Chapter 9

Special Matters

A number of special issues and challenges relate to the development and operation of UAVs in the Air Force. The study group chose to deal with these separately, using individuals or team cells to address the subjects. What follows is a synopsis of these issues and our suggestions. For detail, the reader is referred to Chapter 7 in Volume II.

9.1 Operational Analyses

The Air Force is faced with complex tradeoffs when deciding what and how many UAVs to buy and for what missions. The goal is to provide the Air Force with an approach that can be adapted to its needs, hopefully ensuring that important aspects of the analyses are not overlooked or suppressed unless it is explicit.

Given the complexity of this issue, time should be taken to define, in the broadest possible terms, what the Air Force wants to accomplish by adding UAVs to the force structure. Is it to save money? If so, in what areas? Is it to reduce personnel costs? Is it to complement or supplement manned aircraft in their missions? Is it to replace a manned aircraft system? Is it to do a mission or task the Air Force cannot do today? Each of these questions poses a different set of trade questions that must be carefully asked and issues carefully stated to ensure objectivity and correctness to the extent possible. Aimed premises lead to biased conclusions. The following steps are important to the analysis.

Defining the Missions/Tasks and Operational Concepts. An important part of problem definition is not only to define what missions/tasks to perform and how but also to take stock of what vehicle design and performance characteristics are implied by operational concepts and whether technologies are mature enough to support the design and performance goals.

Relating Technologies to Operational Needs. The next important step is a screening process to determine those concepts that should be included in the trade studies. The relationships between UAV tasks and requirements (high, medium or low altitude, low observables characteristics, endurance, speed, payload, etc.) must be defined. Also, sensor and other mission systems must be related to each of the operational tasks, indicating both the criticality of a given mission system to a task *and* the availability of the technology to support the need.

Elements of Cost. Estimating cost is often an art. This is particularly true for systems that are performing new tasks with technologies not heretofore used. Estimating costs for evolutionary systems and subsystems is not simple, but there is a process and there are analogs which help guide the cost estimator. Parametric approaches against existing manned aircraft costs must be applied with care, for an unmanned aircraft will entail a very different design approach (components, safety factors, testing, etc.).

Comparing UAVs With Manned Systems. To complete the comparison fully and fairly, care must be taken to define and describe in sufficient detail what the manned platforms do and why. It is not necessary that a *single* UAV replicate the manned aircraft mission performance. What matters is that UAVs perform the mission/task more cost-effectively than a manned aircraft.

Choosing the Scenarios for Evaluation. The Air Force is obligated to use some scenarios for force structure analysis. Scenarios that may be more likely than an MRC should also be included. It may be desirable here to use gaming as a means to both select and understand non-MRC scenarios for evaluation. Indeed, the gaming experience will enable a better choice of quantitative analysis methods.

Analysis Tools. Several analytic methods will be needed. At the *system* and *subsystem* level, more *detailed simulations* of performance are needed and have value in selecting and sizing systems. These simulations and analyses produce results in terms of performance at various levels.

A *mission-level* model will be preferred where small numbers of a UAV type are being considered to perform a special mission. The mission-level model will aid in comparing UAV options with one another, as well as with manned aircraft. Important outputs will include survivability per mission and over some number of missions, mission success, resources expended, etc. Outputs from this level could be input to the next level, if appropriate.

Next, a *campaign* methodology that includes resource allocations should be used to determine where UAVs are preferred over conventional options for mission/task accomplishment. The resource allocation aspect is very important. It aids the Air Force in arriving at best use of forces, hence, best return on investment. The resource allocation method is two-sided, permitting intelligent, adaptive behavior by the opponents depending on the objectives they seek to achieve. Currently, dynamic resource allocation is not part of the Air Force's analysis process.

Summary. The operational analysis of UAVs is important to UAV program decisions. The study group found the models for such analysis are not well developed. The Air Force should identify the appropriate activity, assure it is populated with operational, engineering, and modeling experts, and provide the funding to conduct thorough and accurate studies that consider all the factors briefly described above.

9.2 C^3I Architectures

UAVs can be integrated successfully into Air Force air operations if their capabilities are carefully matched to mission needs and to interfaces with ongoing operations. These interfaces can be addressed, in large part, by integrating the UAV with the existing and emerging infrastructure for C^3I. Each mission creates its own needs for C^3I integration, as well as design considerations for the entire vehicle, sensors, onboard computers, and perhaps weapon components.

Important C^3I factors include the vital need to maintain positive control of UAVs, including the capability for human operators to intervene quickly to regain control of an errant, autonomously controlled vehicle. Mission planning systems are on the critical path for mission success for UAVs, and this technology must be enhanced significantly to allow UAV operation with needed C^3I connectivity. New ideas in autonomous controllers and associate systems that support and collaborate with human operators in a hierarchical command structure and new concepts for passing targeting and intelligence data from the sensors to the shooters are being addressed by Service researchers. Several C^3I architectural concepts described in Volume II may offer ways to enhance UAV military mission effectiveness.

