3. Technical Plan

3.1 Payload Integration Plan

3.1.1 Payload Requirements

ACES includes four systems that must be electrically and mechanically integrated: 1) The ALTUS UAV platform, 2) the electrodynamics sensor suite, 3) the Flight Payload Data System (FPDS), and 4) the Payload Ground System (PGS). Table 2.2, provided previously, describes each element of the ACES payload, including the FPDS. Also listed is the thermal and pressure environment required for the various payload components. Note that the sensors have heritage derived from previous rocket or aircraft use, and thus are very reliable. Note also that the total mass of the payload is 183 lb, payload power is 378 W, and payload volume is 6.8 cu ft. Since, the ALTUS aircraft can accommodate payloads up to 330 lb, 800 W and 18.6 cu ft, the ACES payload fits well within aircraft specifications. This was verified in late September 2000 when the ACES payload was successfully integrated and flown on ALTUS over the desert air space near El Mirage, CA. Figure 3.1 shows the ALTUS with the ACES payload onboard during the test flights in September. During flights, the ALTUS and its payload are controlled from the Ground Control Station (GCS) shown in Figure 3.2.

Figure 3.1.—ALTUS takes off with the ACES payload during a test flight at the GA–ASI El Mirage flight test facility on September 28, 2000.

Figure 3.2.—Pilot (left) and co-pilot control the ALTUS during the September 28, 2000 test flight.

3.1.2 Issues and Concerns of the Instrument Team and UAV Provider

3.1.2.1 Instrument Team

The instrument team has no payload weight and balance, thermal and electrical, or avionics issues/concerns. Since essentially the ACES payload has already been successfully integrated and flown onboard the ALTUS there are no significant concerns that have not been addressed.

3.1.2.2 UAV Provider

GA–ASI also has no payload weight and balance, thermal and electrical, or avionics issues/concerns with ACES. However there are three mission-specific modifications or adaptations of the ALTUS UAV system required to support ACES. These are considered low risk, being characteristic of typical GA–ASI efforts in customizing system facets in previous science missions.

First, the ACES mission requirements require elevated altitude close to the Ground Control Station (GCS) site. This demands link geometry that is on the edge of antenna lobe performance regarding the vehicle-mounted, azimuth steered horn antenna. Installation of a wider beam width unit will be implemented without impact to the antenna servomount, its drive, and pointing accuracy. This is regarded as a component change with negligible system risk since, (a) The resultant Line-of-Sight (LOS) range will be in excess of the science mission range, (b) security of the data link system is buffered by the upper and lower Omni antennas (c) the lost link function can fly the vehicle to be “captured” by the Omni antennas and ensure recovery, and (d) El Mirage check flights will confirm system performance prior to any mission flights. The changes described in this paragraph for the LOS antenna-related aspects are typical customizing efforts common to such science missions and are not considered an avionics issue.

Second, a small CCD daylight camera will be mounted on an azimuth-steered servomount to provide an in-aircraft means for identifying cloud conditions to be avoided. This will be commanded through the GCS by the UAV operator and use a GA–ASI flight-proven servomechanism. Candidate systems are those used for the air vehicle steered directional antenna or linear servoactuators. These have been operational and are capable of temperature altitudes required by the mission.

Finally, it is desired that weather information (radar, cloud, lightning, electric fields, etc) be available in real time to the ALTUS pilot to further maintain the UAV system integrity and safety when flying in the vicinity of thunderstorms. The science team will provide this system using previously developed capabilities.

3.1.3 Instrument Modifications and Impact on Payload Integration

The instrument team does plan to modify the payload by adding a fifth field mill and placing the search coil on a nose boom. The first modification will improve the measurement of the full-vector electric field while the second change will reduce even further the effects of Radio Frequency Interference (RFI) generated by the aircraft itself. Some modification of the fairing is required to accommodate the additional field mill, and added mechanical design is required to accommodate a nose boom-mounted search coil. GA–ASI has indicated that such modifications are minor. GA–ASI also indicated that a boom-mounted search coil can be easily accommodated without a risk to safety. The field mill modification to the payload is easily accommodated given the wide payload weight, power, and volume margin that presently exist.

3.1.4 Onboard Communication

There are no onboard communications issues/concerns. All onboard communications between the ACES payload and the ALTUS UAV are handled through a GA–ASI provided and flight-proven payload digital serial interface, defined and described in the ALTUS Aerial Vehicle Payload Integration Manual document (ASI–00112). Functional operation of the ACES onboard communications was verified during the successful SBIR flight program in September 2000.

3.1.5 Interface Control Document Development

ACES Interface Control Documents (ICDs) will be developed for the ACES to UAV, FPDS to ACES sensor, and FPDS to PGS interfaces. These interfaces have been successfully integrated and documented under the previous NASA Phase II SBIR.

The UAV requirements are derived from the ALTUS Aerial Vehicle Payload Integration Manual (GA–ASI document ASI–00112) which delineates mechanical, electrical, and communication interface details to enable incorporation and integration of the science mission payload. This interface has been used on previous science mission deployments and payload test flights from the GA–ASI El Mirage, CA flight test center. As such, this document reflects a mature and proven payload capability that can be used within the ICD structure for the overall science payload without issue or concern.

Under the previous SBIR, detailed electrical and mechanical interfaces between the sensors and the FPDS and the FPDS and ALTUS were described in the Flight Payload Data System Manual (PDS 9902 Rev. 1.4, 2/21/99). The Flight Payload Data System(PDS)/Ground System (PGS) Manual (Ver. 9.0, 3/11/2000) describes FPDS and its interface with the PGS. These documents will serve as a proven starting point for the development of the ACES ICDs.

GA–ASI also maintains a detail PRO–E™ mechanical CAD database for the ALTUS payload bay. This will be modified and made payload specific by including details for windows, ports, and sampling probe attachments. GA–ASI will support ICD development by maintaining these documents in accordance with its ISO 9001 certified practices.

3.1.6 Payload Certification and Test Flights

At the GA–ASI El Mirage flight test facility payload certification is a process of physically and functionally integrating the science mission instrument suite onto the ALTUS aircraft. Payload checkout includes ensuring aircraft system end-to-end checks remain unaffected by the integration. These tests use the GCS along with engine ground running and taxi tests. Since the basic payload has already been integrated and flown on ALTUS at the GA–ASI El Mirage flight test facility, it is anticipated that the ACES certification and test flight activities will benefit from that earlier effort.

Payload integration into the overall UAV system is monitored and supported by GA–ASI flight operations personnel. These will include pilots, mechanical and avionics technicians, and flight operations support individuals that will also be part of the deployment team. When integration is complete and the total UAV/payload system is functionally checked out, local flight tests up to 12,500 feet can proceed. This will occur after a GA–ASI Flight Crew Brief and final approval by the GA–ASI El Mirage Flight Facility Director. For this, the UAV system and payload are assessed for flight readiness along with the flight plan. Approval for flight rests with the Flight Facility Director with recommendations from GA–ASI personnel including pilots, ground crew, and operations support personnel.

3.1.7 Payload Integration Schedule

Based on our experience with the previous ALTUS integration and the maturity of the ACES payload, we anticipate that the integration can be easily accomplished in 2 weeks. However, adequate contingency is built into our schedule to allow for unanticipated problems with either the payload or the aircraft.

3.2 Deployment Plan

3.2.1 Facility Needs

The ALTUS UAV operations need general aviation-type facilities. The deployment sites will provide hangar space to park aircraft, power (120 VAC and 220 VAC), compressed air, air-conditioned office space and furniture, communications (phone, fax, high-speed internet), loading and unloading facilities (e.g., 2,500 lb forklift), and access to a 3,000-foot runway. A variety of services are also required and will be provided at the deployment site including range support, fuel services (e.g., handling and storage), airfield services (e.g., tower support, AGE support), emergency response, and frequency coordination. All these requirements are met at PAFB.

The GCS must be no more than 250 feet from the Ground Data Terminal (GDT). The GDT must have LOS of the taxiways and runways. The GDT can be elevated, and as an option, be situated on top of the GCS trailer. Figure 3.3 shows a GCS trailer at the El Mirage flight test center with the GDT mounted on top. The GCS can be remote from the aircraft hangar. However, there must be a capability to move the aircraft (tow or taxi) from the hangar to a locality near the GCS where a direct-connect line between the ALTUS and the GCS can be established. This requires a ramp area with the GCS within 150 feet of the aircraft. From this position, engine run up and systems checkout (using the direct-connect) will be performed. The aircraft must be capable of taxi out for flight from this location. All these requirements are met at PAFB.

Figure 3.3.—GCS with top-mounted GDT at the El Mirage, CA flight test center.

3.2.2 Expendables

The expendables include 100 octane low-lead aviation gas (available at PAFB), generator diesel fuel, engine oil and lubricants, antifreeze, fuel and oil filters, and wiping rags.

3.2.3 Scope of Deployment

GA–ASI and the PI conducted an initial site survey of KSC and PAFB on November 16, 2000. The purpose of this visit was to narrow in on a proposed mission base. The KSC skid strip, Shuttle landing facility (SLF) and PAFB were visited. While missions could be conducted out of either the KSC skid strip or the NASA aviation hangar at PAFB, the PAFB site is favored due to better access to facilities and being a superior location relative to the mission target area (i.e., the restricted KSC airspace). A follow-up Technical Interchange Meeting (TIM) was held on Feb. 1, 2001 finalizing the selection of PAFB as the deployment base of operations.

Preliminary discussions have already been undertaken with KSC range control and Air Traffic Control (ATC) at the Miami Center. Site meetings were held with range and airspace management personnel to discuss (and finalize, when possible) details about the deployment and airspace management plans pertaining to any special requirements and flying areas or procedures. Also, possible locations have been identified for GCS placement at PAFB and KSC. A detailed physical survey to determine the best location of the GCS and associated GDT to maintain uninterrupted LOS with the vehicle at all times in order to maintain continuous C-band LOS data-link coverage will be conducted after ACES is selected.

3.2.4 Reviews

GA–ASI has a substantial history of working with and through the NASA approval process for the ALTUS II first flight, range operations, and science deployments. Normally, these three events require the organization and delivery of technical, operational, and safety information that culminates in the completion of three safety reviews: Airworthiness Flight Safety Review Board (AFSRB), Flight Readiness Review (FRR), and Deployment Readiness Review (DRR), respectively. In this proposal DRR is considered the same as Operational Readiness Review (ORR).

The Dryden Flight Research Center (DFRC) FRR for ALTUS II was conducted and completed on June 16, 1998 with approval for First Flight. The flight was successfully conducted on June 29, 1998. The ALTUS II system was ASFRB approved by the DFRC on July 7, 1998 for flights on the Edwards AFB range and again on September 9, 1998 for high-altitude range flights. On April 12, 1999, the UAV system was ORR approved by DFRC for the Kauai Pacific Missile Range Facility (PMRF) Science Mission (DOE/ARM–UAV) and flown at PMRF (April 18–May 14, 1999). Copies of those presentations are available.

Based on the approved results of these prior reviews, the excellent ALTUS II operational and flight safety record, and Defense Department approval of GA–ASI flight operations procedures, AFSRB and DRR approvals by the respective NASA Center Flight Operations Office are expected to be routine processes.

The following additional planning documentation will be available for review and approval during the DRR process: Flight and Airspace Management Plan; Range Safety Plan; Frequency Coordination Plan; hazard analysis; HAZMAT provisions and requirements; Local Base Clearance and Access; Logistics Plan; Emergency Response Plan.

3.2.5 Deployment Schedule

One week is allowed in the schedule for completion of the packup activity after the last checkout flight at El Mirage, CA. Likewise, one week is scheduled for the unpack at the PAFB deployment site between arrival and the first functional check flight. Access to the aircraft for payload instrument reinstallation should be available on the second day after arrival at PAFB.

Pilots have a 12-hour day restriction when flying is scheduled. There is no restriction on night or weekend flights except those imposed by the range controller or PI team. The “fatigue factor” of the flight operations/maintenance crew is monitored by the onsite GA–ASI Project Manager (PM). Depending on the tempo, problems encountered, etc., a stand down day may be recommended. This will be discussed with the science mission PI and a mutual solution determined. However, pilot restrictions are not expected to occur due to the fact that mission duration is expected to be approximately 8 hours or less.

There are no restrictions for back-to-back flights except the considerations for the 12-hour pilot /crew rest, equipment availability, range availability, deployment site weather, and other factors. Generally, flights at high altitude require significant preparation prior to flight and back-to-back flights are not routine operations. The decision on back-to-back flights must be based on conditions experienced at the deployment site and made by the PI and GA–ASI team leaders.

3.3 Flight Plan

3.3.1 Mission Flight Concept

The mission flight concept is to conduct flight operations out of PAFB. Missions will be flown over the restricted and warning areas to the north and east of PAFB. Figure 3.4 is an aviation map that depicts the area proposed for ACES. The mission concept is to monitor thunderstorm development over the mainland of Florida and adjacent waters from a position on the KSC range. ALTUS will transition from PAFB under Miami Center’s control, climb to mission altitude, and loiter in position waiting for isolated thunder cells to impact the KSC restricted area. Flights will not be conducted over the populated areas of the Florida mainland. Flights operations and profiles will be conducted at a safe standoff distance to the side or above the thunderstorms as the storms develop within or transit the range. Missions are expected to start in late morning or early afternoon, depending on weather development, and last approximately 5–8 hours before return-to-base (RTB).

