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AIRPORT VISIBILITY MEASURING SYSTEMS ELEMENTS OF DEPLOYMENT COST ANALYSIS

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16. Abstract

This report analyzes the deployment cost for different visibility measuring systems necessary to satisfy CAT I, II, and III operations. The analysis is based on airport operational requirements and data for commercially available visibility measuring equipment.

Estimated deployment schedules of visibility measuring equipment for the FY76-FY85 period are developed. Visibility equipment requirements for each runway category are identified. Eight (8) selected airports are analyzed for their existing visibility equipment, future plans and estimated requirements. Cost comparisons of various alternatives are performed for typical visibility measuring systems.

Commercially available visibility measuring equipment relevant to airport operation are listed and described. Specification and performance characteristics as well as cost factors are considered.

The deployment cost for the SVR system which may become operational in the next few years is investigated. The deployment cost for the airport visibility system (ARVIS) developed by TSC as well as modification kits for the FAA/NBS transmissometer system are analyzed.

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PREFACE

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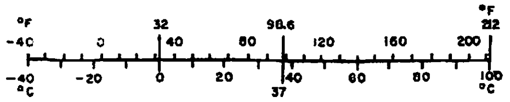
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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LIST OF ABBREVIATIONS AND SYMBOLS

a	Weighting factor (see Equation 16)
$a_0 \ldots a_3$	Constants (see Equation 6)
A	Instrument Approach Factor
A/C	Aircraft
ACÉC	Ateliers de Constructions Électriques de Charleroi, S.A., Belgium
A/D	Analog to Digital Converter
AEG	Allgemeine Elektricitats - Gesellschaft
AEP	Annual enplaned passengers
AF	Air Force
AFCRL	Air Force Cambridge Research Laboratories
AIA	Annual Instrument Approaches
ALCH	Approach Light Contact Height
ARVIS	Airport Visibility System
ASI	Aerospace Systems, Inc.
ASTC	Airport Surface Traffic Control
ATCT	Air Traffic Control Tower
ATIS	Airport Terminal Information System
CAB	Civil Aeronautics Board
CAT I	Category I
CAT II	Category II
CAT III	Category III
CIF	Cost, Insurance, and Freight
CL	Centerline Lighting
CPCU	Control Processor and Control Unit
CRT	Cathode Ray Tube

d	Distance from 100-foot DH to approach runway light bars
d'	Slant visual range
DH	Decision Height
DOD	Department of Defense
E/G	Engine Generator
EG&G	Edgerton, Germeshausen and Grier
E_T	Eye Illuminance threshold
F_A	Constant depending upon approach runway light setting
FAA	Federal Aviation Administration
FDDS	Flight Data Distribution System
FDM	Frequency Division Multiplexing
FFM	Flugwissenschaftliche Forschungsanstalt, Munich
FOB	Free On Board
F_R	Constant depending upon high intensity runway light setting
FSM	Forward Scatter Meter
F&E	Facilities and Equipment
Hz	Hertz
i	Discount Rate
I	Luminous Intensity
I_A	Intensity Approach Light
I_R	Intensity Runway Light
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
I/O	Input/Output
IRA	Industrial Research Associates, Inc., Baltimore, Maryland
L_{100}	Reading of the 100-foot luminance meter (foot-Lamberts)

LED	Light Emitting Diode
Lidar	Light Detection and Ranging
LSI	Lear Siegler, Inc.
LSI	Large Scale Integration
MOD	Modification
MRI	Meteorological Research, Inc.
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
n	Useful economic life
NA	Not Applicable
NAD	Naval Ammunition Depot (name changed to NWSC)
NAFEC	National Aviation Facilities Experimental Center
NASPS	National Aviation System Policy Summary
NBS	National Bureau of Standards
NI	No information
NPA	Non-Precision Approach
NTSB	National Transportation Safety Board
NWS	National Weather Service
NWSC	Naval Weapons Support Center
O&M	Operations and Maintenance
P	Passenger factor
R_{I}^{fy}	Upgraded Category I runways per fiscal year
R_{II}^{fy}	Upgraded Category II runways per fiscal year
R&M	Relocation and Modification
RVO	Runway Visibility by Observer
RVR	Runway Visual Range
RVV	Runway Visual Value
SDCU	Signal Data Converter Unit

S_I	Total RVR systems for Category I runways to be deployed in the FY76-FY85 period
S_I^{fy}	RVR systems for Category I runways to be deployed per fiscal year
S_{II}	Total RVR systems for Category II runways to be deployed in the FY76-FY85 period
S_{II}^{fy}	RVR systems for Category II runways to be deployed per fiscal year
SMSA	Standard Metropolitan Statistical Areas
STOL	Short Take-Off and Landing
SVR	Slant Visual Range
TACAN	Tactical Air Navigation
TDM	Time Division Multiplexing
TDZ	Touchdown Zone
TIPS	Terminal Information Processing System
TRACON	Terminal Radar Approach Control
TSC	Transportation Systems Center
TVR	Taxiway Visual Range
T_W	Aircraft windshield optical transmittance
t_1	New reading of atmospheric transmittance
T_0	Previous mean atmospheric transmittance
T_1	Updated mean atmospheric transmittance
V	Visibility factor
VFR	Visual Flight Rules
VIZ	Mean number of annual hourly observations with Visibility $\leq 1/2$ mile
VOR	Very high frequency omnidirectional range
VORTAC	Combined VOR and TACAN system

$\bar{\sigma}$	Mean atmospheric extinction coefficient
σ_a	Allowable extinction coefficients
σ_T	Extinction coefficient at touchdown transmissometer
σ_{10}	Extinction coefficient measured at the SVR tower 10-foot level
σ_{100}	Extinction coefficient measured at the SVR tower 100-foot level.

1. INTRODUCTION

The instrumented measurement of visibility at airports was instituted by the Federal Aviation Administration (FAA) in 1952 by means of a transmissometer system developed by the National Bureau of Standards (NBS) in 1942. Since then, many similar systems have been deployed in the United States by the FAA as well as other Government agencies (NWS, AF). At present, approximately 350 RVR systems have been deployed, and it is expected that during the next ten years the FAA requirements will call for additional RVR systems. In addition, a large number of existing systems will require retro-fitting and/or upgrading in performance from RVV to RVR. Also, in addition to the current RVR airport requirements, it is expected that the experimental SVR developed by the Naval Weapons Support Center (NWSC), formerly Naval Ammunition Depot (NAD), Crane, Indiana, could become a requirement for all airports with Category II and/or III runways.

Since 1971 the Optical Devices Section of the Transportation Systems Center (TSC), under sponsorship of the FAA, has been carrying out a program of RVR hardware and systems analysis and development. This effort led to the Airport Visibility Measuring System (ARVIS), a systems approach to airport visibility measurement. This system considers the capital investment of deployed FAA/NBS RVR systems, future airport requirements, maintainability and control concepts which will allow changes in systems characteristics through software changes. Also, ARVIS has the capability of complete data logging which allows the visibility description of the airport as well as the photometric status of the visual cues (different airport lights), atmospheric background, and operational conditions of the instrumentation to be recorded at selected periods (5 sec minimum).

This report presents the deployment schedules of FAA visibility measuring equipment requirements for the FY76-FY85 period and develops the elements of deployment cost. This information could form the basis for judgment in the decision-making process on future deployment and/or upgrading of visibility measuring equipment.

2. OBJECTIVE

The prime objective of this study is to conduct an airport visibility measuring system elements of deployment cost analysis. This analysis shall state the elements of deployment for different visibility measuring systems to satisfy CAT I, II, and III operations. The analysis shall be based on commercial equipment characteristics and cost, as well as airport operational requirements.

The deployment schedules of visibility equipment shall be for the FY76-FY85 period. The visibility equipment requirements for each runway category shall be identified. This analysis could be used as a basis to forecast FAA needs over the next ten fiscal years. Eight selected airports shall be analyzed for their existing visibility equipment, future plans and requirements. Elements of cost for various equipment alternatives shall be given.

Commercially available visibility measuring equipment relevant to airport operation shall be listed and described. Relevant specification and performance characteristics as well as cost factors shall be considered.

The elements of cost for deployment of the SVR system, which may become operational in the next few years, shall be investigated.

The Optical Devices Section of TSC is engaged in developing an ARVIS which can be evolved by means of modification kits (Modifications I-IV) from the present FAA/NBS transmissometer systems which are used to measure RVR. The development of the ARVIS is based on the premise that the system is the Airport and what is known today as "RVR System" is in fact an ARVIS Subsystem. Therefore, the ARVIS concept allows system growth to meet all airport visibility category requirements. The existence of RVR systems at airports makes the ARVIS a candidate for use at these airports. To evaluate the modification and ARVIS concept in relationship to the existing FAA and other RVR candidate systems, the following points shall be considered:

> How the ARVIS (Mod III) compares (cost, type of information and capability) with other candidate systems for measuring and reporting visibility along the runway.
>
> Whether the minicomputer for the Mod II can be utilized as a replacement for the signal data converter used with the FAA/NBS transmissometers.

The comparison shall be based on typical airport installations, and elements of deployment costs shall be generated.

3. OPERATIONAL FAA VISIBILITY INFORMATION

This section includes descriptions of information regarding visibility conditions which is gathered, measurement techniques and current methods for data dissemination.

3.1 VISIBILITY INFORMATION

One important factor in operational decisions in aviation is the accuracy of weather analysis and forecasting. Weather prediction and visibility information depend on measurements by human observers and/or instruments.

There are basically two types of visibility measurements reported to the pilot as part of the weather information for the terminal area: 1) prevailing visibility measured by qualified human observers, and 2) Runway Visibility Value (RVV) and Runway Visual Range (RVR) measured by instruments.

Prevailing visibility is the greatest horizontal visibility prevailing throughout at least half of the horizon circle (not necessarily continuous). Prevailing visibility is determined from the control tower level or from some other predetermined site. Variable prevailing visibility is a condition during which the prevailing visibility rapidly increases or decreases by one or more reportable values during the period of observation and is less than three miles. Sector visibility is the greatest distance within a specified portion of the horizon circle at which reference markers having essentially uniform visibility can be seen and identified. Visibility is measured and reported in statute miles, and the values are reported in discrete steps, with the size of the steps increasing with the visibility.

Of primary concern in this report are the two instrumented visibility values, RVV and RVR. RVV is defined as the visibility along an identified runway. Where a transmissometer is used for measurement, the instrument is calibrated to indicate values comparable to those that would be seen by a human observer.

RVR is defined as the maximum distance in the direction of takeoff or landing at which the runway, or the specified lights or markers delineating it, can be seen. RVR corresponds to the visibility from a position above a specified point on the runway centerline at a height corresponding to the average eye level of a pilot at touchdown, which for this purpose is a height of approximately 15 feet (Reference 1).

The purpose of providing runway visual range information is to permit pilots, operators and other users to appraise visibility conditions and, in particular, to determine whether these conditions are above or below established operating minima.

The following variables which affect the pilot's vision do not enter in the calculation of RVR:

a. rain on the windshield of the aircraft;

b. the level of cockpit lighting, which is adjustable;

c. the illumination to which a pilot has been exposed during the preceding few minutes (for example, when passing over approach lights);

d. any effect connected with the motion of a pilot with respect to the runway lights, e.g., the time taken for a pilot to react to a light coming into view;

e. the pilot's vision and any physical or psychological factors affecting it.

Thus, RVR is merely a method of assessing "seeing conditions" for takeoff and landing and not a statement of what a pilot would actually see.

In the United States, RVR is a value determined normally by instruments (usually transmissometers) located alongside the runway. These instruments are calibrated with reference to the sighting of high intensity runway lights or the visual contrast of other targets, whichever yields the greater visual range. Generally, a computer or other signal data processor is used to compute RVR. RVR values are used when the prevailing visibility is 6,000 feet or less and is reported in feet in increments as noted in Table 1. The measurements by a transmissometer take about 48 seconds; the data conversion takes another five seconds. This implies that the RVR values are visibilities averaged over about one minute and are considered valid only for immediate use for local air traffic.

Another concept is the ten-minute RVR value. This consists of the lowest and highest RVR values recorded during the last ten minutes, based on a high-intensity runway light setting of five, regardless of the actual setting. As such, it is a measure of the variability of the visibility.

TABLE 1. RVR REPORTING INCREMENTS.

Transmissometer Baseline (ft)	RVR (ft)	Reporting Increments (ft)
250	600 - 3000	200
	3000 - 6000	500
500	1000 - 4000	200
	4000 - 6000	500

3.2 MEASUREMENT TECHNIQUES

The transmissometer, developed in 1942 and accepted for airport operations in 1952, is one of the basic components of the RVR system now used in more than 350 installations in the U.S. (see Table 4, Section 5). The transmissometer consists of a high-powered projector which directs an intense beam of light at a photo-sensitive receiver at the other end of a baseline which is 250 or 500 feet long. The atmospheric transmittance over the baseline on any particular occasion is measured by comparing the luminous flux entering the receiver with that received in a perfectly clear atmosphere (100 percent transmittance). From the atmospheric transmittance, the visual range of lights of known intensity can be computed if the sensitivity of the eye (visual threshold) is known.

The projector and receiver are properly aligned. This is done partly to obtain the best signal-to-noise ratio in the receiver and partly to minimize errors due to light entering the receiver after scattering and so adding to the light received directly from the projector. Since small changes in alignment can cause large changes in receiver output which can be wrongly interpreted as changes in transmittance, it is necessary to use ruggedly constructed components mounted on firm foundations.

The length of the baseline sets limits of visual ranges that can be measured. Using present FAA instrumentation, the 500-foot baseline gives satisfactory accuracy in RVR measurements down to a lower limit of about 1,000 feet at night (and roughly half these values by day) depending on the characteristics of the runway lights and of the transmissometer in use. The lower limit can be reduced if necessary (e.g., for Categories II or IIIA operations) by using a shorter baseline such as 250 feet or less. In fact, all new RVR installations will use a 250-foot baseline.
With most runway lights and FAA transmissometers, RVR can be measured, with

reasonable accuracy, down to two times the baseline length and up to only about 15 to 20 times the baseline length. This causes some restriction at the upper end of the scale, especially in bright daylight conditions. If the range of values to be reported is more than can be covered by a single transmissometer, it is necessary to use, with present FAA instrumentation, a dual baseline system; i.e., one projector and two separate receivers at different distances — or two entirely separate transmissometers.

RVR is computed from transmissometer measurements, and using Allard's Law or Koschmieder's Law, depending, respectively, on whether the pilot can be expected to obtain his main visual guidance from the runway lights or from the runway and its markings. In other words, RVR is based on the visibility of the runway lights or of the runway and its markings, whichever can be seen further. Factors which are included in the computation of RVR are the background luminance (current U.S. operations require day and night values) and the setting of the high intensity runway lights.

3.3 DATA DISSEMINATION

At controlled airports with a weather station, visibility measurements and their reporting are a joint responsibility of the National Weather Service (NWS) and the FAA. If the visibility is three miles or better, it is usually measured by the NWS and reported to the FAA control tower. This information is relayed to the arriving aircraft by the controllers via voice radio link. Control tower personnel take visual observations using specified markers for visibilities from one to three miles. These observations are supplied to the pilot and to the NWS. Below 6,000 feet visibility, measurements are made either by the personnel in the control tower using markers or by transmissometers along the runway. The visibility values are expressed as RVR when measured with the transmissometer and processed by a signal data converter.

If computations are done by computer, the RVR is usually presented automatically in the control tower and approach control office using remote digital displays; similar displays are installed in the meteorological office or observing station and, in some cases, at a few other points at the airport. If atmospheric transmittance-RVR tables are used, the conversion is usually done in the meteorological observing station, which then transmits the reports to the users via the channel carrying other meteorological reports (e.g., telephone, telewriter, etc.). Attention is drawn to changes of special importance by means of a warning light or buzzer. This is necessary for informing the control tower when the system develops a fault or when the visibility falls below some predetermined threshold.

In the meteorological station, control tower, or elsewhere, a recorder monitors the RVR values displayed, with indications of the corresponding runway and site, and of the time of all changes. In addition, it is common practice to record the output of all transmissometers in operation, i.e., to record the atmospheric transmittance at the various sites.

As an example, Figure 1 shows the visibility information flow in the Logan International airport/aircraft system (Reference 2). Figure 2 shows more specifically the RVR data flow in any airport/aircraft system (Reference 2).

To understand the controller-pilot interface in the visibility information flow, the participation of each controller in this data flow and the RVR values which determine runway operations are reviewed below (Reference 3).

Approach Controller - Pilot. The approach controller has at his disposal an RVR remote digital display unit which gives the RVR values for the given runway. When the prevailing visibility or RVV is 1-1/2 miles or less or when RVR is 6,000 feet

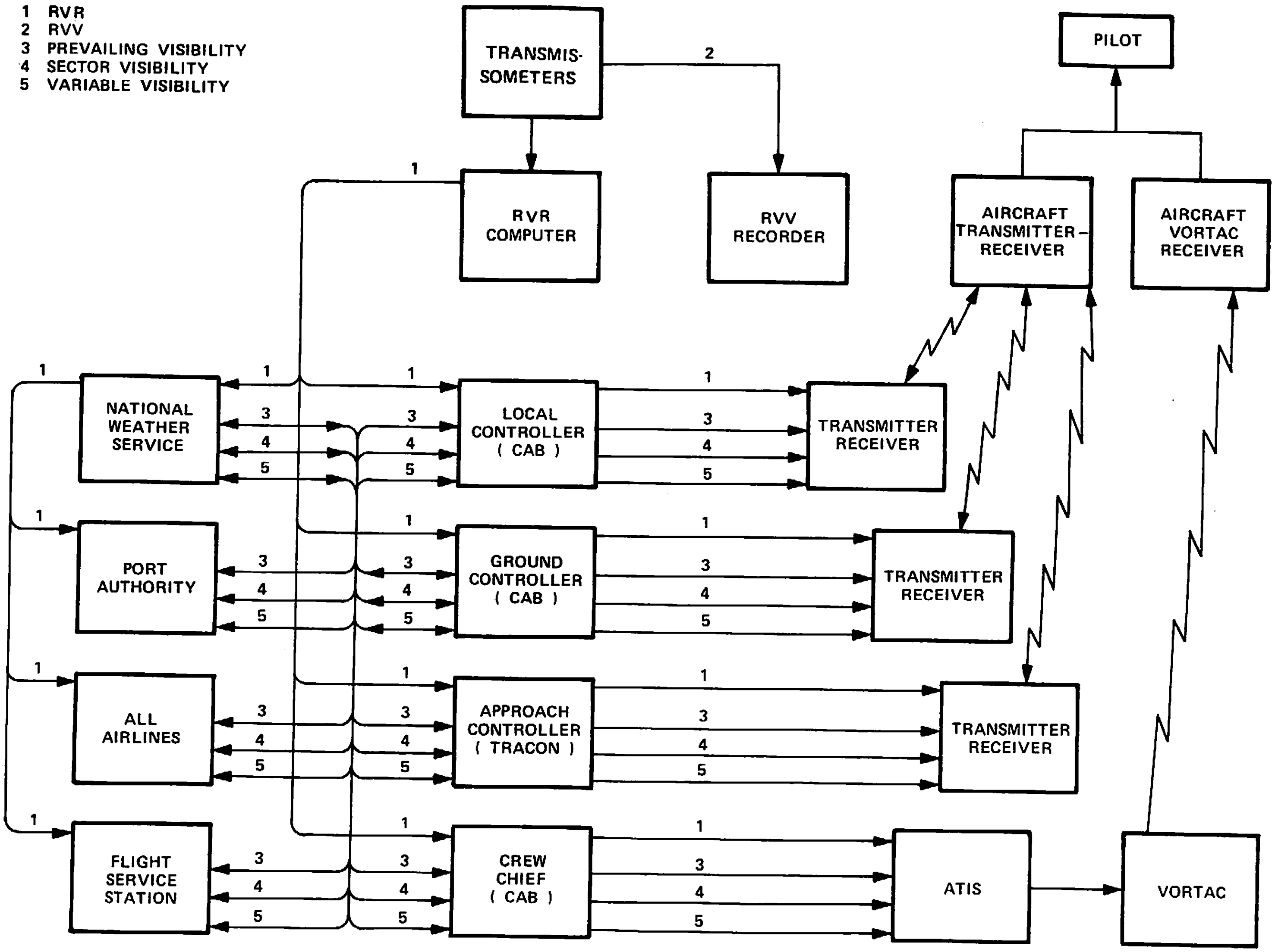

FIGURE 1. CURRENT VISIBILITY INFORMATION FLOW IN AIRPORT/AIRCRAFT SYSTEM, LOGAN AIRPORT, BOSTON, MASSACHUSETTS (REFERENCE 2).

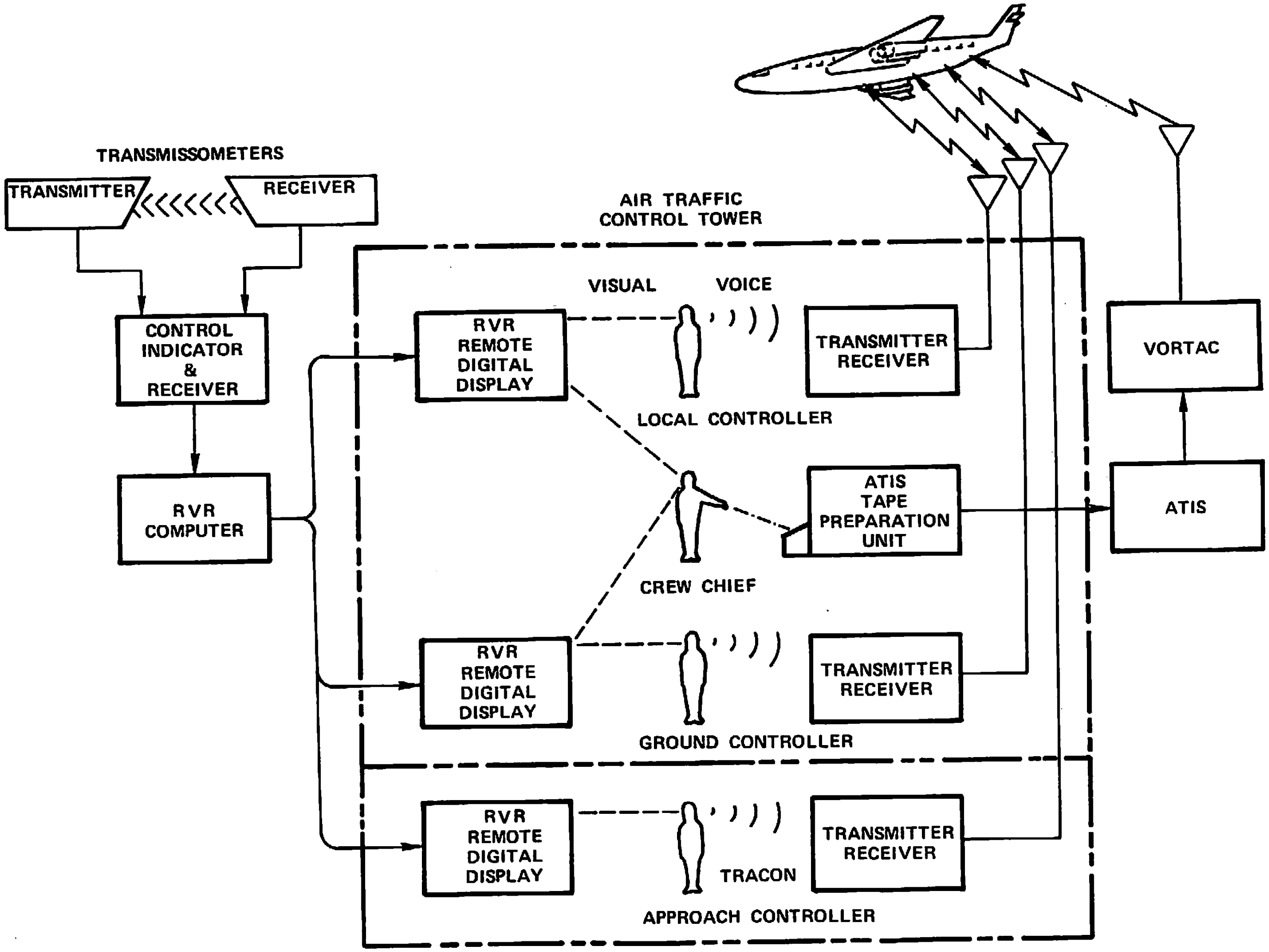

FIGURE 2. RVR DATA FLOW IN AIRPORT/AIRCRAFT SYSTEM (REFERENCE 2).

or less the visibility information is supplied to the pilot by the approach controller via voice link (approach frequency).

Local or Final Controller - Pilot. The local controller also has at his disposal an RVR remote digital display unit. RVR readings below 4,000 feet are supplied to the pilot via voice link by the local controller. This takes place from the time that control of the aircraft is transferred by the approach controller to the local controller.

Ground Controller - Pilot. The responsibility of the ground controller consists of providing advisory information to the pilot during taxiing from the runway to the airport terminal or vice versa. In cases of reduced visibility the ground controller denies takeoff clearance in accordance with the following procedure and criteria:

> "Inform the aircraft of the visibility and do not issue takeoff clearance to an air carrier or commercial aircraft carrying passengers or property for compensation or hire when any of the following conditions exists:
>
> (1) When both touchdown and rollout RVR digital displays are available for the departure runway and either of the following conditions exists:
>
> (a) Touchdown RVR is less than 1,600 feet and rollout is less than 1,000 feet.
>
> (b) Touchdown RVR is less than 1,200 feet regardless of the rollout RVR indication.
>
> (2) If only touchdown RVR is available for the departure runway and either of the following conditions exists:
>
> (a) At locations with an RVR digital display, RVR is less than 1,600 feet.
>
> (b) At locations with an RVR meter, RVR is less than 2,000 feet and prevailing visibility is less than 1/4 statute mile.
>
> (3) If RVR is not available and either RVV or RVO is available for the departure runway, RVV or RVO is less than 1/4 statute mile.
>
> (4) If RVR, RVV or RVO is not available for the departure runway, the prevailing visibility for the airport of departure is less than 1/4 statute mile."

4. PROPOSED ADDITIONAL FAA VISIBILITY INFORMATION

Various techniques for measuring, reporting, and predicting airport visibilities have been proposed. Changes have been suggested not only for the method of measurement but also for the quantity measured.

One visibility measuring system, slant visual range (SVR), which may be installed by the FAA in the future, is discussed in this section. The intent here is to describe this system which could become operational over the next ten years and thus impact on the FAA visibility equipment procurements during that time period. To provide a background and understanding of the proposed system, the measurement techniques and data processing algorithms for this system are discussed. It should be indicated that the SVR measuring system may have the capability to measure the Approach Light Contact Height (ALCH).

In addition, a Taxiway Visual Range (TVR) system has been suggested. Under reduced visibility conditions, this system would assist pilots as they taxi their aircraft from the runway to the terminal. TVR is still in the conceptual stage; therefore, it is not considered in this report.

4.1 SVR

SVR can be defined as the slant distance to the farthest high intensity runway edge light or approach runway light which a pilot will see at an altitude of 100 ft (decision height) on the approach path or, if larger, the slant distance which would have a constant transmittance of 5.5 percent.

A program conducted for the FAA by the Naval Weapons Support Center (NWSC), formerly Naval Ammunition Depot (NAD), Crane, Indiana (References 4 and 5), evaluated techniques for determining approach zone visibility.* This effort commenced in May 1971. A comprehensive flight test program at National Aviation

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* This program was based on the FAA-ER-450-042a Engineering Requirement.

Facilities Experimental Center (NAFEC), and data analysis, complete system specifications were prepared for the FAA such that the system can be commercially produced.

The SVR measurement technique developed by NWSC is based on the use of visibility measurements made from a tower placed at a given distance from the runway. Tests have shown that meaningful predictions of SVR can be made using fully developed operational instruments. It is likely that a version of this system, discussed in detail in the following sections, will become operational within the next few years. The FAA plans to operationally test a prototype SVR system at a CAT II airport beginning in the last quarter of FY77. Although the system is still in the experimental and developmental stage, the final version of this SVR system is not expected to differ significantly from the present engineering model. It should be indicated that the proposed SVR system has the possibility to be extended to report approach light contact height (ALCH).

Another type of SVR system has been proposed (References 6, 7 and 8). It is based on Lidar (light detection and ranging) techniques and has been developed and tested under FAA sponsorship. The Lidar technique is designed to give a measurement of the visibility corresponding to what a pilot would see from a given altitude along a path directed toward the runway. This Lidar SVR technique has been investigated for many years. Prototype development is required before such a system can become operational (Reference 7).

4.1.1 MEASUREMENT TECHNIQUE

The field configuration for an SVR measurement system would consist of two forward scatter meters (FSM), two luminance meters, and one illuminance meter mounted on a 100-foot tower. The tower would be offset 1,300 feet perpendicular to the centerline of the runway 1,000 feet from the runway threshold. A diagram which illustrates the configuration of the tower and its relative position to the runway is shown in Figure 3. Figure 4 presents the block diagram showing the SVR system as proposed by NWSC (Reference 9). A minicomputer would be used for data processing. The flexibility of this system allows changes to signal processing algorithms if additional visibility data is available. Additional sensors could be easily incorporated into the system for special situations or improvements in instrumentation.

One FSM would be located at the 100-foot level of the tower and another at the 10-foot level. Based on the measurements of these two FSMs, a vertical variation of atmospheric forward scatter is obtained. As described subsequently, these measurements are incorporated into an algorithm which gives SVR.

Under daytime conditions, one of the inputs into the proposed SVR system is the illuminance threshold of the pilot. A method was formulated based on physical measurements near the ground and computations to predict the pilot's background illuminance. The computation assumes an atmosphere bounded by two infinite parallel planes which is subdivided into two homogeneous layers: a Rayleigh scattering and a Mie scattering layer. There are two luminance meters incorporated in the proposed system at the 50- and 100-foot levels of the tower. The values measured by the two luminance meters are utilized for the ALCH predictions from a regression equation fitted to multiple scattering data.

4.1.2 DATA PROCESSING TECHNIQUE

The SVR data processing technique has been developed by the NWSC and used at the test and evaluation installation at NAFEC. Operation of the system over a year allowed for proper debugging and verification (References 5 and 9).

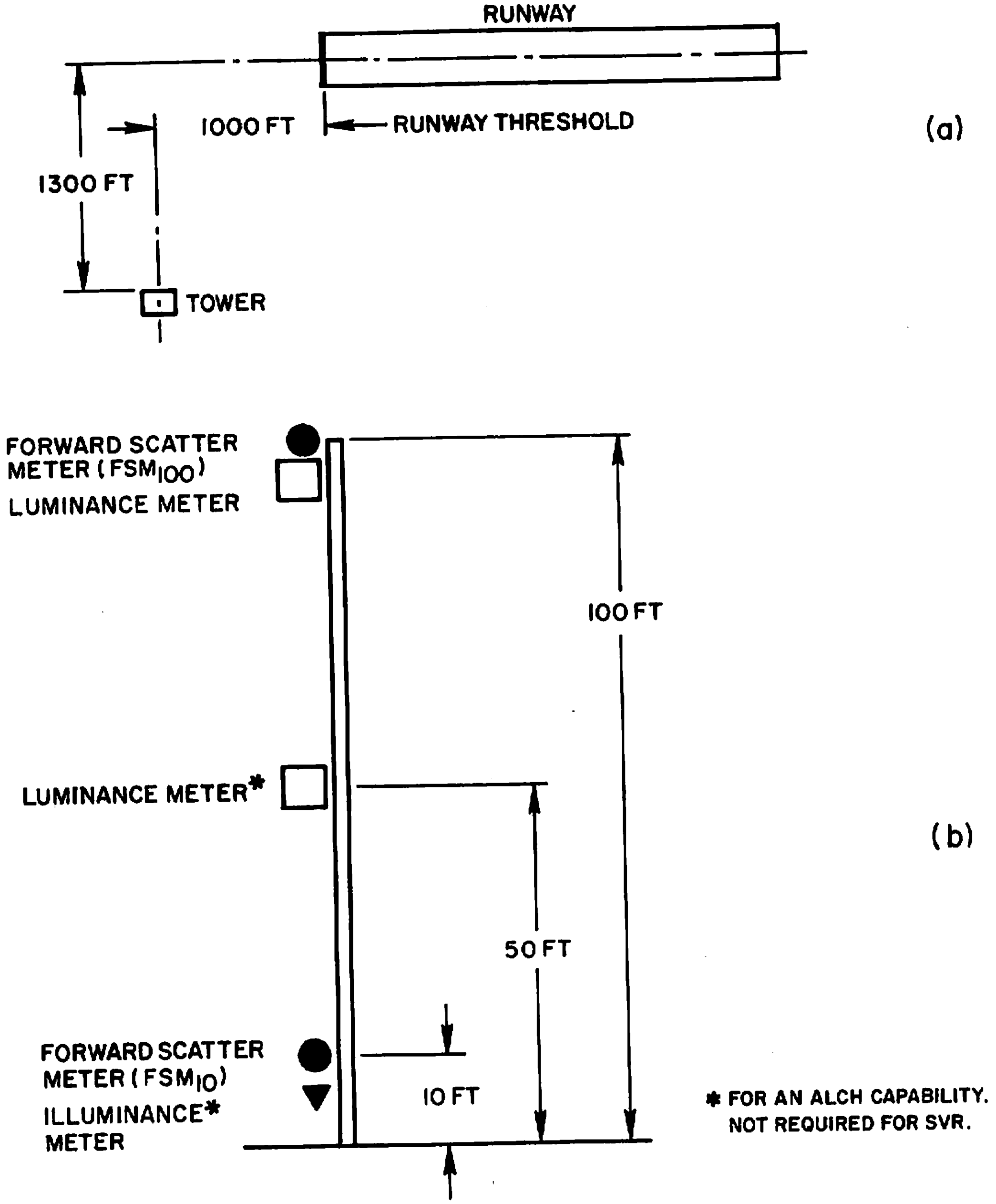

FIGURE 3. SVR EQUIPMENT LOCATION RELATIVE TO RUNWAY AS PROPOSED BY NAVAL WEAPONS SUPPORT CENTER, CRANE, INDIANA; a) LOCATION OF TOWER; b) LOCATION OF FIELD SENSORS ON TOWER (REFERENCE 5).

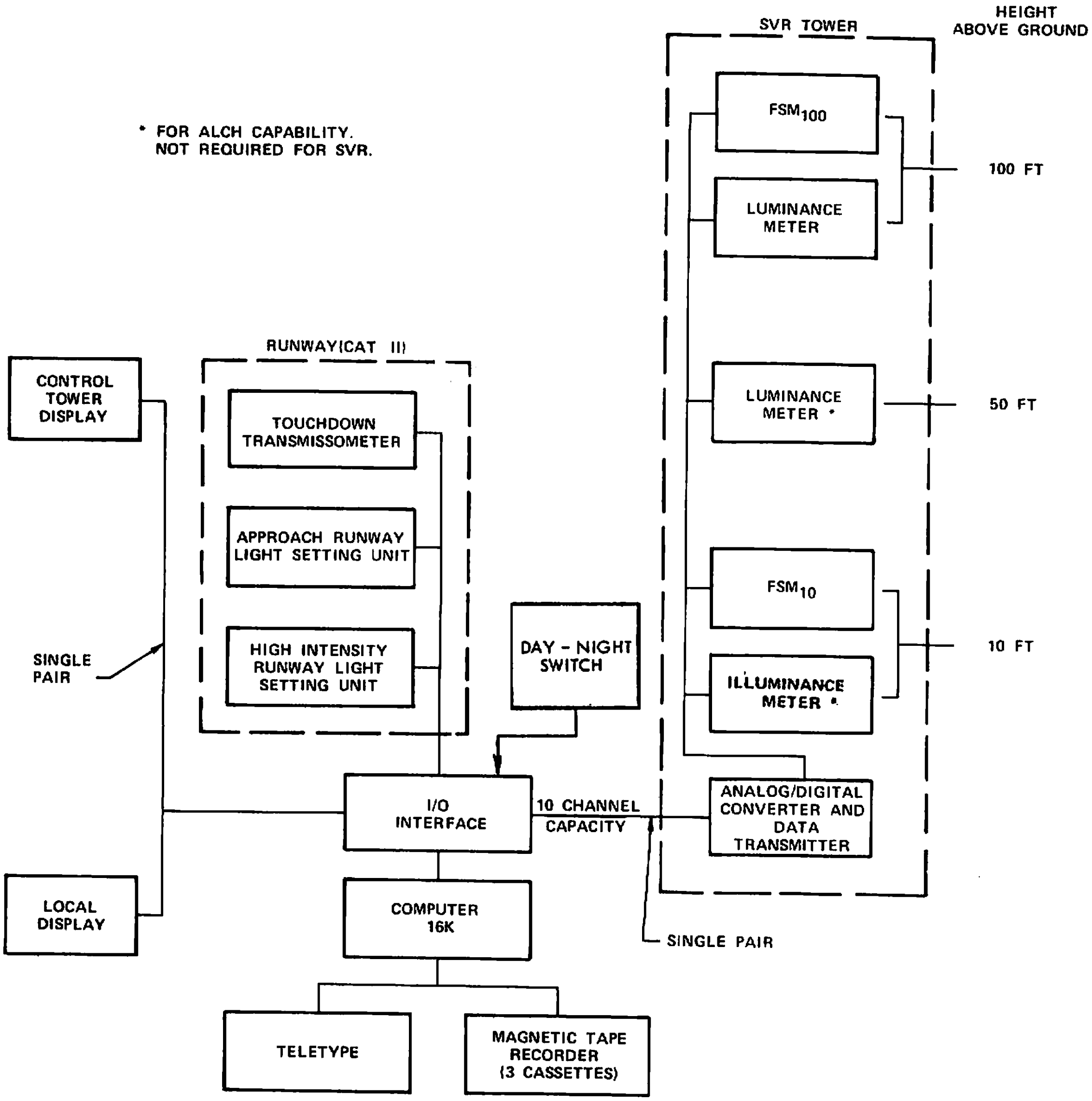

FIGURE 4. SVR SYSTEM AS PROPOSED BY NAVAL WEAPONS SUPPORT CENTER, CRANE, INDIANA (REFERENCE 9).

The intensity of the runway edge lights are 20,000, 4,000 and 800 cd for the respective runway edge light settings 5, 4, and 3. The intensity of approach lights are prorated according to setting and spatial distribution.

The computer system computes SVR for (1) night case or (2) day case. The night case is chosen if the day-night photocell reads under 80 fc and the day case is chosen if the day-night photocell measures an illumination over 80 fc.

SVR Night Case - The computer calculates SVR based on the high intensity runway lights as the source. If SVR $\leq$ 900 ft (where the approach runway lights start), it then calculates SVR based on the intensity of the approach lights.

The illuminance threshold (E_T) necessary to see a high intensity runway light is fixed in the computer as

$$E_T = 7.174 \times 10^{-8} \text{ fc}, \tag{1}$$

for the night case. The relationship between E_T, d' and the high intensity runway light I_R is expressed by the following relationship:

$$E_T = T_W \cdot F_R \cdot I_R \cdot \exp(-\bar{\sigma} \cdot d')/d'^2, \tag{2}$$

where, d' = SVR

T_W = 0.8 = aircraft windshield optical transmittance

F_R = 1.0 for high intensity runway light setting of 5

0.2 for high intensity runway light setting of 4

0.04 for high intensity runway light setting of 3, 2, or 1,

I_R = 20,000 cd (setting 5) and $\bar{\sigma}$ is the mean atmospheric extinction coefficient.

The values of SVR are obtained by numerically solving Equation (2) for d'. The reported SVR values are in hundred feet increments.

The equation that relates $\bar{\sigma}$ to other measurables is:

$$\bar{\sigma} = \left[\frac{\sigma_{10} + \sigma_T}{2} + \sigma_{100}\right] \Big/ 2 , \tag{3}$$

where σ_{10} is the extinction coefficient measured at the SVR tower 10-ft level,

σ_{100} is the extinction coefficient measured at the SVR tower 100-ft level, and

σ_T is the extinction coefficient at touchdown transmissometers.

