constructed in Europe; the other—a transportable facility-was to be used for training at Nellis Air Force Base under normal circumstances. PIAS would use some equipment now used by the ground control processor of the Senior Ruby ELINT system; enhancements would be made available for use by Senior Ruby.

Status

PLSS completed Developmental Testing and Evaluation in 1986 and Operational Utility Evaluation in April. PLSS was intended to be operational by now to counter a "circa 1985" threat. However, its development and procurement have been delayed by several problems, which are discussed below. Last year, the Air Force decided not to request funds for procurement of PLSS in fiscal year 1987 and not to develop ATDL transponders for installation in F-16s.[39] Currently, $675 million[40] has been appropriated through fiscal year 1987 for RDT&E to procure, for the purpose of development, testing, and evaluation, one CPS, six

[35] Department of Defense Appropriations for 1983, Hearings before a Subcommittee of the Committee on Appropriations, House of Representatives, 97th Cong., 2d sess., Part 1 (Washington, DC: U.S. Government Printing Office, USGPO 92-690 0, 1982), pp. 842-866.

[36] Ibid.

[37] Ibid.

[38] Department of Defense Appropriations for 1984, Hearings before a Subcommittee of the Committee on Appropriations, House of Representatives, 98th Cong., 1st sess., Part 4 (Washington, DC: U.S. Government Printing Office, USGPO 19-163 0, 1983), p. 725; Department of Defense Appropriations for 1985, Hearings before a Subcommittee of the Committee on Appropriations, House of Representatives, 98th Cong., 2d sess., Part 5 (Washington, DC: U.S. Government Printing Office, USGPO 34-7740, 1984), pp. 71-76.

[39] If desired, Joint STARS aircraft could receive target updates from the PLSS CPS (via JTIDS) and relay them (via the Joint STARS Weapon Data Link) to aircraft and (optionally) missiles equipped with Joint STARS Weapon Interface Units (WIUs). The Air Force does not currently plan to procure WIUs but began reconsidering procurement of WIUS when plans to procure ATDL transponders— which would have functioned as WIUs–were canceled.

[40] In current (i.e., "then-year") dollars.

SNSs, and three all-up AMSs and a partial AMS requiring refurbishment." No TR-1s have been procured specifically for PLSS.

The results of the Operational Utility Evaluation of PLSS have been reviewed by the Air Force, which recommended program termination. The Department of Defense could concur, recommend continued development, or seek procurement of quantities needed for some level of operational capability. If so directed, the Air Force Systems Command could turn PLSS hardware over to the Tactical Air Command in May 1987 for use in training and to provide a limited operational capability. If TAC desires only a limited operational capability, the Air Force might choose to have the Air Force Logistics Command (AFLC/AZ) manage PLSS as a "unique system."

Problems and Progress

PLSS has encountered several problems and delays during its development. It has not yet demonstrated the system reliability, emitter reporting rate ("throughput"), or emitter location accuracy originally specified. Moreover, during developmental testing, it often reported each actual emitter detected as several distinct emitters. However, its performance has been improving. During developmental testing:

- PLSS achieved an "adjusted" system reliability of about 0.7; the specified system reliability is 0.83.[42]
- PLSS achieved two-thirds of the originally specified throughput; meanwhile, the throughput requirement was reviewed and reduced by one-third, to the value demonstrated by PLSS.
- PLSS demonstrated an emitter location accuracy which improved during the test period for which data was available to OTA and approached specified accuracy on most days at the end of that period.[43] Location errors were very large on some days; however, a 4-day moving average of emitter location error demonstrated decreased to 2.7 times that specified.[44] Some specific causes of high location errors (e.g., loose connector contacts) were identified and corrected.