The decision to abort a flight in process or cancel a scheduled flight for weather rests with the Pilot-in-Command (PIC). Although the flight plan is the beginning point for flight planning, weather impacts safety of flight. The PIC is the final authority on these and all flight matters. However, the PIC will receive considerable support and information from the flight director and science team. The PIC will also be guided by data, standard aviation weather services, ALTUS onboard instruments, and the entire array of ground-based instruments.

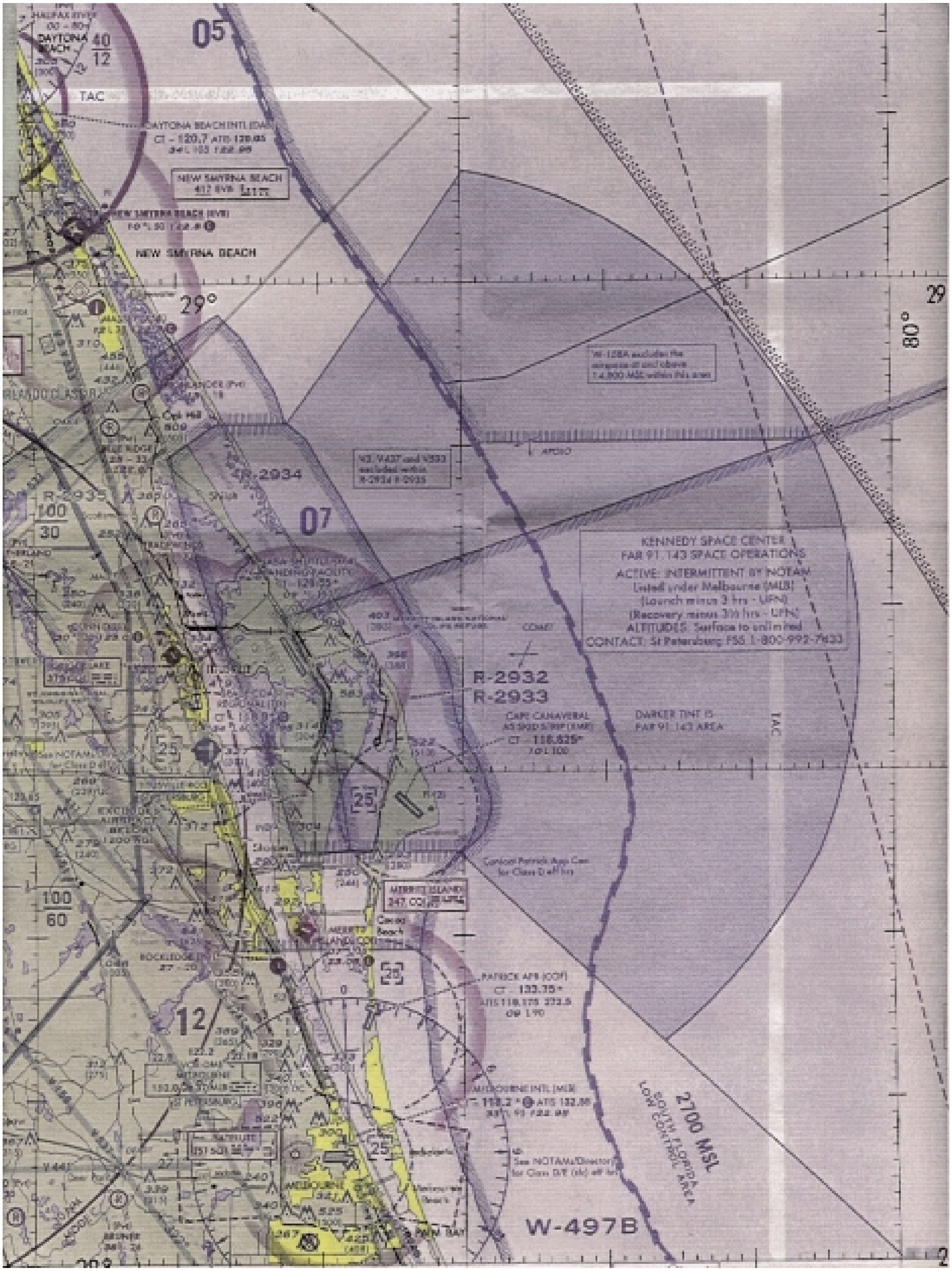


Figure 3.3.—Aeronautical chart showing the restricted and warning areas near KSC and PAFB (*Jacksonville Sectional Aeronautical Chart*, 64th Edition, September 9, 1999).

3.3.2 Mission Flight Location/Profile/Performance

ALTUS flights will be conducted primarily over the coastal waters and KSC, staying within the restricted and warning areas to the north and east of PAFB. ALTUS will begin flights during the early development of these cells and fly north and south along the coastal waters at mission altitude taking measurements of the cell as it approaches the KSC restricted area. Safe standoff margins will be adhered to during the flights. Once the storm impacts the KSC range, ALTUS will continue to profile the storm in the following ways: Staying ahead of the storm (ALTUS is out to sea), staying south of the storm (between the storm and PAFB), flying over the storm, or flying behind the storm (ALTUS is between the coast and the storm which has moved out to sea).

3.3.2.1 Avoidance of Lightning

Areas of weather representing potential danger to the aircraft will be avoided by monitoring onboard and ground-based systems that measure electric fields and lightning in the vicinity of the thunderstorm. Electric field observations will be downlinked real time to the GCS for information necessary to avoid areas of high electric field which might induce a lightning strike to the aircraft. The five electric field mills installed on the aircraft will provide this measurement. An electric field of 25 kV/m has been set as the safe standoff distance for threat of lightning strike. This number has been determined from a Langley Research Center (LRC) Airborne Field Mill (ABFM) program where a LRC Learjet 28/29 was used to conduct over 1,000 penetrations of thunderstorms. During these missions, the Learjet experienced 100 kV/m electric fields without lightning strike. In fact, it was not until levels were in excess of 150 kV/m that the Learjet encountered an actual strike. Of the 1,000 missions flown, the Learjet only drew one strike and this was directly inside the cloud. Therefore, the 25 kV/m level is considered a conservative number.

3.3.2.2 Avoidance of Turbulence (Standoff Distance)

The ALTUS will also maintain a standoff distance of 5 km (~3 n mi) from any storm cell. From past missions experience in the ABFM programs, it was determined that turbulence and lightning were not encountered until within the cloud. Therefore, we believe the 5 km standoff distance is also conservative. Likewise experience in the ABFM program has provided the insight that turbulence above the cells does not occur unless in direct contact with the cloud top. Due to uncertainty of development rates, we have set the margin to be 5,000–10,000-feet above the tops to allow for cloud growth. These distances may be modified as experience is gained during the ACES flight program.

These standoff distances discussed in this section will not adversely impact the quality of science observations obtained. The ACES sensors have high-sensitivity designed to remotely observe and infer the electrical structure of thunderstorms from this range.

3.3.2.3 Performance

The maximum altitude expected for this series of missions is 55,000 feet. ALTUS has experience flying routinely at this altitude (50–55 kft). Mission profiles are expected to typically remain between 40,000 to 50,000 feet. Typical climb rates for ALTUS are approximately 1,000 ft/min at sea level, dropping to about 100 ft/min at 55 kft. These climb rates are suitable for conducting the types of storm missions proposed. Descent rates for ALTUS are between 100 ft/min and 1,000 ft/min. Descent rates are adequate to fly these missions. Maximum descent rate will be a consideration in the RTB decision process. The takeoff distances, ground-rolls, and cross-wind components capability are all within specification needed to conduct operations at PAFB or KSC.

ALTUS has an on station endurance in excess of 8 hours for all missions planned. Missions are to be conducted during daylight hours from early to late afternoon. Typical missions are expected to last in the 5–8 hour time frame. Generally 1 hour is allocated for climb and positioning, 3–6 hours for profiling and 1 hour for descent and landing. Missions will be planned so that adequate fuel reserves are on-board for emergency and contingencies. A minimum 1-hour reserve fuel will be planned.

3.3.3 Flight Planning Criteria

This section defines the criteria and process for flight planning that is conducted just prior to a flight. This section addresses the planned events to be executed once the science team has determined their goals and objectives for the day's flight. Essentially, the GA–ASI flight crew executes those items specified in this section with heavy involvement from the science team.

3.3.3.1 Mission Planning

The GA–ASI flight crew is responsible for the flight planning activities on every deployment. The GA–ASI flight crew are qualified per the minimum training, certification, and currency requirements as mandated in the GA–ASI Flight Procedures Manual (GA–ASI document ASI–00009). GA–ASI pilots draw on their formal aviation piloting training, manned aircraft experience, UAV training, UAV experience, and company procedures to successfully complete the flight planning for each flight.

The GA–ASI system of UAV pilot certification has been in place at GA–ASI since the company's founding and has evolved with the many lessons learned over the years. The GA–ASI's system of UAV pilot certification is unmatched in the UAV industry, has developed the industry's best UAV pilots, and is implemented and maintained at GA–ASI without compromise.

3.3.3.2 Flight Planning Process

The flight planning process summarized below is developed prior to the flight with inputs from the PI, project engineer, and flight service station. The flight planning process culminates in the issuance of the flight card.

Mission Profile. The first step in the flight planning process is to formalize the goals, objectives, and conditions that will meet the PI's success criteria. This information is conveyed at the science team meeting, usually conducted the day before the flight and then again at the GA–ASI Crew Brief (day of flight). This information is usually handed down in the form of weather forecasts, mission planning profiles, and verbal communication of contingencies. This information forms the basis for the detailed flight plan that the GA–ASI flight crew conducts in the next step. If conditions are difficult to predict, several of these plans may be conveyed in order to accumulate contingency plans.

Weather Planning. Per FAR 91 requirements, the pilot avails himself of all current weather information related to his route of flight. The surface analysis, forecasts, prognostic charts, and winds aloft data are checked. This information is used to form the basis of the aircraft performance planning and enters into the pilot's decision process as to whether to conduct the mission. Contingency planning is also considered when the weather data is analyzed.

NOTAMS. Per FAR 91, all Notices-to-Airmen (NOTAMs) affecting the intended flight are checked to see their impact (if any) on the mission. Action is taken as appropriate.

Aircraft Performance Planning. Mission-specific aircraft performance calculations are made including fuel planning, route and altitude planning, takeoff and landing distances, cross-wind component calculations, and time to climb and descend. Aircraft performance and flight profiles form the basis for the day of flight programming, flight plan waypoints, and the lost-link mission waypoints.

Communications. Aircraft VHF communication frequencies for ATIS, ground control, departure control, tower, range, ATC, and approach control are reviewed and logged for future reference on the flight card. The control link frequencies authorized by the frequency manager (requested by GA–ASI) are also listed.

Emergency/Contingency Planning. During the flight planning process, possible emergency planning is conducted for many different aspects of the mission. A specific scenario might be the possibility of an unpredicted weather system, engine out, or other system failures may be discussed and planned for as appropriate for the specific mission. Additionally, contingency plans consisting of alternative mission profiles are developed and made available in case a predicted weather pattern fails to materialize. The PI directs execution of a contingency mission.

3.3.4 Go-No Go Criteria

The initial Go-No Go decision is made with respect to the projected environmental considerations supporting the requirements of the scientific mission. If conditions present an opportunity for the mission to be of value then the first Go-No Go criteria is Go. The remaining Go-No Go decisions should be identified in the flight brief. Usually they are in phase with the flight preparation process and involve the completion of one or more checklists before the criteria can be reported as Go. The idea of the Go-No Go decision path is to build in a gate at each critical step in the experiment to allow for a meeting of the minds of the operational team that it is appropriate, in all respects, to proceed with the mission. By publishing this criteria well in advance, the entire team can identify what the major steps are that need to be completed in order to proceed on the mission. Below is an outline of the steps in this process, which are tuned, to some extent, for each flight:

- Weather above minimums for launch and at time of recovery
- NOTAMs and local traffic not in conflict with mission
- Aircraft conditions and material discrepancies acceptable
- Payload performance checks satisfactory, ground-based support equipment functional
- Chase aircraft (if required) in position
- Clearance from local ATC received
- Ground functional checks complete
- Airborne functional checks of aircraft and payload complete
- Environmental conditions consistent with mission objectives.

This process in no way relieves anyone of the responsibility of alerting the operational team of changes in status of equipment, personnel, or environmental conditions which might affect the success and safety of the mission. On the contrary, identification of the critical elements in the process are hoped to heighten awareness in all personnel to those elements which must be continuously monitored in order to ensure the highest possibility of mission success with the lowest associated probability of hazard to personnel.

3.3.5 Roles and Responsibilities

The PI will be the central control for conduct of the mission. The PI will accept inputs from all concerned when formulating the mission plan. The GA–ASI team leader will be the main point of contact with the PI for mission planning, assisted principally by the PIC.

