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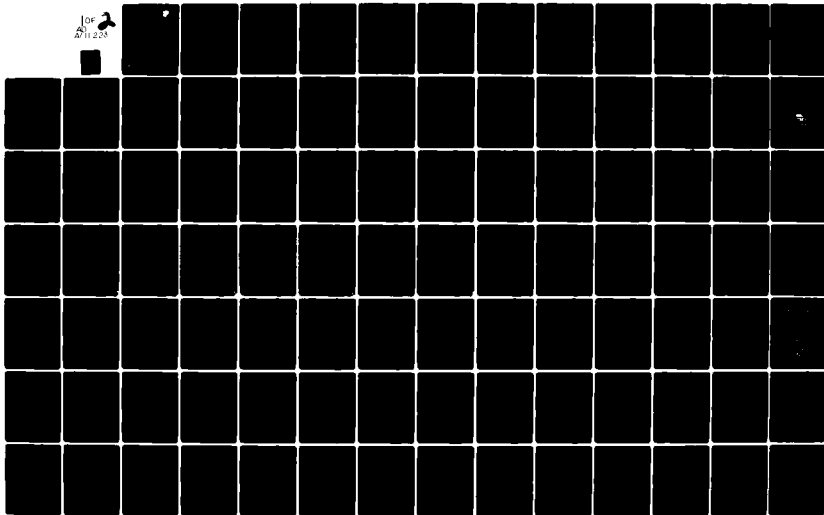
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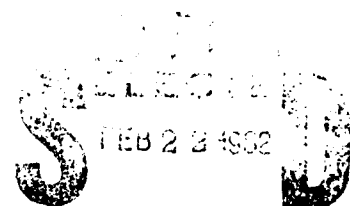


SOURCE ASSESSMENT SYSTEM

Measurement Concept Corporation

Roy H. Senn
M. Lynn Taylor
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Dr. Michael Smith

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selected approach analog-digital video system, is presented.

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TABLE OF CONTENTS

	Page

1.0 INTRODUCTION	1-1
1.1 Objective	1-1
1.2 Background and Scope	1-1
1.3 Organization	1-2
 2.0 FUNCTIONAL ANALYSIS.	 2-1
2.1 Source Assessment at DMAAC	2-1
2.2 SAS Application at DMAHTC	2-19
 3.0 SAS DESIGN REQUIREMENTS.	 3-1
3.1 Characteristics and Scope of Expected Inputs . . .	3-1
3.2 SAS Outputs	3-8
3.3 Evaluation Factors	3-9
 4.0 ALTERNATE SAS DESIGN CONCEPTS.	 4-1
4.1 Direct Optical Viewer (DOV).	4-1
4.2 Microform Optical Projector (MOP).	4-8
4.3 Digital Video System (DVS).	4-15
4.4 Advanced Interactive SAS (AIS)	4-25
 5.0 TRADE-OFF ANALYSIS	 5-1
5.1 Results and Justification	5-2
5.2 Cost Performance	5-24
5.3 Conclusion	5-29
5.4 Recommendation	5-32

TABLE OF CONTENTS
(Continued)

	Page

6.0 PHASE I DESIGN PLAN SUMMARY.	6-1
6.1 Design Overview	6-2
6.2 Analog Image Processing Alternative	6-10
6.3 Estimated Costs	6-11
6.4 Development Effort	6-14
 7.0 SUMMARY	 7-1
 8.0 BIBLIOGRAPHY	 8-1

LIST OF FIGURES

2-1	SDDA "System Flow Chart"	2-2
2-2	Primary Focus of SAS at DMAAC	2-4
2-3	Containment Matrix for Potential DMAAC Media Mix . .	2-12
2-4	SAS Link Between Assessment and Production Support .	2-15
2-5	Source Data Base Processing	2-21
2-6	SAS Linking Assessment & Selection	2-23
4-1	Direct Optical Viewer	4-2
4-2	Use of Masks For Image Separation	4-6
4-3	MOP Work Station	4-9
4-4	MOP Optics	4-11
4-5	Video SAS Work Station	4-16
4-6	Video Input Station	4-17
4-7	Camera Assembly for Digital Video System	4-18
4-8	Advanced Interactive SAS (AIS)	4-26
4-9	AIS Internal Components	4-28
5-1	Cost Performance Summary	5-30
6-1	Source Assessment System Schematic	6-3
6-2	System Configuration	6-4
6-3	Phase I - SAS Subsystem Functions, I/O, components Overview	6-9
6-5	Development Schedule	6-15

LIST OF TABLES

2-1	Major SAS Comparisons	2-14
3-1	Product and Sources Applicable to SAS	3-2
3-2	SAS Physical Subdivision	3-5
5-1	Evaluation Factors Weightings and Ratings	5-3
5-2	Trade-Off Analysis Summary	5-11
5-3	Trade-Off Analysis Ranking	5-16
5-4	Development and Repeat Costs Summary	5-25
5-5	Cost Performance	5-26
6-1	Implementation Cost Items	6-12

LIST OF APPENDICES

APPENDIX A	Example Calculation for DOV Image Brightness. . .	A-1
APPENDIX B	Examination of Video Resolution	B-1

1.0 INTRODUCTION

1.1 Objective

The Final Technical Report (TR) is a contract deliverable for the Source Assessment System (SAS) study. The objective of the TR is to document the results of Mc2's and Singer Corporation/Librascope Division's problem analysis and technical analysis of source assessment at the Defence Mapping Agency's Aerospace Center (DMAAC). It is intended to serve as a companion report, for background and analysis support, to the Final SAS Design Plan delivered to RADC May 1981.

1.2 Background and Scope

The following Phases and Tasks were carried out for the SAS study:

1.0 Analysis Phase

1.1 Functional Analysis

1.2 Definition of Design Requirements

2.0 Design Phase

2.1 Alternate Design Approaches

2.2 Technical Factors

2.3 Trade-off Analysis

2.4 Design Plan

The preliminary results of Tasks 1.1 and 1.2 were delivered to RADC, August 1980, as an Interim Technical Report (ITR). The ITR was a contract deliverable which provided RADC and DMA the opportunity to review and critique the functional analysis and projected requirements prior to the Design Phase. The completion of Tasks 2.1, 2.2 and 2.3 resulted in a trade-off analysis of four alternate design approaches and a recommendation for system design plan based on video technology. These tasks were documented as a Trade-off Analysis Annex to the ITR which was delivered to RADC December 1980. This permitted RADC and DMA to review the trade-off analysis procedures before approving the design plan recommendation.

The following TR updates and combines the contents of the ITR and the Trade-off Analysis Annex. Redundant or superceeded content has been removed and RADC and DMA comments, errata and suggestions have been taken into account. The intent of the TR is a document containing a comprehensive and complete analysis to support Task 2.4 and the resulting SAS Design Plan.

1.3 Organization

Section 2.0 is a functional analysis of the source assessment problem. Current source assessment practice at DMAAC are examined, and near term and future requirements for SAS are presented. Source assessment practice at the Hydrographic and Topographic Center (DMAHTC) is also examined for possible application of a single SAS design at both centers.

Section 3.0 presents SAS design requirements based on the analysis in Section 2.0. The expected mix of formats of DMA sources and products that must be accepted as SAS inputs are documented and major outputs are discussed. A set of 24 performance factors that a comprehensive SAS should address is presented.

In Section 4.0, four (4) design concepts are defined and their inherent advantages and disadvantages are highlighted. In Section 5.0 the 24 performance factors are used as a basis for performing a trade-off analysis on the four (4) design concepts and a recommendation is made for the SAS design.

For completeness, a summary of the Final SAS Design Plan, previously issued as a separate deliverable, is provided in Section 6.0. Section 7.0 summarizes the contents of the TR, reiterating important conclusions and recommendations.

2.0 FUNCTIONAL ANALYSIS

2.1 Source Assessment at DMAAC

DMAAC's primary mission is the support of aeronautical navigation. This responsibility encompasses the maintenance and production of aeronautical charts, and the publication of flight information to ensure up-to-date notice of conditions which present hazards to flight or affect navigation. DMAAC also provides charting support for the space exploration program and has major responsibility for digital data used in the support of flight simulation and the cruise missile

The SAS will be targeted to DMAAC's Scientific Data Department, Data Analysis branch (SDDA) for source management and production support. Figure 2-1 was supplied by SDDA and is a flow chart of this group's activities. The File Update and Maintenance path processes incoming source materials for input to the production support activities. New source materials may take many forms (maps and charts, photography, sensor imagery, etc.) and are received on a continuous basis (DMA charts are reviewed for possible revision on 6, 8, or 12 year cycles), when a specific need arises, or when significant changes have been logged against a product. To maintain an orderly accumulation of sources until they can be applied in a production activity, they must be characterized as to application and cataloged in a systematic manner such that they can be effectively accessed and applied when necessary.

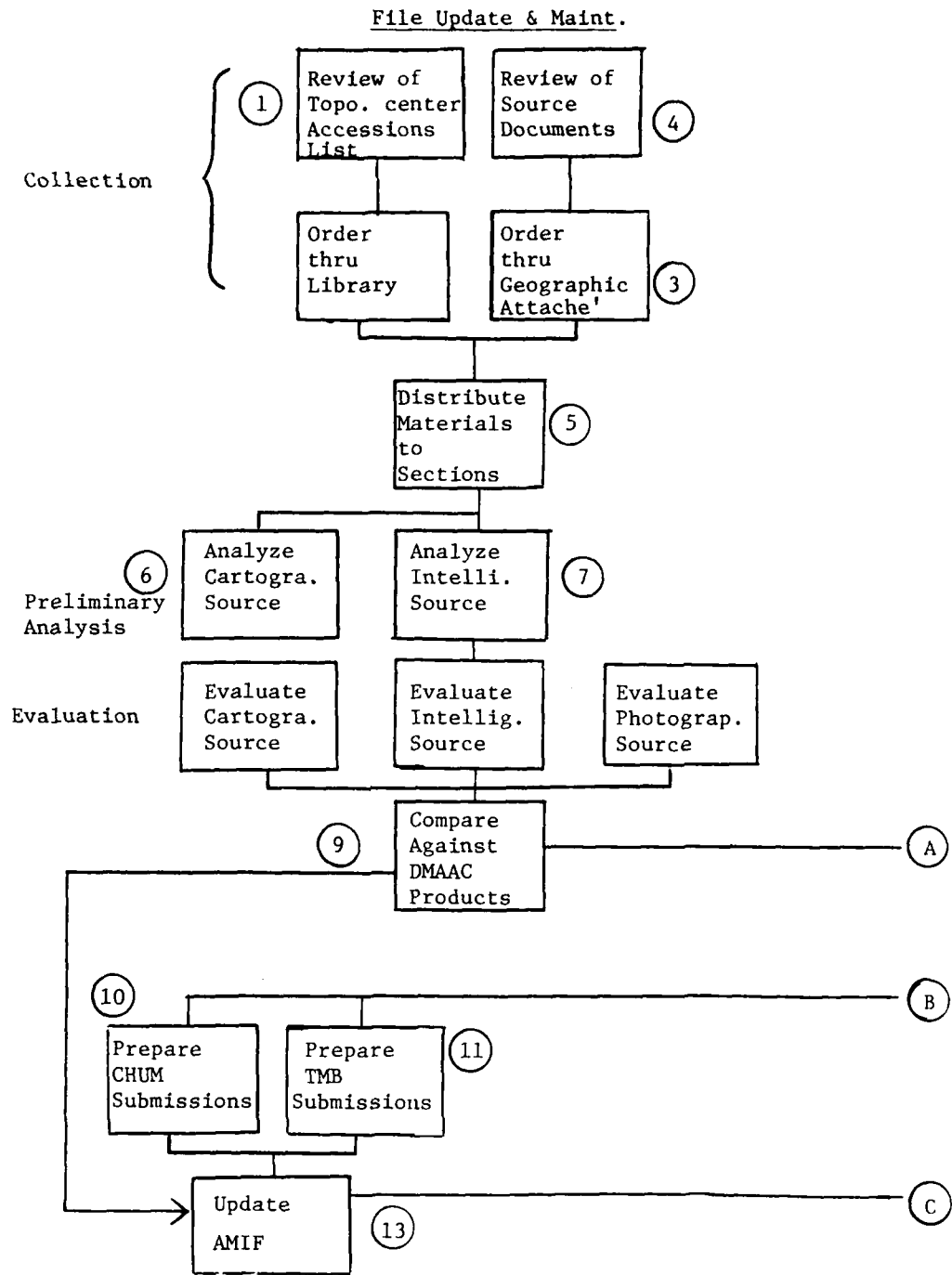


Figure 2-1 SDDA "System Flow Chart" (page 1 of 2)

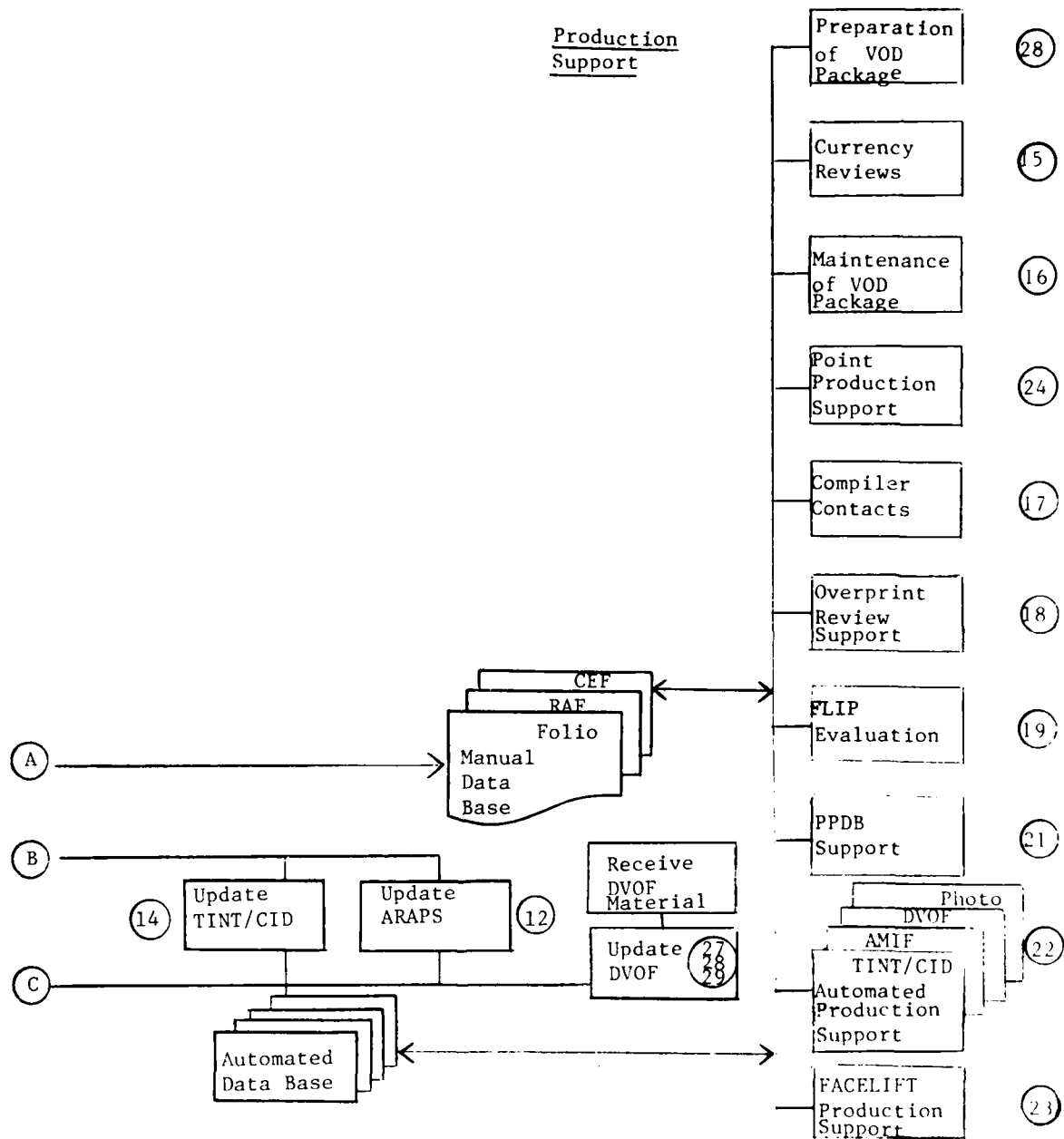


Figure 2-1 SDDA "System Flow Chart" (page 2 of 2)

2.1.1 Functional Overview

The application of a SAS will primarily be in block 9 (Compare Against DMAAC Products) in Figure 2-1. Within block 9, expanded in Figure 2-2 (which was also provided by SDDA), new sources are assessed for their impact by comparing them to existing source or DMA products with similar geographic coverage. Ideally a SAS will improve this process by providing for a variety of input forms and relative scaling for direct comparisons between sources and products.

The review and assessment of new sources that occurs in block 9 produces three important forms of output: hard copy portfolios, updates to the Automated Data Base, and conditions that require up-to-date notice. The hard copy portfolios consisting of the Cartographic Information Folio (FOLIO), the Remedial Action File (RAF) and the Cartographic Evaluation Folder (CEF), accumulate in hard copy form and represent a record of changes and sources that can be applied to DMAAC production. These materials provide the Area Specialist (personnel within SDDA who specialize in a specific geographic region) with annotated graphic references which identify the status of DMAAC products and available sources. The FOLIO is based on the 1:1,000,000 World Aeronautical Chart and is annotated with existing coverage of sources and products. The RAF consists of DMAAC products and their horizontal and vertical accuracies and includes annotations of changes that have accumulated against a product and can be applied during product revision. The CEF is product oriented and contains small overlays or graphics showing potential areas of improvement and supporting source for a major revisions or recompilation.

The Automated Data Base is updated by the "File Update and Maintenance" path in Figure 2-1 and queries and retrieval requests are made against it by the production processess (illustrated on the right). The Area Requirement and Product Status System (ARAPS) stores

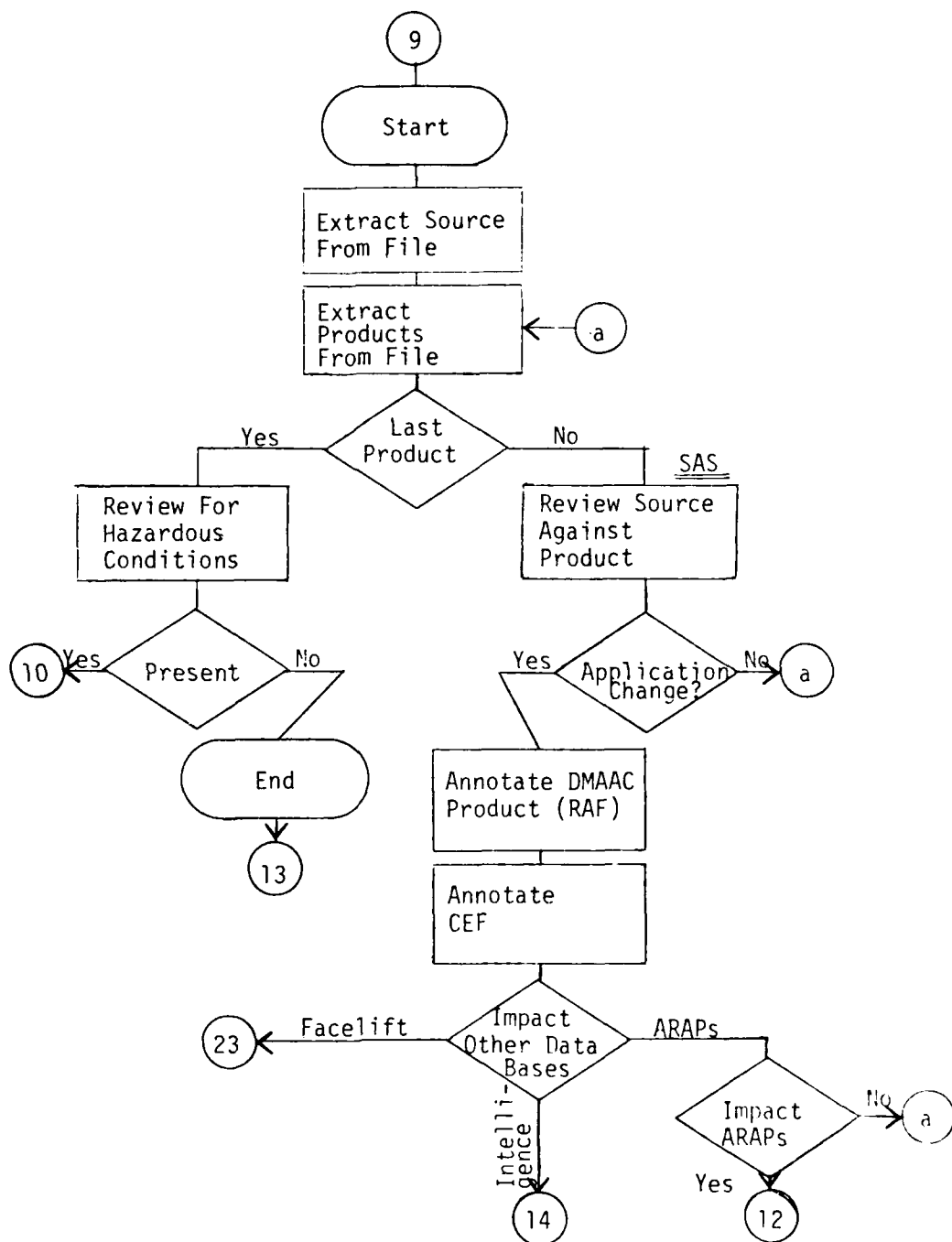


Figure 2-2 Primary Focus of SAS at DMAAC

information on area requirements, priority, source availability, production status and product adequacy. The Automated Map Information File (AMIF) is a detailed description system for cartographic source which are in DMAAC's possession. The Target intelligence File (TINT) contains detailed descriptive information concerning potential military targets. The Cartographic Intelligence Document (CID) is an index of intelligence reports and source holdings that are relevant to mapping applications. The DMA Vertical Obstruction File (D-VOF) is an indexed file containing coordinates and descriptions of vertical obstructions to flight which are used as input to charting products. Although the D-VOF receives inputs through a source other than block 9, it is presumed that the source assessment process may uncover vertical obstructions that must be reported.

Conditions observed in new sources that require immediate attention are reported in the Chart Updating Manual (CHUM) and Target Materials Bulletin (TMB). The CHUM reports error or change conditions which impact navigation or are a direct hazard to flight, but are not on current aeronautical charts. The TMB provides a similar service for reporting changes to Target Materials.

As previously mentioned DMAAC also provides primary support for flight simulation and the cruise missile program. Digital data for these programs stems mainly from four data bases: Terrain Contour Matching (TERCOM), Digital Terrain Elevation Data (DTED), Digital Feature Analysis Data (DFAD) and Vertical Obstruction Data (VOD). TERCOM provides detailed elevation data for terrain directed guidance of the cruise missile. DTED and DFAD provides wide area terrain elevations and cultural/landscape data for flight stimulation. VOD contains vertical obstructions which may affect cruise missile mission planning. Although these programs are not operated by SDDA, they are DMAAC products that require or can serve as cartographic source. An example in Figure 2-1 is the VOD which is supported by the D-VOF, an

existing cartographic directory of vertical obstructions. TERCOM data can be accessed through a directory, the TERCOM Data Management System (TDMS), and DTED and DFAD make up the Digital Land Mass Simulation (DLMS).