The tendency of the PLSS CPS to report each actual emitter detected as several distinct emitters is known as the "association problem." During the test period for which data was available to OTA, four emitters were reported, on the average, for each actual emitter detected. This overreporting indicates a failure of the CPS to recognize successive intercepted signals as coming from the same emitter. When a "hit" occurs (i.e., when the AMSs intercept a signal), the signal parameters are reported to the CPS, which logs them in a buffer. The CPS also estimates an emitter location for each hit, and logs it with the other signal parameters. Before reporting a "new" emitter, CPS software attempts to determine whether the signal parameters of the new hit can be well correlated with those of a previous hit. If so, CPS software would assume that the intercepted signal was emitted by a previously reported emitter and would not report a new emitter.[45] However, because a modern emitter can vary many of its signal parameters (e.g., frequency), CPS software relies heavily on the emitter locations estimated for each hit in attempting to associate logged hits with specific emitters. Hence any fault which reduces emitter location accuracy will reduce the probability of correct emitter-hit association and result in overreporting.

[41] USAF (SAF/LL) private communication.

[42] The "adjusted" system reliability is an estimate of the probability that 1 CPS, 3 AMSs, and 9 SNSs would have completed an 8-hour mission without critical failure if 1 CPS, 4 AMSs, and 16 SNSs had been available and prepared for operation. It is based on demonstrated CPS, AMS, TR-1, and SNS reliabilities—0.99, 0.90, 0.87, and 0.99, respectively.

[43] AF/RDPV and AFSC/SDWD private communication.

[44] A 4-day moving average of emitter location accuracy demonstrated using only two TR-1s—which takes longer—approached six times that specified.

[45] It would, however, refine its estimate of the location of the previously reported emitter.

Some specific faults causing incorrect emitter-hit association were identified and corrected during testing. Improvements in the accuracy with which emitter location can be determined from a single hit would further reduce overreporting. Residual overreporting could be reduced by increasing the tolerance (i.e., the allowable distance) between single-hit emitter location estimates which can be associated with one emitter. This would, however, decrease the accuracy of emitter location reports. If a PLSS Interface Module is installed in the CPS (as originally planned), operators in the PIM could review PLSS location reports before they are disseminated to users and could cancel dissemination of obviously duplicative reports.[46] The PLSS Intelligence Augmentation Subsystem, if fully developed and procured, might also reduce overreporting by "residue processing"—a more sophisticated and time-consuming method for correlating reported signal parameters than that used by the PLSS CPS.

Operational Utility: The View From USAFE

Until this year, PLSS was an important part of the program for improving surveillance in Europe. However, the Air Force has taken the position that other systems or combinations of systems can adequately perform the important functions of PLSS. Attack aircraft can be guided to approximate emitter locations using ELINT from currently operational systems. The systems and procedures used would be too slow and inaccurate to guide missiles to emitter locations, but USAFE opposes procurement of ground-based missiles-or surveillance and control systems for such missiles—on the grounds that they would be too vulnerable[47] and inflexible.[48] These concerns are valid, and the argument has some merit. However, the concern expressed about vulnerability of critical links could apply to other facilities which support air defense suppression, air interdiction, and other tactical air missions. Moreover, PLSS is designed to support air defense suppression, not FOFA; suppression of enemy air defenses would be important even if enemy forces were front-loaded.

Others still see value in PLSS, particularly for targeting modern mobile SAMs. It has already demonstrated an emitter location accuracy which is superior to that of existing theater ELINT systems, as well as a high emitter reporting rate ("throughput") which will be needed to rapidly reconstruct our picture of the enemy's "electronic order of battle" (numbers, types, and locations of emitters) at the outbreak of war if, as expected, enemy radars shut down, move, change frequencies, and begin wartime operation in short on-time, electronically agile modes.[49] Proponents and opponents agree that "association" and reliability must be improved; proponents are more confident that they can be, soon.

Alternatives to PLSS

Combinations of other systems could do the job PLSS was designed for, but not as well. For example:

- ELINT from a Senior Ruby or Guardrail/ Common Sensor system could be used to

[46] Overreporting is not peculiar to PLSS, but occurs to some extent in other intelligence collection and fusion systems. Human judgment is generally necessary-but not infallible—for recognizing duplicative reports. Because PLSS is capable of issuing so many reports per hour, overreporting by PLSS would be particularly bothersome.