Interoperability with existing and emerging C^3I architectures for the Air Force appears to be feasible for UAVs as long as high-level planning includes UAV capabilities and performance constraints. The principal C^3I challenge remains positive control in shared airspace with manned forces, and the key technology needed is powerful software and hardware to enable real-time, onboard mission replanning for the complex set of UAV missions that are anticipated.

9.3 Survivability

Survivability of UAVs is a complex and critical issue. In each specific UAV design, survivability features must be balanced carefully with objectives such as mission performance, cost, and maintainability. Accordingly, in the future UAVs will be designed for very difficult threats at one end of the spectrum and relatively benign threat environments at the other end. The advantage of persistence will make survivability tougher; use of multiple UAVs in clusters will make it easier.

Like designs for manned aircraft, specific UAV designs will require the appropriate mix of signature control, tactics, emission control, and onboard and offboard countermeasures. In all cases, UAV mission planning must be accomplished in a rigorous, high-fidelity manner since threat avoidance, whenever possible, is a fundamental element of survivability for all current and future UAVs. The future UAVs described in this report will certainly require a new generation of mission planning system to rapidly generate specific “best mission cost-benefit” mission plans and flight profiles for each mission-specific set of threats.

An increasing array of signature control technology is available for future UAV designs, when required, in the area of radar cross sections, infrared signature, acoustic signature, and visual signature. These technologies include vehicle shaping, radar absorbing materials, radar absorbing structure, infrared signature reduction techniques, and low-observable sensor apertures, engine inlets, engine nozzles, and other exterior components.

Self-protection can be achieved by several methods, such as onboard passive and active electronic countermeasures, and in very unique situations—such as encounters with major pop-up threats—near-time intervention by the mission controller. In each specific UAV system design, the tradeoffs, usually based on costs of alternative systems, must be made to assure that the selected self-protection capabilities are clearly cost-effective.

To support the design and survivability analysis of a future UAV system, the Air Force and its contractor community have an increasingly more capable and mature inventory of computer codes. However, many of the codes require state-of-the-art parallel supercomputers to be used effectively. In general, then, the tools are available to do realistic survivability analysis of planned UAVs. Also, both the Air Force and several contractors have very capable test facilities to measure the RCS of UAVs at all frequencies, either using the actual UAV or, before the UAV is built, a full-scale, high-fidelity model of the UAV.

This is not to imply that developing, where required, highly survivable UAVs is easy: in fact it is a difficult task. Each specific UAV conceptual design described in Volume II includes a brief statement of the low-observable technology required to achieve a high level of survivability while performing the required mission. It was not within the scope of this study to perform a quantitative survivability analysis of any of the proposed UAVs.

9.4 INF, START, and CFE Agreements

This study led to careful review of the arms control agreements and treaties that may pertain to the future use of UAVs. Although no arms control agreements limit UAVs directly, the Intermediate Nuclear Forces (INF) Treaty and the Strategic Arms Reduction Treaty (START) limit them indirectly or have the potential to do so, depending on system characteristics. Strict reading of the INF definition of “cruise missiles,” that is, “an unmanned, self-propelled weapon delivery vehicle that sustains flight through the use of aerodynamic lift over most of its flight path,” would bring attack UAVs under control. Both treaties use similar criteria to determine if a cruise missile is subject to their provisions: launch mode (air or ground), range (essentially greater than 500 km), and whether or not the missile is a weapon delivery vehicle. Except for the weapon delivery role, cruise missiles and UAVs are similar.

Continuation of the intelligence, surveillance, and reconnaissance role for the UAV appears to be in no conflict with the treaties because it would not be a weapon delivery vehicle. However, conversion of an existing UAV to a weapon delivery role might subject all UAVs of the same type to the arms control restrictions or to a possible ban altogether.

A cruise missile captured under START would be considered a long-range nuclear ALCM until the US demonstrated, during a START exhibition before the Joint Compliance and Inspection Commission, the differences that distinguished it from a long-range nuclear ALCM. Thus distinguished, it would become a long-range ALCM, and if its range exceeded 600 km, the aircraft launching it could be captured as a bomber.

Clearly, the routine operation of UAVs as now envisioned was not contemplated during the treaty negotiations. The START treaty article-by-article analysis states that the cruise missile definition distinguishes cruise missiles from air-to-surface ballistic missiles and remotely piloted airplanes. A thorough review of the negotiation record would be necessary to determine whether this type of UAV could be considered a remotely piloted airplane and thus not captured under START. As specific designs are determined for a weapon delivery vehicle type of UAV, they will require DoD Compliance Review Group analysis early in the program for a case-by-case determination of permitted or prohibited fielding under INF and/or START.

In any event, the treaty provisions should not preclude or limit UAV technology development, for there is a precedent for excluding UAVs,[10] and it is our belief that other UAVs could be excluded as well.

9.5 Acquisition Strategy

In this study of UAV technologies and air combat operations, a review of the acquisition process of current systems is warranted. Certainly, the UAV presents a classic case for the Air Force to combine and integrate both technology and capability. The goal is to insert technology to improve the US capability to win wars.

