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DRONE CONTROL AND DATA RETRIEVAL SYSTEM (DCDRS), PRELIMINARY DESIGN STUDY FINAL REPORT (U)

VOLUME III – TRADE STUDIES AND ANALYSES

PART II – MAN-MACHINE INTERFACE ANALYSIS

Sperry Univac Defense Systems

Technical Report ASD-TR-74-5, Volume III, Part II
April 1974

[redacted]

Prepared for:

Deputy for Reconnaissance/Strike/Electronic Warfare
Aeronautical Systems Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

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DRONE CONTROL AND DATA RETRIEVAL SYSTEM (DCDRS), PRELIMINARY DESIGN STUDY FINAL REPORT

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FOREWORD (U)

This Technical Report was prepared by Sperry Univac Defense Systems under USAF Contract F33657-73-C-0665. This report, submitted on 15 May 1974, describes all technical work accomplished and information gained in performance of the Drone Control and Data Retrieval System (DCDRS) Preliminary Design Study during the time period from 5 March 1973 to 5 October 1973. This effort was accomplished for the Deputy for Reconnaissance/Strike/Electronic Warfare, under the guidance of the Drone/RPV SPO, Launch/Control Systems Group (ASD/RWDTL), Lt Col Robert S. Greever, Chief.

The word "Book" is used interchangeably in this report with the word "Part" to mean the numbered Part of a Volume.

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

WARD W. HEMENWAY, Colonel. USAF
Director, Drone/RPV SPO
Deputy for Recon/Strike/Electronic Warfare

UNCLASSIFIED ABSTRACT

This program is a study effort leading to the preliminary design of the DCDRS. The system must be capable of control and data retrieval from multiple drones, operating through a relay in a dense jamming environment. Low acquisition and ownership costs are stressed.

The approach to the system design was divided into four primary tasks:

- Systems analysis
- System/subsystem trade studies and analyses
- System preliminary design
- System development planning (for follow-on phases)

In the systems analysis task, mission scenarios were developed and analysis was performed to define a broad realistic set of requirements for the DCDRS system. A detailed functional analysis (four levels) was performed to provide a detailed set of functional requirements for each element of the system. These included:

- Command/telemetry requirements
- Data processing and software requirements
- Display/control requirements

A time-phased mission analysis established data flow and computational requirements as a function of mission phase. Vehicle handling capacity, operator utilization, and vehicle phase summaries were also determined.

The subsystem trade studies concentrated on the key design areas of communications, man-machine interface, and data processing (hardware and software). Of the trade studies performed, 16 major trade studies were specifically addressed to the DCDRS subsystems: 8 in communications, 4 in data processing, and 4 for the man-machine interface. These trade studies have defined the approach, concepts, and optimum mechanization of the DCDRS.

A complete DCDRS preliminary design was generated which represents a cost-effective solution to the program objectives. Modular design is provided so that configuration can be varied to support several different missions and deployment of various sizes. Common processors are used throughout elements of the system:

- Drone Control Facility
- Airborne Drone Control Facility
- Launch/Recovery Facility
- Relay
- Drone (RPV)

The software is also modular with a high degree of commonality between the various control facilities.

Draft copies of the Final Report for the study effort were submitted to the Air Force on 12 November 1973; these volumes are the final version of this report.

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MAN-MACHINE INTERFACE ANALYSIS

1. SCOPE

The objectives of this analysis are to determine the tasks to be performed by man, those to be performed by the machine, and those which will be shared. This analysis provides an allocation of functions to man or machine, and is referred to as an automatic vs manual analysis. DCDRS tasks pertinent to consideration of manual participation cover a broad spectrum of functions including planning; briefing; and flight surveillance, monitoring, and control. Earlier man-machine interface studies sponsored by the USAF addressed the latter areas for strike vehicle missions; this analysis applies those results and further considers mixed and RECCE missions in the context of overall DCDRS operations. This analysis complies with the contract DCDRS statement of work, paragraph 4.21.2.n.

2. SUMMARY

Table 1 summarizes the major man-machine related technical characteristics (functions) that were analyzed. For each major function, the recommended automatic or manual allocation (design method) is described, together with the significant performance parameters driving the selected method. Tables 3 through 6 describe in further detail the allocation of functions by mission phase for each DCDRS element. From the results of the analysis, it is concluded that a high level of automation of many functions is required, but that some form of manual participation is normally necessary.

3. ANALYSIS AND TECHNICAL APPROACH

The man-machine interface analysis, or automatic versus manual determination, is essentially Level 3, man-machine allocation analysis, of a four-level system functional analysis. It was preceded by Levels 1 and 2. Level 1, DCDRS functional flow analysis, provided functional flow of the gross system functions among the various DCDRS and external system elements in a time ordered way. Level 2, functional analysis of individual elements, defined a system design approach, indicating the various data processing and communications functions required, and, in addition, the following display and control oriented functions: situation, status, control, caution and warning display data and interactive or discrete control data. Thus an allocation of functions to man or machine was accomplished by analysis of the Level 2 data on a function by function basis, for each mission type and phase, as described in paragraph 5. Rationale for the manual, machine, or combined approach selected is documented therein.