[47] USAFE has argued that:

> systems necessary to feed precision attack ground-based sy-tems ., become high priority targets for the enemy. We believe the Soviets might make whatever sacrifice necessary to destroy one of these critical links. These same high technology systems enhance the precision attack capability of manned systems, yet without them, man can be given the approximate target location and rough timing estimates. He then becomes the precision attack system.
>
> HQ USAFE. FOFA: USAFE View, briefing to OTA Staff, Apr. 16 1986.

[48] USAFE opposes investing in systems designed specifically to support FOFA. USAFE has argued that if Warsaw Forces are massed forward ("front-loaded") rather than echeloned, there would be few follow-on forces to attack, and systems designed specifically to attack them would be largely useless. Manned attack aircraft could be used for other purposes. [I bid.]

[49] Private communication.

cue an ASARS-II or Joint STARS radar to scan a suspected SAM deployment area in an attempt to recognize and precisely locate the SAM battery. However, Senior Ruby is less sensitive than PLSS and might not detect sidelobe or backlobe pulses from modem radars-it might have to wait for a mainlobe pulse. The whole process of emitter location estimation, tasking of ASARS-II or Joint STARS, and interpretation of the returned radar imagery would take much longer than would emitter location estimation by PLSS.

- Alternatively, AN/TPQ-37 "Firefinder" radars could be used to locate SAM launchers as soon as they fire. The nominal range of these radars is less than that of the above-mentioned systems, although they might detect large SAMs at greater than nominal range.
- The originally planned ability of PLSS to provide in-flight target updates to aircraft and missiles could be emulated by using Joint STARS aircraft to relay updates from the surrogate sensors to aircraft and missiles. To receive target updates, each attack aircraft or missile would have to be equipped with a Joint STARS Weapon Interface Unit.
- An alternative to providing missiles with in-flight target updates would be to attack emitters with long-endurance ARMs which have loiter capability, such as the TACIT RAINBOW missiles being developed for the Air Force. Unlike a PLSS-guided missile, an ARM could not attack a radar antenna after it ceases radiating. However, a TACIT RAINBOW missile could loiter until a target radar turns on again (or until its fuel is exhausted).

Summary

PLSS continues to be troubled by technical problems, but its performance is improving and it could provide unique and valuable RSTA and attack control capabilities. Some, but not all, capabilities demonstrated by PLSS could be provided in the near term by combinations of other systems such as Joint STARS and the Tactical Reconnaissance System. The Commander in Chief, United States Air Forces Europe (CINCUSAFE) has judged that the additional capabilities of PLSS are not worth its cost in resources diverted.

UNMANNED AERIAL VEHICLES

Unmanned aerial vehicles[50] could be used to perform RSTA for FOFA. They would be cheaper than manned aircraft and less hazardous to pilots. Small UAVs could not simultaneously provide the coverage and revisit rate that Joint-STARS would. However, they could reconnoiter more limited areas, particularly areas masked from Joint STARS by terrain and vegetation, and could be used to distinguish armored from unarmored vehicles. They could support attacks using MLRS or ATACMS; close in, they could be used for artillery fire direction and adjustment. UAVs are being developed for the Army, Navy, Air Force, and Marine Corps; others are in development, production, and use by allied nations.

UAVs which could be used for FOFA include:

- the Aquila RPV, which is being developed for the U.S. Army[51] to perform reconnaissance and target designation functions primarily in support of close combat;
- various domestic and foreign-made "non-developmental" UAVs which have been proposed as alternatives to Aquila;
- smaller "Light Division UAVs" of more limited capability to support smaller units;

[50] Unmanned aerial vehicles (UAVs) include remotely piloted vehicles (RPVs)—unmanned aircraft which require remote control by human pilots-as well as autonomous aircraft (drones), which do not. They also include aerial vehicles which permit, but do not require, remote control by human pilots.