Once the planning phase is complete and flight operations commence, the PI assumes the responsibility for conduct of the experiment and execution of the mission plan. He begins the process by accepting the Go criteria for the mission. Subsequently all responsible personnel, either from the payload side or from GA–ASI, will report that the appropriate checklist is complete and that they are go for the next phase. The PI, assisted by the GA–ASI team, will coordinate production of the appropriate checklists and maintain the master checklist. The pilot will be personally responsible for safety of flight from taxi to final landing. The GA–ASI team has collective responsibility for the safe conduct of the flight and will support the pilot in preparation for and in execution of the flight plan. The GA–ASI mechanics are responsible for the material condition of the aircraft and safety of ground operations including maintenance of the aircraft and the payload.

3.4 Non-NASA Aircraft Safety Plan

3.4.1 NASA Safety Review Process for UAV

The Marshall Space Flight Center (MSFC) aviation safety officer for the ACES project will define the NASA safety reviews for the UAV. The MSFC aviation safety officer is Larry Fine. Three reviews are currently identified to occur during the project. The first safety review will be the Airworthiness Flight Safety Review (AFSR) to be done at MSFC during the design phase of the ACES project. GA–ASI will present to the AFSRB the capabilities of the UAV with the payload and safety issues. Information listed in sections 3.4.2–3.4.9 will be presented to the AFSRB in greater detail. The second safety review, the FRR, will occur prior to the certification flight at GA–ASI flight range at El Mirage. Information from the integration of the payload to the aircraft will be presented to the MSFC aviation safety officer. All safety issues from the first review will be presented and closed prior to the certification flight. The third safety review will be at the PAFB prior to the first flight of the campaign. This safety review will be held in conjunction with the DRR. The issues that will be addressed are all safety issues related to the PAFB (frequency, KSC flight range, etc.) as well as the aircraft safety issues, flight plan, and ground operations. The PAFB safety officer will chair the safety review at PAFB. For the second campaign, only a DRR to address safety issues will be required. Additional safety reviews (e.g., FRR) may be considered if there are changes to the payload or aircraft.

3.4.2 Flight Parameters of the ACES Program

The flight operations requirements proposed for ACES fall within the parameters of the ALTUS aircraft. Indeed, safety has been the prime consideration in establishing standoff distances, lightning avoidance rules, mission procedures, and property/population avoidance (i.e., location of flights within KSC range airspace).

3.4.3 Airworthiness of Aircraft

ALTUS is the most proven, tested, and confirmed high-altitude UAV system in existence. As discussed in detail in Section 3.2.4, the ALTUS II aircraft has passed several AFSRBs, FRRs, and DRRs. In addition, ALTUS I (the identical aircraft system with the exception of the propulsion system.) passed AFSRB for flights at Edwards AFB and Ponca City, OK. These prior approvals are the basis for the responsible NASA Center Flight Operations Office AFSRB process. Minor fine tuning of the ALTUS II system can be accommodated to meet individual range differences. GA–ASI will support the NASA AFSRB as required by the PI team.

Presently there are no Federal guidelines for the design and certification of UAVs nor has the FAA certified the ALTUS II system, or any other UAV system, under Federal Aviation Regulations. However, GA–ASI established company guidelines and used parts of FAR–23, the FAA standards for general aviation and commuter aircraft that enhanced the design, manufacturing, and performance aspects of the aircraft. Numerous iterations of R&D and delivery testing, using approved acceptance test procedures, for 80 aircraft have verified the airworthiness of the GA–ASI product design.

As of October, 2000 the ALTUS II UAV system has flown 70 flights/209 flight hours with no incidents. With the exception of the optimized propulsion system, all the ALTUS subsystems are the same systems that fly on the Predator system. The Predator system is now proven with over 22,000 hours to date.

3.4.4 Capability of Aircraft to Meet the ACES Flight Requirements

The ALTUS capabilities will not only meet the ACES science requirements, its capabilities of high altitude, coupled with low flight speed and long duration make it ideally and, in fact, uniquely suited for achieving the proposed science objectives requiring the observation of a thunderstorm throughout its life cycle.

3.4.5 Background and Experience of Operators

GA–ASI assigns only its most experienced pilots to fly the ALTUS II system. Currently, Tim Just (GA–ASI chief pilot), Jason McDermott (flew NASA PMRF mission in July 1999), and Steve De La Cruz are authorized to fly as PIC. All personnel assigned to fly UAVs are FAA rated and instrument qualified. Assigned copilots are also fully qualified in the UAV system and function as backup to the PIC to assist on long-duration missions and possible emergency situations.

3.4.6 Demands Placed on UAV Service Provider

There is no requirement or situation envisioned in supporting ACES that would place undue demands on GA–ASI or expose them to risks beyond their capacity to manage. GA–ASI deploys and supports UAV system operations on a worldwide basis, 24 hours per day, 365 days per year. They are experts in the flying of UAVs in combat, test and engineering (T&E), and science missions. GA–ASI has over 26,000 hours of UAV flight experience and conducts flight operations with the expectation that all customer flight objectives will/can be met. GA–ASI does not fly unless its personnel, UAV systems, and the customer payloads/data collection systems are ready. When an unplanned event occurs (e.g., unplanned weather or system malfunction), the safety of the aircraft and people/facilities in the range area (if applicable) are the primary concern.

3.4.7 System Hazards

The system hazards on the ALTUS system are well recognized and documented. Control measures have been developed and incorporated as standardized procedures in checklists and Standard Operating Procedures (SOP). Emergency procedures are routinely practiced by pilots and checked during annual check rides. The ALTUS system (ALTUS I & II) has been on numerous scientific deployments and has recorded 272 flight hours without incident.

Ground hazard mitigation at the operating site primarily involves the safe handling of fuels and lubricants and the specialized handling of the parachute pyrotechnic rocket. Specialized equipment is available (fueler/defueler, oil drains, and 50-gal oil barrel) for the fuel and lubricants handling. The install/deinstall procedure for the parachute rocket is covered by specific procedures and only performed by a trained technician. Flight line personnel must be constantly aware of operating propellers in the vicinity of the UAV. GA–ASI SOP is that only a single individual is permitted in the vicinity of an aircraft with the engine running. All other personnel must remain behind a specific barrier line.

Flight operation hazards are identified for all phases of flight—taxi, takeoff, flight, landing, and taxi to the hangar area. Thirty-nine potential aircraft failure modes have been analyzed, assessed, categorized, and controls implemented to deal with the hazard event. These risks have been presented in previous NASA AFSRBs and will be again presented for the NASA UAV Science Demonstration Project (SDP) AFSRB.

Collision avoidance risk of UAVs with other vehicles is controlled in the NASA UAV SDP program by using Government restricted areas, where possible, for all phases of the mission. All missions are planned above 18,000 feet mean sea level (MSL) in controlled or restricted airspace (ACES missions will be conducted above 40,000 feet). Since transit to/from the range area cannot be conducted in controlled airspace, a chase plane will be provided. Details of controlling this risk will be finalized in the Airspace Management Plan through coordination with the Miami Center. Permission to fly in the local area will be granted by the FAA issuance of a Certificate of Authorization.

3.4.8 Mission Vulnerability to Identified System Hazards

GA–ASI's experienced flight operation personnel consider the ACES mission vulnerability and risk low with respect to the hazards identified in Section 3.4.7 above. GA–ASI personnel have successfully and safely managed all less than catastrophic category failures to date. There have been no catastrophic failures to date and there is low risk of that occurrence.

Individual mission sortie failures due to GA–ASI aircraft systems hazard-mode occurrence may be experienced. However, thus far, the mission success rate of every science mission GA–ASI UAV systems/flight operations personnel have participated is 100 percent.

3.4.9 Safeguards

There are no known additional safeguards above and beyond standard company procedures planned or anticipated for the ACES mission. All of the known safeguards (e.g. proven software lost-link capability; proven, high-reliability parts, installation of approved FTS; system maturity, and Defense Logistics Agency approved flight operations manual/procedures, etc.) to avoid or deal with system hazards are already built into GA–ASI's hardware, software, flight operations manuals/procedures, training, checklists, and flight operations crew experience. All of the experience and lessons learned from over 15 combat deployments and 26,000 UAV flight hours are focused on every deployment.

3.5 Airspace Management Plan

3.5.1 Flight Range Selection

The KSC restricted airspace complex (KSC range) has been selected as the operational location for the ACES mission. A preliminary site survey of the KSC range, skid strip, SLF, and PAFB along with airspace coordination has begun. Meetings have been conducted with operational and airspace authorities at KSC, PAFB and FAA ATC. As noted in section 3.2, PAFB has been selected as the deployment site.

A preliminary airspace analysis has been conducted for the area. The KSC airspace is comprised of four restricted areas that form an operational area that is ~45 n mi east to west and 50 n mi north to south (see Figure 3.4). Warning areas lie to the east and south of the restricted area complex. The restricted area is normally operational for Shuttle launches but can be activated for any other purposes that have included UAV operations in the past. Table 3.1 outlines KSC and vicinity restricted areas and warning areas. The SLF lies within the R–2934 restricted area and the skid strip lies within restricted area R–2932/2933 (see Figure 3.4).

During ACES, the ALTUS will typically fly at 40,000 feet and above. The planned ALTUS flight altitudes will serve to facilitate the Miami Center's coordination of commercial traffic, if needed, to transition through the area since the commercial air carrier traffic in the Space Coast area is primarily concentrated in the 29,000 feet to 37,000-feet altitudes.

3.5.2 Range/Air Space Approval Plan

Approval of the planned flights takes two parallel paths. First, KSC Range Airspace Control must approve operations within the range. Mr. Ron Wilson, an airspace manager for the KSC Range Airspace Control has been briefed and can see no reason why we cannot operate on the range provided we do not interfere with Space Shuttle landing operations, which have top priority at KSC. Additionally, the FAA requires a Certificate of Authorization secured from FAA Regional headquarters in Atlanta. Mr. Hank Tracey of the Miami Center has offered to put together the necessary information for us to forward to Atlanta. He has successfully done this for other UAV operations in the past. For flights that enter into class A airspace (above 18,000 feet) an IFR flight plan will be filed.

3.5.3 Roles and Responsibilities

The GA–ASI team is primarily responsible for the safe operation of the aircraft. GA–ASI must exercise due regard to FAA and range regulations and restrictions imposed by company policy. They must also operate the aircraft so as to conform to time-critical direction of the relevant ATC controller. Once these roles are established, limited negotiation room exists within certain bounds with the final objective being mission accomplishment with an acceptable level of safety. If the mission, as planned, can be completed without exception to the operating limitations imposed by ATC or the aircraft operating limitations there is no need for negotiations.

Table 3.1.—Restricted and warning areas in the vicinity of KSC, Florida.

Number	Altitude	Time of Use	Controlling Agency
R–2932	SFC to 5,000	Continuous	Miami Center
R–2933	5,000 to unlimited	Intermittent by NOTAM	Miami Center
R–2934	Unlimited	Intermittent by NOTAM (normally 24 hr in advance)	Miami Center
R–2935	11,000 to unlimited	Intermittent by NOTAM (normally 24 hr in advance)	Miami Center
W–497A	Unlimated	By NOTAM	Miami Center
W–497–B	Unlimated	By NOTAM	Miami Center
W–158–A	To FL 430	Continuous	Jacksonville Center
FAR 91.143	SFC to unlimited	Intermittent by NOTAM	Miami Center

Inevitably though, the science mission cannot be flown exactly as planned. At this point both sides are required to prioritize their requirements and a process of negotiation and optimization begins. After each flight the PI will review mission objectives and reprioritize them in order to ensure as many objectives as possible are completed. The GA–ASI team will in turn review the operational plan to ensure the proper level of safety is maintained while completing as many operational objectives as possible. The overriding responsibility of both groups is to conduct the operation with a minimum of risk to personnel and property. The GA–ASI is never released from its primary responsibility of conducting flight operations with an acceptable level of safety. The PI is never released from being ultimately responsible for the conduct of the experiment.

3.5.4 Schedule

Formulation of the schedule evolves in harmony with the roles and responsibilities. The PI originally writes the schedule with mission accomplishment being the primary driver. Flights can be conducted back-to-back for limited periods (usually less than 1 week) depending on an onsite evaluation of the equipment/crew status. Initial screening by the GA–ASI team seeks only a cursory review to ensure that the schedule can be supported, give crew rest, and manning requirements. As the mission proceeds, the schedule is reviewed daily as part of the mission planning process. Mission accomplishments to date, aircraft maintenance requirements, crew fatigue, and external factors (weather, range availability, etc.) are evaluated using the compromise philosophy discussed above to continuously evolve a viable schedule.

4. Management Plan

Scientists from NASA/Marshall Space Flight Center (MSFC)/National Space Science and Technology Center (NSSTC) and NASA/Goddard Space Flight Center (GSFC) have formed a partnership for the proposed ACES scientific Uninhabited Aerial Vehicle (UAV) mission in response to NASA Research Announcement (NRA) NRA–00–OES–02. The ACES management plan is built upon the organization shown in Figure 4.1. The ACES team is led by the Principal Investigator (PI), Dr. Richard Blakeslee, who has overall responsibility for all aspects of the ACES project.