Table 1. Degree of Automation of Functions

Technical Characteristics (Functions)	Selected Method	Performance Parameters (Rationale)
Mission, Flight Planning and Replanning	Automatic with manual inputs	Large amount of detailed data
Orientation and Briefing	Manual with autovisual aids	Flexibility - realistic environment
Checkout and Maintenance	Automatic	Number of operations, time, life cycle cost
Reporting	Automatic with verification	Rapid, unambiguous, error free
Launch	Automatic with manual override	Precision steering required
Handoffs	Automatic with manual inputs	Fatigue and complexity
Enroute Vehicle and Mode Control	Automatic with manual override	Fatigue, multi-vehicle control required
Situation Monitoring	Manual/visual with computer assist	Positive separation assurance
Status Monitoring	Automatic with manual inputs	Number of operations, fatigue
Mission Execution	Manual initiation and verification	Operator responsibility
Target Acquisition and Cueing Aids	Manual/visual with automatic cueing	Visual perception, operator assist
Vehicle Control During Weapon Delivery	Automatic with manual sensor aiming	Precision steering, unburdening operator
Bomb Damage Assessment	Manual/visual	Visual perception
Recovery	Automatic with manual override	Precision steering required

It is noteworthy that the Rockwell International RPV MMI Study report recommended that most functions be performed automatically or assisted by computation. We concur with this conclusion that a high level of automation is required for many of the functions. Table 2 generalizes some of the quantitative trade studies performed in that MMI study functional analysis, the results of which were applied to the DCDRS man-machine allocation.

The allocation of functions resulting from this analysis provides an input to Level 4, element block diagrams, which also contain tabular characteristics of the functions including update rates, event times, range, and resolution. Additionally, the total man-machine system interface design process includes the definition of DCDRS organization structure, operator tasks and time loading, numbers of personnel, and gross operating procedures. The accomplishment of all of the aforementioned tasks is a highly iterative process which may, in turn, require further iterations in the functional man-machine allocation analysis itself.

4. FUNCTIONAL AND TECHNICAL CHARACTERISTICS

The following paragraphs describe the significant functions which are part of the man-machine interface. These functions are discussed in terms of their overall system application since many recur during various mission phases and are applicable to ground control, air control, operations and planning, launch and recovery control, and relay drone control DCDRS system elements. The various methods of manual or machine participation that were considered are identified. The rationale for selection of one of these methods in each general functional area is noted together with the consistency of approach to permit a unified system design. This part of the analysis provides a bridge between the functional requirements and the detailed allocation of each function to man or machine, which is covered in paragraph 5 of this report.

a. Mission and Flight Planning and Replanning. This function requires the conversion of FRAG data into programs for both the vehicle and the ground computer. In performing this planning task, the data from the FRAG must be converted into an RPV flight profile within the constraints of vehicle performance, intelligence data, time on target, and other RPV routes. Approaches to the planning task include complete manual planning and programming with manual data insertion, completely automatic programming, and automatic programming with manually inserted inputs. The last method was selected in conformance with table 2 because of the large amount of detailed information that can be handled by the computer and the ability of the computer to resolve flight conflicts and to provide for detailed programs. Manual inputs

Table 2. MMI Trade Studies

Function	Selected Approach
Flight control	Programmed guidance/autopilot with manual override: • Select outer loop holds or preprogrammed change (e.g., jink) • Fly-to pushbutton input
Targeting	Manual detection, joystick track and commit
Tactical decision making	Voice information interchange
Checkout and maintenance management	Automatic with manual participation
Mission planning	Automatic with manual participation
Orientation briefing	Manual with visual aids

are required at the executive decision level to provide for the interpretation of threat and weather data and to assess priorities at the local level.

b. Orientation and Briefing. This function requires the preparation and presentation of the flight plan data to the various operators in a form that will provide them with the pertinent facts required to conduct their phases of the mission. Approaches to orientation and briefing include complete manual briefing with the minimum use of aids, fully automatic presentation of data, and a combination of manual briefing supported by processed information. The last method was selected for briefing both terminal and enroute operators with the implementation dictated by the particular requirements of the individual tasks. It was also selected because it provides for the free interchange of ideas between briefer and operator to resolve any questionable areas. The support afforded by processed information places the operator in a realistic environment and presents the data in the format he will use during the mission.

c. Checkout and Maintenance. This function, which covers the checkout of all equipments pertinent to DCDRS operation, must be performed rapidly with a degree of completeness that assures a full-up system with alternate backup readiness. A fully manual system, a computer aided system, and an automatic system were considered. The automatic system with manual monitoring, according to table 2, was selected because of the total number of operations required to achieve an in-depth check of all equipments to assure a high level of confidence in system operation. Using a fully manual approach to achieve the same response times and performance levels would lead to higher life cycle costs.

d. Reporting. This function covers issuing reports to various TAC operating groups to indicate items such as takeoff conformance and other ongoing operational events. Consideration was given to fully manual voice and automatic transmission of canned messages with operator notification. The reasons for selecting automatically initiated canned messages with operator notification were the routine nature of each of these messages; the requirement for verification of message transmission; and the rapid, unambiguous, and error free means afforded by this method. Voice communication is available as a backup to this automatic mode.