[51] By the Austin Division of the Lockheed Missiles& Space Co.

- a larger, longer-range Intelligence and Electronic Warfare (IEW) UAV which could perform multiple missions to the depth of a corps commander's area of interest;
- expendable UAVs for jamming and lethal attack ("kamikaze UAVs");
- air-launched UAVs for reconnaissance, jamming, and lethal attack; and
- advanced-technology UAVs, in the more distant future.

The Aquila RPV

The Aquila (figure 10-3) is the airborne platform used by the Target Acquisition Designation Aerial Reconnaissance System (TADARS), which also includes truck-mounted rail launchers, recovery nets, air vehicle transporters, maintenance shelters, and ground-control stations. The Aquila RPV is intended to perform reconnaissance, target acquisition, artillery fire adjustment, and damage assessment, and laser designation of targets for the Copperhead cannon-launched guided projectile (CLGP), Hellfire and the AGM-65E Maverick[52] anti-armor missiles, and laser-guided bombs. Aquila carries a Modular Integrated Communications and Navigation System air data terminal (MICNS ADT) and a mission payload system (MPS) consisting of a laser rangefinder/designator system and a TV camera (for daytime use). It could carry other payloads which are now being developed—e.g., a forward-looking infrared (FLIR) sensor (for daytime or nighttime use), or a bistatic radar module for detecting vehicles illuminated by a Joint STARS radar or aircraft illuminated by an AWACS radar.[53]

Problems and Progress

The TADARS program schedule and budget have been overrun several times. The program office and the prime contractor attribute major delays primarily to unforeseen difficulties meeting payload mass constraints, stabilizing the TV camera and especially the laser designator, and operating with the data rate reduction and processing delay incurred when the MICNS is operated at high anti-jam levels.[54] Human factors were also cited: in some early tests, TADARS was operated by contractor personnel or by highly trained aviation or intelligence specialists. The program has since been transferred from the Army's Aviation Systems Command (AVSCOM) to the Missile Command (MICOM), and in recent tests TADARS has been operated by personnel of lower Military Occupational Specialty (MOS) level (Specialist 4).

The ability of the program to achieve its technical goals appeared doubtful in September 1985, when the Army stopped the developmental test program after test systems failed to pass 21 of 149 performance specifications. Subsequently, Lockheed's Austin Division conducted, at its expense, a test-fix-test effort, and demonstrated correction of most shortcomings, as well as an ability to designate stationary and moving targets for Copperhead shells and Hellfire missiles.

During Developmental Test 11A, begun in February 1986, TADARS met all but two system performance specifications: total system mission reliability (0.75 specified for IOC, 0.62 demonstrated) and probability of autotracking for 95 percent of 3 minutes (0.9 specified, 0.75 demonstrated). TADARS subsequently exceeded the total system mission reliability specification during collective training (0.77 demonstrated), and Lockheed reports that an autotrack probability of 0.92 was demonstrated in subsequent company tests.[55]

[52] A Marine Corps weapon launched from A-6E Intruder aircraft to provide close air support to Marines, who now designate targets using the hand-held Modular Universal Laser Equipment (MULE) to assist A-6 crews with IFF (identification: friend or foe).

[53] Dom Giglio and Phil Emmerman (USA HDL), "Radar Technology/Signal Information Processing, in Symposium, 28-30 January 1986, Reconnaissance, Surveillance, and Target Acquisition (RSTA), Compendium of Government Briefings, Volume 2 (Adelphi, MD: U.S. Army Harry Diamond Laboratories, 1986)].

[54] A non-secure data link was used in early tests.

[55] Lockheed Missiles & Space Co., Inc., Austin Division, briefing to OTA staff, Dec. 10, 1986.