Key elements of the management plan are as follows:

- The Project Office (PO) at the NSSTC is directly coupled to the team's science and technical infrastructure and is responsible to the PI in the management of the project. The core of the PO is composed of the ACES Project Manager (PM), Mr. Tony Kim and the ACES Lead Systems Engineer (LSE), Mr. Sonny Mitchell. The PO and PI are physically located in the same facility at the NSSTC to provide a cohesive team and for timely resolution of project issues. This integrated approach will facilitate coordination and total project oversight, thereby ensuring overall project success.

- Although NASA Procedures and Guidelines (NPG) 7120.5A—NASA Program and Project Management Processes and Requirements—is not a requirement for the UAVSDP, the PM will manage the ACES project using NPG 7120.5A as a guide tailored for the size and complexity of the UAV project.

- A detailed work breakdown structure (WBS), by phases, has been developed in concert with all the team member's institutions and is the primary tool for delineating details of the tasks.

- Adequate technical and programmatic reserves have been budgeted and baselined. Their allocation will be centrally managed by the PM with concurrence of the PI.

- The PO has established a comprehensive review process, including reviews by an independent technical team, to access discipline practices and status the projects progress to baseline plans and project readiness for deployment.

- Significant risk assessment and mitigation has been completed with the successful flight of the ACES instruments on the ALTUS UAV under a previous Small Business Innovative Research (SBIR) contract.

- Finally, the management plan is built upon the dedication and personal commitment of each team

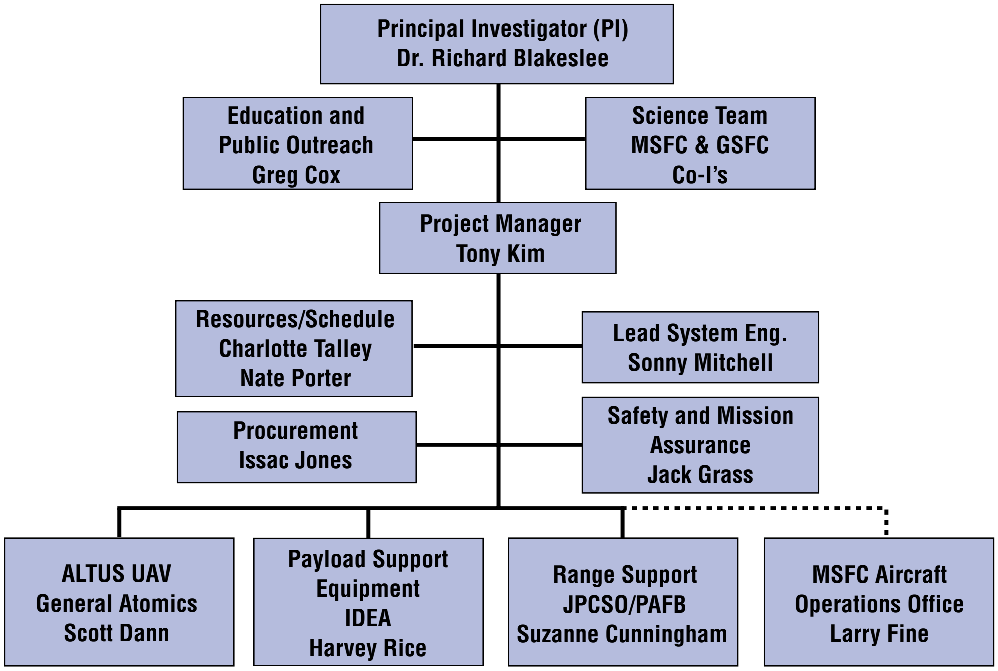


Figure 4.1.—ACES organization chart.

member, with the full support of their institution. Team characteristics have been demonstrated throughout the ACES implementation study phase and during the technology development and demonstration activities preceding this proposal.

MSFC is an ISO 9001 certified Center and the ACES project will follow all applicable ISO procedures.

4.1 Management Organization

4.1.1 Roles and Responsibilities

The ACES experiment involves four primary institutions with critical roles in science, hardware, outreach, and post-flight data analysis. These institutions are identified in Table 4.1. It should be noted that the ACES partners bring considerable experience to the proposed effort including aircraft operations (GA–ASI), sensor development, and thunderstorm and other science investigations using aircraft, spacecraft, and rocket platforms. We believe this combined investigator experience makes us a very unique team in terms of developing and successfully flying a payload that will meet the science and demonstration objectives of the UAV NRA. Our combined experience means that the team can deploy instruments that possess substantial heritage, are of low risk, and can be successfully delivered in the required time. The team has already had a very successful and quick integration effort during the September, 2000 test flights as described in Section 3.1. These test flights culminated in the acquisition of valuable data characterizing the excellent electrical properties of the ALTUS platform thus, demonstrating its suitability for the proposed ACES science mission.

Table 4.2 details the roles and responsibilities of each of the scientific investigators and other key personnel involved in the project. The team consists of a number of individuals with extensive experience in their related disciplines. Previous experience dictates that we define an operations interface coordinator who acts as the liaison between the scientists providing experimental sensors and General Atomics-Aeronautical Systems, Inc. (GA–ASI) providing the ALTUS platform and telemetry downlink. The PI will be the primary operations interface for the project. We identify the LSE as the integration lead. As with our prior flight, we identify Mr. Harvey Rice of IDEA, responsible for the Flight Payload Data System (FPDS). The FPDS is the electrical interface between the scientific sensor suite and the GA–ASI telemetry downlink system. The FPDS builder must be familiar with interfaces on both sides of the data system. As the FPDS builder, Mr. Rice is already familiar with each of the individual sensor's interfaces, the ALTUS data link interface, and has already successfully integrated this sensor suite to the ALTUS via the central FPDS.

Table 4.1.—Major institutions involved in ACES and their associated role.

Institution	Role
NASA/Marshall Space Flight Center	PI institution including program management, lead institution for integration, and responsibility for electric field sensors, optical pulse sensor, and conductivity probe. Lead center for postflight data analysis, archival, and distribution. Lead center for outreach efforts.
General Atomics	Provider of ALTUS UAV and support personnel.
NASA/Goddard Space Flight Center	Responsible for DC and AC magnetic field sensors and postflight data analysis.
IDEA	Responsible for the FPDS. Integration support.

Table 4.2.—ACES roles and responsibilites.

Key Personnel	ACES Roles and Responsibilities
Dr. Richard J. Blakeslee (MSFC)	PI, responsible for cost, schedule, and technical resources of ACES; oversees electrical and optical sensors.
Mr. Tony Kim (MSFC)	Oversees system development, and holds cost and schedule reserves.
Mr. Sonny Mitchell (MSFC)	Establishes and maintains performance specifications, verification and test plans, interface documents, and provides systems engineering oversight; integration lead.
Dr. Douglas M. Mach (MSFC/UAH)	Co–I, responsible for electrical and optical sensor calibration, integration, and analysis; ACES team liaison with Educational Outreach.
Mr. Harvey J. Rice (IDEA)	Co–I, designer and builder of FPDS. Integration and operations support.
Mr. Scott Dann (GA–ASI)	Program manager of the ALTUS UAV.
Mr. Ron Schramm (GA–ASI)	Lead integration engineer for the ALTUS UAV.
Dr. Richard A. Goldberg (GSFC)	Co–I, aids in defining science goals and translation to payload requirements.
Dr. William M. Farrell (GSFC)	Co–I, leads design and builds of magnetic search coil.
Dr. Michael D. Desch (GSFC)	Co–I, oversees RFI reduction between payload/platform and oversees ground software development.
Mr. Jeffrey G. Houser (GSFC)	Co–I, responsible for fabrication, calibration, and integration of search coil and magnetometer; leads design of RFI reduction testing.
Mr. Greg Cox (MSFC/UAH)	Provides leadership and guidance in the development of the ACES lesson plan package.

4.1.2 Changes in Personnel From Original Proposal

Changes in key personnel from the original proposal include the designation of a PM and LSE. These changes were brought about with the definition of the ACES PO. The PO will provide a formal management and systems engineering approach with personnel experienced in managing flight systems. In October, 2000, Dr. Tomo-o Ushio accepted a university appointment in Japan and will no longer participate as a Co-I. Dr.'s. Richard Blakeslee and Doug Mach will assume responsibility for the electric field change sensor. Both have extensive field experience using and interpreting data from this instrument.

4.1.3 Organization Structure

ACES core management comes from within the MSFC/NSSTC. These functions include the PI, PM, and LSE. A centralized management team, within the same institution and location, will facilitate program oversight and management of all program aspects including scientific, design, schedules, and resources on a continuous day-to-day basis which is of utmost importance in this scientific endeavor. The PM's residence in the institution providing systems engineering and payload development and integration is key to providing effective management to cost and schedule. The PM's support staff is drawn from within MSFC directorates. The relationship between team institutions and organizations is discussed in Section 4.1.4. The ACES organizational structure, shown in Figure 4.1, is based on the project WBS. This defines the flowdown of roles and responsibilities to all team member organizations. Table 4.3 shows the alignment of the top level WBS for the project with the responsible organizations.

Table 4.3.—Work breakdown structure and institutional responsibility alignment.

WBS Number	Element Description	Lead Responsibility
1.1	Project management	MSFC/NSSTC
1.2	ACES payload	MSFC/NSSTC
1.2.1	Sensor subsystems	MSFC/NSSTC, GSFC (joint)
1.2.2	Data subsystems	MSFC/NSSTC, IDEA (joint)
1.2.3	Payload support equipment	IDEA
1.3	ALTUS UAV	GA–ASI
1.4	Systems engineering, integration, and tests	MSFC/NSSTC
1.5	Operations	MSFC/NSSTC, GA–ASI
1.6	Science and data management	MSFC/NSSTC, GSFC (joint)
1.7	Education and public outreach	MSFC/NSSTC
1.8	Safety and mission assurance	MSFC S&MA Office

4.1.4 Relationships Between Team Institutions and Organizations

The relationship between ACES team institutions and organizations is shown in Figure 4.2 while details of the roles and responsibilities of each team organization are provided in Section 4.1.1. Program guidlines flow from NASA/Ames Research Center (ARC) UAVSDP Office to the ACES PO. Technical direction flows from the ACES PO to all team organizations. The figure also shows the flow of contract funding. When direct contracting mechanisms are inappropriate, team institutions will be linked by a Memoranda of Agreement (MOA). The ACES PM authorizes funding transfers to all team member organizations.

4.1.5 Experience and Capabilities of Team Member Organizations

4.1.5.1 MSFC/NSSTC

The NSSTC is a research and education institution headquartered in Huntsville, AL that provides an environment focused on selected key scientific disciplines. The NSSTC includes the PI organization—the Global Hydrology and Climate Center (GHCC), and the ACES PO—the Science Systems Development Department (SSDD). Scientists at GHCC have extensive experience in and a proven history of successful scientific investigations. Recent field campaigns include TEFLUN A, B (1998), CAMEX 3 (1998), and TRMM/LBA (1999).

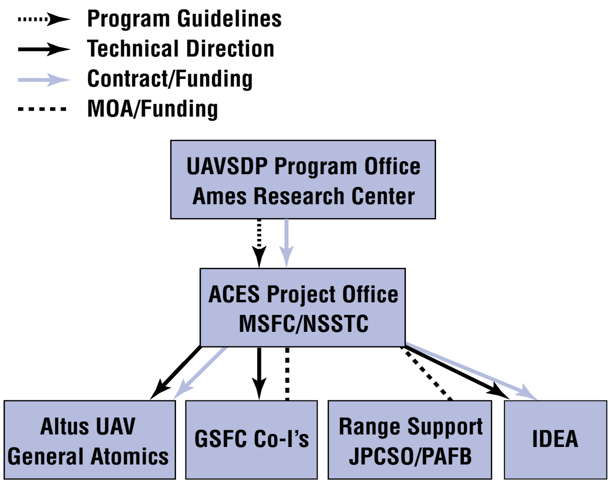


Figure 4.2.—Relationship between team institutions and organizations.

The SSDD combines NSSTC support for project management, systems engineering, and engineering design capabilities under one organization. SSDD personnel have an extensive knowledge of program/project management and systems engineering, having led a team to define MSFC's implementation of NPG 7120.5A. Past and ongoing flight project activities include:

- Optical Transient Detector (OTD)
- Lightning Mapper Sensor (LMS) flying on the TRMM mission
- Solar-B Project
- GLAST Burst Monitor (GBM) for the GLAST mission
- Solar X-Ray Imager (SXI) for the Geostationary Operational Environmental Satellite (GOES–M) mission
- Differential Ion Flux Probe—Mass Analysis (DIFP–M) instrument for the ProSEDS project
- Microgravity Crystal Growth Demonstration Project for the Future-X Program
- High Energy Replicated Optics (HERO) research balloon flight project.

4.1.5.2 GSFC

GSFC Co-Is are from the Laboratory of Extraterrestrial Physics (LEP) which has a 30-year history of involvement in scientific instrumentation and analysis. LEP has the expertise and facilities needed to support the instrumentation and analyses required for this proposed UAV investigation. LEP scientists have extensive investigator experience in space flight and rocket programs including the GGS/WIND mission, CASSINI Saturn mission, Mars Surveyor Program, NLC–91 rocket program, MAC-Epsilon rocket program, Guara/MALTED rocket program (Brazil, 1995) and DROPPS rocket program (Norway, 1999).