If, by solving Equation (2) $d' \leq 900$ ft, then SVR is calculated based on the intensity of the approach light since the first SVR value is smaller than the distance from the pilot at DH to the lights. The distance d from the 100-foot DH to the 1st, 2nd, 3rd, 4th, and 5th approach runway light bars are approximately 900, 800, 700, 600, and 500 ft respectively. Based on these predetermined distances d, allowable extinction coefficients σ_a are calculated in accordance with the following equation:

$$\sigma_a = -\ell_n \left[E_T \cdot d^2 / (T_W \cdot F_A \cdot 5I_A)\right]/d , \tag{4}$$

where E_T, T_W, and F_A are defined as for Equation (2), and I_A is the intensity of the approach runway light lamp* for setting 5 and in the pilot line of sight from the 100-foot DH. The relationship between approach runway light setting F_A and the luminous intensity I_A is the same as for the high-intensity runway lights. Table 2 gives the relationship between approach runway light bars I_A and d.

---

* The approach light system uses Q20A/PAR 56 lamps rated at 300 w.

TABLE 2. RELATIONSHIP BETWEEN APPROACH RUNWAY BAR NUMBER, LAMP LUMINOUS INTENSITY, AND CORRESPONDING DISTANCE TO GIVEN BAR FROM DECISION HEIGHT.

Approach Runway Light Bar Number	Luminous Lamp Intensity x5 (cd)*	Distance (ft)
1	$I_1 = 104000$	$d_1 = 905$
2	$I_2 = 100000$	$d_2 = 806$
3	$I_3 = 93000$	$d_3 = 707$
4	$I_4 = 76000$	$d_4 = 608$
5	$I_5 = 39000$	$d_5 = 509$

The extinction coefficient $\bar{\sigma}$ (Equation (3)) is then compared to σ_a for the first approach light bar. If $\sigma_a < \bar{\sigma}$ for the first approach light bar, then comparison between $\bar{\sigma}$ and σ_a is made for the second approach light bar. The process is continued until $\sigma_a \geq \bar{\sigma}$, or until the first five light bars are checked. Once σ_a is found to be greater than $\bar{\sigma}$, the light bar which corresponds to the last computed σ_a is used to set SVR = d. If $\sigma_a < \bar{\sigma}$ for the first five lights, SVR = 0.

SVR Day Case - As in the night case, SVR is calculated based on the high intensity runway lights if SVR > 900 ft, or approach lights if SVR ≤ 900 ft. The mean extinction coefficient $\bar{\sigma}$ is calculated from Equation (3) as in the SVR night case.

The luminance meter reading of the high intensity runway lights at 100 ft, L_{100}, is used as the luminance which determines the adaptation level of the pilot. The illuminance threshold E_T is computed using the following equation **:

$$E_T = 10^y, \tag{5}$$

---

* For a justification of the integration effect of the lights (5) in a bar, see Reference 5.

** H. R. Blackwell, Contrast Thresholds of the Human Eye, JOSA 36 624-646 (1946).

where $y = a_0 + a_1x + a_2x^2 + a_3x^3$, (6)

$x = \log_{10}(T_W \cdot L_{100})$, (7)

$a_0 = -7.6104$,

$a_1 = .640386$,

$a_2 = .06497$,

$a_3 = -0.0031469$,

L_{100} = reading of the 100-ft luminance meter (fℓ).

Thus, with $\bar{\sigma}$ given by Equation (3) and E_T defined by Equation (5), SVR can be computed by numerically solving Equation (2).

If SVR $\leq$ 900 ft, the L_{100} value is used to calculate E_T using Equation (5). Then σ_a is computed as in Equation (4) and comparison between $\bar{\sigma}$ and σ_a is done the same as for the night case approach runway lights. That is, $\bar{\sigma}$ is compared to σ_a for each of the first five light bars. For the first light bar for which $\bar{\sigma} \leq \sigma_a$, SVR is set equal to d, the distance between pilot at DH and the light bar considered. If $\bar{\sigma} > \sigma_a$ for all five light bars, SVR = 0.

Once an SVR is calculated by either of the above procedures, the following check is then performed. Koschmieder's equation is applied to find the range d' at which 5.5 percent transmission exists for the estimated extinction coefficient $\bar{\sigma}$. That is:

$$d' = 2.9/\bar{\sigma} \qquad (8)$$

If d' is greater than the SVR just calculated, then SVR is redefined as d'.

4.2 ALCH

The ALCH is the height on the glidepath at which a pilot will see and should continue to see a minimum of five light bars of approach lights at 100-ft spacings, if extended to touchdown, assuming a standard cockpit cut-off angle of 15 deg.

ALCH Day and Night Cases - The ALCH calculations for day and night conditions are discussed in the NWSC reports and documents (Reference 9). Since it does not exist as of this time, an FAA requirement for ALCH is not discussed in this report.

5. VISIBILITY MEASURING SYSTEMS DEPLOYMENT ANALYSIS AND SCHEDULES

The purpose of this section is to develop a realistic schedule over the next ten fiscal years (FY76-FY85), based on currently available data, for FAA deployment of airport visibility measurement systems. This requires a detailed look at the deployment criteria as they apply to long-range FAA planning. Airport visibility measurement system requirements are bound by the weather minimums allowable for aircraft takeoffs and landings. Thus, the approach taken for the development of estimated deployment schedules is to first identify the FAA visibility system requirements for each category. A detailed analysis was made of projected runway category upgrading using eight representative airports to determine estimates of the additional visibility equipment to be procured, based on the FAA requirements. The existing and future runway networks were determined from FAA documents in order to specify the approximate number of runways which will require additional visibility measurement equipment. Finally, based on the projected runway network and the estimated requirements for equipment per runway, RVR and SVR deployment schedules were developed.

5.1 RVR DEPLOYMENT CRITERIA

The primary document for determining the criteria for installation of RVV and RVR systems is FAA Order 6560.10, "Runway Visual Range," (Reference 10). This document describes the RVR system and specifies the visibility measurement system requirements for all Category I, II, and III runways. Reference 10 has the following statements regarding visibility system requirements and runway operational criteria.

5.1.1 VISIBILITY SYSTEM REQUIREMENTS

The visibility system requirements follow (Reference 10).

"a. All new and relocated transmissometer equipments are to be established with a 250-foot baseline.

b. Siting and installation criteria for transmissometer facilities are contained in FAA-STD-008.

c. A retrofit program for existing installations, including replacement of RVV/RVR meters (used as a primary system) with a digital readout, to conform to these requirements should be established as funds become available.

d. At those airports with identical low published RVR instrument minima for more than one runway, the Flight Standards air carrier representative in cooperation with the Air Traffic Control Facility Chief, shall determine which runway is to be the "Designated RVR Runway." This designation shall not change unless the RVR landing minima for that runway changes or another runway supports a lower RVR landing minima.

e. Category I

(1) RVR systems will not normally be installed at low density Category I ILS locations unless a special operational requirement exists which can be supported by a climatological study; i.e., dense fog, blowing dust/sand, smog, etc., and the following additional requirements are met:

(a) Air carrier operations are conducted on the ILS runway.

(b) The airport has at least 700 Annual Instrument Approaches (AIA).

(c) Landing minimums of at least 200 feet decision height and 2400 RVR can be expected on the ILS runway.

(2) RVR systems presently installed at Category I locations not meeting the above requirements, may be retained. Relocation will not be authorized unless the above requirements are met.

(3) When RVR systems are being installed, only a touchdown system will be required. Many of the present Category I RVR locations are installed on a 500-foot baseline. Modification or relocation of these facilities will not be affected, however, just to reduce the baseline to 250 feet.

f. Category II

(1) For operations at 1600 RVR or greater, only a touchdown transmissometer is required.

"

(2) For authorization below 1600 RVR, transmissometers are required at both the touchdown and rollout ends of the Category II runway. Additionally, a midpoint RVR will be required on a Category II runway when the runway length is in excess of 8,000 feet.

(3) When a Category I runway is upgraded to a Category II runway, the rollout transmissometer must be on a 250-foot baseline. An existing touchdown transmissometer may be retained on a 500-foot baseline.

g. Category IIIA - Touchdown, midpoint and rollout systems will be required for all locations. A 250-foot baseline will be required for all systems."

5.1.2 RUNWAY OPERATIONAL CRITERIA

RVR systems are not provided at all Category I locations. All Category II and IIIA runways will be equipped with RVR in accordance with previously stated requirements. Operational use will be predicated on all systems operating normally. RVR data will be disseminated to pilots in accordance with air traffic control procedures and as requested (Reference 2).

A summary of the runway operational criteria follows (Reference 10).

"a. Arriving Aircraft

(1) Category I Weather Conditions (1800 RVR or greater)

(a) Touchdown RVR - required (controlling)

(b) If available, midpoint and/or rollout RVR will be provided upon request

Note: Minima below 2,400 feet will not be authorized unless Touchdown Zone (TDZ) and Centerline Lighting (CL) are available.

(2) Category II Weather Conditions (1200 RVR to 1800 RVR)

(a) Touchdown RVR - required (controlling)

(b) Touchdown RVR (controlling) and rollout RVR - required whenever minima are less than 1600 RVR. Midpoint RVR required for runways more than 8,000 feet in length.

(3) Category IIIA Weather Conditions (700 RVR to 1200 RVR)

" (a) Touchdown, midpoint and rollout RVR required. (Touchdown and midpoint RVR are controlling.)

b. Departing Aircraft

(1) Weather Conditions 1600 RVR or greater

(a) Touchdown RVR (controlling)

(2) Weather Conditions below 1600 RVR to 1000 RVR

(a) Touchdown minimum 1200 RVR; rollout minimum 1000 RVR (both controlling)

Note: Minima below 1600 RVR will not be authorized unless the runways are equipped with CL lights and two operative transmissometers.

(3) Weather Conditions below 1000 RVR when approved

(a) 700 RVR minimum for touchdown and midpoint RVRs. 600 RVR minimum for rollout RVR. (All are controlling.) "

RVV equipment generally consists of a transmissometer with a calibrated meter output and is not coupled to a computer. The current trend is away from installation of RVV, with most RVV systems being upgraded to RVR or replaced with a full RVR system when the corresponding runway is upgraded or RVR equipment becomes available.

As shown in Table 3, Category I installations may have either one RVR or none. The criteria for determining whether a Category I runway shall be equipped with an RVR is explicitly defined in the FAA Order 7031.B, "Airway Planning Standard Number One - Terminal Air Navigation Facilities and Air Traffic Control Services" (Reference 11). This criterion states:

"A Touchdown RVR system ... shall be installed with a Category I ILS with approach lights (when funds and equipment become available) provided that the airport can meet the requirements contained herein. Such qualification exists when the sum of the following three equations as applied to that airport is equal to or exceeds 1.0.

TABLE 3. FAA VISIBILITY MEASURING SYSTEM REQUIREMENTS AND RUNWAY OPERATIONAL CRITERIA FOR ARRIVING AIRCRAFT.*

Visibility Category	RVR Minima (ft)	Visibility Measuring Systems		Runway Operational Criteria for Arriving Aircraft
		Number & Type	Requirements	
I	1800	None	--	--
		One RVV	--	--
		One RVR	Transmissometer at touchdown	$RVR \geq 1800$ ft RVR touchdown controlling
II	1200	One RVR	Transmissometer at touchdown. Existing 500-ft baseline acceptable. New installations 250-ft baseline.	1600 ft $<$ RVR $<$ 1800 ft RVR touchdown controlling
		Two RVR	Transmissometer at touchdown and at rollout	1200 ft $<$ RVR $<$ 1600 ft RVR touchdown controlling
		Three RVR	For runways longer than 8000 ft. Transmissometer at touchdown, midpoint and rollout	1200 ft $<$ RVR $<$ 1600 ft RVR touchdown controlling
		Three RVR & One SVR**	Addition of SVR for DH = 100 ft	1200 ft $<$ RVR $<$ 1600 ft RVR touchdown controlling
IIIA	700	Three RVR	Transmissometer at touchdown, midpoint and rollout. All transmissometers will be 250-ft baseline.	700 ft $<$ RVR $<$ 1200 ft RVR touchdown controlling RVR midpoint controlling
		Three RVR & One SVR**	Addition of SVR for DH = 100 ft	700 ft $<$ RVR $<$ 1200 ft RVR touchdown controlling RVR midpoint controlling

*Based on data from Reference 10.
**SVR is not currently an FAA requirement; it is part of a future plan.

"

$$0.5 \times AEP \times (10^{-5}) = P \qquad (9)$$

$$0.2 \times AIA \times (7.14 \times 10^{-4}) = A \qquad (10)$$

$$0.3 \times VIZ \times (1.28 \times 10^{-2}) = V \qquad (11)$$

where:

AEP = Annual Enplaned Passengers,

AIA = Annual Instrument Approaches,

VIZ = Mean Number of Annual Hourly Observations with Visibility ≤ 1/2 Mile,

P = Passenger Factor,

A = Instrument Approach Factor,

V = Visibility Factor.

[$P + A + V \geq 1.0$ to qualify for RVR installation]

The sum of equations (9), (10), and (11) is called the RVR Installation Index.

> Note 1. Any airport with less than 15 annual hourly observations of visibilities of 1/2 mile or less shall not qualify for an RVR system regardless of index value.
>
> Note 2. The RVR is specified as a component of the Category II and Category III ILS within Order 6560.10, dated September 12, 1972 (or most recent revision), subject, 'Runway Visual Range (RVR).' "

Exceptions to the above criteria will be considered if supported by a staff study and the recommendation of the Regional Director.

At an airport with multiple Category I ILS runways, only the primary runway will be considered for an RVR system. (Installation of multiple RVR systems will be considered if supported by a staff study and the recommendation of the Regional Director.)

The siting criteria and installation standards for RVR equipment are contained in FAA Order 6990.3, "Siting and Installation Standards for Runway Visual Range Equipment for Category I and II Operation," (Reference 12). This FAA Order details the criteria for site selection, alignment, tolerances, and placement of equipment. The preferred location of a touchdown transmissometer is with the projector placed near the glideslope building (ILS) and the receiver 250 feet away toward the direction of aircraft approaching the ILS runway. Neither unit can be closer than 400 feet from the runway centerline or closer than 150 feet from the taxiway centerline. An angle of 14.5 degrees is maintained between the centerline of the runway and the baseline between projector and receiver. The beam shall be directed away from the runway. Specifications for other transmissometers and alternate locations are also noted in the same order.

5.2 SVR DEPLOYMENT CRITERIA

As discussed earlier, the SVR system is at the experimental stage. Since it may become operational during the time frame analyzed (FY76-FY85), an estimate of an SVR deployment schedule is included. Discussions on deployment of this equipment with FAA Headquarters personnel* indicate that the following assumptions are reasonable:

There will be, at most, one SVR system per airport.

SVR will be used at Category II installations which have a minimum DH of 100 feet.

SVR will not be operational before 1978, but may be in operational tests at about that time.

The SVR deployment schedule presented herein is based on the above assumptions and the following additional assumption:

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* Hilsenrod, A. (FAA ARD-451): July 1975.

> Since the SVR is an advanced system, its deployment is likely to follow the pattern of initial Category III installations.

No justification for the above additional assumption is given other than that it seems reasonable, and that no other criteria have been selected by the FAA.

5.3 PRESENT RVR SYSTEMS DEPLOYED AND/OR IN FAA INVENTORY

The RVR systems currently deployed in the United States are summarized in Table 4 (References 13 and 14). The runway network existing in 1975 is identified in terms of the number of Category I, II, and IIIA runways in operation, and the RVR systems installed at each.

TABLE 4. FAA DEPLOYED AND/OR APPROVED RVR SYSTEMS PER RUNWAY CATEGORY AS OF 1975.

Runways		RVR Systems	
Category	Number	Total Number	Average Number Per Runway
I	586	271*	0.46
II	48	77	1.60
IIIA	2	6	3.00

* Includes those with RVV only.

The status report of Category II locations* identifies 36 commissioned Category II runways and 2 commissioned Category IIIA runways. In addition, 12 runways are expected to be upgraded to Category II during 1975 (Table 5). Thus, there would be a total of 48 Category II runways by the end of 1975. The FAA National Aviation System Plan, Fiscal Years 1976-1985 (Reference 13) indicates 37 commissioned and 11 approved

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* Status Report of Category II Locations, FAA Memorandum from Chief, Program Management Staff, ATF-4, April 17, 1975.

TABLE 5. FAA FY75 RVR TASKER SYSTEMS MODEL 500 UNDER PROCUREMENT AND/OR PROPOSED DEPLOYMENT.*

Airport/Location	No. of RVR Systems	Installation Purpose
O'Hare International Chicago, Illinois	5	Upgrade to CAT II
Newark International Newark, New Jersey	2	
John F. Kennedy International New York, New York	3	
LaGuardia Airport New York, New York	2	
Akron/Canton Regional Canton, Ohio	1	Replacing Obsolete Equipment Upgrading from RVV, etc.
Snohomish County (Paine Field) Everett, Washington	1	
Kansas City International Kansas City, Missouri	1	
Pleasant Hill Landing Strip Mansfield, Ohio	1	
Spokane International Spokane, Washington	1	
Muni Airport Youngstown, Ohio	1	

*Hilsenrod, A. (FAA ARD-451): Correspondence to H. Ingrao (DOT/TSC), 13 March 1975. Regarding FAA FY75 RVR equipments under procurement.

Category II installations for 1975, which also totals to 48 runways by the end of 1975. Only two runways are commissioned Category IIIA with no other Category IIIA runways to be commissioned in 1975.

There are a total of 77 RVR systems installed on the Category II runways. This implies there is an average of about 1.6 RVRs per Category II runway. Each Category IIIA runway has three RVRs.

The FAA ten-year plan (Reference 13) indicates a total of 586 Category I runways for 1975 (465 commissioned and 121 approved but not yet commissioned). The FAA Airway Facilities Service Master File (Reference 14) indicates that there is a total of 363 transmissometers and RVR systems in the field. Subtracting the number at Category II and IIIA locations, as well as the number decommissioned, indicates that visibility equipment is at 271 Category I locations. Since there is, at most, one RVR per Category I runway, this implies that RVR equipment is at 46 percent of those locations (including locations which have only a transmissometer).

The FAA Airways Facilities Division in Washington indicated that there <u>will</u> be procurement of visibility equipment in FY76; however, the final procurement requirements have not yet been determined.

The current FAA supplies of visibility measuring equipment are shown in Table 6.* The main items in the inventory are the Tasker RVR systems Model 400 (items RVR 400) and Model 500 (items RVR-500). The Model 400 is no longer manufactured, thus there will be no replacements for these stock items.
These and other commercially available visibility items are described in Section 6.

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* Hilsenrod, A. (FAA ARD-451): Correspondence to H. Ingrao (DOT/TSC) July 11, 1975. Regarding FAA inventories of visibility equipment and cabling costs.

TABLE 6. FAA INVENTORY OF TASKER SYSTEMS VISIBILITY MEASURING EQUIPMENT AS OF JULY 11, 1975.*

FAA Stock Number	Description	Number of Units
RVR 400/1 6660-00-432-57661	Signal Data Converter	25
RVR 400/2 6660-00-432-57671	Power Supply and Control Unit	24
RVR 400/4P 6660-00-432-57681	RVR Remote Display Programmer	80
RVR 400/12T 8200-00-300-08551	Transmissometer Support Tower Assembly	25
RVR 500/1 9066-00-605-07761	Computer Main Frame	5
RVR 500/2 9066-00-605-07771	Signal Data Converter Module	14
RVR 500/4P 9066-00-605-07781	RVR Remote Display Programmer	5
RVR 500/3 9066-00-605-07081	Ambient Light Sensor	5
RVR 500/10 9260-00-609-44391	Transmissometer System	24
RVR 500/12TM 9266-00-605-80861	Transmissometer Support Tower Assembly, Modified	63

* Hilsenrod, A. (FAA ARD-451): Correspondence to H. C. Ingrao (DOT/TSC) dated July 11, 1975.

5.4 RVR SYSTEMS DEPLOYMENT ANALYSIS FOR FY76-FY85

This section presents the RVR systems deployment analysis. Deployed RVR equipment was recorded and determinations made from the projected runway improvements as to what additional visibility equipment will be required. The same air traffic hub structure developed by the FAA and used in economic and operations research procedures is used in this study to group representative airports that serve the different hub types.

The following presents an understanding of air traffic hubs based on the FAA description (Reference 15). Air traffic hubs are not airports; they are the cities and Standard Metropolitan Statistical Areas (SMSA) requiring aviation services. An SMSA is comprised of a county that contains at least one city of 50,000 population, or twin cities with a combined population of at least 50,000, plus any contiguous counties that are metropolitan in character and have similar economic and social relationships. These metropolitan areas constitute a primary focal point for the transportation research program of the FAA, and the analyses of individual cities within an area are treated in relationship to the entire area. In those instances where two or more individually certificated communities are located in an SMSA, those communities are grouped under the SMSA definition.

Individual communities fall into four hub classifications (see Table 7) as determined by each community's percentage of the total enplaned revenue passengers in all services and all operations of U. S. certificated route air carriers within the 50 States, the District of Columbia, and other U. S. areas designated by the FAA. FY74 hub classifications are based on 198,545,371 total annual enplaned revenue passengers.

TABLE 7. PERCENTAGE AND NUMBER OF ENPLANED PASSENGERS IN HUB CLASSIFICATIONS FOR FY74.

Hub Classification	Percent of Total Enplaned Passengers	Number of Enplaned Passengers
Large (L)	1.00 or more	1,985,454 or more
Medium (M)	0.25 to 0.99	496,363 to 1,985,453
Small (S)	0.05 to 0.24	99,273 to 496,362
Non-hub (N)	Less than 0.05	Less than 99,273

Geographic locations of the air traffic hubs are shown in Figure 5.

The individual airports selected included: William B. Hartsfield Atlanta International, Gen. Edward L. Logan International, O'Hare International, Los Angeles International, John F. Kennedy International (all large hubs); San Antonio International (medium hub); Bangor International (small hub); and Long Beach/Daugherty Field (non-hub).

This selection was made in order to consider "typical" requirements for a complete range of airports (large, medium, small, and non air traffic hubs). Large hub airports dominate the sample, but large hubs are also the locations at which the majority of the upgradings to Category II and IIIA take place.

The detailed deployment analysis for each airport is presented in this section. The primary sources of information for the airport data are the FAA Airways Facilities Service (Reference 14), Jeppesen approach charts (Reference 16) and FAA Headquarters correspondence.* The Airway Facilities Service provided information on existing and planned visibility equipment, and the Jeppesen charts were used to identify information such as runway lengths and landing decision heights.

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*Status Report of Category II Locations, FAA Memorandum from Chief, Program Management Staff, ATF-4, April 17, 1975.

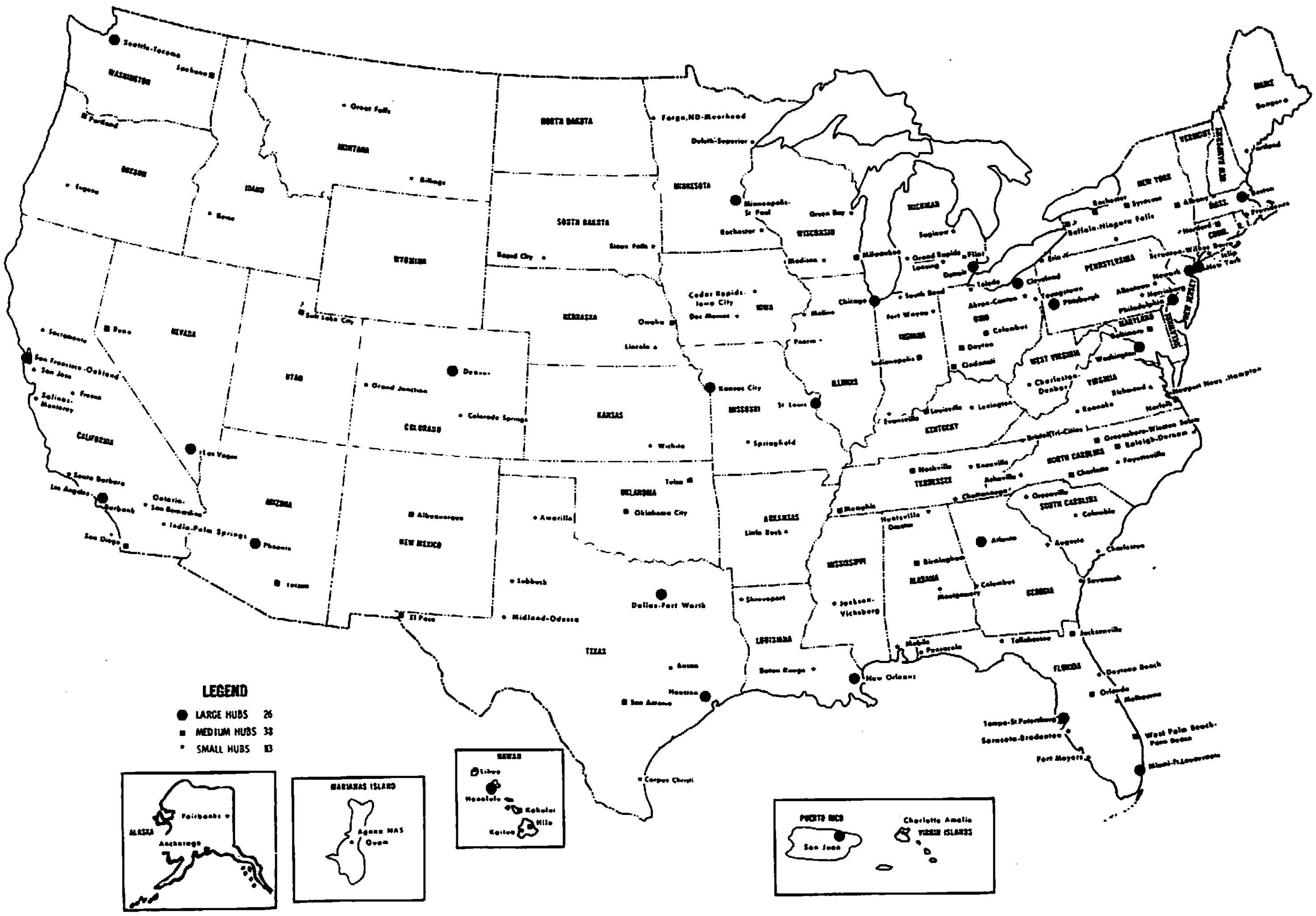

FIGURE 5. LOCATIONS OF AIR TRAFFIC HUBS (REFERENCE 15).

5.4.1 LARGE AIR TRAFFIC HUBS

5.4.1.1 WILLIAM B. HARTSFIELD ATLANTA INTERNATIONAL AIRPORT

The runway layout for this airport is given in Figure 6. A summary of the current runway data is shown in Table 8.

A) Present Deployment

The William B. Hartsfield Atlanta International Airport (serving Atlanta, Georgia) is one of two airports currently equipped with a Category IIIA runway (the other is Dulles International).

There are a total of five RVRs at Hartsfield Atlanta airport. There are five transmissometers and five corresponding RVR computers. All transmissometers are on a 250-foot baseline. Runway 9R-27L is currently equipped with three transmissometers. Because of the equipment locations, relative to Runway 9L-27R, RVR capability exists when and if Runway 9L-27R is upgraded.

B) Proposed Deployment

No additional runways at Hartsfield Atlanta airport have been identified at the present time for upgrading to Category II or IIIA. The only additional RVR purchase anticipated at this time is the establishment of a midpoint RVR for Runway 8. A midpoint RVR will be required for the 8-26 runway (10,000 feet) due to the Category II approach to Runway 8. Visibility information provided by deployed RVR equipment on other runways will be useful for Runway 15 coverage.

Based on SVR deployment criteria (Subsection 5.2) such a system is expected to be deployed at Runway 9R.

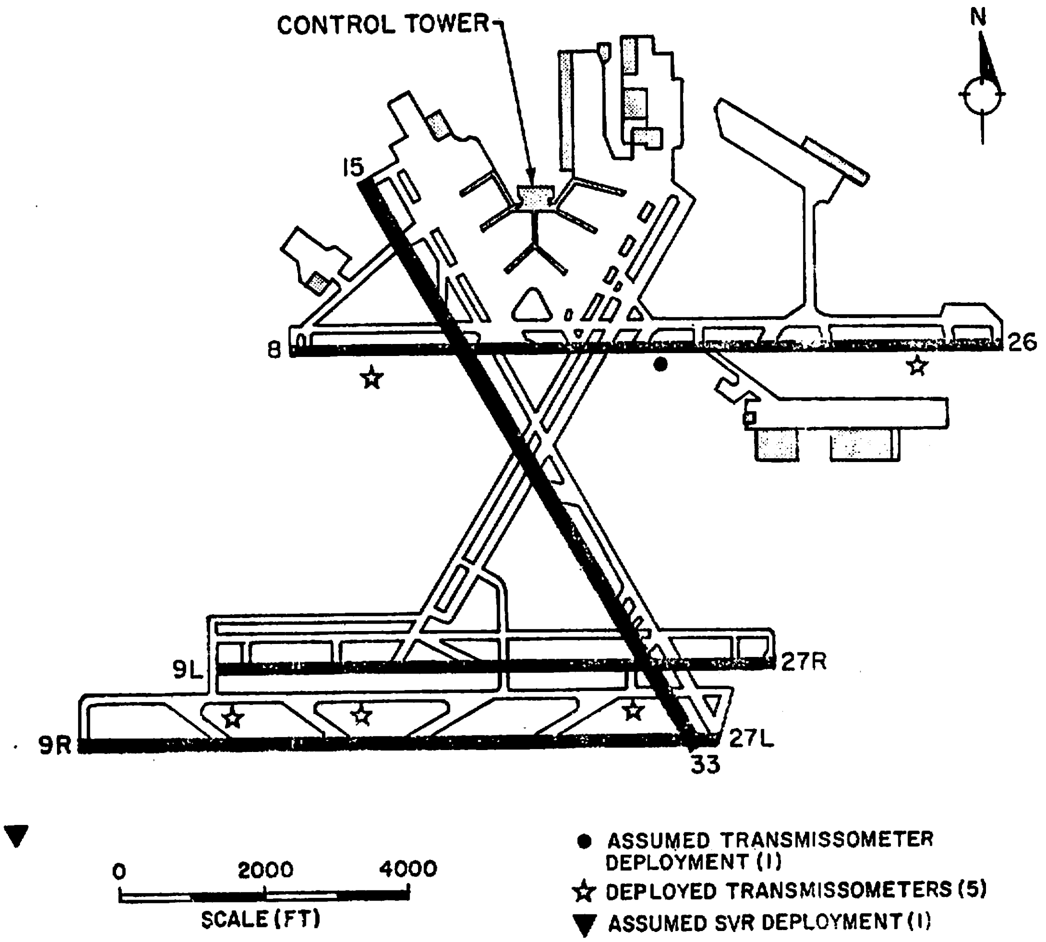

FIGURE 6. RUNWAY LAYOUT OF WILLIAM B. HARTSFIELD ATLANTA INTERNATIONAL AIRPORT.

TABLE 8. RUNWAY AND RVR DATA SUMMARY (WILLIAM B. HARTSFIELD ATLANTA INTERNATIONAL AIRPORT).*

Runway		Operation						
		Present (FY75)				Projected Changes (FY76-FY85)		
Designation	Usable Length (ft)	CAT	Min. DH (ft)	Min. RVR (ft)	RVR Equip.**	CAT	Add'l. RVR Equipment	Est. Date
8	10,000	II	150	1,600	2 RVR	None	1 Midpoint RVR	FY76
26	10,000	I	200	2,400			-	-
9R	9,000	IIIA	None	700	3 RVR	None	-	-
27L	9,000	I	250	4,000				
9L	8,000	NPA	NA	5,000	***	None	-	-
27R	8,000	NPA	NA	4,000				
15	7,387	VFR	NA	NA	***	None	-	-
33	9,067	VFR	NA	NA				

NPA	Non-Precision Approach
NA	Not Applicable
VFR	Visual Flight Rules
*	References 14 and 16
**	RVRs use IRA computers
***	Runways 9L, 27R, and 33 could use one of the three transmissometers on Runway 9R-27L.

5.4.1.2 GENERAL EDWARD L. LOGAN INTERNATIONAL AIRPORT

The airport layout plan for Logan International Airport (serving Boston, Massachusetts) is shown in Figure 7, and the runway data summary is shown in Table 9.

A) Present Deployment

Currently Logan International has three transmissometers, two on 250-foot baselines on runways 4R and 33L and one on a 500-foot baseline on runway 22L. There are two computers, one each for the transmissometers at 4R and 33L (Tasker 400s). No computer is currently in operation for the transmissometer at 22L; thus, it is used for determining RVV rather than RVR.

B) Projected Deployment

The only plan at Logan International is to eventually upgrade runway 4R to Category II. There are many problems associated with this. The primary one is that to use more of the runway for landing in Category II conditions, approaching aircraft may be low enough to encounter ships' masts passing in the adjacent channel and/or obstructions at Castle Island. Thus, until this is resolved, 4R will remain Category I. When it is upgraded to Category II, the RVV at the rollout end must be upgraded to an RVR (i.e., a computer installed in the tower to calculate RVR). Two additional RVR sites, one at the intersection of Runways 15R-33L and 4R-22L and the other at the rollout end of 33L, must be installed for a total of three RVRs on 4R. This is required since the usable length will be increased to beyond 8,000 feet. Hypothetically, if 4R were then to be upgraded from Category II to IIIA, no additional visibility equipment would be required.

Based on SVR deployment criteria (Subsection 5.2), such a system is expected to be deployed at Runway 4R.

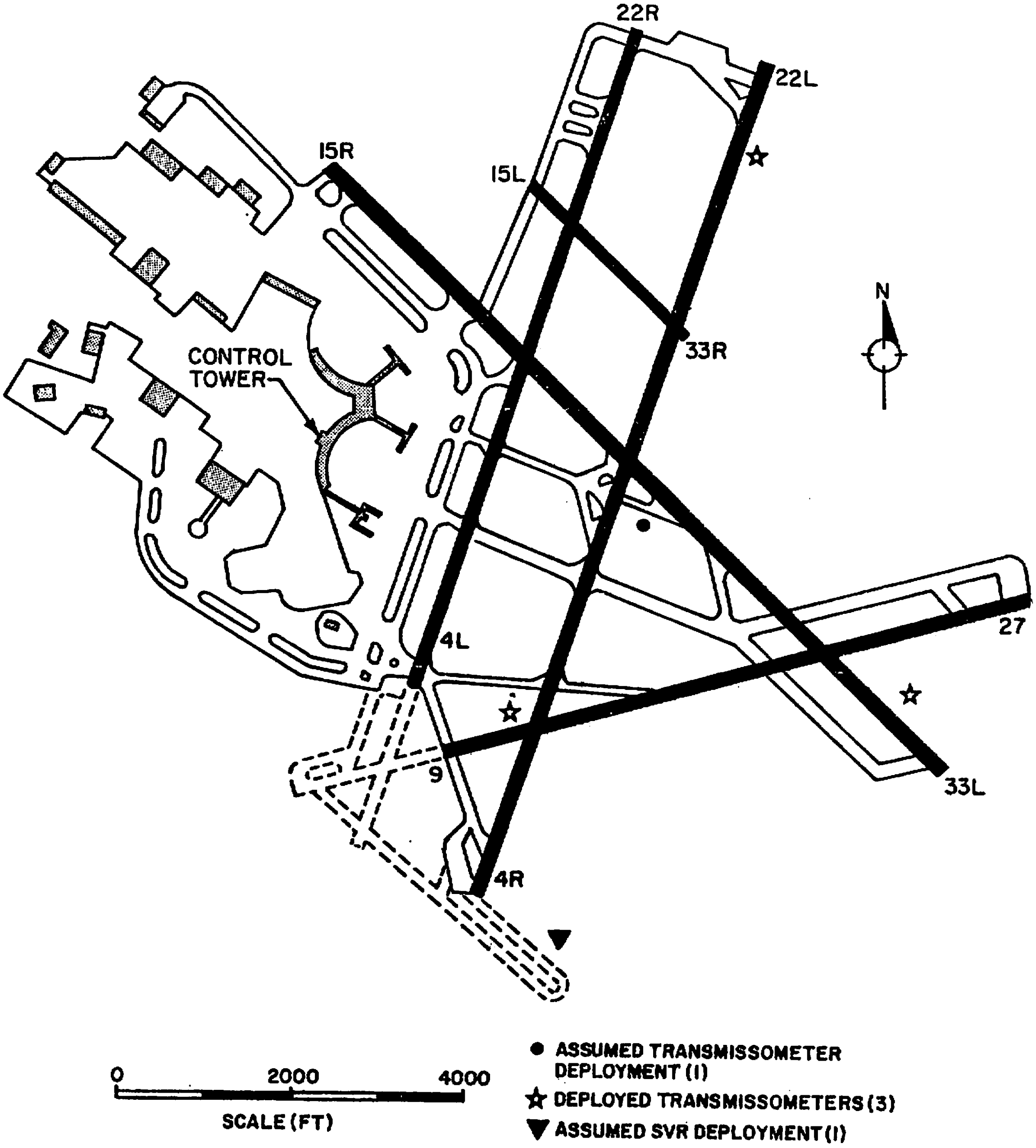

FIGURE 7. RUNWAY LAYOUT OF GENERAL EDWARD L. LOGAN INTERNATIONAL AIRPORT.

TABLE 9. RUNWAY AND RVR DATA SUMMARY (GENERAL EDWARD L. LOGAN INTERNATIONAL AIRPORT).*

Runway		Operation						
Designation	Usable Length (ft)	Present (FY75)				Projected Changes (FY76-FY85)		
		CAT	Min. DH (ft)	Min. RVR (ft)	RVR Equip.**	CAT	Add'l. RVR Equipment	Est. Date
4R	7,493	I	200	2,400	1 RVR	II	1RVR	Indef. ***
22L	10,000	NPA	NA	NA	1 RVV		Upgrade to RVR	
4L	7,870	NPA	NA	NA	+	None	-	-
22R	7,042	NPA	NA	NA	None			
9	7,021	VFR	NA	NA	+	None	-	-
27	7,021	NPA	NA	NA	None			
15R	9,190	I	250	NA	None	None	-	-
33L	10,080	I	200	2,400	1 RVR			
15L	2,468	VFR	NA	NA	None	None	-	-
33R	2,468	VFR	NA	NA	None			

NPA	Non-Precision Approach
NA	Not Applicable
VFR	Visual Flight Rules
*	References 14 and 16
**	RVRs use Tasker 400 computers
***	Date for upgrading runway 4R to CAT II delayed pending resolution of how to handle problem of ships' masts passing in adjacent channel.
+	Runways 4L and 9 each use Runway 4R RVR for takeoff.

5.4.1.3 O'HARE INTERNATIONAL AIRPORT

An airport layout plan is shown in Figure 8. The runway data summary for O'Hare International Airport (serving Chicago, Illinois) is shown in Table 10.

A) Present Deployment

O'Hare International is currently the only airport in the U.S. with two Category II runways. There are currently four RVR and 1 RVV systems deployed at O'Hare International as shown in Figure 8 and noted in Table 10.

B) Proposed Deployment

Except for establishment of Category IIIA on Runway 14L, specific FAA plans for O'Hare have not been finalized; the projected changes identified in Table 10 are those which the airport operator anticipates over the next 10 to 15 years.*

As shown in Table 10, four additional RVR systems (Runways 4R-22L and 9R-27L) will be required at O'Hare. Currently all RVR computers are manufactured by IRA; however, the FAA has included five Tasker Systems Model 500 for O'Hare International Airport in their FY75 requests.**

C) Remarks

Projected additional instrument approaches to O'Hare include Category IIIA on Runway 14R, and Category I approaches to 4R-22L, and 9L. Additional transmissometer requirements will be for a midpoint RVR on 14R-32L, midpoint RVR on 14L-32R, and touchdown rollout RVRs on 4R-22L.

Based on SVR deployment criteria (Subsection 5.2), such a system is expected to be deployed at Runway 14R.

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*Downes, W. E., Jr. (Commissioner of Aviation, Dept. of Aviation, Chicago, Illinois): Correspondence to J. R. Wiley (Aerospace Systems, Inc.) April 14, 1975. Regarding existing and planned visibility systems at O'Hare Airport.

**Hilsenrod, A. (FAA ARD-451): Correspondence to H. Ingrao (DOT/TSC) 13 March, 1975. Regarding existing and planned visibility systems at O'Hare Airport.