Although the comparison function in block 9, Figure 2-1, is the main focus of the SAS, a more comprehensive capability is desired which may impact the analysis and evaluation steps (block 6 and 7) and better unify the File Update and Maintenance Procedures. In addition the briefings at DMAAC indicate that support of production activities is an essential mission. A production assignment might require an area specialist to consult the FOLIO, RAF or CEF and retrieve available source documents, possibly by querying one of the Automated Data Bases. At this point, since available source may vary in format and scale, a SAS may again be brought into play. In this case the sources have already been assessed and the SAS is being utilized to explore some aspect important to the production assignment.

To summarize, the SDDA branch of DMAAC has responsibility for:

- o Managing the selection and indexing of cartographic source materials.
- o Recommending these sources for support of a variety of production and maintenance processes.

Incoming sources are first analyzed and evaluated to determine their application and quality, then, to determine their impact, compared to existing products. It is this comparison function that a SAS will be employed. If the contents of a source merit its retention three forms of output may be produced:

- o Annotation in the hardcopy portfolios

- o Updates to the Automated Data Base
- o Updates to the CHUM and TMB

The primary direct maintenance activities in the SDDA are the issuance of updates to the CHUM and TMB.

2.1.2 Current Source Assessment Practices

Currently, formal assessment of new sources is not as distinct from production support as indicated by Figure 2-1. In the true source assessment process new sources are examined with respect to available products for possible revisions, and then categorized as to use in production by annotating the FOLIO, RAF or CEF and updating the Automated Data Base. After receiving a productions support assignment, an Area Specialist will consult the FOLIO, RAF, CEF or Automated Data Base, depending on the assignment, and then retrieve the indicated supporting source. In many such production assignments a mix of source materials and existing DMAAC products must again be compared, at a more detailed level, to detect differences impacting the production activity.

Whether examination and comparison of sources is performed as an assessment process or a production process the Area Specialist is hampered by the following:

0 Lack of an efficient means to compare sources or DMAAC products:

The inability to compare graphic sources and products at the same scale on a one-to-one basis is a hindrance to good assessment procedure. The reason for this difficulty is based on the fact that DMA source and product graphics exhibit different scales, projections, media, geographic coverage and forms of representations (e.g., symbology, color, etc.). Various methods of contending with the necessity of mixed format comparisons were observed at DMAAC:

- Annotation or highlighting of maps and charts to limit examination to particular areas of importance.
- A graphic source or product might be folded so the area of interest can be placed adjacent to the same area on another source.
- Features on one source may be copied onto a mylar overlay which can then be placed on top a second graphic.
- The use of a standard reproduction copier with reduction capability is used to produce scaled overlays even though the material is only slightly translucent and the distortion from such a device can be considerable.

- Various measuring devices such as rulers or proportional dividers are required to compensate for scale differences.

- o A lack of comprehensive assessment capability: The above list directly relates to the need for upgraded assessment capability. It appears that DMAAC personnel who perform assessment or production support must contend the best they can, given a limited set of devices and tools, with changing assessment requirements. This includes occasional use of equipment intended for other purposes. The reproduction copier is an example.
- o Non-standard assessment practices: Also, specific, department wide assessment procedures were not evident. Each assessment specialist must rely on various, non-standard approaches to accomplish assignments. This is somewhat unavoidable because geographic areas have different requirements as do production support procedures, but a first level of procedural standardization made possible by improved equipment can make production support less specialized and more efficient.
- o A need to improve access to advance source types: The above discussion of current source assessment and production support has applied mainly to graphics (maps, charts, overlays). DMA reliance on photographic and electronic reconnaissance is increasing, as is the use of digital data. Presently only

standard film viewers, stereoscopes, and magnifiers are available for assessment of photographic media and there is no practical mechanism to accurately compare photography with other sources, for the purpose of assessment. Many forms of source can, of course, be converted. Photography or maps can be re-photographed at a different scale, digital data can be transformed, plotted, etc., but this means relying on special services which may require extensive turn-around time and are too cumbersome for efficient assessment and responsive production support.

To recapitulate, SDDA is faced with a growing volume and diversified selection of source materials for production support. Traditional assessment techniques are manual and costly. The absence of upgraded assessment tools prevents source assessment from being accomplished to the degree that is required, thus hampering production support.

2.1.3 DMAAC Requirements for a SAS

Based on the functional analysis two basic fundamental capabilities which a SAS must provide include:

- o Superposition and/or side-to-side viewing at the same or similar scale, of source materials and DMAAC products for one-to-one comparisons.
- o Input mechanisms to accept sources and DMA products of many different formats and physical characteristics.

The ability to view overlapping coverage of sources and products at the same scale in a common viewing plane or side-by-side, is a basic requirement. If a source assessment device or system could compare images in an accurate, clear, bright manner with a little manual intervention, many of DMAAC's assessment goals could be achieved. The inability to properly compare sources and products at the same scale and the necessity to do visual comparison by moving the eyes back and forth between dissimilar sources make current source assessment a laborious task.

The requirement to accept many forms of sources and products as input makes comparison in a common frame of reference difficult to achieve. Figure 2-3 (provided by DMAAC) is a matrix of sources and products showing the comparisons that are performed by assessment personnel. Each source or product has a melange of physical characteristics that a SAS must take into account. It is likely that a SAS designed to take every mix into account would be prohibitively expensive, cumbersome and in actuality is possibly unachievable. In Figure 2-3, for example, there are 278 combinations shown.

It is hoped that a SAS can be developed that will be a reasonable device or system and still take into account over 80% of the sources and products that DMAAC might encounter. Solid cells indicate comparisons that are most prevalent. Table 2-1 is a condensation of Figure 2-3 based on comparisons of major importance. It is hoped that these can serve as a basis for scoping a practical and economical system.

Figure 2-3 and Table 2-1 are based on the current mix of sources. Photographic sources and digital products are projected to be key areas. The photographic sources are various types of reconnaissance imagery and represent a wide range of scales and applications. DTED and DFAD are digital files of terrain and cultural data. Expectations

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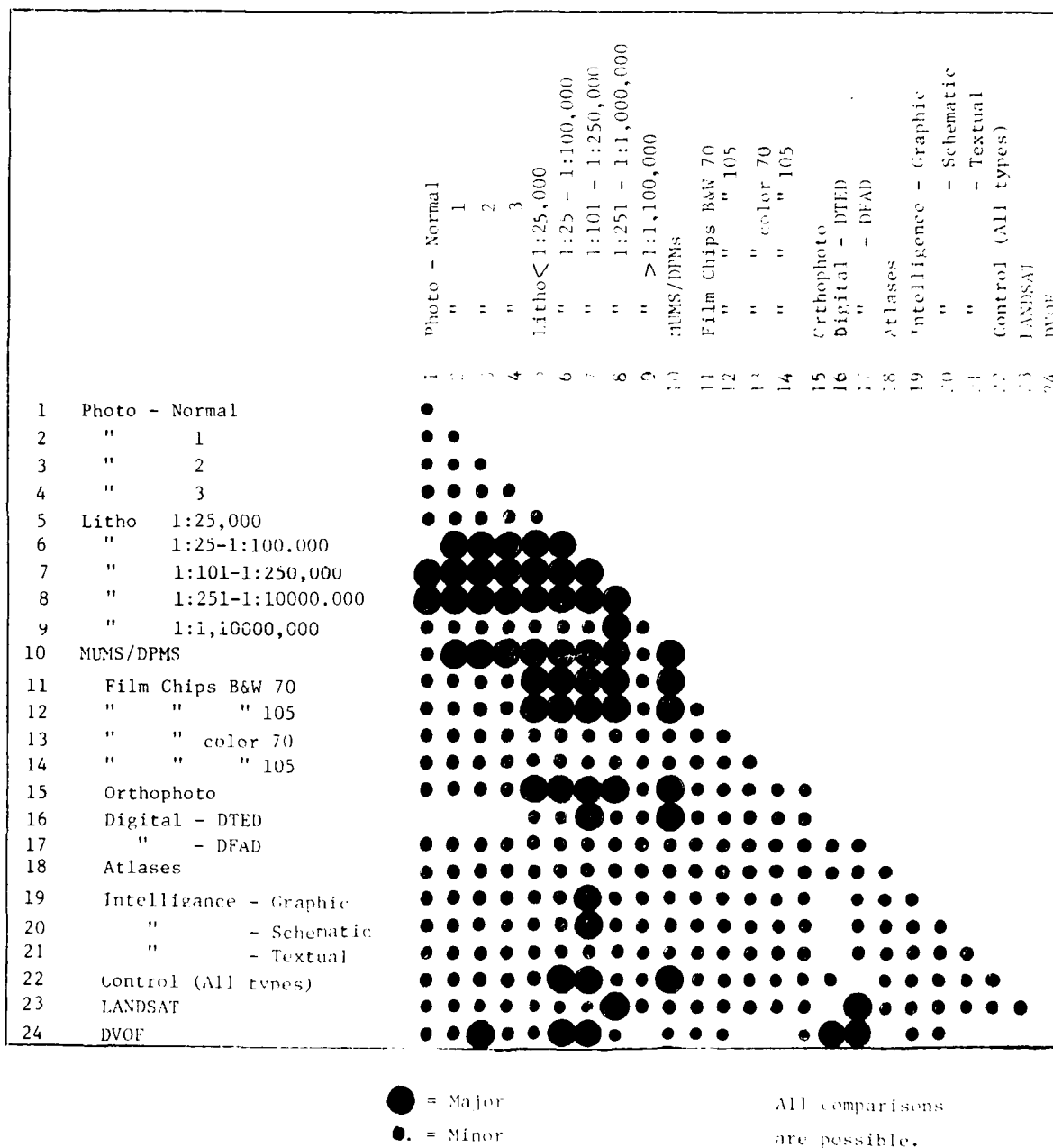


Figure 2-3 Containment Matrix for Potential DMAAC Media Mix

at DMAAC are that the use of graphics (maps, charts, etc.) as sources will continue and the use of photographic and digital information will significantly increase in the next 2-5 years.

There was also some interest in simultaneous comparison of more than two sources and products. The most useful example being comparison of sensor imagery source to DMA charting products. Presumably the goal would be to determine the relative completeness and currency of a DMA map/chart and a non-DMA map/chart, with the imagery providing the authoritative basis to validate content and currency.

In addition to providing the above fundamental features a SAS must function in SDDA as a system providing the following services:

- o A SAS must provide a formal system for source assessment:

Since a source's arrival at SDDA does not normally coincide with a production requirement for that source, a source must be properly assessed and cataloged so when a need for production support does occur the availability and application of that source are readily apparent. The source assessment process should produce an output that will replace or augment the hard copy folios (FOLIO, RAF, CEF), the Automated Data Base (AMIF, ARAPS, etc.) and the CHUM and TMB. The phrase "replace or augment" is intended to point out that a SAS may provide output that will make these existing data bases redundant and therefore unnecessary, or add to them to make them more comprehensive. The potential output of a SAS may range from written notes by a user to hard copy graphics and a digital link to the Automated Data

MAJOR INPUT	TOTAL NUMBER OF COMPARISONS
1:100,000 < Litho ≤ 1:250,000	17
1:250,000 < Litho ≤ 1:1,000,000	14
1:25,000 < Litho ≤ 1:100,000	13
MUMS/DPMS	13
1:24,000 < Litho ≤ 1:25,000	7
Photo Type 2	5
Film Chips B&W 70mm	5
Film Chips B&W 105mm	5
Orthophoto	5
D-VOF	5
Photo Type 1	4
Photo Type 3	4
Digital - DTED	3
Control (All Types)	3
Photo Normal	2
Digital - DFAD	2
LANDSAT	2
Litho > 1:1,000,000	1
Intelligence - Graphic	1
Intelligence - Schematic	1

Table 2-1 Major SAS Comparisons

Base. Whatever the nature of an eventual SAS, it must function within the existing environment as a formal system.

- o A SAS must link source assessment and production support: A SAS should provide a link between the source assessment process and production support. As already suggested this will be accomplished through new or existing data bases, but the SAS should also be available for real-time production support. Even well planned assessment will not account for every contingency encountered in production support and it is assumed that an Area Specialist will often employ the SAS in specific production support activities. See Figure 2-4.

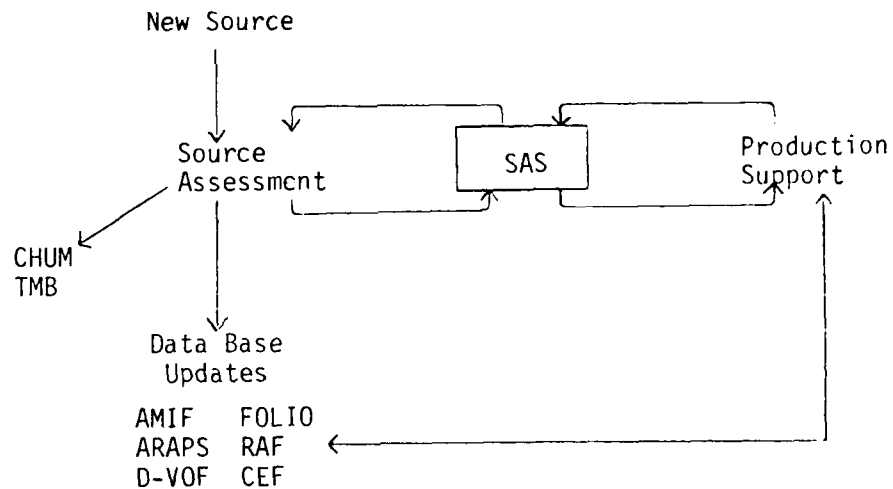


Figure 2-4 SAS Link Between Assessment and Production Support

- o A SAS must be accessible: A SAS must be readily accessible to those who must use its capability. It is possible that a final SAS configuration may turn out to be a complex unified system, too large and expensive to purchase in large quantities. Since traditional source assessment and production support has been performed at the desk or light table, such a system may prove cumbersome if it is not readily accessible by many users. Certain SAS functions should be distributed at, or close to a user's normal work station. Such a work station SAS would provide fundamental comparison capabilities while more complex problems would be dealt with at a centralized SAS.
- o A SAS must support high production levels: A SAS should be volume oriented. There should be no complex media-to-media conversion techniques, such as digitizing, that are difficult and time consuming to complete. The SAS should be simple and straightforward to use. Potential users of a SAS are interested in cartographic analysis and should not be expected to run through lengthy system set-up procedures.
- o A SAS should standardize assessment tools and practices: A SAS should minimize the need for personalized comparison methods. Ideally a SAS will provide standard comparison, display, measurement and documentation facilities that will contend with nearly all problems associated with assessment or production support. A SAS should also provide a framework such that assessment and production support can be performed in a step-by-step systematic manner, with

all personnel adhering to this procedure. Such steps might be based on a level of detail, supplying updates to the data bases, or production support at the level of detail required for each task.

2.1.4 Phased Development Approach

The development and implementation of a SAS has been partitioned into two major time frames Phase I for FY81-FY83, and a Phase II targeted for FY84-FY86. These phases have been assigned for the following reasons:

- o To account for a changing mix of sources and products (inputs to SAS) and possible new forms of source or products that may be developed or become available during the FY81-FY83 time period.
- o To provide a basic set of requirements for a Phase I SAS permitting an early implementation and more opportunity for use of off-the-shelf components.
- o An operational Phase I SAS will provide experience which can further guide and refine the Phase II design. Decisions can be made, based on empirical results and assessment of Phase I, as to which enhancements are appropriate or whether an adjustment in technology level is warranted.
- o Phase II will be able to take advantage of improvements that may occur in the technology selected for Phase I or new technology that may mature in the 1981-1983 time frame.

Since the mix of sources and applications that either a Phase I or a Phase II SAS may encounter is very large, priority has been assigned by SDDA to the most common comparisons. Phase I priorities are based on the current mix shown in Figure 2-4. Phase II priorities result from an educated forecast which recognizes an expected increase in the occurrence of digital data as a form of source materials or as cartographic products. These graphic comparison priorities are listed below:

<u>Phase I</u>	<u>Phase II</u>
1) Sensor Imagery to Maps/Charts	1) Sensor Imagery to Maps/Charts
2) Maps/Charts to Maps/Charts	2) Digital Data to Maps/Charts
3) Sensor Imagery to Sensor Imagery	3) Sensor Imagery to Sensor Imagery
4) Sensor Imagery to Digital Data	4) Sensor Imagery to Digital Data

The SAS design plan in Section 6.0 is directed at Phase I and the above priorities. The Phase I design plan is based on the premise that the bulk of assessment and production support assignments will be comprised of photo imagery to map/chart comparisons which are of first importance, and map/chart to map/chart comparisons which are second in importance. If a SAS can effectively deal with a wide range of these inputs a large subset of other possible combinations can also be accommodated, for example comparing maps/charts to control graphics such as multi-use manuscripts (MUMS). The primary considerations for Phase II are based on: expanded digital input/output and storage, improved image transformation and manipulation capabilities, and possible augmentation/replacement of technology limited components.

2.2 SAS Application at DMAHTC

Although the SAS design is intended to target the specific requirements of DMAAC, there may be significant commonality of function at DMAHTC such that the proposed system is capable of serving, with little modifications, at both centers. The following analysis of DMAHTC functional requirements is included in this report to address the possibility of considerable cost and time savings to DMA by employing the same SAS design at both DMAAC and DMAHTC.

DMAHTC is the DMA production center for topographic maps and nautical charts. To support this production, collection programs and libraries are maintained for:

- o Geodetic Data
- o Bathymetric data
- o Geographic Names
- o Maps and charts produced outside DMAHTC
- o Sensor imagery

In addition DMAHTC serves as the DMA screening center and repository for mapping and charting sources, produces a portion of the terrain elevation feature analysis data (i.e., DTED and DFAD) for the radar simulation program, and issues up-to-date notices concerning hazardous conditions and navigation at sea.

2.2.1 Functional Overview

Figure 2-5 was provided by DMAHTC personnel at an on-site briefing.

This figure outlines a source processing system similar to that in Figure 2-1. The Preprocessing, Assessment and Screening block on the left reviews new source materials as to their currency, quality and application. Since the arrival of a source does not normally coincide with a production requirement, an accepted source must be filed in a data base such that its application, availability and location can be readily determined. The Area Requirements and Product System (topographic and hydrographic portion) ARAPS, the Area Collection Requirements and Evaluation System (ACRES) and the Product Maintenance System (PMS) are collection management systems which link DMAHTC's products and production schedules to available sources. On the right side of Figure source selection for a specific production request is accomplished by using the product requirements in conjunction with ARAPS, ACRES or PMS to access the library, file or data base.

DMAHTC catalogs its source holdings into the following six systems:

- o DoD Map and Chart Information System (MACIS)
- o DoD Geodetic Information System (GIS)
- o DoD Bathymetric Information System (BIS)
- o DoD Foreign Place Names Information System (FPNIS)
- o Imagery Information System (IIS)
- o Digital Topographic Information System (DTIS)

SOURCE DATA BASE PROCESSING

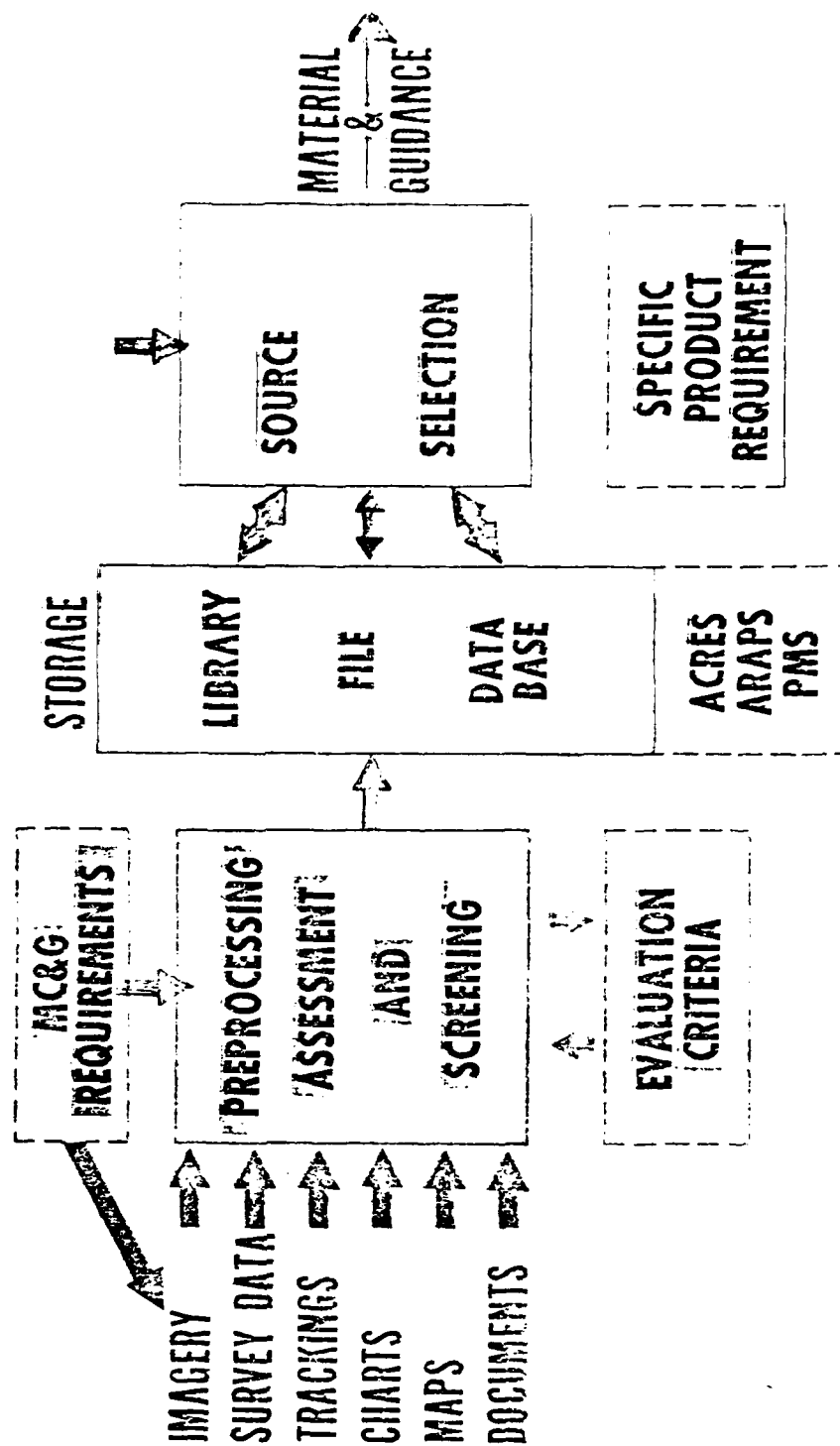


Figure 2-5 Source Data Base Processing

The main thrust for an improved source assessment capability at DMAHTC is for a near term system (within two years) to support: the DoD Map and Chart Information System (MACIS); and assessment of hydrographic chart currency.

In MACIS SAS might be used in a production mode to compare maps and charts, obtained from sources outside DMA, with DMA products. Such a SAS will require the capability to allow two large graphics (maps or charts) to be compared at the same scale. Eventually a SAS will be required to take other forms of source into account. Of primary importance is digital data, probably from the Digital and Topographic Information System (DTIS) and imagery from the Imagery Information System (IIS).

