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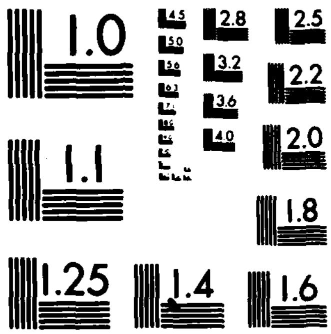
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TACTICAL DIVISION NOTE
TDN 86-2

THE UNMANNED AIR RECONNAISSANCE SYSTEM

Briefing given at
13th Annual Association for Unmanned Vehicle Systems
(AUVS) Symposium
21 July 1986

July 1986

Prepared by
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Manager
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ANSER

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THE UNMANNED AIR RECONNAISSANCE SYSTEM

Robert B.Piper
Benjamin Glatt
*ANSER, Arlington, Virginia

July 1986

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OVERVIEW

- CURSORY LOOK AT VIETNAM EXPERIENCE
- DEFICIENCIES IN RECONNAISSANCE RPVs
- GENERIC UNMANNED AIR RECONNAISSANCE VEHICLE (UARV)
- UARV MISSIONS AND CONCEPT OF OPERATIONS
- DATA RATES
- DATA LINK
- GENERIC DATA-LINK COST
- COST EFFECTIVENESS
- CONCLUSIONS

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OVERVIEW

This study and associatied substudies were precursors to the Tactical Air Reconnaissance System (TARS) and the Unmanned Air Reconnaisance System (UARS) programs. The TARS program will develop the sensors for the UARS, and the UARS program will develop an unmanned vehicle jointly with the Navy.

This slide depicts the outline for the briefing.

The study first assessed our Vietnam experience with remotely piloted vehicles (RPVs) and documented the problems/deficiencies with these systems.

From this data, a generic UARV was defined.

With the generic vehicle design as a constraint, the UARS Mission and concept of operations were developed. This was actually an iterative process (i.e., matching missions, concepts of operation, sensors and vehicle characteristics).

The data rates were treated separately in the study because electro-optical (EO) and infrared (IR) digital systems generate an enormous amount of data, and handling this data is a major problem for these systems.

Data links were also treated separately because they present a problem for the UARV in terms of power requirements, size, weight, and cost.

The cost presented are for the generic UARV and only indicate the general magnitude of the cost.

Cost/effectiveness will be discussed briefly.

Conclusions.

UNMANNED AIR RECONNAISSANCE VEHICLE (UARV): VIETNAM EXPERIENCE

BUFFALO HUNTER

MAY—JULY 1972

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UNMANNED AIR RECONNAISSANCE VEHICLE (UARV): VIETNAM EXPERIENCE

BUFFALO HUNTER

Buffalo Hunter was the code name for a reconnaissance RPV program in Vietnam from 1969 to 1972.

Buffalo Hunter operated out of U-Tapao. The reconnaissance vehicle was a Ryan SPA-147SC (a modified BQM-34). The RPVs were launched from C-130s and generally recovered by a CH-3 Helicopter (air recovery). The vehicle design and configuration was greatly influenced by the urgency of the Department of Defense (DOD) request. Thus, existing vehicles, cameras, and guidance systems were used to meet the requirements.

The following slides review the target coverage rate of the SPA-147.

BUFFALO HUNTER TARGET COVERAGE: MAY—JULY 1972

TARGETS ATTEMPTED:	1,114
TARGETS LOST:	422
TARGET COVERAGE RATE:	62%

THE 422 TARGETS WERE LOST FOR THE FOLLOWING REASONS:

NAVIGATION:	257 (23%)
LOST RPV:	96 (9%)
CAMERA MALFUNCTION:	40 (4%)
WEATHER:	25 (2%)
UNKNOWN:	4 (0.4%)

SOURCE: BUFFALO HUNTER EFFECTIVENESS UPDATE (U) HQ PACAF, JAN 1973

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BUFFALO HUNTER TARGET COVERAGE: MAY-JULY 1972

This slide documents the target coverage rate from May through July 1972. The data are from a study performed by Pacific Air Forces (PACAF) in 1974.