4.1.5.3 GA–ASI

GA–ASI is the leader in UAV development, manufacture, and operation. The ALTUS II aircraft proposed for ACES is a derivative of the Predator system. The Predator system is now proven with 22,000 hours of fleet experience. The ALTUS II system has flown 70 flights/ 209 flight hours without incidents. GA–ASI has operated ALTUS in support of science missions in Kauai, Oklahoma, California, and the Florida Keys. In addition, GA–ASI has operated ALTUS in both restricted and public-use airspace.

4.1.5.4 IDEA, LLC

The Aerospace Engineering Group of IDEA, LLC is a small business that has participated in several high-technology programs for NASA. IDEA has provided experienced engineers, scientists, technicians and program management personnel to the GSFC, the Kennedy Space Center (KSC), and the Langley Research Center (LRC).

Since 1988, IDEA has supported numerous scientific instrument developments and related activities. The Shuttle Solar Backscatter Ultraviolet (SSBUV), Total Ozone Mapping Spectrometer (TOMS), SOLSE, SAGE II, CRISTA, Lidars, Cassini, and a NASA SBIR Phase II system (consisting of an ALTUS UAV, a suite of 10 sensors supported by a VXI bus data system and associated GSE) are some of the instruments and systems for which IDEA has provided the full range of design, development, fabrication, and operational support. These instruments and support systems fly on the Shuttle, balloons, sounding rockets, UAVs, aircraft, and satellites. The staff of IDEA have been recognized for outstanding performance and dedication.

As previously noted, IDEA's SBIR Phase II payload (essentially ACES) was successfully integrated onto the ALTUS and had two development flights during September, 2000. The proposed ACES project will benefit from IDEA's continued engineering, hardware, and operations involvement as well as through its practical integration experience with the ALTUS platform.

4.1.6 Decision-Making Process

The WBS and organization structure define the limits of individual authority and responsibility relative to cost, schedule, and technical requirements. At the top level the PI, PM, and LSE jointly establish overall project goals including budget allocations, project master schedules, and top-level technical requirements. The PI is the final authority regarding changes that affect project scope, while the PM is the delegated day-to-day authority on the allocation of overall resources, schedules, and requirements. Subsystem managers have the authority to establish and maintain cost, schedule, and requirements flowdowns within their subsystem. As long as changes are within a particular subsystem manager's scope of responsibility and do not impact externally imposed constraints (requirements, interfaces, schedule milestones, costs, or critical path), no approval is required of any higher authority.

4.2 Work Breakdown Structure

The ACES level 3 project WBS is shown in Figure 4.3. The ACES project WBS has been broken down by project phases to the major task level in Table 4.4. The overall ACES WBS has been used to develop the project schedule and has also been used to develop the ACES workforce-staffing plan, by phase, found in Section 6.4 of this proposal. A detailed WBS dictionary, by project phase, is provided in Section 6.4 with the full detailed

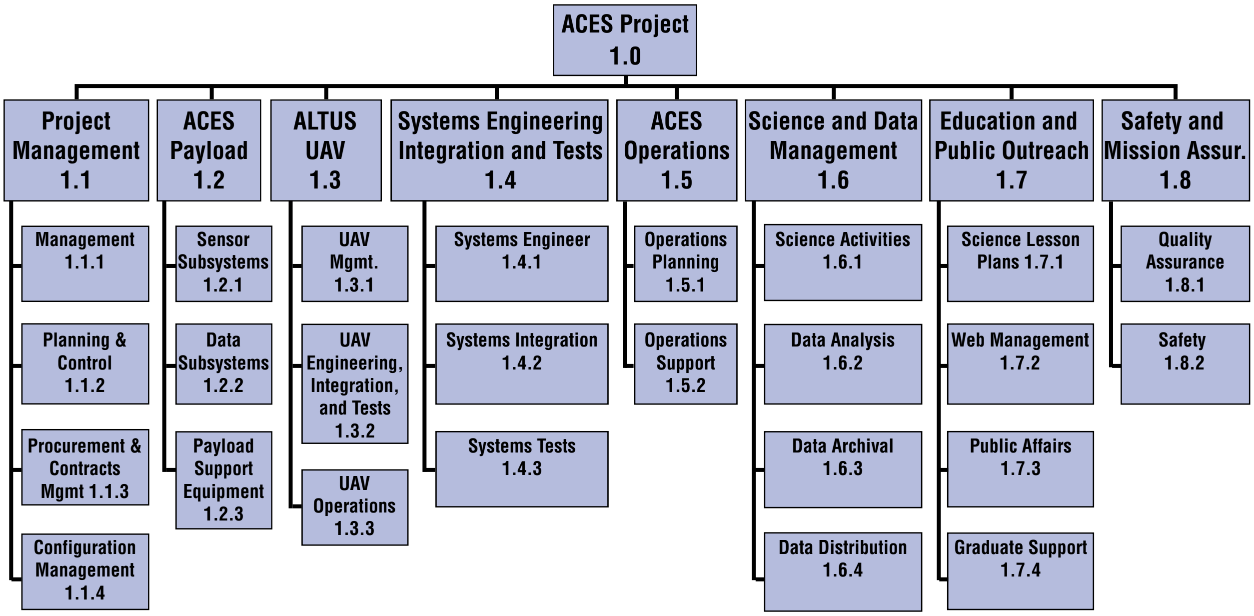


Figure 4.3.—ACES WBS structure.

WBS dictionary provided in Section 6.5.3. Project phases are defined as predeployment (payload development and mission planning), deployment (mobilization, flight/mission operations, and demobilization), and postdeployment (analysis/reporting).

4.3 Project Control Plan

Although NPG 7120.5A—NASA Program and Project Management Processes and Requirements—is not a requirement for the UAVSDP, the PM will manage the ACES project using NPG 7120.5A as a guide tailored for the size and complexity of the UAV project. The ACES project is managed utilizing a hierarchical WBS, with all work package schedules captured in an integrated project schedule. The resources plan and schedule provided in this proposal will become the baseline by which the ACES project is measured. System and subsystem technical requirements and parameters are baselined and managed, with configuration control handled by a Configuration Control Board (CCB). The CCB reviews and controls all proposed changes of scope, requirements, and design and authorizes implementation of these changes. The ACES PM serves as the sole ACES documentation repository and maintains copies of all quality records per MSFC ISO work instructions. These management processes are detailed in the following sections.

4.3.1 Systems Engineering

The ACES project will implement a systems engineering approach using SP–6105, NASA Systems Engineering Handbook and Marshall Procedures and Guidelines (MPG) 8060.1 as a guide, tailoring the process for the size and complexity of the ACES project.

Table 4.4.—ACES WBS by project phases.

WBS element	Element Description	Lead Responsibility	Applicable Phase		
			Predeploy	Deploy	Postdeploy
1.1	Project management	MSFC	X	X	X
1.2	ACES payload	MSFC	X		
1.2.1	Sensor subsystems	MSFC	X		
1.2.2	Data subsystems	MSFC	X		
1.2.3	Payload support equipment	IDEA	X		
1.3	ALTUS UAV	GA	X	X	
1.4	Systems engineering, integration, and tests	MSFC	X	X	
1.5	ACES operations	MSFC	X	X	
1.6	Science and data management	MSFC	X	X	X
1.7	Education and public outreach	MSFC	X	X	X
1.8	Safety and mission assurance	MSFC	X	X	

Overall project requirements will flow from the ACES Science Requirements Document (SRD) and the ALTUS Aerial Vehicle Payload Integration Manual (GA–ASI document ASI–00112) to the ACES Requirements, Verification, and Compliance (RVC) document, then to the ACES-to-UAV Interface Contol Document (ICD) and sensor subsystem requirements documents and ICDs. Figure 4.4 outlines the flowdown of ACES project requirements. The ACES science team will develop the ACES SRD. The RVC and ICDs will be developed by the ACES LSE with input from GA–ASI and IDEA. GA–ASI and IDEA will approve the ACES payload to ALTUS ICD and the ACES sensors to FPDS ICD respectively. The LSE is responsible for ensuring that the requirements are complete, accurately defined and documented, unambiguous, and appropriately allocated to the ACES subsystem elements. All requirements will be rigidly controlled using configuration management techniques described in section 4.3.4. All requirements will be thoroughly verified by test, analysis, or inspection. GA–ASI will provide input into the ACES-to-ALTUS ICD.

4.3.2 Resources and Schedule Management

4.3.2.1 Resources Management

The PM, assisted by an experienced resource analyst, will be responsible for conducting resources management including reserves management, institutional requirements, project requirements, contracts status, monthly reports, and other resources requirements. To monitor project manpower and costs and ensure compliance with baselines, the PM will utilize the Marshall Accounting and Resources Tracking System (MARTS). MARTS is an effective Centerwide accounting database containing all transactions related to all resources at MSFC including information on commitments, obligations, costs, disbursements, variances, contracts, and purchase orders. MARTS provides daily updates of all MSFC financial information and will be used in reporting ACES manpower and cost status.

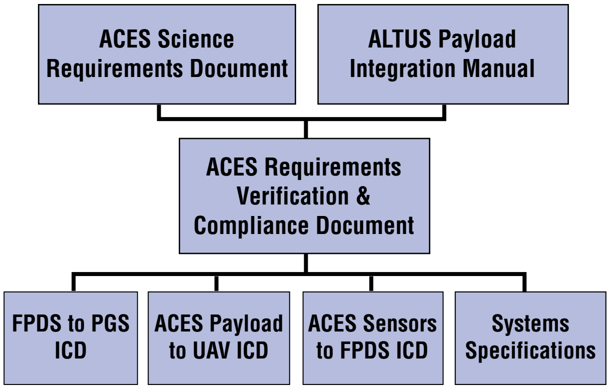


Figure 4.4.—ACES requirements flowdown.

The PI will control/manage the science budget with contingency funds, in case greater than anticipated activity is required by the science team for risk mitigation or oversight. Hardware development and operations budgets will be controlled/managed by the PM with contingency funds. The distribution of contingency funds to WBS elements will be based upon continuous risk analysis. The PM will release contingency funds only with the approval of the PI. Resources will be identified/controlled by the ACES PM through the development and implementation of the NASA program operating plan (POP). Resources management will be accomplished through proper interface with the ARC UAVSDP PO.

4.3.2.2 Schedule Management

The PM, assisted by an experienced schedule manager, will maintain the ACES master schedule provided in section 6.5.1. The PM will determine schedule logic, hold and assign schedule reserve, and develop appropriate milestones for tracking and reporting. Any changes to the ACES master schedule and associated milestones must be approved by the ACES PI. The scheduling process ensures that project schedules are integrated with the project’s cost estimate and authorized budgets. The schedule incorporates major project milestones/reviews, key technical events, key decision points, logic relationships, and interdependencies into an integrated hierarchy of schedules that establish and maintain vertical and horizontal relationships between and among all systems and subsystems. Responsible team members have been identified for each line item in the detailed schedule. The PO will use Microsoft Project 2000™, a cost effective and widely used tool, for schedule management. Project 2000™ data is exportable to Microsoft Excel™ for further cost analysis or cross-platform data transfer.

4.3.2.3 Metrics

The ACES project control tools formally maintain the project’s cost and schedule baselines, while providing for the development and generation of timely performance measurement data and reports. These data and corresponding reports provide the PM with the necessary visibility to analyze progress and identify any significant problems and issues in order to establish and implement corrective action. Use of the ACES project control tools will provide for the orderly and systematic authorization of work and project budget and identify potential problem areas in sufficient time to implement proper management actions. The ACES metrics will consist of major project review milestones, hardware delivery dates, and budget variances.

4.3.3 Contract Management

4.3.3.1 PI Institution with the UAV Provider

The ACES PO will establish a firm-fixed-price-incentive-award contract with the UAV provider, GA–ASI. The contract will establish a fixed price for UAV management, engineering, integration and test, mission planning, mobilization, and demobilization and a fixed hourly rate for flight operations. During the field campaign, many variables affect the number of flight hours accomplished. Using this type of contract arrangement, NASA pays only for the number of flight hours accomplished. The ACES systems heritage and definition are such that a fixed price contract will be cost effective and prevent cost overruns to the ACES project. Payment milestones will be established and monthly progress reports are required detailing the status of technical progress against the baseline plan.

4.3.3.2 PI Institution With the Co-I Institution and the Flight Range

An MOA will be established between the PI and the Co-I institution, GSFC, and between the ACES PO and the Joint Planning and Customer Service Office (JPCSO) for KSC and Patrick Air Force Base (PAFB) support of the ACES investigation. These types of agreements have served past projects well by establishing concise statements of work and scope of responsibility for each team institution, along with budget and management authorities.

4.3.3.3 PI Institution With the FPDS and Payload Support Equipment Provider

The ACES PO will establish a firm-fixed-price-incentive-award contract with the FPDS and payload support equipment provider, IDEA. The contract will establish a fixed price for the design modifications, fabrication, assembly, and tests of the FPDS and support equipment and support for the ACES payload and ACES/UAV integration and test activities. A fixed-price contract is appropriate since these tasks are well understood following the previous integration activities of the ACES suite and the ALTUS UAV. Payment milestones will be established and monthly progress reports are required detailing the status of technical progress against the baseline plan.