The assessment of hydrographic chart currency is similar to DMAAC's maintenance of the RAF and associated CHUM/TMB updates, in that newly acquired hydrographic charts are compared with currently published DMA hydrographic charts. Significant changes are annotated on a chart standard and submitted for input to the Notice to Marineers weekly publication.

As suggested for DMAAC in Section 2.1, there is most likely application for a SAS at DMAHTC in both the assessment and screening process, and the source selection (or product support) process. It appears that one of the goals is better definition and categorization of sources in the assessment process. If the application of a new source can be defined to a high degree in the assessment process, selection of sources for production support will be more straightforward and less detailed review of these sources will be necessary. This, however, is probably an ideal situation and in most cases, even though the sources are better defined, the production specialist will again want to compare his sources and products. Figure 2-6 reconfigures Figure 2-5 to show this possibility.

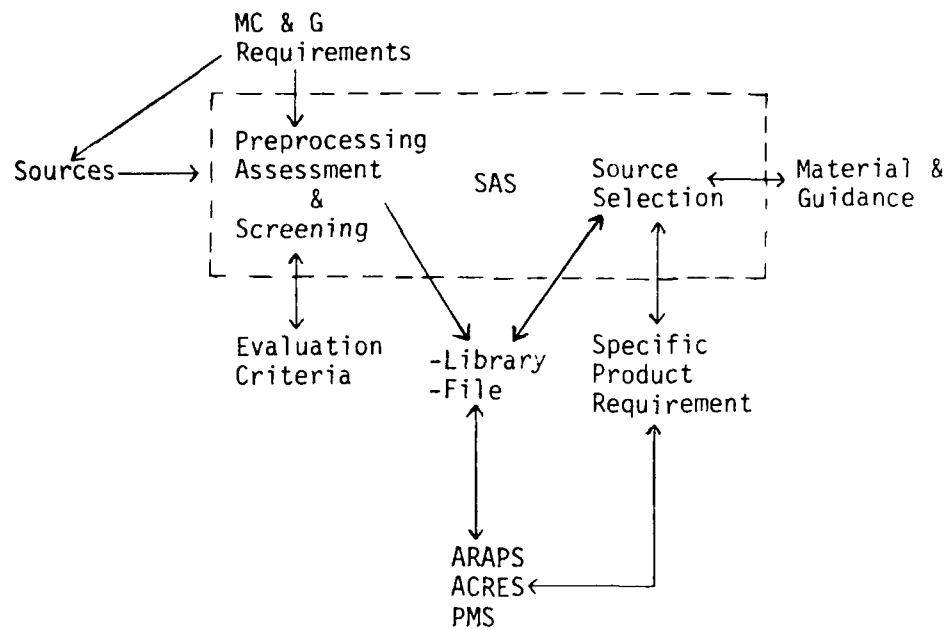


Figure 2-6 SAS Linking Assessment & Selection

2.2.2 Current Source Assessment Practices at DMAHTC

As in DMAAC assessment functions are not clearly separated from production functions. This again is due to a need for improved "up-front" assessment so that requests for production support can be efficiently and systematically addressed.

The same problems hamper specialists at HTC as they do in AC:

- o An inability to compare sources or DMA products at the same scale
- o A lack of assessment tools
- o A lack of standard assessment methods
- o An inability to assess certain forms of source

Specialists employ any means they can find to compare sources and products. One specialist interviewed was checking the agreement of depth soundings on two different charts depicting the same area. Because these charts used different scales and were produced by different organizations it was very difficult to determine the corresponding location of depth soundings. It was necessary to measure each location from a common reference point (in itself difficult to select) and convert them to the same scale. A true scale black and white transparency of one chart was overlayed with the second chart on a light table. This transparency helped, but did not solve the problem of scale differences. The necessity of such procedures overly complicates the need for high volume and thorough assessment and responsive production support.

2.2.3 DMAHTC Requirements for a SAS

DMAHTC is attempting to systemize its assessment and storage of cartographic sources through the use of a comprehensive data management system based on screening and computerized indexing of library holdings. The lack of a SAS at DMAHTC limits the well defined separation of assessment of incoming source materials from production support as depicted in Figure 2-6. If assessment of sources is limited to a cursory examination, they will not be properly assessed as to their value and the production support and source selection process will continue to be burdened with unnecessarily detailed review. Snap judgements in the assessment process could either fail to eliminate sources of dubious value or misdirect valuable accessions.

A comprehensive SAS at DMAHTC should be thought of in terms of a system rather than a device. Such a SAS would link with DMAHTC data files and produce outputs that replace or complement current files or libraries. DMAHTC envisions a SAS with a link to Source Information Management System (SIMS). SIMS is a data management system and may reside on a central site or specialized processor. SIMS will provide a standard means of access to all indices of DMAHTC source holdings and the SAS should be able to take advantage of this interface. The most elementary method would be the data entry of SAS user notes. A more direct method is a hardware link to the SIMS system. Such a link would enable the user of SAS to query the data base directory through SIMS, for related production information, or enter SAS generated graphics or reports, under the control of SIMS, into information systems such as MACIS.

2.2.4 SAS Consideratons Specific to DMAHTC

DMAHTC is primarily responsible for topographic and hydrographic products but the requirements for a SAS do not differ greatly from those at DMAAC. There is the same need to compare multi-formatted

sources and products at a common frame of reference and to improve the linkage between the source assessment function and production support, so that efficient assessment and up-to-date notice for navigation, and responsive support for DMA production is available. However, special consideration should be given to routine assessment of nautical chart acquisitions and the detection in these charts of hazards to navigation at sea. A SAS that addresses this function is not required to accept the extensive mix of input formats that a SAS at DMAAC may encounter. DMAHTC is more concerned with a device that can compare hydrographic chart acquisitions and products in an efficient manner than with a comprehensive SAS for detailed assessment. Such SAS must be simple in the sense that detailed analysis capability is unnecessary but must be sophisticated in the ability to give clear sharp images and provide the user with rapid set-up. Primary features for a DMAHTC Phase I SAS are as follows:

- o Volume processing and rapid detection of difference is more important than detailed examination.
- o It must have the capability to compare, at the same scale, at least two charts. The physical size of these graphics not including borders can average 32" x 40" and be as large as 40" x 60".
- o The ability to enlarge a small scale graphic to match a large scale graphic must be present.
- o It must be quick and convenient to operate for volume assessment.
- o The input of sensor imagery is important at DMAHTC but the ability to compare charts to charts should have highest priority.

From the above specifications it appears that a SAS must have capability for rapid set-up. Ideally a user could simply place his inputs on the input surface, only approximately positioned, and from then on do all his image manipulation from a working position using remote controls.

As at DMAAC, increasing use of digital mapping and control data is expected at DMAHTC and the most important Phase II upgrade will be the ability to accept, display and compare digital data. There was also interest by DMAHTC representatives to link a SAS into an automated data base system for access and retrieval of such data.

3.0 SAS DESIGN REQUIREMENTS

The primary objective of the SAS development is an efficient means to visually compare the contents of DMA products and cartographic sources with the same geographic coverage so that discrepancies are readily evident. This would not be a difficult problem if all potential inputs (products and sources) were the same format and physical nature but this is not the case. This section attempts to isolate the design issues so that the large mix of potential inputs and wide range of applications that a SAS must take into account can be effectively dealt with.

3.1 Characteristics and Scope of Expected Inputs

Table 3-1 outlines the content and physical nature of each source or DMA product which is expected to occur as input to a Phase I SAS. Table 3-2 subdivides these inputs using examples from Table 3-1, in the hope of limiting the SAS to several discrete input channels. The subdivisions are based on the following:

- o Size (Large - Small)

The hard copy materials are divided by size because the optical parameter and input mechanisms will, at some point, fall into a different realm. The size of an optic is linked to the size of the subject through its light gathering capability and the physical mechanisms for inputting a large object or a small object into a SAS should be quite different. To cite an extreme case, it is not likely that mechanical-optical equipment designed for a 30" x 40" chart can effectively handle a 35mm film chip. A small format size of 11" x 11" is a convenient cut off

TYPE	DMA		PURPOSE/USAGE	PHYSICAL CHARACTERIS		
	PRODUCT	SOURCE ONLY		SIZE		MEDIA
				TOTAL	ACTIVE	
Aerial Photography		X	Basic source for assessment of DMA product currency, content, locational verification. Can be rectified and scaled if timeframe and use warrant.		Variable frame & panoramic formats H~5"-9" W~9"-18"	Roll positive film mostly
DMAAC Aeronautical Charts	ATC		Planning, briefings, and operations	22"x29"	~18"x26"	Litho
	JOG-A/R		Planning, navigation, tactical operations	22"x29"	~18"x26"	Litho
	TPC		Planning, navigation, tactical operations	42"x58:	~36"x52"	Litho
	ONC		Planning & low altitude navigation	42"x58"	~40"x56"	Litho
	JNC*		Planning, long range enroute navigation	42"x58"	~38"x53"	Litho
	GNC*		General planning and briefings	42"x58"	~39"x55"	Litho
*Not specifically applicable to SAS						
DMAHTC Topographic Maps	X		Basic topo series for a wide range of military planning, operations, and exercises. Other special topographic maps are also produced.	22 1/2" x 29"	~18"x22"-25"	Litho
Other Topo Maps						
USGS Foreign		X X	Control source for detailed, large scale work	23"x29"	~18"x 23"	Litho

Table 3-1 DMA Product and Sources Applicable to SAS

(1 of 3)

PHYSICAL CHARACTERISTICS				REFERENCE FRAME	
SIZE	ACTIVE	MEDIA	DEPICTION METHODS	SCALE(S)	PROJECTIONS
IL					
	Variable frame & panoramic film formats H 5"-9" W 9"-18"	Roll positive film mostly	Continuous tone B&W	Variable ~ 1:20,000 to 1:125,000	N/A
9"	~18"x26"	Litho	Colors/Tints/Symbols	1:200,000	LCC/PS
9"	~18"x26"	Litho	"	1:250,000	TM/PS
18:	~36"x52"	Litho	"	1:500,000	LCC/PS
18"	~40"x56"	Litho	"	1:1,000,000	LCC/PS
18"	~38"x53"	Litho	"	1:2,000,000	TM/LCC
18"	~39"x55"	Litho	"	1:5,000,000	TM/LCC
2"	~18"x22"-25"	Litho	Colors/Tints/Symbols	1:50,000	UTM
"	~18"x 23"	Litho	Colors/Tints/Symbols	1:24,000 1:62,500 1:50,000	UTM

TYPE	DMA		PURPOSE/USAGE	PHYSICAL CHARAC			
	PRODUCT	SOURCE ONLY		SIZE		M	
				TOTAL	ACTIVE		
DMAHTC Nautical Charts	Port and Harbor Approach Coastal Combat Bottom Contour Misc.		} Navigation planning and operations.	Range from 20"x30" to 40"x60"		L	
MUM/DPM		X		Multi-Use and Direct Positioning Manuscripts. Used as control source for planimetric feature information.	~ 22"x29"	?	Tr M
70 mm/105 mm Film Chips		X		Microforms of reference maps and charts. Used primarily for quick reference and where limited use original is held in library.	~ 2 3/4" x 3 1/4"	-	B& Ne Fi
Orthophoto		X		Used as precise control source for detailed extraction of planimetric data.	Various ~ 24"x32"	-	Fi
DTED	X			Terrain matrix digital data used mostly for support to DLMS Program.	N/A	N/A	Ma ta 80 15

TABLE 3

PURPOSE/USAGE	PHYSICAL CHARACTERISTICS				REFERENCE FRAME	
	SIZE		MEDIA	DEPICTION METHODS	SCALE(S)	PROJECTIONS
	TOTAL	ACTIVE				
tion planning and ions.	Range from 20"x30" to 40"x60"		Litho	Colors/Tints/ Symbols	1:10,000 1:30,000 1:160,000 1:50,000 1:1,088,700 1:1,500 to 1:11,000,000	TM TM TM TM Misc.
and Direct Positioning s. Used as control planimetric feature n.	~ 22"x29"	?	Translucent Mylar	Mostly colored pencil lines and symbols	1:200,000 1:250,000 1:500,000	?
of reference maps and sed primarily for quick and where limited use s held in library.	~ 2 3/4" x 3 1/4"	-	B&W Negative Film	N/A	Various	Various
ecise control source for xtraction of planimetric	Various ~ 24"x32"	-	Film print	B&W continuous tone	Usually original photo scale or scaled to compilation scale	-
rix digital data used support to DLMS Program.	N/A	N/A	Magnetic tape 9-track 800 FPI/NRZI or 1500 FPI/PE	Matrix of 100 m elevation values in 1° x 1° data files. Geographics.	N/A	N/A (WGS Horiz. Datum and MSL Vertical Datum)

TABLE 3-1 DMA Product and Sources Applicable to SAS
(2 of 3)

TYPE	DMA		PURPOSE/USAGE	PHYSICAL CHARACTERISTICS		
	PRODUCT	SOURCE ONLY		SIZE		MEDIA
				TOTAL	ACTIVE	
DFAD	X		Culture and landscape Categorization based on radar significance in support of DLMS Program.	N/A	N/A	Same as DTED
Atlases		X	General reference	Various		Book format
Intelligence Documents		X	Special reference graphics and schematics for specific research or verification of size/height.	Normally report format (~8 1/2"x4")		Book format
Control		X	Precise control points which are photo or map identifiable	Digital or listings		
LANDSAT		X	Newly acquired source for verification/update of medium to small scale charts; and auto. landscape class for DLMS.	2.2"x 2.2" 7.3" x 7.3"	<2.2" <7.3"	Digital Film or Print
D-VOF	X		Vertical obstruction digital file to support flight planning.	N/A	N/A	?

Table 3-1 DMA Product and Sources Applicable to SAS
(3 of 3)

PHYSICAL CHARACTERISTICS			REFERENCE FRAME		
SIZE		MEDIA	DEPICTION METHODS	SCALE(S)	PROJECTIONS
AL	ACTIVE				
	N/A	Same as DTED	File sizes vary Geographics.	N/A	N/A (WGS Horiz. Datum and MSL Vertical Datum)
Various		Book form	Color and highly generalized		Various
Normally port format (8 1/2"x4")		Book form	Linework or photo	Various/Unknown	
Digital or listings			Tabular	N/A	N/A
	<2.2" <7.3"	Digital Film or Print	Multi- spectral pixel data	Small scale ≤1:1,000,000	Optional- Space Oblique Mercator
	N/A	?	Point location and description data	N/A	N/A

SAS INPUT	
<u>Large Opaque Sheets (>11" x 11")</u>	<u>Small Opaque Items (<11" x 11")</u>
<u>Type:</u> Maps, Charts, Drawings Photographic Prints <u>Technical Considerations:</u> Size - Large input system required - Optical axis must also be large Lighting - Object must be lighted by reflection - Light will be lost at surface by reflection and scattering - Large focal length optics require heavy lighting	<u>Type:</u> Not common, but may be found in textual data <u>Technical Considerations:</u> Optical and physical manipulation fall into realm different from large sheets <u>Examples:</u> Atlases Intelligence - graphic - schematic - textual
<u>Large Transparent Items (>11" x 11")</u>	<u>Small Transparent Items (<11" x 11")</u>
<u>Type:</u> Photographic Positives Photographic Negatives Drawings on Transparent or Translucent Material <u>Technical Considerations:</u> Size - Similar to large opaque sheets Lighting - Transmittence of light is a concern rather than reflectance.	<u>Type:</u> Photographic Positives Photographic Negatives (Common Photographic Formats, often in roll form) <u>Technical Considerations:</u> Optical and physical manipulation falls into realm different from large sheets <u>Examples:</u> Film Chips 70mm Film Chips 105mm LANDSAT

Table 3-2 SAS Physical Subdivision

(page 1 of 2)

<u>SAS INPUT (CONT'D)</u>	
<u>User Control</u>	
<u>Type:</u>	<u>Type:</u>
Vector	Image positioning
Raster	scaling
Matrix	distortion
	enhancement
<u>Technical Considerations:</u>	<u>Technical Considerations:</u>
Allows a great deal of image manipulation.	Optical limitations
Optical conversion would be necessary.	Mechanical/optical interface
- liquid crystal (from proposal)	Electronic/optical interface
- D/A video	Electronic/mechanical interface
Extensive processing might be necessary to convert to useful form. For example, vector data may require conversion to raster data.	
<u>Electronic Analog</u>	
<u>Type:</u>	<u>Examples:</u> Electronic Beam Recorder
Electronic data may be recorded on tape in an analog manner	
<u>Technical Considerations:</u>	
Electronic to optical conversion	
Analog to digital conversion	

Table 3-2 SAS Physical Subdivision (page 2 of 2)

based on common formats of photographic inputs.

o Viewing Mode (Opaque - Transparent)

Hard copy materials are also divided by the viewing mode or the use of lighting, into opaque and transparent groups. The lighting design for opaque items is expected to differ from that for transparent items and in general is much more of a problem, because most light is lost at the surface of such a material. Although many materials fall between totally opaque and totally transparent, their intended viewing method is usually obvious.

o Medium (Hard Copy - Electronic)

Electronic data cannot be viewed directly and is usually stored on a magnetic medium. No significant analog source has been identified by DMA thus nearly all electronic source is assumed to be digital. To provide digital input, a SAS will require: an input device such as a tape drive or digital data link; a processor to drive the input device and convert the data to a usable form; and a means of converting the data to a visible form.

o Purpose (Data - Control)

The last division distinguishes user control from data or information. User control suggests a large range of possibility and is related to the range of SAS functions. User control could be entirely manual and be as elementary as sliding an input graphic around on

a light table, or could be very sophisticated providing, most likely through a digital system, complete control (geometric manipulations) over all aspects of the image.

A decision must be made concerning the input paths or channels that will ultimately be included in a SAS. These channels should be chosen using such parameters as expense, usefulness and priority. A Phase I SAS at DMAAC must have an input channel for maps and charts and one for photographic films, and a second input for maps and charts is highly desirable.

3.2 SAS Outputs

The SAS should produce the following results:

- o Enhanced assessment
 - Increased efficiency
 - Better detection
- o Hardcopy documentation including updates to the hardcopy portfolios
- o Updates to the automated data bases

The phrase "enhanced assessment" is of course a qualitative factor, but is intended to point out a most important function of a SAS. For a reasonably basic SAS its usefulness will manifest itself only as insights from the user. Such a SAS would impact existing procedures only through the actions the user might take after gaining these insights. Enhanced assessment is subdivided to demonstrate that

efficiency of use and better detection of differences between products and sources will provide this service.

An extended SAS might produce hardcopy graphics or printed output to augment the hardcopy portfolios (FOLIO, RAF and CEF). A typical use of such output might be as follows. A portion of a small scale map is enlarged for comparison with a large scale map. After the user has analyzed this comparison, he requests a hardcopy of the enlarged portion of the small scale map. This copy can then be annotated by the user and entered into the RAF for further reference. Such a procedure provides a valuable graphic which did not previously exist and the ability to annotate without marking a one-of-a-kind original.

For the Automated Data Bases like AMIF or ARAPS, the SAS could employ an adjacent terminal which would be linked to a computer with a central data base. The user could then interact with the data bases in real-time, updating them when the user determined that such an update was necessary. At a higher level a SAS might have a direct link to these data bases and, by user demand, augment these data bases with graphic or textual data.

3.3 Evaluation Factors

The mix of potential inputs to a SAS and the wide range of applications that a SAS may be required to deal with necessitate a means to contain the design issues. This section defines a set of 24 factors which were arrived at through a consensus of project personnel. These factors will serve as criteria for evaluating the four design concepts described in Section 4.0.

Each factor could very likely be further broken down or their scope may overlap in some areas but it is felt that this is a sound, meaningful set of factors which is manageable from an analysis

standpoint. They are subdivided as follows:

- o Input Capabilities
- o Performance Criteria
- o Functional and Imaging Characteristics
- o Human Engineering (Operational Characteristics)
- o Implementation Considerations

INPUT CAPABILITIES:

(1) Ability to Image Maps and Charts

Maps and charts are man-made and depict the cartographer's preception of a geographic area. Maps and charts generalize reality and contain only geographic features and supplementary information relevant to the intended use of the product. Features that are shown are usually symbolized in some form (e.g., colors, tints, lines, points, symbols, etc.). Maps/charts are produced in a projected form which allows the curved surface of the earth to be presented on a flat surface in a standardized manner.

This input must be provided in a SAS because maps and charts are products of DMA and their currency and quality must be maintained. A primary mission of the SAS will be to benchmark (i.e., verify currency, completeness, and accuracy) DMA's products against incoming source. These incoming sources may be photographic or digital but also could be map and charts produced outside of DMA.

(2) Ability to Display Photographic Transparencites (≤11" x 11")

Sensor imagery and visible light photography are normally in the form of photographic film transparencies which are viewed by transmitted light. This is a very prominent form of source and is a mandatory SAS input. A transparency may also occur as a photocopy of a map, chart or document.

Film transparencies are usually simpler to image because the format is smaller and viewing by transmitted light is more efficient, but their ability to deliver high resolution and a wide spectral response must be maintained or their value will be reduced.

(3) Ability to Image Digital Products and Sources

The input and display of digital data is mandatory for a Phase II (FY84-FY86) SAS. DMA is responsible for the completeness, accuracy and currency of several important digital products required for advanced weapon systems, and it is necessary to benchmark these digital products against new sources or other products. Digital data may also occur as a source. Multispectral sensor imagery, for example, can be recorded digitally.

Digital data is expected to grow in importance with respect to both source data and products. For SAS to directly accept such data, digital technology must be employed. A computer would be required to control input devices, process information and encode electronic data for graphic display.

(4) Ability to Image Miscellaneous Hardcopy

The previous three factors dealt with the most important SAS inputs but there is wide variety of less common inputs that should be taken into account by a SAS design. Some examples are as follows:

- o Photographic prints
- o Large transparent overlays
- o Microforms of various formats
- o Small graphics or photographs intermixed with textual data

Photographic prints for instance are viewed with reflected light as maps and charts are, but have a different reflective surface and contain much more detail. Microforms can be imaged like imagery transparencies but small formats may require different optical/mechanical parameters. Other possible inputs may require special considerations. How well a SAS design can account for these special cases is the issue here.

(5) Input of Source Evaluation Data

The system should allow for entry, review, and/or edit of alphanumeric information describing an individual source in terms of corner coordinates (geographic coverage), projection, datums, scale, producer, date, and evaluation factors. Evaluation includes the facility to determine H/V accuracies based on recording of source locations and comparison with known geographic locations, or visual comparison of a source with a graphic representing a known accuracy.

(6) Number and Mix of Inputs that can be Simultaneously Compared

It is mandatory that a SAS be able to compare two different inputs. The capability to compare sensor imagery with maps and charts is given the highest priority. In many instances new sources will be maps or charts obtained outside of DMA, making the ability to compare maps and charts with maps and charts very important. A valuable feature of a SAS would be the ability to simultaneously compare more than two inputs. A reconnaissance photo, for example, may be used as a base reference to determine the relative quality of two different maps with overlapping coverage. The ability to input digital data for

comparison to maps and charts and to sensor imagery respectively are first priority and second priority goals for Phase II (FY84-FY86) requirement. An ideal SAS (whatever the input formats) will have complete freedom to mix these inputs for direct comparison.