Two important points:

- o Coverage (62 percent) was acceptable
- o Major cause for target loss was navigation errors

These data indicate the amount of planned targets actually covered; they do not include the numerous targets of opportunity that RPVs covered. The RPVs gained a number of firsts (i.e., the first SAM-2 photographed). The value of these "free-bees" was degraded by the same navigational problems that caused the loss of planned targets. Because of inaccuracies in navigation, the interpretors were unable to reconstruct the mission profile and determine with any accuracy the location of these targets.

BUFFALO HUNTER EXPERIENCE: 1969—1972

TARGETS WERE LOST FOR THE FOLLOWING REASONS:

NAVIGATION:	48.5 %
ATTRITION:	20.9 %
WEATHER:	26.3 %
MALFUNCTIONS:	4.3 %
TARGET COVERAGE RATE:	40.5 %

NAVIGATION WAS THE MAJOR SOURCE OF FAILURE OF UNMANNED SYSTEMS.

SOURCE: BUFFALO HUNTER EFFECTIVENESS UPDATE (U) HQ PACAF, JAN 1973

BUFFALO HUNTER EXPERIENCE:
1969-1972

This slide shows the experience from 1969 to 1972.

Lost targets were caused mostly by navigational errors.

The target coverage rate was lower because of the higher attrition and weather losses.

RECONNAISSANCE RPV DEFICIENCIES

- NAVIGATION
- REAL-TIME IMAGERY
- NIGHT/ALL-WEATHER OPERATIONS

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RECONNAISSANCE RPV DEFICIENCIES

Vietnam RPVs did not have a navigation system that was accurate enough to consistently place the vehicle over planned targets.

The RPV carried a film camera. This required that the vehicle return to base; the film be down-loaded, delivered to a photo-processing and interpretation facility, and developed; and the photo-interpretors review the film and prepare the intelligence reports. Thus, when the vehicle returned undamaged and with usable exposed film, there was still much time before intelligence information was available.

The film camera was a clear-daylight system. There were some attempts to use a flash system at night, but the system was essentially limited to clear weather and daytime. Attempts were made to fly the vehicle either under the clouds or in areas that were clear of weather. As shown on the previous slide, a number of missions were lost due to weather.

GENERIC UARV CONFIGURATION

- FORWARD OBLIQUE OR WIDE-ANGLE VERTICAL EO CAMERA
- IR LINESCANNER
- DATA LINK
- GPS/INS NAVIGATION SYSTEM
- TAPE RECORDER
- DATA MANAGEMENT SYSTEM
- PARACHUTE/AIR BAG RECOVERY SYSTEM

GENERIC UARV CONFIGURATION:

Based on the Vietnam experience, we developed the following design configuration for the UARV:

Because they offer real-time imagery, haze penetration, extended photographic days, and picture enhancement possibilities, EO cameras were chosen to replace the film cameras.

The IR linescanner represents the best night/all-weather capability available. There would be a digitized system for real-time imagery transmissions.

The data link is essential for real-time imagery transmission.

A GPS/INS navigation system will provide the navigational accuracy that reconnaissance systems require.

There will be a need for a high-density, high-speed tape recorder to store imagery data obtained during the mission.

The data management system turns the equipment on and off, routes sensor data from the cameras, annotates the tape records with time and location data, digitizes and compresses the IR linescanner data, and processes all digital signals for the tape recording and/or data link transmission.

Given the UARS cost estimates (shown later in this briefing), the author believes this system will be too expensive to be expendable. The UARV must be recoverable and easily/quickly turned around.

UARS MISSIONS

- HEAVILY DEFENDED TARGETS
- REVISIT OF TARGETS PREVIOUSLY FOUND BY MANNED SYSTEMS
- BOMB DAMAGE ASSESSMENT
- FIXED TARGETS
  - —AIRFIELDS
  - —BRIDGES
  - —RAIL HEADS
  - —HIGHWAY CHOKE POINTS

UARS MISSIONS

What missions can the UARS perform? What missions should the UARS perform?

We decided the UARS should be designed for specific target types from the myriad of targets that must be covered. The UARS would augment the manned systems, making the total reconnaissance force more effective.