4.3.4 Configuration Management

Configuration management (CM) is the process through which ACES documents the functional and physical baselines, controls changes to those baselines, and provides information on the state of change action. The PO plans to start placing requirements and design documents under configuration management shortly after the Systems Requirements Review (SRR). An ACES CCB will be established to ensure the baseline of the design and will be responsible for ACES configuration control. The ACES CCB will approve and issue standard drawing numbers. Any ACES document or drawing that is issued a number will then be considered to be an ACES controlled document/drawing and will thereafter be subject to change/redline approval and signature of the ACES CCB. ACES working drawings will be held by the responsible engineer. Paper copies of all final ACES fabrication drawings will be held by the ACES PM, who will serve as the project repository for all controlled drawings and documents. The ACES CCB will sign and date all controlled document/drawing baselines/redlines. The latest date of CCB signature will always indicate the controlling iteration of that drawing. As a minimum, the ACES CCB will consist of the ACES PM (chair), PI, LSE, Safety and Mission Assurance representative, and the design engineer (for subject component) and will sign all controlled drawings and documents. A representative from GA–ASI and IDEA will also serve on the board, as required, to address issues with ACES to UAV interfaces and payload support equipment respectively.

Technical nonconformance reporting and disposition will be conducted within the ACES team and will be resolved by the members of the ACES CCB. The ACES team will evaluate and the CCB members will resolve all issues of potential impact upon mission safety and performance. Should circumstances require it, experts from outside the ACES team will be sought for further comment and opinion. Nonconformances will be documented on MSFC Form (3473) Discrepancy Record (DR) and controlled and dispositioned by the ACES CCB. The CCB Chairman has final approval authority for CCB actions.

Configuration of the ALTUS II UAV system is managed in accordance with the ANSI/ASOC Q–9001–9004 (ISO–9001–9004) certification awarded on October 15, 1999. All GA–ASI UAV systems are managed in accordance with this policy. The GA–ASI project engineer is responsible for the CM of the ALTUS II system during payload integration and test flights. Pro E™ drawings of the payload are not required by GA–ASI for CM purposes.

4.3.5 Project Assessment

4.3.5.1 Management Reviews

Management reviews will include formal and informal status reviews with SSDD management and the ARC

UAVSDP Program Office. For informal status, the ACES PO will provide a monthly assessment of performance against the baseline schedule, key milestones, and schedule metrics such as program slack, and milestone completion rates, and schedule performance index. ACES project control tools will generate monthly electronic reports of cost, schedule, and performance baselines. The SSDD and UAVSDP Office will receive written monthly reports from these project tools as well as accomplishments since the last reporting period, plans for the next reporting period, current risks and risk mitigation plans, and status of issues and concerns. These reports will be reviewed between the PO and the UAVSDP via monthly teleconference.

The ACES PI and PO will also present formal phase reviews to the UAVSDP Office with a complete status of cost, schedule, and technical progress against the baseline including risks and risk mitigation plans. These phase reviews will take place at the end of each project phase and will provide the UAVSDP Program Office a decision point prior to proceeding to the next phase of the project. In particular, the first campaign postdeployment phase review will provide a decision point for descoping the second campaign should the science and demonstration components of this proposal be satisfactorily achieved.

4.3.5.2 Technical Reviews

We are proposing to streamline the ACES design reviews with the elimination of a preliminary design review since: 1) The ACES payload exists and has already flown on the ALTUS UAV under an SBIR, and 2) modifications to the previously flown instrument suite are minor.

The ACES PM will conduct three major internal technical reviews: A project-level System Requirements Review (SRR), a project-level Critical Design Review (CDR), and a project-level predelivery/posttest Preship Review (PSR). These internal reviews will be conducted in accordance with MSFC ISO procedures. The Preship Review will provide the UAVSDP with a decision point prior to initiating the deployment phase. In addition, the ACES PO, with MSFC Systems Management Office concurrence, will establish an internal MSFC red team to provide an objective, nonadvocate review of the plans and processes in place to ensure that mission success and safety are being considered and implemented. The red team reviews will be held in parallel with the SRR and the two PSRs.

Following the deployment campaign, the PI will provide UAVSDP with a status of the deployment activities to provide a decision point prior to transition into the postdeployment phase.

4.3.5.3 Safety Reviews

The PO will conduct an Airworthiness Flight Safety Review (AFSR) at MSFC and a Flight Readiness Review (FRR) at GA–ASI and a Deployment Readiness Review (DRR) at PAFB to certify the following:

- Hardware/software is ready for flight
- Open work is planned and understood
- Constraints to launch are identified
- Flight operations personnel, documentation, and critical facilities are ready to support operations.

4.3.6 Team Member Coordination and Communication

The ACES development team recognizes the importance of frequent and open communication both formally and informally. Formal communication will take place in the form of status reviews and design reviews. Informally, the project will use a variety of communication resources to status issues and track progress against the baseline. The location of the ACES PO and PI in the same facility at the NSSTC will provide opportunity for daily face-to-face communication. The only team members not able to conduct daily face-to-face communication with the ACES PI or PM are the GSFC Co-Is, the IDEA contractors, and the GA–ASI contractors. Weekly scheduled teleconferences, coordinated between the PI, PM, GSFC, IDEA, and GA–ASI will be held to assess progress and discuss issues and near-term plans. The ACES team will use telephone, fax, and electronic mail for communications as required. Site visits by all team members will also be performed as required.

4.4 Master Schedule

The overall ACES WBS has been used to develop the project schedule. A top level ACES schedule is shown in Figure 4.5. The ACES master schedule is provided in Section 6.5.1. A detailed line-item schedule is provided in Section 6.5.2.

4.5 Project Risk Assessment and Management Plan

Significant risk mitigation for ACES has already been accomplished. Under a separate SBIR, the proposed ACES payload was integrated and flown aboard the ALTUS. **It should be noted that the successful completion of this SBIR grant has permitted the conception, design, development, and flight testing of a complete, end-to-end UAV-based science demonstration project, thereby substantially reducing the risks and potential cost overruns to the program for which we are currently proposing.** In essence, we already possess a working

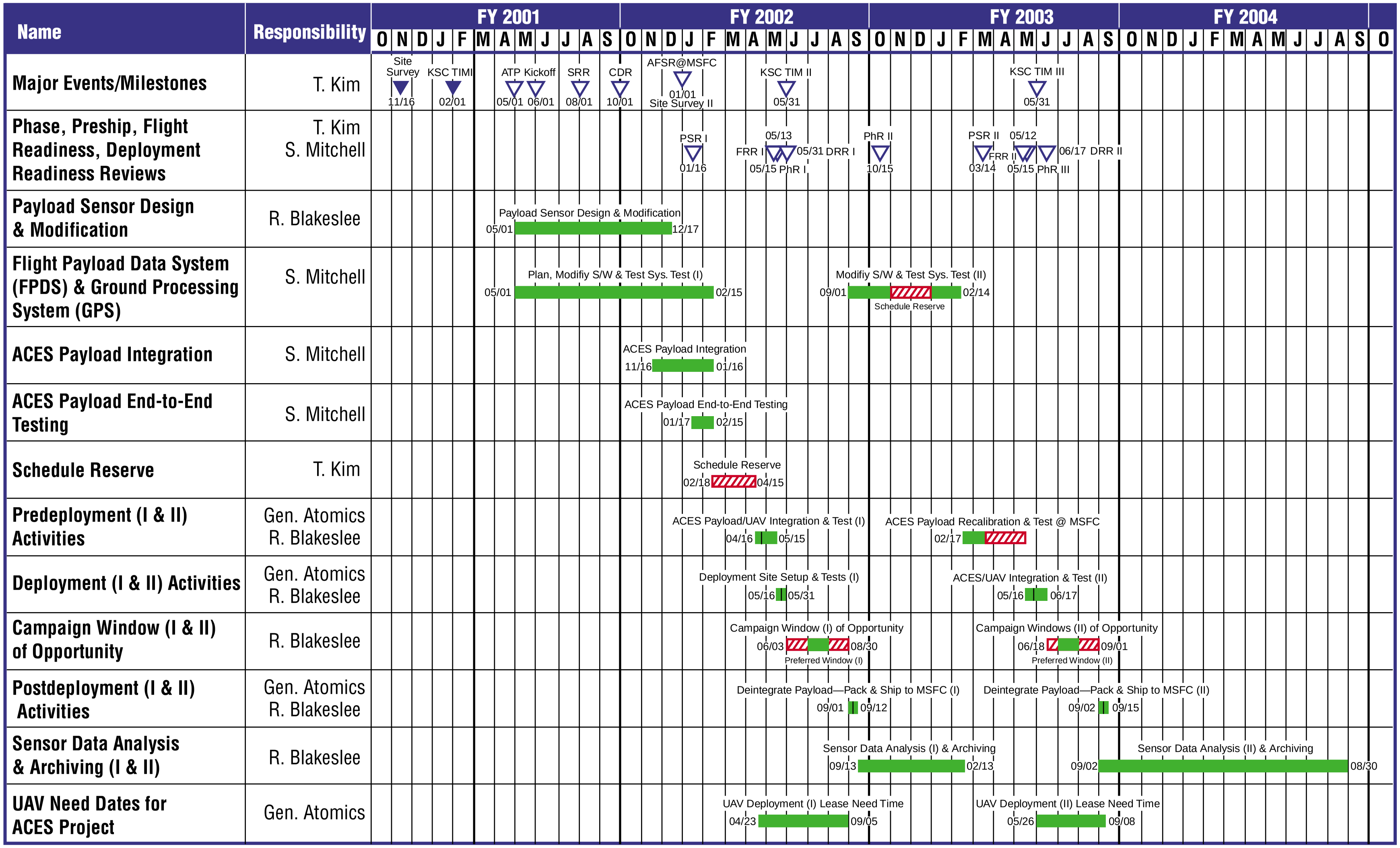


Figure 4.5.—Top level ACES schedule.

sensor suite, a successful integration plan, and have conducted a series of test flights with complete data throughput. The modifications (see Section 3.1) are considered ancillary in nature to the package already built.

This SBIR effort verified physical and functional compatibility. Of special note, it removed any risk associated with interfaces and electromagnetic compatibility, or with the aircraft being an unsuitable platform for making electrical measurements. In fact, the ALTUS was found to be an electrically quiet aircraft, ensuring that the proposed thunderstorm electrical measurements can be easily and successfully achieved.

In the sections that follow, we discuss the risk associated with scope (i.e., technical risks), schedule, and budget along with the risk management approach that will be adopted.

4.5.1 Scope

The ACES payload margins are summarized in Table 4.5.

4.5.1.1 Payload Power

Payload electrical power consumption is prevented from being a risk item by payload power budgeting. This is achieved through measurement and characterization at the integration level conducted by the science team prior to the ALTUS payload integration phase at the GA–ASI El Mirage, CA flight operations facility. This will then be consolidated by a total payload power measurement when installed onto the ALTUS and fully functional. As noted in Section 3.3.1, the ACES payload requires only 378 W, well below the 800 W available; hence, payload power is considered low risk.

4.5.1.2 Payload Mass

Payload mass is prevented from being a risk item by detailed payload weight budgeting. On arrival at the El Mirage facility, the payload items will be weighed along with all mounting and installation hardware. The proposed ACES payload weight is 183 lb (see Section 3.1.1) which includes mounting and installation hardware. At this level, there is sufficient contingency margin without encroaching on the ALTUS 330 lb payload weight limit.

Table 4.5.—ACES payload margins.

Risk	ACES Requirement	ALTUS Limit	Margin
Payload mass	183 lbs	330 lbs	147 lbs
Payload power	378 watts	800 watts	422 watts
Payload volume	6.8 cu ft	18.6 cu ft	11.8 cu ft

4.5.1.3 Payload Volume

Payload volume is prevented from being a risk item by configuring the equipment suite within the payload envelope details, presented in the ALTUS Aerial Vehicle Payload Integration Manual (GA–ASI document ASI–00112). The existing ACES payload has a volume of 6.8 cu ft, falling well within the 18.6 cu ft available for payloads.

4.5.1.4 UAV Altitude

The risk to achieve flight to the required 40,000 to 55,000 feet mission altitude range is considered low. The ALTUS system has demonstrated flight at this altitude in prior NASA flight programs. ALTUS has flown at 55,000 feet for up to 4 hours and at 50,000 feet for 8 hours.

4.5.1.5 UAV Availability

The ALTUS system is fully dedicated to the ACES project from the beginning of ACES/UAV integration and tests through the completion of each deployment campaign. Schedule margins are discussed in section 4.5.2.

4.5.1.6 UAV Turnaround Time

As previously discussed, GA–ASI's planning factor for normal turnaround of flights is one flight every 3 days. However, the actual factor has to be determined onsite during deployment, considering all of the factors of weather, mission payload performance, range availability, etc. Back-to-back missions will be considered.

4.5.1.7 UAV Weather Capabilities

The ALTUS UAV is the equivalent of a light airplane. As such, it is subjected to the same weather restrictions, i.e., turbulence, thunderstorms, crosswind limitations, etc. ALTUS can fly in IFR conditions. ALTUS cannot fly into known icing conditions and it cannot fly at night without an infrared nose camera installed for landing. It is not planned that ALTUS will conduct any night missions as part of this deployment.