PERFORMANCE CRITERIA

(7) RESOLUTION

It is desirable to distinguish and identify the finest cartographic details on each source. Fine lines such as contours may be as small as 0.004 inches wide. Typographical characters may be as small as 0.030 inches high, requiring approximately 0.004 inch resolution for readability. Detail in photographic images may require a resolution finer than 0.001 inch. In order to maintain such detail anywhere over a large area of input, it is necessary to have a large number of resolution elements in the system. A SAS should not drastically subdivide the input format.

(8) Accuracy

To deliver accurate comparisons a SAS must be consistent between object-to-image paths. For example, the components that are required to image a map may introduce errors different from those introduced from the components required to image an photographic transparency, but the combined effect of these errors should not allow images to diverge beyond the diameter of the smallest cartographic object of interest.

(9) Scaling Range

It is mandatory for a SAS to support relative scaling between inputs of 4:1. It is important that a small scale input be enlarged to match large scale inputs. Relative scaling of 10 to 1 would be very desirable and cover nearly all potential sources and products. The most powerful SAS would permit independent, continuous enlarging of all inputs.

(10) Image Brightness

The SAS must deliver combined images that are bright enough to be comfortably viewed for long periods of time. A display should have a peak image brightness of approximately 50 foot Lamberts. Dimmer displays are satisfactory in subdued lighting. A brightness of only 1 foot Lambert would require complete darkness to be discernable.

(11) Uniformity of Image Brightness

The SAS generated images must be uniformly bright across their extent, such that combined images can be effectively viewed.

(12) Image Size

The SAS should provide an image large enough such that a substantial portion of the largest format can be viewed at close to its original scale.

FUNCTIONAL AND IMAGING CHARACTERISTICS:

(13) Identification or Separation of Input Images

When two or more images are being compared the information clutter may prevent the user from distinguishing the content of one input from that of another. A SAS should provide methods using color, texture, lighting or split images to separate the contents of one source from that of another.

(14) Feature Suppression or Enhancement

The ability to enhance or suppress classes of features by color, gray shades, or pattern is valuable. Such processing can serve to clarify inputs, minimize information clutter and emphasize certain features which are of particular concern to the user.

(15) Global Image Registration

It is desirable to be able to register two or more input images over the entirety of their overlapping coverage. This avoids the necessity of re-registering the images as they are scanned. Also, if the field of view of the SAS is smaller than the smallest of the sources to be compared, multiple subfields may be required to completely compare two sources. It is important that the registration of sources be maintained over many or possibly all subfields after initial adjustment. To accomplish this each imaging path must be consistent within certain tolerances (see factor 8) and it may be necessary to correct for distortions associated with sensor imagery and map projections.

(16) Real Time Registration

In general, the initial attempt to register two inputs may only approximate registration in certain areas. Provisions for immediate operator feedback is desirable so that fine-tuning of image registration can be maximized. Ideally this can be performed from a central position while the user views a composite image.

(17) True Color Recognition and Display

The SAS user would like the images of colored inputs to depict the same hues observed on the inputs.

(18) Tonal Gray Level Recognition and Display

If color is not available in a source (sensor imagery recorded on black and white photographic film for example) gray levels are the only way to distinguish features. A SAS should be able to separate gray levels to a degree equal to or in excess to that of a human eye.

(19) Hardcopy Outputs

A most important output of a SAS is a clearer understanding of the relative currency, completeness and accuracy of DMA products and potential sources. It is possible that a user's record of his observations represent a sufficient output of SAS, but hardcopy graphic or textual output are useful options. Graphics may represent new images of the original inputs and serve to document the user's observations. These graphics might show scaled, combined, or enhanced images of the originals. Textual outputs will permit a user to build analysis reports as he reviews source/product comparisons.

HUMAN ENGINEERING:

(20) Setup Time

Goals of a good design are high throughput and user convenience. The user should not be required to carry out elaborate set-up procedures as a pre-condition to performing his assignment. Input mechanisms should allow all important forms of input to be entered without bending, cutting, or otherwise degrading their utility. Time consuming processes for reformatting sources to a convenient form, such as lengthy photographic reproduction or digitization, are to be avoided. Registration of images should be accomplished at a central location.

(21) User Interface

The user should have control of both his inputs and his images from a central location where the image display can be readily seen. Coarse and fine adjustments should be available and electromechanical links would be superior to strictly manual controls. The SAS should be able to function in an environment which provides comfortable working conditions.

(22) Accessibility of Inputs

On occasion the SAS user may need to annotate, take measurements or otherwise interact with his inputs. The SAS must provide a means to do this by allowing the user either direct accessibility of the inputs or indirect accessibility through displayed images. To perform interaction through the displayed images, images must either be presented on a flat working surface while maintaining a high degree of correlation with the original input, or virtual "point-location" tools must be added into the images. For example, if an electronic display is employed the user could key annotation into the image and then demand a hard copy graphic to obtain an annotated version of the original input.

IMPLEMENTATION:

(23) Phase I/Phase II Transition

An ideal SAS will provide for Phase I (FY81-FY83) needs and provide a smooth growth path to extended functions for Phase II (FY84-FY86) needs. Less desirable systems may provide only Phase I requirements with little potential for growth to Phase II.

(24) Technological Risk

Risk in this sense is the probability that the development of the SAS will not exceed estimated costs and that the fabricated SAS will meet design goals. An off-the-shelf system will entail the least risk while reliance on a conceptual only technology represents the highest risk. In between is the possibility of assembling a SAS from off-the-shelf components or using technology which is new but well established in the laboratory.

4.0 ALTERNATE SAS DESIGN CONCEPTS

The four design concepts described in this section address the source assessment problem using known technologies to the best advantage. While each of these concepts can perform a variety of assessment functions, each has inherent limitations that must be taken into account by the tradeoff analysis in Section 5.0. The descriptions are only conceptual at this point but they have been defined to sufficient level for the evaluation exercise. While conceptual only, the functional scope of these designs takes into account practical limits of the technologies utilized.

4.1 Direct Optical Viewer (DOV)

4.1.1 Description

The Direct Optical Viewer or DOV is a basic optical approach to source assessment. Graphic input, such as maps and charts, are mounted on a copy board and illuminated with high power lamps. A portion of the light, diffusely reflected from the document, is captured by a lens and projected on a viewing screen. Transparent photographic inputs will be imaged in the same manner, except that the copy board will be switched to backlighting. This will allow map to map, map to transparency, and transparency to transparency comparisons. See Figure 4-1.

A small processor or a communications link to a central computer facility, along with a display terminal, will be included as part of this configuration. This equipment will not be part of the imaging system but will be available for display and edit of input descriptive data. Also, an optional digitizer and computational facility can be added for possible mensuration or feature extraction purposes. Functional characteristics of this system are as follows:

- o High Resolution - Resolution is limited only by optics and the inherent resolutions of the input in question.

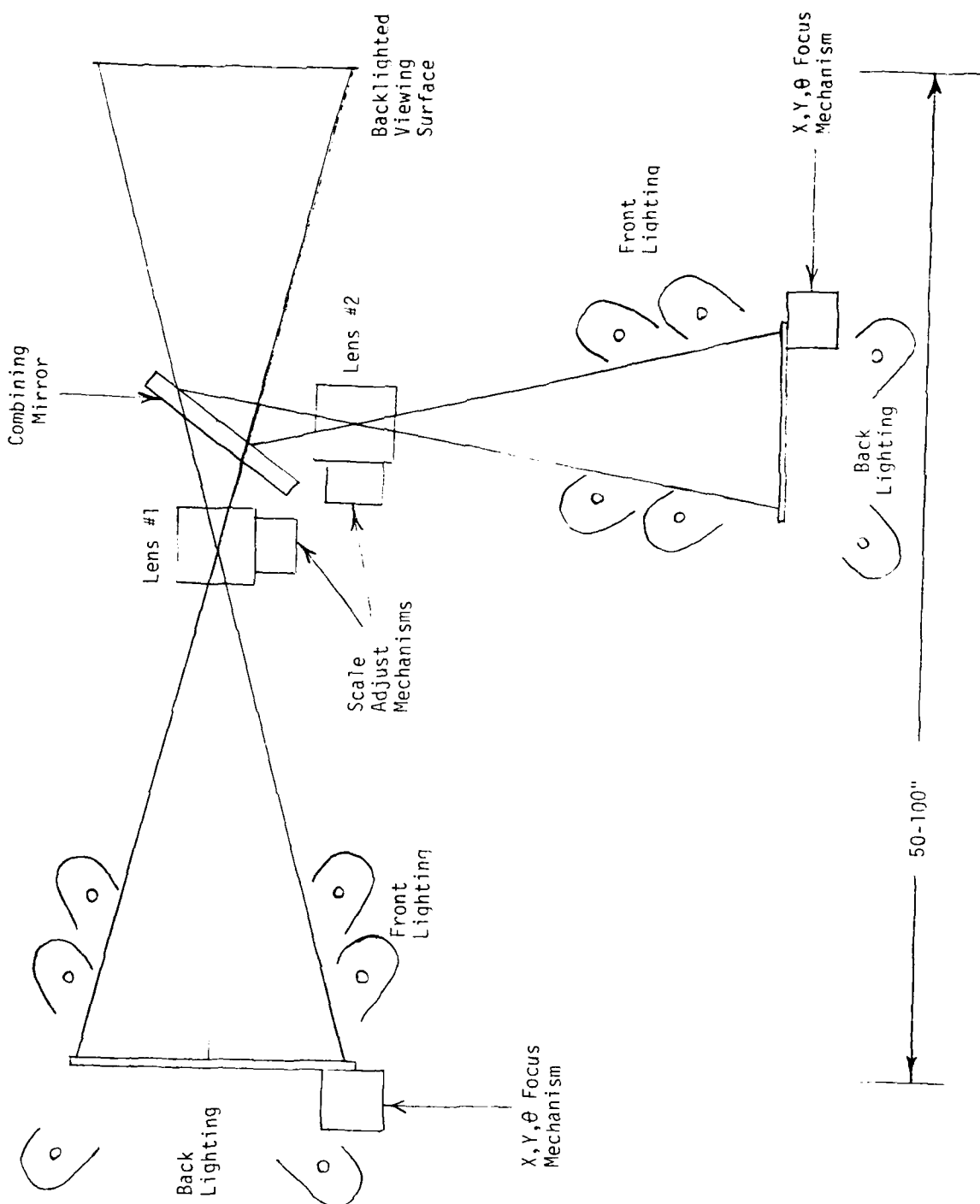


Figure 4-1 Direct Optical Viewer

At the enlargements expected ($\leq 5\times$) the resolution of this device will be essentially that of the input.

- o Restricted Viewing or Low Image Brightness - If the input is a transparency, a focused illumination system will provide a very bright image but for reflectively viewed inputs such as maps and charts, which must be viewed by diffusely reflected light, the ability to deliver a bright image is severely limited. A calculated example with typical parameters is demonstrated in Appendix A.

Design of this system would first be specified for a full field view on a light table-like surface, but it is very likely that to ensure acceptable image brightness, an aerial image or a restricted field of view will be necessary. While this will ensure a bright image, the user will be physically separated from his source and restricted in his viewing angle.

- o True Color Recognition and Presentation - For colored inputs color reproduction will be impaired only by optical design and essentially provide exact replication.
- o Horizontal Positioning - For alignment of images horizontal translation in two directions will be provided for each input. This will be accomplished with electromechanical linkage which will allow very accurate positioning with little physical effort from the user.
- o Horizontal Rotational Positioning - Also for alignment, independent rotation of each input will be available.

- o Independent Continuous Scaling - Independent continuous enlarging will be provided, but a ratio of at least 4:1 will be a practical upper limit. See Appendix A.
- o Comprehensive Lighting Control - Independent adjustments of intensity of source illumination will be included for optimum viewing comfort and to compensate for scaling changes between inputs (projected images will become dimmer as they are enlarged and may be washed out by the brighter image of an unscaled source). Flickering will be included as a means of separating one superimposed image from another. The entry device for large reflectively viewed graphics will also be backlighted for large transparent overlays.
- o Comprehensive and Convenient User Controls - User controls will be grouped close to the viewing surface for convenience. Mechanical movements of the projecting apparatus will have electronic links to the user's console for centralized control and accurate positioning. Coarse and fine adjustments for all operations will be included.
- o Computational and Data Management Facilities Computer facilities will be available as part of the system to perform the following:
 - Input and display of descriptive data
 - Input and display of evaluation data
 - Editing capability for the above inputs, and output of edited data in either hardcopy or electronic form

- Digitizing capability for mensuration or feature extraction (if image brightness is sufficient for wide field viewing, digitizing mechanisms can be applied directly on a light table-like image).
 - Optional communications to other computing sites for access to remote data bases
- o Image Separation Features - In many instances, when complex inputs are being compared, it will be difficult to distinguish the image of one input from that of another. Facilities will be provided so that color, pattern or texture can be placed into the optical paths of separate inputs for visual discrimination. Masks will also be placed into the optical path to partially blank each image permitting inputs to be compared edge-to-edge. See Figure 4-2 for a graphic explanation. Flickering of light sources, as described above under lighting control, is another means of separating images.
- o Comparison of More Than Two Inputs - It is difficult to combine many forms of input in this system due to optical/mechanical constraints and relatively low levels of luminescence for reflectively viewed inputs. In Phase I digital products can be displayed as maps or photo transparencies by first plotting the required data on sheet materials or photographic film. For Phase II the capability of entering digital data directly by projecting a video display into the image is possible.

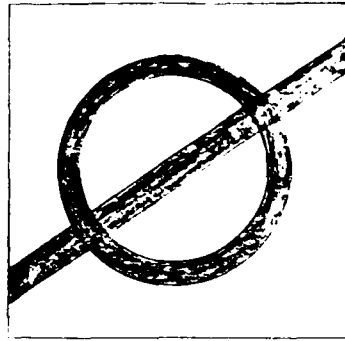


Image #1

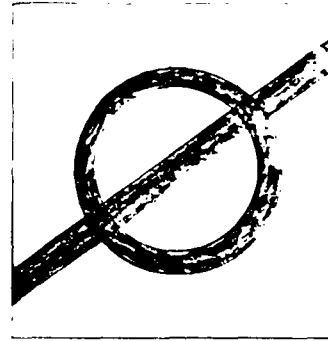
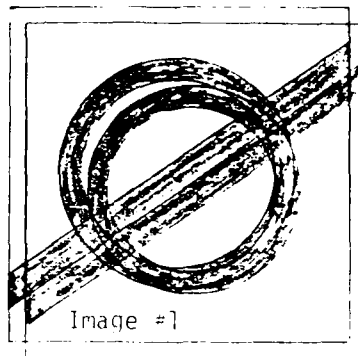


Image #2

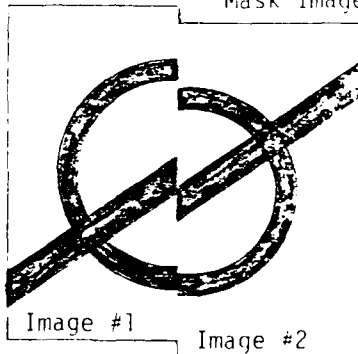


Superimposed But
Non-Aligned Images

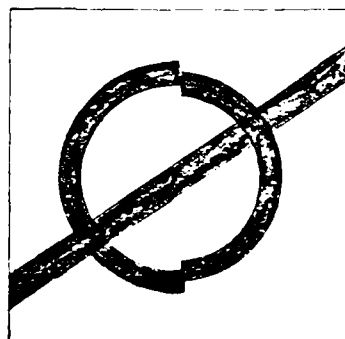
Mask Image #2

Image #2

Mask Image #1



Masks Inserted



Images Aligned With
Masks in Place. Size
Discrepancy in Circles
Is Now Apparent

Figure 4-2 Use of Masks For Image Separation

4.1.2 Summary

Advantages

- High resolution for hardcopy inputs
- Direct Use of Sensor Imagery
- Simplicity of operations
- Low maintenance
- Direct use of hardcopy inputs

Disadvantages

- Low light levels or restricted viewing for reflectively viewed inputs
- Phase II inclusion of digital data by video projection would result in low resolution and low image brightness
- High intensity lighting is necessary to sufficiently illuminate reflectively viewed inputs, possibly damaging one-of-a-kind inputs and making it necessary to provide facilities for removal of heat
- Geometric correction very difficult

4.2 Microform Optical Projector (MOP)

4.2.1 Description

The Microform Optical Projector, or MOP, is a modification of the DOV which improves the imaging of reflectively viewed inputs such as maps and charts. A separate, self contained Rapid Copy Subsystem (RCS), capable of serving multiple optical projection work station, would be used to reproduce reflectively viewed inputs as microform color transparencies. The resulting transparencies will permit a bright, sharp, full view image and allow optical design parameters to be less critical. The RCS will be operated in a normal working environment much like a plain paper copier. Premixed chemistry will be refreshed from throwaway containers and film will be entered by preloaded cassette or handloaded from a light proof shroud. A commercial example of a system with capability close to that required for the RCS is the Pos One 700 marketed by the visual Graphics Corporation.

Figure 4-3 shows the optical work station. The viewing surface is configured like a light table and tilted upward from the horizontal. A digitizing/computational facility is included and controlled by an integrated microprocessor. A numeric, digital readout from this facility displays digitized values or computational results. A word processing terminal linked to a central site computer is added for the display and edit of source/product descriptive or evaluation data. The optical

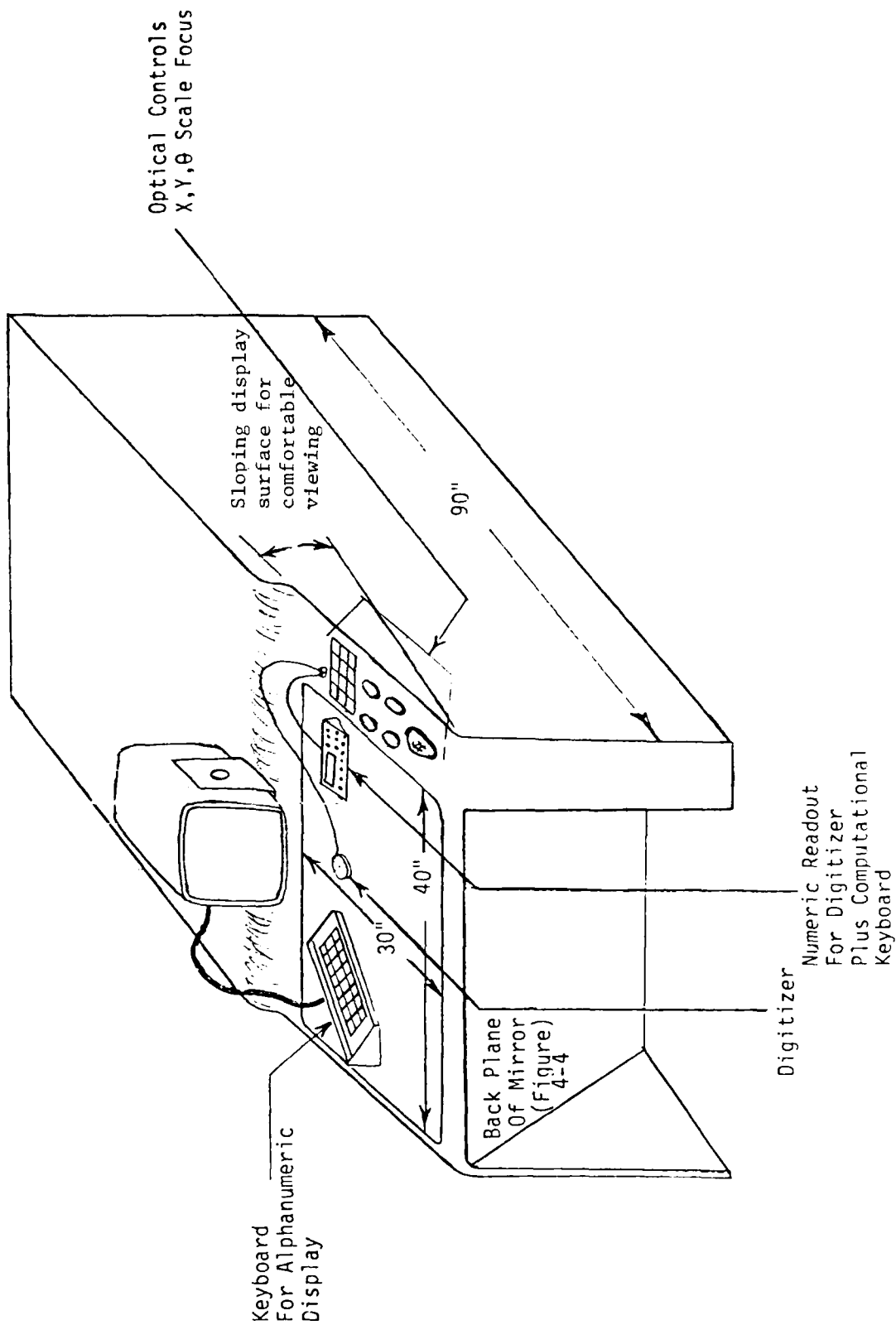


Figure 4-3 MOP Work Station

system shown in Figure 4-4 projects the images from the back of the work station. Control of these optics for alignment of images are adjacent to the viewing surface. Characteristics of the combined RCS and MOP are as follows:

- o High Resolution - Resolution is limited by optics and the grain size of photographic material to which inputs are reproduced. Only at the upper range of expected enlargements will film grain size be a factor.
- o Full Image, Light Table-like Viewing - The image will be viewed in the open on a backlighted working surface configured like a light table.
- o Bright Images - Transparent photocopies of reflectively viewed inputs will permit brightness levels of at least 50 foot Lamberts for all hardcopy sources or products. This level of brightness can be viewed in a normal office environment if the image is shaded from direct overhead lighting.
- o True Color Recognition and Presentation - Color reproduction will be approximated according to the color resolution of transparency films.