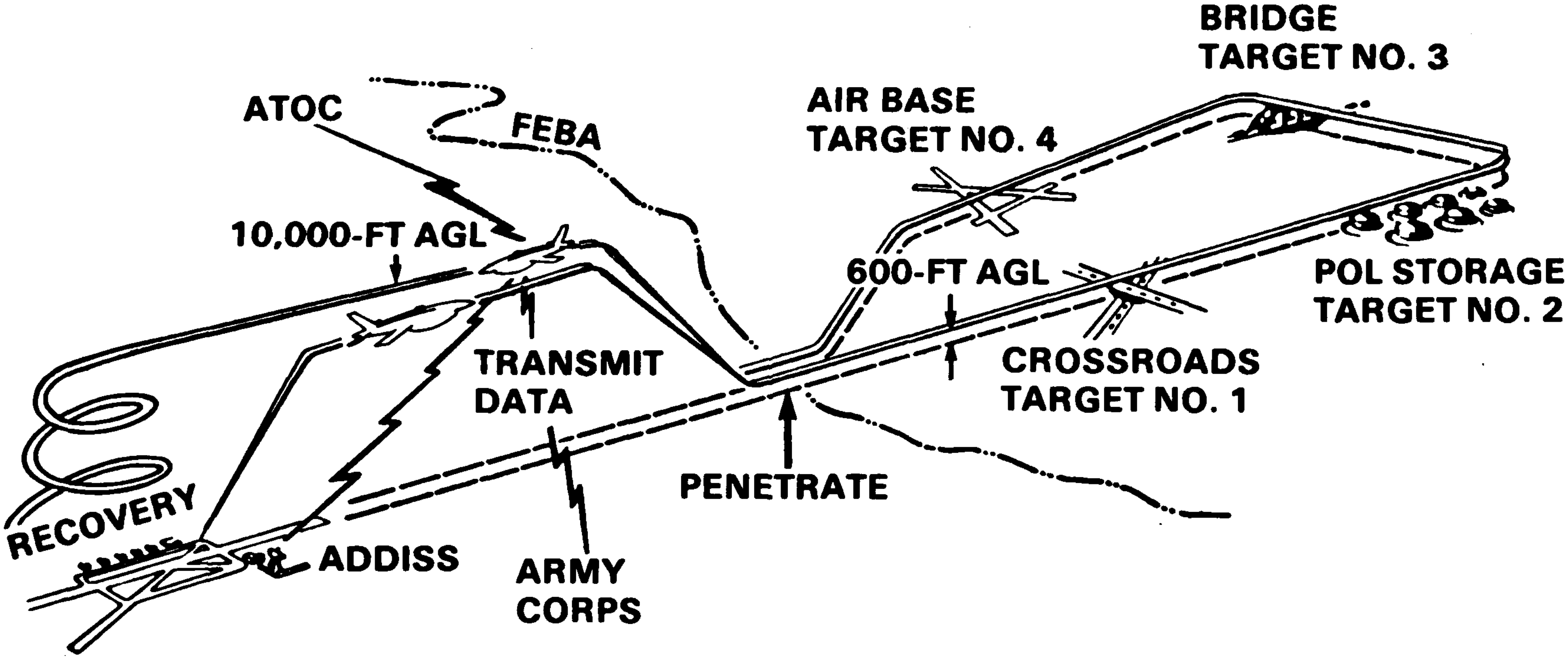
The UARS is ideally suited for missions against heavily defended fixed targets.

It does not appear feasible at this time to provide a UARS with the complex artificial intelligence (AI) necessary to allow it to respond to targets of opportunity as would be necessary in an area search or road reconnaissance. Also, because of the high data rates generated by EO and IR sensors, it does not appear cost effective to tape everything on ingress and egress.

BDA and target revisits are also a good use of the UARS, particularly if the targets are heavily defended.

The Theater Intelligence, Reconnaissance, and Surveillance (TIRS) study revealed that in a European scenario, there are almost a limitless number of reconnaissance targets, and augmenting the force with the UARS will allow concentration of more manned systems against targets that require a man in the loop for detection and/or recognition of threat systems or activities.