4.5.1.8 UAV Range Constraints

The ALTUS is range constrained by range distance as previously identified. ALTUS missions will remain within 125 n mi distance from the PAFB ground control system (GCS) site. Additionally, the aircraft will not be flown directly over the PAFB GCS site to avoid a data link deadzone directly overhead. The standard minimum radius for flight near the GCS site is altitude dependent; e.g., at 55,000 feet the minimum radius is 30 n mi and at 16,000 feet the minimum radius is 16 n mi. Adjustments and modifications to the C-band antenna are planned to accommodate the ACES mission. The C-band antenna will be modified to increase the beam width and narrow the deadzone due to the high altitudes that will have to be flown in close proximity to GCS for this deployment. Engineering system check flights of this system will be flown at El Mirage prior to deployment.

4.5.1.9 Other Risk Mitigation Options

During ACES deployment, flight plans will be prioritized by risk with less risky flight plans executed. This would include, to the degree possible, operating ALTUS at a lower altitude and acquiring storm observations farther away from the storm. Initial storm engagement rules, worked out between the science team and the UAV provider, are believed to be very conservative. Also, as noted earlier, to reduce the risk of lightning strike to the aircraft, onboard electric field sensors will monitor ambient electric fields.

4.5.2 Schedule Risks Mitigation

The ACES project schedule has been developed to provide adequate schedule margin for risk mitigation. Approximately 2 months of schedule slack exist between the completion of sensor integration and tests and the start of the ACES payload/UAV integration and tests. In addition, a 3-month window has been identified for the flight campaign. The ACES campaign is planned for 1 month thereby providing a 2-month schedule reserve for the campaign itself. Likewise, a similar amount of schedule reserve exists between the first and second field campaigns.

4.5.3 Budget Mitigation

We have proposed to conduct two field campaigns during this investigation. Therefore, we would be able to successfully accommodate a descoped mission, consisting of one field campaign, should funding levels be at a much lower level. The major impact of such a reduced mission would essentially be to reduce the observations by half, thus decreasing the overall measurement statistics. In addition, we would lose the opportunity to improve upon and extend measurements made in the first campaign. The ACES project cost plan has included a 10 % contingency for cost reserves.

4.5.4 Risk Management Plan

The proposed mission has been designed to mitigate the effects of risks on the successful outcome of the investigation. It is possible, however, that unanticipated events may occur that will introduce risk areas during project implementation. The PM will implement an ongoing process that will allow, in fact encourage, each individual on the project team to bring any perceived or actual risks to management's attention at their first occurrence. The ACES project will use a hierarchical approach to how risk will be managed and will use a descending order decision path for mitigating risk. The first level to resolve risk is by the allocation of technical resources and margins. If that is an insufficient or inappropriate solution, then cost and schedule reserves will be used. Finally, descoping is a last resort and, if used, will be coordinated with the UAVSDP Office. Figure 4.6 depicts the ACES risk management process. The first step is to identify project risks including technical, cost, and schedule. Since ACES instruments and instrument software exist and are of proven design and flight heritage, the elements of risk are primarily cost, schedule, and the UAV.

4.6 Liability Assessment Plan

GA–ASI has included the cost of liability and hull insurance for the ALTUS II UAV aircraft in the cost proposal. The insurance is provided by a commercial insurance policy based on the evaluated replacement cost/risk of the aircraft/equipment. Aircraft insurance cost is based on a per-flight-hour basis and is included in the flight-hour cost. During transit to/from deployment sites, the UAV system is insured by the commercial shipper as part of the transportation cost or is included as a separate item by GA–ASI as an identifiable cost. Insurance of ground-based equipment at the deployment site is borne by GA–ASI's general insurance policy coverage. Third party liability is provided by GA–ASI's general liability coverage. This coverage is in the amount of $6.2M and covers GA–ASI liability.

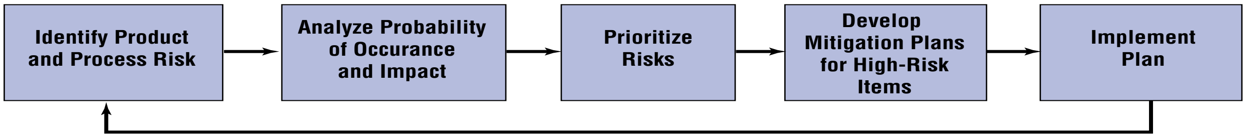


Figure 4.6.—Risk management process.

5. Outreach Plan

5.1 Outreach Concept

We will develop an outreach effort with three major components as shown in Table 5.1. The overall goals of our outreach are to increase public awareness of the ACES project and the NASA Earth Science Enterprise (ESE) and inform the public of the purpose and benefits of ACES and the ESE. This outreach will create a positive public image of NASA and the ESE.

The U.S. public already has a heightened interest in meteorological and storm related research due to the many programs on the Discovery Channel, PBS Nova, and others dealing with severe storm and lightning research. In addition, many TV stations around the country regularly include real-time lightning strike graphics during their weather broadcasts, and often preempt regular programming during periods of local severe weather with special weather reports.

The public also has a great fascination for cutting-edge technology. The ALTUS UAV represents an exciting new generation of aircraft pushing the frontiers of technology with its future and applications still to be established. Perhaps, as proposed by ACES, that future will include using UAV aircraft as meteorological research platforms. Like the severe storm and weather research noted above, cutting-edge technology (especially that involving aviation) is the focus of popular programs on the Discovery Channel, Nova, and elsewhere on TV and in print.

By capitalizing on the great interest in science, weather, and technology that already exists with the American public, we maintain it will be easy to get the public interested and excited about the ACES program. Our confidence that this will be the case is bolstered by the excellent response several recent NASA-sponsored programs have received including the Tropical Rainfall Measuring Mission (TRMM); the Lightning Imaging Sensor (LIS), a sensor on the TRMM platform; the Optical Transient Detector (OTD), the predecessor to LIS; Lightning Imaging Sensor Data Application Demonstration (LISDAD), a demonstration of the value of total lightning measurements; and the Convective and Moisture Experiment (CAMEX), a large field program with recent focus on hurricanes. These highly visible missions have generated an enthusiastic and strong public interest resulting in good publicity for NASA and these programs.

We will adopt a three-fold approach to generate an effective and broad outreach. Access to traditional news services with the aid of the Marshall Space Flight Center (MSFC) public affairs office (PAO) will create immediate coverage in the form of good press. More in-depth treatments and information about the project will be made available through Web-based outreach. Finally, we intend to create an innovative education project designed to inspire the next generation of scientists and engineers that will achieve long-term benefits to ESE and NASA.

5.2 Media Outreach

5.2.1 Public Affairs

We will utilize the MSFC PAO to coordinate, facilitate, and guide the promotion of the ACES program with the traditional news media. This office provides an immediate and effective outreach to the public. A wide audience is reached and broad public interest generated through the production of original news stories and timely press releases that convey the importance and significance of ACES research. These press releases and news stories will be coordinated to coincide with key project events. Examples include project selection, initiation of science flights, and scientific discoveries. Special events, such as hosting a media day at the deployment site, can be planned to showcase both the aircraft and highlight the planned science mission.

We have ample evidence that this outreach will be successful. Through our association with public affairs, the lightning team at MSFC regularly engages in media contacts. Our research and its relevance to NASA, ESE objectives, and the nation have regularly been profiled on Good Morning America, the Discovery Channel, the Discovery Science Channel, and PBS, as well as through radio and newspaper stories. Even real-time Web interviews have been conducted. The International Conference on Atmospheric Electricity (the foremost conference in the world in this field) was hosted by the MSFC

Table 5.1.—Methods for achieving public awareness provided by the ACES outreach.

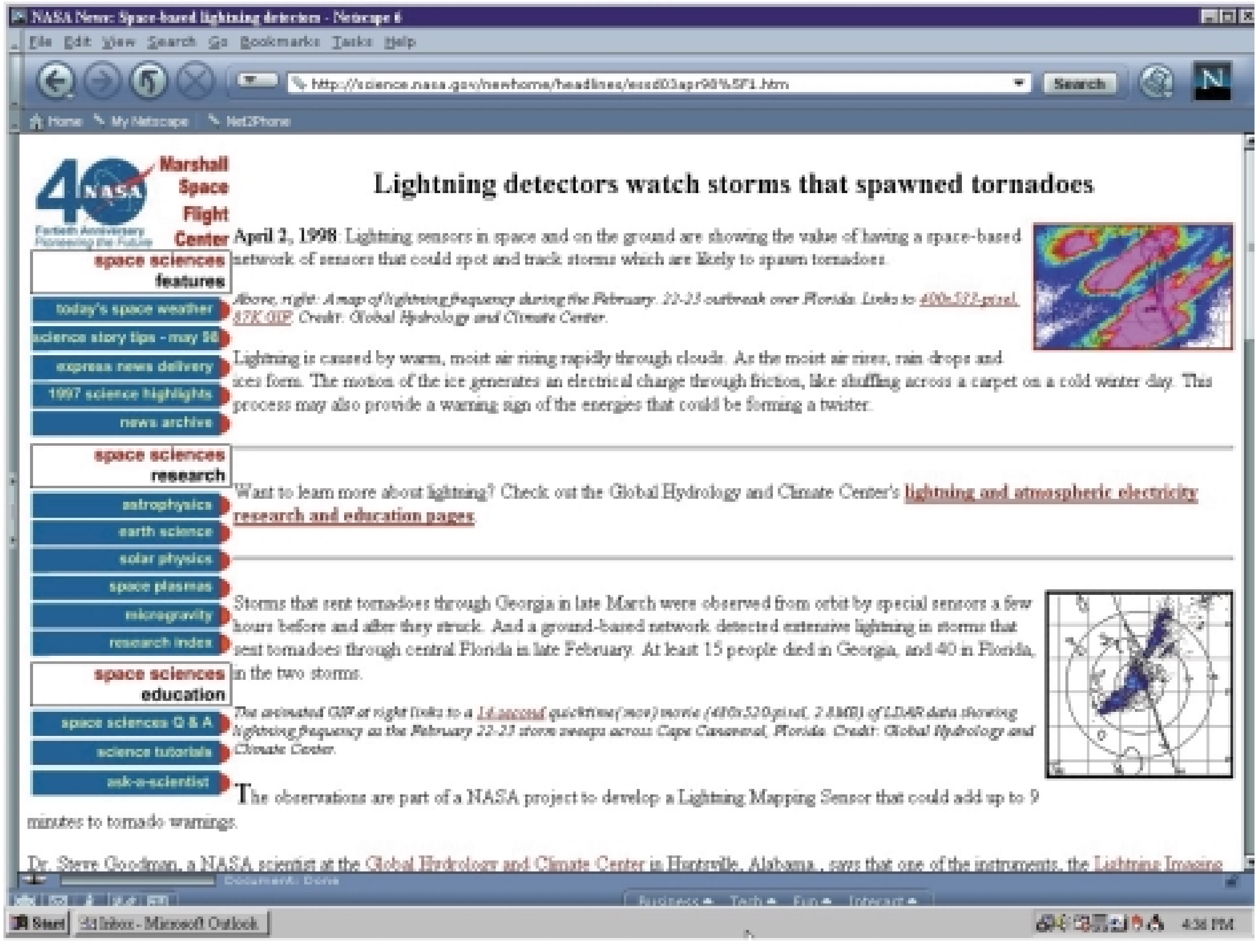
Outreach Component	Impact and Benefits to NASA and ESE	Outreach Coverage	Informational Content	Method to Acheive Public Awareness
Traditional media	Immediate	Broad based	Introductory	Hear and see
Web based	In-depth	Target groups	Comprehensive	Explore and study
Educational lesson plan	Inspirational	Students and teachers	Focused	Learn by doing, “hands on”

lightning group in 1999. That conference generated a great deal of public interest and received wide coverage, including considerable coverage highlighting and benefiting NASA ESE. We will apply this same successful approach to ACES.

5.2.2 Web-Based Outreach

Outreach through traditional media sources, while immediate and beneficial, has the major draw back that it is often short-lived. In addition, comprehensive treatment of key issues is often not provided. Web-based outreach provides the means to address both these shortcomings while providing an alternative and complementary method to inform the public and distribute information about this project and its results. In addition, it is possible to target specific groups of individuals (e.g., students, teachers, scientists, general public, news media, etc.) to better communicate the purpose, benefits, and results of ACES to the nation and these target groups.

The MSFC lightning team, NSSTC/Global Hydrology and Climate Center (GHCC) teams, and the NSSTC/Global Hydrology Research Center (GHRC) have developed highly acclaimed and frequently accessed Web sites highlighting science programs, spacecraft, field campaigns, data products and data services. Example sites include www.ghcc.msfc.nasa.gov, thunder.msfc.nasa.gov, ghrc.nsstc.nasa.gov and ghrc.nsstc.nasa.gov/camex3. Figure 5.1 illustrates a link to a Web page that highlights research results from our lightning group. We will pattern the ACES project Web site after these successful sites. The same resources, personnel, and expertise used to create those sites will be applied to the development of the ACES Web pages. The site will be linked to key sites at the NSSTC (see examples above). The project Web site will include: mission description, aircraft, and sensors overview; news and events; deployment information; operation plans; browse products; and database access. This site will be created early in the project, support ACES campaign activities, and live on after the mission to provide information and data access.