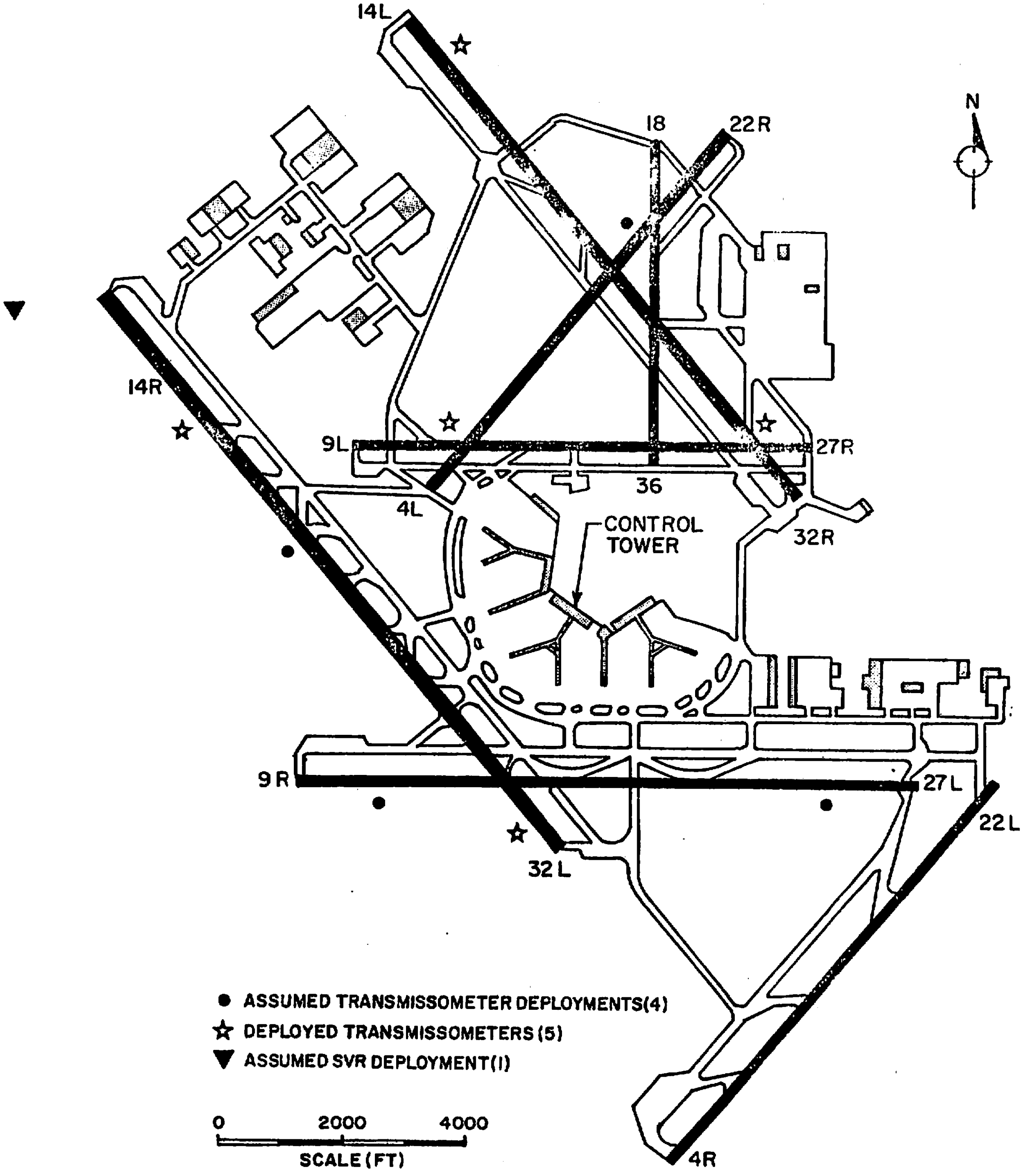

FIGURE 8. RUNWAY LAYOUT OF CHICAGO O'HARE INTERNATIONAL AIRPORT.

TABLE 10. RUNWAY AND RVR DATA SUMMARY (CHICAGO O'HARE INTERNATIONAL AIRPORT).*

Runway		Operation						
		Present (FY75)				Projected Change (FY76-FY85)		
Designation	Usable Length (ft)	CAT	Min. DH (ft)	Min. RVR (ft)	RVR Equip.**	CAT	Add'l. RVR Equipment	Est. Date
4R	8,070	NPA	260	NA	None	I	1 RVR	Indef.
22L	8,070	NPA	250	NA	None	I	1 RVR	
4L	7,500	NPA	NA	NA	1 RVV	I	Upgrade to RVR	Indef.
22R	7,500	NPA	250	NA		I		
9R	10,140	I	200	NA	None	I	1 RVR	1980s
27L	10,140	I	200	NA	None	I	1 RVR	
9L	7,416	NPA	NA	NA	***	I	-	Indef.
27R	7,416	I	200	2,400	***	I	-	
14R	11,600	II	100	1,200	2 RVR	IIIA	1 Midpoint RVR	FY76
32L	11,600	I	200	1,800		I	-	-
14L	10,003	II	100	1,200	2 RVR	IIIA	1 Midpoint RVR	FY76
32R	10,003	I	200	2,400		I	-	-
18	5,341	VFR	NA	NA	None	None	-	-
36+	5,341	VFR	NA	NA	None			

NPA	Non-Precision Approach
NA	Not Applicable
VFR	Visual Flight Rules

* Hilsenrod, A. (FAA ARD-451): Correspondence to H. Ingrao (DOT/TSC) 13 March 1975. Regarding FAA FY75 RVR equipment under procurement.
Downes, W.E. (Commissioner of Aviation, Department of Aviation Chicago, Illinois): Correspondence to J. R. Wiley (Aerospace Systems, Inc.) 14April 1975. Regarding existing and planned visibility systems at O'Hare International.
References 14 and 16.

** RVRs currently have IRA computers; however, five Tasker 500s have been procured (FY75) to replace current computers.

*** Runway 9L uses 4L RVV, 27R uses 32R RVR.

\+ Runway 36 used for takeoff only.

5.4.1.4 LOS ANGELES INTERNATIONAL AIRPORT

The airport layout and runway data summary for Los Angeles International Airport are shown in Figure 9 and Table 11, respectively.

A) Present Deployment

Los Angeles International currently has four RVR systems which serve as touchdown and rollout for all four major runways. Each RVR currently uses an SSR Model FAA 7871 Signal Data Converter.

B) Projected Deployment

The changes anticipated at Los Angeles International are the installation of a Category II runway at 6L-24R in FY76 and upgrading of 25L to Category II at some indefinite time in the future. The FAA anticipates installation of a Category IIIA runway at Los Angeles International sometime in FY77, probably runway 24R or 25L.

The only visibility equipment procurements required to meet these changes are the installation of midpoint RVRs on both 24R and 25L. Thus, regardless of which runway is eventually upgraded to Category IIIA, no other visibility systems will be required.

Based on SVR deployment criteria (Subsection 5.2), such a system is expected to be deployed at Runway 24R.

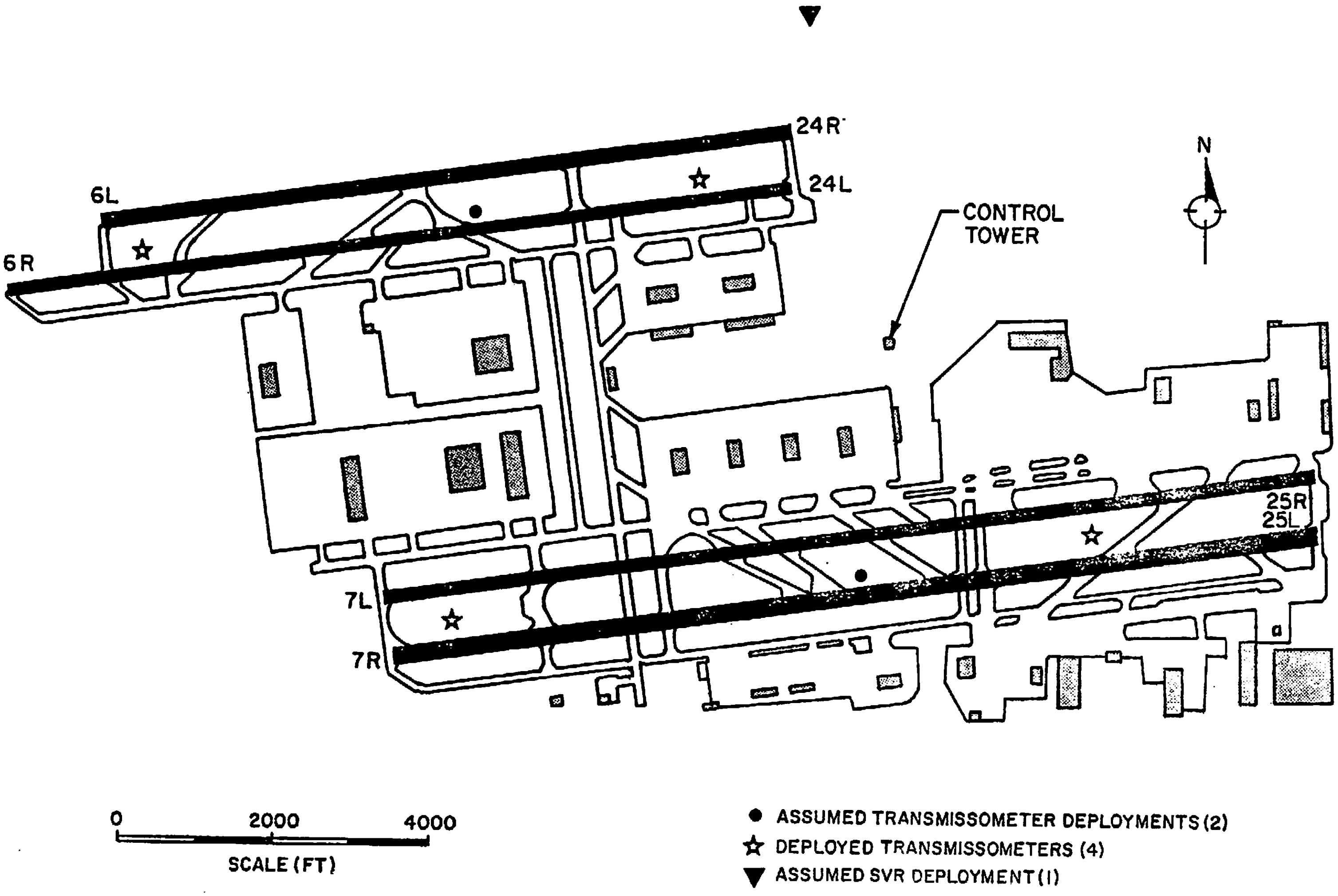

FIGURE 9. RUNWAY LAYOUT OF LOS ANGELES INTERNATIONAL AIRPORT.

TABLE 11. RUNWAY AND RVR DATA SUMMARY (LOS ANGELES INTERNATIONAL AIRPORT).*

Runway		Operation						
		Present (FY75)				Projected Changes (FY76-FY85)		
Designation	Usable Length (ft)	CAT	Min. DH (ft)	Min. RVR (ft)	RVR Equip.**	CAT	Add'l. RVR Equipment	Est. Date
6R	9,953	I	200	2,400	2 RVR	None	***	-
24L	10,284	I	250	4,000		-		
6L	8,924	VFR	NA	NA	***	None	1 Midpoint RVR	-
24R+	8,924	I	120	1,200		II		FY76
7R	11,992	NPA	NA	5,000	2 RVR	None	1 Midpoint RVR	-
25L+	11,401	I	200	2,400		II		Indef.
7L	12,090	I	200	2,400	***	None	***	-
25R	11,490	I	200	2,400				

* References 14 and 16.
** RVRs use SSR Model FAA 7871 Signal Data Converter.
*** Each RVR serves two parallel runways.
\+ FAA anticipates installation of a CAT IIIA runway (probably 24R or 25L) in FY77.

5.4.1.5 JOHN F. KENNEDY INTERNATIONAL AIRPORT

The airport layout plan for the John F. Kennedy International Airport (serving New York City) is shown in Figure 10; the runway data summary is shown in Table 12.

A) Present Deployment

Currently there are five RVR systems at Kennedy, each of which uses an IRA computer.

B) Proposed Deployment

The FAA FY75 visibility equipment procurement identifies three Tasker System 500s for Kennedy International for the purpose of upgrading to Category II. Since runway 13L is scheduled for Category II operations in FY76, presumably the existing IRA computer for the 13L rollout RVR will be replaced with the Tasker 500, and the new touchdown and midpoint RVRs will also use Tasker 500 equipment.

The FAA has selected Kennedy International Airport for one Category IIIA runway in FY76, probably runway 4R. This will require installation of a midpoint RVR. No other projected changes at Kennedy Airport will require the installation of new visibility equipment.

Based on SVR deployment criteria (Subsection 5.2), such a system is expected to be deployed at Runway 4R.

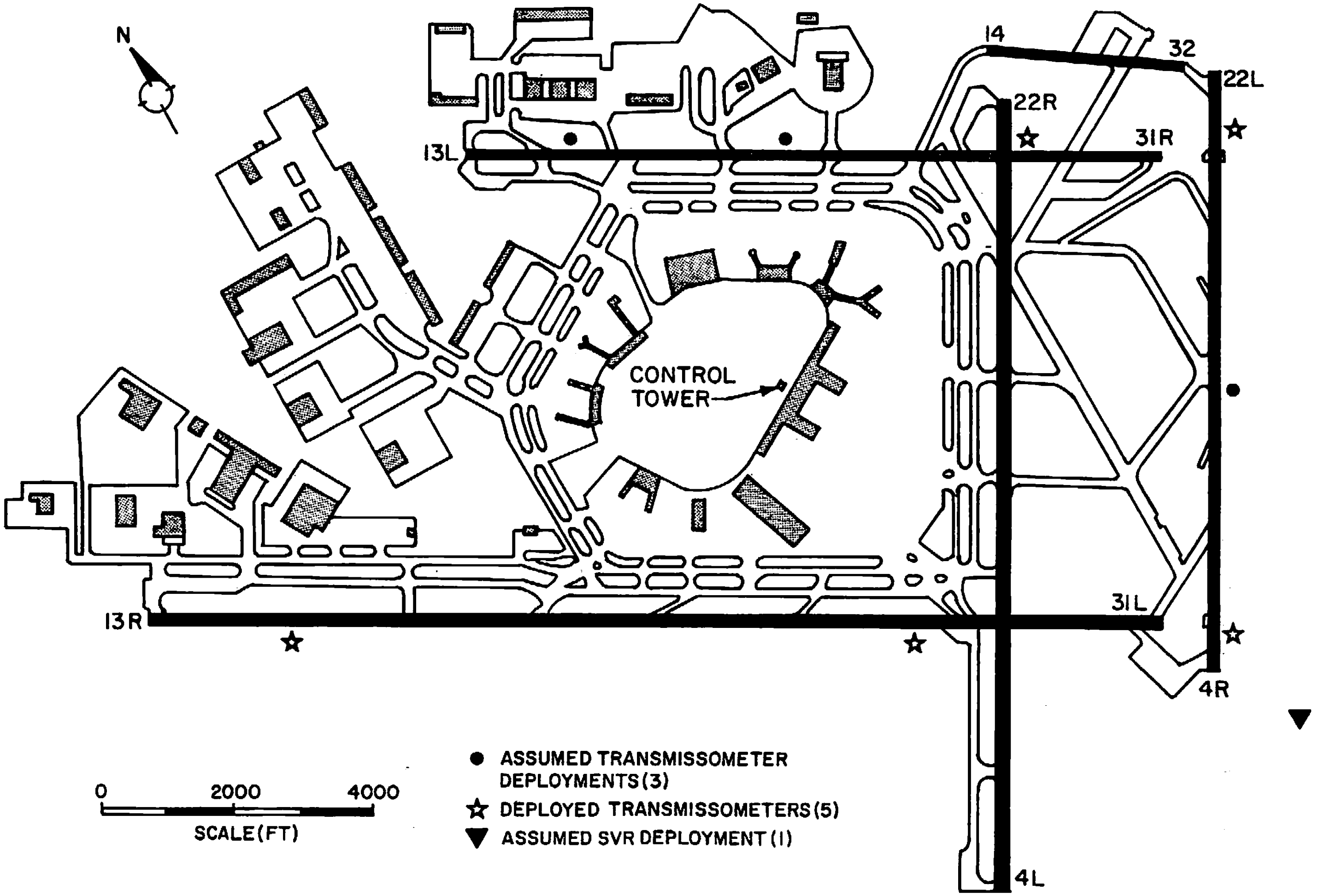

FIGURE 10. RUNWAY LAYOUT OF JOHN F. KENNEDY INTERNATIONAL AIRPORT.

TABLE 12. RUNWAY AND RVR DATA SUMMARY (JOHN F. KENNEDY INTERNATIONAL AIRPORT).*

Runway		Operation						
Designation	Usable Length (ft)	Present (FY75)				Projected Changes (FY76-FY85)		
		CAT	Min. DH (ft)	Min. RVR (ft)	RVR Equip.**	CAT	Add'l. RVR Equipment	Est. Date
4R	8,400	II	100	1,200	2 RVR	IIIA	1 Midpoint RVR	FY76
22L	8,400	I	200	1,800		II		
4L	11,352	I	300	NA	None	None	-	-
22R	8,330	I	250	NA	None			
13R	11,972	NPA	NA	NA	2 RVR	I	-	Indef.
31L	11,252	I	250	4,000				
13L	9,015	I	200	NA	None	II	2 RVR***	FY76
31R	8,976	I	250	4,000	1 RVR	I		
14	2,762	VFR	NA	NA	None	None	-	-
32	2,762	VFR	NA	NA	None			

NPA	Non-Precision Approach
NA	Not Applicable
VFR	Visual Flight Rules
*	Hilsenrod, A. (FAA ARD-451): Correspondence to H. Ingrao (DOT/TSC) 13 March 1975. Regarding FAA FY75 RVR equipment under procurement. References 14 and 16.
**	RVRs use IRA computers.
***	Touchdown RVR to be installed at 13L FY76. Midpoint RVR installation indefinite.

5.4.2 MEDIUM AIR TRAFFIC HUB — SAN ANTONIO INTERNATIONAL AIRPORT

The airport layout plan for San Antonio International Airport is shown in Figure 11; the runway data summary is presented in Table 13.

A) Present Deployment

The San Antonio International Airport currently has three RVR systems. The RVR system on 12R rollout also serves as the touchdown RVR for 3R. All RVRs use the IRA computers.

B) Proposed Deployment

Although no definite plans for runway upgrading have been made by the FAA, the projected changes identified in Table 13 are those which the airport operator anticipates.* Upgrading runway 12R to Category IIIA will not require additional RVRs, since three already exist. Since runway 3R is less than 8,000 feet, upgrading it to Category II would require installation of only a rollout RVR. Runway 12L is planned to be extended to the length of 12R, and if upgraded to Category II, would probably require two additional RVR systems. The touchdown RVR on 12R may meet the siting criteria for 12L as well.

Based on SVR deployment criteria (Subsection 5.2), such a system is expected to be deployed at Runway 12R.

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*Rafferty, T.A. (Director of Aviation, Department of Aviation, San Antonio, Texas): Correspondence to J. R. Wiley (Aerospace Systems, Inc.), March 17, 1975. Regarding existing and planned visibility systems at San Antonio International.

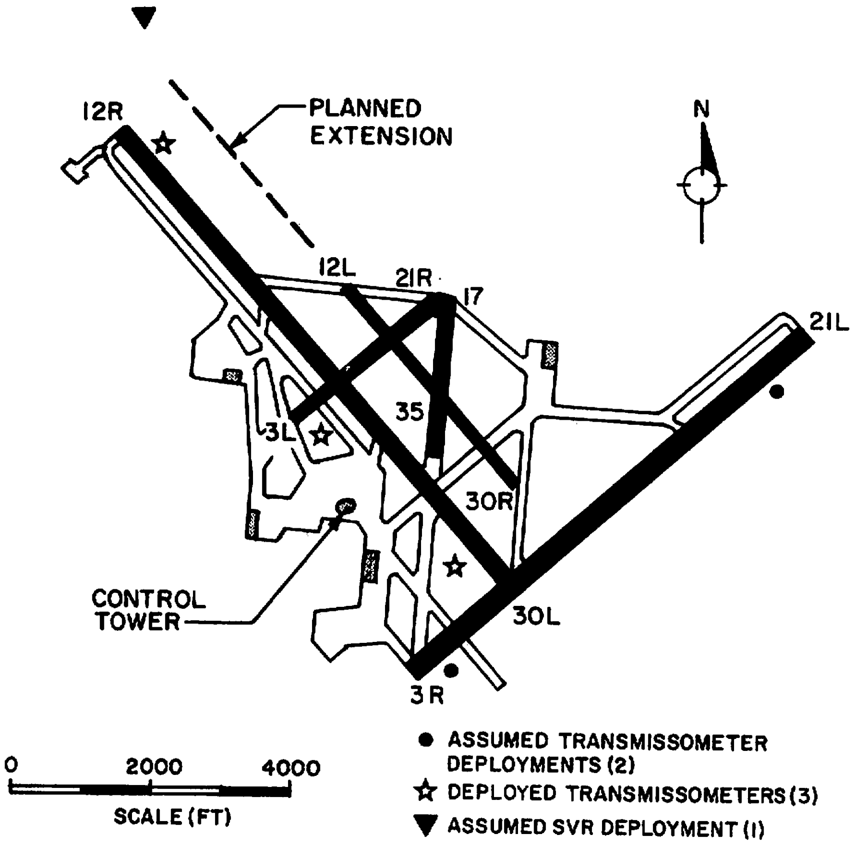

FIGURE 11. RUNWAY LAYOUT OF SAN ANTONIO INTERNATIONAL AIRPORT.

TABLE 13. RUNWAY AND RVR DATA SUMMARY (SAN ANTONIO INTERNATIONAL AIRPORT).*

Runway		Operation						
		Present (FY75)				Projected Changes (FY76-FY85)		
Designation	Usable Length (ft)	CAT	Min. DH (ft)	Min. RVR (ft)	RVR Equip.**	CAT	Add'l. RVR Equipment	Est. Date
3R	7,502	I	250	NA	***	II	1 rollout RVR	FY80
21L	7,502	NPA	NA	NA	-	None	-	-
3L	2,624	VFR	NA	NA	None	None	-	-
21R	2,624	VFR	NA	NA	None			
12R	8,500	II	150	1,600	3 RVR	IIIA	-	FY80
30L	8,500	I	200	2,400		None	-	-
12L	3,601	VFR	NA	NA	None	II	+	FY80-FY85
30R	3,601	VFR	NA	NA	None	-	-	-
17	2,400	NPA	NA	NA	None	None	-	-
35	2,400	VFR	NA	NA	None			

NPA	Non-Precision Approach
NA	Not Applicable
VFR	Visual Flight Rules
*	Rofferty, T.A. (Director of Aviation, Department of Aviation, San Antonio, Texas): Correspondence to J.R. Wiley (Aerospace Systems, Inc.) 17 March 1975. Regarding existing and planned visibility systems at San Antonio International. References 14 and 16.
**	RVRs use IRA computers.
***	12R rollout RVR is also used as touchdown for 3R.
+	Runway 12L may be extended to 8,500 ft and made CAT II. This projection is very indefinite.

5.4.3 SMALL AIR TRAFFIC HUB — BANGOR INTERNATIONAL AIRPORT

The airport layout for Bangor International Airport is shown in Figure 12; the runway data summary is shown in Table 14.

A) Present Deployment

Bangor currently has two transmissometers, one at each end of the runway, each one on a 500-foot baseline. There is one computer, a Cardion AN/FNN/1. A switch in the control tower enables the controller to select the transmissometer signals which are processed by the computer. Thus, depending on wind direction and weather, either transmissometer may be part of a full RVR system. Since there is only one computer, however, both transmissometers cannot be used at the same time for RVR.

B) Projected Deployment

The FAA has no definite plans for upgrading runway 15-33. No SVR deployment is anticipated.

C) Remarks

However, if this runway were ever upgraded to Category II, a midpoint RVR system would be required. Also, an additional RVR computer would be required for the existing transmissometers. If the runway were subsequently upgraded to Category IIIA from Category II, no additional visibility equipment would be needed to meet the present FAA requirements.

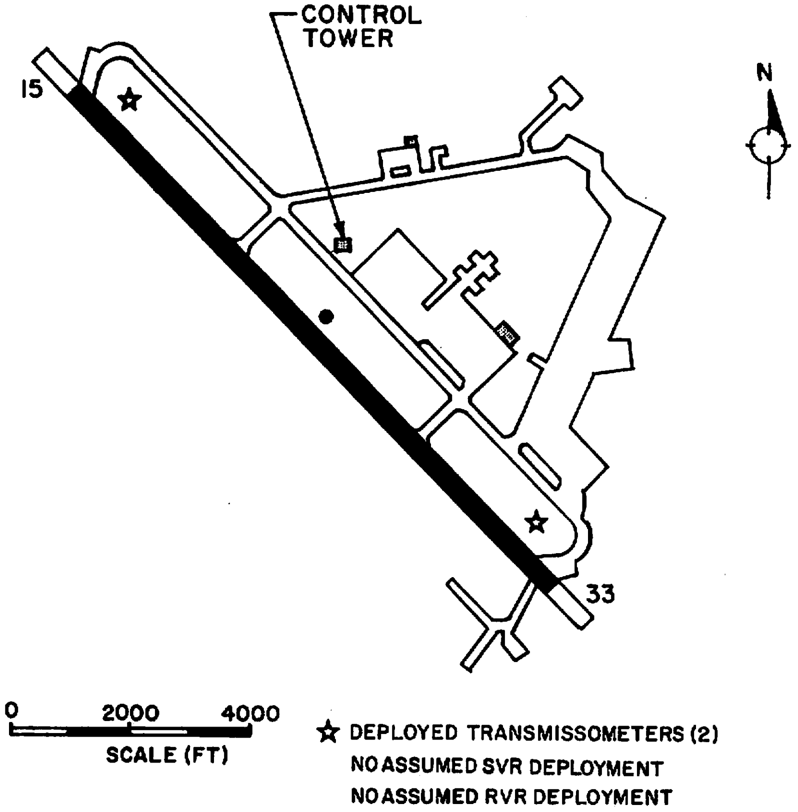

FIGURE 12. RUNWAY LAYOUT OF BANGOR INTERNATIONAL AIRPORT.

TABLE 14. RUNWAY AND RVR DATA SUMMARY (BANGOR INTERNATIONAL AIRPORT).*

Runway		Operation						
Designation	Usable Length (ft)	Present (FY75)				Projected Changes (FY76-FY85)		
		CAT	Min. DH (ft)	Min. RVR (ft)	RVR Equip.	CAT	Add'l. RVR Equipment	Est. Date
15	11,438	NPA	NA	4,000	**	None	None	-
33	11,438	I	200	2,400	**	None		-

NPA Non-Precision Approach.
NA Not Applicable.
* References 14 and 16.
** There are two transmissometers; one computer (Cardion AN/FNN/1) can serve either. Therefore, either transmissometer may be part of a full system.

5.4.4 NON-HUB — LONG BEACH (DAUGHERTY FIELD) AIRPORT

The airport layout for Long Beach (Daugherty Field) Airport is shown in Figure 13; the runway data summary is shown in Table 15.

A) Present Deployment

Long Beach Airport currently has one RVR system, and that is near the touchdown end of runway 30; the RVR uses an IRA computer.

B) Proposed Deployment

No FAA plans for installing a Category II or Category IIIA runway have been made, since this airport is so close to Los Angeles International and since it is primarily a general aviation facility.

No SVR deployment is anticipated.

C) Remarks

Considering the layout of the airport, if runway 30 were upgraded to Category II, both a midpoint and a rollout RVR system would be required. If subsequent to that, runway 30 was made a Category IIIA installation, no additional RVR systems would be required.

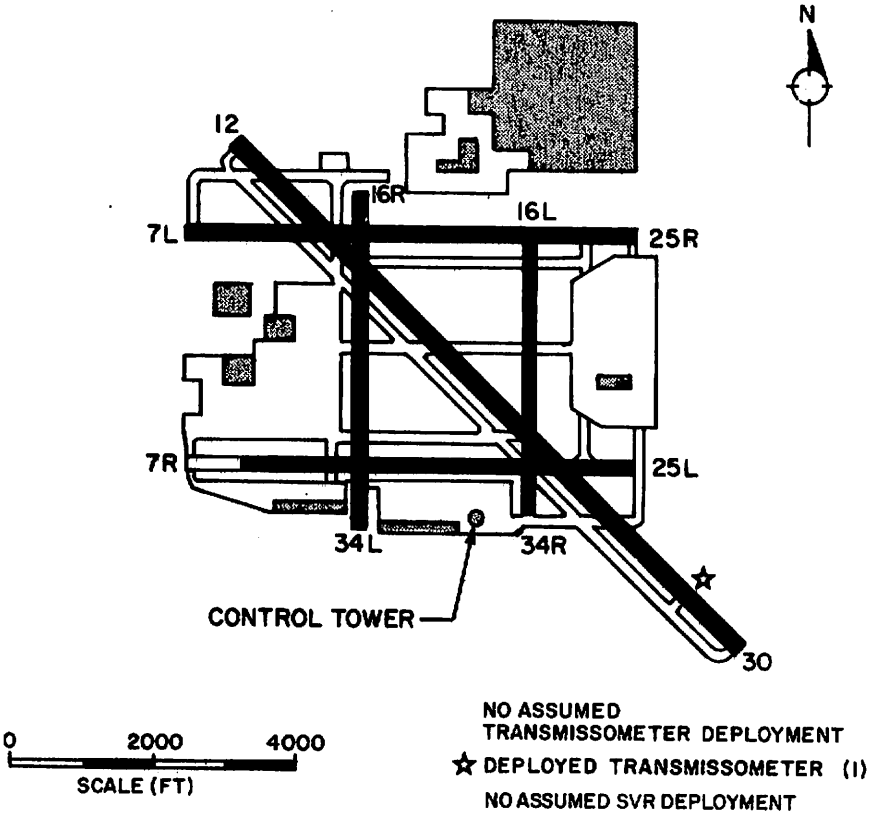

FIGURE 13. RUNWAY LAYOUT OF LONG BEACH (DAUGHERTY FIELD) AIRPORT.

TABLE 15. RUNWAY AND RVR DATA SUMMARY (LONG BEACH [DAUGHERTY FIELD] AIRPORT).*

Runway		Operation						
		Present (FY75)				Projected Changes (FY76-FY85)		
Designation	Usable Length (ft)	CAT	Min. DH (ft)	Min. RVR (ft)	RVR Equip.**	CAT	Add'l. RVR Equipment	Est. Date
7R	5,420	VFR	NA	NA	None	None	-	-
25L	5,420	VFR	NA	NA	None			
7L	4,886	VFR	NA	NA	None	None	-	-
25R	5,661	NPA	NA	NA	None			
12	8,651	NPA	NA	NA	None	None	-	-
30	10,000	I	250	4,000	1 RVR			
16R	4,699	VFR	NA	NA	None	None	-	-
34L	4,460	VFR	NA	NA	None			
16L	3,842	VFR	NA	NA	None	None	-	-
34R	3,965	VFR	NA	NA	None			

NPA Non-Precision Approach
NA Not Applicable
VFR Visual Flight Rules
* References 14 and 16
** The RVR uses an IRA computer.

5.4.5 SUMMARY

A summary of the results is shown in Table 16. Although the sample is small, it is felt that the average of new RVR equipment required per given runway is typical for similar runway categories at other locations.

When installing a new Category II runway, one additional RVR is always required at the rollout end for operations with RVR below 1,600 feet. Also, the runway selected for Category II status is typically the primary runway at the airport and, as such, is nearly always greater than 8,000 feet. Thus, it requires a midpoint RVR as well. These situations are tempered by the cases where an RVR on one runway also serves another or the runway is less than 8,000 feet long. Thus, the average of 1.33 additional RVRs per new Category II installation is heuristically reasonable.

Nearly all planned Category IIIA upgradings are on runways greater than 8,000 feet. They are usually the same runways which required three RVRs when upgraded to Category II. Thus, the average additional RVRs required per Category IIIA runway would be considerably less than one, and the average additional RVRs required for a new Category IIIA runway determined in Table 16 seems acceptable.

5.5 ESTIMATED DEPLOYMENT SCHEDULES (FY76-FY85)

Based on information presented earlier, estimated deployment schedules have been developed for RVR systems followed by estimates for SVR deployment.

TABLE 16. SUMMARY OF PROJECTED RVR VISIBILITY MEASURING EQUIPMENT REQUIRED TO UPGRADE RUNWAYS (FY76–FY85).

	New CAT I		Upgrade to CAT II			Upgrade to CAT IIIA	
Airport/Hub or Location	Number of Runways	Additional RVR	Number of Runways	Upgrade RVV	Additional RVR	Number of Runways	Additional RVR
Large Hubs:							
William B. Hartsfield Atlanta International Atlanta, Georgia	0	0	0	0	0	1*	1
Gen. Edward L. Logan International Boston, Massachusetts	0	0	1	1	1	1*	0
O'Hare International Chicago, Illinois	5	2	0	0	0	2	2
Los Angeles International Los Angeles, California	0	0	2	0	2	2*	0
John F. Kennedy International New York, New York	1	0	2	0	3	2*	1
Medium Hub:							
San Antonio International San Antonio, Texas	0	0	1	0	2	2*	0
Small Hub:							
Bangor International Bangor, Maine	0	0	0	0	0	0	0
Non-Hub:							
Long Beach (Daugherty Field) Long Beach, California	1	1	0	0	0	0	0
TOTAL	7	3	6	1	8	10	4
Additional RVR / Number of Corresponding Runways		0.43		0.17	1.33		0.40

*Number of CAT IIIA Runways proposed by upgrading all CAT II Runways.

5.5.1 RVR SYSTEMS DEPLOYMENT

The number of improved and new Category I, II, and IIIA runways which are planned through 1985 are determined primarily from information contained in the FAA ten-year plan (Reference 13).

The following indicates the fiscal year and location of airports which will have Category IIIA runways.*

Seattle, Washington	FY76
Houston, Texas	FY76
Kansas City, Missouri	FY76
New York, New York	FY76
Chicago, Illinois	FY76
San Francisco, California	FY76
Portland, Oregon	FY77
New Orleans, Louisiana	FY77
Los Angeles, California	FY77
Milwaukee, Wisconsin	FY78
Covington, Kentucky	FY78
Philadelphia, Pennsylvania	FY78.

The above dates differ with the FAA ten-year plan, which identifies a total of only ten additional Category III runways through 1980.

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* Hilsenrod, A. (FAA ARD-451): Correspondence to H. Ingrao (DOT/TSC), March 17, 1975, regarding estimated Category III implementation dates.

Using the ten-year plan and the above information, Table 17 presents a summary of the Category I, II and III runways planned over the next ten years.

The deployment of Category I runways for the next ten years is shown in Table 17. Information on individual years is not provided in the FAA ten-year aviation plan for the FY81-FY85 time frame as shown in the table. For the deployment of the visibility equipment developed in the following section, it is assumed that those 150 runways are established at the equal rate of 30 per year for the five years FY81-FY85.

The expected deployment of Category II runways is also shown in Table 17. Note that after FY77 no new Category II runways are planned except for three to be established sometime in the FY81-FY85 time frame. For the equipment deployment schedule, it is assumed that these runways are upgraded one per year in FY81, FY82, and FY83.

TABLE 17. FAA CATEGORY I, II AND III PLANNED RUNWAYS (FY76-FY85).

	Number of Runways						
Installations	FY76	FY77	FY78	FY79	FY80	FY81-FY85	Total
Category I							
Establish	22	10	25	50	40	150	297
Replace/Relocate	9	25	0	0	0	0	34
Category II	18	3	0	0	0	3	24
Category III	6	3	20	20	15	60	124

To determine precise requirements for visibility equipment at new Category I installations over the next ten years using the criteria presented in Subsection 5.1 would require solving equations 9, 10, and 11 (see page 5-6) for every existing or proposed runway for each of the next ten years. In addition, forecasts of the annual enplaned passengers, annual instrument approaches and mean number of low visibility hours should be considered. A more expedient approach for the estimated deployment is to use the ratio of existing number of RVR equipment to the corresponding runways and to assume that this ratio can be applied to the projected Category I installations.

As shown earlier in Table 4, this ratio per existing Category I installation is 0.46. Although this number includes RVVs (i.e., transmissometers only), it seems clear that all future visibility equipment installations will be full RVR systems. Notice that this number is in close agreement with the ratio 0.43 determined from the relatively small sample of eight airports studied in detail earlier and summarized in Table 16. Thus the number of RVR systems S_I^{fy} to be deployed per fiscal year is found from the upgraded Category I runways R_I^{fy} in that fiscal year by:

$$0.46 \times R_I^{fy} = S_I^{fy} . \qquad (12)$$

For the period FY76-FY85, the total number of RVR systems Category I, S_I, will be:

$$\sum_{fy76}^{fy85} S_I^{fy} = S_I . \qquad (13)$$

The results are shown in Table 18. A total of 138 new RVR systems are estimated to meet Category I requirements over the next ten years.

As identified in the FAA ten year plan, Category II runways are established by upgrading existing Category I runways. When compared to the plans for Category I and II

TABLE 18. FAA RVR SYSTEMS ESTIMATED DEPLOYMENT SCHEDULE (FY76-FY85).

Installation	FY76	FY77	FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	Total
Category I	10	5	12	23	18	14	14	14	14	14	138
Category II	24	4	0	0	0	1	1	1	0	0	31
Category III	2	1	8	8	6	30	30	30	30	30	175
Replacement	6	6	6	6	6	6	6	6	6	6	60
Total	42	16	26	37	30	51	51		50	50	404

over the next ten years, there are very few planned Category II installations. Thus, the estimated number of RVRs to meet new Category II requirements is a small part of the total estimated number of RVRs which are to be deployed over the next ten years.

The number of systems S_{II}^{fy} to be deployed per fiscal year is found from Category II runways R_{II}^{fy} in that fiscal year by:

$$1.33 \times R_{II}^{fy} = S_{II}^{fy} . \tag{14}$$

The total number of RVR systems Category II, S_{II}, for the period FY76-FY85 will be:

$$\sum_{fy76}^{fy85} S_{II}^{fy} = S_{II} . \tag{15}$$

The results are shown in Table 18. A total of 31 new RVR systems are estimated to meet Category II requirements over the next ten years.

To determine the additional RVR equipment required for new Category III locations necessitates a slightly different approach. This is true since the average number (0.43) determined from the sample airports analyzed applies to Category III locations established from Category II runways. There are expected to be a total of 126 Category III runways by 1985, but only 72 Category II runways by that time (Reference 13). Since there are more Category III planned than the total existing and planned Category II, it is clear that all Category III runways cannot be established by upgrading Category II installations.

A Category III RVR estimated deployment schedule is developed based on the following assumptions:

1. There will be only one Category III runway per airport.
2. This runway will be the "primary runway" of the airport.
3. The primary runway is also the runway which is the first to be upgraded to Category I and/or II.
4. As of 1975, there are 48 commissioned or approved Category II runways (Table 4). There are another 21 Category II runways planned through FY80 (Table 17) for a total of 69 runways.
5. There are a total of 64 planned Category III runways through 1980. It appears that the Category III runways established through FY80 will be obtained by upgrading Category II runways.
6. From FY81-FY85, Category III runways will be established by upgrading Category I runways.

In accordance with data given in item 5, the number of Category II runways should be only slightly greater than the number of airports with a Category II runway. The data given in item 4 implies that there could be as many as five airports with two Category II runways. Thus, through FY80 all Category III runways are assumed to be the result of upgrading Category II installations, and the RVR equipment-per-runway ratio (0.43) determined in Table 16 is used.

From FY81-FY85 Category III runways are established by upgrading Category I. From data given in Table 4, 46 percent of Category I runways have one RVR system installed. The FAA requirements state that all Category III installations will have three RVR systems. Thus, since 12 Category III installations will be developed each year after FY80, we find that 46 percent of these 12 will be on runways already equipped with one RVR system, and 54 percent will require three RVR systems. This works out to six installations requiring two RVR systems each, and six requiring three RVR systems, for a total of 30 systems each year from FY81-FY85. The results are shown in Table 18. A total of 175 new RVR systems are estimated to meet Category III requirements over the next ten years.