TYPICAL TACTICAL RECONNAISSANCE MISSION (HI-LO-LO-HI)



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CONCEPT OF OPERATIONS

In a combat scenario, the HI-LO-LO-HI mission would be a typical profile for the UARS. This profile would minimize the UARV's exposure to defenses by minimizing its time in a defense system envelope and minimizing the total number of defenses that can engage the UARV.

In other scenarios, the mission may call for a mid-altitude standoff profile or, if defenses are light, a mid-altitude overflight.

In this scenario, the UARV would overfly a number of preplanned, fixed targets. It is assumed that the sensors would be programmed to operate only in the target areas, and imagery data would be recorded and transmitted via data link during egress.

Given the planned missions and the concept of operations for the UARS, the generic UARV is further defined on the next slide.

GENERIC UARV (REQUIREMENTS)

AERODYNAMIC ENVELOPE	LOW- AND MEDIUM-ALTITUDE MISSIONS
LONG RANGE	COUNTER-AIR AND INTERDICTION TARGETS
FAST	HIGH SUBSONIC SPEED
LARGE PAYLOAD	300 LB
NIGHT/ALL-WEATHER CAPABLE	IR SENSORS
REAL-TIME INTELLIGENCE	DATA LINK
RECOVERABLE	PARACHUTE/AIR BAG RECOVERY
LAUNCH OPTIONS	EITHER GROUND- OR AIR-LAUNCH CAPABILITY

GENERIC UARV
(REQUIREMENTS)

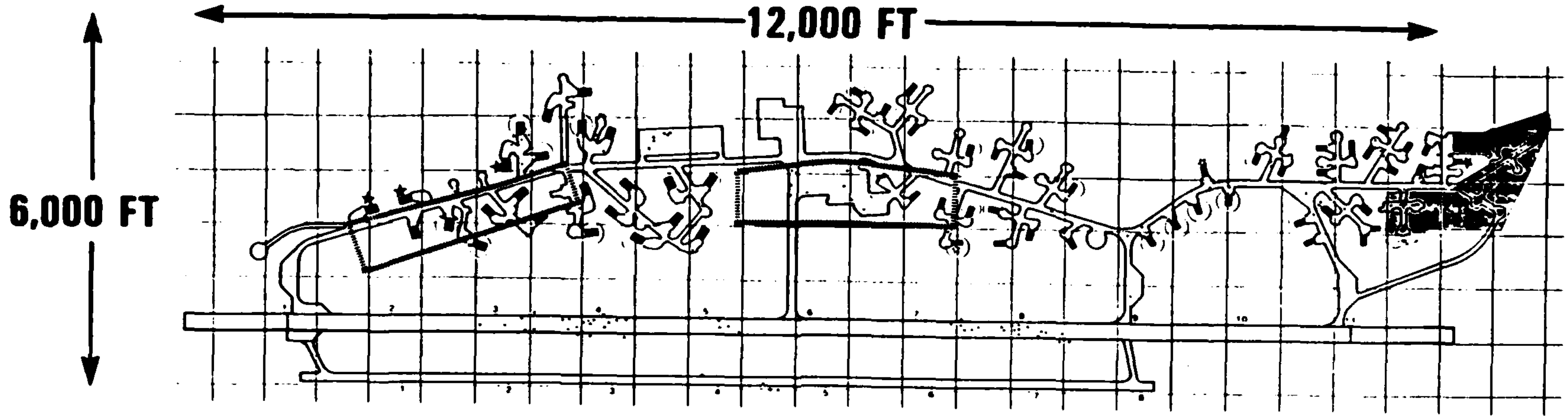
To cover all possible reconnaissance requirements, the UARV must be able to operate throughout most of the aerodynamic envelope currently used by the manned systems.

The location of many of the counter-air and interdiction targets requires that the UARV have "long legs."

The need for IR sensors, a data link, and a recovery system have been covered previously.

The air-launch option would allow the UARV's "legs" to be extended. It also may be the fastest way to respond to contingency requirements.