e. Launch. This function is associated with the method of launch employed, varying with air launch, rail launch and runway takeoff. The methods considered were manual control of the vehicle to provide stabilized path control, and, for runway takeoff, alignment on the runway; automatic control of the vehicle with the operator providing guidance through outer loop steering; and automatic control and guidance with the operator monitoring progress and providing outer loop steering only by exception. The last method was selected as it provides the precision and speed of response required to maintain flight under multiple rail and air launch conditions. If launch is by runway takeoff, visual monitoring may be provided through the EO sensor, if available, or by a remote operator visually monitoring the runway alignment at the takeoff facility. If the operator is included in the monitoring loop, he can quickly take over outer loop control to provide a high level of operational success as an independent backup to the automatic control system.

f. Handoffs. This function covers the exchange of control responsibility between the launch, enroute, terminal, and recovery operators as the RPV's progress through the mission phases. This is essentially a change in monitoring responsibility as the RPV's are programmed under automatic control. Also required are exchanges of data link paths among the RPV's, ground (or air) control stations , and relays as the RPV's pass through the effective antenna patterns. Alternative methods of providing for the above included manual control of all data link acquisitions with operator verification and exchange of RPV control responsibility by voice; automatic control of all data link acquisitions, with operator verification and exchange of RPV control responsibility by voice; automatic control of all data link acquisitions with operator notification of failure to acquire; and exchange of RPV control responsibility by operator-initiated message. The last method was selected as it provides for automatic computation of complex mathematics required for antenna pointing and data link acquisitions, a task rapidly and accurately performed by the machine. Failure to acquire is presented as a caution and warning signal with the operator available to initiate manual acquisition procedures or to effect alternative plans (e.g., programmed return to base). Handoff is a routine procedure most efficiently performed by utilizing canned messages initiated by a discrete operator action. Voice communication will provide a rapid and flexible backup mode to handle abnormal handoff situations.

g. Enroute Vehicle and Mode Control. This function covers the vehicle control methods during the phases of flight wherein multiple vehicles are under control of one operator. The requirement is to insure fully stabilized flight and close adherence to flight plan. The various methods of vehicle control considered during and after the MMI effort were manual flight and guidance control; semiautomatic control and guidance with automatic flight control and manual up-date steering; and programmed guidance and automatic flight control with manual intervention available through outer loop program and mode selection. The last method was selected, in accordance with table 2, as it relieves the operator of routine guidance and flight control duties which would be fatiguing and burdensome during control of multiple vehicles. This method permits control by exception, providing the operator with the capability of changing the internal RPV programs through alternative mode selection and flight reference changes. This method permits the operator to perform his tasks of evaluating the overall conduct of the mission, assuring RPV separation, counteracting enemy threats, and coordinating his handoffs with other operators.

h. Situation Monitoring. This function covers monitoring of the RPV's ongoing situation. Situation monitoring is used by the operators to assure themselves that the vehicles for which they are responsible are performing satisfactorily and safely, and that they are adhering to the mission plan. The methods considered for situation monitoring were visual with the display of relative positions of the vehicles, visual with a readout of the individual coordinates of each vehicle, and fully automatic flight following with appropriate cautions and warnings. The selected method was visual with the display of the relative position of the vehicles. In this method, with the vehicles under automatic flight control, mission progress can be determined by evaluation of the overall positions of the RPV's and separation can be assured by noting their relative positions. Upcoming events and handoffs are automatically displayed to alert the operator. In the other method, the operator would have difficulty in assimilating the situation quickly enough to make a required response.

i. Status Monitoring. This function covers monitoring of both RPV operating subsystems and elements of the DCDRS. The requirement is to assure that all equipments are operating properly and, if a malfunction has occurred, to show which equipment has failed. The monitoring methods include manual judgment and evaluation of multiple operating parameters and automatic fault detection and indication of out-of-tolerance conditions through the use of warning signals. The automatic fault detection method was selected because of the number of variables that must be monitored, the improved judgment provided in assessing the overall operation under diverse operating conditions, and the resulting reduction in required space.

j. Mission Execution. This function is associated with the initiation and control of the prime mission equipment when direct manual participation is not required while the mission is being executed. This occurs during mixed (EW, chaff, photo RECCE, leaflet drop, and area sensor emplacement) and RECCE (ELINT and SIGINT) missions. Methods considered were fully automatic, as a function of vehicle location and time with operator notification, and manual initiation and operator monitoring. The latter method was selected, as the initiation of the prime mission requires a level of responsible operator decision, coordination with external personnel and a judgment of mission situation prior to execution.

k. Target Acquisition and Cueing Aids. This function requires the detection, recognition, and acquisition (DRA) of the target, which precedes the final weapon delivery phase of a mission. During this acquisition phase, the target must be located, positively identified, and subsequently entered into the weapon system through a designating procedure. Methods considered in performing this function include manual visual DRA, automatic pattern recognition for target comparison against stored data, and target location based on a comparison between known coordinates and the navigation position of the vehicle. The manual visual technique was selected, in accordance with table 2, because of the complexity of target patterns and the ability of the human to provide visual perception to the complex task. The human can provide the adaptation required to coordinate the differences between the stored target data and the appearance of the target as it is approached and finally positive target identification. The navigation technique was considered to be too inaccurate, and the automatic pattern recognition technique although potentially useful for operator search cueing has not been demonstrated to provide the necessary adaptation between stored and target data.