Another element considered in the RVR systems deployment schedule is the replacement of obsolete equipment. Discussions with FAA personnel in the New England Regional Office indicated that replacement of RVR systems is decided by the Regional Offices, subject to approval from FAA Headquarters, on an as-needed basis. No specific criteria exist for determining when to replace "obsolete" or "malfunctioning" equipment. The FAA Headquarters identified six RVR systems procured in FY75 which are designated as replacement RVR systems*. Since no other data is available, and since it seems reasonable that some replacements will be required in the future, the number of replacement equipment is assumed to remain at this level through the period of interest, FY76-FY85. Since the total number of deployed RVR systems is growing with time, this implies that a smaller percentage of equipment will be required to be replaced. This seems reasonable since in general the newer equipment is more reliable and has a longer lifetime than the older equipment.

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*Hilsenrod, A. (FAA ARD-451): Correspondence to H. Ingrao (DOT/TSC), 13 March 1975. Regarding FAA FY75 RVR Equipments Under Procurement.

A retrofit program for existing installations, including RVV/RVR could be implemented by means of modification kits. At this point, a criteria does not exist which allows an estimate of the number of systems to be retrofitted in the period FY76-FY85.

5.5.2 SVR SYSTEMS DEPLOYMENT

The SVR deployment schedule shown in Table 19 follows the pattern of Category III installations shown in Table 17, but initial deployment is in 1978. The first operational and pilot's acceptance tests of the SVR are planned at Logan International (Boston) and Los Angeles International, and, if successful, are likely to be the first approved SVR sites. This may occur in the 1978 time frame which gives some further justification for the schedule selected. The deployment continues through 1984, at which time there are as many SVRs as projected Category II installations.

TABLE 19. FAA SVR SYSTEMS ESTIMATED DEPLOYMENT SCHEDULE (FY76-FY85).*

FY76	FY77	FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	Total
0	0	2	6	3	20	20	15	6	0	72

*Each SVR system requires the installation of a 100-foot tower.

6. COMMERCIALLY AVAILABLE VISIBILITY MEASURING EQUIPMENT

The following subsections identify alphabetically by corporate source the visibility measuring systems, subsystems and main components which are commercially available. All data included herein have been provided by the manufacturer and are subject to change by the manufacturer. Modification kits for visibility equipment are also described. Cost information, when available, is included.

6.1 ALLGEMEINE ELEKTRICITATS-GESELLSCHAFT, WEST GERMANY — SCATTERED LIGHT RECORDER

During a period of more than five years the Flugwissenschaftliche Forschungsanstalt, Munich, West Germany (FFM) conducted the research and development which is the basis of a scattered light recorder. The recorder was developed in cooperation with AEG and it is marketed as AEG/FFM Scattered Light Recorder (Reference 17).

The AEG Scattered Light Recorder Type STR-V22-56-MS 04 measures the scattered light a flash lamp is generating in an optically limited scattering volume and indicates the visual range. It has a two decade range, and a logarithmic scale. Its accuracy is $\pm5\%$ of the threshold value, and it has a $\pm5\%$ error of linearity. The range of angle of scattered light is 10° to 120°, and the measuring volume is 780 cm^3. Lifetime of the flash lamp is one year, and the power input is 187 to 250 V, 50 Hz, 200 VA (heating included). The dimensions of the unit are about 69 x 16 x 6 in., with a weight of about 120 lbs. Accessories such as fog warning contact or error control digital display can be supplied with the AEG/FFM Scattered Light Recorder.

No up-to-date price data or delivery schedule is available.

6.2 ATELIERS DE CONSTRUCTIONS ELECTRIQUES DE CHARLEROI, SA, BELGIUM — VIDEOMETER

The ACÉC in cooperation with the Belgian Air Ministry developed an RVR system designated Videometer. This system uses a closed television system as a sensor. The first report of the Videometer (References 18 and 19) was in 1965.

The Videometer is essentially a television camera mounted alongside the runway which is calibrated to "see" the same as a human observer and uses the same type of lights and spacings used by the pilot as his visual cues. It is basically composed of two main parts: one part for observation, i.e., a marker light row; and an electronic part for measurements, i.e., television camera, monitor, control and display panel.

A different marker light row equipped with the same lights as used on the runway is installed, offset approximately 225 ft from the edge of the runway. Lamps are the 200 W type. They are spaced in accordance with the recommendation of an ICAO joint meeting held in February 1964: approximately 150 ft apart over the first 1,500 ft then at 300 ft. A television camera is placed approximately 15 ft high, which corresponds to ICAO recommendations. This camera is provided with a variable focus lens (zoom); it scans the light row in groups of three successive units (for example, lamps 1, 2 and 3; 2, 3 and 4; 3, 4 and 5; etc.).

The principle of a visibility measurement consists of obtaining on a television screen an image of a group of three lights, the first and the second one being fairly visible, while the third one is not as visible; the distance between the camera and the second light indicates, in this case, the RVR value.

The Videometer was tested in the Brussels Airport and at the fog chamber at the University of California Field Station, Richmond (Reference 20).

No up-to-date price data or delivery schedule is available.

6.3 EDGERTON, GERMESHAUSEN & GRIER — FORWARD SCATTER METER

The Environmental Equipment Division of EG&G developed the Forward Scatter Meter (FSM) Model 207 several years ago. This unit received extensive testing by the Air Force Cambridge Research Laboratories (AFCRL) (Reference 21), NAFEC and NWS. These extensive tests were in some instances of a comparison type with the FAA/NBS transmissometer.

The EG&G FSM Model 207 (Reference 22) is fabricated as a single unit consisting of a cabinet housing the control unit, control panel and associated electronics, and two support arms holding the projector and receiver assemblies. Power input and signal output terminals are located at the rear of the cabinet behind a removable access cover.

The instrument contains a light source and photo detector separated by approximately 4 ft and mounted from a common electronics enclosure. The light source is configured to project a cone-shaped beam of light over the range of 20° to 50° from the center axis toward the photo detector. A silicon photo detector looks toward the light source and is similarly configured to accept light only from a cone-shaped volume of the same dimensions. The resulting sampling volume is approximately 1.67 cu ft.

Light energy impinging on the photo detector from scattering caused by particulates or aerosols in the sampling volume is linearly related to the atmospheric extinction coefficient. Logarithmic converters provide convenient voltage outputs corresponding to visual-range values from 200 to 20,000 ft. Light energy-source output is maintained constant through an independent light detector and electronic feedback loop. Light source modulation at 292 Hz and synchronous signal demodulation effectively eliminate interference from background luminance.

Solid-state electronics with regulated power supplies provide stable, long-term, drift-free analog outputs. Output signals are low impedance analog DC voltages of 0 to +5 V. A readout meter is also provided in the electronics enclosure for local voltage indication.

Calibration of the Model 207 can be accomplished under adverse conditions by use of a specially designed calibration device which is available as an accessory item. The device introduces a standardized scattering medium between the light source and photo detector, and excludes atmospheric media thereby preventing the atmosphere from interfering with the calibration of the meter.

Equipment specifications are as follows:

Visual Range - Based on 5% Contrast Ratio:	200 feet to 20,000 ft
Measurement Volume:	1.7 cu ft* minimum
Measurement Accuracy:	±5% of forward scattered coefficient
Power:	115 vac ±10%, 60 ±5% single phase, 200 W
Ambient Temperature:	-30°C to +50°C
Weight:	135 lb

Mounting:	Single pipe with optional guy wires
Deployment:	Unattended in ice, snow, rain and similar hostile environments
Orientation:	The receiver optics should face in a northerly direction to avoid direct sun rays into the receiver.
Time Constants (Linear Output)	
Operate and Test Positions:	20 sec nominal
All Other Test Positions:	2 sec nominal.

The November 1975 prices of the Model 207 is $9,800 for quantities up to 4 units, $8,900 for 5 to 9 units and $8,200 from 10 units and up. A calibrator is required to set up and adjust the Model 207 during routine maintenance periods. The calibrator cost is $980. Delivery can be made usually within forty-five (45) days after the receipt of the order, depending on order backlogs.

6.4 IMPULSPHYSIK GmbH, WEST GERMANY

The company Impulsphysik GmbH, at Hamburg-Rissen, West Germany, has, over the years, developed a large number of meteorological equipment especially in the field of visibility measurements.

6.4.1 FUMOSENS

The Fumosens is a fog detector (Reference 23) based on light scattered forward from the fog particles. It consists essentially of a flash lamp and a photodiode, between which are placed screens so that no direct light, or light scattered through an angle of less than 20°, can reach the photodiode from the lamp. In clear air, no light from the lamp reaches the photodiode. However, when visibility is poor, some light is scattered towards the receiver by the fog particles. The resulting output current in the photodiode circuit may be used to operate relays controlling illuminated fog warning or speed limit signs at pre-set values of current and hence of visibility. If warnings are required for more than one fog density, a corresponding number of threshold values may be used to operate the necessary signs.

The receiver in the Fumosens distinguishes between the signal from the flash lamp and daylight or other stray light. The white light of the spark lamp ensures the measured visibility will be representative of what will be seen by human eyes.

The Type A Model 13/5100 uses 110/220 V power input, 50/60 Hz, 50 W, and has a measuring range of 20 to 3000 meters visibility. Its operating temperature range is -30° to +45° C. The Output DC analog signal, 0 to 1mA, is independent from the ohmic resistance of recorder and connection line, between 0 and 20,000 ohms. The price for one unit (February 1975) is $4,300.

6.4.2 SKOPOGRAPH

The Skopograph (References 24, 25, and 26) is one of a family of meteorological air traffic safety instruments. It functions as a transmissometer over a wide transmittance range. The system consists of a pulsed light projector, photoelectric receiver and a recorder or a direct meter indicator.

The Skopograph projector has a pulsed, white light with a high, constant peak output of very short duration, flashing about once a second. This light passes over the baseline to the receiver, which responds only to the short projector pulses and measures their intensity. The receiver has a discriminating circuit to eliminate noise from ambient white light. The remote strip chart recorder cable connected to the receiver a long distance away continuously records the light intensity. Any fog, rain, snow or suspended particles in the air along the baseline change the visibility, and increases or decreases thereof are clearly noted on the visibility scale of the recorder or the accessory indicator. All controls are on the recorder housing for automatic, remote operation of the system. A stabilizer maintains the circuit voltage level with input variations of +10 percent to -20 percent. Electronic power consumption is 60 W, but the heating system requires 80 W. Dimensions are 35 x 17.5 x 64 in.; the weight is 175 lbs.

The receiver has a discriminator circuit to eliminate false measurements from ambient or other light. A vacuum type phototube is used in the system for measuring the intensity of the pulsed flashes received. Its transistorized circuitry is mounted on a plug-in chassis for ease in inspection or exhange. Its operating voltage is the same as the projector; power consumption is 500 W for the electronics and 250 W for the heating system. This weighs 16.5 lbs and its dimensions are 14.5 x 7.5 x 5 in. For price information, see Subsection 8.2.1.

6.4.3 VIDEOGRAPH

The Videography is a visibility meter based on the measurement of back-scattered light (References 27, 28, and 29). The instrument consists of a pulsed light projector and a photo-sensitive receiver mounted above it in the same unit.

The projector emits a narrow beam of light into the atmosphere. This beam intersects the axis of the receiver at a distance of about 15 ft in front of the Videograph. Aerosol particles in this zone scatter some of the light in the projector beam back into the receiver. The intensity of the back-scattered light is measured by the receiver and indicated on a meter graduated in visibility. Normally the calibration is in terms of equivalent daylight visibility assuming a 2 percent or 5 percent threshold of luminance contrast. When the visibility falls below a pre-set level, a built-in alarm device closes a pair of contacts for the operation of a warning signal.

Available accessories are a recorder and two types of direct indicator, one equipped with an alarm-tripping device for up to eight visibility levels. These accessories can be used singly or in combinations and they can be installed at points remote from the Videograph.

The Videography was designed as a visibility meter for use at lighthouse stations; it is equally suitable for incorporation into automatic weather stations for monitoring visibility around airports, or as an aid in the control of traffic on roads and waterways.

The observation scale is 0.1 to 10 nautical miles on an internal meter. An alarm tripping delay in turning the alarm on is adjustable from 0 to 5 min. Delay in shutting off the alarm is adjustable from 0 to 8 min. These delays are available to obviate repeated on-off in the event of rapidly changing conditions. The output of the receiver may be read directly from a meter, fed to a standard 1 milliampere recorder, telemetered by landline or radio. The videograph is 21.5 x 12.5 x 46.9 in. and weighs 130 lbs. Casing and all exterior metal parts are made of salt-resistant alloy. Casing is gasket sealed and windows are provided with an internal heating circuit.

The power supply may vary from 11V to 14V. The unit consumes 6 W when continuously operating, and 28 additional watts when instrument heating is on. Electronics are solid state. There are no moving parts, except meters. Light source is xenon flash lamp. Life expectancy is a minimum of two years. Pulsing rate is three per second.

The following detailed unit prices have been supplied by the manufacturer:

Equipment	Price
13/3000 Videograph B, low power consumption type, updating time about 7 minutes, including one alarm contact without recorder	$ 8,040
13/3020 Automatic fail safe device, checking the transmitter operation permanently and quantitatively as well as the receiver, either upon request or automatically	460

Equipment	Price
13/3030 Impulse Generator	$ 450
13/3306 Direct Indicator (mounted in housing) with alarm tripping device, eight alarm signals adjustable at different levels	1,770
13/3300 Recorder, visibility-calibrated, including built-in operation	2,600

6.4.4 SKOPOLOG

The standard Skopolog RVR System consists of: Skopograph transmissometer (see Subsection 6.4.2), RVR computer, Digistep digital converter, recorders and remote digital displays, and Stilbus background luminance sensor.

The outputs of the Skopograph transmissometer and the Stilbus background luminance sensor are fed to the RVR computer. This computer also has an input for the runway light intensity setting. All input data are processed automatically but can also be fed to the computer manually for test purposes. Remote test facilities for the field instruments are available. The computed RVR data are digitized by the Digistep converter according to ICAO recommendations. The resulting RVR values are indicated on digital displays.

Analog recorders can be connected directly to the RVR computer to record the input and output data for use in accident investigations, operational studies, etc.

The remote control unit is designed for up to three Skopograph transmissometers. Remote controls enable checking Skopograph operation on request. This control unit allows projector and receiver to be switched on and projector to be switched off separately for zero check.

The RVR computer calculates the RVR values continuously over the range of background luminance -- e.g., night, twilight, day, bright fog. Furthermore the computer is programmed according to the real intensity distribution of the runway lights. This method of calculating RVR, based on the exact position of the pilot with respect to the beams of the runway lights, avoids errors which could impose limitations on takeoffs and landings or, on the other hand, could give the pilot an overly optimistic impression of visibility conditions.

The RVR computer for a single channel processes the visibility data from the Skopograph transmissometer. The computer has inputs for

a) atmospheric transmittance
b) background luminance
c) runway light intensity.

Inputs b) and c) are inserted either automatically or manually. The controls for the manual setting are behind the front panel for safety reasons. On the front panel are situated the main switch with pilot lamp and, grouped together, the controls and indicator lamps for the alarm device. The optical and acoustical alarm can be set to any desired value within the measuring range. Behind the panel are the controls for setting the updating time within the range 5 to 60 sec.

A 19-inch plug-in unit houses the integrated circuit electronics which are easily accessible when the front door is opened. All components are mounted on standard size plug-in printed circuit boards. The computer has its own power supply.

The RVR computer has an analog output to drive the RVR recorder. This computer is also the basic unit for all multi-channel RVR systems.

The selector extends the basic computer unit to a multiple channel system. By means of a time-multiplex system, up to 10 Skopograph transmissometers are automatically connected to the input of the central computer.

The printed circuit boards of standard size are housed in a 19-in. plug-in unit. The controls are behind a locked door for safety reasons: Individual channels can be hand selected for checking the system. Indication of the selected channel is by means of light emitting diodes.

The Digistep single-channel unit converts the analog RVR data supplied by the RVR computer into digital values. These values are rounded down to the nearest point on the chosen RVR reporting scale in compliance with ICAO recommendations. The rounded down values are shown on the display unit on the front panel. Light emitting diodes (LEDs) indicate values of less than 50 m or more than 2000 m. The tendency of visibility conditions either to increase or decrease is shown by a + or - sign in front of the actual RVR value. The Digistep single-channel unit transmits the RVR values by means of a digital serial code over a 2-wire cable.

Several recorders can be connected to the same Skopograph system. A 19-inch rack version and recording systems without remote controls are available. Potentiometric recorders with up to 12 channels are available.

The multi-channel recorder contains a moving coil 2-channel recording system for either metallized or ink recording paper. The scales are graduated in RVR values. Standard chart speed is 60 mm/h.

Next to the recording system are placed the remote controls for the Skopograph transmissometer. Several recorders can be connected to the same system.

The stilbus background luminance sensor is equipped with photoresistors and an optical system and measures the background luminance. A built-in heater protects it against condensation, frost and icing. It can be mounted separately close to the RVR computer or near the runway on the Skopograph transmissometer.

For price information, see Subsection 8.2.1.

6.5 INTERNATIONAL LASER SYSTEMS, INC. — VISIBILITY SENSOR, MODEL VS-1

International Laser Systems, Inc. located in Orlando, Florida, specializes in optical communication devices, laser applications, and related instrumentation. As part of their commercial product line, the company produces the Model VS-1 Visibility Sensor, a transmissometer using a 250 ft. baseline.

The transmitter unit contains an amplitude-stabilized Ga-As laser transmitter, transmitter optics and an associated alignment mechanism, a power supply and heater circuits. The transmitter electronics are packaged on three separate plug-in printed circuit boards.

A pulse-repetition-rate oscillator produces a 1,000-Hz pulse train which is fed to the laser modulator. The modulator provides drive current pulses to the laser diode at the pulse repetition rate. A lens collects the laser diode output power and collimates it into a 1° beam.

A folding mirror is provided to fold the laser beam from the vertical to the horizontal plane. This mirror has a tilt adjustment for beam alignment in the vertical plane. Azimuth alignment is accomplished by rotating the interior frame with jack screws. A sighting scope mounted on the mirror is utilized for aiming the transmitter at the receiver.

Amplitude stabilization of the laser diode over the given temperature range is accomplished by sampling the laser output collected through a hole in the middle of the folding mirror. The collected light illuminates a photodiode installed on the power monitor board.

The laser diode's normal output of 20- to 30-W is controlled at a reference 5-W level by the power monitor. This margin permits output stabilization over a wide range of temperature and laser diode aging and provides a continuously accurate reference for transmission measurements.

The receiving unit contains the receiver optics, an alignment mechanism, an optical receiver, a peak detector, level detectors, a relay and current loop output circuit, a power supply and heater circuits. The receiver electronics are packaged on four separate plug-in printed circuit boards.

Optical pulses from the transmitter are reflected by the folding mirror and collected by the lens. A field stop is located at the focal point of the lens to establish the receiver's 1.5° field-of-view. An optical filter - located behind the field stop - is used to block background radiation (sunlight) from the photodetector. A large-area PIN diode is utilized to allow the receiver board to be removed and replaced without affecting the optical characteristics of the unit.

Except for the sighting scope, which is not needed, the receiver contains all the alignment provisions included in the transmitter.

The received optical pulses are detected by the photodetector and routed to two channels — one without amplification and the other with a gain of 50. These two signals drive a dual-input peak detector. The high-gain (50x) input is only active for weak signals corresponding to severe fog conditions. Output of the peak detector is a dc voltage equal to the average peak detected optical pulse.

Output of the peak detector is parallel-fed to a four-stage level detector. The slicing level of each level detector is adjustable by a 10-turn potentiometer on the reference voltage input to each comparator. These adjustments are factory set to given levels.

Four relay outputs are provided for the various visibility levels. A logic circuit is incorporated to prevent more than one relay operating at any one time. The lowest visibility level relay has priority over upper levels. These relay outputs can automatically operate a display or other device at the selected level.

A 1.0-mA current loop also is provided for remote monitoring of the discrete visibility levels on a single panel meter or chart recorder. The loop current is set by a separate contact on the appropriate relay. A transistor current source is utilized for the loop so as to be insensitive to loop resistance over the specified range.

An integral panel meter is provided for alignment and test of the system.

The computed MTBF for the VS-1 is 2,655 hrs. This figure is based on the parts count method per MIL-Handbook-217B. The parts stress analysis method would most probably give an extended MTBF as the circuits are conservatively designed. The laser diode is excluded from the above MTBF as reliability data is not available on this device. Experience and best guess indicate a MTBF of greater than 2,000 hrs for the laser diode.

Concerning MTTR, the cover can be removed in a few minutes and defective printed circuit board located with the aid of the internal test features within 10 to 15 min by an experienced technician. By providing spare printed circuit boards, the MTTR should be 10 to 15 min.

The specifications for the Model VS-1 Visibility Sensor (Reference 30) are as follows:

Distance between Transmitter and Receiver	250 ft ± 10 ft
Receiver Signal Outputs at Different Visibilities	
Visibility	Output Current
Greater than 1,000 feet	1.0 ma
Between 1,000 and 500 feet	0.8 ma
Between 500 and 300 feet	0.6 ma
Between 300 and 100 feet	0.4 ma
Less than 100 feet	0.2 ma
Power Supply	115 or 220 V, 50/60 Hz, 55 Watts, each end
Operating Temperature	-40°F to +140°F
Size	
Transmitter	8.6 x 24 in. (Dia x H)
Receiver	8.6 x 24 in. (Dia x H)
Weight	
Transmitter	35 lbs
Receiver	35 lbs
Mounting of Transmitter and Receiver	Mounts on 3-in. schedule 80 pipe (3.5 in. O.D.)

The system is particularly suited for the highway environment, but can be configured for airport use.

The prices* as of 1 November 1975, are $6,750 for 1 to 4 VS-1 units, $5,890 each for 5 to 9 units, $4,790 for 10 to 24 units and $4,250 for 25 units and up. It should be pointed out that MBTF calculated (MIL-S-217-B) for the VS-1 unit is 2,650 hrs. The estimated MTTR is only a few minutes.

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* Price information letter, November 26, 1975, D. R. Woods (International Laser Systems, Inc.) to H. C. Ingrao (DOT/TSC).

6.6 LEAR SIEGLER, INC.

Lear Siegler, Inc. (LSI) has an agreement with Marconi Radar Systems, Ltd. for marketing, in the U.S., IVR systems, MET-1 and the transmissometer model SM5.

6.6.1 RVR SYSTEM MODEL IVR-2

The RVR model IVR-2 system is manufactured by Marconi Radar System, Ltd. (see Subsection 6.7.2) and is marketed in the U.S. by LSI Astrionics Division (Santa Monica, California).

6.6.2 ENVIRONMENTAL TRANSMISSOMETER MODEL MET-1

The MET-1 transmissometer is manufactured by Marconi Radar System, Ltd. (see Subsection 6.7.2) and is marketed in the U.S. LSI Astrionics Division (Santa Monica, California). The November 1975 price for one MET-1 transmissometer is $10,000.* Since the MET-1 is a new commercial product, it is expected that as soon as the MET-1 goes into full-scale production (mid to late CY76), the price will fall to around $6,000 each.

6.6.3 SM5 TRANSMISSOMETER

The SM5 transmissometer is manufactured by Marconi Radar Systems, Ltd. (see Subsection 6.7.3) and marketed in the U.S. by the LSI Environmental Technology Division (Englewood, California). The model SM5 transmissometer is used in all RVR systems manufactured by Marconi. This company also has the SM4 model used in highway visibility measurements. More recently the SM4 and SM5 model designation changed to VM4 and VM5, respectively.

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* Price information letter, December 1, 1975, D. St. Lawrence (Lear Liegler, Inc.) to Hector Ingrao (DOT/TSC).

The price supplied by LSI in November 1975 is for one complete SM5 unit (catalog #90-001), $12,646. This unit includes the SM5 transmissometer at $9,195, four-point alarm level detector, with variable averaging time intervals, indicators and controls, $1,850; a set of protective housings, $1,935; and a calibration kit including neutral density filters, $250.

6.7 MARCONI RADAR SYSTEMS, LTD., UNITED KINGDOM

Marconi, Ltd., has developed several RVR systems. Brief descriptions of the IVR-2 and MET-1 are included herein. All Marconi RVR systems use the SM5 transmissometer which is manufactured in Germany. Descriptions of the IVR-1 are not included since this model has been superseded by the IVR-2 and this by the IVR-MK2. The IVR-MK2 Category II system is virtually the same as the IVR-2 system. Alternative modules permit a simple and quick upgrading to full Category III.

The system can serve up to six field sites under a range of environmental and service conditions. For price information, see Subsection 8.2.2.

The earlier system, IVR-1 (Reference 31) has successfully completed on evaluation period at NAFEC, Atlantic City. Marconi has an agreement with Astronics Division (see Subsection 6.6) in the U.S. for the exclusive distribution of the IVR system and MET-1. LSI is also distributing the SM5 transmissometer in the U.S. as discussed in Subsection 6.6.

6.7.1 RVR SYSTEM MODEL IVR-2

The Marconi IVR-2 system (References 32 and 33) has been used in all three visibility categories. The measuring instrument is a transmissometer which consists of a transmit/receive unit and a tetrahedral reflector mirror, placed 60 ft apart to give an optical baseline of 2 x 60 ft. Up to six transmissometers can be handled by the minicomputer in the IVR-2 system.

The central processing unit usually installed in the telecommunications equipment room incorporates a general purpose minicomputer, which in addition to receiving information from the field sites, accepts signals by wired connections indicating the runway light setting, the direction of the runway in use and the time reference for the airport. From this data it performs the computation of RVR, looks after calibration and integrity checking and controls the format and logging of data.

Data is stored ever 1.5 sec and RVR is calculated for presentation every 15 sec. The values of RVR and transmission at the field sites, together with the time and other necessary particulars, are printed out by a teletype whenever RVR changes. Identical information is punched onto paper tape in case there is a requirement for computer collation with other air traffic control records.

The computer is a Digital Equipment Corporation PDP-8E. The interface is specially designed for the IVR-2 system. The computer control panel can be manually "locked out" when the RVR program is running to prevent accidental interference to normal operation.

The IVR-2 incorporates relatively sophisticated software in the computer for the calculation of RVR. The technique used is described in a recently presented paper (Reference 34).

The following data summary was provided by Marconi. The main supply is 220/240 V ±6%, 50 Hz (47-51), single phase. Other supplies can be accepted. Power (standard configuration) for each field site is 1.5 kW; for the central processing unit 2 kW are required. Outdoor units operate within 15°C to 55°C. The transmissometer housing dimensions are 72 x 29 x 22 in. The weight is 195 lb.

For price information, see Subsection 8.2.2.

6.7.2 ENVIRONMENTAL TRANSMISSOMETER MODEL MET-1

The MET-1 is a compact transmissometer recently developed by Marconi (Reference 35).

These are two features of MET-1: (1) directly measures the atmospheric transmittance; and (2) makes absolute measurements of atmospheric transmittance using a self-calibration technique.

MET-1 is a compact transmissometer. The standard instrument operates over a folded baseline of 6 x 6 ft. For ground level installations, it is supported at the required operating height on a single, central support pillar. Other measurement baselines can be provided, thereby extending the range of atmospheric extinction coefficients that can usefully be measured.

For installations employing a large number of sensors and having adequate data transfer capacity, a more cost-effective system can be provided using centralized data processing and control modules (see ARVIS, Section 7). This type of system also offers the possibility of significantly improving the accuracy of the atmospheric transmittance data obtained, by using a longer digital word.

The light source used is an electronically modulated light emitting diode. A retro-reflector at the other end of the instrument baseline reflects radiation to the transmitter optics to be focussed onto a silicon photodiode. The receiver incorporates a phase sensitive detector to provide a good analog signal-to-noise ratio. Analog signals are subsequently digitized and processed to derive atmospheric transmittance.

MET-1 periodically and automatically recalibrates itself. This feature is based on the use of a reference reflector to measure and correct for drift in the instrument. In addition, periods of clear weather can be identified and use as a reference standard for 100 percent transmittance to normalize the overall instrument characteristic.

The MET-1 specifications are as follows:

Weight	Standard configuration: 35kg
Overall Dimensions	Standard configuration: 0.71m high, 3.0m long
Environment	Temperature: -10°C to +50°C Humidity: 0% to 100% Wind: normally limited by site mounting arrangements
Power Supply	115v/230v ± 10% 47 - 62 Hz
Power Consumption	20W
Light Source	Ga As light emmitting diode Wavelength: 650nm Modulation: 1kHz
Output Signal	Parallel 8-bit word; TTL compatible
Dynamic Range & Accuracy	Standard instrument Atmospheric transmittance error: ±0.4% of full scale Meteorological visibility: typically 10m ± 1m to 800m ± 200m.

For price information, see Subsection 6.6.2.

6.7.3 SM5 TRANSMISSOMETER

The SM5 transmissometer (Reference 36) consists of an optical head containing the optical measuring equipment (a light source, light receiver and electronic evaluating unit) and a reflector.

The transmissometer employs the principle of autocollimation. The retroreflector is equipped with an air flushing attachment. In the optical head the light from a lamp is split into two beams. One of the beams leaves the optical head after passing through an optical system and reaches the reflector which can be situated up to 150 meters away. In this an image of the shielded aperture of the optical systems is formed. The arrangement minimizes sensitivity to alignment of the system. The second light beam serves as a comparison light beam, and this as well as the light beam from the reflector is returned to a common receiver, i.e., a photosensitive element. A rotating disc with a system of holes modulates the measuring light beam at 3.9 kHz, and the comparison light beam at 1.5 kHz.

In the evaluating unit the signal voltages from the photosensitive element are amplified together and are then divided by filters to two channels in which the signals are rectified. The resulting DC voltages are proportional to the corresponding signal voltages. The voltage from the comparison signal is fed back to a regulator which controls the common initial amplifier in front of the gate in such a way that the DC voltage in the comparison channel will remain constant. In this way all causes of error which would affect both channels are eliminated.

A relationship exists between the measured light transmittance and visibility in accordance with the German Standard DIN 5037. The instrument has a photopic response.

The following are the SM5 components and relevant technical data:

Transmissometer

1 Optical head with air buffer dust protecting tube
1 Reflector with air buffer dust protecting tube
or
1 Optical head with air flushing attachment
1 Reflector with air flushing attachment.

Air Flushing Attachment

2 Blowers with filters and connecting tubes
2 Five-core connecting cables for connecting the blower on the optical head to the connecting point and the blower for the reflector to the connecting point
1 Three-core connecting cable for the power supply for the optical head.

Optical Head with Dust Protecting Tube or Air Flushing Attachment

Baseline	
(distance between optical head and reflector)	up to 150 m
Objective lens (diameter)	100 mm
Lamp	
operating voltage	4.5; 5.2; 6.0 V
mean working life	10,000 h at 4.5 V
Recorder and control unit output	
control current	20 mA, max.
control voltage	6 V
Transmittance range	0 to 100%
Transmittance range in accordance with DIN 5037	10% to 90%
Visibility range	40 to 850 m 65 to 1400 m 130 to 3000 m 260 to 5500 m
Operating voltage	220 V ± 10%
Operating frequency	50 ± 2 Hz or 60 ± 2 Hz
Power consumption approx.	35 W
Connecting cable	
(optical head to control unit; optical head to recorder)	2.5 km, max.
Permissible ambient temperature	-30 to +60°C
Weight	
optical head with air buffer dust protecting tube	31 kg
optical head with air flushing attachment	31 kg

Reflector with Air Buffer Dust Protecting Tube or Air Flushing Attachment

Type of enclosure	internal parts dust and spray water protected
Permissible ambient temperature	-30 to +60°C
Weight	
reflector with air buffer dust protecting tube	10 kg
reflector with air flushing attachment	10 kg.

For price information, see Subsection 6.6.3.

6.8 METEOROLOGICAL RESEARCH INSTRUMENTATION — FOG VISIOMETER

Meteorology Research, Inc. of Altadena, California, develops meteorological instrumentation. The Fog Visiometer is an instrument that is marketed for transportation (aviation, maritime, highway) applications (Reference 37).

The MRI Fog Visiometer Model 1580 is an instrument that measures the amount of total scattering over all angles and over a range of particle sizes; i.e., haze, fog, and rain. The Fog Visiometer has been developed based on the integrated scattering principle of the MRI Integrating Nephelometer. The instrument contains a light source composed of a pulsed xenon flash lamp and an opal glass diffuser. The light source illuminates a pencil shaped test volume defined by collimating apertures in the sensor. The sensor is a photomultiplier tube with appropriate electronics which synchronously detects the flashed light and integrates its value over a period of time. The Fog Visiometer is designed to measure the fog *in situ* without altering its character. In addition, the instrument is rugged and designed for unattended operation. The collimating optics are lensless and continuously purged with clean air.

The instrument is normally calibrated for measurements of visibilities between 260 ft and 2 mi. A wide range of adjustment is provided permitting operation up to 15 mi or down to 25 ft depending on application. The electronics is compact and uses solid-state integrated circuitry. The minimum accuracy is ± 15 percent scattering coefficient in normal atmospheric haze, fog, and precipitation. Over-range capability is present at both ends of scale, but at a reduced accuracy. An output signal is available for recording or as a means of providing the visibility indication at a remote point. The output is 0 to 5 VDC for the visibility range selected. This output is from a low impedance source (less than 10 ohms) which will provide a signal up to 5 ma.

The unit requires 1/2 amp 100 VAC power. A single calibration is required for all conditions: day, night, sunrise or sunset. An internal optical/mechanical system is provided. This sytem allows the zero set and gain set in the field independent of the visibility conditions at the time of calibration. The power input is 105-125 V AC, 60 Hz, 50 W maximum. Unit dimensions are 53 x 6.5 x 11.5 in; the total weight of the unit is about 43 lbs.

A January 1975 price of the model 1580 provided by the manufacturer was $4,890.

6.9 SNECMA, FRANCE — LYNX TRANSMISSOMETER SYSTEM

The Elecma Electronics Division of SNECMA located in Suresnes, France developed the Lynx TI 561 (Reference 38), an RVR system using transmissometers as sensors. A Lynx TI 561 was installed at NAFEC in 1971 for test and evaluation purposes.

The Lynx TI 561 measures the atmospheric transmittance with 0.2 percent accuracy of maximum value for 100-ft and 130-ft bases, and 0.5 to 1 percent accuracy of maximum value for 160-ft and 250-ft bases. The power supply requirement is 110 or 220 V ± 15 percent, 50 or 60 Hz. The operating temperature range is -30 to +50°C and the weight is 33 lbs (transmitter or receiver).

The RVR is computed taking into account the atmospheric transmittance, runway lights luminous intensity, and atmospheric background luminance. In addition, the runway lighting characteristics, and contrast and illumination thresholds are also taken into consideration. The atmospheric transmittance is converted into RVR by means of a network of five curves recorded on a magnetic core memory. The choice of the conversion curve depends on the background luminance (luminance sensor) and on the runway light luminous intensity.

The Lynx RVR computer automatically performs the following functions: selection of appropriate conversion curve, computing and display up to three RVRs from three transmissometers, remote transmission of the computed RVRs, and fault detection and warning. The power supply requirement is 110 or 220 V ±15 percent, 50 or 60 Hz. The operating temperature range is from 0 to +50°C and the weight is 60 lbs.

For visibilities lower than 2,600 ft, the display is in 80-ft increments. For visibilities between 2,600 ft and 7,000 ft, the display is in 160-ft increments. The three visibilities are computed every 60 sec, under steady conditions or instantaneously, in case another conversion curve is being selected. The memory is protected against main power variations or interruptions.

For price information, see Subsection 8.2.3.

6.10 TASKER SYSTEMS

Tasker Systems, a division of Whittaker Corporation of Los Angeles, California, produces RVR instrumentation. Recently Tasker Systems design a new system, the RVR 500 which supersedes previous systems. They also have designed modification kits for the FAA/NBS transmissometers.

6.10.1 RVR SYSTEM MODEL 400

Although the FAA has many RVR 400 systems currently deployed, and they are still available from Tasker on a special order basis, current and future procurements are for the RVR 500 systems.

The RVR 400 System provides functions similar to those of the RVR 500 System detailed in the next section. The basis differences are that the RVR 400 is limited in table selection by having only three day tables and three night tables, there is no continuous failure monitoring in the 400 systems, and update cycle is fixed at 48 sec. These units consist of the following:

RVR 400/1 - Signal Data Converter
RVR 400/2 - Power Supply and Control Unit
RVR 400/4P - Remote Display Programmer
RVR 400/5 - Runway Light Setting Unit
RVR 400/10 - Transmissometer System
RVR 400/12T - Tower for Transmissometer System.

6.10.2 RVR SYSTEM MODEL 500

The RVR 500 Series (References 39 and 40) provides improved reliability, has reduced size and weight, uses integrated circuits (IC), and at the same time performs more functions that the older RVR 400 equipment.

The new series consists of the following:

RVR 500/1 - Computer Main Frame
RVR 500/2 - Signal Data Converter Module
RVR 500/3 - Ambient Light Sensor
RVR 500/4P - Remote Display Programmer
RVR 500/5 - Runway Light Setting Unit
RVR 500/10 - Transmissometer Systems
RVR 500/12TM - Support Tower Assembly, Modified.

For price information, see Subsection 8.2.4.

Some of the new units are detailed below.

Signal Data Converter Module

The Signal Data Converter (SDC) Assembly includes four independent signal data converter channels along with two separate power supplies. In use, the assembly is capable of processing the output from three transmissometers while the fourth processing channel is a spare. Similarly, one of the two power supplies furnishes power to the three operating channels and the other power supply can be energized to operate the spare channel. Either of the two power supplies may be switch-selected from the front panel to provide power to the three active units. The spare power supply and spare processing channel may also be activated by front panel control. Input signals for any one of the three active units may be fed to the spare unit so that the operation of the three active units may be checked one at a time by comparison with the spare unit. All four processing channels are plug-in modules so that a malfunctioning unit may be immediately replaced by the spare unit.

The SDC module accepts inputs from a transmissometer, a runway light setting unit, and an ambient light sensor to determine runway visibility. The unit uses a table look-up method that involves the storage of solutions to the visibility equations in the form of tables of transmittance for various combinations of ambient illumination and runway light settings. The unit accepts four values of ambient illumination, bright day, normal day, intermediate day, and night, in accordance with current ICAO recommendations.

The table entries are derived by either Allard's law or Koschmieder's law depending upon the brightness of the runway edge lights. When the brightness of the runway edge lights is such that they are the pilot's primary visual targets, the computation is based on Allard's law. If the runway edge lights are not bright enough to be the pilot's primary visual target, the computation is based on Koschmieder's law.

The SDC can be programmed to change any variable and to produce a new set of Read-only Memory IC's to accommodate different baselines, to change runway light brightness levels, to change ambient illumination levels, to display RVR in meters rather than feet or to change other parameters.

The SDC is capable of operating with a dual baseline transmissometer so that RVR values as low as 100 ft can be reliably determined. The processing channel provides resolution of RVR values in 100-ft increments from 100 ft to 1400 ft, in 200-ft increments from 1400 ft to 2000 ft and in 500-ft increments from 2,000 ft to 6,000 ft.

The data processing channel is capable of determining a new RVR value as often as every 15 sec. This computation is based on a 1 minute average of the transmissometer output. To do this, the transmissometer output pulses are counted for 15-sec periods. Three such count values are always kept in storage, so that at the end of each 15-sec period, a full minute of count history is available. These are totalled and the background count is subtracted to produce a net count. This net count is used to compare with stored table entry data to determine RVR. The runway edge light brightness and the ambient illumination level determine which one of the sixteen tables is to be used.

The RVR data is also transmitted as a serially encoded, frequency-shift-keyed, message to the RVR Display Programmer at intervals of approximately 2 sec. Each time a new RVR determination is made a special indicator bit is set to flag the first transmission of a new RVR value. The output message contains four identity bits so that identification of the data source and processing channel can be carried throughout the system for ultimate recording. Status bits such as ambient light level, runway light settings, Fail and RVR Trend are also transmitted. The last part of the message consists of the binary coded decimal RVR value. These bits activate the four solid state decimal read outs in the programmer.

Ambient Light Sensor

The ambient light sensor measures the incident ambient illumination and selects one of four values to be used in the RVR computation.

Remote Display Programmer

The RVR Display Programmer can accept inputs up to ten signal data converter channels. Normally, three of these ten data input sources are selected for display at any one time. This provides readout of RVR and status values for touch down, midpoint and roll out areas of an instrumented runway. The ten input channels provide full instrumentation for up to three separate runways. Internally lighted thumbwheel switches are provided on the front panel of the unit and associated with each of the three display channels so that the appropriate input data selections can be accomplished. Each display channel is capable of selecting any one of the ten input signals. For each channel, the input data is temporarily stored and parity checked before it is accepted for display.

Runway Light Setting Unit

The runway light setting unit supplies the SDC with input data relating to the runway edge lights setting.