Figure 10-3.—The Aquila Remotely Piloted Vehicle

SOURCE Lockheed Missiles & Space Co Inc (Austin Division)

Status

As of March 1,1987, TADARS is in full-scale development. $820 million[56] has already been appropriated for RDT&E through fiscal year 1987; 12 air vehicles and 5 Remote [MICNS] Ground Terminals (RGTs) have been procured for development, testing, and evaluation. The Army proposes to begin serial production of air vehicles and Ground Control Stations this year for an initial operational capability (IOC) date of 1991. The Army currently plans to procure a total of 376 air vehicles and 53 Ground Control Stations. The Army estimates that total program acquisition cost will be $2.2 billion-i. e., appropriation of about $1.4 billion more will be required.

Alternatives to Aquila

Problems with TADARS have stimulated suggestions that a domestic or foreign-made "non-developmental" UAV be procured as an alternative to Aquila. UAVs which could perform some of the functions of TADARS include:

- Skyeye (made in the United States by Lear-Siegler)

[56] In current (i.e., "then-year") dollars,

- Pioneer 1 (made in Israel by AAI/Mazlat)[57]
- CL-289 (made in Canada by Canadair)
- Heron-26 (made in Italy by Meteor)[58]
- Mirach-100 (made in Italy by Meteor)
- Phoenix (made in the United Kingdom by GEC Avionics)

Two of these—Skyeye and Pioneer 1–are now in service with U.S. forces but are not specifically designed to operate in the climate and jamming expected in central Europe and do not have the target location and designation capabilities of TADARS. In fact, none of these meets all specifications for, or provides the capabilities of TADARS, and modification of one to have capabilities roughly comparable to those of TADARS would probably cost more and take longer than would completing development and procurement of TADARS.[59] Now that TADARS is performing as specified, arguments for procuring one of these UAVs in place of TADARS rest upon cost rather than performance or schedule: A reconnaissance UAV with no laser designation capability and little[60] or no jam resistance could be purchased immediately and at lower cost, although delivery might take as long as delivery of Aquila.

However, procurement of one of these in lieu of TADARS would have the following drawbacks:

- None of these meets all specifications for TADARS, which requires use of components, and assembly, testing, and documentation practices which meet standard military specifications.
- None of these could provide the target location accuracy of TADARS without relying on an operator to identify map features on the TV display. Their target location errors (without such map-display correlation) are too large to locate targets for artillery and missiles but adequate to locate targets for aircraft flying armed reconnaissance missions or to cue sensors which could locate targets more accurately.
- None of these, without modification, could designate targets by laser. This would seriously limit utilization of Copperhead;[61] however, with its range of about 16 kilometers, Copperhead could reach only about 10 kilometers beyond the FLOT.
- Some have inferior or nonexistent electronic counter-countermeasures (ECCM). For example, the Pioneer-1, entering service with the U.S. Navy and the U.S. Marine Corps for evaluation, lacks ECCM to protect its data links from jamming,[62] as does the Skyeye RPV, which has been used by the Army in Thailand and Honduras. Good ECCM will be essential to counter Warsaw Pact jamming in Europe; RPVs with inadequate ECCM might be of little value.
- None has a target-autotrack feature; none is designed to interface with TACFIRE and AFATADS. Most lack ballistically hardened ground control stations with nuclear-biological-chemical protection.[63]
- Some have radar cross-sections higher than that of Aquila, but the differences are of little consequence.[64]

[57] The Pioneer 1 is a successor to Mazlat's Mastiff Mk3 and Scout-800 RPVs, which are no longer offered for sale.

[58] The Heron-26 is an improved version of Meteor's Mirach-20 "Pelican," Its manufacturer, Meteor Costruzioni Aeronautiche ed Elettroniche, is represented in the United States by Pacific Aerosystems.

[59] U.S. Congress, General Accounting Office, *Aquila Remotely-Piloted Vehicle: Recent Developments and Alternatives* (Washington, DC: General Accounting Office, report GAO/NSIAD-86-41BR, January 1986). This would require installation of the MICNS ADT, laser rangefinder/designator, and TV (or FLIR) camera developed for Aquila.