The simulation studies conducted at Boeing confirmed that orientation pictures were important in familiarizing the operator with the target area. The familiarization was useful in a process of broad scene scanning to locate prominent features prior to actual target detection, further substantiating the role of manual target detection. As a result of the simulation, it was found that a fixed frame rate in the order of one picture per second would not substantially reduce operator target detection capability.

Having made an initial acquisition of the suspected area, the operator manually controls the zoom level to enlarge the target area for further search. Automatic stops will be provided to the operator to control the zoom to specific values. Zoom size corresponding to the field of view of the EO weapon is particularly important to permit a direct comparison in size between both sensors. This correspondence will aid the operator in transferring the target from the primary sensor to the weapon sensor for final targeting.

The type of image or contrast enhancement needed to suit the particular target characteristics will be preselected before a mission. Cueing aids will automatically indicate the most likely area of target location based on RPV location and navigation and target uncertainties. This data will provide the operator with a most likely area to start his search problem. The cueing will continue to indicate this ground area as the target is approached. Automatic cueing will also be provided for estimated time to target, thereby permitting the operator to predict the approximate size of the target. The time cueing will also assist the operator to compare the scene with the orientation data, which exists at a known distance to the target. Further automatic cue positioning will indicate the alignment between the designated target and the boresight of the vehicle. This alignment will indicate to the operator when the target will probably be located within the field of view of the boresighted weapon head.

Manual controls will be provided to the operator to designate search areas, to commit targets to the system, to steer the aiming cues, weapon head, or vehicle, and to provide image control through zoom and enhancement.

l. Vehicle Control During Weapon Delivery. This function is associated with both the previously discussed target acquisition and with the final weapon delivery phase. Precise vehicle steering is required while the target is being acquired and the weapon is being delivered. Methods considered were manual steering of the vehicle during the acquisition and aiming, and automatic vehicle steering as a function of sensor aiming. The latter method was selected as it permits the operator to concentrate his attention on acquisition of the target and aiming refinement, while still providing the precise vehicle steering required. A two-level task of vehicle steering and target acquisition was considered too much of a burden to the operator and would result in reduced accuracy of weapon delivery.

m. Bomb Damage Assessment. This function is associated with rapid or more thorough evaluation of the strike success. It may or may not be performed by the same vehicle that conducted the strike. The method employed conforms with that selected for the attack on the target; that is, visual detection.

n. Recovery. This function is associated with the method ot recovery employed and will vary for non-runway and runway landings. The methods considered were (1) manual control of the vehicle to provide for positioning in a recovery window or for approach and landing and (2) automatic control of vehicle steering with the operator providing monitoring and outer loop steering control by exception. The latter method was selected as it provides the precision guidance needed to position the vehicle and an acceptable level of operator workload. For a runway landing, visual monitoring may be provided through the EO sensor, if available, or by direct GCA if the EO sensor is not available. When the operator is included in the monitoring loop, he can quickly take over outer loop control (control by exception) to provide a high level of operational success as an independent backup to the automatic control system.

5. SPECIFIC AREAS OF INVESTIGATION

Tables 3 through 6 describe the detailed allocation of functions for the man-machine interface analysis. The tables, which cover planning, ground control (air control is similar), launch and recovery, and DCDRS logistics define the selected methods for performing the required functions and the rationale and key factors that were the driving parameters in the selections. In these allocations, operator performance was considered to be the predominant factor. That is, automation was provided wherever possible to unburden the operator, but not to eliminate operator participation or to remove him from system control. Where pertinent to the man-machine allocation, the factors of cost, risk, schedule, flexibility, growth, and modularity were considered for their impact in the total system interface design.

6. CONCLUSIONS AND RECOMMENDATIONS

The man-machine interface analysis assigned tasks to be performed by the man, tasks to be performed by the machine, and tasks that will be shared. Results of the analysis, conducted on an individual task basis, demonstrated that a high level of automation of many functions is required, but that manual participation in some form is normally necessary. The recommended general allocation of functions is as follows:

- Vehicle guidance and control during all mission phases should be automatic with manual override modes for backup, coordination of certain mission execution phases, and tactical maneuvers or quick reaction replanning.

- Target acquisition and BDA should be performed manually (visual) with automatic and manually controlled cueing aids provided.

- Most situation and status monitoring, mission reporting, and operator and communication handoffs should be performed automatically with the operators participating directly, but in an executive manner.

- Mission and flight planning, orientation and briefing, and check-out and maintenance are offline functions in which computerized and automated equipment should assume a major role, but the operator must participate significantly during briefing operations and planning refinement.

As noted earlier, this man-machine interface analysis was predicated on DCDRS system functional analyses and other studies completed and in-process. While specific conclusions may change as a consequence of design iterations, the aforementioned basic conclusions and recommendations are expected to remain valid.