Lightning detectors watch storms that spawned tornadoes

April 2, 1998: Lightning sensors in space and on the ground are showing the value of having a space-based network of sensors that could spot and track storms which are likely to spawn tornadoes.

Above, right: A map of lightning frequency during the February 22-23 outbreak over Florida. Links to 400x573-pixel, 87K GIF. Credit: Global Hydrology and Climate Center.

Lightning is caused by warm, moist air rising rapidly through clouds. As the moist air rises, rain drops and ices form. The motion of the ice generates an electrical charge through friction, like shuffling across a carpet on a cold winter day. This process may also provide a warning sign of the energies that could be forming a twister.

Want to learn more about lightning? Check out the Global Hydrology and Climate Center's lightning and atmospheric electricity research and education pages.

Storms that sent tornadoes through Georgia in late March were observed from orbit by special sensors a few hours before and after they struck. And a ground-based network detected extensive lightning in storms that sent tornadoes through central Florida in late February. At least 15 people died in Georgia, and 40 in Florida, in the two storms.

The animated GIF at right links to a 14-second quicktime(.mov) movie (480x520-pixel, 2.8MB) of LDAR data showing lightning frequency as the February 22-23 storm sweeps across Cape Canaveral, Florida. Credit: Global Hydrology and Climate Center.

The observations are part of a NASA project to develop a Lightning Mapping Sensor that could add up to 9 minutes to tornado warnings.

Dr. Steve Goodman, a NASA scientist at the Global Hydrology and Climate Center in Huntsville, Alabama., says that one of the instruments, the Lightning Imaging

Figure 5.1.—Web page “screen capture” from the popular science.nasa.gov site promoting lightning research at NASA.

We also plan to make use of the Science@NASA Web sites developed and sponsored by the Science Directorate at MSFC. In fact, the stated mission of Science@NASA is to help the public understand how exciting NASA research is and to help NASA scientists fulfill their outreach responsibilities. The sites supported by the MSFC Science Directorate include:

- science.nasa.gov
- kids.msfc.nasa.gov
- www.thursdaysclassroom.com.

Also, starting in January, 2001 the MSFC Education Programs Department has begun NASAexplores, a new Internet-based lesson plan delivery service (see www.nasaexplores.com). NASAexplores provides educational content based on real—not theoretical—research, development, and events. This program provides excellent synergy with the education outreach that we are proposing for ACES as discussed in the next section.

5.3 Education Outreach

5.3.1 Lesson Plan Concept

We will create an innovative lesson plan package that will bring the ACES project into American classrooms. Lesson plans will be developed for teachers in the 3–5, 6–8, and 9–12 grade levels, based on actual ACES field activities. We envision that the lesson plans will result in a significant long-term impact and value to NASA and ESE by influencing and inspiring the next generation of scientists and engineers for many years following the ACES program. The lesson plans will help students experience the fun and excitement of NASA research while learning important scientific concepts. From a science standpoint, the lesson plans will focus on meteorology, weather, and weather forecasting. More importantly, the lessons will address the decision-making process that directs the conduct of the scientific research. The students will be able to apply the decision making skills learned from the ACES lesson plan to their everyday life.

Weather forecasting will be a key activity during the ACES field campaigns (this is true for all aircraft campaigns). The ALTUS aircraft will only be sent on missions on days that have a high probability for storm development within the observational domain at KSC to best utilize the limited number of flight hours available to the program. Weather must also be considered at the base of operations, since storms and crosswinds can adversely impact the ability of ALTUS to safely takeoff or return. Yet weather is not the only consideration for making a Go-No Go decision. The number of flight hours and days remaining in the deployment must also be considered. For example, the ALTUS might be sent on a day with marginal storm prospects if only a few days remain in the campaign. On the other hand, the ALTUS might be held down on a day with a good probability of storms if the forecast for the following day is even better (or if instrument, crew rest, or other factors dictate a down day).

The lesson plans will be designed to teach meteorology and forecasting concepts. Moreover, the lesson plans will have students make Go-No Go decisions based on selected input data, helping them learn to digest data, deal with information gaps (or faulty information), and develop and improve their decision-making skills. Following instruction provided within the lesson package, students will be given the opportunity to make the same type of “real-time” Go-No Go decisions that were made in the field using the actual data employed during the campaign. This will convey a better appreciation for the research process and demonstrate that the “answers are not always found in the back of the book.”

The majority of the materials needed to develop the lesson plans will be derived from the data, forecast information, and decisions made during the deployment phase. We will use actual forecast data, decisions, and results. During the deployment, we plan to videotape the preflight weather briefings and the postflight (if one occurred) debriefs. Following deployment, the videos, field notes, and acquired data (including aircraft video and sensor observations) will be gathered together to prepare the lesson plans. The lesson plans will be tailored to each age group. For example, the lower-grade version will have fewer variables and less ambiguity while the upper levels will have more variables, ambiguity, and missing/bad data. During each campaign, we should have as many as 30-days worth of forecasts and ancillary data to develop exercises in the decision-making process.

5.3.2 Lesson Plan Structure

The lesson plan package will be divided into two parts, with Part I focusing on meteorological fundamentals and Part II introducing specific applications and the flight decision exercises. Part I of the lesson plan package will begin with an introduction to the ACES program. We will describe, in age appropriate language, the importance and benefit of the ACES science demonstration and its relevance to broader NASA Earth science themes. We will also present details pertaining to the ALTUS aircraft system, the scientific instrumentation suite, and science measurements. Following the introduction, one or more self-contained lessons on fundamental meteorological and weather concepts will be presented.

Part II of the lesson plan package contains the really innovative part of this educational outreach. It will begin with a primer on how to forecast the probability of thunderstorm occurrence in the target area using the data sets that will be provided. Reference back to the Part I basic meteorology results will help the students understand the physical basis for the forecast. Next, following the forecast primer, the real fun begins. Students, working alone or in teams, will make forecasts using actual ACES data sets. They will have to decide either to fly or not fly the aircraft based on the current forecast, the forecast for the next day, and the conditions of the aircraft, crew, and instrumentation. Following their decision, they will learn what the experts in the field decided (and why), and what actually occurred (and why). In Section 5.3.3, we present an example of how this process would proceed. Data from each day available during the month-long deployment will be offered in the flight decision exercises presented in Part II of the lesson plans. We intend to include all our "real-life" cases, including ones where WE missed the forecast. We will also include cases where we did forecast correctly, but were unable to capitalize on the good forecast due to instrument, aircraft, or other problems. This will allow the students to see all aspects of scientific research.

For the good flight days, we will present special lesson additions dealing with some aspect of the science observations acquired that day. Some teachers may want to concentrate on these days where we obtained good flight data and lead discussions on these results. In all cases, the teachers will be given leeway and flexibility to tailor the lessons to their own class.

5.3.3 Discussion of the Flight Decision Exercises

Making a Go-No Go flight decision based on actual ACES data sets represents the unique aspect of the proposed lesson plans. Once the students have completed the forecasting primer in Part II, they may start a flight decision exercise. As noted earlier, a team approach may be very effective. Since almost all of our flight and nonflight days will be presented, the teacher will be able to choose between days that have easy, moderate, or difficult solutions. The target grade level (either mid-elementary, middle school, or advanced high school) will also determine the complexity and quantity of the data presentation. At the more advanced levels, missing (sites that did not report weather conditions) or bad data (sites that reported erroneous data) may be considered as well.

The students will make the thunderstorm forecast using techniques presented in the primer. Older students may be asked to provide an additional forecast at the ALTUS airfield (e.g., what is the possibility that a return to base may be adversely impacted by storms), determine the impact of the missing or bad data on their forecast, or consider other data (e.g., days or flight hours remaining in the deployment) as they make their Go-No Go decision.

Once the students have made their forecasts and Go-No Go decision, we will present to them the forecast and flight decision that was actually made in the field. This presentation may be provided in different formats (e.g., text, graphics, or video). This presentation will also be preflight, that is, the forecast from the experts will be from the same set of "knowledge" that the students used. We will tell them what we did with the data (including any forecaster discussions of the data). This will present opportunities for the students to see if there was anything in the data that they missed (or even things in the data that the experts missed).

The next step is the forecast and flight decision validation. We will describe to the students what actually happened. We may have made a correct Go decision and collected important storm data. Perhaps the experts in the field predicted storms and nothing happened. Perhaps the opposite result occurred, with the development of wonderful storms that we could only watch from the ground because we made a No Go decision. Perhaps we predicted storms but the ALTUS experienced a mechanical problem and could not fly. We will present a discussion of the forecast we made and the actual weather that occurred that day. Regardless of the outcome, we will present a discussion of the forecast we made and the actual weather that occurred that day. If the weather turned out different than the forecast, we will attempt to explain why this happened. On occasions when the students do a better job than the experts in predicting storms, they will be challenged to identify and explain why they did better. In each case, we will provide information to the teacher that will give the students opportunities to learn from both good and bad forecast decisions.

After participating in several "flight day decisions," the students should begin to learn that basic research is exciting, fun, and a career path they might think about pursuing. They should also learn that there are systematic approaches to finding solutions to problems that have no easy answers. The students will learn from their "incorrect" forecasts and decisions, learn to recognize false or misleading data, and make sure that the data supports their conclusions. Most importantly, the students will learn the basic concepts of the scientific method, quantitative reasoning, and data analysis and that these systematic approaches to problem solving can be applied to their everyday decisions.

5.3.4 Lesson Plan Development

We recognize the importance of involving teachers and educators in the development of the proposed lesson plan package so that it will be educational and fun, user friendly and flexible, and relevant to the needs of today's teachers and students. At the same time, the plans must prominently promote the purpose and benefits provided by NASA and ESE. To ensure that this will occur, we will work closely with Mr. Greg Cox of the University of Alabama in Huntsville (UAH) Global Learning and Observations to Benefit the Environment (GLOBE) program who will provide leadership, guidance, and expertise to this activity. Greg Cox is a Space Grant Fellow supporting K–12 math, science, and technology reform issues in Alabama, and a former consultant to the MSFC Education Office. We will also consult with master teachers in our area who teach students in the grade levels we are targeting with this lesson plan package. In addition, we will coordinate and consult with the MSFC Education Programs Department to tap into the resources, experience base, and distribution techniques that this department offers. Dr. Doug Mach will oversee the lesson plan development and serve as the lead interface between the teachers and the ACES science team.

Together, we will proceed to outline the best format and content needed to provide lesson plans compatible with current teaching methods and curricula. We will produce a document to guide us in gathering the relevant information required from the ACES deployment to facilitate quick integration of the forecast and flight data into the lesson plan database. During deployment, we will acquire the relevant information into the lesson plan format. After deployment, we will consult again with Greg Cox, the master teachers, and others to create the actual lesson plan package. We will test the lesson plan on students in the Huntsville and Hartselle, AL school system. We will use the feedback we gather from these tests to refine the lesson plan format. Once the lesson plan format and database are finalized, we will create a CD set for distribution to schools around the country. We envision that the lessons may also be made available on the Web for access and download. In addition, we will work with the MSFC Educations Programs Office for inclusion of lesson plans into the Web-based NASAexplores program.

We will configure our lesson plan to be as flexible as possible. We want teachers to use the lessons in their classrooms regardless of the amount of time they can devote to the subject. We will make each section as self-contained as possible so that teachers can choose the sections they want to present to their students. We will provide a teacher's guide that will detail the goals and major points of each lesson and suggest possible ways the lesson can be integrated into the teacher's own curriculum. With the support of our master teachers, we intend to make the ACES lesson plan package simple to use, interesting, fun, and relevant.

5.4 Relationship With Ongoing Activities

The ACES outreach program is not being developed from scratch or in a vacuum. Rather, as discussed in the previous sections, the ACES outreach components will take great advantage of the existing and highly successful outreach activities that are ongoing at MSFC. Many of these services (e.g., Public Affairs, Science@NASA, NASAexplores, etc.) will be provided at little or no cost to the ACES program. The professional staffs associated with these services already know how to inform and excite the public and increase public awareness. These goals align with the ACES outreach objectives. Therefore, we will utilize their help to communicate the purpose, benefits, and results of the ACES program to the public in an exciting and clear manner. This will provide significant savings in time, resources (personnel and dollars), and development while dramatically increasing the probability that the ACES outreach plan will successfully achieve its outreach objectives.

5.5 Graduate Student Participation

In the first proposal submission, we proposed to support a graduate student in the atmospheric or computer sciences. We will maintain that support. The graduate will participate in pre-mission preparations, in the field deployment, and subsequent data processing, analysis and research. The student will gain invaluable experience from his or her "hands on" field research, along with the practical aspect of tuition and salary coverage. NASA and the country will also benefit since the experience will help train him or her to be part of the next generation of space scientists. It is possible for the graduate student to be involved in all aspects of the project (the level of responsibility will depend on whether the student is working toward an MS or Ph.D. degree). Opportunities will exits to work with sensor hardware, meteorology, and computer software, depending on the interests and background of the student.