6.10.3 SOLID STATE TRANSMISSOMETER MODIFICATION KITS

In 1971, TSC proposed to the FAA (Reference 41) a modification approach to upgrade the performance and to reduce maintainability of FAA/NBS transmissometers in service. Also, the modification kit approach as developed by TSC allows a transformation of the present FAA/NBS transmissometers into software-oriented systems.

During 1974-75, Tasker Systems developed a series of modification kits (Reference 42) to achieve some of the modifications suggested by TSC. The kits marketed by Tasker to modify and/or upgrade FAA/NBS transmissometers are:

FAA/NBS Unit	Modification Kit Designation
Projector	None
Projector Power Supply	Projector Power Supply (P/N 711707-01)
Transmissometer Receiver	Pulse Amplifier (P/N 711701-01)
Amplifier-Power Supply	Amplifier-Power Supply (P/N 711708-01)
Regulator	None
Transmissometer Indicator	Graphic Recorder (P/N 711715-01)
Recording Milliameter	None.

The price (November 1975) for a complete modification kit set (P/N 711707-01, P/N 711701-01, and P/N 711708-01) is $3,700 each in quantities of 100 sets, $3,000 each in quantities of 200 sets, and $2,700 each for 300 sets.

The following is a description of the modification kits as supplied by Tasker Systems:

Projector Power Supply

The Projector Power Supply Modification Kit consists of a 25 amp current-regulated DC power supply. It holds the established value constant within 0.15 percent for all causes, including primary voltage and frequency variation, ambient temperature, and lamp filament resistance changes due to filament "evaporation." The lamp light output will thus be constant to within ±1 percent or better. Regulation of the output current rather than the output voltage prevents the current surge at turn-on. It also eliminates the overshoot in light output; instead there is a slight undershoot, amounting to 2 or 3 percent, resulting in an RVR reading that may be slightly pessimistic until the lamp filament reaches equilibrium (about a minute).

The output current of the Projector Power Supply is adjustable over the range of about 0.5 amp to 24 amp, and operates from a nominal 120/220/240 VAC ± 15 percent, 45 to 65 Hz. The ambient temperature range is -50°C to +70°C, and the relative humidity range is 0-95 percent (inside the cabinet).

The modification kit control panel includes the lamp current setting potentiometer (0 to 24 amps), with a selector switch that allows the transmittance meter to be used to measure the lamp voltage (0-10 V), the lamp current (0-25 amps) or the transmittance (0-100 percent). The control panel also includes a test jack for monitoring the pulsed output signal from the transmissometer .

Pulse Amplifier

The modifications to the Pulse Amplifier include changes to the optical elements and replacement of the electronics to achieve an entirely solid-state unit. The modified unit retains the series of baffles used in the original FAA/NBS transmissometer. The new photo detector is a hermetically sealed Silicon PIN diode with photo sensitive surface only 0.2 inch in diameter. A new lens and lens mount are provided to produce an image on the photo sensitive surface that is only 0.1 inch in diameter. The image can then "wander" from the exact center because of small alignment errors or drifts. After modification, the alignment characteristics of the receiver will be essentially identical to the original unmodified units. The photo detector current drives an operational amplifier integrator which produces a varying slope ramp. When the ramp reaches a pre-determined voltage, a limit detector develops a reset pulse for the integrator. The repetition rate of the reset pulses is proportional to the amount of light reaching the photo diode. Because the new photo detector is about 200 times more sensitive than the old detector, the amount of current produced is correspondingly greater. The operating voltages are much lower ± 13 V instead of

+225 V) making the leakage resistances non-critical. The MTBF of the amplifier is estimated to be about 112,000 hr or nearly 13 years.

Amplifier Power Supply

The Amplifier Power Supply Modification Kit is a solid-state unit which mechanically and electrically is compatible with the FAA/NBS transmissometer. The circuitry is more stable in performance and has improved linearity characteristics. It has a low power consumption, thus the internal temperature is lower.

Graphic Recorder

The Graphic Recorder Modification Kit consists of solid-state power supplies, pulse rate-to-dc current converter, calibration circuits and the recorder.

6.11 OTHER SYSTEMS — SCHLUMBERGER

There are other RVR systems and transmissometers commercially available; however, many of these do not have the same operational environment testing as the ones presented earlier in this section. It is considered unwarranted to list each of these at this time with the exception of the Helios-Caviar RVR system.

The Helios-Caviar (Reference 43) RVR system includes a transmissometer, control and signal processing units. The central unit Caviar provides: 1) in analog form, the continuous value of the transmissivity of the atmosphere from 0 to 100 percent and of the background luminance from 0 to 12,000 cd/m^2; and 2) in digital form, a message intended for remote data dissemination, either by telephone line or by radio link. The latter message includes atmospheric transmittance, background luminance, intensity of runway lights, operating alarms and RVR.

Operating characteristics of the Helios-Caviar are as follows:

Visibility Range

From 30 m to several km, depending on installation and application
Determined every second
Maximum memory capacity: 2,000 data points

Atmospheric Transmittance

Measured every second
Duration - 10 ms
Accuracy better than 0.8%
Analog output 0-5 mA, limited by the duration of the measurement or filtered by 32, 64, or 128 sec time constant

Background Luminance

Range - 0-12,000 cd/m^2
Linearity better than 2%
Analog output 0-5 mA, limited by the duration of the measurement or filtered on 10 or 47 sec time constant (adjustable)

Operating Conditions

Power-Supply: 110 or 220 V ± 15 percent, 50 or 60 Hz, 600 VA
Temperature: -55°C to +65°C

No up-to-date price information and delivery schedule were available at the time this report was prepared.

7. AIRPORT VISIBILITY SYSTEM (ARVIS)

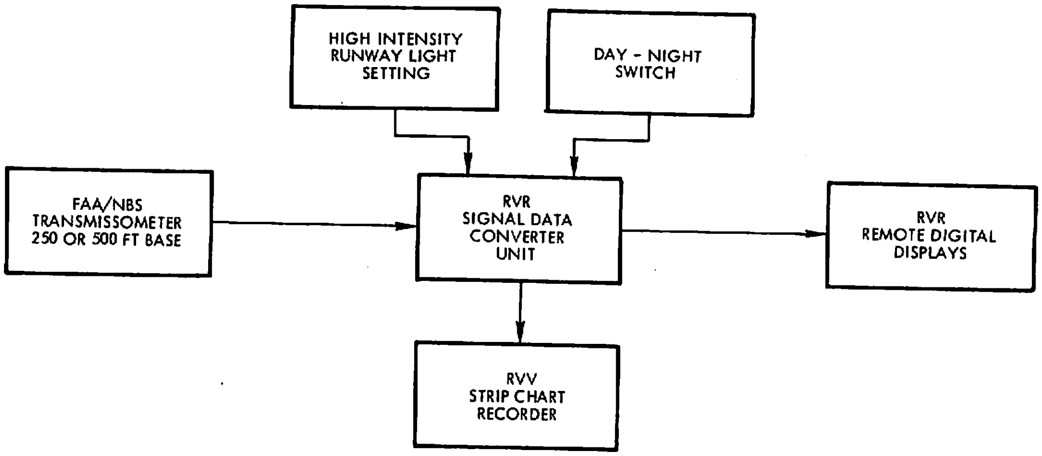
7.1 INTRODUCTION

The present FAA/NBS RVR instrumentation has well served its function of gathering visibility data, computing RVR values and disseminating the information. It is clear, however, that future demands of ever increasing traffic, lowered landing minima and extensive automation of the landing process and information dissemination will require new approaches to the entire airport visibility measuring techniques. One of the approaches foreseen is the evolution of the present RVR instrumentation into a comprehensive system, increasing its accuracy, adding flexibility using a software approach, and generally improving the quality of the disseminated information as well as its output rate. The criteria to have a software oriented system precluded the consideration of analog computers as the data processing hardware. Nevertheless, for some simple instrument installations, analog computers to calculate RVR should be considered.

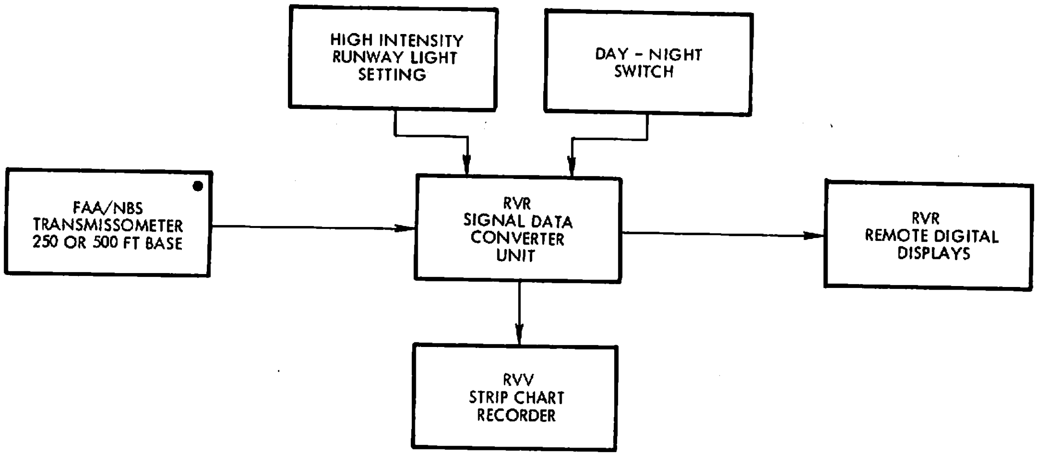
To ensure that changes in the existing visibility instrumentation will not compromise airport safety or efficiency and to introduce changes as required, it is proposed that these be made as a series of successive modifications of the present FAA/NBS RVR system (see Reference 41). The full system is expected to be reached after a four-step modification process (Figure 14).

The ultimate goal is to monitor and measure the visibility along all the runways and taxiways of an airport using system concepts and state-of-the-art equipment. TSC has proposed the development of an Airport Visibility System (ARVIS) to satisfy this goal.

PRESENT FAA RVR MEASURING SYSTEM



1ST MODIFICATION (MOD I)

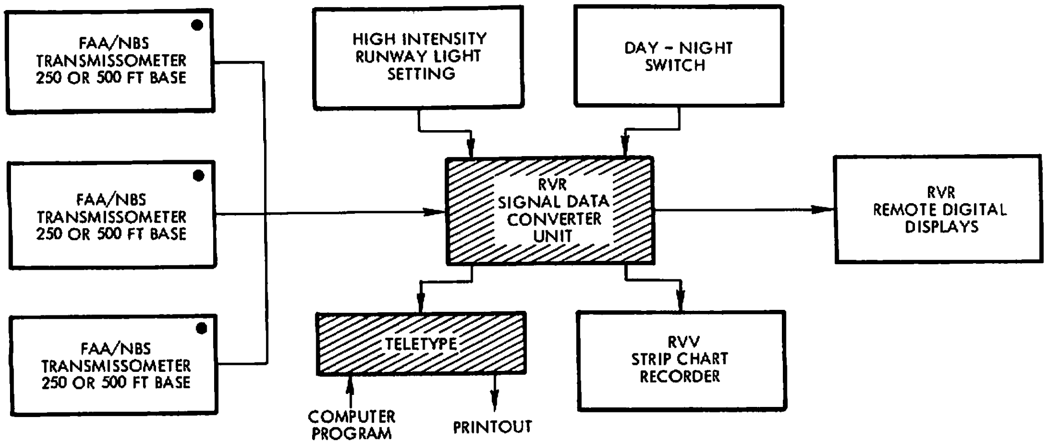


NOTE:

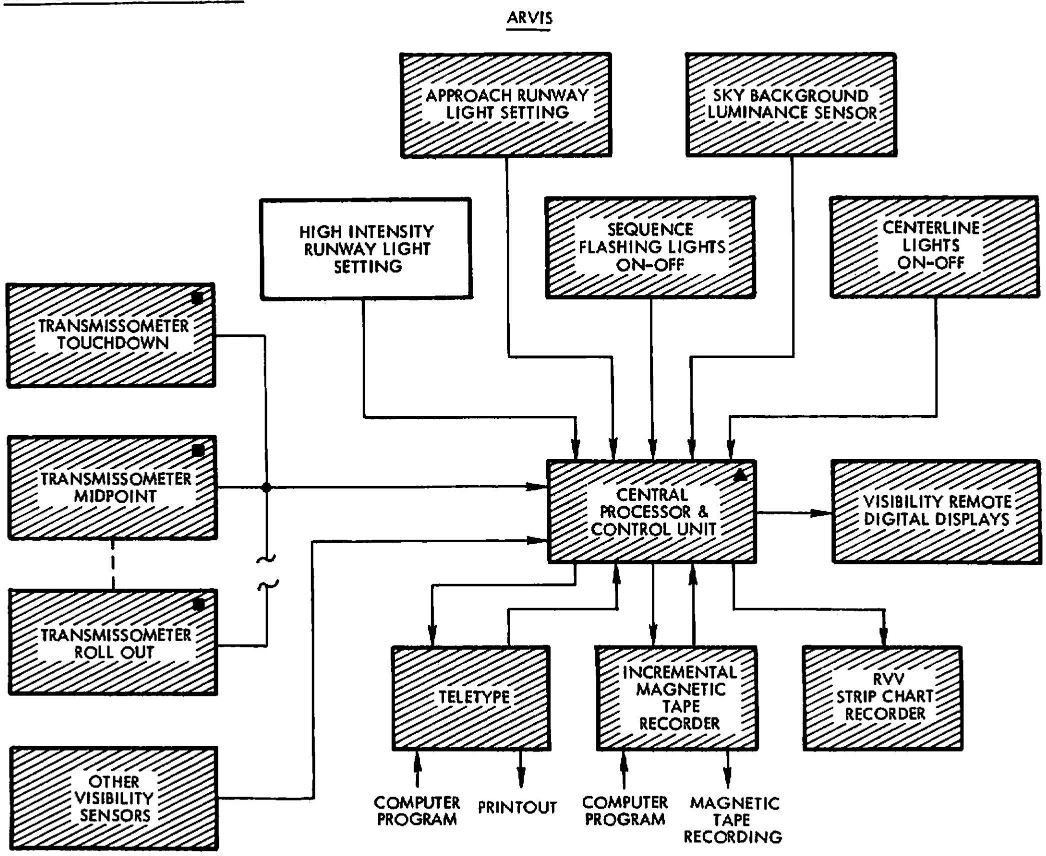
- ● CHANGE OF CIRCUITRY TO SOLID STATE COMPONENTS
- ■ EITHER 75, 250 OR 500 FT BASES TRANSMISSOMETER OR IN ANY COMBINATION
- ▲ THE SAME AS THE SDCU IN THE 2ND MODIFICATION BUT WITH ADDITIONAL MODULES FOR ADDED INPUTS AND/OR FUNCTIONS
- ▨ ADDITIONS, SUBTRACTIONS, SUBSTITUTIONS AND/OR MODIFICATIONS TO PRESENT FAA RVR MEASURING SYSTEM COMPONENTS

FIGURE 14. EVOLUTION FROM PRESENT FAA RVR SYSTEM TO ARVIS (REFERENCE 41).

2ND MODIFICATION (MOD II)



3RD MODIFICATION (MOD III)



4TH MODIFICATION (MOD IV)

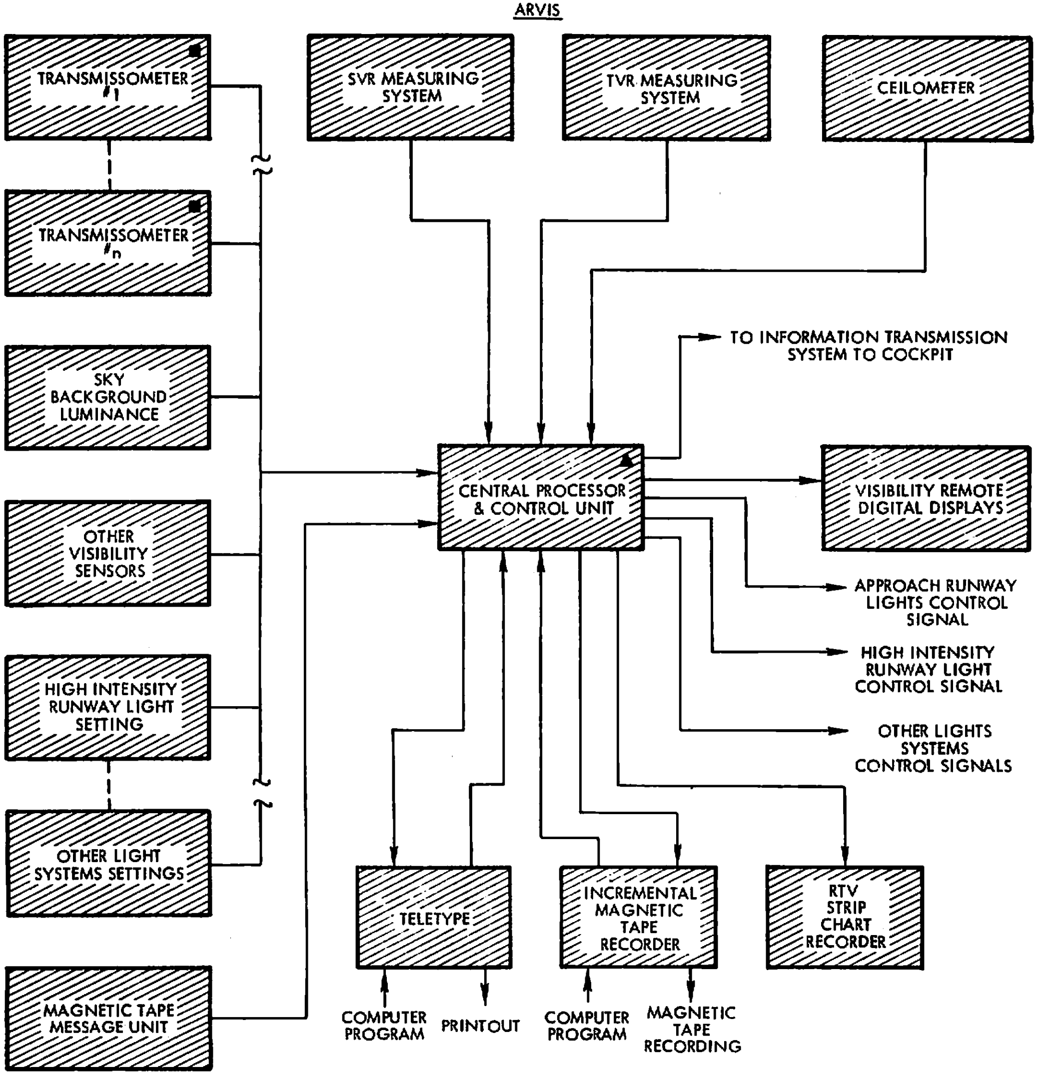


FIGURE 14. (CONCLUDED).

7.2 AIRPORT AS SYSTEM

The terms, systems, systems concept, systems approach, systems philosophy, systems design, etc. are used quite frequently without realizing the engineering implication of these terms and thus without realizing the principles associated with the methodology of systems engineering (Reference 44). There are many definitions for the term system. A brief definition (Reference 45) states:

> "A system is an array of components designed to achieve an objective according to plan."

However, "systems engineering is used to describe an approach which views an entire system of components as an entity rather than simply as an assembly of individual parts; i.e., a system in which each component is designed to fit properly with the other components rather than to function by itself" (Reference 46).

The FAA states in "National Aviation System Policy Summary (NASPS)" (Reference 47), item 8.3.3.1, "System requirements: To authorize operations in accordance with the visibility minimums, a requirement exists for a visibility measurement system having the capability of determining and reporting existing visibility on the airport and in the final approach area." The FAA requirements as stated in the NASPS do not imply transmissometer systems, RVR systems, or nephelometer systems, but an entire visibility measuring system to report existing visibilities on the airport and the final approach area. The same FAA NASPS document in item 8.3.3.3 establishes the goal of the visibility measuring system as: "To provide an RVR system for all Category II and III runways, to develop and implement visual range measurements systems for heliports and STOL ports. An additional goal is to provide visual range measurements for taxiways supporting those Category III operations which will allow landing minimums of zero decision height and zero visibility (0, DH/0) but will need some minimum visibility for post landing taxi operations." The main problem regarding the design of a visibility measuring system lies in its complexity, therefore considering details and thus losing the systems viewpoint. The designer must somehow deal with the various subsystems and component parts in such a way as to optimize the cost effectiveness of the overall system, avoiding the dangers of suboptimization.* The principle of suboptimization states that the optimization of each subsystem independently will not in general lead to an optimum system, and more strongly, that improvement of a particular subsystem may actually worsen the overall system. In the development of the ARVIS concept, the system is the airport (runways, taxiways, lighting system, visibility sensors, etc.)

7.3 ARVIS AS SOFTWARE ORIENTED SYSTEM

The advantages of a software-oriented system as opposed to a fixed look-up table type system are many. These advantages have been demonstrated in the TSC breadboard ARVIS, by the NAD SVR system, and by the RVR Marconi systems. The Marconi systems are used in several installations and extensive field data has been gathered mainly at Heathrow Airport in the United Kingdom (References 32, 33, and 34).

In the ARVIS, fixed smoothing and RVR update rates have been implemented which are software selectable. It would be easy to implement an adaptive system that would automatically change the integration or smoothing rate according to visibility conditions. Marconi (Reference 48) has attempted some of these techniques. A desirable averaging function is one which would have the ability to follow rapidly

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*The term suboptimization was introduced by C. J. Hitch (Sub-Optimization in Operations Problems, J. Ops. Res. Soc. Am. Vol. 1, pp 87-99, 1953).

changing visibility conditions with little or no time delay and to integrate RVR or SVR fluctuations over a long period when the average visibility was constant. Marconi uses a running weighted mean, the weighting of which is modified by the rate of change of atmospheric transmittance. The relationship used is:

$$T_1 = (t_1 + aT_0) \frac{1}{1+a} , \tag{16}$$

where T_1 = updated mean transmittance
T_0 = previous mean
t_1 = new reading
a = weighting factor.

The weighting factor is a function of the difference between t_1 and T_0 and its value increases as the difference between t_1 and T_0 increases. The software system also permits separating the update rate of the displayed value from the update rate used in the algorithm. It is undesirable to increase update rates to the display to more than about once in about 10 seconds since it might confuse the control tower operator.

Future systems may have an array of sensors throughout the airport that would permit a prediction of what the visibility would be in the next 15 seconds to one minute. By using a combination of the trend (trend indicators, +, –,=, are a normal output of the Tasker 500 system), inputs from wind speed, wind direction indicators and ceilometers, and by using the proper smoothing algorithms, meaningful short term predictions may be possible that would be useful in CAT II and CAT III conditions.

A dedicated visibility measurement system can easily interface with other systems at the airport. The Terminal Information Processing System (TIPS) (Reference 49) formerly known as the Flight Data Distribution System (FDDS), is expected to provide the functions for a complete flight data handling system for air traffic control. Digitized weather information, including RVR, SVR, ceiling height, wind direction, wind velocity, temperature and barometric pressure, can all be processed in the ARVIS computer and sent on one hardware interface to the TIPS processor. Along with information from other systems such as the Airport Surface Traffic Control Program (ASTC) and Wake Vortex avoidance systems, the TIPS system can use this information to output to control tower displays.

The ARVIS system may have its own dedicated CRT display in those airports where it would be desirable. Proper equipment organization in the tower must occur in order to allow an efficient man/machine relationship. The dissemination of information from weather sensors can be shared on a common display.

A dedicated ARVIS computer should be compatible with repair and maintenance philosophies that the FAA applies to other systems. The implementation of an interface for remote failure analysis, diagnosis and repair would allow a maintenance technician at some central point to dial the remote computer system and run diagnostic routines via the communications line, read back the output indication of the status, deduce what failure mechanism has occurred, call the local maintenance man and describe what repair should be made in order to bring the system back into operation.

In providing information to displays, flexibility must be provided between having all conceivably needed information on a large comprehensive display as opposed to calling specifically needed information on a smaller display. The software capability of the ARVIS permits the implementation of this display flexibility. A simple keyboard associated with the display unit would permit the controller to select the type of additional information he needs at a particular time.

7.4 EVOLUTIONARY STAGES IN DEVELOPMENT OF ARVIS FROM PRESENT FAA INSTRUMENTATION

The first modification (MOD I) consists of the modernization of present transmissometers (projector power supply and receiver) by using solid state circuitry and components. The second modification (MOD II) will consist of, in addition to MOD I, the substitution of the present RVR computer with a SDCU and teletype with the capability of handling the simultaneous signals from several transmissometers distributed along runways.

The third modifcation (MOD III) implies a system approach to the airport visibility measurements and reporting. By considering the airport as the system, all visibility measuring sensors in the airport, all light systems used as visual cues, and sky background luminance sensor are integrated in a true ARVIS. The ARVIS is a software oriented system in which performance characteristics (frequency of RVR updating, different processing of visibility data, selection of display data in accordance to specific airport needs, etc.) can be changed without hardware modifications.

The implementation of MOD III consists of the expansion of the MOD II SDCU to a Central Processor and Control Unit (CPCU), the replacement of the MOD I (or MOD II) receiver for one with the capability of internal calibration and larger dynamic range for CAT I, II and IIIB operation, and a slave control which is part of the ARVIS control and failure monitoring system.

The fourth modification (MOD IV) consists of a more comprehensive expansion of the ARVIS MOD III system with the inclusion of SVR and TVR data, automatic control of the airport lighting settings in accordance with the visibility conditions, and automatic transmission to the pilot of the visibility information required. This automatic transmission will eliminate the burden on the controller to relay this terminal information to the pilot. Nevertheless, the controller will be in parallel with this information channel and will have the possibility to override it, if required.

Removal of FAA/NBS RVR system units and corresponding replacements and/or additions in the proposed TSC modifications are given in Table 20.

7.4.1 MODIFICATION I

In the first modification, MOD I, of the standard FAA/NBS 250-ft base transmissometer developed by TSC, the original pulse generator, receiver amplifier, power supply (A100-6), and projector power supply (A300-1) is removed from the system. The receiver housing and optics, the projector, the enclosures for the receiver amplifier and the power supply are retained. The solid state receiver (10-R-250), is mechanically interchangeable with the original pulse generator. It is designed to be used in conjunction with the existing RVR signal data converter. The pulse rate of the 10-R-250 receiver is compatible with the existing RVR computer. An additional design feature of the 10-R-250 receiver is the utilization of a photopic filter ahead of the silicon detector. The filter bandpass was chosen so the detector sees a wavelength spectrum more closely matching the response of the eye of an observer by rejecting a high background level in the near infrared.

The 10-R-250 receiver can be used in either 500- or 75-ft baseline transmissometers by introducing minor optical modifications. These modified receivers will be identified respectively as 10-R-500 and 10-R-75.

The original projector power supply (A300-1) is replaced with a solid programmable state d.c. power supply and control (12-P) capable of providing stabilized d.c. power to the projector lamp under wide excursions of line input voltage and frequency (105-132 V and 47 to 440 Hz) to facilitate operation under emergency

TABLE 20. REMOVAL OF FAA/NBS RVR SYSTEM UNITS AND CORRESPONDING REPLACEMENTS AND/OR ADDITIONS IN PROPOSED TSC MODIFICATIONS.

MOD	FAA/NBS RVR System Unit to be Removed[+]	TSC Modification Unit to be Installed
I[++]	Pulse Generator Receiver Amplifier - Power Supply (A100-L)	*Receiver No. 10-R-250 or No. 10-R-500
	Projector Power Supply (A300-1)	Projector Power Supply and Control No. 12-P
II	Pulse Generator Receiver Amplifier - Power Supply (A100-L)	*Receiver No. 10-R -250 or No. 10-R-500
	Projector Power Supply (A300-1)	Projector Power Supply and Control No. 12-P
	Signal Data Converter Unit and Power Supply	Minicomputer No. 24-C; I/O Interface No. 26-1; Teletype No. 28-T
III (ARVIS)[+++]	Pulse Generator Receiver Amplifier - Power Supply (A100-L)	**Receiver No. 30-R-250 or No. 30-R-75
	Projector Power Supply (A300-1)	**Projector Power Supply and Control No. 12-P
	---	**Slave Control No. 32-S
	Day/Night Switch	Sky Background Luminance Meter No. 34-L
	Signal Data Converter Unit and Power Supply	Minicomputer No. 24-C; I/O Interface No. 35-I; Teletype No. 28-T
	---	Incremental Digital Tape Recorder No. 36-R
	Indicator A-200	Master Control No. 37-M
	---	Photometric Display No. 38-P
	Remote Display	***Remote Digital RVR Display No. 39-D
	RVV Recorder A-400	Strip Chart Recorder No. 31-R
IV (ARVIS)	Expansion of MOD III to satisfy future airport operational requirements. Hardware is not identified as yet.	

[+] Information on RVR system units is given in Reference 3.

[++] Hardware description of units and field tests described in TSC report (in preparation).

[+++] Hardware description in TSC report (in preparation).

* The receiver No. 10-R-250 or No. 10-R-500 can be modified to operate in a 75-ft base transmissometer by introducing minor optical modifications. (This receiver is designated No. 10-R-75.)

** Number of units depends on number of transmissometers modified.

*** Number of displays as airport operations require.

power conditions. In addition, the d.c. voltage for the projector lamp is set at 5V, increasing considerably the projector lamp life (lamp nominal rating 6V), this reducing system downtime and maintenance. To further increase the lifetime of the projector lamp, the 12-P power supply and control maintains 0.5V applied to the filament when the transmissometer background is measured. The power supply incorporates additional sensing circuits which facilitate the identification of failure modes in the projector system (power supply and/or lamp filament). The failure mode identification is basic to the MOD III system but is not active in the MOD I or II systems.

7.4.2 MODIFICATION II

The second modification, MOD II, will consist of, in addition to MOD I, the substitution of the present signal data converter unit and power supply with a mini-computer, input/output interface, and teletype. This modification has the capability of handling several transmissometers simultaneously. The Modification II and the algorithms to compute RVR have been developed and are discussed in Reference 50.

7.4.3 MODIFICATION III, ARVIS

The third modification, MOD III, entails a true approach to airport visibility measurements and therefore with this modification the ARVIS concept is satisfied. The TSC developed ARVIS MOD III block diagram for one runway (Reference 50) is shown as Figure 15. To implement MOD III, the following units have to be installed as replacements in the present FAA/NBS RVR system or as additions (see Table 20):

a. Receiver No. 30-R-250 or No. 30-R-75

b. Projector Power Supply and Control No. 12-P

c. Slave Control No. 32-S

d. Sky Background Luminance Meter No. 34-L

e. Minicomputer No. 24-C; I/O Interface No. 35-I; Teletype No. 28-T

f. Incremental Digital Tape Recorder No. 36-R

g. Master Control No. 37-M

h. Photometric Display No. 38-P

CPCU

i. Strip Chart Recorder No. 31-R

j. Remote Digital RVR Display No. 39-D.

The receiver uses solid state components, has an internal optical calibration system, and failure mode detection circuitry. The No. 30-R-250 is the receiver that operates in a 250-ft base and the No. 30-R-75 is the receiver that operates in a 75-ft base and can measure atmospheric transmittances corresponding to the 100-6,000 ft RVR range.

The receiver intercalibration functions are exercised periodically and provide optical detection and electronics check by sequencing through several modes: atmospheric transmittance, atmospheric background, calibration of the detector and associated electronics and transmissometer background. This is achieved by modifying the optical path viewed by the detector using a six stage optical turret assembly motor driven on the command of timing circuits in the CPCU. A miniature stabilized incandescent lamp (derated to provide extended life operation in excess of 100,000 hr) is used as the receiver calibration source. Calibration is achieved at 100 percent, 50 percent, and 10 percent equivalent atmospheric transmittance through the use of neutral density filters.

The receiver output calibration levels are compared with present levels in the CPCU to activate failure mode indicators when the calibration levels fall outside a certain tolerance range indicating that corrective maintenance is required.

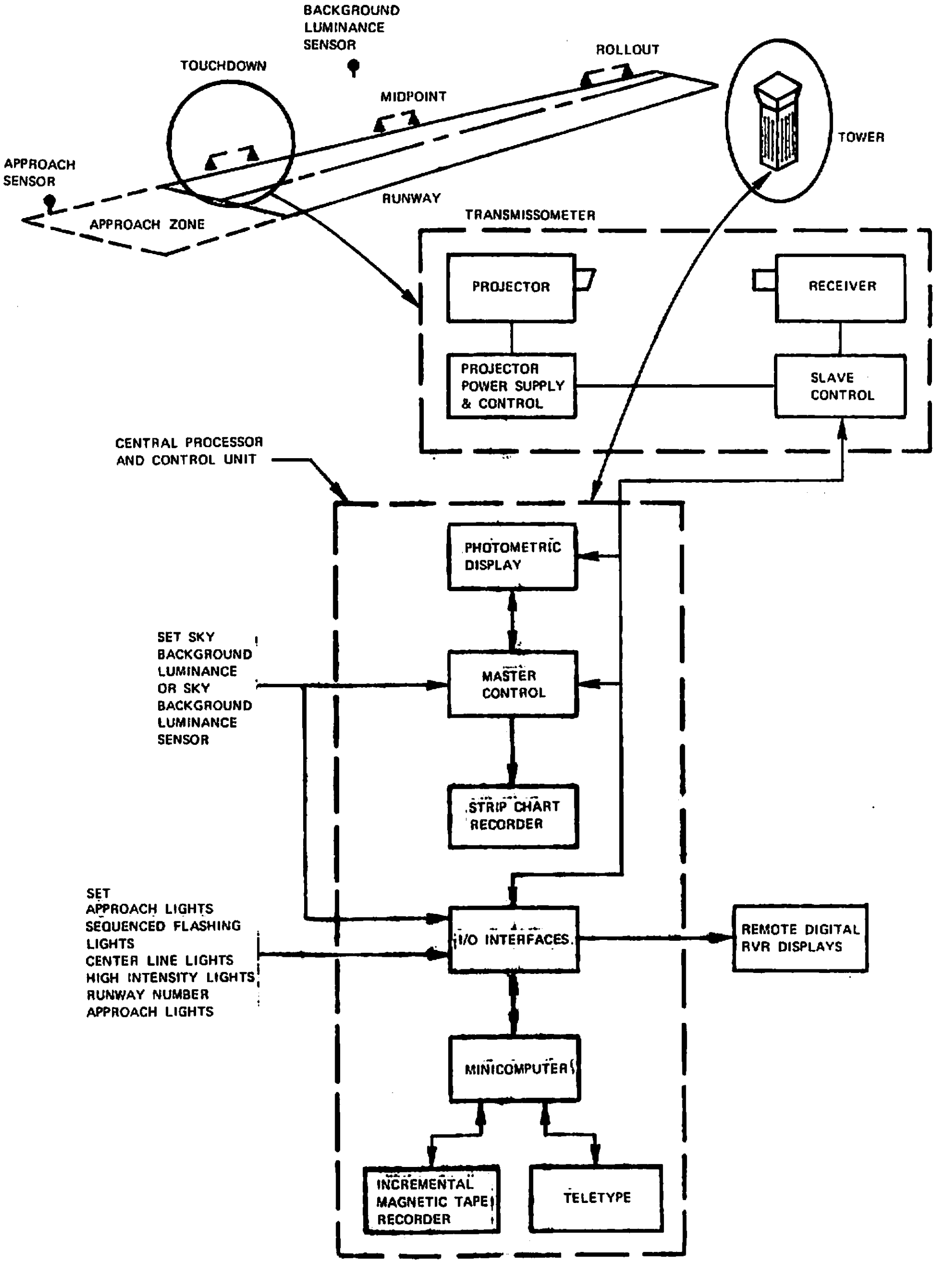

FIGURE 15. TSC DEVELOPED ARVIS MOD III (REFERENCE 50).

The other failure modes indicate malfunctions in the receiver heaters, heaters for the optics, the receiver blower, receiver power supply, projector lamp and projector power supply. The projector power supply and control No. 12-P is physically the same used in MOD I and II with a connection difference. The failure modes circuits are connected, via the slave control No. 32-S, to the CPCU. These circuits will indicate failure of the power supply and/or lamp filament.

The slave control No. 32-S receives command signals via a modem from the CPCU to exercise given functions by the receiver and/or power supply and control 12-P. Also the No. 32-S transmits via a modem to the CPCU data failure signals and operational mode status of the 32-R-75.

Figure 16 shows the CPCU which consists of the minicomputer, input/output interface, teletype, incremental tape recorder, master control, photometric display, and strip chart recorder. The operation of the CPCU is governed by mode selection switches on the Master Control. In the automatic mode an operational sequence is followed and the actual particular mode of operation is verified by the slave control.

In this mode, atmospheric transmittance measurements are made over a 5 minute period followed by a 50 sec atmospheric background measurement interval. This sequence is alternately repeated for 10 cycles and is then followed by a maintenance statuc checking sequence to assure normal transmissometer receiver operation as previously described. The latter sequence is performed during the last minute and 40 seconds of every hour. The time sequence in the CPCU can easily be varied to accommodate airport operational requirements.

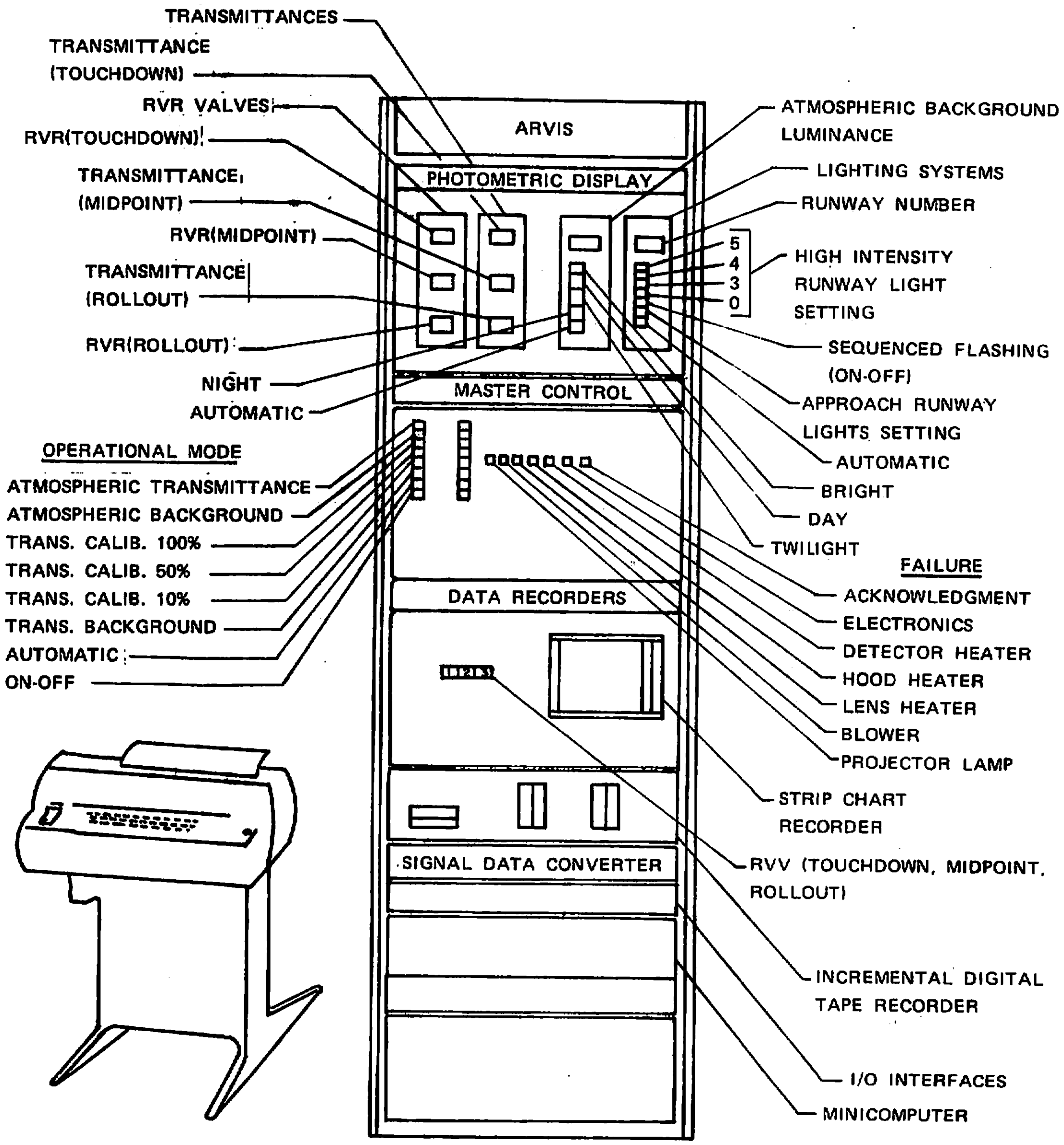

FIGURE 16. CENTRAL PROCESSOR AND CONTROL UNIT OF TSC ARVIS (REFERENCE 50).