AIRFIELD TARGET—DATA RATES



- AREA SAMPLED
  - —(2 x 6,000) x (2 x 12,000) = 288 MEGASAMPLES
  - —8 BITS/SAMPLE = 2,304 MEGABITS
- SAMPLE RATE
  - —500 KNOTS = 844 FT/SEC
  - —TIME TO RECORD DATA = 12,000/844 = 14.2 SEC
- DATA RATE
  - —2,304/14.2 = 162 MEGABITS/SEC

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AIRFIELD TARGET - DATA RATES

As mentioned previously, one of the problems with EO and IR digital systems is that they generate data at extremely high rates.

This slide is included to explain why the data rates are so high.

The target selected is an airfield. To cover the airfield, it is assumed that you would need to survey an area 6,000 feet wide by 12,000 feet long. This should guarantee that you cover all hangers, revetments, taxiways, runways, and so forth.

If the resolution desired is 1 foot, then the scene should be sampled at 1/2-foot intervals (Nyquist Frequency*). Therefore, for this target there would be 288 megasamples.

If you use 8 bits/sample, you can show 256 shades of gray in your picture, and the EO picture would be indistinguishable from the original scene. This results in 2,304 megabits for this target.

Assuming the data is collected in a single pass at 500 knots (844 ft/sec), the time needed to record the data is 14.2 seconds.

Thus, the data rate for this target at this airspeed is approximately 162 megabits/sec.

This would be typical of the data rates of a single EO sensor. An IR linescanner can have four times this rate.

This quantity of data is more than any current, small, aircraft-certified tape recorder can handle. Therefore, this study assumed some data reduction would be necessary.

* The Nyquist Frequency is the sampling frequency required to guarantee that the imagery data is unambiguously sampled.

DATA RATE REDUCTION

- REDUCE THE NUMBER OF BITS PER SAMPLE (DATA COMPRESSION)
- SEND DATA AT A SLOWER RATE THAN RATE AT WHICH IT IS RECEIVED
- COMBINATION OF THE FIRST TWO

DATA RATE REDUCTION

There are three ways to reduce the data rate:

- Data Compression: Data compression can and should be done, but the amount of compression one can make without a loss of resolution is limited by the entropy of the scene. Data compression techniques take advantage of the correlation between successive samples. Thus, the more correlation, the more one can compress the data without losing resolution. The target chosen for this study should have large areas of high correlation such as the runways, the grass strips between and around the runways, and the hangers. It should be possible to compress these data to 2 bits/sample (vice 8). Targets with high entropy, such as a tank regiment (dug in and camouflaged), would have very little correlation between successive samples. These targets would require more bits per sample to guarantee the resolution, but studies show that it will still be possible to reduce the data to at least 4 bits/sample (vice 8).

- Record/Transmission Rates: One can use a buffer in the system to allow the data either to be recorded or transmitted at a slower rate than the collection rate.

  This study assumed that data compression would be used, and two levels of data compression (2 and 4 bits/sample), were considered.

- Combination of First Two: The data rate can be reduced by using a combination of the previous two methods.

DATA LINK TRADEOFFS

- DATA RATES: FUNCTION OF
  - —SENSOR DATA RATE
  - —HOW MUCH OF THE DATA YOU NEED
  - —HOW FAST YOU NEED IT
- RANGE: FUNCTION OF
  - —LINE–OF–SIGHT
  - —TRANSMITTER/RECEIVER POWER
  - —TRANSMITTER/RECEIVER ANTENNA GAIN
  - —SIGNAL-TO-NOISE RATIOS
  - —BANDWIDTH
  - —JAMMING
- COST: FUNCTION OF
  - —ALL OF THE ABOVE!!!!!!

DATA LINK TRADEOFFS

The data link selected is a function of the amount of data to be transmitted, the data rate, and the transmission distance. These factors all effect the size, weight, power requirements, complexity, and cost of the selected system.

This study concluded that data link relays to either a satellite or an aircraft were too costly, complex, and easily jammed for consideration in the UARS.

Two generic data links were considered. A 240-megabits/sec system and a 15-megabits/sec system.

The 240 megabits/sec system could easily transmit the data generated by one sensor covering the airfield in the study, but the data must be compressed to get it on the tape recorder. The tape recorder is the storage medium until the UARV is within the ground station's line of sight. The tape recorder is also the backup system (i.e., the tape can be processed after the UARV is recovered.