[60] GEC Avionics Phoenix and its ground station both use highly directional antennas, which would contribute to the claimed jam resistance of its control and data links, Meteor claims that the data link of its Mirach-100 is jam resistant. OTA knows of no analysis that compares the jam resistance of these systems with that of TADARS. The uplink (control link) of the Pioneer 1 has anti-jam features; its downlink (data link) relies on terrain masking against ground-based j ammers.

[61] Unless Copperhead seekers are replaced by autonomous seekers now being developed. See U.S. Congress, Office of Technology Assessment, *Technologies for NATO's* Follow-On Forces *Attack Concept—Special* Report, OTA-ISC-312 (Washington, DC: U.S. Government Printing Office, July 1986).

[62] B. M. Greeley, Jr., "Symposium Display Underscores RPV Advances, Service Needs, " *Aviation Week and Space Technology*, Aug. 4, 1986, pp. 124-125.

[63] The ground control station for the Phoenix has nuclear-biological-chemical environmental protection; ballistic protection is not claimed.

[64] Doubling a UAV's radar cross-section would increase by only 20 percent the range at which it could be detected by enemy radar.

The Light Division UAV

The Army is developing a "Light Division UAV" which is smaller and of lesser capability than Aquila. It could be more easily launched, controlled, and recovered by Army division elements operating near the FLOT.

The IEW UAV

The Army hopes to field a larger, longer range Intelligence and Electronic Warfare (IEW) UAV by late 1987. The Army plans to select a non-developmental platform this summer after a fly-off;[65] candidates may include some RPVs which have been proposed as alternatives to Aquila, as well as others.[66] It could fly to the depth of a corps commander's area of interest, carrying some of the UAV payloads now being developed by the Army to perform surveillance (by means of synthetic-aperture radar, MTI radar, and infrared or millimeter-wave passive thermal imaging); collection of electronic intelligence, communications intelligence, and meteorological intelligence; communications relaying; and radar or communications jamming.[67] With some of these payloads, the UAV could be very valuable for FOFA.

Expendable UAVs

The Army is also developing expendable UAVs to perform jamming and to support special operational forces, as well as "kamikaze" UAVs to attack certain targets. Although useful for FOFA, these would not be intended primarily for RSTA.

Air-Launched UAVs

The Navy and Air Force are developing air-launched UAVs for reconnaissance, jamming, and lethal attack. An air-launch capability could give them great range and simplify their employment in coordination with strikes by manned aircraft.

Advanced-Technology UAVs

These concepts do not begin to exhaust the possibilities of UAVs which could someday perform RSTA for FOFA. UAVs incorporating advanced technology (e.g., radioisotope-powered heat engines) or merely ingenious design could operate for very long periods at high altitude.[68]

Issues and Options

TADARS has been an issue in Congress primarily because its schedule and budget have been overrun. Congress has several options for future funding of TADARS:

- Congress could fund procurement of TADARS and development of a FLIR for TADARS, subject to the requirement (stipulated in the fiscal year 1987 Defense Authorization and Appropriations Acts) that TADARS meet performance specifications and that the Army negotiate a contract which limits its liability.
- Congress could deny funding for TADARS and express an expectation that the Army would cancel the program and make do without TADARS. This would save money, and some functions which TADARS was to perform could be performed by other systems.[69] The effectiveness of artillery and MLRS—which can be used for

[65] Private communication.

[66] Don Dugdale, "Tapping the Potential of Unmanned Air Vehicles," *Defense Electronics*, October 1986, pp. 109 ff.

[67] Don Kurtz (NASA Jet Propulsion Laboratory), "The ADEA UAV Payload Testbed Program," in Symposium, 28-30 January 1986, Reconnaissance, Surveillance, and Target Acquisition (RSTA), Compendium of Government Briefings, Volume 2 (Unclassified) (Adelphi, MD: U.S. Army Harry Diamond Laboratories, 1986). See also vol. 2 of this report.