Table 3. Allocation of Functions Analysis - Planning Station

Function	Selected Method	Rationale (Key Factors)
PREPLANNING		
1. Initiate facility self-test	Manually initiated auto test	Supervisory command required Number of operations (time and cost)
2. Receive and insert FRAG order	Automatic computer entry Manual review	Speed for replanning and amount of data Planning operator appraisal of overall plan required
	Manual insertion	Required for backup and autonomous voice/hard copy input
3. Receive and insert other planning data		
Weather (insert in pictorial displays)	Manual (digital table)*	Manual interpretation and computer insertion required
Threat instruction - EOB	Manual (digital table)*	Manual interpretation and computer insertion required
ATC Coord., AOB, manned aircraft	Manual (digital table)*	Manual interpretation and computer insertion required
Interface, other constraints	Manual (digital table)*	Manual interpretation and computer insertion required
4. Receive resource status	Automatic computer entry Manual review	Speed for preplanning and amount of data Planning operator appraisal of overall resources required
	Manual insertion	Required for backup and voice/hard copy input
5. Process FRAG orders	Manual review	Operator confirmation of developed plan required
Relay optimization	Automatic	Complex mathematical computation
Time optimization	Automatic	Large amount of data handling
6. Process orientation data (TUOC)		
Selection of material	Manual	Human judgment of complex data
Assembly and formatting	Manual, machine aided	Requires manual decisions; machine formatting required
Annotation	Manual	Human judgment relating diverse data; hard copy

*Could be digitized data; auto insert after manual review

Table 3. Allocation of Functions Analysis - Planning Station - Continued

Function	Selected Method	Rationale (Key Factors)
PREPLANNING (Cont)		
7. Flight plan generation		
Flight strips	Automatic hard copy print-out - manual review	Large amount of data; operator confirmation of sample quantities prior to transmit
Flight programs (RPV, relay, ADCF) Flight contingency programs Vehicle time history (command 3d position/velocity/ID and PME actions)	Automatic; with supervisory appraisal through fast time enroute situation display	Detailed complex data; visual confidence check of input/programs required
8. Briefing generation		
Selection and notation of material	Manual	Human judgment of complex data
9. Briefing and rehearsal		
Enroute mission rehearsal	Automatic fast time enroute situation display with verbal information exchange briefer/enroute operator	Provides visual association; keys briefer and operator to pertinent data factors
Terminal mission briefing (see item 5)	Verbal information exchange	Interactive communication
REPLANNING		
10. Additional targets (second strike)*		
Operator reassign	Automatic computer entry	Speed for replanning and amount of data
Handoff reschedule	Manual review	Planning operator appraisal of plan required
Launch and recovery reschedule	Manual insertion	Required for backup and voice/hard copy input
11. Lost vehicles		
Complete time optimization for new vehicle	Automatic	Large amount of data handling
Reschedule for other vehicles as required	Automatic	Large amount of data handling
Flight plan gen. and adjust.	Automatic with supervisory appraisal through fast time enroute situation display	Detailed complex data; visual confidence check of input/programs required

*Strike mission

Table 3. Allocation of Functions Analysis - Planning Station - Continued

Function	Selected Method	Rationale (Key Factors)
REPLANNING (Cont)		
12. Quick reaction capability (TAF)		
Receive special instructions	Automatic computer entry	Speed for replanning and amount of data
	Manual review	Planning operator appraisal of overall plan required
	Manual insertion	Required for voice/hard copy input
Transmit implementation	Automatic; manual review	Large amount of data; operator confirmation of sample quantities prior to transmit
Operator action and verification	Automatic; with supervisory appraisal through fast time enroute situation display	Detailed complex data; visual confidence check input/programs required
13. Backup another DCF*		
Receive mission time history DCF*, channel, codes, failure status	Automatic computer entry	Speed for replanning and amount of data
	Manual insertion	Required for voice input
Revert to emergency condition, stop launch cycle of RPV's	Automatic	Large amount of data handling
Establish communications with lost RPV's* and relays* through backup relay	Automatic	Large amount of data handling
Determine range capability of RPV's*	Automatic	Large amount of data handling
Replan for slowed mission schedule and recovery at L/R* and L/R sites	Automatic	Complex mathematical computation
	Manual review	Operator confirmation of developed plan required
14. Degraded facilities and resources -		
MMI (console, control)	Automatic computer entry	Speed for replanning and amount of data
Computation	Manual review	Planning operator appraisal of overall resources required
Communication	Manual insertion	Required for backup and voice/CW status input

*Facility and elements requiring backup

Table 4. Allocation of Functions Analysis - Ground Control Station

Function	Selected Method	Rationale (Key Factors)
PLANNING (Set up ground station)		
1. Receive control station plan	Data link*/printer	Large information content; permanent copy referral
2. Receive flight strips	Data link*/printer	Multiple copies and categories required
SYSTEM READINESS TESTS AND BRIEFING/REHEARSAL		
1. Initiate facility self-test	Manually initiated auto test	Supervisory command required Number of operations (time and cost)
2. Verify facility operating status	Manual examination	Initial confirmation; continuing checks automatic
3. Obtain resource data and compare with planning requirements	Manual examination	Initial confirmation; further reporting by exception
4. Start replan cycle for contingencies	Manual interpretation and message formulation; computer aided	Executive decision from multiple alternatives
PRELAUNCH		
1. Initiate RPV (or relay) program insertion	Manually initiated	Supervisory command required
Verify program complete	Manually verified	Supervisory appraisal
2. Load and store planning data	Automatic	Number of operations (time and cost)
Verify inserted plan data	Manually verified, all consoles	Operator appraisal required to establish reasonableness
	Automatic data checks	As applicable
3. Verify vehicle/remote installation checkout	Manually verified	Supervisory appraisal
4. Verify vehicle initialization	Manually verified	Supervisory appraisal