The commands are transmitted to the receiver and projector over a two wire telephone line via the Slave Control Unit which is located near the receiver in the field. The automatic sequence may be interrupted at any time to initiate a specific operational mode by depressing the appropriate Master Control button. Once a manual mode selection is made, it remains until another mode selection is initiated. Once the automatic mode is reselected, the system continues to cycle as previously described. Should a malfunction occur in the monitored circuits of the transmissometer, transmissometer receiver, projector lamp or projector power supply, a failure signal will be transmitted to the Master Control and a light indicator and an alarm signal will be triggered. The alarm may be turned off if the CPCU operator depresses the "failure acknowledge" button; however, the specific failure indicator will remain lighted until corrective field maintenance is implemented. The system will continue to operate but with the possibility of system performance degradation or damage.

The Photometric Display contains LED readouts arranged in columnar fashion. The second column, top to bottom, displays atmospheric transmittances for transmissometers at the touchdown, midpoint and rollout locations on the runway. These values are processed in the minicomputer and displayed in the first column as RVR values at touchdown, midpoint and rollout. The third columnar display indicates the instrumented background luminance level on the runway ("automatic" switch setting) or alternatively, a value set in manually by the operator (i.e., bright, day, twilight or night switch setting). The fourth columnar display contains a LED readout indicating the specific runway instrumented. A set of pushbutton switches is available for the insertion of high intensity runway light settings 5, 4, 3, or 0 into the minicomputer for RVR computations. In the automatic position, appropriate high intensity runway light settings are fed to the minicomputer for RVR computation.

```
09:01:50      --OPERATOR INTERRUPT  --

.LI
DATE(DY,MO,19YR): 25,4,75
TIME(HR,MN,SC): 9,0,0
 NO. OF RECORDS= 20


                 TSC AIRPORT RUNWAY VISIBILITY SYSTEM
                             DATE: 04/25/75

T             BASE          SECS          PRATE

+00001        +00250        +00003        +10000
+00002        +00250        +00003        +10000
+00003        +00060        +00003        +10000

  TIME        T MODE  BL  RIL   LOGET     NPUL      ANPUL     RVR     FAILURE

             (1)      (2) (3)   (4)       (5)       (6)               (7)
09:01:25      1   1    B   0   +03496    +13123    +00023    +00875
09:01:25      2  *1    B   0   +03496    +24092    +00016    +03298
09:01:25      3  *1    B   0   +03496    +23288    +00016    +00684
09:01:40      1   1    B   0   +03496    +13106    +00023    +00875
09:01:40      2  *1    B   0   +03496    +24031    +00016    +03255
09:01:41      3  *1    B   0   +03496    +23024    +00016    +00655
(8) 09:01:50  -- OPERATOR INTERRUPT --
```

NOTES:

(1) Transmissometer Number

(2) Background Luminance

(3) Runway Intensity Lighting

(4) Log (ET)

(5) Pulse Count/Time Window

(6) Atmospheric Background "Noise"

(7) Hardware/Software Failure(s)

(8) Recorded Operator Intervention

FIGURE 17. SAMPLE PRINTOUT OF ARVIS (MOD III) RECORDED DATA.

In the Data Recorders section of the CPCU there is a strip chart recorder and an incremental digital tape recorder. The strip chart recorder allows continuous atmospheric transmittance recording within 0.2 percent of full scale for any one of the transmissometers on the runway, selectable by means of its associated switch. Of greater significance, however, is the incorporation of a dual cassette incremental digital tape recorder which records all the available photometric data and ARVIS status. The information which is incrementally recorded every 10 seconds consists of the following: a) time in month, day, hour, minute, and second; b) runway light status, i.e., approach lights, sequenced flashing lights, background luminance input mode, background luminance; c) RVR for each of the transmissometers; d) atmospheric transmittance for each of the three transmissometers; and e) failure mode status for all three transmissometers (see Figure 17).

A software and hardware interface is supplied to read the information on the cassette and write the information on a teletype. A provision is made so the software can be entered into the minicomputer by appropriate teletype command which activates the cassette with the computer program. The program is read from the cassette and loaded in the minicomputer. The cassette recorder provides historical evidence of total system conditions at all times to facilitate critical reviews of operational integrity, especially in accident investigation.

The Power Supply accomplishes power control, conversion and distribution to the aforementioned in the CPCU.

7.4.3.1 COMPUTER CHARACTERISTICS

The minicomputer in the CPCU is flexible and expandable to handle those functions that are not yet fully defined. Since visibility is a relatively slow varying function high input-output rates are not necessary. A sampling rate of once per second for transmissometers and visibility sensors is probably the highest input rate that need be considered. If future sensors (such as Lidars for SVR) are implemented that require high sample rates or complicated data processing, a local processor can be implemented with the particular sensor so that the data fed to the ARVIS computer is smoothed and supplied at a low data rate.

With the current developments in computer technology, it is not inconceivable that the requirements of the ARVIS computer may be met in the future by a small microprocessor with associated memory modules and peripherals. For the purposes of this study, it is assumed, however, that a minicomputer such as that used in the present ARVIS and the NWSC SVR system will be used.

Based on the experience gained with the ARVIS, the following general requirements can be said to be necessary for the computer:

Word length - 16 bits.

Memory - 4K minimum, expandable up to at least 32K.

I/O capability - no practical limitation. By providing the required interface modules, the computer shall be able to accept inputs from as many as 20 to 30 sensors and output to as many as 10 devices. Typical outputs include the data to the control tower remote display units, a CRT, and another computer (if necessary). Addressing capability of I/O devices shall be much higher (e.g., 64 - most computers can address 256 or more devices).

Power fail and restart module.

Bootstrap loader module.

Real time clock.

Instructor set - comprehensive including arithmetic, logical, shift, data load/store, transfer/compare, branch and I/O.

Registers - at least eight registers to ensure programming efficiency.

Instruction execution time - compatible with I/O communications and software program calculations. Typical arithmetic operations should be well under 10 μsec in order to handle computations with a multiplicity of sensors and output devices.

Interrupts - the computer shall have several single line multi-level priority interrupts to handle real time clock and I/O devices.

Since many computers meet the requirements stated above, the computer selection is based mainly upon software support, the ease of generating programs as well as making changes in programs.

The data logging device to record and preserve a historical record of the data and status of the visibility system is available from many computer peripheral manufacturers as well as the computer manufacturers themselves. If possible, it is probably better to select this data logging device from the computer manufacturer. This permits both hardware and software compatibility with the digital computer. In the TSC breadboard ARVIS, a dual cassette unit is employed. The advantages of the cassette system are that the actual cassette is small, inexpensive, and reusable. Storage of the cassettes is simple and one cassette can store approximately twelve hours of data (depending on the amount of data and the data rate). In the ARVIS, data is recorded every fifteen seconds. In order to minimize the amount of data recorded, an adaptive rate may be employed. Data can be stored at a much slower rate, perhaps once every few minutes, but if the airport photometric conditions are changing rapidly, the rate can be increased.

Another data logging device that may be considered is the floppy disc. Floppy disc systems are becoming more reliable and the cost is comparable to a cassette system. Although the disc itself is larger and more expensive than a cassette, it can store much more data. Furthermore, the floppy disc can be used as an auxiliary storage memory device or a buffer memory and can also be used for software program generation.

7.4.3.2 INPUT/OUTPUT COMPUTER INTERFACE

The present FAA/NBS transmissometers send a pulse train with a maximum frequency of 4000 pulses per minute (100 percent atmospheric transmittance) to the RVR signal data converter, and the pulses are counted for approximately 45 seconds. In the ARVIS system, the transmissometer output was modified to be a pulse train with a maximum rate of 10 kHz. The output of each sensor is sent to a counter contained in the I/O interface. The time interval for counting, controlled by software, can be as fast as one second and as slow as three seconds without overflowing for a 16 bit counter.

A fully deployed ARVIS can accept inputs from either type of transmissometer (assuming proper interface circuits are used to accept the pulse train), since the time window can be controlled by software. This would permit using the computer with existing transmissometers and signal interfaces. In an actual airport configuration where the sensors, such as transmissometers, forward scatter meters, luminance meters, ceilometers, etc., are used to feed data to the computer over a two wire cable, it would be desirable to have the flexibility of controlling the sampling rate as well as to minimize the transmission rate to the computer so that low bit rates can be used at frequencies as high as once per second. To transmit data over thousands of feet of cable, serial communications should be used. This can be mechanized by using a voltage to digital encoder at the sensor and converting the digital data to serial form. The voltage to digital converter should be an integrating type A/D so that the average value of the signal is generated. It is undesirable to use a successive approximation encoder since these encoders generally use a sample and hold circuit with a small aperture time that may sample the visibility information over a time interval when the signal may have sudden peaks due to electronic or other types of noise that are not indicative of the phenomenon being measured. An integrating A/D of the ramp type with eight bit accuracy would probably suffice. With a ± half bit uncertainty and a voltage with a full scale value corresponding to 6000 ft, the quantization error would be $\frac{6000}{2^8}$ or 23.4 ft, accurate enough for low visibility ranges. Alternatively, a voltage to frequency converter may be used with a counter and auxiliary buffer register at the sensor. The output of the buffer register can now be converted to serial form and sent to the computer. Either type of analog to digital converter, the ramp type encoder or the voltage to frequency converter with counter and buffer register, is fairly economical, easy to mechanize, and lends itself to a series digital communication system. The analog to digital converter can also be multiplexed to measure housekeeping signals as well as visibility data. Power supply voltages, calibration signals, voltage references, etc. can be measured on the same A/D converter. Digital data such as mode and failure identification, device identification and parity can be formatted with the output of the A/D converter into a series digital word. The sensor will also receive a series digital word from the computer to command operational modes background checks or self check routines. Since the data rates are slow, half duplex operation over two wire lines will probably be sufficient. Transmission and reception need not occur simultaneously.

At the computer, an I/O device controller could contain the necessary timing and logic to send sequenced commands to the various sensors. The data coming back from the sensors could interrupt the computer and be accepted in normal fashion. The I/O device controller will separate the data from each device, identify the device, and perform a series to parallel conversion, if the computer I/O architecture is set up for only parallel inputs.

Communication with remote output displays will also be performed in a serial digital form. Typical output devices that will receive data, besides the local control-display panel in the same equipment rack as the computer, include remote displays in the control tower, a CRT dedicated to the visibility system or another data processing system such as TIPS (Reference 49), which may have its own display on which visibility information may be presented. Output devices may employ bidirectional communication since the operator may want to send commands to the computer to select and control the information to be displayed. Bidirectional communication from the control tower also permits the operator to remotely command calibrations and self-check routines.

The heart of the I/O communications system is at the computer and it is part of I/O interface. All of the timing, control, sequencing, device identification, and interrogation of I/O devices will be controlled here. From a cost/performance trade-off, it is desired to minimize the cost and complexity of the electronics at the sensor. One can envision the design of a "normalized" I/O interface that can be installed with each sensor. This "normalized" I/O interface would contain the A/D converter, parallel to serial conversion and control logic for reception and transmission. The design should allow for small and simple variations of the control logic to interface with different types of sensors to accommodate scaling of voltages, and the variations in modes of operation. The I/O communication components could be purchased from different manufacturers including the computer manufacturers themselves. The availability of microcircuits and their associated peripheral devices appear to be attractive for this type of application. The Motorola MC6800 microprocessor is available with a host of large scale integration (LSI) devices including programmable logic interface units, I/O data controls, and modems for remote communications. The use of these devices in large quantities should permit low cost, and reliable I/O packages with flexibility for different operating modes and compatibility with a modular design permitting simple addition of modules to handle additional I/O interfaces.

The exact methods and details of formatting the serial communication links between sensors and the minicomputer cannot be decided until more exact definitions of data and control signals are established. It is highly probable, however, that asynchronous transmission may be possible even with a multitude of sensors. Asynchronous transmission is least efficient, requiring extra signals to be transmitted with each data character to identify the beginning and end of character. As mentioned before, however, the data rates are low enough to make this a strong possibility and the circuitry required at the sensor is simple. The low data rates should also permit half-duplex transmission (no simultaneous transmission and reception). Allowable error rates will also dictate the transmission technique selected as well as the modem selection.

Some minicomputers are available with an asynchronous data communications multiplexer, which can control the transmission of a large number of low speed asynchronous lines. The use of this multiplexer is warranted when the crossover point between the cost of several single line controllers and the multiplexer is exceeded. Considerations of the geography of the sensors and the costs of cabling enter into the decision of multiplexing two or more sensors on one cable.

Multiplexing of inputs from the sensors to the minicomputer can be performed either with time division multiplexing (TDM) or frequency division multiplexing (FDM). TDM is usually more efficient than FDM since a considerable amount of bandwidth is wasted in an FDM in order to separate the low speed channels.

The final choice of the communications system must allow enough margin so that additional sensors may be added and that the maximum data rates are not exceeded.

7.4.4 MODIFICATION IV, ARVIS

In the fourth modification, MOD IV, the ARVIS will take into account all the various light targets used for visual cues, such as high intensity runway lights, taxiway lights, centerline runway lights, approach runway lights, and other lighting systems. It is expected that the CPCU will be able to use this information to calculate and display TVR and SVR. Also, there may be a need in the future to determine and display ceiling information.

The operational definition of TVR is not yet certain. Thus the method for determining TVR is not established. In the case of SVR, there may be a need for rather specialized observational method and data analysis. It is possible that the CPCU will have to be expanded in MOD IV to handle these increased data input-output demands. However, there are several minicomputers available on the market today which have expandable memories and modular architecture. It appears, too, that the very near-future will bring minicomputers with even more capacity, more flexibility and lower prices. Therefore, it is believed that the requirements of this final stage in the evolution of the visibility measuring system can be met by modular architecture and a minimum amount of additional CPCU hardware.

In MOD IV, Figure 14 additional functions are shown for the overall visibility measuring system. An information transmission system will send special message units and visibility information to the cockpit display. The scope of this task will depend on the type of cockpit visibility display selected and the data link chosen by the FAA to handle the information.

Due to the complexities of problems to be solved in the MOD IV which have not yet been defined (i.e., TVR, SVR, data link), hardware cannot be precisely identified in this level of ARVIS. Therefore, the purpose of indicating this level of modification is to show that the ARVIS (MOD III) has the capability of being expanded to take care of future operational requirements.

7.5 SYSTEM FLEXIBILITY AND GROWTH CAPABILITY

One of the main features of the ARVIS is the flexibility it affords and its capability for growth. Software is easily changed and new software modules can be added as new interfaces to additional visibility sensors and display devices are added. Memory modules may be added as required and the I/O interfaces expanded as new requirements emerge without obsoleting existing installations. A growth oriented system is based on the concept of the minicomputer family. The family concept provides upward software compatibility with additional computing power. The characteristics of a family are a common data format, a common instruction set and the capability of running the same higher-level software, regardless of where the machine fits within the family. The family members differ from each other in terms of the range of available memory, the number of I/O channels, the execution speed and the types of peripherals that can be interfaced to the computer. These characteristics affect the "viability" of the computer and in planning the initial system, "viability" is just as important as reliability, maintainability and performance.

Present RVR systems send their data to remote display units in the control tower and other information centers. The RVR information displayed could be from different transmissometers. In the ARVIS a simple fixed RVR numerical display will be a limitation in the system capabilities. A software oriented display such as a CRT type is almost necessary to realize the full ARVIS capabilities. In addition, the TIPS should be considered as one of the approaches suitable for visibility display. Besides CRTs, plasma displays using matrix techniques could be considered. They are available as both alphanumeric displays as well as larger displays that can generate graphics.

8. ELEMENTS OF DEPLOYMENT COST FOR TYPICAL RVR SYSTEMS COMMERCIALLY AVAILABLE

Typical costs for establishing visibility equipment on runways are presented in this section. Cost elements included are equipment purchase, installation, field cabling, maintenance, training, and provisioning. Equipment from different manufacturers will affect the costs of purchase, provisioning, installation, and maintenance; training is not likely to vary significantly for different equipment. For foreign-made systems, prices are given CIF Port of New York plus custom duties.

System development costs and access roads to the field site are not included in this cost estimate.

8.1 COST ESTIMATING METHODOLOGY

The FAA has standardized the facilities and equipment (F&E) cost estimates in F&E Cost Estimate Summaries Handbook (Reference 50). The methodology for these estimates is expressed as follows:

"a. The cost estimates are developed on the basis of accomplishing a typical individual project. This typical project is defined as that project that will be done most often by the regions. A narration is included for each cost estimate describing the typical project. Projects not in agreement with this description will vary in cost from the one noted. These cost estimates represent only direct costs associated with the projects. (Cost for items such as training and training equipment are not included and must be provided for separately.)

b. The regional costs are developed either on the basis of adjusted historic data or standard estimating procedures. Standard estimating procedures are used most often for projects not done before and these costs will be more susceptible to modification based on future experience.

c. The equipment cost estimates are based on one of three different methods:

   (1) Estimates based on knowledge of the industry but no prior procurements of this equipment have been made.

" (2) Estimates based on items listed in the current FAA Stock Catalog.

(3) Estimates based on a previous acquisition of a certain number of units in a certain year."

The Handbook continues:

"e. When specific information is available, provisioning cost estimates will reflect this known cost data, otherwise use the following percentages of equipment cost:

Communications equipment	20 percent
ILS/VOR/TACAN/DME	15 percent
Radar/Beacon/RML	30 percent
Radar Displays	50 percent
E/G, Lighting Systems, Miscellaneous	10 percent

f. Factory inspection and Washington office freight cost estimates are based on actual costs where known and are so indicated, otherwise they are based on the percentage formulas that follow:

(1) Factory inspection. Three (3) percent of plant material cost and three (3) percent of electronic equipment cost.

(2) Washington office freight. Ten (10) percent of plant material cost and three (3) percent of electronic equipment cost."

Specifically, the Handbook refers to the installation of RVR as follows:

"This cost estimate is to establish a system consisting of one transmissometer, one signal data converter, one digital readout, a receiver decoder, and a computer selector. The transmissometer is located near the glide slope of the ILS, and uses spare glide slope cables for connection to the RVR equipment in the ATCT. This equipment configuration is the largest, most complicated system being installed. Many systems may be less complicated and require less equipment.

The regional costs are based on adjusted historic information. No site preparation or roads are anticipated.

Equipment costs and provisioning are based on a previous acquisition. Factory inspection is based on the percentage formulas as outlined in the Foreword. The freight costs are estimated on basis on similar type equipment shipments."

The information reflected in this report refers to the deployment cost only; however, in order to establish a reference to the full life-cycle cost of the system, some elements of this life-cycle cost are discussed. These elements include the definition of a cost category structure, amortized capital costs, the use and limitations of budgetary data for deriving the cost base, and the system element cost approach for estimating detailed cost base formulations. For all functional categories in the Airport and Airway System cost base, costs can be separated into four cost categories (Reference 51):

a. Research and Development (R&D)
b. Facilities and Equipment (F&E)
c. Relocation and Modification (R&M)
d. Operations and Maintenance (O&M).

In accordance with Reference 51 the cost categories are defined as:

> "R&D costs are defined to include all expenditures needed to bring a new concept or system element to a point where prototype equipment or pilot facility is operating or can be tested in the Airport and Airway System inventory.
>
> F&E costs are the one-time capital expenditures required for the procurement and installation of new facilities and/or equipment. F&E costs include all land costs, engineering, site preparation and construction, construction materiel, electronic equipment and installation, and freight.
>
> Every year substantial expenditures are made to modify and renovate existing facilities. In most budget reports, these relocation and modification (R&M) investment costs are included along with appropriations for new facilities and equipment. R&M costs are expressed in terms of the average annual expenditure to upgrade and modernize each element in the Airport and Airway System. In this way, the wide fluctuations in R&M costs which typically exist in actual budget appropriations are avoided in the cost base formulation.
>
> The final cost category refers to the annual expenses needed to operate and maintain all items in the Airport and Airway System. Operations costs include all direct personnel and overhead who 'operate' the equipment and perform the primary functions of air traffic control. Operations costs are estimated for all 'manned' Airport and Airway System

> "facilities. Maintenance costs include the direct maintenance personnel, all stocks and stores, flight checks, and overhead costs needed to keep the inventory of facilities and equipment in satisfactory operating condition."

In regard to capital costs Reference 51 indicates:

> "The decision of whether capital costs (or R&D and F&E costs) should be amortized raises a number of key issues. The calculation involves the conversion of capital investment costs into a series of annual expenditures. In order to amortize capital costs, the following formula was used:
>
> $$\text{Equivalent Annual Cost} = \text{Capital Cost} \times \text{Capital Recovery Factor}$$
>
> where Capital Recovery Factor = $[i(1 + i)^n/(1 + i)^n - 1]$
>
> n = useful economic life
>
> i = discount rate
>
> The primary reason for making this calculation is to match the capital costs of a facility with its useful economic life. This advantage of amortized costs must be weighed against the need to estimate economic lives, select discount rates, and evaluate capital costs made prior to the base period.
>
> A discount rate of 10 percent was used in the computations of amortized costs. This rate is consistent with the Office of Management and Budget guidance for public investment analyses and reflects the opportunity cost of public investments. Failure to account for this opportunity cost could lead to excessive capital investment. The 10 percent rate is based on average rates of return for investments made in the private sector."

The useful economic life of the elements that enter into the Airport and Airway System ranges from a low of 13 years for radar approach facilities to a high of 40 years for airport runways. Therefore, due to the nature of the equipment, the useful economic life of RVR systems could be assumed as 15 years. In the full life-cycle cost, a zero salvage value at the end of the RVR system economic life should be assumed, basically due to the difficulty in getting salvage value estimates. The F&E costs could be amortized over the RVR system economic life and the R&D cost could be treated as capital investment with the amortization period also taken equal to the RVR system economic life.

8.2 EQUIPMENT PURCHASE

The purchase cost of RVR equipment varies considerably with manufacturer and with accessory equipment ordered. Elements of cost for those standard RVR systems provided by manufacturers are presented in this subsection.

The FAA procurement cycle is approximately 9 months and the average delivery time varies with the manufacturer and is usually from 12 to 24 months, although in some instances 30 to 60 day delivery is possible.

8.2.1 SKOPOLOG

The Skopolog units and system purchasing cost shown in Table 21 are given by FF Impulsphysics Corporation, as of December 1975.*

8.2.2 MARCONI IVR-2

The IVR-2 system purchasing costs are given by Lear Siegler, Inc., Astronics Division as of December 1975.** The purchasing costs include factory to Port of New York freight costs and custom duties. The cost is approximately $125 K for an IVR-2 system with three transmissometers for CAT II operation. A ten (10) percent discount should be considered for orders including ten or more systems.

8.2.3 LYNX

The Lynx T1561 RVR System purchasing costs are shown in Table 22. These are the 1971 prices paid by NAFEC for the system procured for test and evaluation

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*FF Impulsphysics Corporation letter R. T. Brown to TSC/DOT H. C. Ingrao, 12/15/75.

**St. Lawrence, D. (Lear Siegler, Inc., Astronics Division): Correspondence to H. Ingrao (TSC/DOT) December 1, 1975. Regarding costs.

TABLE 21. PURCHASE COSTS (FY76) FOR SKOPOLOG UNITS AND SYSTEMS.

UNIT				RVR SYSTEM		
	Quantity Range			No. of Transmissometers		
Description	1 - 4	5 - 9	10 & up	1	2	3
	Price ($ K)*			Price ($ K)*		
Skopograph Transmitter 13/1100	5.9	5.7	5.6	5.9	11.8	17.7
Skopograph Receiver 13/1200	8.2	7.9	7.8	8.2	16.4	24.6
RVR Computer Single Channel 13/1700	7.1	6.9	6.7	17.1		
Selector 13/1700 + 1701 RVR Computer with Skopograph Inputs	11.4	11.0	10.8	Not Req.	11.4	11.4
Digistep Digital Converter Single Channel 13/1720	2.9	2.9	2.8	2.9	5.9	
Digistep Digital Converter 3-Channel 13/1723	5.9	5.7	5.6			5.9
Digital Display Single Channel 13/1730	1.7	1.7	1.6	1.7	3.4	
Digital Display 3-Channel With Decoder 13/1733	4.8	4.7	4.6			4.8
Stilbus Sensor 13/1710	1.5	1.5	1.4	1.5	1.5	1.5
Recorder w/o Housing 13/1325	1.4	1.4	1.3	1.1		4.3
2-Channel Recorder w/o Housing 13/1323	2.1	2.0	2.0		2.1	
Remote Control Unit for 3 Skopograph 13/1400	1.8	1.8	1.7		1.8	1.8
Recorder With Control Unit 13/1300	2.1	2.0	1.9	2.1		
Subtotal	56.8	55.2	53.8	29.8	54.3	72.0
Provisioning Costs, 10%	5.7	5.5	5.4	3.0	5.4	7.2
Factory Inspection, 3%	1.7	1.7	1.6	0.9	1.6	2.2
Subtotal	7.4	7.2	7.0	3.9	7.0	9.4
Freight Cost, 6%	3.4	3.3	3.2	1.8	3.3	4.3
Custom Duties, 10%	5.7	5.5	5.4	3.0	5.4	7.2
Subtotal (Freight)	9.1	8.8	8.6	4.8	8.7	11.5
Total (Washington Office Cost)	73.3	71.2	69.4	38.5	70.0	92.9

*Price FOB Hamburg, West Germany using exchange rate 2.63 DM per U.S. dollar.
**From Hamburg to the Port of NY 3 percent; within the USA an additional 3 percent.

TABLE 22. PURCHASE COSTS (FY71) FOR LYNX UNITS AND SYSTEMS.*

UNIT				RVR SYSTEM		
Description	Quantity Range			No. of Transmissometers		
	1 - 4	5 - 9	10 & up	1	2	3
	Price ($ K)			Price ($ K)		
Transmissometer and related field hardware	12.0	-	-	12.0	NA	NA
Computer memory rack	6.3	-	-	6.3	NA	NA
Computer logic rack	5.4	-	-	5.4	NA	NA
Luminance sensor	2.0	-	-	2.0	NA	NA
Loader unit (paper tape)	5.0	-	-	5.0	NA	NA
RVR display and cables	2.7	-	-	2.7	NA	NA
RVR remote display receiver	3.4	-	-	3.4	NA	NA
RVR remote display unit	1.9	-	-	1.9	NA	NA
Subtotal	38.7	-	-	38.7	NA	NA
Provisioning Costs, 10%	3.9	-	-	3.9	NA	NA
Factory Inspection	-	-	-	NI	NA	NA
Subtotal	3.9	-	-	3.9	NA	NA
Freight Cost	-	-	-	NI	NA	NA
Custom Duties	-	-	-	NI	NA	NA
Subtotal (Freight)	-	-	-	NI	NA	NA
Total (Washington Office Cost)	42.5	-	-	42.5	NA	NA

*The purchase costs given are FY71 prices paid by NAFEC for one system (one transmissometer) for test and evaluation purposes. The costs for two and three transmissometers are generated from that data.

NI = No information.

NA = Not applicable.

purposes. The prices were verified by R. J. Bank Co. (Arlington, Va.), the SNECMA U. S. representative for the Lynx system at the time of the NAFEC procurement. No substantial effort was made to complete the purchasing cost information since on a single system basis using FY71 prices, the cost is higher than the other available systems.

8.2.4 TASKER SYSTEMS MODEL 500

The unit and RVR system purchasing costs shown in Table 23 are based on RVR equipment cost planning data given by Tasker Systems, as of March 10, 1976, for the Model 500. Since Tasker builds this equipment to customer order only, the pricing for each specific order is based upon direct cost estimates and the burden rates applicable at the time of order.

The quantity prices used in Table 23 are based upon current costs of material and labor and are valid through 30 April 1976. As a planning guide, the inflationary effect on costs are assumed by Tasker to be approximately nine (9) percent per year. Also, to allow adequate amortization of program start-up and administrative costs, the pricing data is based upon a minimum order size of $100,000.

8.3 INSTALLATION

Installation of RVR equipment is handled by the local FAA Regional Office. Cost estimates are made by the region for each site and sent to FAA Headquarters for approval. The forms used by the regions are the Project Materiel List, FAA Form 4650-1 (Appendix A); the Cost Estimates, Item Summary, FAA Form 2500-70-1 (Appendix B); and the Cost Estimate, Item Explanation, FAA Form 2500-40 (Appendix C). The costs involved could vary significantly for each region and site, depending upon local labor costs, material and site preparation required. A detailed cost estimate to install one transmissometer is provided by the local FAA Regional Office, Airways Facilities Division. Our estimate (FY76 prices) is as follows:

TABLE 23. PURCHASE COSTS (FY76) FOR TASKER 500 UNITS AND SYSTEMS.

UNIT				RVR SYSTEM		
Description	Quantity Range			No. of Transmissometers		
	1	7 - 10	21 - 27	1	2	3
	Price ($ K)			Price ($ K)$^{+}$		
RVR 500/1 Main Frame*	6.0	4.3	3.3	4.3	4.3	4.3
RVR 500/2 SDC Module	6.4	4.1	3.4	4.1	8.2	12.3
RVR 500/3 Ambient Light Sensor Unit	2.3	1.5	1.2	1.5	1.5	1.5
RVR 500/4P Remote Display Programmer	10.5	6.2	4.6	6.2	6.2	6.2
RVR 500/5 Runway Light Setting Unit	1.8	1.1	0.8	1.1	1.1	1.1
RVR 500/10 Transmissometer Systems	24.3	15.7	13.5	15.7	31.4	47.1
RVR 500/12TM Tower, Modified	3.6	3.2	3.0	3.2	6.4	9.6
Subtotal	54.9	36.1	29.8	36.1	59.1	82.1
Provisioning Costs, 10%	5.5	3.6	3.0	3.6	5.9	8.2
Factory Inspection, 3%	1.6	1.1	0.9	1.1	1.8	2.5
Subtotal	7.1	4.8	3.9	4.7	7.7	10.7
Freight Cost, 3%	1.6	1.1	0.9	1.1	1.8	2.5
Custom Duties	NA	NA	NA	NA	NA	NA
Subtotal (Freight)	1.6	1.1	0.9	1.1	1.8	2.5
Total(Washington Office Cost)	62.0	42.0	34.6	41.9	68.6	95.3

\+ = Prices based on quantity range of 7 - 10.

NA = Not applicable.

		Detail Amount	Summary Amount	Total
Engineering				
Civil	10 man-days at $150/day	$ 1,500		
Electronic	10 man-days at $150/day	1,500		
Drafting	7 man-days at $80/day	560		
	Total Engineering		$3,560	
Construction				
Supervision:	18 man-days at $150/day	$ 2,700		
Utilities installed by hookup to local ILS		300		
Support items, cable, etc. (regional equipment purchase)		2,300		
Cost for two concrete bases, trenching, erect towers, etc. (includes construction personnel)		10,000		
	Total Construction		$15,300	
Electronic Installation				
Electronic Technician:	18 man-days at $150/day	$ 2,700		
Alignment (transmissometer), test wire hookups, install RVR computer, light sensor unit, runway light setting unit		no charge		
Regional purchases (connectors, cables, clamps, etc.)		200		
Regional freight		200		
	Total Electronic Installation		$3,100	
	Subtotal - Regional Cost			$21,960

Discussions with the New England Regional office indicated that the sample cost of establishing a complete RVR system is approximately $28 K (estimate FY77) which compares with the installation cost of $21.9 K obtained above.

Thus, the cost for installation of a typical FAA/NBS RVR system including two transmissometers, all electronic equipment, and three remote displays is estimated as $40.3 K and for three transmissometers, $58.7 K.

Other typical RVR FAA/NBS system installation costs are:

Transmissometer only*+ (hookup, alignment and test):	
Electronic technician: 6 man-days at $150/day	$ 900
Replacement of RVR System*+ (remove existing computer main frame, install replacement computer main frame RVR displays): 17 man-days at $150/day	2,550
Relocation of one Transmissometer Tower**+	
Construction cost (7700 x 0.6)	4,620

Installation costs for the Skopolog and Lynx systems are less since they do not require the installation of towers as in the RVR FAA/NBS system. Therefore, the construction cost is reduced from $15.3K to $4.6K for a Skopolog system with one transmissometer, and $6K and $8K for two and three transmissometer systems, respectively. This consideration is also applicable to the Lynx and Marconi systems.

8.4 MODIFICATION KIT INSTALLATION

In the case of modification kits of the type developed by TSC and/or Tasker Industries, installation would be handled by the local FAA Regional Office. The forms used by the regions are shown in Appendices A, B and C. This format has been used for the purpose of this cost deployment analysis. The costs involved could vary significantly for each region and site, depending upon local labor costs, and material.

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* Excludes transmissometer.

** Relocation of one transmissometer tower to change baseline length.

\+ This includes technician(s) travel time.

Our estimate using FY76 prices is as follows:

		Detail Amount	Summary Amount	Total
Engineering				
Civil				
Electronic	1 man-day at $150/day	$150		
Drafting	1 man-day at $ 80/day	$ 80		
	Total Engineering		$230	
Electronic Installation				
Electronic Technician	2 man-days at $150/day	$300		
Alignment transmissometer, test wire hookups, etc.)		NC		
Regional purchases (connectors, cables, clamps, etc.)		$ 50		
Regional Freight		$ 50		
	Total Electronic Installation		$400	
	Subtotal - Regional Cost			$630

8.5 FIELD CABLING

The cost of installed cables (transmissometer signals and electrical power) for new RVR equipment can be significant, especially since several thousand feet of trenching and cable may be required. In some cases, such as replacement of an existing transmissometer, the present cables can often be used. Also, as in the case at Logan International Airport (Boston), existing spare cable may be used for some RVR installations. However, the availability and use of existing cables cannot be relied upon, and the following estimates of trenching and cable costs* are presented (FY77 budget estimates):

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*Hilsenrod, A. (DOT/FAA ARD-451): Correspondence to H. Ingrao (DOT/TSC) July 11, 1975. Regarding FAA inventories of visibility equipment and cabling costs.

Item	Cost Per Foot
Trenching and burying cable	$5.00
Transmissometer Cable, 12 pair conductor #19 armored, stock No. 6145-00-765-67101	0.90
Power Cable, 3 pair conductor #8 armored, 600 volt, stock No. 6145-00867-46331	1.50
Total	$7.40

8.6 MAINTENANCE

The maintenance required for RVR equipment is given in terms of average hours per month and average man years of effort. The numbers presented here are from the FAA National Standards — Facility Sector Staffing (Reference 52).

The staffing required is determined first by listing all RVR equipment and by determining the number of "points" associated with that equipment, as noted in Table 24. Once the total number of points is determined in this way, the system "class" is determined by examining Table 25; the man-hours per month and man-years maintenance staffing required for this class is then found in Table 26. Based on the criteria outlined and data given in Tables 24, 25, and 26, the total number of points for an RVR system with one transmissometer is 1,110, which corresponds to a Class C maintenance and therefore a 0.51 man-year staffing for maintenance.

Thus, using the same example as before, a complete system consisting of three transmissometers, three signal data converters, six remote display units, and one each of the other computer equipment elements results in the following:

3 transmissometer systems at 300 each	900
3 signal data converters at 275 each	825
6 remote displays at 100 each	600
1 each remaining items from Table 24	435
Total Points	2,760

This gives a Class E installation or a maintenance staffing level of 1.12 man-years. The same computation for an RVR installation with two transmissometers gives a Class D installation or a maintenance staffing level of 1 man-year.

TABLE 24. FAA MAINTENANCE POINT COUNT FOR RVR EQUIPMENT (REFERENCE 52).

Item		Points	
Transmissometer Equipment			
Transmissometer System		245	
Recorder		50	
Meter		5	
	Subtotal		300
Computer Equipment			
Signal Data Converter		275	
Time Base Generator		50	
Receiver Decoder		230	
Control and Power Supply		50	
Signal Line Modifier		25	
Runway Light Intensity Unit		15	
Day/Night Switch (Photocell)		15	
Computer Selector		50	
Remote Digital Display Unit		100	
	Subtotal		810
	Total		1,110

TABLE 25. FAA MAINTENANCE RVR EQUIPMENT CLASS DETERMINATION (REFERENCE 52).

Class	Point Count
A	< 400
B	401 - 600
C	601 - 1200
D	1201 - 2200
E	2201 - 3000
F	3001 - 4000

TABLE 26. NATIONAL STANDARDS - FACILITY SECTOR STAFFING MAN-YEARS PER FACILITY (REFERENCE 52).

Class	Man-Hours per Month	Man-Hours per Year	Man-Years
A	33	396	0.19
B	46	552	0.27
C	89	1068	0.51
D	173	2076	1.00
E	193	2316	1.12
F	278	3336	1.60

Maintenance operations for the present FAA/NBS RVR instrumentation requires electronic technicians in the middle of the GS 11 scale ($17.5K). Considering a 35 percent overhead*, the cost for one man-year would be $23.6K. Therefore, the maintenance cost for an FAA/NBS RVR system with one transmissometer is $12K, for two transmissometers it is $23.6K, and for three it is $26.4K. For the Skopolog, Lynx, and

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* The overhead percentage will depend on the type of operation (i.e., F&E reimbursable agreement, etc.)

Marconi systems, we do not know at this time the level of expertise and training required by the electronic technician to properly maintain the systems. It should be pointed out that due to the nature of the RVR instrumentation (safety), FAA personnel maintain full and positive control; therefore, no contractor personnel can be considered for the maintenance of this instrumentation.

8.7 TRAINING

At present, the FAA usually trains personnel from high density facilities (i.e., those with many RVRs). It is possible that sometime in the future the FAA will train personnel from other airports. Formerly the training consisted of a two to three week course at the FAA Aeronautical Center facilities in Oklahoma City. Training on new Tasker 500 equipment is presently being handled at the Tasker Industries facilities as a two week course. Discussions with M. Sliwa, FAA New England Regional Office, indicated that $150/day is the rule-of-thumb estimated cost for training on visibility equipment. This includes salary, per diem, and travel expenses.

The training for present RVR instrumentation is a three-week course; thus an RVR FAA certified technician costs $2.25K for training. It is safe to assume that training for other RVR systems will be approximately the same.

8.8 PROVISIONING

It is estimated that for E/G, lighting systems, and miscellaneous (Reference 50), ten (10) percent of the equipment purchase cost per year (ten-year amortization) is for provisioning. The provisioning for the typical RVR installations using commercially available systems considered in this report is included in Table 27.

8.9 TOTAL DEPLOYMENT COST ESTIMATES FOR TYPICAL RVR INSTALLATIONS

Based on the results of this section, Table 27 summarizes the estimated deployment costs for typical one, two and three transmissometer RVR installations.

The Washington office costs given in Table 27 indicate that the price of the Tasker 500 system is comparable to that of the Skopolog and the Lynx and almost 30 percent lower than the price of the IVR-2 for a 3 transmissometer system. When the subtotals of the Regional Office are added, the total Tasker 500 system deployment cost is higher than the one for the Skopolog system due to transmissometer tower deployment costs. It is important to notice that we are comparing deployment costs and no considerations of cost-effectiveness or life-cycle are being made.

TABLE 27. SUMMARY OF ESTIMATED DEPLOYMENT COSTS FOR TYPICAL RVR INSTALLATIONS USING COMMERCIALLY AVAILABLE SYSTEMS.*

Item Explanation	Number of Transmissometers											
	Skopolog			Marconi+ IVR-2			Lynx			Tasker 500		
	1	2	3	1	2	3	1	2	3	1	2	3
Washington Office Cost												
RVR System Cost	29.8	54.3	72.0	NI	NI	125.0	38.6	-	-	36.1	59.1	82.1
Provisioning, 10%	3.0	5.4	7.2	NI	NI	12.5	3.9	-	-	3.6	5.9	8.2
Factory Inspection, 3%	0.9	1.6	2.2	NI	NI	3.7	-	-	-	1.1	1.8	2.5
Freight Cost	4.8	8.7	11.5	NI	NI	-	-	-	-	1.1	1.8	2.5
Subtotal - ** Washington Office Cost	38.5	70.0	92.9	NI	NI	141.2	42.5			41.9	68.6	95.3
Regional Cost												
Engineering	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Construction	4.0	6.0	8.0	4.0	6.0	8.0	4.0	6.0	8.0	15.3	30.6	45.9
Electronic Installation	3.1	6.2	9.3	3.1	6.2	9.3	3.1	6.2	9.3	3.1	6.2	9.3
Subtotal - Regional Cost	10.6	15.7	20.8	10.6	15.7	20.8	10.6	15.7	20.8	21.9	40.3	58.7
Total	49.1	85.7	113.7	-	-	162.0	53.1	-	-	63.8	108.9	154.0

*Estimates are given in thousands of dollars.