Recently, the ACTD has emerged as a method of shortening the time to demonstrate a system operationally. Development of the Tier II Plus and Tier III Minus systems has followed this methodology. The SAB strongly supports the ACTD concept. As this demonstration model matures, there are opportunities to improve the transition process to field truly superior UAV systems.

During the current UAV ACTDs, the lessons learned must be collected and analyzed. An early lesson is that the designer must pay careful attention to the reliability, maintainability, and supportability aspects of the program. Since these are technology demonstrations heavily concentrated on engineering solutions, the long-term life-cycle concerns often are neglected. Another lesson learned is that an event-oriented transition plan from demonstration through production is necessary. Management decisions need to designate accountability and responsibility for the various phases of the program. Event-driven milestones with coordinated entrance and exit criteria are required.

Early in the demonstration phase, it is important to consider the threat postulated against the use of such vehicles. A parallel effort to begin drafting a System Threat Assessment Review based on intelligence estimates would be important for downstream decisions on configuration, force size, and production. Modeling and simulation of the end-to-end systems are required to achieve the confidence levels for reliability. Experience, including an accident, indicates that a disciplined flight test approach that utilizes the Air Force's extensive airplane heritage is required.

It is important to hold a single entity responsible for the total system in the development of UAVs. Government integration has led to problems in other programs in the Air Force. Although faced with difficult interface and integration challenges, the Government should resist becoming the Total System Performance Responsibility leader and leave that to the prime contractor. Strong leadership by the Government in establishing guidance, standards, and common environments is essential for successful integration of varied payloads and equipment.

It is unlikely that the desired production version of a UAV would be identical to that demonstrated in the ACTD; it would probably include lessons learned during the ACTD. The study group recommends a parallel engineering task to evolve a "preferred weapon system

[10] The Tacit Rainbow radar-killing UAV was specifically excluded from the START treaty, though it was never produced.

concept." This would be an effort to evolve a production design during the ACTD, but an entirely separate effort that would not dilute or compromise the demonstration effort. This parallel effort would complement the technical demonstration in allowing configuration, performance, payload, operational concepts, and supportability concepts to be considered and traded to achieve the most cost-effective solution.

Similarly, it is recommended that operations and support and MPT planning and programming be accomplished in parallel with the ACTD.

In summary, the SAB strongly supports shortening the technology demonstration timelines. The new national security paradigm demands that the Air Force leverage technology to be more effective with less force structure. Life-cycle considerations for supportability must be integrated into a logical transition plan from demonstration to production. Clear accountability and responsibilities must be established. A method of evolving a "preferred weapon system concept" is offered to ensure long-term military utility. The threat postulated for the period of service must be considered to provide adequate survivability for the UAV. Finally, some cost flexibility must be allowed to incorporate the final trades necessary to satisfy the Services' operational requirements.

9.6 Airspace Management and Deconfliction

The issue of airspace management and deconfliction is key to successful operation in civil and military environments. The UAVs under consideration in this study must operate in diverse airspace environments, so appropriate approaches to airspace deconfliction are essential. For the high-altitude long-endurance aircraft, it is a relatively long climb to uncontrolled airspace (FAA-controlled airspace now extends to 60,000 feet). Such climbs require long climb corridors through what may be crowded airspace. Lower altitude UAV operations, which may be characteristic of attack aircraft concepts, will involve flight through controlled airspace, even in peacetime, for training and exercise missions. In wartime, when airspace environments are extremely crowded in certain areas, additional precautions are necessary. At this time, little thinking, planning, or action to develop agreements, rules, and procedures has been accomplished.

For operation in FAA-controlled civil airspace, there has been a desire to apply the traditional rule of "see-and-be-seen" to the UAV. This was translated into the requirement for a chase aircraft, or the use of restricted/prohibited airspace, for all UAV operations. Alternatively, one-time FAA approvals have been granted based on letter requests. There is currently an activity to define Advisory Circulars[11] to outline the desired approach to UAV flight operations, pilot qualifications, etc. FAA regulations for the design and manufacture of unmanned aircraft are also being reviewed for possible revision. Military representatives are participating in the meetings, and due consideration to alternatives to chase aircraft is being proposed.

[11] Advisory Circulars are official FAA documents that define issues and recommend solutions. They are not regulatory in nature.

In civil airspace controlled by other nations, international agreements are needed, the alternative being ad hoc binational agreements. The study group knows of no activity to initiate international (ICAO) discussions on UAV flight operations.

In the case of military UAV operations in areas for which airspace management and deconfliction is the responsibility of the theater commander, there are procedures for airspace coordination. The Airspace Coordination Order (ACO) decrees the sole-use corridors, designates control authorities (e.g., AWACS, CRC, etc.), establishes rules, and provides procedures for the safe passage and orbits of all manned aircraft, long-range artillery, air defense weapons, and missiles. Free fire zones and flight corridors are established as a function of time-of-day, and hence a highly dynamic airspace deconfliction process is essential.

The Air Force must begin now to think through the issue of airspace deconfliction for the broad range of environments and scenarios expected in the future.