The 15 megabits/sec system would require the data to be transmitted at a slower rate than the collection rate. This could be done by using the tape recorder as the buffer.

ESTIMATED COST OF GENERIC UARV

	THOUSANDS OF DOLLARS
AIRFRAME	500 - 1,000
ENGINE	50 - 100
EO SENSORS	100 - 250
IR LINE SCANNER	300 - 500
RECORDERS	100 - 200
SYSTEM MANAGER	100
DATA LINK	80 - 200
NAVIGATION SYSTEM	100
TOTAL	1,330 - 2,450

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ESTIMATED COST OF GENERIC UARV

The costs shown here are based on contractor estimates and are subject to all the standard caveats.

- Airframe: The airframe must be large and fairly complex to meet mission requirements(i.e., carry EO and IR sensors, a GPS/INS navigation system, a data link, a tape recorder, and a data management system, and penetrate deep into enemy territory at low level.

- Engine: There are very few off-the-shelf engines for this vehicle, and their prices vary with their expected fuel specifics and reliability.

- EO Sensors: The cost of the EO sensors will depend on quantity, time, and complexity. Commonality between manned and unmanned, Air Force and Navy, should reduce the unit cost.

- IR Linescanner: The IR systems are still the most complex and expensive of the sensors. These prices may decrease, but it does not appear that this will occur in the near future.

- Recorders: Many companies are working in the field of high speed, high-density recorders and this may drive the cost down. Currently, only the tape recorders cañ work at the high data rates required by imagery systems. Other systems have the storage capacity but cannot operate at the required data rates.

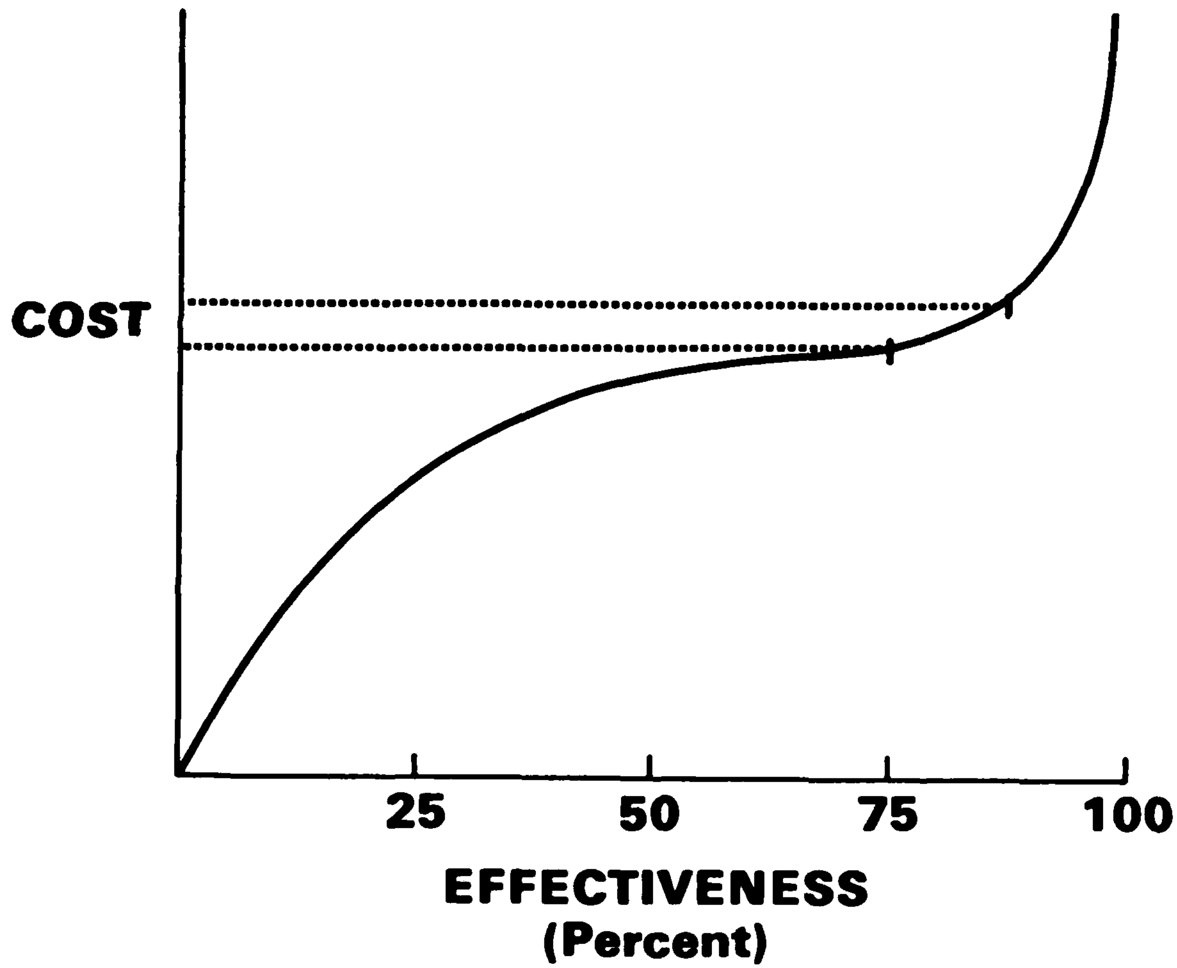
- System Managers: The cost of the management system will be a function of the tasks required. Data-compression software/ hardware and the associated buffer will represent a large portion of the cost.