[68] See, e.g., R. Dale Reed, "High-Flying Mini-Sniffer RPV: Mars Bound?" *Astronautics and Aeronautics*, June 1978, pp. 26-39; Victor C. Clarke, et al., "A Mars Airplane?" *Astronautics and Aeronautics*, January 1979, pp. 42-54; and vol. 2 of this report.

[69] For example, acquisition of moving targets for MLRS could be performed by Mohawk now, or by Joint STARS or the Army's proposed IEW UAV in the future, if these programs continue. However, Mohawk imagery is not available continuously or in real time, and the IEW UAV is not required to locate targets with great precision or to designate them with a laser.

short-range FOFA— would suffer without TADARS.

- Congress could deny funding for TADARS and express an interest in considering a request for appropriations to procure a non-developmental U.S. or foreign-made UAV. No such UAV has the capabilities of TADARS, and many would be too susceptible to jamming or environmental extremes, but some could perform RSTA for FOFA.

Concern about duplication of effort has emerged as another issue because of the apparent proliferation of UAV programs. Congress addressed this in the fiscal year 1987 Defense Authorization and Appropriations Acts, which required the Department of Defense to submit a "Master Plan" for UAVs with its fiscal year 1988 funding request. This "Master Plan" should justify the capabilities required of the various UAVs now in development and may indicate why a diverse mixed force is preferred over a smaller force of multi-role UAVs.

Summary

Unmanned aerial vehicles could perform RSTA for FOFA. Small UAVs could not have the coverage and revisit rate of large airborne radars such as Joint STARS, but they could reconnoiter limited areas masked from Joint STARS by terrain and vegetation and could distinguish armored from unarmored vehicles. UAVs are being developed for the Army, Navy, Air Force, and Marine Corps, and by our NATO Allies.

The Army's TADARS could perform short-range RSTA for FOFA. It appears that all major problems which have plagued TADARS have been corrected. Completing development and procurement of TADARS would probably be quicker and no more costly than procuring and modifying a different RPV system to have comparable capability. Some other U.S. and allied UAV systems are cheaper but less capable; many are unsuitable for use in Central Europe, but some could be useful for FOFA. Some U.S. and allied UAV systems now in development could perform RSTA for FOFA at longer range; the Army's IEW UAV may be particularly useful.

THE TWO-WAY STREET: OPPORTUNITIES FOR COOPERATIVE DEVELOPMENT AND PRODUCTION OF RSTA SYSTEMS

Because of security concerns and technological disparity, development and production of RSTA systems usually provide fewer opportunities for Alliance cooperation than do development and production of weapons and munitions. However, the United States has recently bought some foreign-made reconnaissance systems— Israeli RPVs—and could buy others from its NATO partners. Candidates include unmanned aerial vehicles, Airbus Industrie A300 aircraft for use as platforms for Joint STARS, and equipment which would enable Joint STARS Ground Station Modules to receive, process, and display radar imagery from allied airborne radar systems such as the British ASTOR I and ASTOR C systems and the French ORCHIDEE system. Candidate UAVs were discussed above, in the section on UAVs; this section discusses opportunities for cooperation with Allies in producing airborne radar systems.

Interoperable or Co-Produced Airborne Radar Systems

The Airborne Radar Demonstrator System (ARDS) project is a U.S.-British-French effort to achieve interoperability[70] of airborne sur-

[70] Specifically, level-4 interoperability: compatibility at the data link level and below, in terms of the Open Systems Interconnection (0S1) terminology defined by the International Standards Organization (1S0).

face-surveillance systems. ARDS is directed by Project Group 21 (P/G 21) of NATO's National Army Armaments Group (NAAG). Among the airborne platform/sensor configurations being evaluated are:

1. The ASTOR-I Airborne STand-Off Radar system[71] developed for the British Ministry of Defense. It uses a Ferranti MTI radar on a Pilatus Britten-Norman BN-2T twin-turboprop Islander.[72]
2. The ASTOR-C system, which consists of a British Aircraft Corp./English Electric Canberra twin-turbojet platform carrying a fixed-target-indicating Demonstration Synthetic-Aperture Radar (DEMSAR), which is based on the design of the U.S. UPD-7 radar.
3. The French ORCHIDEE[73] radar system—now in development—which will be carried by Super Puma helicopters.[74]

The ASTOR-I and ASTOR-C were designed to record radar data for post-flight processing; they have no airborne data link. They would be of much greater utility for FOFA if equipped with a data link to permit near-real-time exploitation. In one series of demonstrations by P/G 21, an ASTOR I platform used a Joint STARS Surveillance and Control Data Link air data terminal to transmit MTI data to a Joint STARS Ground Station Module. P/G 21 may also attempt to demonstrate the capability of an SCDL air data terminal to transmit raw fixed-target imagery ("phase history") from a ASTOR-C DEMSAR to a GSM for processing and display by equipment which would have to be added to the GSM.

ORCHIDEE platforms will be equipped with Electronique Serge-Dassault (E SD) data link terminals to transmit MTI information to similarly equipped ORCHIDEE ground stations. Army GSMs could be adapted to receive and display MTI information from ORCHIDEE in a variety of ways. The most straightforward would be for ORCHIDEE ground stations to transmit MTI information to Army GSMs via electrical or optical cable or using the French-Belgian RITA mobile telephone equipment now being procured by the Army. P/G 21 is likely to attempt a demonstration of ORCHIDEE/GSM interoperability in this fashion. Alternatively, ORCHIDEE platforms could be equipped with SCDL air data terminals for two-way or down-link data communications with similarly equipped GSMs.

If ASTOR or ORCHIDEE platforms were equipped with SCDL equipment, GSMs could receive and exploit the information they collect. With relatively little modification, GSMs could receive and exploit MTI data from ASTOR-I or ORCHIDEE; processing and exploitation of fixed-target imagery from ASTOR-C would require more extensive modification. These interoperabilities, if implemented, would provide Army users with additional sources of airborne MTI surveillance data and would provide U.S. GSM equipment manufacturers with opportunities for foreign sales or production licensing.

Airbus Industrie A300 Platforms for Joint STARS

It appears that Airbus Industrie A300 jet transport aircraft could be modified to serve as platforms for Joint STARS prime mission equipment.[75] Modifications which the Air Force would probably require include interior reconfiguration and installation of militarized flight-deck avionics, single-point and air-to-air refueling ports, and a radome.[76] A300 aircraft, if ordered soon for use as operational platforms, could be modified and "stuffed" with Joint STARS prime mission equipment as soon as E-8As could.[77]

This possibility presents opportunities for the United States to purchase A300 platforms

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"Formerly called CASTOR: Corps Airborne Stand-Off Radar.
"*Jane's All the World's Aircraft 1985-86* (New York: Jane's Publishing, Inc., 1985), pp. 297-299.
[73]Observatoire Radar Coherent Heliporte d'Investigation Des Elements Ennemis.
"Anon., "The Orchidee Battlefield Surveillance System,' *International Defense Review*, June 1986, p. 720.

"USAF, AF/RDPV, private communication.
[76]ANSER Corp., personal communication, July 22, 1986.
"They could not be ready for use as full-scale development platforms; two E-8As (modified and stuffed EC-18Bs) have already been ordered for full-scale development use.

for U.S. Joint STARS aircraft, for Allies to purchase Joint STARS prime mission equipment for use on allied Joint STARS aircraft, and for co-production of Joint STARS aircraft for U.S. and allied procurement. Allied use of Joint STARS would generate sales of GSMs or their components.

The Joint STARS Joint Program Office has proposed investigation of possibilities for Alliance cooperation on Joint STARS to the Air Staff. Neither the Air Force nor the Department of Defense have yet announced a position on the proposal.