*Applicable to quick reaction inputs only; normally hand carried

Table 4 Allocation of Functions Analysis - Ground Control Station - Continued

Function	Selected Method	Rationale (Key Factors)
LAUNCH		
1. Takeoff verification (off report	Manual verification	Operator and supervisor appraisal required
2. Issue conformance report	Interractive canned message (voice backup)	Rapid; unambiguous and error free
Nonconformance report	Manual interpretation and message formulation; computer aided	Executive decision from multiple alternatives
3. Establish vehicle track (ID/pos/direction)	Automatic; manual verification (based on step 1 timing and predicted path)	Accuracy and workload (manual backup available)
4. Imitiate flight data recording and verify	Automatic; manual verification (based on step 3)	Routine task; easily automated (manual backup available)
5. Monitor stabilized path/systems	Manual monitoring	Enroute operator appraisal prior to handoff acceptance
6. Perform on-going functions (standby)	Enroute operator Backup to launch operator	Available as handoff is imminent
7. Handoff to enroute operator	Data communication between operators, voice backup	Positive operator agreement required; voice provides rapid and flexible contingency mode
8. Transmit tracking data	Automatic (DL to TAF)	Large amount of repetitive detailed information required

Table 4. Allocation of Functions Analysis - Ground Control Station - Continued

Function	Selected Method	Rationale (Key Factors)
ENROUTE		
1. Antenna pointing CMD computations	Automatic	High speed mathematical computation
2. Navigation		
Tracking	Automatic	High speed mathematical computation
Updating	Automatic (with manual visual update growth)	High speed mathematical computation (man provides unique visual perception input)
3. On-board status monitoring	Automatic (with manual verification by exception)	Continuous evaluation of a large amount of data (reduced fatigue and improved response to malfunction)
4. Path control	Automatic except as noted below	Accuracy, multivehicle workload
Revised program	Automatic with notification of change	Operator appraisal of new situation required
Override steering/mode control	Manual outer loop control	Operator response to immediate situation; no preprogrammed alternate available
Jinking	Manual select canned manual	Operator appraisal required; vehicle performance; operator workload
5. Situation monitoring	Automatic flight following and threat warning with alert signals, manual responsibility for separation assurance and rendezvous	Multi-vehicle control with independent human appraisal or flexible mission performance
6. Data link handoffs	Automatic with indication; manual intervention for exceptions	Routine task; easily automated (manual backup available)
MISSION EXECUTION		
1. Perform window comparison	Automatic (with manual verification)	Operator appraisal
2. Adjust flight parameters and select modes	Manual outer loop control	Operator response to immediate situation (vernier control)
3. Coordinate mission with TAF elements	Voice communication	Voice provides rapid and flexible coordination mode

Table 4. Allocation of Functions Analysis - Ground Control Station - Continued

Function	Selected Method	Rationale (Key Factors)
MISSION EXECUTION (Cont)		
4. Command PME and verification	Manual initiation and verification	Requires responsible operator decision
5. Receive and transmit PME data	Automatic relay and status	Real time wide band data precludes manual participation except for status monitoring
6. Notification and conduct of orientation (terminal operator)	Automatic notification and manual selection and perusal	Time notification routine automation task maximum flexibility; minimum cost
7. Handoff to terminal operator	Automatic handoff notification and manually controlled data communication between operators	Positive operator agreement required; voice provides rapid and flexible contingency mode
8. Perform weapon (or sensor) checkout	Automatic with manual initiation and verification	Rapid performance evaluation; operator appraisal
9. Perform navigation update (same as item 10 below)		
10. Search and acquisition	Manual search target and commit automatic vehicle steering	Man provides unique visual perception for DRA Precision steering and reduced workload burden
11. Attack, release and BDA	Manual enable and BDA;	Requires responsible operator decision; man provides unique visual perception for BDA Precision steering and release; reduced workload burden
12. Initial mission reporting		
Strike	Manually composed message	Only means for quick BDA
Leaflet drop	Automatic	Operator workload and quick response
Photo RECCE	Automatic	Operator workload and quick response
13. Handoff to enroute operator (same as item 7 above)		
14. Perform enroute ongoing functions (same as enroute items 1 through 6)		

Table 4. Allocation of Functions Analysis - Ground Control Station - Continued

Function	Selected Method	Rationale (Key Factors)
RETURN ENROUTE AND RECOVERY		
1. Respond to request for RPV ID and verification	Manually controlled data communication between operators, voice backup	Positive operator agreement required; voice provides rapid and flexible contingency mode
2. Monitor stabilized path/systems (same as launch item 5)		
3. Handoff to recovery operator (same as launch item 7)		
4. Verify recording and track reporting off	Automatic; manual verification	Operator appraisal required
5. Receive recovery notification and record	Manual	Cost, workload compatible
POST-FLIGHT OPERATIONS		
1. Data extraction		
Flight strips	Manual	Multiple copies must be collected from various consoles
Narrow band	Manual	Large amount of stored data must be collected; automatically moved up to remote processor
Voice, Mission video, orientation data	Manual	Large amount of stored data must be collected for processing and filing
2. Maintenance	Manual; prepare equipment repair request (form 1)	Operator and supervisor judgment and appraisal required
IN-FLIGHT TRAINING AND REHEARSAL		
1. Mission supervision	Manual observation of automatically generated data in fast time at planning station	Visual observation of actual displays/information optimizes performance Slack time and formatted data available at planning station