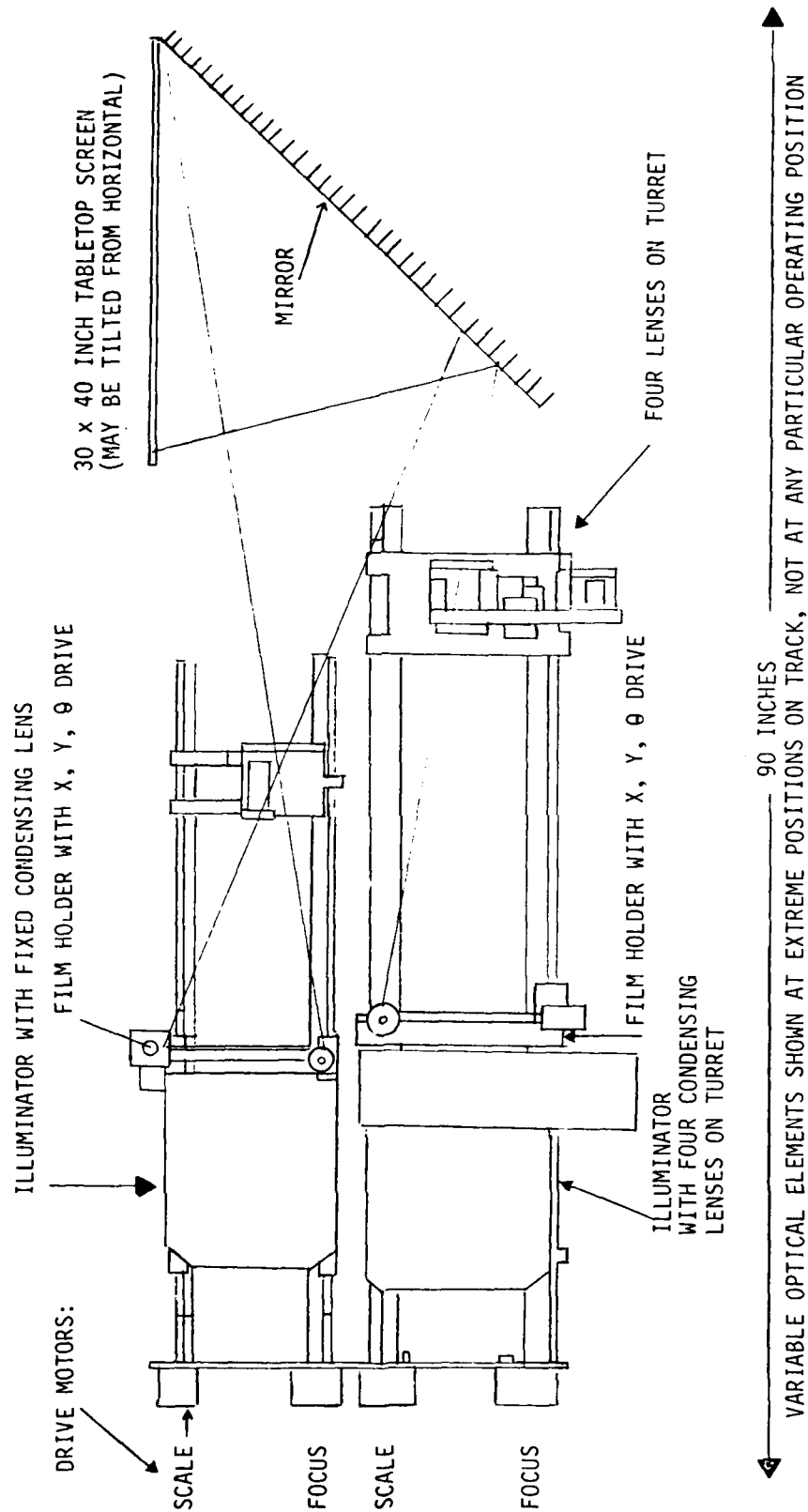


Figure 4-4 MOP Optics

- o Horizontal Positioning - For alignment of images, independent horizontal translation in two directions will be provided for each input. This will be implemented with electromechanical linkage which will allow accurate positioning with a minimum of physical input for the user.
- o Horizontal Rotation - Also for alignment of images, independent rotation using electromechanical links will be available for each input.
- o Tilting of the Optical Axis - The optical axis of the projected input will be individually tiltable relative to the image plane. This will create keystone distortion which can be used to simulate a degree of correction for differences in geographic projections or geometric distortions related to aerial sensor data. The amount of the distortion will be restricted by optical limitations such as light fall-off and depth of field.
- o Independent Continuous Scaling - Independent continuous enlargement for each input to a ratio of at least 5:1 will be provided.
- o Scaling via the RCS - Limited scaling of hardcopy input can be performed in the RCS for special scaling problems such as unusually small or large sources or products. Fixed settings relative to the film format will be employed.
- o Comprehensive Lighting Control - Independent adjustments of intensity of input illumination will be included. Intensity adjustments will compensate for scaling and relative transparency, and optimize viewing comfort. To help the separation of images a flickering feature will permit one image to be rapidly flickered. This will emphasize differences between two inputs.

- o Comprehensive and Convenient User Controls - User controls will be grouped close to the viewing surface. Mechanical movements of the projection apparatus will have electronic links to the users console for precise positioning with little physical effort by the user. Coarse and fine adjustments for all operations will be included.

- o Computational and Data Management Facilities - Computer facilities will be available as part of projection work station to perform the following utilities:
 - Input and display of source and product descriptive data

 - Input and display of source and product evaluation data

 - Editing capability of the above inputs and output of edited data in either hardcopy or electronic form

 - Digitizing and computational capability for mensuration or feature extraction.

- o Image Separation via the Projection System - Color or texture can also be placed into separate optical paths of the projector to encode sources for visual separation. Masks will be available for insertion into the optical path to partially blank each image and permit sources to be compared edge-to-edge. See Figure 4-2 for graphic explanation. Flickering light sources to achieve separation has been previously discussed under lighting control.

- o Feature Suppression via the RCS - For complex, multicolor hardcopy, color filtering can be used in the photographic step to enhance certain color coded features at the expense of others. The filtered image will be copied onto monochrome film and the resulting monochrome transparencies will be simplified with certain classes of unimportant features largely removed from the image.
- o Comparison of More Than Two Inputs - Luminescence is no longer the problem it was in the DOV but the optical mechanical constraints still limit generality so the design goal for hardcopy input will again be two individual optical channels. Digital data can be included by first plotting such data at a convenient scale onto transparent or translucent material that can be used as overlays on the light table surface.
- o Microform Library - Color transparencies of maps and charts generated by the RCS could be used to augment existing microform libraries or could be used to supplement existing data bases such as the SDDA portfolio. These transparencies can also minimize handling of originals and replace or supplement current backup capability.

4.2.2 Summary

Advantages

- High quality image
limited only by film
resolution and optics
- Full field viewing

Disadvantages

- Photographic step
for reflectively viewed
inputs
- RCS will require
a high level of
maintenance

- Bright image
- Light table-like viewing on a work surface
- Direct use of sensor imagery
- Increased opportunity for image separation and feature enhancement techniques
- Limited geometric correction
- Potential for extending existing microform libraries for backup or preservation of original sources
- No direct entry of digital products or sources

4.3 Digital Video System

4.3.1 Description

Figure 4-5 depicts a SAS based on video technology. A corresponding region in each input is scanned by a video camera. The cameras are lowered or raised and the lenses focused so the inputs can be compared at the same scale. Controls for scanning, alignment and focusing will be performed at a central console.

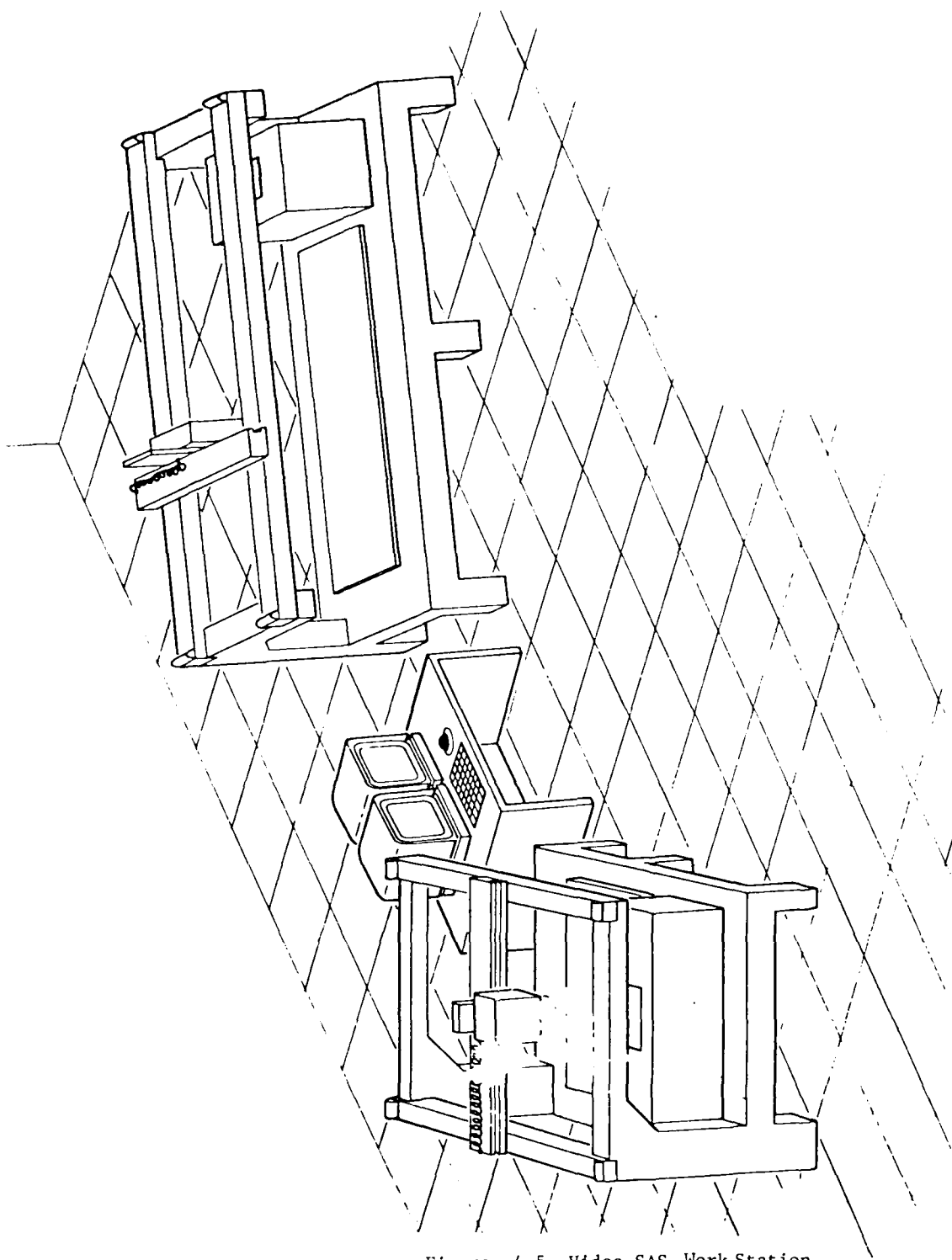


Figure 4-5 Video SAS Work Station

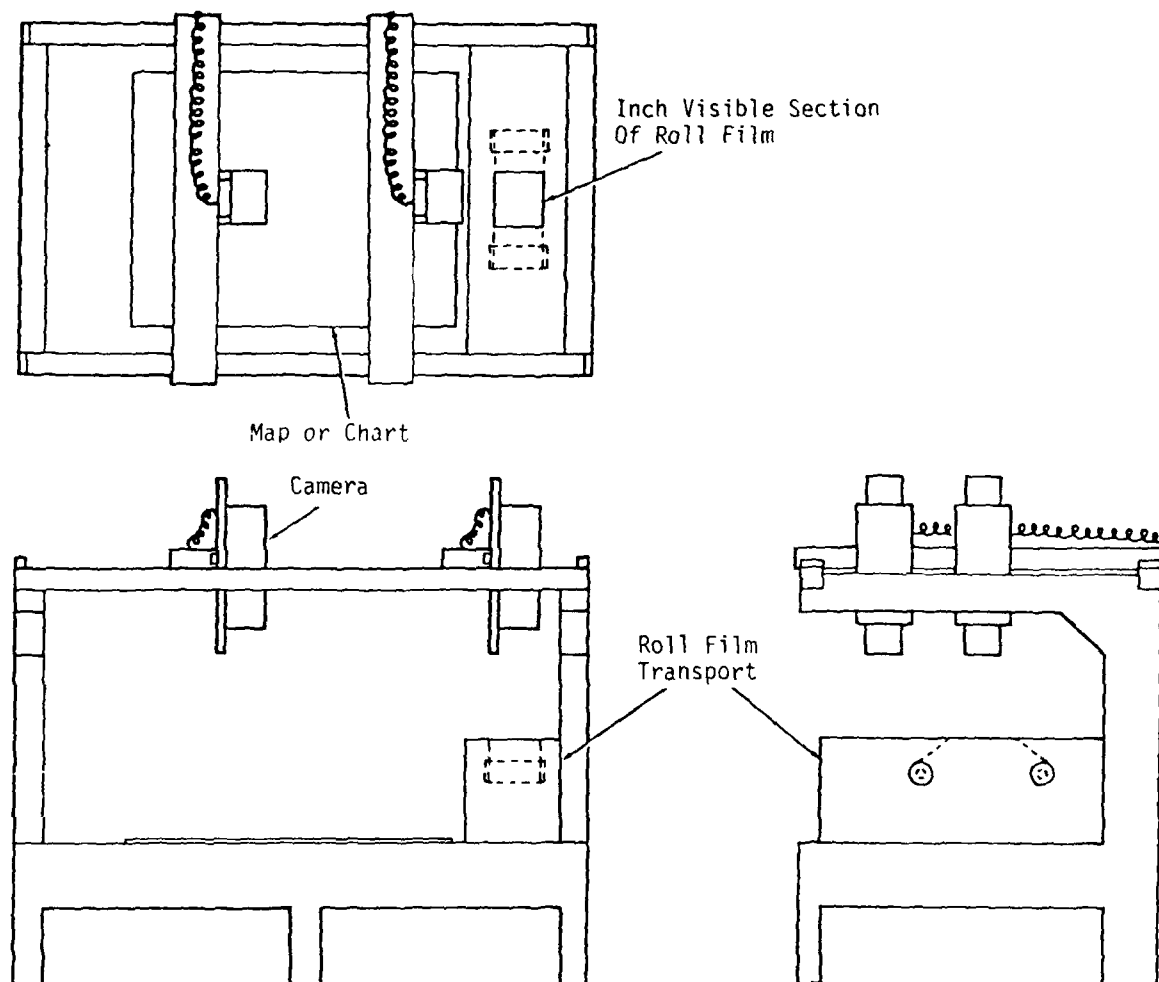


Figure 4-6 Video Input Station

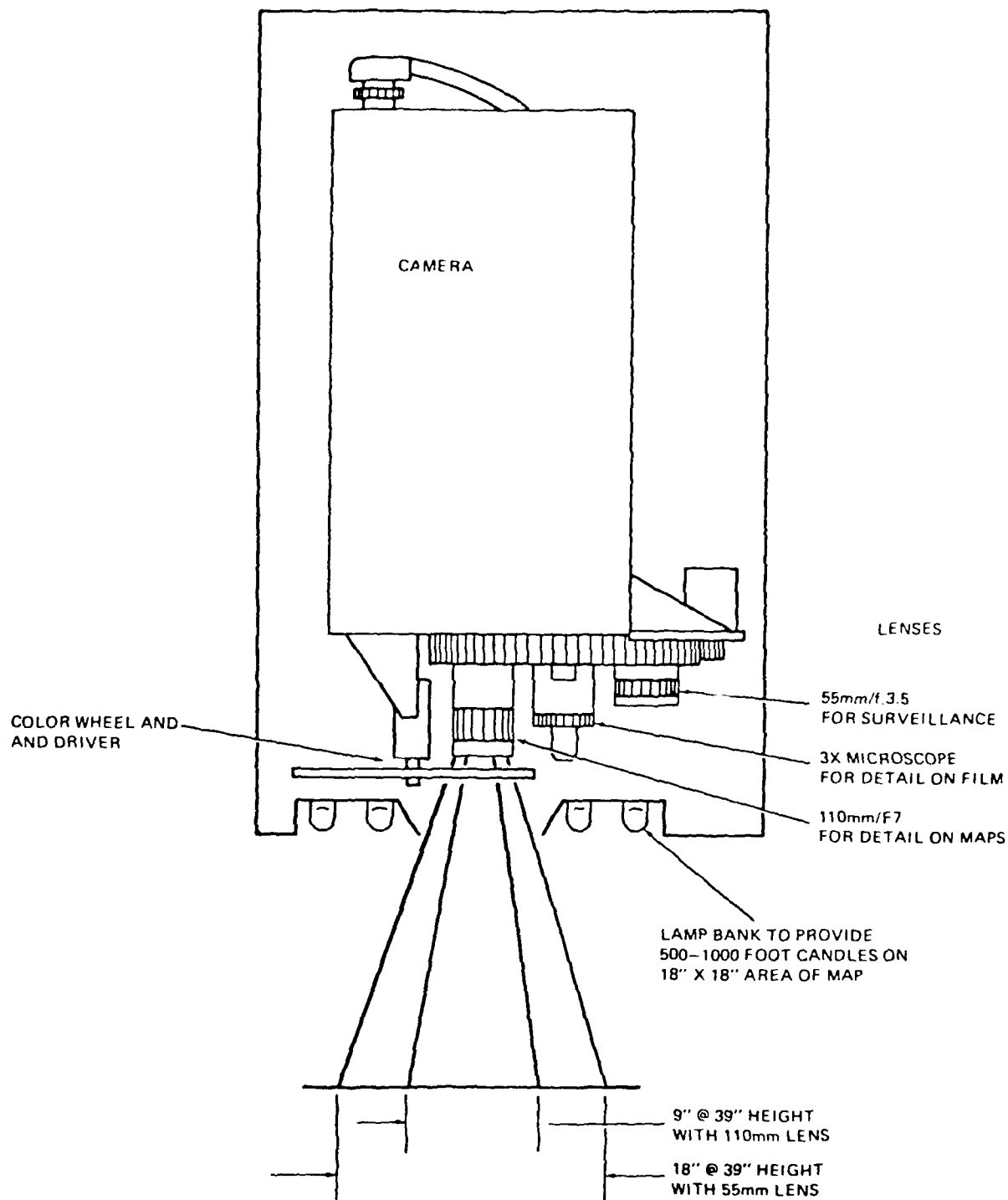


Figure 4-7 Camera Assembly for Digital Video System

Figure 4-6 shows details of the video input station. This station is depicted as permitting viewing of either maps and charts, or imagery transparencies. A roll film transport facility is placed at one end so a camera can be positioned above. A closeup of the video camera and associated optics are shown in Figure 4-7. The electronic images generated by the video cameras will be digitized by analog to digital converters to permit very generalized processing in a digital computer. Digital products or sources will be entered through standard digital I/O peripherals. The features of this system are as follows:

- o Electronic Imagery - Video cameras will be combined with analog to digital convertors to convert input images to a digital data stream. Such a data stream can be transmitted over flexible conductors avoiding the complex, structured optical links found in the purely optical systems. Additionally, digital imagery will permit complex image manipulation using a digital computer, well beyond what is practically possible with strictly optical/mechanical system.
- o Video Resolution - Resolution will be limited by the state-of-the-art video resolution (1024 in excess of by 1024 elements (pixels)) for the highest resolution black and white camera. If the focal length of the lens is selected such that one resolution element is 0.004 inch, the size of the field of view will be six (6) to eight (8) inches (see Appendix B). While this small field of view is satisfactory for comparison, a surveillance mode will be necessary to allow wide field viewing, of perhaps 24 x 24 inches, for overview and locality reference.
- o Video Display State-of-the-art video displays will be used. These displays will have a 19" diagonal, at least 1024 x 1024 resolution elements and full color. Extra data

- o channels will be provided for at least one more display, allowing side-by-side comparisons in addition to superpositional comparisons. The video displays will also have computer readable cursors to provide means for the user to interact with his images.
- o Bright Images - The video cameras and displays will deliver between 40 and 50 foot Lamberts. This is sufficient for operation in an office environment if a glare hood is used.
- o True Color Recognition and Presentation - Colored inputs will be displayed in approximate true colors. Color imaging will be impacted by the spectral response of video cameras, the phosphors used in video displays and computer memory bits dedicated to encoding color hues.
- o False Color Display - Any image stored in computer memory can be assigned false colors, pixel by pixel, by the user. False colors can be used for image separation and enhancement purposes.

- o Horizontal Translation - For alignment of images, independent horizontal translation in two directions will be provided for each input. This will be accomplished by relative movement between the video camera and its target, and be controlled at a central console via an electromechanical link.
- o Horizontal Rotation - In a similar manner, also for alignment, independent horizontal rotation will be provided for each input.
- o Scaling - Independent enlarging in a ratio of at least 4:1 will be provided using lens extension or a lens turret on the video camera. This will be used for convenience when small adjustments are necessary or especially large scale discrepancies are present.
- o Lighting Control - Control of lighting will be implemented. Independent adjustments of separate inputs for lighting intensity will compensate scaling differences and surface characteristics. The input interfaces will have selectable front and back lighting for both reflection and transmission viewing.
- o Comprehensive Centralized User Control - Control of the SAS will be centralized, conveniently located and interfaced to the mechanical/optical system through the digital computer. Computer driven controls can simplify operations for the user. For instance a trackball can be used to align images. Positional changes indicated by the trackball are scaled by the computer and output to mechanical systems to position the video cameras.

- o Digital Processing - A digital computer, which receives, processes and displays digital images, is a necessary component of a video system. This computer can be specified for enough processing power and I/O capacity to provide for the following capabilities:
 - Additional hardware for the Phase II goal of direct digital inputs.
 - Input, display, edit, and hardcopy or magnetic output of source descriptive and evaluation data.
 - Modular upgrade for additional hardcopy inputs for general multi-level comparisons.
 - Modular upgrade for additional video displays to provide a variety of display modes.
 - Digitizing capability for mensuration or feature extraction.
 - Application software for extended digital image analysis.
 - Capability to accept a wide variety of digital peripherals for mass storage, hardcopy text or graphics, or digital inputs.
 - Communications with other computing sites for possible access to remote data bases.

- o Electronic Image Separation - With digital processing, color or textural keys can be added into source images to encode them for visual separation. Images may also be partially blanked in a variety of ways permitting source to be compared edge-to-edge in addition to being superimposed. See Figure 4-2 for an example.
- o Electronic Feature Suppression or Enhancement - Any source image can be digitally processed to clarify or emphasize certain features which are especially significant to the user. Techniques such as edge enhancement, averaging or spatial filtering can be applied.
- o Generalized Geometric Correction - Images can be corrected by digital processing for differences in map projections, imagery geometries or imaging errors in the system itself.
- o General Multi-Input Comparison - The number of video inputs that can be compared are limited only by I/O and memory capacities of the computer. Multiple levels of inputs can be stored, processed and displayed. This can be accomplished in space by using multiple video inputs or in time by saving series of images in memory or mass storage.
- o Multi-Displays - More than one display can provide a wide range of side-by-side display modes for better comprehension of imaged sources or products.

- o Phase I/Phase II Growth Paths - A Phase I system would have two video inputs, one video display, and a digital computer which can be upgraded for Phase II needs such as digital mapping inputs, additional displays, and input and edit of descriptive source data. Such a growth path would also provide hands-on experience which would suggest the most valuable upgrades.
- o Available Technology - The main components required for a video system rely on current technology and are largely available on an off-the-shelf basis.

4.3.2 Summary

Advantages

- Excellent opportunities for Phase I design and smooth growth to Phase II requirements
- Required components are readily available
- Generalized image processing for separation, enhancement and correction
- Digital inputs are readily accepted

Disadvantages

- Resolution cannot meet that obtainable with optical or photographic systems
- Segmentation of inputs is required to obtain acceptable resolution, ruling out simultaneous wide field viewing

- Conversion of images
to a digital data stream
avoids inflexible and
cumbersome optical displays
- Modular upgrade for additional video inputs and displays
- Simple addition of
peripheral hardware for increased
processing power, input/output
and mass storage

4.4 Advanced Interactive SAS (AIS)

4.4.1 Description

The advanced interactive SAS or AIS extends the MOP by including a high resolution liquid crystal (HRLC) display system to meet phase II (1984-1986) requirements for input of digital products or sources. As in the MOP, the primary means of displaying reflectively viewed hardcopy (largely maps and charts) is through a photographic reduction step using a self-contained RCS. The RCS will produce positive color transparencies which will permit a reasonable design for the projection optics, a full view image and performance compatible with the HRLC. Reasonable optical design is especially important since the optical system must accommodate the liquid crystal components and still make possible a practical sized SAS. The format of sensor imagery will be compatible with the photocopy transparencies and imaged with the same projection optics.