**See Tables 21, 22 and 23. In the case of imported equipment the RVR system cost given in this table includes shipping charges to the Port of N.Y. and custom duties.

+See Subsection 8.2.2.

NI=No information

9. ELEMENTS OF DEPLOYMENT COST FOR PROPOSED ARVIS INSTALLATION

In this section estimated costs for establishing MOD I, II and III (ARVIS) installations is presented. Due to the nature of these modifications and since there are not in existence as commercial products many of the units required to implement the modifications, the estimates are within item c(1) of the Cost Estimating Methodology (see Subsection 8.1).

As discussed in Section 7, the ARVIS is currently in the development stage by TSC and it will be tested and evaluated at NAFEC in the near future. The scheduling of this test is, at present, contingent to budget allocation only. Cost items included are purchase, installation, field cabling, maintenance, training, freight, factory inspection and provisioning. System development costs, access road to the field site and regional freight are not included in the cost estimate.

9.1 COST ESTIMATING METHODOLOGY

TSC has developed the MOD I, II and III and implemented them in the form of breadboard. MOD I has been laboratory and field tested. One field test* took place at Tasker Systems from May to June 1974. A second test* took place at NAFEC during November 1974.

The MOD II and III have been tested at TSC in 1974 - 75 during development. The engineering specifications of MOD I and II are well defined; therefore, the cost estimating will be based on the cost and engineering experience gathered by TSC during the development breadboard of these two modifications.

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* TSC report is in preparation.

The estimate for the prototype will be based on materials, electrical and mechanical engineering, drafting, manufacturing, electrical and environmental tests and documentation.

9.2 EQUIPMENT PURCHASE

The MOD I, II and III have been developed and thoroughly tested in the laboratory at TSC. The MOD I has been thoroughly tested at Tasker Systems and NAFEC. To reach the prototype (preproduction) stage of the different modification units it is required to develop the prototype models based on the TSC specification. Therefore, the prototype cost per unit will reflect an engineering effort and four units of each type as a deliverable.

9.2.1 MOD I

In the MOD I the estimated R&D cost (FY76) to implement the present MOD I specifications to the prototype stage will be $145K which includes four prototypes MOD I fully engineered, tested and documented. That means $36.2K per modification set (receiver and projector power supply and control).

For the MOD I production model, and for the type of hardware and quantity range under consideration, it is assumed that the manufacturing and test costs are 100% of the material costs and that the instruction manual, documentation, marketing, price and profit is also 100% of the material costs. For 5 to 9 units the material cost for a MOD I set is $1.3K, for 10-29 $1.0K and for 30-99 $0.9K. Therefore, the respective estimated total purchase costs per unit (see Table 28) are $3.9K, $3.0K and $1.8K.

9.2.2 MOD II

For the MOD II, estimated purchase costs for the receiver and projector power supply and control units are the same as for the MOD I. The estimated R&D

cost (FY76) to implement the present MOD II specifications to the prototype stage will be $267K which includes four prototypes MOD II fully engineered, tested and documented with the associated software. In the $267K estimate has been included also the MOD I units that are common to the MOD II. For these production MOD II units, and for the type of hardware and quantity range under consideration, an 8K memory minicomputer with minor additions is estimated $6K+, a teletype with the interface $2.0K+, and the I/O interface at $3K. The estimated purchase cost of the I/O includes the hardware integration. The total estimated purchase cost (FY76) of electronic units for the MOD II are in Table 29. If the MOD II is evolved from a MOD I the development and/or procurement costs of the units common to the two modifications should be deducted.

TABLE 28. ESTIMATED PURCHASE COST (FY76) OF ELECTRONIC UNITS FOR MOD I.

Unit Description	Price ($K)			
	Proto-* type	Number of Units		
		5-9**	10-29**	30-99**
Receiver No. 10-R-250 or No. 10-R-500	18.1	1.9	1.5	0.9
Projector Power Supply and Control No. 12-P	18.1	1.9	1.5	0.9
Subtotal	36.2	3.9	3.0	1.8
Provisioning, 10%	3.6	0.4	0.3	0.2
Factory Inspection, 3%	1.1	0.1	0.1	0.1
Subtotal	4.7	0.5	0.4	0.3
Freight Cost, 3%	1.1	0.1	0.1	0.1
Custom Duties	-	-	-	-
Subtotal	1.1	0.1	0.1	0.1
Total (Washington Office Cost)	42.0	4.4	3.5	2.2

*Based on four sets.

**The R&D cost for the prototype is not included as an element of cost.

+Based on PDP-11 Digital Equipment Corporation 1975 prices.

TABLE 29. ESTIMATED PURCHASE COST (FY76) OF ELECTRONIC UNITS FOR MOD II.

Unit Description	Price			
	Proto-* type	Price ($K)		
		5-9**	10-29**	30-99**
Receiver No. 10-R-250 or No. 10-R-500	18.1	1.9	1.5	0.9
Projector Power Supply and Control No. 12-P	18.1	1.9	1.5	0.9
Minicomputer No. 24-C	6.0	6.0	5.5	5.5
I/O Interface No. 26-1	22.5	3.0	2.5	2.3
Teletype No. 28-T	2.0	2.0	1.8	1.8
Subtotal	66.7	14.8	12.8	11.4
Provisioning, 10%	6.7	1.5	1.3	1.1
Factory Inspection, 3%	2.0	0.4	0.4	0.3
Subtotal	8.7	1.9	1.7	1.4
Freight Cost, 3%	2.0	0.4	0.4	0.3
Custom Duties	-	-	-	-
Subtotal (Freight)	2.0	0.4	0.4	0.3
Total (Washington Office Cost)	77.4	17.1	14.9	13.1

*Based on four sets.
**The R&D cost for the prototype is not included as an element of cost.

9.2.3 MOD III ARVIS

The estimated R&D cost (FY76) to implement the present MOD III specifications to the prototype stage will be $497.6K which includes four prototypes MOD III fully engineered, tested and documented and with the associated software. That means $124.4K per ARVIS system. For the MOD III, we suggest to include minicomputer redundancy to increase reliability in the operation since all the airport visibility measuring equipment will be serviced by only one minicomputer.

The estimate is based on a 16K* minicomputer at $9.2K; I/O interface at $5.7K; incremental digital tape recorder at $5.3K; teletype at $2.0K; high speed tape reader at $1.6K; and minicomputer redundancy at $9.2K. The estimated purchase costs (FY76) of electronic units for the MOD III ARVIS are in Table 30. If the MOD III is evolved from a MOD I or MOD II the development and/or procurement costs of the units common to the MOD III and the previous modifications should be deducted.

9.3 INSTALLATION

It is assumed that the MOD I, II and III installations will be handled by the local FAA Regional Office. The MOD I and II have been designed in such a way that the removal of the FAA/NBS transmissometer units and the installation of the corresponding MOD units replacement can be achieved in the field and using only hand tools of the type found in an electrician's tool box. The MOD III ARVIS will require the same type of tools, equipment and personnel that is required for the Tasker 500 system and minicomputer installations.

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*To accommodate SVR compilation, the 8K (MOD II) minicomputer should be expanded to 16K word, 16 bit core.

TABLE 30. ESTIMATED PURCHASE COSTS (FY76) OF ELECTRONIC UNITS FOR MOD III ARVIS.

Unit				ARVIS		
Description	Quantity Range			No. of Transmissometers		
	Prototype*	5 - 9	10 & up	1	2	3
	Price ($K)			Price ($K)**		
Receiver 30-R-250 or Receiver 30-R-75	20.0	3.6	3.0	3.0	6.0	9.0
Projector Power Supply & Control No. 12-P	18.1	1.9	1.5	1.5	3.0	4.5
Slave Control 32-S	19.0	3.9	3.0	3.0	6.0	9.0
Sky Background Luminance Meter No. 34-L	4.0	1.7	1.4	1.4	1.4	1.4
Minicomputer ***	19.5	19.5	19.5	19.5	19.5	19.5
I/O Interface No. 34-I	10.0	5.7	5.7	5.7	5.7	5.7
Teletype No. 28-T	2.0	2.0	1.8	1.8	1.8	1.8
Incremental Digital Tape Recorder No. 36-R	5.8	5.8	5.3	5.3	5.3	5.3
Master Control No. 37-M	9.0	2.8	2.0	2.0	2.0	2.0
Photometric Display No. 38-P	5.0	3.9	3.0	3.0	3.0	3.0
Remote Digital RVR Display No. 39-D	12.0	6.3	5.0	5.0	5.0	5.0
Subtotal	124.4	57.1	51.2	51.2	58.7	66.2
Provisioning, 10%	12.4	5.7	5.1	5.1	5.9	6.6
Factory Inspection, 3%	3.7	1.7	1.5	1.5	1.8	1.9
Subtotal	16.1	7.4	6.6	6.6	7.7	8.5
Freight Cost, 3%	3.7	1.7	1.5	1.5	1.8	1.9
Custom Duties	-	-	-	-	-	-
Subtotal (Freight)	3.7	1.7	1.5	1.5	1.8	1.9
Total (Washington Office Cost)	144.2	66.2	59.3	59.3	68.2	76.6

* Based on four sets.

** The R&D cost for the prototype is not included as an element of cost.

*** Minicomputer with redundancy and associated high-speed tape reader.

9.3.1 MOD I

Our estimate for a MOD I installation following the FAA Form 2500-40 is:

		Detail Amount	Summary Amount	Total
Engineering				
Civil	0 man-day	0		
Electronic	1 man-day at $150/day	$150		
Drafting	1 man-day at $80/day	$ 80		
	Total Engineering		$230	
Electronic Installation				
Electronic Technician	2 man-days at $150/day	$300		
Regional purchases (connectors, cables, clamps, etc.)		$100		
	Total Electronic Installation		$400	
	Subtotal-Regional Cost			$630

It should be pointed out that there are no construction costs.

For two transmitters the estimated cost for a MOD I installation is $930 and for three transmissometers it is $1,230.

9.3.2 MOD II

The MOD II installation cost estimate could be made as a step up of the cost estimated for the MOD I since it is an expansion of the MOD I. The increase in installation cost will be mainly in the system debugging, the test of program, and overall system test. This cost increase over the MOD I installation will reflect an estimated 200 percent increase in the electronic installation ($800). Therefore, the costs will be:

	Summary Amount
Engineering	$ 230
Construction	0
Electronic Installation	$1,200
Subtotal-Regional Cost	$1,430

Therefore, the estimated MOD II installation cost for one transmissometer is $1,430. The cost for two transmissometers, due to non-recurrent costs, will be $1,830 and for three, $2,230.

9.3.3 MOD III ARVIS

The estimated installation cost for a MOD III ARVIS with one transmissometer is:

Engineering			Detail Amount	Summary Amount	Total
	Civil	0 man-day	0		
	Electronic	1 man-day at $150/day	$ 150		
	Drafting	1 man-day at $80/day	$ 80		
		Total Engineering		$ 230	
Electronic Installation					
	Technician	10 man-days at $150/day	$1,500		
	Regional purchases (connectors, cables, clamps, etc.)		$ 100		
		Total Electronic Installation		$1,600	
		Subtotal-Regional Cost			$1,830

For MOD III ARVIS installations with additional transmissometers, two extra man-days and an additional $100 in regional purchases per additional transmissometer should be considered. Therefore, the estimated installation cost for a MOD III ARVIS with two transmissometers will be $2,230, with three $2,630, and with four $3,030.

9.4 FIELD CABLING

The installation of the MOD I or II does not require any installation of cables (transmissometer signals and electrical power) since these two modifications only replace and/or delete existing units in the FAA/NBS transmissometer system. The installation of the MOD III requires the transmission of control signals from the master to the slave control unit and vice versa. This requires an additional cable or a transmission scheme that could use the transmissometer signal cable to transmit the control signals.

9.5 MAINTENANCE

The maintenance required for the RVR MOD I, MOD II and MOD III ARVIS is given in terms of average hours per month and average man-years of effort.

9.5.1 MOD I

For the MOD I we adjust the numbers presented in the FAA National Standards - Facility Sector Staffing (Reference 52) to reflect the changes from vacuum tube to solid state technology. The MOD I changes are made only in the transmissometer; therefore, the points relevant to the computer equipment (see Table 24) remain the same (810) and the points for the transmissometer change by an estimated 50% reduction to 122. Therefore, the total maintenance point count is 988 which makes the MOD I a class C installation (see Table 25). This requires a 0.51 man-year staffing for maintenance. That means that MOD I requires the same level of staffing for maintenance as the standard FAA/NBS system, since the MOD I affects only the transmissometer and not the computer equipment which carries 810% of the maintenance point count. If this analysis is extended to three RVR MOD I systems there is no change with respect to the FAA/NBS RVR system; that is, 1.12 man-years staffing is still required for maintenance.

9.5.2 MOD II

For the MOD II system the maintenance point count has a major change over the MOD I since it affects the computer equipment. Table 31 gives the detailed count.

TABLE 31. ESTIMATED MAINTENANCE POINT COUNT FOR RVR MOD II EQUIPMENT.

Item	Points	
Transmissometer Equipment		
MOD II transmissometer system*	122	
Subtotal	122	
Computer Equipment		
Minicomputer No. 24-C	50	
I/O Interface No. 26-I	50	
Teletype No. 28-T	50	
Control and Power Supply	50	
Signal Line Modifier	25	
Runway Light Intensity Unit	15	
Day/Night Switch (Photocell)	15	
Computer Selector	50	
Remote Digital Display Unit	100	
Subtotal	405	
Total		527

*The MOD II consists of the MOD I plus additional changes in the computer equipment (see Table 20).

The total maintenance point count for the MOD II system is 527 which makes it a class B system (see Table 25) requiring 0.27 man-year staffing for maintenance. That means that MOD II requires one half the manpower to maintain a standard RVR FAA/NBS system.

For a MOD II system using three transmissometers, 0.6 man-year will be required which again will be one half the manpower required to maintain a standard system.

9.5.3 MOD III ARVIS

The estimated maintenance point count for the MOD III ARVIS is comparable to that shown in Table 31 for MOD II. Therefore, the conclusions given in Subsection 9.5.2 are applicable.

9.6 TRAINING

The MOD I or MOD II maintains the main system concept used in the FAA/NBS RVR system. The main differences lie in the usage of a solid state detector, integrated circuits and a software oriented computer (minicomputer). Therefore, we should consider two aspects of the training: personnel already trained at the FAA Aeronautical Center (Subsection 8.6) on RVR equipment and untrained personnel. For the trained personnel, it will require 3 days to learn the circuitry and maintenance of MOD I and one week for the MOD II at the facilities of the manufacturer. For untrained personnel, it will take a three-week course as is required for the present FAA/NBS RVR system. The same three-week course should be required for the MOD III ARVIS. As a rule-of-thumb, $150/day is estimated for training costs. Therefore, assuming FAA personnel trained on the FAA/NBS RVR equipment, the training costs are:

MOD I	3 days at $150/day	$ 450
MOD II	5 days at $150/day	$ 750
MOD III	21 days at $150/day	$3,150

9.7 PROVISIONING

The same criteria used in Subsection 8.7 are considered for provisioning; that is, ten (10) percent of the equipment purchase cost.

9.8 TOTAL COST PER MOD INSTALLATION

Based on the results of this section, Table 32 summarizes the estimated deployment costs for typical one, two and three transmissometer RVR installations using the MOD I, II or III modification level. It is important to notice that we are comparing <u>deployment costs</u> and no considerations of cost-effectiveness or life-cycle are being made.

TABLE 32. ESTIMATED TOTAL COSTS PER MOD I, II OR III INSTALLATION.

Item Explanation	Price ($K)								
	MOD I			MOD II			MOD III		
	No. of Transmissometers								
	1	2	3	1	2	3	1	2	3
Washington Office Cost									
MOD Unit Cost*	3.0	6.0	9.0	12.8	15.8	18.8	51.2	58.7	66.2
Provisioning, 10%	0.3	0.6	0.9	1.3	1.6	1.9	5.1	5.9	6.6
Factory Inspection, 3%	0.1	0.2	0.3	0.4	0.5	0.6	1.5	1.8	1.9
Freight Cost, 3%	0.1	0.2	0.3	0.4	0.5	0.6	1.5	1.8	1.9
Subtotal - Washington Office Cost	3.5	7.0	10.5	14.9	18.4	21.9	59.3	68.2	76.6
Regional Cost									
Engineering	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electronic Installation	0.4	0.7	1.0	1.2	1.6	2.1	1.6	2.0	2.4
Subtotal - Regional Cost	0.6	0.9	1.2	1.4	1.8	2.3	1.8	2.2	2.6
Total	4.1	7.9	11.7	16.3	20.2	24.2	61.1	70.4	79.2

*The unit costs are based on estimated purchase costs for 10-29 units per order (see Tables 28, 29 and 30).

10. ELEMENTS OF DEPLOYMENT COST FOR FAA PROPOSED SVR SYSTEM

In this section, typical cost for establishing an SVR system on CAT II runways is presented. As discussed in Section 4, the SVR system is currently in the developmental stage by NWSC and it is under test and evaluation at NAFEC. Operational demonstrations are planned for two airports with CAT II runways. Consequently, the only available cost information for an SVR system are those for the operational demonstration program. Cost items included are purchase, installation, field cabling, maintenance, training, freight costs, factory inspection and provisional costs. For foreign-made systems, the prices are given CIF port of New York. System development costs, access road to the field site and regional freight are not included in the cost estimate.

10.1 COST ESTIMATING METHODOLOGY

The F&E Cost Estimate Summaries Handbook (Reference 50) and specifically the Handbook information which refers to the installation of RVR (see Subsection 8.1) is applicable to the installation of SVR due to the similarity of the instrumentation.

10.2 EQUIPMENT PURCHASE

The SVR system developed at NWSC is at the breadboard stage and it will require an engineering effort to bring the breadboard to the prototype (preproduction) level. It is estimated that the engineering effort will be at the $400K level which will include the delivery of a preproduction system with full documentation. In this section we analyze the equipment purchase cost for the units that integrate the SVR system once fully engineered. Purchase costs for three different SVR options are given in Table 33. These options are based on the usage of three reasonable alternatives to measure (directly or indirectly) the atmospheric transmittance at 100 and 10 feet above the ground (see Subsection 4.3).

TABLE 33. ESTIMATED TOTAL COSTS (FY76) OF ELECTRONIC EQUIPMENT FOR THE FAA SVR SYSTEM.

Item	Unit Cost ($K)	No.	Price ($K)		
			Option A	Option B	Option C
Forward Scatter Meter**	10.8	2	21.6	-	-
Compact Forward Scatter Meter+	6.0	2	-	12.0	-
Compact Transmissometer++	6.0	2	-	-	12.0
Luminance Meter***	2.0	2	4.0	4.0	4.0
Illuminance Meter	2.0	1	2.0	2.0	2.0
Minicomputer (16K) and Peripherals	19.5	1	19.5	19.5	19.5
I/O Interface	5.7	1	5.7	5.7	5.7
SVR Display	5.0	1	5.0	5.0	5.0
Magnetic Tape Recorder (3 cassettes)	5.3	1	5.3	5.3	5.3
Analog/Digital Converter and Data Transmitter	8.5	1	8.5	8.5	8.5
Anemometer	0.5	1	0.5	0.5	0.5
High Intensity Runway Light Setting Unit*	-	1	-	-	-
Approach Runway Light Setting Unit*	-	1	-	-	-
Touchdown Transmissometer*	-	1	-	-	-
Miscellaneous Equipment (racks, meters, spare parts)	6.0	-	6.0	6.0	6.0
100-ft Tower, Accessories and Installation Hardware	25.0	1	25.0	25.0	25.0
Subtotal	-	-	103.1	93.5	93.5
Provisioning, 10%	-	-	10.3	9.4	9.4
Factory Inspection, 3%	-	-	3.1	2.8	2.8
Subtotal	-	-	13.4	12.2	12.2
Freight Cost, 3%	-	-	3.1	2.8	2.8
Custom Duties, 10%+++	-	-	-	1.2	1.2
Subtotal (Freight)	-	-	3.1	4.0	4.0
Total (Washington Office Cost)	-	-	119.6	109.7	109.7

* The SVR system requires a touchdown transmissometer and associated equipment. In this estimate, it is assumed that such transmissometer is deployed (CAT II runway) and, therefore, it is not part of the estimate.

** Based on EG&G FSM Model 206 purchase costs (see Section 6.3.1).

*** Only one Luminance meter is needed for SVR. The additional meter is for the ALCH capability.

+ Based on Fumosens $4.3K purchase costs (see Subsection 6.4.1), plus the addition of an estimated $1.7K interface.

++ Based on MET-1 purchase costs (see Subsection 6.6.2).

+++ Applicable only to imported sensors.

The approximate FAA hardware procurement cycle is nine months and the average delivery time which varies with the manufacturer, is usually up to six months for the small quantities considered in the SVR procurement.

10.3 INSTALLATION

Installation of RVR equipment is handled by the local FAA Regional Office. In the case of the SVR equipment, since it is not operational, and is in the transition from development to an operational demonstration, it will be handled by FAA Headquarters with the cooperation of the respective FAA Regional Office.

The forms used by the regions are the Project Materiel Lists, FAA Form 4650-1, the Cost Estimates, Item Summaries, FAA Form 2500-70-1, and the Cost Estimate, Item Explanation, FAA Form 2500-40 (Appendices A, B and C). The same material has been used for the purpose of this installation cost analysis. The costs involved could vary significantly for each region and site, depending upon local labor costs, material and site preparation required. Our estimate (FY76 prices) is:

		Detail Amount	Summary Amount	Total
Engineering				
Civil	20 man-days at $150/day	$3,000		
Electronic	20 man-days at $150/day	3,000		
Drafting	30 man-days at $ 80/day	2,400		
	Total Engineering		$8,400	
Construction				
Supervision	30 man-days at $150/day	4,500		
Cable installation		18,500		
Regional Purchases		2,300		
Cost for concrete base, tower erection, etc.		10,000		
	Total Construction		$35,300	

	Detail Amount	Summary Amount	Total
Electronic Installation			
Electronic Technician 22 man-days at $150/day	$3,300		
Regional Purchases	500		
Regional Freight	500		
Total Electronic Installation		$4,300	
Subtotal-Regional Cost			$48,000

10.4 FIELD CABLING

The cost of installed cables for the SVR equipment can be significant, especially since several thousand feet of trenching and cable may be required away from the runway. The SVR tower will be installed at a 1,300 ft distance from the axis of the runway (see Figure 3). The intersection of the perpendicular to the axis of the runway, passing through the position of the SVR tower, will be at approximately 2,000 ft from the touchdown zone. Therefore, the distance from the SVR tower to the ILS housing (touchdown zone) will be on the order of 2,500 ft. It is assumed for the SVR installation under discussion that an existing spare cable may be available from the ILS housing to the airport control tower and that only a cable from the SVR tower to the ILS will have to be provided. The type of cable, cable and trenching costs ($7.40 per foot) given in Subsection 8.4 are applicable. Therefore, the estimated field cabling for an SVR installation is $7.40/ft x 2,500 ft = $18,500.

10.5 MAINTENANCE

The maintenance required for the SVR equipment will be given in terms of average hours per month and average man-years of effort. The numbers presented here will be based on the FAA National Standards - Facility Sector Staffing (Reference 52) based on the similarity between RVR and SVR instrumentation.

The staffing required is determined first by listing all SVR equipment and by determining the number of "points" associated with that equipment, as noted in Table 24.

Once the total number of points is determined in this way, the maintaining equipment "class" is determined by examining Table 25; the man-years maintenance staffing required for this class is then found in Table 26.

The estimated maintenance point count is given in Table 34. The 1200 point count is a class D maintenance equipment which requires a one man-year staffing.

TABLE 34. ESTIMATED MAINTENANCE POINT COUNT FOR SVR EQUIPMENT*

Item	Points	
Field Equipment		
Forward Scatter Meter (2)	200	
Luminance Meter (2)	30	
Illuminance Meter	30	
Anemometer	40	
Subtotal		300
Computer Equipment		
Minicomputer (16K) and Peripherals	250	
Sensor-Computer	120	
Analog/Digital Converter and Data Transmitter	120	
Digital Cassette Tape Recorder	275	
High Intensity Runway Light Setting Unit	15	
Approach Runway Light Setting Unit	15	
SVR Display	100	
Subtotal		895
Total		1195

*Point count based on analogy of Reference 53 data.

It is assumed that the SVR system will be configured in such a way that the maintenance could be performed by electronic technicians in the middle GS 11 scale ($17.5K), that means the same GS level as for the present RVR instrumentation. Considering 35 percent overhead*, one man-year cost would be $23.6K.

10.6 TRAINING

Since the SVR will be a new system, there is no FAA precedent on training for this particular system. Therefore, it is assumed that the personnel training for the first few deployed SVR systems will be handled by the contractors and in their facilities.

Based on the experience of the RVR system (see Subsection 8.6), a four week training course for the SVR at $150 per day is estimated. This includes salary, per diem, and travel expenses. Therefore, an SVR trained technician will cost $3K.

10.7 PROVISIONING

The provisioning costs for SVR will follow the same criteria used for RVR systems (Subsection 8.7), that is, ten (10) percent of the equipment purchase cost.

10.8 TOTAL COST PER SVR INSTALLATION

Based on the results of this section, Table 35 summarizes the estimated deployment cost for the FAA proposed SVR system. The total costs are $167.6K, $157.7K and $157.7K for Options A, B, and C, respectively. Attention should be directed to the fact that the installation of an SVR system implies the use in the corresponding runway of an RVR system. Thus, the SVR system will share the use of the touchdown transmissometer, the approach runway light setting unit, and the high intensity runway light setting unit. Therefore, the corresponding unit costs are not reflected in the estimated total SVR system deployment cost.

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*The overhead percentage will depend on the type of operation (i.e., F&E reimbursable agreement, etc.).

If the SVR system is installed in an airport with an ARVIS (MOD III) the SVR becomes part of the overall ARVIS and will share the minicomputer I/O interface and display. Thus, the total price for the SVR system Option 1 will be $89.5K or almost 30 percent cost reduction of the SVR stand-alone total price.

TABLE 35. DEPLOYMENT COST ESTIMATE FOR FAA PROPOSED SVR SYSTEM.

Item Explanation	Cost ($K)		
	Option A	Option B	Option C
Washington Office Cost			
SVR System	103.1	93.5	93.5
Provisioning, 10%	10.3	9.4	9.4
Factory Inspection, 3%	3.1	2.8	2.8
Freight Cost, 3%	3.1	2.8	2.8
Custom Duties, 10%*	-	1.2	1.2
Subtotal Washington Office Cost	119.6	109.7	109.7
Regional Cost			
Engineering	8.4	8.4	8.4
Construction	35.3	35.3	35.3
Electronic Installation	4.3	4.3	4.3
Subtotal Regional Cost	48.0	48.0	48.0
Total	167.6	157.7	157.7

*Applicable only to imported sensors.

11. TYPICAL VISIBILITY MEASURING SYSTEM UPGRADE DEPLOYMENT COSTS

This section presents estimated deployment costs for establishing visibility measuring equipment in airports which presently have RVR instrumentation, in order to meet the requirements of the FY76-FY85 period. Based on the elements of deployment costs as estimated in Section 8, it is clear that the two competitive systems commercially available are the Tasker 500 and the Skopolog. It should be indicated that the Tasker 500 meets the FAA requirements, including the location of the axis of the transmissometer above the ground (15 feet) which is not met by the Skopolog. Also, the Tasker 500 is compatible with the existing FAA/NBS RVR systems. Due to the above facts, the estimated deployment costs for typical installations will be based on the Tasker 500. This cost criteria does not mean a final selection and recommendation of the Tasker 500. These costs will be compared with the estimated deployment costs of the MOD III ARVIS, for the same installations, as developed in Section 9. The typical systems will be the ones generated by the needs of the airports described in Subsection 5.4.

11.1 COST ESTIMATING METHODOLOGY

The cost estimating methodology for the typical visibility measuring systems is based on the methodology developed in Subsections 8.1, 9.1, and 10.1. It should be pointed out that in some of the installations to be analyzed in this section, some adjustments should be made on the costs evolved in Section 8. More specifically, the Tasker 500 can make use of the existing towers on which present FAA/NBS transmissometers are mounted and also can make use of the present transmissometers or modified versions by means of the Tasker Modification Kits. Since we are interested in estimated deployment cost ratios and/or differentials between implementation of a given installation with Tasker 500 and MOD III ARVIS, costs of cabling and access roads to the field site are not included. Therefore, when referring to the estimated deployment costs of the Los Angeles International Airport, for example, the estimated cost can establish ratios and/or differentials for a decision making criteria of the lowest deployment cost system, but does not imply that the deployment can be carried out with a budget equal to the estimated cost. To reach the amount for the deployment budget, the deployment costs particular to the given airport, which have not been taken into account in the estimates used to obtain the ratios, should be added.

11.2 SUGGESTED SYSTEMS OPTIONS FOR FY76-FY85

Typical systems for FY76-FY85 will reflect some of the options that the decision maker will have to confront. Suggested deployment options and associated costs are described in this Subsection.

Option 1: In this option, it is assumed that during the period FY76-FY85 the airport RVR equipment needs will be satisfied with Tasker 500 equipment. SVR will be implemented in accordance with the NWSC development (Section 4).

All cost information about the Tasker 500 is from Table 27; all cost information about the SVR is from Table 35. To account for equipment already at the airport, the costs of towers, transmissometers, etc. may be deducted from the cost of the Tasker 500 system. This cost information is from Table 23.

Option 2: Option 1 did not consider replacement and/or updating of presently deployed equipment. It will be difficult to assume that the original FAA/NBS RVR system at airports will continue to be operationally acceptable (maintenance) until FY85. Option 2 introduces Tasker Modification Kits to the existing RVR systems. As in Option 1, it is assumed that future needs will be satisfied with Tasker 500 equipment and an SVR system as developed by NWSC.

In addition to sources given for Option 1, cost information for Tasker Modification Kits is from Subsection 6.10.3; cost information for the engineering and electronic installation of the Modification Kits is from Subsection 8.3.1.

Option 3: In this option, it is assumed that during the period FY76-FY85 the existing RVR systems will be replaced with Tasker 500s in addition to the installation of projected systems. Therefore, from the cost of the replacement Tasker 500 systems must be deducted the cost of the towers and ambient light sensors which are already installed at the airport. Also, to this must be added the cost of additional runway light setting units so that every runway of the airport is equipped.

Cost information on the towers, ambient light sensors and runway light setting units are from Table 23; all other cost information is the same as for Option 1.

Option 4: In this option it is assumed that the requirement of extra RVR systems are satisfied by installing an ARVIS (MOD III). The SVR system will share the ARVIS computer. To the cost of the ARVIS (MOD III) must be added the cost of towers and transmissometers without electronics ($15.7K - 3.7K = $12.0K) and other equipment when necessary. Since the SVR shares the ARVIS computer, from the cost of the SVR ($103.1K) must be deducted the cost of the minicomputer ($19.5K), I/O interface ($5.7K) and display ($5K) for a cost of $72.9K.

Cost information on the ARVIS (MOD III) comes from Table 30; on the towers and transmissometers from Table 23. Cost information on the SVR comes from Tables 33 and 35. Engineering, construction and electronic installation costs for the ARVIS (MOD III) come from Table 27.

Option 5: In this option it is assumed that the existing RVR systems are upgraded by using ARVIS Modification Kits in the transmissometers and using the centralized computer capability of the ARVIS (MOD III) which is installed to fulfill the requirement of extra RVR systems. As in Option 4, to the cost of the ARVIS (MOD III) must be added the cost of the towers and transmissometers (without electronics) and other equipment when necessary; from the cost of the SVR must be deducted the cost of the minicomputer, I/O interface and display.

Cost information is the same as for Option 4. The ARVIS Modification Kits are comprised of a receiver ($3.0K), a power supply ($1.5K) and a slave control ($3.0K), as shown in Table 30.

Options 1 through 5, detailed previously, are summarized for the airports described in Subsection 5.4. This information is shown in Tables 36 through 41. Each table consists of two parts:

(a) shows the deployment costs of each option; and

(b) details the computations used to arrive at the costs presented in (a).

The basis for computations in (b) are as previously noted in Subsection 11.3.

11.3 DEPLOYMENT COST EVALUATION

The five options discussed in Subsection 11.3 represent the major deployment alternatives to be considered in the FY76-FY85 period. But what are the criteria to choose between the options? So far in this report we developed only the elements of cost. No other criteria have been developed to assess the options.

The difference between the least expensive alternative, Option 1, which allows only compliance with FAA regulations in the FY76-FY85 period and Options 2 or 3 which address maintenance and operational considerations lies only on the needs created by the RVR equipment already deployed. The selection of one option over the other has to be judged on the needs of the specific airport considered. For airports serving large air traffic hubs, on the basis of the five airports analyzed, the mean total deployment cost of Option 2 is only 7 percent higher than the total deployment cost of Option 1, and the Option 3 is 50 percent higher than Option 1.

The comparison of the ARVIS (III) deployment cost and the deployment cost of RVR systems available as commercial products is indicated by the ratios of Options 4 and 5 to Options 2 and 3 respectively. The first ratio indicates that the total deployment cost of the ARVIS (III), Option 4, is the same as Option 1; Option 5 is 6 percent higher than the cost of Option 2 and 26 percent less than Option 3. Only one airport which

TABLE 36(a). SUGGESTED DEPLOYMENT OPTIONS TO SATISFY FY76-FY85 VISIBILITY MEASURING EQUIPMENT NEEDS FOR WILLIAM B. HARTSFIELD ATLANTA INTERNATIONAL AIRPORT.

Item Explanation	Price ($K)				
	Option 1	Option 2	Option 3	Option 4	Option 5
Washington Office Cost:					
RVR System					
Tasker 500	36.1	36.1	148.9	-	-
SVR	103.1	103.1	103.1	72.9	72.9
Tasker Mod Kits	-	18.5	-	-	-
ARVIS (Mod III)*	-	-	-	66.4	-
ARVIS (Mod III)**	-	-	-	-	66.4
ARVIS Mod Kits	-	-	-	-	37.5
Provisioning, 10%	13.9	15.8	25.2	13.9	17.7
Factory Inspection, 3%	4.2	4.7	7.6	4.2	5.3
Freight Cost, 3%	4.2	4.7	7.6	4.2	5.3
Subtotal Washington Office Cost	161.5	182.9	292.4	161.6	205.1
Regional Cost:					
Engineering	11.9	12.1	15.4	11.9	12.1
Construction	50.6	50.6	50.6	50.6	50.6
Electronic Installation	7.4	9.4	22.9	7.4	10.6
Subtotal Regional Cost	69.9	72.1	88.9	69.9	73.3
TOTAL	231.4	255.0	381.3	231.5	278.4

*Includes one additional RVR to the existing five RVR systems.
**Includes one additional RVR to the existing five RVR systems and elimination of all IRA computers.

TABLE 36(b). COMPUTATIONS RELATING TO DEPLOYMENT OPTIONS AT WILLIAM B. HARTSFIELD ATLANTA INTERNATIONAL AIRPORT.

	RVR System	Engineering	Construction	Electronic Installation
Option 1:				
1 Tasker 500	$ 36.1K	$ 3.5K	$ 15.3K	$ 3.1K
1 SVR	103.1K	8.4K	35.3K	4.3K
Totals	$ 139.2K	11.9K	50.6K	7.4K
Option 2:				
Option 1 Totals	$ 139.2K	$ 11.9K	$ 50.6K	$ 7.4K
5 Tasker Mod Kits	18.5K	1.0K	--	2.0K
Totals	157.7K	12.9K	50.6K	9.4K
Option 3:				
6 Tasker 500*	$ 164.2K			
5 Towers	-16.0K			
1 Ambient Light Sensor	-1.5K			
2 Runway Light Setting Units	+2.2K			
Tasker 500 Subtotal	148.9K	$ 7.0K	$ 15.3K	$ 18.6K
SVR	103.1K	8.4K	35.3K	4.3K
Totals	252.0K	15.4K	50.6K	22.9K
Option 4:				
1 ARVIS (MOD III)	$ 51.2K			
1 Tower	+3.2K			
1 Transmissometer	+12.0K			
ARVIS Subtotal	66.4K	$ 3.5K	$ 15.3K	$ 3.1K
SVR	72.9K	8.4K	35.3K	4.3K
Totals	139.3K	11.9K	50.6K	7.4K
Option 5:				
Option 4 Totals	$ 139.3K	$ 11.9K	$ 50.6K	$ 7.4K
5 ARVIS Mod Kits	37.5K	0.2K	--	3.2K
	176.8K	12.1K	50.6K	10.6K

TABLE 37(a). SUGGESTED DEPLOYMENT OPTIONS TO SATISFY FY76-FY85 VISIBILITY MEASURING EQUIPMENT NEEDS FOR GENERAL EDWARD L. LOGAN INTERNATIONAL AIRPORT.

Item Explanation	Price ($K)				
	Option 1	Option 2	Option 3	Option 4	Option 5
Washington Office Cost:					
RVR System					
Tasker 500+	37.6	37.5	130.1	-	-
SVR	103.1	103.1	103.1	72.9	72.9
Tasker Mod Kits	-	11.1	-	-	-
ARVIS (Mod III)*	-	-	-	69.4	-
ARVIS (Mod III)**	-	-	-	-	69.4
ARVIS Mod Kits	-	-	-	-	22.5
Provisioning, 10%	14.1	15.2	23.3	14.2	16.5
Factory Inspection, 3%	4.2	4.6	7.0	4.3	4.9
Freight Cost, 3%	4.2	4.6	7.0	4.3	4.9
Subtotal Washington Office Cost	163.2	176.1	270.5	165.1	191.1
Regional Cost:					
Engineering	11.9	12.5	22.4	11.9	12.5
Construction	50.6	50.6	50.6	50.6	50.6
Electronic Installation	7.4	8.6	16.7	7.4	9.8
Subtotal Regional Cost	69.9	71.7	89.7	69.9	72.9
TOTAL	233.1	247.8	360.2	235.0	264.0

*Includes one additional RVR to the existing RVR systems and one RVV system.

**Includes one additional RVR to the existing RVR systems and elimination of all IRA computers.

+Includes 1 RVV upgrade presently deployed and 1 RVR.

TABLE 37(b). COMPUTATIONS RELATING TO DEPLOYMENT OPTIONS AT GENERAL EDWARD L. LOGAN INTERNATIONAL AIRPORT.

	RVR System	Engineering	Construction	Electronic Installation
Option 1:				
2 Tasker 500	$ 59.1K			
Transmissometer	-15.7K			
Tower	-3.2K			
1 Ambient Light Sensor	-1.5K			
Runway Light Setting Unit	-1.1K			
Tasker 500 Subtotal	37.6K	$ 3.5K	$ 15.3K	$ 3.1K
SVR	103.1K	8.4K	35.3K	4.3K
Totals	140.7K	11.9K	50.6K	7.4K
Option 2:				
Option 1 Totals	140.7K	$ 11.9K	$ 50.6K	$ 7.4K
3 Tasker Mod Kits	11.1K	0.6K	--	1.2K
Totals	151.8K	12.5K	50.6K	8.6K
Option 3:				
3 Tasker 500	$ 82.1K			
2 Tasker 500	59.1K			
3 Towers	-9.6K			
1 Ambient Light Sensor	-1.5K			
Tasker 500 Subtotal	130.1K	$ 14.0K*	$ 15.3K	$ 12.4K*
SVR	103.1K	8.4K	35.3K	4.3K
Totals	233.2K	22.4K	50.6K	16.7K
Option 4:				
1 ARVIS (MOD III)	$ 51.2K			
Tower	3.2K			
Transmissometer	12.0K			
Slave Control	3.0K			
ARVIS Subtotal	$ 69.4K	$ 3.5K	$ 15.3K	$ 3.1K
SVR	72.9K	8.4K	35.3K	4.3K
	142.3K	11.9K	50.6K	7.4K
Option 5:				
Option 4 Totals	142.3K	$ 11.9K	$ 50.6K	$ 7.4K
3 ARVIS Mod Kits	22.5K	0.6K	--	2.4K**
	164.8K	12.5K	50.6K	9.8K

* Includes 4 Tasker 500.