Table 4. Allocation of Functions Analysis - Ground Control Station - Continued

Function	Selected Method	Rationale (Key Factors)
IN FLIGHT TRAINING AND REHEARSAL		
2. Contingency supervision	Same as 1 except real time	Same as 1 except cannot speed up desired type rehearsal
3. Enroute situation monitoring	Same as 1 above	Same as 1 above
4. Mission execution (RECCE/support	Same as 2 above	Same as 2 above
5. Mission execution	Manual selection of orientation data	One-to-one rehearsal of terminal operator orientation
6. Launch (GNC and status)	Same as 2 above	One or several RPV's sufficient for real time evaluation
7. Recovery (GNC and status)	Same as 2 above	One or several RPV's sufficient for real time evaluation

Table 5. Allocation of Functions Analysis - Launch and Recovery

Function	Selected Method	Rationale (Key Factors)
SYSTEM READINESS TEST		
1. Initiate facility self-test		
Accept test initiation and performance	Manually initiated auto test	Supervisory command required Number of operations (time and cost)
Verify system readiness	Manual examination	Initial confirmation; continuing checks automatic
PRELAUNCH		
2. Accept and store planning data		
Launch sequences and flight strips	Data link*/printer	Multiple copies and categories required
Channel codes and flight programs	Manually initiated Automatic insertion	Supervisory command required Number of operations (time and cost)
Contingency programs	Manually verified	Supervisory appraisal
3. Accept logistics readied vehicle	Interractive message (voice)	Rapid; unambiguous; positive operator agreement
4. Vehicle system checkout		
Establish and verify data link	Manually initiated	Supervisory command required
Initiate vehicle computer check Load and verify flight and contingency program	Automatic	Large amount of data handling
Checkout and verify vehicle systems	Manually verified	Supervisory appraisal
5. Perform vehicle store check	Automatic Manually verified	Number of operations (time and cost) Supervisory appraisal
6. Perform overall vehicle initialization	Automatic Manually verified	Number of operations (time and cost) Supervisory appraisal
7. Configure for launch and desafe	Automatic Manually verified	Number of operations (time and cost) Supervisory appraisal

Table 5. Allocation of Functions Analysis - Launch and Recovery - Continued

Function	Selected Method	Rationale (Key Factors)
LAUNCH		
8. Signal engine start	Manually initiated	Operator command required
9 Provide engine performance analysis and verify	Automatic (with manual verification by exception)	Continuous evaluation of a large amount of data (reduced fatigue and improved response to malfunction)
10. Signal switch to internal power	Automatic	Routine task; easily automated
11. Acquire data link communications (as applicable)	Automatic with indication; manual intervention for exception	Routine task; easily automated (manual backup available)
12. Final flight control and flight programmer check	Automatic (with manual verification by exception)	Evaluation of a large amount of data
13. Execute launch control functions	Automatic (with manual outer loop control by exception)	Accuracy; operator workload Operator response to immediate situation (backup)
14. Provide off report	Interactive canned message (voice backup)	Rapid; unambiguous and error free
15. Monitor vehicle system climbout performance	Manual monitor	Launch operator appraisal prior to handoff to enroute operator
16. Monitor stabilized path systems	Manual monitor	Launch operator appraisal prior to handoff to enroute operator
17. Perform handoff	Data communication between operators; voice backup	Positive operator agreement required; voice provides rapid and flexible contingency mode

Table 5. Allocation of Functions Analysis - Launch and Recovery - Continued

Function	Selected Method	Rationale (Key Factors)
MONITOR ENROUTE AND RECOVERY		
18. Monitor stabilized path/ systems	Manual monitor	Recovery operator appraisal prior to handoff from enroute operator
19. Accept handoff	Data communication between operators; voice backup	Positive operator agreement required; voice provides rapid and flexible contingency mode
20. Monitor vehicle approach	Manual monitor	Recovery operator appraisal prior to recovery
21. Shut down engine, as required	Manually initiated auto sequence	Operator command required; routine detailed tasks; easily automated
22. Jettison fuel, as required	Manually initiated auto sequence	Operator command required; routine detailed tasks; easily automated
23. Deploy recovery system	Manually initiated auto sequence	Operator command required; routine detailed tasks; easily automated
24. Handoff to special recovery guidance	Automatic (with manual outer loop control by exception)	Accuracy; operator workload Operator response to immediate situation (backup)
25. Issue recovery notification	Interactive canned message (voice backup)	Rapid; unambiguous and error free