ESTIMATED COST OF GENERIC UARV (cont)

- <u>Data Link</u>: These prices represent the range of possible data links from the narrow-band system with the omnidirectional antenna to the system with a trainable antenna. Installation costs and space problems for the wide-band system were not included in this study.

- <u>Navigation System</u>: This is the low end of the GPS/INS navigation system. This assumes a rather simple INS that is updated frequently by the GPS system, thereby maintaining required accuracy.

COST VERSUS EFFECTIVENESS OF THE UNMANNED AIR RECONNAISSANCE SYSTEM



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COST/EFFECTIVENESS

This slide is included only to emphasize that there is a minimum amount of money that must be spent to implement a UARS that can effectively perform the reconnaissance mission as defined in the Tactical Air Command (TAC) Statement of Operational Need (SON).

The UARS must be able to

- o Penetrate deeply into heavily defended territory
- o Operate in all weather* and at night
- o Provide imagery with high resolution
- o Provide real-time or near-real-time intelligence.

An unmanned reconnaissance system with this capability is expensive.

This study has not modeled the UARS against the threat, but previous studies have shown that the UARS can suffer rather high attrition and still be cost effective. This is true because the UARS has historically cost one-tenth the manned system. Our cost estimates indicate that this will still be the case, and attrition studies indicate that a low, high-speed, small target should have a high probability of survival.

The cost driver is the need for a rather sophisticated sensor suite. The vehicle's survival is meaningless if it cannot gather the required intelligence.

* All-weather operation is the objective of the reconnaissance SON, but the systems currently being considered are for under-the-weather day/night reconnaissance.

CONCLUSIONS

- EXISTING TECHNOLOGY PROVIDES UARS CAPABLE OF EFFECTIVELY AUGMENTING MANNED RECONNAISSANCE SYSTEMS
- UARS COULD BE EMPLOYED TO COVER HEAVILY DEFENDED POINT TARGETS
- INS/GPS NAVIGATION SYSTEM MEETS SYSTEM ACCURACY REQUIREMENTS
- IR LINE SCANNER AND ELECTRO-OPTICAL DAY VISUAL CAMERAS PROVIDE DAY/NIGHT UNDER-THE-WEATHER CAPABILITY
- DATA LINK OF DIGITAL INFORMATION PROVIDES NEAR-REAL-TIME INTELLIGENCE

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This was a briefing given at the 13th Annual symposium of the Association for Unmanned Vehicles Systems (AUVS). The study took a cursory look at the experience in Vietnam with Unmanned Reconnaissance Systems, identified defiencies, and proposed a generic unmanned system for the next generation of reconnaissance vehicles.

The study concluded that: the technology exists today to produce an unmanned reconnaissance system that could operate effectively aganist fixed targets. The UARS could have a day/night under-the-weather capability and provide near-real-time intelligence.

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