** $1.6K + $0.4K x 2 = $2.4K.

TABLE 38(a). SUGGESTED DEPLOYMENT OPTIONS TO SATISFY FY76-FY85 VISIBILITY MEASURING EQUIPMENT NEEDS FOR O'HARE INTERNATIONAL AIRPORT.

Item Explanation	Price ($K)				
	Option 1	Option 2	Option 3	Option 4	Option 5
Washington Office Cost:					
RVR System					
Tasker 500	119.3	119.3	227.3	-	-
SVR	103.1	103.1	103.1	72.9	72.9
Tasker Mod Kits	-	18.5	-	-	-
ARVIS (Mod III)*	-	-	-	140.3	-
ARVIS (Mod III)**	-	-	-	-	140.3
ARVIS Mod Kits	-	-	-	-	37.5
Provisioning, 10%	22.2	24.1	33.0	21.3	25.1
Factory Inspection, 3%	6.7	7.2	9.9	6.4	7.5
Freight Cost, 3%	6.7	7.2	9.9	6.4	7.5
Subtotal Washington Office Cost	258.0	279.4	383.2	247.3	290.8
Regional Cost:					
Engineering	22.4	23.4	39.9	22.4	23.4
Construction	96.5	96.5	96.5	96.5	96.5
Electronic Installation	16.7	18.7	32.2	16.7	27.9
Subtotal Regional Cost	135.6	138.6	168.6	135.6	147.8
TOTAL	393.6	418.0	551.8	382.9	438.6

*Includes four additional RVR to the existing four RVR systems and one RVV system.

**Includes four additional RVR to the existing four RVR systems and elimination of all IRA computers.

TABLE 38(b). COMPUTATIONS RELATING TO DEPLOYMENT OPTIONS AT O'HARE INTERNATIONAL AIRPORT.

	RVR System	Engineering	Construction	Electronic Installation
Option 1:				
3 Tasker 500	$ 82.1K			
2 Tasker 500	59.1K			
1 Tower	-3.2K			
2 Ambient Light Sensors	-3.0K			
1 Transmissometers	-15.7K			
Tasker 500 Subtotal*	$ 119.3K	$ 14.0K	$ 61.2K	$ 12.4K
SVR	103.1K	8.4K	35.3K	4.3K
Totals	222.4K	22.4K	96.5K	16.7K
Option 2:				
Option 1 Total	$ 222.4K	$ 22.4K	$ 96.5K	$ 16.7K
5 Tasker Mod Kits	18.5K	1.0K	--	2.0K
Totals	240.9K	23.4K	96.5K	18.7K
Option 3:				
9 Tasker 500†	$ 246.3K			
5 Towers	-16.0K			
2 Ambient Light Sensor	-3.0K			
Tasker 500 Subtotal**	$ 227.3K	$ 31.5K	$ 61.2K	$ 27.9K
SVR	103.1K	8.4K	35.3K	4.3K
	330.4K	39.9K	96.5K	32.2K
Option 4:				
3 ARVIS (MOD III)	$ 66.2K			
4 Towers	12.8K			
4 Transmissometers	48.0K			
1 Receiver	3.0K			
1 Power Supply	1.5K			
1 Share Control	3.8K			
1 Master Control	2.0K			
1 Photometric Display	3.0K			
ARVIS Subtotal	$ 140.3K	$ 14.0K	$ 61.2K	$ 12.4K
SVR	72.9K	8.4K	35.3K	12.3K
Total	213.2K	22.4K	96.5K	24.7K
Option 5:				
Option 4 Total	$ 213.2K	$ 22.4K	$ 96.5K	$ 24.7K
5 ARVIS Mod Kits	37.5K	1.0K	--	3.2K***
	250.7K	23.4K	96.5K	27.9K

* Engineering, Construction, and Electronic Installation based on 4 units.

** Engineering, Construction, and Electronic Installation based on 9 units.

*** $1.6K + $0.4K x 4 = $3.2K.

† Tasker 500s come in sets of 3 units at $82.1K per set.

TABLE 39(a). SUGGESTED DEPLOYMENT OPTIONS TO SATISFY FY76-FY85 VISIBILITY MEASURING EQUIPMENT NEEDS FOR LOS ANGELES INTERNATIONAL AIRPORT.

Item Explanation	Price ($K)				
	Option 1	Option 2	Option 3	Option 4	Option 5
Washington Office Cost:					
RVR System					
Tasker 500	56.5	56.5	152.1	-	-
SVR	103.1	103.1	103.1	72.9	72.9
Tasker Mod Kits	-	14.8	-	-	-
ARVIS (Mod III)*	-	-	-	89.1	-
ARVIS (Mod III)**	-	-	-	-	89.1
ARVIS Mod Kits	-	-	-	-	30.0
Provisioning, 10%	16.0	17.4	25.5	16.2	19.2
Factory Inspection, 3%	4.8	5.2	4.6	4.9	5.8
Freight Cost, 3%	4.8	5.2	4.6	4.9	5.8
Subtotal Washington Office Cost	185.2	202.2	289.9	188.0	222.8
Regional Cost:					
Engineering	15.4	16.2	29.4	15.4	16.2
Construction	65.9	65.9	65.9	65.9	65.9
Electronic Installation	10.5	12.1	22.9	10.5	13.3
Subtotal Regional Cost	91.8	94.2	118.2	91.8	95.4
TOTAL	277.0	296.4	408.1	279.8	318.2

*Includes two additional RVR to the existing four RVR systems.

**Includes two additional RVR to the existing four and elimination of all SSR model FAA 7871 computers.

TABLE 39(b). COMPUTATIONS RELATING TO DEPLOYMENT OPTIONS AT LOS ANGELES INTERNATIONAL AIRPORT.

	RVR System	Engineering	Construction	Electronic Installation
Option 1:				
2 Tasker 500	$ 59.1K			
1 Ambient Light Sensor	-1.5K			
1 Light Setting Unit	-1.1K			
Tasker 500 Subtotal	56.5K	$ 7.0K	$ 30.6K	$ 6.2K
SVR	103.1K	8.4K	35.3K	4.3K
Totals	159.6K	15.4K	65.9K	10.5K
Option 2:				
Option 1 Totals	$159.6K	$ 15.4K	$ 65.9K	$ 10.5K
4 Tasker Mod Kits	14.8K	0.8K	--	1.6K
	174.4K	16.2K	65.9K	12.1K
Option 3:				
6 Tasker 500*	$164.2K			
4 Towers	-12.8K			
1 Ambient Light Sensor	-1.5K			
2 Runway Light Setting Units	+2.2K			
Tasker 500 Subtotal	152.1K	$ 21.0K	$ 30.6K	$ 18.6K
	103.1K	8.4K	35.3K	4.3K
Totals	255.2K	29.4K	65.9K	22.9K
Option 4:				
2 ARVIS (MOD III)	$ 58.7K			
2 Towers	6.4K			
2 Transmissometers	24.0K			
ARVIS Subtotal	89.1K	$ 7.0K	$ 30.6K	$ 6.2K
SVR	72.9K	8.0K	35.3K	4.3K
Totals	162.0K	15.4K	65.9K	10.5K
Option 5:				
Option 4 Totals	162.0K	$ 15.4K	$ 65.9K	$ 10.5K
4 ARVIS Mod Kits	30.0K	0.8K	--	2.8K**
	192.0K	16.2K	65.9K	13.3K

* Tasker 500s come in sets of 3 units at $82.1K per set.

** $1.6K + $0.4K x 3 = $2.8K.

TABLE 40(a). SUGGESTED DEPLOYMENT OPTIONS TO SATISFY FY76-FY85 VISIBILITY MEASURING EQUIPMENT NEEDS FOR JOHN F. KENNEDY INTERNATIONAL AIRPORT.

Item Explanation	Price ($K)				
	Option 1	Option 2	Option 3	Option 4	Option 5
Washington Office Cost:					
RVR System					
Tasker 500	82.1	82.1	206.5	-	-
SVR	103.1	103.1	103.1	72.9	72.9
Tasker Mod Kits	-	18.5	-	-	-
ARVIS (Mod III)*	-	-	-	111.8	-
ARVIS (Mod III)**	-	-	-	-	111.8
ARVIS Mod Kits	-	-	-	-	37.5
Provisioning, 10%	18.5	20.4	31.0	18.5	22.2
Factory Inspection, 3%	5.6	6.1	9.3	5.6	6.7
Freight Cost, 3%	5.6	6.1	9.3	5.6	6.7
Subtotal Washington Office Cost	214.9	236.3	359.2	214.4	257.8
Regional Cost:					
Engineering	18.9	19.9	37.4	18.9	19.9
Construction	81.2	81.2	81.2	81.2	81.2
Electronic Installation	13.6	15.6	29.1	13.6	16.8
Subtotal Regional Cost	113.7	116.7	147.7	113.7	117.9
TOTAL	328.6	353.0	506.9	328.1	375.7

*Includes three additional RVR to the existing five RVR systems.

**Includes three additional RVR to the existing five RVR systems and elimination of all IRA computers.

TABLE 40(b). COMPUTATIONS RELATING TO DEPLOYMENT OPTIONS AT JOHN F. KENNEDY INTERNATIONAL AIRPORT.

	RVR System	Engineering	Construction	Electronic Installation
Option 1:				
3 Tasker 500	$ 82.1K	$ 10.5K	$ 45.9K	$ 9.3K
SVR	103.1K	8.4K	35.3K	4.3K
Totals	185.2K	18.9K	81.2K	13.6K
Option 2:				
Option 1 Totals	$185.2K	$ 18.9K	$ 81.2K	$ 13.6K
5 Mod Kits	18.5K	1.0K	--	2.0K
	203.7K	19.9K	81.2K	15.6K
Option 3:				
6 Tasker 500*	164.2K			
2 Tasker 500	59.1K			
5 Towers	-16.0K			
2 Ambient Light Sensors	-3.0K			
2 Runway Light Setting Units	+2.2K			
Tasker 500		$ 1.0K**		
Subtotal	206.5K	$ 28.0K	$ 45.9K	$ 24.8K
SVR	103.1K	8.4K	35.3K	4.3K
Totals	309.6K	37.4K	81.2K	29.1K
Option 4:				
3 ARVIS (MOD III)	$ 66.2K			
3 Towers	9.6K			
3 Transmissometers	36.0K			
ARVIS Subtotal	111.8K	$ 10.5K	$ 45.9K	$ 9.3K
SVR	72.9K	8.4K	35.3K	4.3K
Totals	184.7K	18.9K	81.2K	13.6K
Option 5:				
Option 4 Total	$184.7K	$ 18.9K	$ 81.2K	$ 13.6K
5 ARVIS Mod Kits	37.5K	1.0K	--	3.2K***
	222.2K	19.9K	81.2K	16.8K

* Tasker 500s come in sets of 3 units each, at $82.1K per set.

** Cost of 5 Mod Kits at $0.2K each.

*** $1.6K + $0.4K x 4 = $3.2K.

TABLE 41(a). SUGGESTED DEPLOYMENT OPTIONS TO SATISFY FY76-FY85 VISIBILITY MEASURING EQUIPMENT NEEDS FOR SAN ANTONIO INTERNATIONAL AIRPORT.

Item Explanation	Price ($K)				
	Option 1	Option 2	Option 3	Option 4	Option 5
Washington Office Cost:					
RVR System					
Tasker 500	57.6	57.6	133.4	-	-
SVR	103.1	103.1	103.1	72.9	72.9
Tasker Mod Kits	-	11.1	-	-	-
ARVIS (Mod III)*	-	-	-	89.1	-
ARVIS (Mod III)**	-	-	-	-	89.1
ARVIS Mod Kits	-	-	-	-	22.5
Provisioning, 10%	16.1	17.2	23.7	16.2	18.5
Factory Inspection, 3%	4.8	5.2	7.1	4.9	5.6
Freight Cost, 3%	4.8	5.2	7.1	4.9	5.6
Subtotal Washington Office Cost	186.4	199.4	274.4	188.0	214.2
Regional Cost:					
Engineering	15.4	16.0	25.9	15.4	16.0
Construction	65.9	65.9	65.9	65.9	65.9
Electronic Installation	10.5	11.7	19.8	10.5	13.3
Subtotal Regional Cost	91.8	93.6	111.6	91.8	95.2
TOTAL	278.2	293.0	386.0	279.8	309.4

*Includes two additional RVR to the existing three RVR systems.
**Includes two additional RVR to the existing three RVR systems and elimination of all IRA computers.

TABLE 41(b). COMPUTATIONS RELATING TO DEPLOYMENT OPTIONS AT SAN ANTONIO INTERNATIONAL AIRPORT.

	RVR System	Engineering	Construction	Electronic Installation
Option 1:				
2 Tasker 500	$ 59.1K			
1 Ambient Light Sensor	-1.5K			
Tasker 500 Subtotal	57.6K	$ 7.0K	$ 30.6K	$ 6.2K
SVR	103.1K	8.4K	35.3K	4.3K
Totals	160.7K	15.4K	65.9K	10.5K
Option 2:				
Option 1 Totals	$160.7K	$ 15.4K	$ 65.9K	$ 10.5K
3 Mod Kits	11.1K	0.6K	--	1.2K
	171.8K	16.0K	65.9K	11.7K
Option 3:				
3 Tasker 500	$ 82.1K			
2 Tasker 500	59.1K			
1 Ambient Light Sensor	-1.5K			
3 Towers	-9.6K			
3 Runway Lighting Units	+3.3K			
Tasker 500 Subtotal	133.4K	$ 17.5K	$ 30.6K	$ 15.5K
SVR	103.1K	8.4K	35.3K	4.3K
Totals	236.5K	25.9K	65.9K	19.8K
Option 4:				
2 ARVIS (MOD III)	$ 58.7K			
2 Towers	6.4K			
2 Transmissometers	24.0K			
ARVIS Subtotal	89.1K	$ 7.0K	30.6K	6.2K
SVR	72.9K	8.4K	35.3K	4.3K
Totals	162.0K	15.4K	65.9K	10.5K
Option 5:				
Option 4 Totals	$162.0K	$ 15.4K	$ 65.9K	$ 10.5K
3 ARVIS Mod Kits	22.5K	0.6K	--	2.8K
	184.5K	16.0K	65.9K	13.3K

serves a medium air traffic hub, San Antonio International, is analyzed in this report. Options 2 and 3 are higher than Option 1 by 5 percent and 39 percent, respectively Option 4 is 1 percent higher than Option 1; Option 5 is 6 percent higher than Option 2 and 20 percent lower than Option 3.

The results of the deployment cost evaluation are summarized in Table 42.

TABLE 42. COST RATIOS BETWEEN SUGGESTED DEPLOYMENT OPTIONS TO SATISFY FY76-FY85 VISIBILITY MEASURING EQUIPMENT NEEDS.

Airport	Option 2 / Option 1		Option 3 / Option 1		Option 4 / Option 1		Option 5 / Option 2		Option 5 / Option 3	
	A	B	A	B	A	B	A	B	A	B
William B. Hartsfield Atlanta International	1.13	1.10	1.81	1.65	1.00	1.00	1.12	1.09	0.70	0.73
Gen. Edward L. Logan International	1.08	1.06	1.66	1.55	1.01	1.01	1.09	1.07	0.71	0.73
O'Hare International	1.08	1.06	1.49	1.40	0.96	0.97	1.04	1.05	0.76	0.79
Los Angeles International	1.09	1.07	1.56	1.47	1.01	1.01	1.10	1.07	0.77	0.78
John F. Kennedy International	1.10	1.07	1.67	1.54	1.00	1.00	1.09	1.06	0.72	0.74
Mean Ratios - Large Air Traffic Hubs	1.10	1.07	1.64	1.52	1.00	1.00	1.09	1.07	0.73	0.75
San Antonio International	1.07	1.05	1.47	1.39	1.01	1.01	1.07	1.06	0.78	0.80

A - Subtotal Washington Office Cost

B - Total Deployment Cost

11.4 ECONOMIC ANALYSIS

Emphasis is placed on the fact that this report addresses itself to a deployment cost analysis and not to an economic analysis of airport visibility measuring systems. A generic definition of economic analysis is (Reference 54): "An economic analysis postulates alternative means of satisfying an objective and investigates the costs and benefits of each of these alternatives." The economic analysis can be achieved via different approaches, each one directed to a specific answer and at different stages of the decision making process. Usually the scope of the different approaches are confused and the similarities and differences between them not fully appreciated. Therefore, it appears appropriate to survey at this point some definitions of the main analyses which are: System Analysis, Cost-Effectiveness, Value Engineering, Life Cycle Costing and Trade-off Analysis. A definition of System Analysis is (Reference 55): "Inquiry to assist decision makers in choosing preferred future courses of action by (1) systematically examining and re-examining the relevant objectives and the alternative policies or strategies for achieving them; and (2) comparing quantitatively where possible the economic costs, effectiveness (benefits), and risks of the alternatives. It is more a research strategy than a method or technique, and in its present state of development it is more an art than a science. In sum, systems analysis may be viewed as an approach to, or way of looking at complex problems of choice under conditions of uncertainty."

Another approach to choose alternatives within an economic reference framework is the Cost Effectiveness analysis which could be defined as (Reference 56): "(The) procedure by which the costs of alternative means of achieving a stated effectiveness, or, conversely, the effectiveness of alternative means for a given cost, are compared in a series of numerical indices. The objective of the analysis is to isolate the alternative or combination of alternatives that either gives the greatest "expected effectivenss for a given expected cost or a given expected effectiveness for the least expected cost. It is recognized that a cost-effectiveness analysis does not and cannot mean precisely the same thing to all practitioners in the field."

Value Engineering in the Department of Defense (DOD) context is defined as (Reference 55): "A systematic effort directed at analyzing the functional requirements of DOD systems, equipment, facilities, procedures, and supplied for the purpose of achieving the essential functions at the lowest total cost, consistent with the needed performance, reliability, quality, and maintainability." This definition is also applicable to non-DOD systems.

It is interesting to note the similarities and differences between Cost-Effectiveness and Value Engineering. In this regard, DOD states (Reference 55): "Both represent a systematic analysis of alternative ways of accomplishing given functions and of the costs associated with each alternative. As practiced, however, they are applied at entirely different levels. DOD cost effectiveness studies are employed in the very early planning stage to compare the overall mission effectiveness and associated costs of alternative concepts in broad contexts. Typically, cost effectivenss studies might compare the mission effectivenss and economic impact of (1) alternative designs for fighter aircraft for a particular type of air support missions, or (2) missiles versus aircraft for a strategic mission, or (3) massive airlifts versus overseas prepositioning of equipment for rapid response."

A definition of Life Cycle Costs and its relationship to Value Engineering is given as (Reference 57): "Life cycle costs include all costs incident to the planning, design, construction, operation, maintenance, supply disposal and relocation of a system or facility; calculated in terms of present value. It is a method used to compare and evaluate the total costs of competing proposals for identical functions based on the anticipated life of the facility or product to be acquired. This approach determines the least costly of several alternatives. However, the selected alternative may only "represent the best of several poor candidates. Value Engineering may be used to develop additional worthy alternatives to consider before selecting the best choice. Whereas life cycle costing emphasizes cost visibility, Value Engineering seeks value optimization. The two disciplines are complementary because the former is required to achieve the latter."

A definition of Trade-offs and its relationship to Value Engineering is given as (Reference 57): "Trade-offs by definition and usage involve interrelated changes. Thus; reliability, quality, or maintainability is reduced to bring cost down; floor loading or lighting levels are increased, so cost goes up; delivery is expedited and cost goes up; etc. By contrast, Value Engineering makes necessary function or performance a constant rather than a variable. In Value Engineering, necessary function may not be reduced as a means of reducing cost. To say that Value Engineering involves trade-offs, then, is to deny the basic principle of Value Engineering - providing necessary function at lowest overall cost.

"Whereas essential performance is never traded off for lower cost in Value Engineering, the way of accomplishing this performance may be altered to reduce cost. That is, the necessary performance of components of certain products-systems may be derived from the performance of other components in the system. In this restricted sense, Value Engineering may be thought to involve exchanges to allow for use of standardized parts in the system, or to reduce the cost of integrating components into the system. But the necessary performance of the product/system itself is not changed."

As pointed out in this subsection, a deployment recommendation for a given visibility measuring system cannot be made on the basis of deployment cost alone. The present report developed in detail the "elements of cost" for RVR and SVR systems and suggested only the elements of benefit. The benefit determination provided by an

ARVIS (MOD III) system deployed at an airport which requires an accident investigation, was not quantified but only suggested. The benefit determination provided by the system to provide visibility and operational data of the runway served by the system has been suggested but not quantified. The same statement is applicable to future interaction with TIPS, the flexibility of changing system characteristics by software changes only, etc.

It clearly appears that a Value Engineering analysis will be required to develop a full set of elements of judgment for the future deployment of RVR and SVR systems once the elements of benefit become definable.

12. SUMMARY AND CONCLUSIONS

Based on the objectives set forth in Section 2, this section presents a summary of the airport visibility measuring systems elements of deployment cost analysis and the conclusions of this analysis.

12.1 SUMMARY

a. Present and proposed FAA operational visibility information was identified and described.

b. The FAA RVR and SVR system deployment criteria were identified and described.

c. The RVR and SVR deployment schedules were developed for the FY76-FY85 period based on FAA documentation and information sources.

d. Visibility measuring equipment were identified for each runway operation (CAT I, II and III).

e. Eight selected airports were analyzed for their existing visibility measuring equipment, future plans and requirements.

f. Commercially available RVR measuring equipment relevant to airport operations were identified, performance characteristics described, and equipment purchase costs given.

g. Installation, maintenance, training and provisioning costs were given for commercially available RVR systems. The costs were expressed in terms of Washington Office Costs and Regional Office Costs.

h. The SVR system developed by NWSC was analyzed, performance characteristics described, and estimated equipment purchase costs given.

i. Installation, maintenance, training and provisioning costs were given for the NWSC SVR system. The costs were given for different alternatives and expressed in terms of Washington Office Costs and Regional Office Costs.

j. The modification kits for present FAA/NBS RVR systems developed at TSC and the ARVIS were discussed. The estimated Washington Office Costs and Regional Office Costs were given.

k. Installation, maintenance, training and provisioning costs were given for the modification kits and the ARVIS.

l. Comparison of deployment costs of commercial RVR systems and the ARVIS system were given for the different options which reflect the needs of different airports.

m. The type of visibility information supplied by the ARVIS and its expandable capabilities in comparison with commercially available RVR systems were described and analyzed.

12.2 CONCLUSIONS

a. Based on FAA documentation and information sources, an estimated deployment of 404 RVR systems, including replacement and new deployments are expected during the FY76-FY85 period.

b. An estimated deployment of 72 SVR systems is expected during the FY76-FY85 period.

c. Five major deployment alternatives were identified as options to meet the FAA requirements during the FY76-FY85 period. The choice between options depends upon maintenance needs created by the RVR equipment already deployed, the needs of the specific airport considered, the requirements the National Transportation Safety Board (NTSB) may introduce, the requirements to prepare runway climatological summaries using automatic data processing, etc.

d. Strictly on a mean cost deployment basis to satisfy the needs of airports serving large air traffic hubs during the FY76-FY85 period, the ARVIS III is 25 percent lower than installations using all new RVR equipment commercially available. The ARVIS III is 7 percent more expensive than installations for similar airports which will use only additional RVR equipment commercially available and modification kits for the existing FAA/NBS RVR equipment. The same deployment cost comparison would exist with installations using RVR commercially available equipment to satisfy the minimum needs for the same airports and period.

e. The ARVIS III, as a software oriented system, can change performance characteristics (RVR frequency update, smoothing functions, RVR history, RVR differences, etc.) without changing hardware.

f. The ARVIS III has self-checking transmissometers, extended life projector light, failure mode monitoring, capabilities to give visibility values for different visual cues, etc.

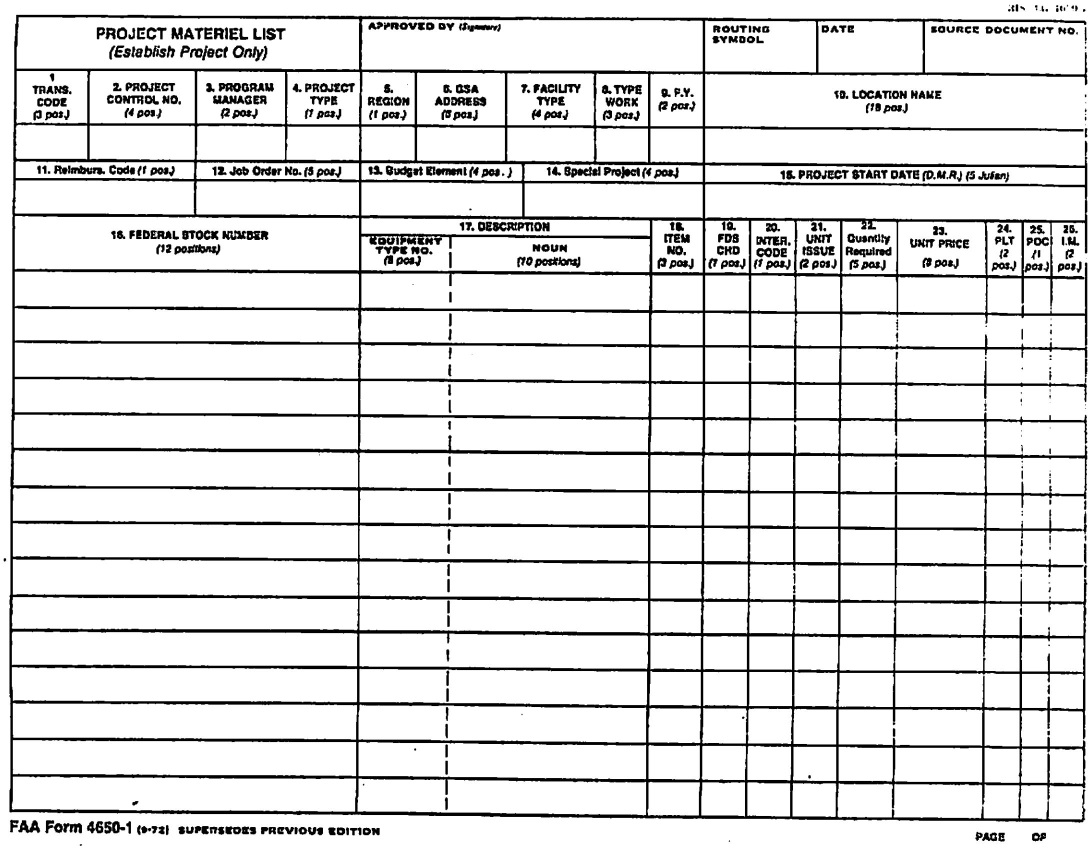
g. The ARVIS III has a redundant computer. In case of computer failure, a standby computer automatically enters into service.

h. The ARVIS III can feed the TIPS without any major hardware change.

i. The ARVIS III has an incremental magnetic tape recorder which records, as often as required (5 seconds minimum) all the airport photometric parameters (High Intensity Runway Light setting, Approach Light setting, Flashing lights, Sky Luminance, etc.), atmospheric transmittance, system internal calibration, system failures, system failures acknowledged by the operator, time at which the failure has been repaired, etc. These comprise all the elements required to reconstruct the visibility conditions at the airport and the ARVIS readiness. This is of paramount importance in accident investigations or to obtain runway visibility statistics and/or runway operations characteristics.

APPENDIX A

PROJECT MATERIEL LIST, FAA FORM 4650-1



PROJECT MATERIEL LIST
(Establish Project Only)

APPROVED BY *(Signature)*

ROUTING SYMBOL

DATE

SOURCE DOCUMENT NO.

1 TRANS. CODE *(3 pos.)*	2. PROJECT CONTROL NO. *(4 pos.)*	3. PROGRAM MANAGER *(2 pos.)*	4. PROJECT TYPE *(1 pos.)*	5. REGION *(1 pos.)*	6. GSA ADDRESS *(5 pos.)*	7. FACILITY TYPE *(4 pos.)*	8. TYPE WORK *(3 pos.)*	9. F.Y. *(2 pos.)*	10. LOCATION NAME *(18 pos.)*

11. Reimburs. Code *(1 pos.)*	12. Job Order No. *(5 pos.)*	13. Budget Element *(4 pos.)*	14. Special Project *(4 pos.)*	15. PROJECT START DATE *(D.M.R.)* *(5 Julian)*

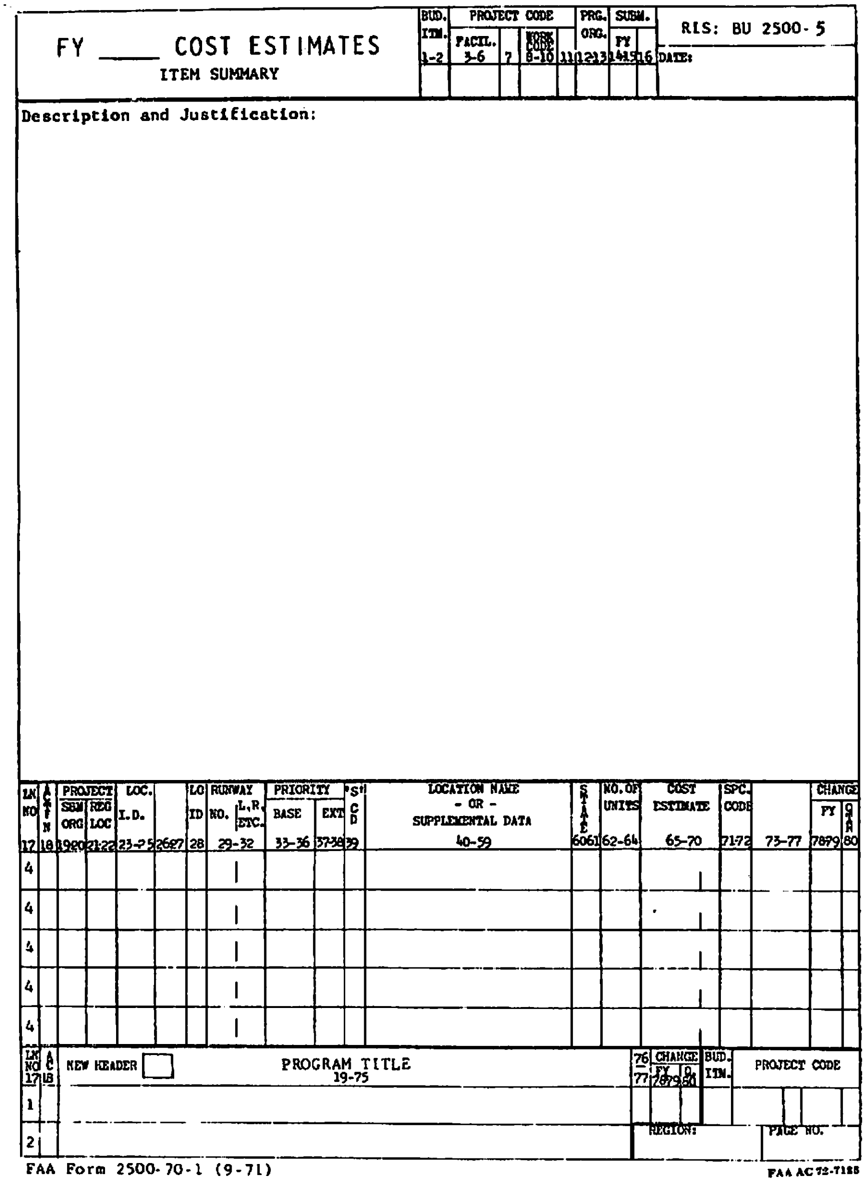
16. FEDERAL STOCK NUMBER *(12 positions)*	17. DESCRIPTION		18. ITEM NO. *(3 pos.)*	19. FDS CHD *(1 pos.)*	20. INTER. CODE *(1 pos.)*	21. UNIT ISSUE *(2 pos.)*	22. Quantity Required *(5 pos.)*	23. UNIT PRICE *(8 pos.)*	24. PLT *(2 pos.)*	25. POC *(1 pos.)*	26. I.M. *(2 pos.)*
	EQUIPMENT TYPE NO. *(8 pos.)*	NOUN *(10 positions)*									

FAA Form 4650-1 (9-72) SUPERSEDES PREVIOUS EDITION

PAGE OF

APPENDIX B

COST ESTIMATES, ITEM SUMMARY, FAA FORM 2500-70-1



FY _____ COST ESTIMATES ITEM SUMMARY	BUD. ITM.	PROJECT CODE				PRG. ORG.	SUBM.		RIS: BU 2500-5
		FACIL.		WORK CODE			FY		
	1-2	3-6	7	8-10	11	1213	1415	16	DATE:

Description and Justification:

LN NO	ACFN	PROJECT SBM ORG	PROJECT REG LOC	LOC. I.D.		LO ID	RUNWAY NO. L,R, ETC.	PRIORITY BASE	PRIORITY EXT	SCD	LOCATION NAME - OR - SUPPLEMENTAL DATA	STATE	NO. OF UNITS	COST ESTIMATE	SPC. CODE		CHANGE FY	CHANGE QTR
17	18	1920	21-22	23-25	2627	28	29-32	33-36	3738	39	40-59	6061	62-64	65-70	71-72	73-77	7879	80
4																		
4																		
4																		
4																		
4																		

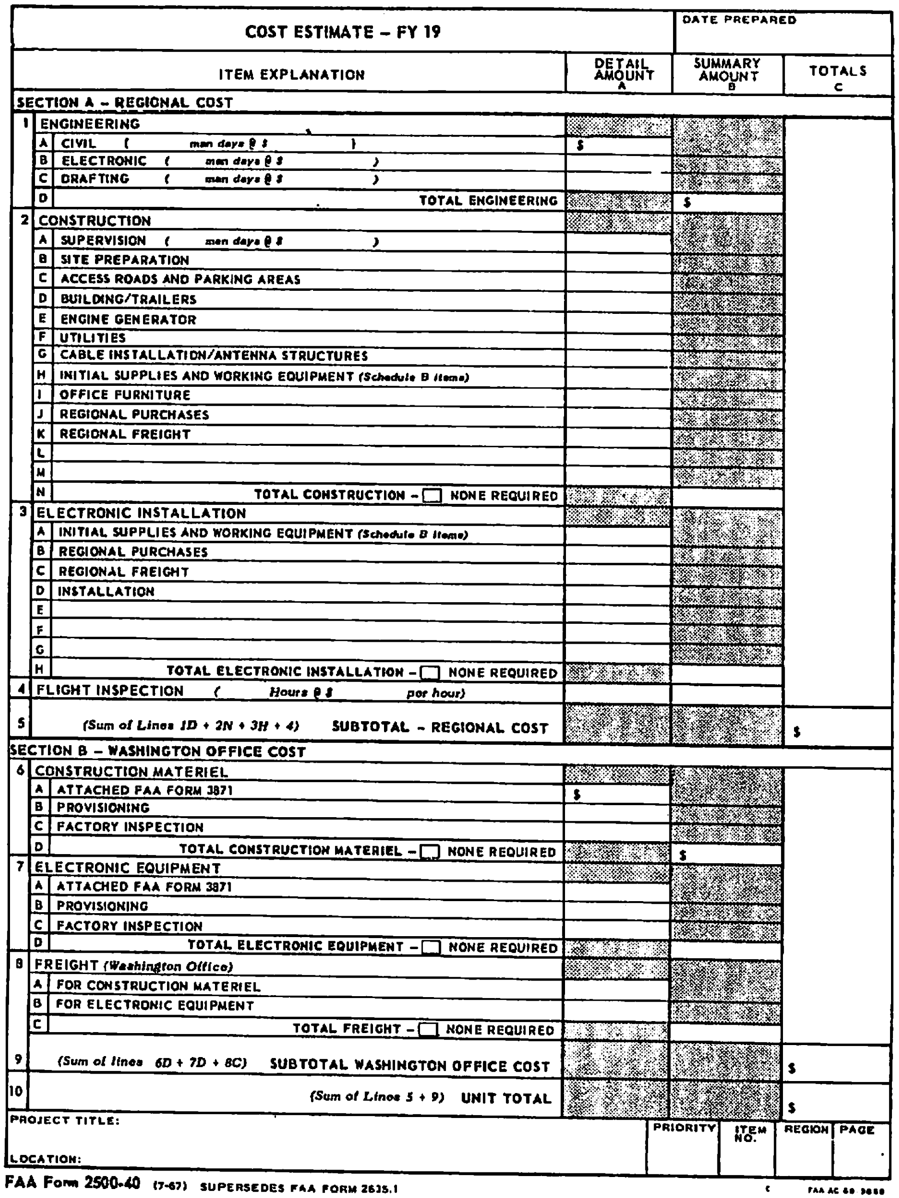
LN NO	AC	NEW HEADER ☐ PROGRAM TITLE	76	CHANGE FY	CHANGE Q.	BUD. ITM.	PROJECT CODE
17	18	19-75	77	7879	80		
1							
2			REGION:				PAGE NO.

FAA Form 2500-70-1 (9-71)

FAA AC 72-7185

APPENDIX C

COST ESTIMATE, ITEM EXPLANATION, FAA FORM 2500-40



		COST ESTIMATE – FY 19	DATE PREPARED		
		ITEM EXPLANATION	DETAIL AMOUNT A	SUMMARY AMOUNT B	TOTALS C
SECTION A – REGIONAL COST					
1		ENGINEERING	▨	▨	
	A	CIVIL (*man days @ $*)	$	▨	
	B	ELECTRONIC (*man days @ $*)		▨	
	C	DRAFTING (*man days @ $*)		▨	
	D	TOTAL ENGINEERING	▨	$	
2		CONSTRUCTION	▨	▨	
	A	SUPERVISION (*man days @ $*)		▨	
	B	SITE PREPARATION		▨	
	C	ACCESS ROADS AND PARKING AREAS		▨	
	D	BUILDING/TRAILERS		▨	
	E	ENGINE GENERATOR		▨	
	F	UTILITIES		▨	
	G	CABLE INSTALLATION/ANTENNA STRUCTURES		▨	
	H	INITIAL SUPPLIES AND WORKING EQUIPMENT *(Schedule B items)*		▨	
	I	OFFICE FURNITURE		▨	
	J	REGIONAL PURCHASES		▨	
	K	REGIONAL FREIGHT		▨	
	L			▨	
	M			▨	
	N	TOTAL CONSTRUCTION – ☐ NONE REQUIRED	▨		
3		ELECTRONIC INSTALLATION	▨	▨	
	A	INITIAL SUPPLIES AND WORKING EQUIPMENT *(Schedule B items)*		▨	
	B	REGIONAL PURCHASES		▨	
	C	REGIONAL FREIGHT		▨	
	D	INSTALLATION		▨	
	E			▨	
	F			▨	
	G			▨	
	H	TOTAL ELECTRONIC INSTALLATION – ☐ NONE REQUIRED	▨		
4		FLIGHT INSPECTION (*Hours @ $ per hour)*			
5		*(Sum of Lines 1D + 2N + 3H + 4)* SUBTOTAL – REGIONAL COST	▨	▨	$
SECTION B – WASHINGTON OFFICE COST					
6		CONSTRUCTION MATERIEL	▨	▨	
	A	ATTACHED FAA FORM 3871	$	▨	
	B	PROVISIONING		▨	
	C	FACTORY INSPECTION		▨	
	D	TOTAL CONSTRUCTION MATERIEL – ☐ NONE REQUIRED	▨	$	
7		ELECTRONIC EQUIPMENT	▨	▨	
	A	ATTACHED FAA FORM 3871		▨	
	B	PROVISIONING		▨	
	C	FACTORY INSPECTION		▨	
	D	TOTAL ELECTRONIC EQUIPMENT – ☐ NONE REQUIRED	▨		
8		FREIGHT *(Washington Office)*	▨	▨	
	A	FOR CONSTRUCTION MATERIEL		▨	
	B	FOR ELECTRONIC EQUIPMENT		▨	
	C	TOTAL FREIGHT – ☐ NONE REQUIRED	▨		
9		*(Sum of lines 6D + 7D + 8C)* SUBTOTAL WASHINGTON OFFICE COST	▨	▨	$
10		*(Sum of Lines 5 + 9)* UNIT TOTAL	▨	▨	$

PROJECT TITLE: LOCATION:	PRIORITY	ITEM NO.	REGION	PAGE

FAA Form 2500-40 (7-67) SUPERSEDES FAA FORM 2635.1

FAA AC 68 9688

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