Figure 4-8 conceptualizes the AIS. Imagery transparencies and photocopies of maps or charts are projected directly, and mixed on a light table surface with projected output from the HRLC. The figure suggests the multiple paths of inputs that are possible. Hard copy

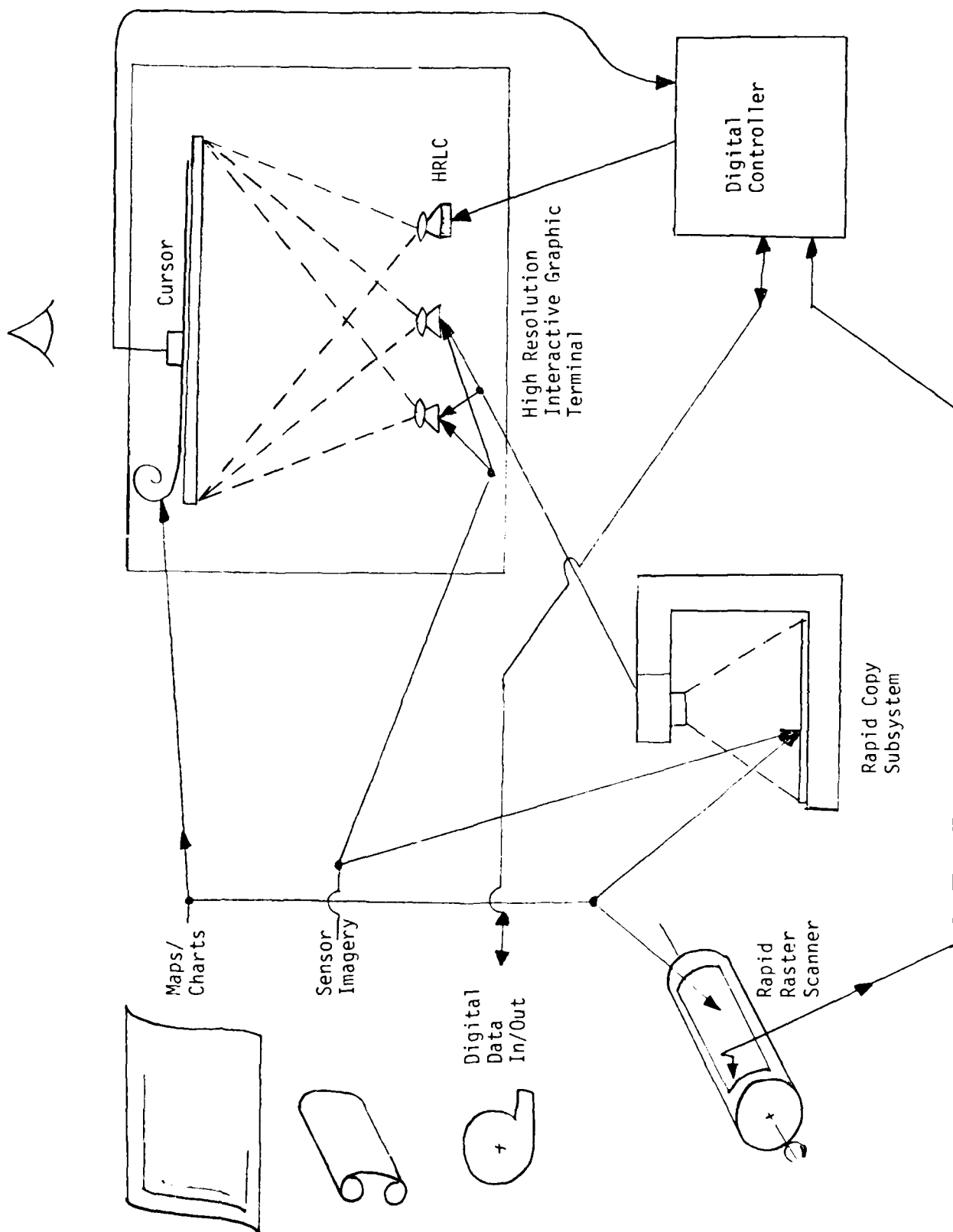


Figure 4-8 Advanced Interactive SAS (AIS)

can be photocopied using the RCS or, for special applications, digitized for input through the HRLC. Devices such as the illustrated raster scanner can be directly connected to the embedded digital controller. Transparent or semi-transparent materials can be used as overlays on the light table surface. A hand held cursor can interact with the HRLC to permit mensuration or feature extraction from displayed hardcopy. The user work station will be similar to that shown in Figure 4-3 for the MOP, but it must be able to incorporate the HRLC components in addition to the microform projection components. Figure 4-9 is a block diagram of the required components. There are two paths for microform projection and one for the information written on the HRLC. One microform image is combined with the HRLC light path to permit detection by the digitizing cursor.

Characteristics of this system are as follows:

- o High Resolution - The HRLC will be able to resolve elements comparable with the smallest found on mapping products, about 4 mils. The sensor imagery and map/chart reduction will be limited only by the optical system and the grain size of photographic films.
- o Full Image, Light Table-like Viewing - The image will be 30" x 40", and will be viewed in the open on a backlighted working surface, configured much like a light table.
- o Bright Images - The HRLC, sensor imagery and photocopies will permit brightness levels in the neighborhood of 50 foot Lamberts. This level of brightness can be viewed in a normal working environment if the image is shaded.
- o True Color Recognition and Presentation - Color reproduction will be approximated according to the color resolution transparency films.

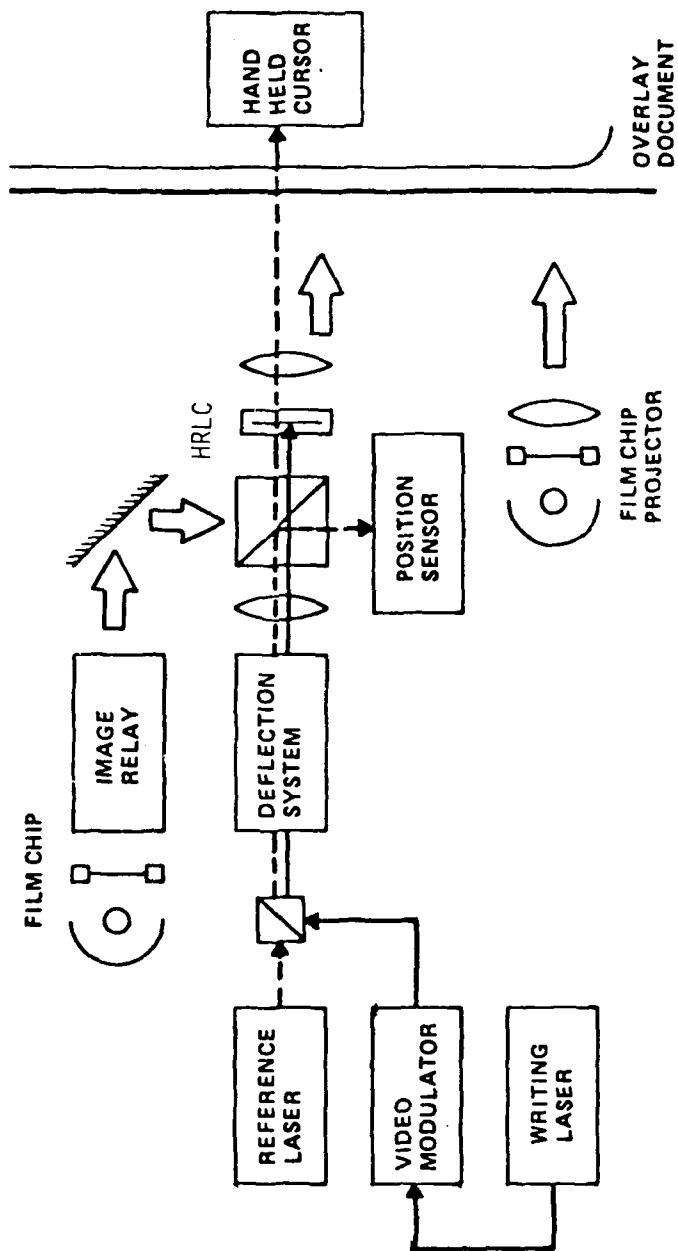


Figure 4-9 AIS Internal Components

- o Horizontal Translation - For alignment of hardcopy source, independent horizontal translation in two directions will be provided for each projected source. This will be implemented with electromechanical linkage (or digital processing in the case of digital input) which will allow accurate positioning with a minimum of physical effort for the user.
- o Horizontal Rotation - Also for alignment of images, independent rotation will also be available for each projected source.
- o Independent Continuous Scaling - Independent continuous enlarging of all inputs to a ratio of at least 4:1 will be provided.
- o Scaling via the RCS - Limited scaling of reduced inputs can be performed in the RCS for special scaling problems such as exceptionally large or small formats. A series of fixed settings relative to the film size will be included in the RCS.
- o Comprehensive Lighting Control - Control of lighting for projected inputs will be included in this SAS design. Light intensity will be adjustable for viewing comfort, compensation for scaling differences, compensation for relative transparency, and to match light output to the HRLC display. To help separate superimposed images a flickering feature will permit one image to be rapidly blinked. This will emphasize differences between the images of two inputs.
- o Comprehensive and Convenient User Controls - User controls will be grouped close to the viewing surface. Mechanical movements of the projection apparatus will have electronic links to the user's console for precise positioning with little physical effort by the user. Coarse and fine adjustments for operations will be included.

- o Digital Processing - A digital controller is required to accept digital input and drive the HRLC display and it can be specified to provide additional features such as:
 - Input and display of source or product descriptive data.
 - Input and display of source or product evaluation data.
 - Editing capability and output in hardcopy or magnetic form for the above inputs.
 - Generalized positioning and scaling of digital data for mixing with projected inputs.
 - Generalized geometric processing for digital inputs so they may be accurately superimposed with projected inputs.
 - Capability to accept a wide range of peripherals such as the raster scanner in Figure 4-8. Such a device can be used to account for special digital processing requirements for sheet or photographic materials.
 - Digitizing Capability (See Figure 4-9). For mensuration or feature extraction from digital or non-digital inputs. A digitizing cursor can optically and electronically link the viewing surface with the HRLC.
 - Optional communications to other computing sites for remote data base acquisition.
- o Feature Suppression via the RCS - For complex, multicolor hardcopy, color filtering can be used in the photocopy step to enhance certain color coded features at the expense of others. The filtered image will be copied onto monochrome

- o film and the resulting transparency will be simplified with certain classes of unimportant features largely removed from the image.
- o Image Separation via the Projection System - Color or texture can also be placed into separate optical paths of the projector to encode inputs for visual separation. Masks will also be available for insertion into the optical path to partially blank each image and permit inputs to be compared edge-to-edge. See Figure 4-2 for a graphic explanation. Flickering one image, mentioned under lighting control, is also available.
- o Generalized Processing for Digital Inputs - As mentioned above, under digital processing, very general geometric corrections and image processing can be applied to digital products and sources. This includes compensation for geographic projections when digital data is compared to maps and charts, adjustments for geometry associated with sensor imagery and errors associated with the optical portion of the SAS. Such processing is only limited by available software and processor capacity.
- o Multi-Path Assessment - In Figure 4-8, three potential paths are shown for maps, charts and similar inputs, direct use of the light table surface, photographic reproduction using the RCS or digital conversion using the raster scanner. Similar paths can be applied to the sensor imagery.
- o More Than Two Input Comparison - The physical dimensions of the photocopy transparencies will be close to that of the sensor imagery so these sources can be generally combined in two optical paths. These images can be fully mixed with the digital HRLC display and transparent or semi-transparent inputs can be compared on the light table-like viewing surface.

4.4.2 Summary

Advantages

- Directly accepts digital information
- High resolution display for digital and hardcopy source
- Light table-like viewing
- Full field viewing
- Embedded digital controller allowing many digital processing options
- Interaction with images for mensuration or evaluation functions
- Multiple imaging paths for hardcopy sources
- At least three layers of source may be superimposed, mixing maps/charts, sensor imagery and digital data
- Photographic step provides potential for extending existing and microform libraries of maps and charts for backup or preservation of original sources

Disadvantages

- Photo reduction step for maps/charts digital sources
- RCS camera requires dedicated operator for efficient operation and maintenance
- Only limited geometric correction and enhancement for hardcopy
- HRLC displays have only limited ability to depict digital data encoded with gray levels
- Liquid crystal technology requires additional development

5.0 TRADE-OFF ANALYSIS

The 24 evaluation factors defined in Section 3.3 will serve as a basis for evaluating the four design concepts described in Section 4.0. A quantitative rating scheme is used so a numeric value can be assigned, based on each design concept's ability to deal with each factor. A perfect rating of 10 is given to a design which can fully meet all aspects of a evaluation factor. If a design does not address a factor at all, it is assigned a zero (0). Intermediate values set estimated break points based on required SAS performance and allow each design to be properly rated. Since the impact of each evaluation factor ranges from critical to purely optional, each is given a relative weighting as follows:

Weighting

<u>Value</u>	<u>Description</u>
5	The evaluation factor is fundamental. If this factor is not dealt with, a SAS cannot perform its intended mission.
4	The evaluation factor is very important. If this factor is not well addressed, the scope of the SAS will be restricted or its operation will be cumbersome.
3	The evaluation factor is important. The ability to fully address this factor will improve the efficiency of assessment procedures or widen the range of possible inputs.

2 The evaluation factor is a useful option which increases the scope of operational capability, providing flexibility for techniques or acceptance of very specialized inputs.

1 Provisions for this evaluation does not support the SAS in meeting beyond its primary mission of source/product comparison and assessment.

These weighting values will be multiplied by the assigned rating for each evaluation factor. The results will then be added in a columnar fashion to obtain a relative, quantitative evaluation of each of the four design concepts. Table 5-1 presents the 24 evaluation factors along with their weighted value, the rationale for this weighting and the associated rating scheme.

In such a procedure the numeric ratings are not absolute but form a point of concurrence among project personnel. Each of the four (4) designs was discussed in light of each evaluation factor so that a mutually agreeable rating could be arrived at.

5.1 Results and Justification

Table 5-2 summarizes the results of the tradeoff analysis. The first column itemizes the 24 evaluation factors and the second column lists the weighting assigned to each factor. Columns 3 through 10 are paired under each of the design concepts and contain the rankings and weighted rankings of each design-factor combination.

The columns are subtotaled under each subdivision (Input Capability, Performance Criteria, Functional and Imaging Characteristics, Human Engineering, Implementation) and grand totaled at the bottom of the table. To avoid grossly over-evaluating a particular subdivision, subtotal rankings were normalized to 100. For instance, a perfect score under Input Capability would gross 230 point (23×10) while a perfect rating under Implementation would

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FACTOR	WEIGHTING	RATING
(1) Ability to Image Maps and Charts	5 Fundamental requirement	10 Maps and charts are directly accepted and imaged over their entirety. 5 Maps and charts can be directly accepted but must be subdivided in the imaging process. 2 Maps and charts can be imaged in their entirety but must undergo a preprocessing step.
(2) Ability to Display Photographic Transparencies (≤11" x 11")	5 Fundamental requirement	10 Can be accepted directly and imaged over their entirety. 5 Can be directly accepted but must be imaged in a subdivided form. 2 Can be imaged in their entirety but must undergo a preprocessing step.
(3) Ability to Image Digital Products and Sources	4 A SAS without digital capability will still fulfill Phase I requirements	10 Can accept and display digital data in matrix, vector and raster format. 8 Can accept and display digital data only in matrix and vector form. 2 Can accept and display digital data only through a hardcopy process. 0 Cannot accept digital data in any form.

Table 5-1 Evaluation Factors Weightings and Ratings (page 1 of 8)

FACTOR	WEIGHTING	RATING
(4) Ability to Image Miscellaneous Hardcopy	2 Optional ability for extended range and flexibility	10 Can accept any hardcopy format 5 Can accept one or two hardcopy materials other than maps and charts 0 Cannot accept any special hardcopy formats
(5) Input of Source Evaluation Data	2 Useful option which increases scope of operational capability	10 Can provide comprehensive entry, review, edit and mensuration capability 5 Can provide only entry and review of evaluation data 0 Does not provide this capability
(6) Number of Mix of Inputs that can be simultaneously compared	5 It is mandatory for SAS to be able to compare two inputs on a one-to-one basis.	10 Maps, charts, sensor imagery and digital data can be freely mixed for one-to-one comparisons. 7 Three inputs can be simultaneously compared on a one-to-one basis, a single sensor image and two maps or charts. Capability exists for Phase II inclusion of digital data. 5 A map or chart can be compared to a sensor image or a map or chart but only two inputs can be compared at a time. Direct input for digital data can be added at a future date. 5 A sensor image can be compared to two maps or charts on a one-to-one basis but there are no direct means to enter digital data. 0 A map or chart can be compared to a sensor image or a map or chart but here are no direct means to include digital data.

Table 5-1 Evaluation Factors Weightings and Ratings (page 2 of 7)

FACTOR	WEIGHTING	RATING
(7) Resolution	5 It is mandatory that a SAS resolve detail that is significant to source assessment.	10 A 4 mil or smaller feature can be resolved over a 30" x 40" area. 8 A 4 mil feature can be resolved in 12" x 16" area. 5 An area as small as 9" x 12" is required to resolve a 4 mil feature. 0 An area $\leq 6"$ x 9" is required to resolve a 4 mil feature.
(8) Accuracy	5 It is mandatory that the SAS does not introduce errors which exceed the accuracies of the inputs.	10 Accuracy $\geq +2$ mils 7 Accuracy = ± 4 mils 3 Accuracy = ± 6 mils 0 Accuracy $\leq \pm 10$ mils
(9) Scaling Range	5 It is a SAS requirement that inputs can be viewed at the same scale.	10 Continuous, independent relative enlargement $\geq 10:1$ is provided 5 Continuous enlargement of 4:1 is provided 0 Enlargements of only 2:1 are possible, enlargements must be done in steps or only one input can be enlarged

Table 5-1 Evaluation Factors Weighting and Ratings (page 3 of 8)

FACTOR	WEIGHTING	RATING
(10) Image Brightness	5 An image must be sufficiently bright to permit quick and effortless viewing of cartographic/photographic detail.	10 A brightness $\geq$ 60 foot Lamberts 5 25 foot Lamberts 0 4 foot Lamberts
(11) Uniformity of Image Brightness	5 Portions of an image cannot be below visibility	10 Fall off is undetectable 5 Fall off is detectable but all detail is visible 0 Portions of the image are too dark to be seen
(12) Image Size	5 A user cannot practically use a display that shows only a small percentage of his input or severely reduces the scale.	10 A 30" x 40" or larger input can be viewed at a scale $\geq$ its actual scale. 8 A 24" x 32" input can be viewed in its entirety at a scale $\geq$ its actual scale. 5 A 9" x 12" input can be viewed in its entirety. 0 Only an input $\leq$ 6" x 8" can be displayed in its entirety at its original scale.

Table 5-1 Evaluation Factors Weightings and Ratings (page 4 of 8)

FACTOR	WEIGHTING	RATING
(13) Identification or Separation of Input Images	5 A SAS cannot perform its primary function if displayed detail cannot be easily distinguished by source.	10 A wide selection of capabilities is possible so separation can be tailored to the inputs in question. 5 A limited set of methods is provided. 0 No special techniques for separation.
(14) Feature Suppression or Enhancement	3 This capability will enhance the ability of a SAS to cover specialized assignments.	10 A wide selection of capabilities is available so feature suppression or enhancement can be tailored to specific problems. 5 A limited set of methods for feature enhancement or suppression is available. 0 No capability is possible.
(15) Global Image Registration	4 It is assumed that scaled inputs will register over a limited field without this capability so that, while it is very important its primary value will be improvement of operational efficiency.	10 Any inputs can be registered over the entirety of their overlapping coverage. 5 Inputs can be registered over 25% of their overlapping coverage. 0 Inputs can only be registered over an area <10% of their overlapping coverage.

Table 5-1 Evaluation Factors Weightings and Ratings (page 5 of 8)

FACTOR	WEIGHTING	RATING
(16) Real Time Registration	5 It is mandatory that a user be able to conveniently re-register his inputs as he locally scans the images.	10 The user can make all required adjustments in ≤ 10 seconds. 5 It takes the user 30 seconds to make all required adjustments. 0 It requires excessive time (> 1 minute) to make all required adjustments.
(17) True Color Recognition and Display	2 Maps and Charts are the only predominate form of input which is normally colored, but the coloring scheme uses relatively few separate hues and tests have shown that these hues can usually be distinguished by gray shades.	10 Available range of hues permit colored imaging to replicate the original input. 5 True color can be approximated by a limited range of hues. 0 Monochrome imagery only.
(18) Tonal Gray Level Recognition and Display	5 A fundamental feature	10 A continuous range of gray levels can be recognized and displayed. 8 16 gray levels 5 8 gray levels 0 2 gray levels

Table 5-1 Evaluation Factors Weightings and Ratings (page 6 of 8)

FACTOR	WEIGHTING	RATING
(19) Hardcopy Outputs	2 Outputs in addition to user understanding are not critical.	10 Textual plus continuous raster, color and line graphics 7 Textual plus line graphics 5 Textual or line graphics only 0 No capability
(20) Setup Time	4 While very important, lack of performance in this area will not preclude the ability to perform assessment.	10 $\leq$ 5 minutes 5 10 minutes 0 $\geq$ 20 minutes
(21) User Interface	3 Important but lack of convenience features does not preclude assessment functions.	10 The user can control SAS functions from a centralized position using automatic controls, and work in comfortable position and environment. 5 The user must occasionally leave his working position to operate controls or view images from a limited position. 0 A user must often change position to operate controls, must view his images from a fixed position or work in a special environment.

Table 5-1 Evaluation Factors Weightings and Ratings (page 7 of 8)

FACTOR	WEIGHTING	RATING
(22) Accessibility of Inputs	3 Improves efficiency of many assessment assignments	10 A user can freely access his inputs and they are close to his working position. 5 A user can only interact with his inputs indirectly through the image or other means. 0 No means are available to interact with the inputs.
(23) Phase I/Phase II Transition	4 Important but not crucial to primary assessment capabilities.	10 Technology provides for Phase I requirements and straightforward growth to full Phase II capability. 5 Technology provides for Phase I requirements but extensive redesign would be necessary to meet Phase II requirement. 0 Technology provides for only Phase I requirements and different technology is necessary to address Phase II requirements.
(24) Technological Risk	4 Important but does not rule out the ability to provide a great deal of assessment capability.	10 Complete system can be purchased off-the-shelf. 8 All components of the system can be purchased off-the-shelf. 5 A required primary technology is well established but the components require design and construction to provide the specialized needs of source assessment. 0 All components rely on a high risk technology.