Table 6. Allocation of Functions Analysis - DCDRS Logistics

Function	Selected Method	Rationale (Key Factors)
1. Provide resource status		
Monitor spares complement	Automatic accounting of available and needed spares	Central bookkeeping needed, implying large amount routine data handling
	Manual data insertion* into computer	Minimum cost, sufficient speed provided
Receive status from TAF maintenance	Automatic	Large amount of data
Schedule DCDRS maintenance	Automatic scheduling; manual revision and monitoring	Focus supervisor's attention to overall requirements and potential problem areas while eliminating multiple routine tasks
Monitor DCDRS maintenance activity	Automatic scheduling; manual revision and monitoring	
Monitor equipment availability		
Recorder supplies	Fully automatic, offline handling	Large amount of data; low priority (emergency reorders manual for increased overall handling speed and response emphasis)
Request non-DCDRS maintenance	(see item 6 below)	
Report DCDRS logistics status	Automatic data transfer	Large amount of data; rapid and timely response
2. Receive equipment orders		
Check availability of equipment	Manual review and selection; automatically prepared lists	Human judgment of acceptability and/or time to complete assessment of multiple alternates
Assign equipment	Manual review and selection; automatically prepared lists	
Perform vehicle buildup	Manual handling and installation**	Minimum cost approach
Transport vehicle to launch	Manual handling and installation**	Minimum cost approach
Adjust resource status	Automatic data transfer	Large amount of data, rapid and timely response

*Spares consumed by maintenance personnel

**Utilizing appropriate transport/handling/alignment vehicles and/or fixtures

Table 6. Allocation of Functions Analysis - DCDRS Logistics - Continued

Function	Selected Method	Rationale (Key Factors)
3. Perform system self-test	(Periodic test of shelf equipment and GSE or preinstallation test of spares)	
Connect equipment	Manual with assist from any handling equipment	Low frequency task; least costly approach
Initiate test	Manual initiation, automatic testing	Minimum number and skills of personnel; amount, speed and accuracy of data
Collect test results	Automatic data transfer	Minimum personnel; amount and speed of data
Modify resource data	Automatic, with manual review and monitoring	Supervisory judgment allows local contingency operation to avoid unnecessary replanning
Transmit resource data	Automatic data transfer	Minimum personnel, amount, and speed of data
4. Receive recovery notification	Voice message, possible alert of maintenance crew	Most rapid, flexible, unambiguous approach
Dispatch transport team*	Manual chart briefing and status data	Most flexible and rapid method
Transport vehicles*	Manually controlled machines	Machine strength, speed required
5. Transfer recorded data*	Manual handling, vehicular aided transport	Minimum cost approach
6. Initiate refurbishment and maintenance		
Perform post-flight inspections	Manual with assist from self-test circuitry and any required handling equipment	Most rapid, flexible, thorough, and economical approach
Remove and replace defective LRU	Manual with assist from self-test circuitry and any required handling equipment	Most rapid, flexible, thorough, and economical approach
Transport defective LRU to repair station	Manual with assist from self-test circuitry and any required handling equipment	Most rapid, flexible, thorough, and economical approach
Request non-DCDRS maintenance	Manual, contingency operation only (voice)	Positive intercommunication required to achieve desired performance
Initiate DCDRS LRU repair	Manual with assist from field support equipment	Fully automatic repair cycle not feasible
Monitor maintenance activity	(see item 1 above)	(see item 1 above)
Adjust resource status	Automatic data transfer	Large amount of data; rapid and timely response

*Not specific DCDRS functions

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Airborne drone control facility (ADCF)						
Air data system (ADS)						
Air Force Logistics Command (AFLC)						
Air Force Systems Command (AFSC)						
Aerospace ground equipment (AGE)						
Alphanumerics (A/N)						
Air order of battle (AOB)						
Air traffic control (ATC)						
Bomb damage assessment (BDA)						
Built in test equipment (BITE)						
Character generator and refresh memory (CG and RM)						
Communications intelligence (COMMINT)						
Central processor unit (CPU)						
Control reporting center (CRC)						
Control reporting post (CRP)						
Character and vector generator (CVG)						
Direct air support center (DASC)						
Drone control and data retrieval system (DCDRS)						
Drone control facility (DCF)						
Digital data link (DDL)						
Differential phase shift keying (DPSK)						
Data source terminal (DST)						
Electronic countermeasures (ECM)						
Environmental control unit (ECU)						
Electronic intelligence (ELINT)						
Electromagnetic compatibility (EMC)						
Electromagnetic interference (EMI)						
Electro optical (EO)						
Electronic order of battle (EOB)						
Electrical power generator (EPG)						
Forward air control post (FACP)						
Forward edge of battle area (FEBA)						
Fragmentary (order) (FRAG)						
Ground control station (GCS)						
High altitude reconnaissance center (HARC)						
Integrated logistics support (ILS)						
Land line interface (LLI/F)						
Launch and recovery (L/R)						
Launch and recovery control facility - low value (LRCF-LV)						

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Launch and recovery control facility - high value (LRCF-HV)						
Multibeam (MB)						
Omnidirectional (OMNI)						
Operations and planning station (OPS or O/PS)						
Pulse code modulation (PCM)						
Precision emitter locator (PEL)						
Prime mission equipment (PME)						
Performance monitoring system (PMS)						
Pseudorandom noise (PN)						
Phase shift keying (PSK)						
Rocket assisted takeoff (RATO)						
Reconnaissance (RECCE)						
Radius of action (ROA)						
Remotely piloted vehicle (RPV)						
Special repair activity (SRA)						
Strike support (SS)						
Tactical air control center (TACC)						
Tactical air control system (TACS)						
Tactical air force (TAF)						
Tactical information processing information (TIPI)						
Time of arrival/distance measuring equipment (TOA/DME)						
Transmit and receive (T/R)						
Track support unit (TSU)						

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