Table 5-1 Evaluation Factors Weightings and Ratings (page 8 of 8)

Evaluation Factors	Assigned Weighting	Direct Optical Viewer		Microform Optical Projector w/Keystone		Digital Video System		Advanced Interactive SAS	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
<u>Input Capability</u>									
(1) Maps and Charts	5	6	30	2	10	5	25	2	10
(2) Imagery Transparencies	5	10	50	10	50	5	25	10	50
(3) Digital Inputs	4	2	8	2	8	10	40	8	32
(4) Miscellaneous Hardcopy	2	5	10	7	14	9	18	7	14
(5) Evaluation Data	2	6	12	6	12	9	18	9	18
(6) Number and Mix of Inputs	5	0	0	0	0	9	45	5	25
Subtotal	23	29	110	27	94	47	171	41	149
Normalized Subtotal			47.8		40.9		74.3		64.8

Table 5-2 Trade-Off Analysis Summary (Page 1 of 5)

Evaluation Factors		Assigned Weighting		Direct Optical Viewer		Microform Optical Projector w/Keystone		Digital Video System		Advanced Interactive SAS	
				Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
<u>Performance Requirement</u>											
(7)	Resolution	5	8	40	50	10	50	0	0	10	50
(8)	Accuracy	5	9	45	35	7	35	5	25	7	35
(9)	Scaling Range	5	5	25	45	9	45	9	45	9	45
(10)	Image Brightness	5	1	5	45	9	45	9	45	9	45
(11)	Uniformity of Image Brightness	5	8	40	45	9	45	9	45	9	45
(12)	Image Size	5	8	40	50	10	50	0	0	10	50
Subtotal		30	39	195	270	54	270	32	160	54	270
Normalized Subtotal				65.0	90.0		90.0		53.3		90.0

Table 5-2 Trade-Off Analysis Summary (Page 2 of 5)

Evaluation Factors	Assigned Weighting	Direct Optical Viewer		Microform Optical Projector w/Keystone		Digital Video System		Advanced Interactive SAS		
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	
<u>Functional and Imaging Characteristics</u>										
(13) Separation of Inputs	5	3	15	5	25	9	45	5	25	
(14) Feature Enhancement/Suppression	3	1	3	3	9	9	27	3	9	
(15) Global Registration	4	0	0	6	24	8	32	6	24	
(16) Real-Time Registration	5	9	45	9	45	8	40	9	45	
(17) True Color Perception	2	10	20	9	18	5	10	9	18	
(18) Gray Scale Detection	5	10	50	10	50	8	40	10	50	
(19) Hard Copy Outputs	2	5	10	5	10	9	18	6	12	
Subtotal	26	38	143	47	181	56	212	48	183	
Normalized Subtotal			55.0		69.6		81.5		70.4	

Evaluation Factors	Assigned Weighting	Direct Optical Viewer		Microform Optical Projector w/Keystone		Digital Video System		Advanced Interactive SAS	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
<u>Human Engineering</u>									
(20) Setup Time	4	10	40	3	12	8	32	3	12
(21) Users Interface	3	4	12	9	27	8	24	9	27
(22) Accessibility of Inputs	3	4	12	7	21	8	24	7	21
Subtotal	10	18	64	19	60	24	80	19	60
Normalized Subtotal			64.0		60.0		80.0		60.0

Table 5-2 Trade-Off Analysis Summary (Page 4 of 5)

Evaluation Factors	Assigned Weighting	Direct Optical Viewer		Microform Optical Projector w/Keystone		Digital Video System		Advanced Interactive SAS	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
<u>Implementation</u>									
(23) Phase I/Phase II	4	0	0	2	8	9	36	8	32
(24) Technical Risk	4	5	20	5	20	8	32	2	8
Subtotal	8	5	20	7	28	17	68	10	40
Normalized Subtotal			25.0		35.0		85.0		50.0
Total Rating	97	129	532	154	633	176	691	172	702
Normalized Total			257		296		374		335

Table 5-2 Trade-Off Analysis Summary (Page 5 of 5)

gross only 80 (8 x 10). To compensate for this discrepancy the normalized subtotals are computed as:

$$\text{Normalized Subtotal} = (100/\text{perfect score}) \times \text{Subtotal}$$

To arrive at a normalized subtotal for the Input Capability example, each subtotal is multiplied by 0.435 or $100 - 230$. To arrive at the normalized total, the normalized subtotals are added in a columnar fashion.

Table 5-3 summarizes the results of Table 5-2 by listing the four design concepts in order of their ranking.

<u>NORMALIZED RANKING</u>		<u>UNNORMALIZED RANKING</u>	
<u>Design Concept</u>	<u>Totals</u>	<u>Design Concept</u>	<u>Totals</u>
DVS	374	AIS	702
AIS	335	DVS	691
MOP	296	MOP	633
DOV	257	DOV	532

Table 5-3 Trade-Off Analysis Ranking

The normalized totals indicate the DVS as the primary candidate for a SAS but the unnormalized totals suggest that the AIS is the desirable candidate. However, it is felt that the normalized totals are more valid for this analysis. The unnormalized totals do not reflect the fact that some subdivisions contain more evaluation factors than others. The subdivisions could also be weighted if, for instance,

performance was considered more significant than input capability, but it is just as enlightening to examine them individually. If this is done performance criteria is the key issue. The DVS was superior in every subdivision except performance, where it ranked lowest. To make the DVS a final choice for a SAS, its lack of performance must be measured against its superiority in every other category.

The rationale which led to the ratings in Table 5-2 and the resulting rankings in Table 5-3 is documented according to each evaluation factor as follows:

Input Capability

(1) Ability to Image Maps and Charts

The DOV is ranked a 6 because, while it may be possible to image a map or chart directly with a full field view, low light levels may force the design to use a restricted angle of view. See Appendix A.

The MOP and AIS are ranked low because a preprocessing step is required to obtain an acceptable microform of a map or chart. The DVS is ranked a 5 because low resolution will necessitate a subdivided image.

(2) Ability to Display Imagery Transparencies (< 11" X 11")

The DOV, MOP and AIS should have no difficulty displaying an imagery transparency. The DVS is ranked only a 5 because the image will be subdivided to obtain desired resolution elements.

(3) Ability to Image Digital Products and Sources

The DVS is capable of accepting and imaging all formats of digital data. The AIS is given only an 8 because the HRLC is limited in its ability to depict gray shades. The DOV and MOP can accept only line

or character plots of digital data and are therefore rated only a 2.

(4) Ability to Image Miscellaneous Hardcopy

The DOV is given only a 5 because strict optical design will limit flexibility. The MOP and AIS are ranked higher because the photocopy step can be used to reduce a variety of hardcopy to a standard format and high light levels permit the optics to be more generalized. The DVS can directly image nearly all forms of hardcopy input.

(5) Input of Source Evaluation Data

The DOV and MOP can be specified to provide this capability by including a separate mini-computer facility or a link to a central computer, but the DVS and AIS are judged to offer more in this area because they require a built-in digital processor which can be extended quite generally.

(6) Number and Mix of Inputs that can be Simultaneously Compared

The DOV and MOP will be structured for two optical inputs for maps, charts or transparencies. The AIS will have two optical inputs plus digital. The DVS is very general allowing images to be compared from space (two video inputs) and from time (images saved on mass storage) for multi-level comparisons.

Performance Criteria

(7) Resolution

The DOV, MOP and AIS can all deliver high resolution images. The DOV is slightly downgraded because low brightness may lower true resolution. The DVS can be expected to require a subfield in the neighborhood of 6" x 9" to resolve a 4 mil feature.

(8) Accuracy

Accuracy is difficult to fix before an actual design is accomplished but the DOV which uses a single optical path should have little difficulty with accuracy. The MOP and AIS require a two-step optical path, the RCS and the projection system, and therefore, opportunity for inaccuracies are more prevalent. The DVS is further down-rated due to optical-electronic interfaces for both input and output.

(9) Scaling Range

The MOP, DVS or AIS should be able to deliver continuous independent enlargement close to a 10:1 ratio. The DOV is downrated because strict optical design will limit the scaling range.

(10) Image Brightness

The MOP, DVS and AIS should be able to deliver over 30 foot Lamberts.

The DOV will be significantly inferior and maximum output for reflectively viewed inputs will be less than five (5) foot Lamberts.

(11) Uniformity of Image Brightness

The MOP, DVS and AIS may exhibit some falloff of brightness at the perimeter of the image due to optical constraints but it is unlikely that this will be detectable under normal circumstances. The DOV is rated lower because low light levels may force an optical compromise such as a limited viewing field or angle.

(12) Image Size

The DOV may be able to deliver a full view image of a 30" x 40" chart but is rated low because lack of light may require the design to use a limited field or angle of view. The DVS is limited by resolution to approximately a 6" x 9" field. The MOP and AIS should not have difficulty imaging a large chart in its entirety.

Functional and Imaging Characteristics

(13) Separation of Inputs

Separation techniques can be accomplished in the DOV by inserting filters or masks into the optical path or by flickering the projection lighting. The MOP and AIS offer more possibilities by utilization of the RCS. The DVS offers, by far, the most opportunity for separation through techniques such as false color assignment and mathematical processing.

(14) Feature Suppression or Enhancement

Selective enhancement or suppression of features requires similar but more complex capabilities than image separation. For this capability the DVS has an even greater advantage over the other concepts.

(15) Global Registration

The DOV is given a 0 because strict optical design associated with low light levels will not allow for the added complexity of geometric correction. The MOP and AIS are rated a 6 because a degree of optical correction is possible, either keystone or anamorphic. Very general corrections can be accomplished by the DVS. For example, parameters associated with geographic projections or imagery corrections could be entered by the user, allowing a best fit between two inputs to be calculated and applied to the imaging sequence.

However, because the DVS has limited resolution, these corrections can be applied only over a small field of view and therefore the DVS is not given a maximum rating.

(16) Real Time Registration

The DOV, MOP and AIS should all be capable of reasonably quick fine tuning of registration, using electro-mechanical links for translation, rotation and enlargement. The DVS is rated less because it will require realignment a number of small subfields.

(17) True Color Recognition and Display

The DOV is only limited by optics and image colors will essentially be those of the input. The MOP and AIS are ranked slightly lower because dye layers used in the photocopy step for maps and charts are discrete and do not truly represent the physical spectrum. The DVS is limited by vidicon spectral response, phosphors used in the display and a discrete color spectrum and is therefore assigned only a 5.

(18) Tonal Gray Level Recognition and Display

The DOV, MOP and AIS will all provide a continuous range of gray shades which is only limited by the transparency films used for imagery. The DVS is limited by the number of digital memory bits assigned to gray shades which results in limited discrete levels.

(19) Hardcopy Outputs

The DOV and MOP will be capable of textual output through the use of an adjacent but separate minicomputer or a link to a central computing facility. The DVS offers a high degree of power in this area because images are in electronic form and can readily be output to a textual or graphic device. The AIS also requires a built-in processor but since it still images maps, charts and imagery

transparencies directly, there is less opportunity for new output.

(20) Setup Time

The DOV provides the best configuration for quick setup. A user simply places his inputs in front of the imaging optics. The MOP and AIS are ranked low because of the necessity of preprocessing maps and charts. The DVS is ranked higher but is judged somewhat less convenient because only a subfield of the input can be seen at any one time making it necessary for a user to locate his area of interest by first employing a surveillance mode.

(21) Users Interface

The DOV is ranked low because the minimal light levels of the image may require a limited field or angle of view and an environment with severely subdued lighting. The MOP and AIS provide light table-like viewing in a conventional cartographic environment. The DVS, while offering comfortable viewing, presents an interface that tends to isolate the user from his image and differs from traditional work methods.

(22) Accessibility of Inputs

Due to strict optical requirements and the need for high intensity lighting in the DOV, it is not likely that a user can easily access his inputs. There will, however, be indirect access through the imaging surface and an attached digitizer. The MOP and AIS offer facilities similar to those of the DOV but are ranked higher because the photocopy step for maps and charts allow the original input to be brought to the viewing surface for annotation. The DVS is ranked higher because it offers opportunity for a high degree of interaction through the image and can be easily configured such that the inputs are close to the viewing position. See Figure 4-5.

Implementation

(23) Phase I/Phase II Transition

The DVS, by far, offers the most opportunity for Phase I to Phase II growth. This would be largely a matter of adding processing power, peripherals and software. Although the AIS takes into account the Phase II requirement for digital data, it is ranked slightly lower because it does not have the flexibility for growth that the DVS has and would be expensive to build for only Phase I requirements. The DOV provides limited opportunity for direct digital inputs or a wider mix of inputs, largely due to inherently low brightness levels. The MOP is rated a 2 because the image brightness and photocopy step do provide some expansion capability for hardcopy and there is potential for direct entry of digital data through the use of a video projection system.

(24) Technological Risk

Many of the DVS video and digital components can be purchased off-the-shelf. The DOV and MOP will use well-established technologies but will need custom-designing. The HRLC components required for the AIS need more development and therefore present an element of risk.

5.2 Cost Performance

Although the DVS was ranked highest by the Trade-off Analysis it is also valuable to examine each design concept in terms of cost performance. True costs incurred from the implementations of any of the four (4) proposed systems are difficult to fix at the design concept level, but it should be possible to project realistic cost magnitudes and relative costs between concepts. Table 5-4 shows a projected range of costs for each of the concepts. The costs are broken down into repeat costs that reflect the cost of components and installation that are incurred for every unit purchased, and first-time costs that include development or first-time costs such as design, specifications, first-time fabrication, integration and test. Table 5-5 shows these costs along with their trade-off performance rating and resulting cost performance. The cost performance was computed by dividing the rating by the cost such that the largest numeric value represents the best dollar performance.

The results suggest that the DOV offers the best cost performance regardless of relatively poorer technical performance indicated by the Trade-off Analysis. Since the DOV is not the best performer it represents a risk to DMAAC in that, if implemented, it may not perform adequately. With this in mind the possibility of a DVS with a better cost performance was explored. This exercise revealed an optional approach based on an Analog Video System or AVS, that can serve as a Phase I SAS and may represent a savings between \$160K and \$360K.

In the AVS concept video cameras and displays and input devices are retained but digital control and image processing is replaced by analog electronics. An analog system would permit a limited but useful set of functions for scaled, side-by-side or superimposed comparison of sources and products. The AVS can be rated against the 24 evaluation factor as were the other four design concepts. If this is done it parallels the DVS quite closely. It suffers somewhat due to decreased generality (a strong point in the DVS) but offers

	Development Costs (\$1000)		Repeat Costs (\$1000)		Total First Time Costs (\$1000)	
	Low	High	Low	High	Low	High
Direct Optical Viewer	\$85	\$130	\$50	\$80	\$135	\$210
Microform Optical Projector	\$115	\$180	\$50	\$70	\$165	\$250
Digital Video System	\$160	\$280	\$170	\$250	\$330	\$530
Advanced Interactive SAS	\$450	\$725	\$350	\$530	\$800	\$1255

Table 5-4 Development and Repeat Costs Summary

Design Concepts	Direct Optical Viewer		Microform Optical Projector		Digital Video System		Advanced Interactive SAS	
	Low	High	Low	High	Low	High	Low	High
Expected First Time Costs (\$1000)	\$135	\$210	\$165	\$250	\$330	\$530	\$800	\$1255
Trade-Off Performance Rating	257		294		374		335	
Performance/ Cost Ratio	19.0	12.2	17.8	11.8	11.3	7.1	4.2	2.7

Table 5-5 Cost Performance

equivalent performance and still shows good growth potential. Evaluation factors impacted by the AVS, updated ratings and the rationale for these changes are as follows:

(3) Ability to Image Digital Products and Sources

Rating: 5

There is no longer the opportunity for direct digital input but it is possible to link in digital data through a digital to analog (D/A) conversion system.

(5) Input of Source Evaluation Data

Rating: 6

As in the DOV and MOP, evaluation data will now be entered through a small detached processor or a terminal linked to a central computing facility.

(6) Number and mix of Inputs that can be Simultaneously Viewed

Rating: 8

While not as flexible as the DVS, the AVS can readily accept additional video inputs and is capable of storing analog data on magnetic media.

(13) Identification and Separation of Input Images

Rating: 7

Separation capabilities can be hardwired into an analog processor but the variety is much less and there will be no opportunity to easily change them.

(14) Feature Suppression or Enhancement

Rating: 7

Argument same as factor 13.

(15) Global Image Registration

Rating: 2

Could be wired in but resulting cost would negate economic advantages

(17) True Color Recognition and Display

Rating: 0

No longer any opportunity for true color imaging.

(18) Tonal Gray Level Recognition and Display

Rating: 10

Slightly improved. There is no longer any limitation linked to discrete memory. Continuous gray scale is now possible limited only by frequency response of the video camera.

(19) Hardcopy Outputs

Rating: 5

No longer any comprehensive hardcopy capability. A small detached minicomputer or link to a central site will be used for textual output, similar to the DOV or MOP.

(23) Phase I/Phase II Transition

Rating: 7

Phase I to Phase II transition is still good but changing to digital presents a bigger step and staying with analog is limiting.

If the DVS evaluation in Section 5.1 is adjusted for the above exceptions the AVS obtains a total normalized rating of 332. It is projected that repeat costs for an AVS will fall between \$60K and \$80K and first time costs between \$110K and \$170K. This gives the AVS a cost performance between 19.5 and 13.3 making it competitive with the MOP and DOV. Figure 5-1 depicts side-by-side cost performance ranges of the five (5) design concepts.

5.3 Conclusion

Sections 3.0, 4.0 and 5.0 led to a quantitative tradeoff analysis of four (4) design concepts, the DOV, MOP, DVS and AIS. These concepts are each specifically designed to address the wide mix of source assessment requirements and employ a variety of available technologies. However, to select a technological concept for targetting by the SAS Design Plan, performance, costs and risks must all be considered. The technologies that are available for a SAS have not provided a perfect answer. Each of the design concepts perform well in concept but each has a drawback that entails some risk, associated with the technology it relies on, that the tradeoff analysis tacitly assumes can be overcome. These drawbacks are itemized as follows:

- o DOV

- Low brightness levels for reflectively viewed inputs, is very close to the lower limit of acceptability. See Appendix A. There is an assumption that a brightness level less than 5 foot Lamberts is acceptable and there is a risk that a final implementation of this system can not deliver light output at an acceptable level.

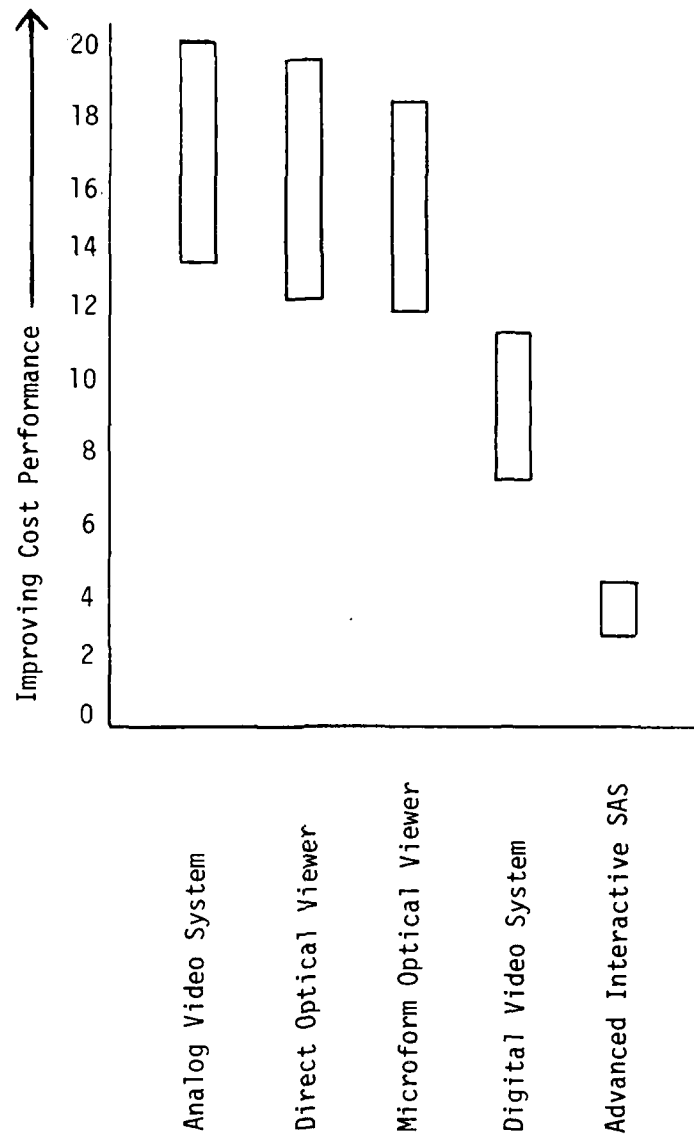


Figure 5-1 Cost Performance Summary

- o MOP

Reliance on an RCS, which may be inconvenient for source assessment specialists, require high levels of maintenance or incur high daily production cost. The risk involves the ability to purchase or construct a RCS that can minimize these drawbacks.

- o DVS

Limited resolution of a conventional video camera necessitates subdividing the input for imaging. The risk connected with this system is whether or not the control features can be designed such that the inputs can be conveniently and efficiently scanned subsection by subsection.

- o AIS

The design concept also relies on an RCS for maps and charts and also depends on a new technology that still needs development, presenting risk in the areas of cost and attainable performance.

The above drawbacks, and associated potential risks must temper any conclusions drawn from the tradeoff analysis. Given good technical and cost performance, each design concept must be closely examined in light of the ability of design approaches to overcome or minimize technical limitations and man/machine difficulties. The tradeoff analysis exercise and subsequent review of the results in light of the above limitations produced the following major conclusions:

(1) The DOV should be dropped from further consideration. Although the cost performance is good, expected brightness levels from reflectively viewed multiple inputs are very close to the lower limit of acceptability and present too much of a risk factor.

(2) The AIS should be deferred from current consideration due to complexity, cost/risk, and development time frame factors. It is

capable of high performance for all important forms of input but, due to the reliance on a developmental technology, its cost performance rank is significantly below other systems. The required use of a RCS further weakens its position.

(3) The DVS obtained the highest overall ranking in the performance evaluation, although after factoring of cost, the DVS fell below the MOP approach. An AVS analog (a possible interim version of the DVS) is an option that delivers high cost performance for Phase I, superior to that of the MOP. Also, many components of the AVS can be retained as part of a Phase II DVS. Therefore, the combined AVS/DVS approach for short and long term SAS requirements appears quite promising.

5.4 Recommendation

Based on the above analysis, the following recommendations are offered for the direction of the SAS project:

(1) The SAS design plan should target the AVS/DVS. This technology approach ranked high in the tradeoff analysis and offers a high degree of graphic manipulation and display capabilities. Of the four (4) concepts the AVS/DVS approach offers the most potential to grow with changing source assessment requirements. Components can largely be purchased off-the-shelf and its most serious limitation, relatively low resolution, is judged to present less of a problem than those associated with the other three concepts. The AVS option will offer better cost performance and many of the components could be retained for Phase II digital video. The effectiveness of an analog to digital transition versus a purely digital growth path should be determined early during the design.

(2) If cost performance exceeds technical scope as a concern, the MOP should be considered as an alternate choice for design and development, particularly in support of a Phase I only (non-digital

DB) device for map to chart and chart to imagery assessment. While it does not offer the growth potential, it offers high performance, with a bright, sharp, full-view image, for viewing/comparison of maps, charts and imagery transparencies. It also offers good cost performance and represents a natural extension to traditional assessment equipment and methods. As emphasized previously, the success of this concept is dependent on the ability of the RCS to be self contained, offer relatively low maintenance, provide copies with little delay and have reasonable production costs. While the potential for achievement of these capabilities remains an issue, we do not view these problems as major or insurmountable.

(3) The DVS is also capable of meeting DMAHTC requirements especially in the area of production support, but for up-front (i.e., product maintenance) assessment of hydrographic chart acquisitions and detection of hazards to nautical navigation there is less need for generalized input capability. For these functions a simpler, more economical SAS which is able to accept pairs of charts for same scale, side-by-side or superimposed comparison in an efficient manner should be considered.

The MOP concept would be suitable if the acquisitions can be routinely photo reduced to microform transparencies. The AVS concept is also an alternative if the resolution drawback can be overcome by good design. It offers lower costs than the DVS, can be easily configured to accept pairs of charts and offers the possibility of straightforward upgrades to DVS capability for problems requiring more generalized input and extended processing capabilities.

6.0 PHASE I DESIGN PLAN SUMMARY

A video approach for the design of a Source Assessment System was recommended in Section 5.0 after trade-off and cost analysis of four technology approaches presented in Section 4.0. Preliminary to the Design Plan task a series of visits to vendor sites were undertaken, at the request of RADC, to verify the ability of video technology to deliver sufficient resolution. Personnel representing RADC, DMAAC, Mc2 and Singer/Librascope participated, and demonstrations were observed at: a manufacturer of very high resolution video camera and displays; two suppliers of digital video image processing systems; and a manufacturer of an analytical stereoplotter that shows functional similarities to those that a video SAS might exhibit.

These visits were successful since they prompted an agreement between the attendees that video technology is a viable direction for source assessment. They were also valuable in furthering an understanding of user requirements and placing them in the context of "state-of-the-art" video equipment. That is, given the advantages of a video system and its limitations, those special functional capabilities that should be included in a video SAS were further delineated.

The Final Design Plan, delivered to RADC as a separate document, presents a relatively powerful Phase I (FY81-FY83) SAS. Nearly all basic technology will be developed and in place for the initial phase. Phase II (FY84-FY86) development will be limited to upgrades necessary to accommodate increasing use of external digital data and improving resolution of digital imaging and processing equipment.

Where possible "off-the-shelf" components will be utilized; although special design, fabrication and integration of the input stations will be required. Because the Design Plan addresses a comprehensive SAS, and development of specialized input stations is required, the target of the development phase should be a prototype model.

6.1 Design Overview

Figure 6-1 depicts the SAS as it may appear to a user. The SAS design allows for optional combinations of input station configuration, but for clarity a single input station specialized for map/chart viewing is shown at the right and a single input station specialized for film viewing is shown on the left. The user console is in the center and is sized to provide sufficient table space for graphics and hardcopy documentation. To the left rear of the console is an equipment rack for all electronic gear, including camera controllers, digital processors, I/O devices, A/D and D/A converters, etc.

Figure 6-2 is a system configuration. The input station for film accepts cut and roll film so that it can be conveniently presented to a video camera that can deliver in excess of 1000 x 1000 picture elements. The video camera employs an optical design that is suited for the resolution of small detail in photographic imagery and can be positioned and focused, remotely, from the user's console. The input station for map/charts serves a similar function but is designed for the physical and visual characteristics of maps and charts.

A third input station is required for direct map/chart to map/chart comparisons, although a cost saving alternative for an initial SAS would be a software capability for storage/retrieval of one of the video imaged maps/charts. A first map, preferably the smaller format of the two to minimize required coverage, would be placed into the map/chart input station and be imaged over user selected subareas and saved on mass storage. The second map will then replace the first in the input station for comparison with the stored images.

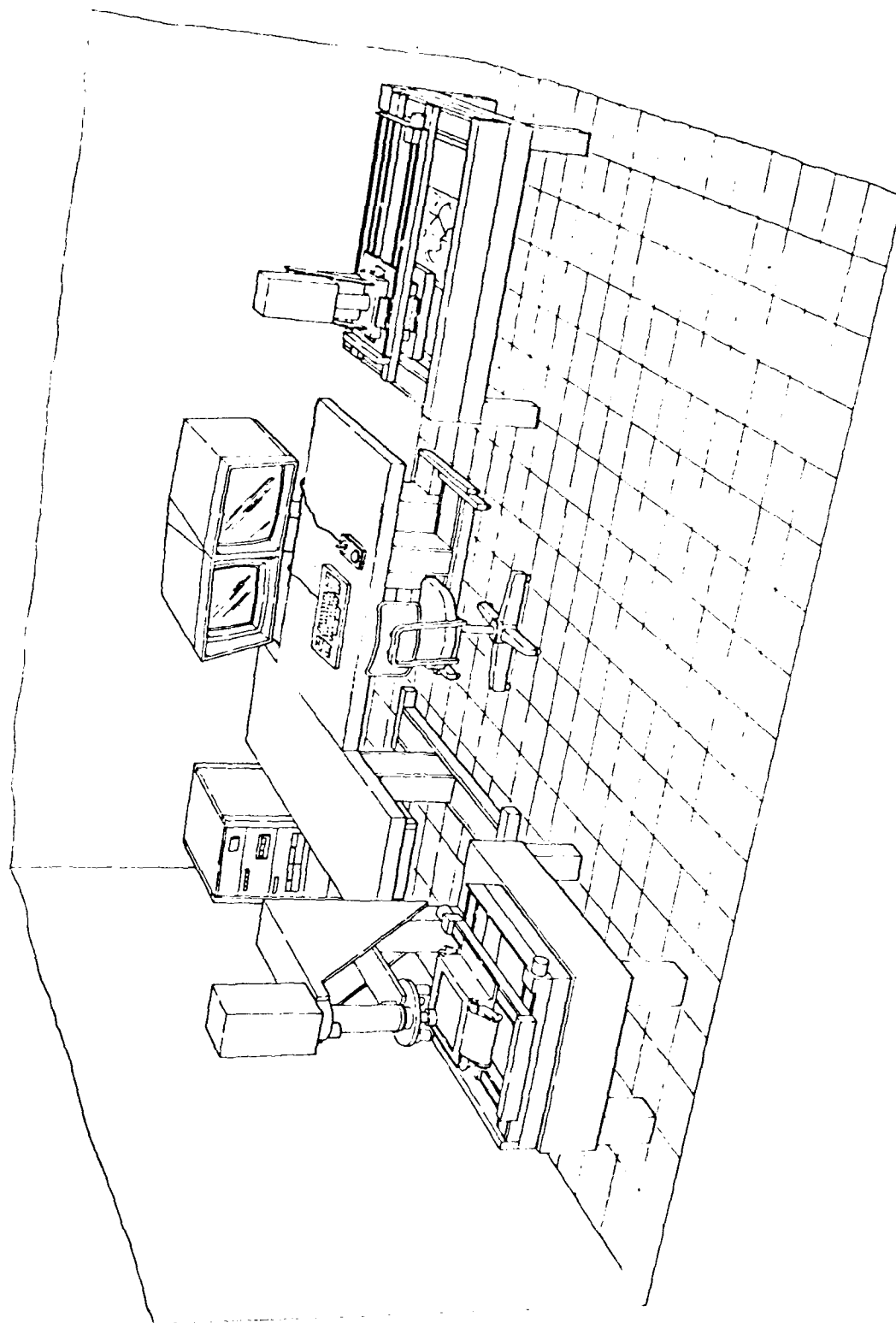


Figure 6-1 Source Assessment System Schematic

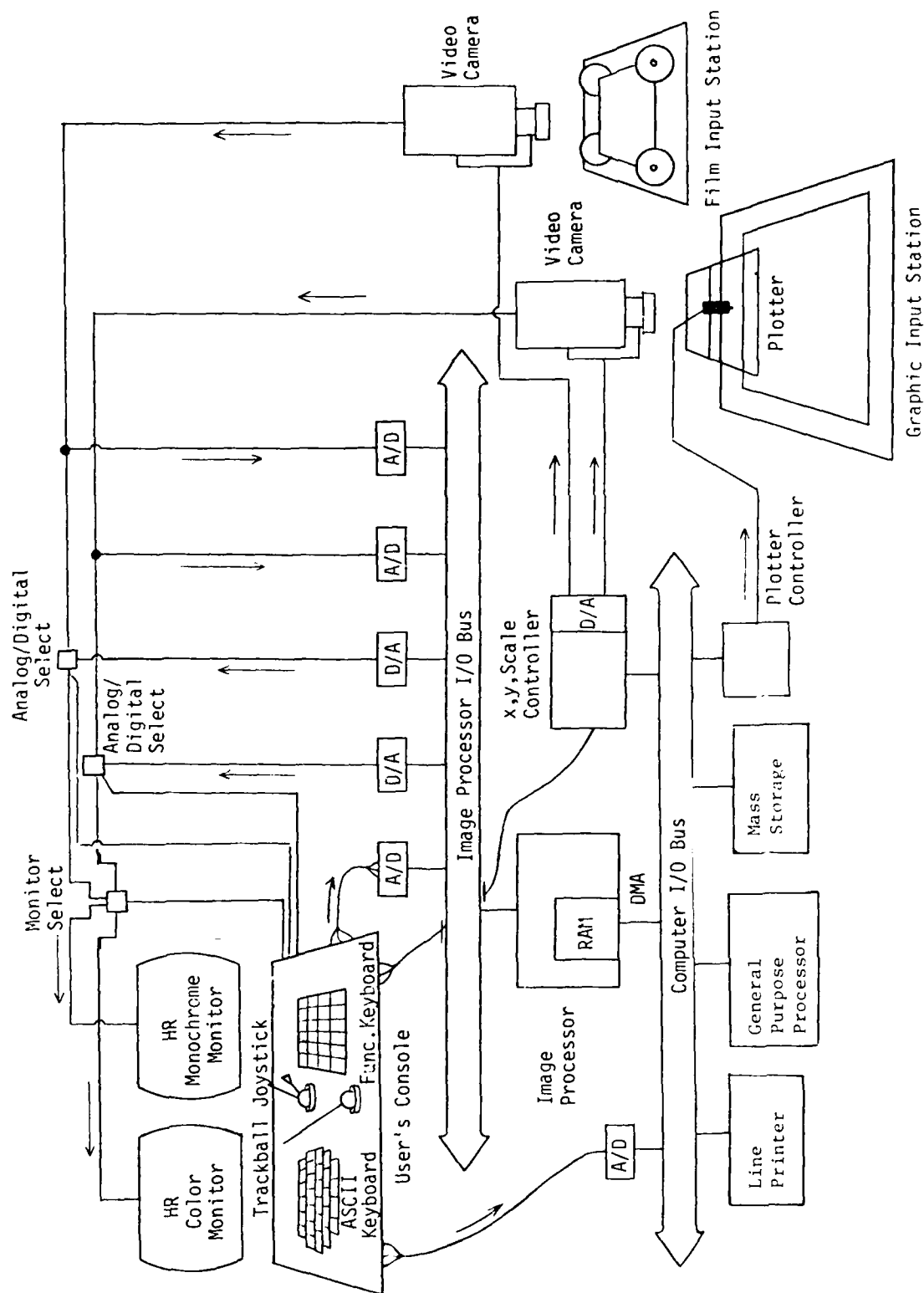


Figure 6-2 System Configuration
6-4

For general purpose viewing, graphics placed in the input stations can be scanned and imaged in an analog fashion and be directly displayed, side-by-side on high resolution monitors at the user's console. If complex image enhancement and analysis, under user's control, is required, graphic inputs can be selectively digitized as input to a digital computer specialized for high speed image processing.

A general purpose computer supports the image processor by providing computing facilities that cannot be practically performed by the image processor. Examples are:

- o System control and overall coordination of system operations
- o Comprehensive I/O for digital data
- o Control for a variety of peripherals for data I/O and user interaction
- o General purpose software for program development, data management and specialized mathematical computation.

Available image processors vary widely in their level of functionality, so the selection of a general purpose computer and the functions assigned to it will depend on the selected image processor. In a conventional configuration the image processor looks like a peripheral to the general purpose computer. It contains a Random Access Memory (RAM) used for image refresh, which can also be loaded by the general purpose processor via a Direct Memory Access (DMA). This makes possible high speed data transfers between the image processor and the general purpose computers.

The users console is equipped with the following features:

- o High Resolution Monochrome Monitor

This monitor will display, at a resolution in excess of 1000 x 1000 picture elements and at least 256 contrast levels, imagery received directly from the video input stations, or indirectly via the image processor.

- o High Resolution Color Monitor

The second monitor will exhibit similar performance and permit side-by-side viewing. The inclusion of color capability will permit the display of colored images received from the image processor. The user can interact with the image processor to select color for highlighting or keying significant features within the image.

- o ASCII and Function Keyboard

The ASCII keys provide alphanumeric entry for a cartographic oriented user dialogue with the SAS. It allows the user to input commands and to respond to instructions or requests from the system. The function keys, buttons or switches control often repeated or routine operations of the input stations and the processor.

- o Joystick

The joystick will control coarse, x-y and angular translations, lens zoom for the input stations and realtime manipulation of the image processor generated displays.

- o Trackball

The trackball extends the functions of the joystick by providing fine adjustments at the input stations (i.e. translation and zoom).

Other important devices shown in Figure 6-2 are:

- o Integrated Plotter

This plotter is part of the map/chart input station and is mounted beneath the video camera such that its operation can be viewed on a monitor. It is intended to annotate inputs with simple graphics, symbolism or alphanumerics under direct view and control of the user.

An alternative to this plotter would be a conventional (on-line or off-line) plotter. Such a plotter would be purchased as a separate unit and be capable of serving multiple SASs. This method, however, would require a separate plotting step and a procedure for maintaining registration between the original, as viewed in the SAS input stations, and the resulting annotated plot.

For either alternative the user will create annotations on the video monitor, permitting him to correct and edit before directly plotting them or entering them into an annotation file.

- o Input Station Controller

This device translates joystick and trackball movements

into translations and zoom of the video camera. It also interfaces to the general purpose computer so that geometric relationships between inputs can be computed, permitting compensated, coordinated scanning and scaling between inputs.

- o Monitor Selection Switches

The user will be able to select the input for each monitor. Choices include direct analog input from any attached input station (monitor select) and digitally processed images from the image processor (analog/digital select).

The SAS design has been partitioned into functional subsystems (see Figure 6-3) based on a logical coupling of major system functions. Also shown in Figure 6-3 are major inputs/outputs and components of each subsystem. The three subsystems and their major roles are as follows:

- o Input/Output Subsystem: purpose is to perform all hardcopy graphic input imaging, graphic plotting and analog to digital conversion.
- o Image Processing Subsystem: performs all special image and graphic processing, display, and manipulation.
- o Control and General Processing Subsystem: provides all major system control and subsystem coordination, general purpose processing, digital file input and output, and data management and storage.

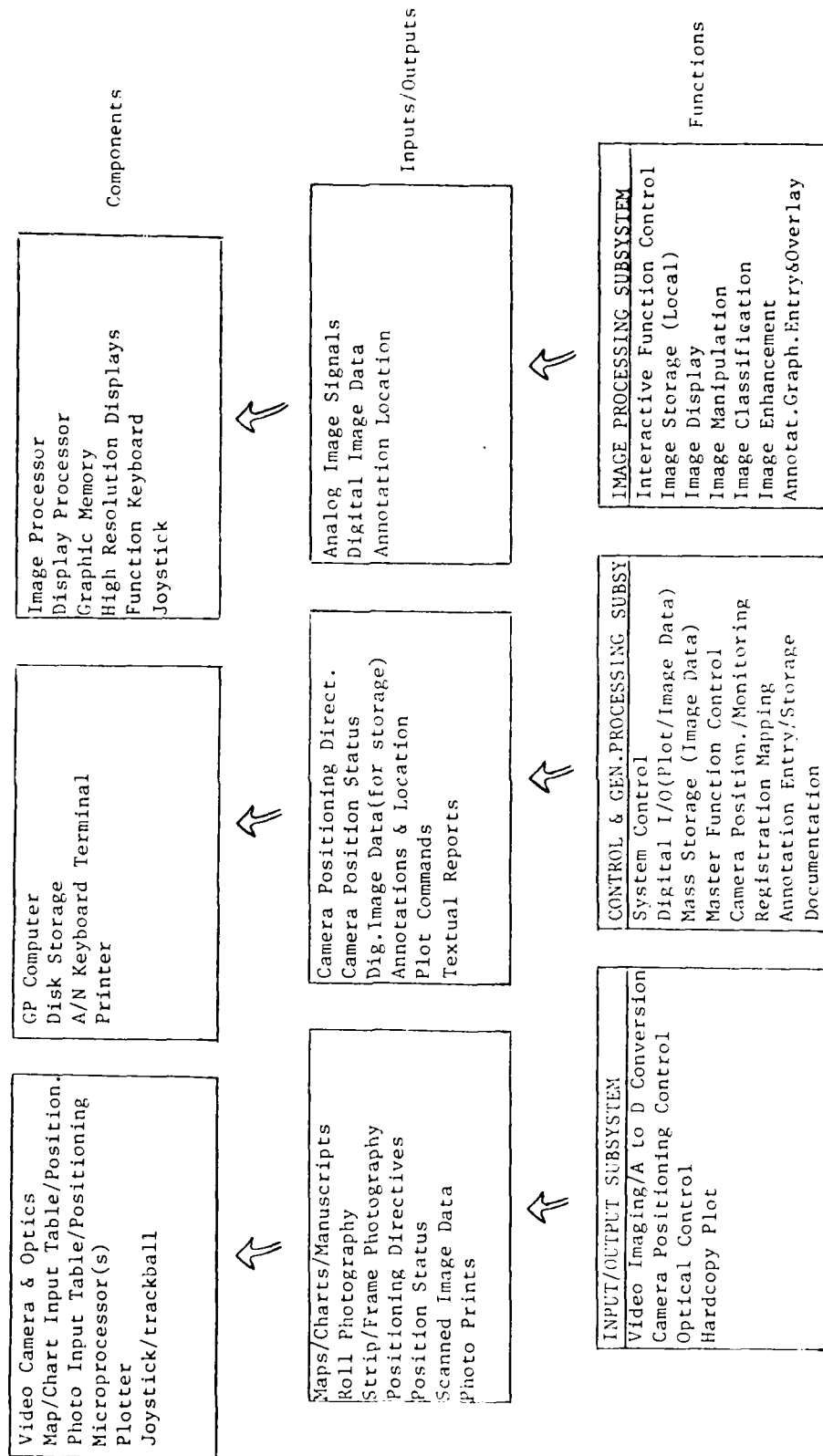


Figure 6-3 Phase I - SAS Subsystem Functions, I/O, & Components Overview

6.2 Analog Image Processing Alternative

A cost savings alternative for a Phase I (short term) SAS is to replace the digital image processor with an analog image processor. Such a device can provide, at low cost, a limited but useful set of comparison functions. An example of such a system, the AP-3 Analog Encoder is manufactured by Interpretation Systems Incorporated. The encoder can accept seven video inputs (from video cameras or other sources) an overlay an two of them for one-to-one comparison or subtract them for difference detection. Compared images can also be color encoded or flickered for image separation. The designs for the input stations would not be impacted by this alternative. The user will be able to image his inputs in real-time as he horizontally scans or enlarges them using hardwired controls located at his console. Final images would be compared using selected analog option.

The analog alternative represents significant limitations relative to the powerful Phase I SAS presented in Section 6.1. It should be considered interim to the Phase I implementation, as it does not negate an eventual upgrade to digital imaging and processing. Suggested advantages are:

- o Initial low cost
- o Early implementation
- o Simplicity of operation
- o Opportunity to plan for expansion based on experience

6.3 Estimated Costs

Table 6-1 presents estimated costs for each subsystem component of the Phase I SAS discussed in Section 6.1. Costs are broken out, where applicable, in the following categories.

- o Special Design/Specifications: One time costs stemming from the design, specification, planning and special tooling that must support actual SAS implementation.
- o Purchase Items: Repeat costs resulting from the procurement of "off-the-shelf" components.
- o Special Development/Integration: Repeat costs associated with the fabrication of specialized components and the integration of all components into a functional system.

It should be noted that the estimated repeat costs for the DVS design plan exceed those projected in the trade-off analysis. This increase was revealed by a more detailed examination of the design requirements that was necessary to develop the SAS Design Plan. Important impact areas were a better definition of the physical requirements of the input stations and improved insights in the costs associated with Special Development/Integration.

The analog processing alternative has to be considered as an interim Phase I SAS which has no digital capability. An analog processor that can deliver a resolution in excess of 1000 TV lines is expected to cost \$20K. The deletion of all digital components would save \$355K giving a net savings in excess of \$300K and total costs less than \$300K for the first unit.

<u>Repeat Costs</u>				
<u>Subsystem Components</u>	<u>Special Design/spec.</u>	<u>Purchased Items</u>	<u>Special Development / Integration</u>	<u>Totals</u>
Graphic Input/Output Subsystem				
First Map/Chart Input Station:				
Camera	1	17	2	20
Optics	6	5	8	19
Integrated Plotter	15	5	1	21
X-Y Positioning Device	5	12	3	20
Input Platform	3	4	4	11
Illumination	<u>2</u>	<u>2</u>	<u>2</u>	<u>6</u>
SUBTOTAL	\$32K	\$45K	\$20K	\$97K
Film Input Station:				
Camera	1	17	2	20
Optics	2	8	8	18
X-Y Positioning Device	1	10	1	12
Film Handling Device	3	7	4	14
Illumination	<u>4</u>	<u>4</u>	<u>2</u>	<u>10</u>
SUBTOTAL	\$11K	\$46K	\$17K	\$74K
Second Map/Chart Input Station		\$45K	\$20K	\$65K

Table 6-1 Implementation Cost Items (Page 1 of 2)

<u>Subsystem Components</u>	<u>Repeat Costs</u>			<u>Totals</u>
	<u>Special Design/Spec.</u>	<u>Purchased Items</u>	<u>Special Development Integration</u>	
Control Functions	\$10K	\$5K	\$10K	\$25K
Image Processing Subsystem		\$135K	\$10K	\$145K
Control Processing Subsystem:				
Mini-Computer/128/KB		45K	10K	
Disk Controller/Two Drives				45K
Terminal				10K
Printer		5K		
System Software				5K
Special System Software	20K			20K
Application Software	130K			130K
SUBTOTAL	\$150K	\$50K	\$10K	\$210K
TOTAL	\$203	\$326K	\$87K	
Total One-Time Costs				\$203K
Total Repeat Costs				\$413K
Total Cost for First SAS				\$616K

Table 6-1 Implementation Cost Items (Page 2 of 2)

6.4 Development Effort

The development effort required following this design analysis and planning effort, should consist of:

- o Requirements Verification
- o Detailed Design Specification
- o Implementation
 - Hardware Acquisition (off-the-shelf)
 - Special Hardware Development and Integration
 - Software Development
 - System Integration and Checkout
- o Demonstration and Evaluation

These major system development phases are shown in Figure 6-5 in terms of estimated time span and sequencing over an eighteen (18) month period.

To afford an opportunity for a fall back to a simpler prototype, with lower costs and earlier implementation, an analog option was suggested. The development schedule is expected to be reduced by six (6) months. This alternative would include the design, fabrication and integration of the input stations which represents the major portion of special development. Inclusion of digital capability would be planned as later phased upgrades.

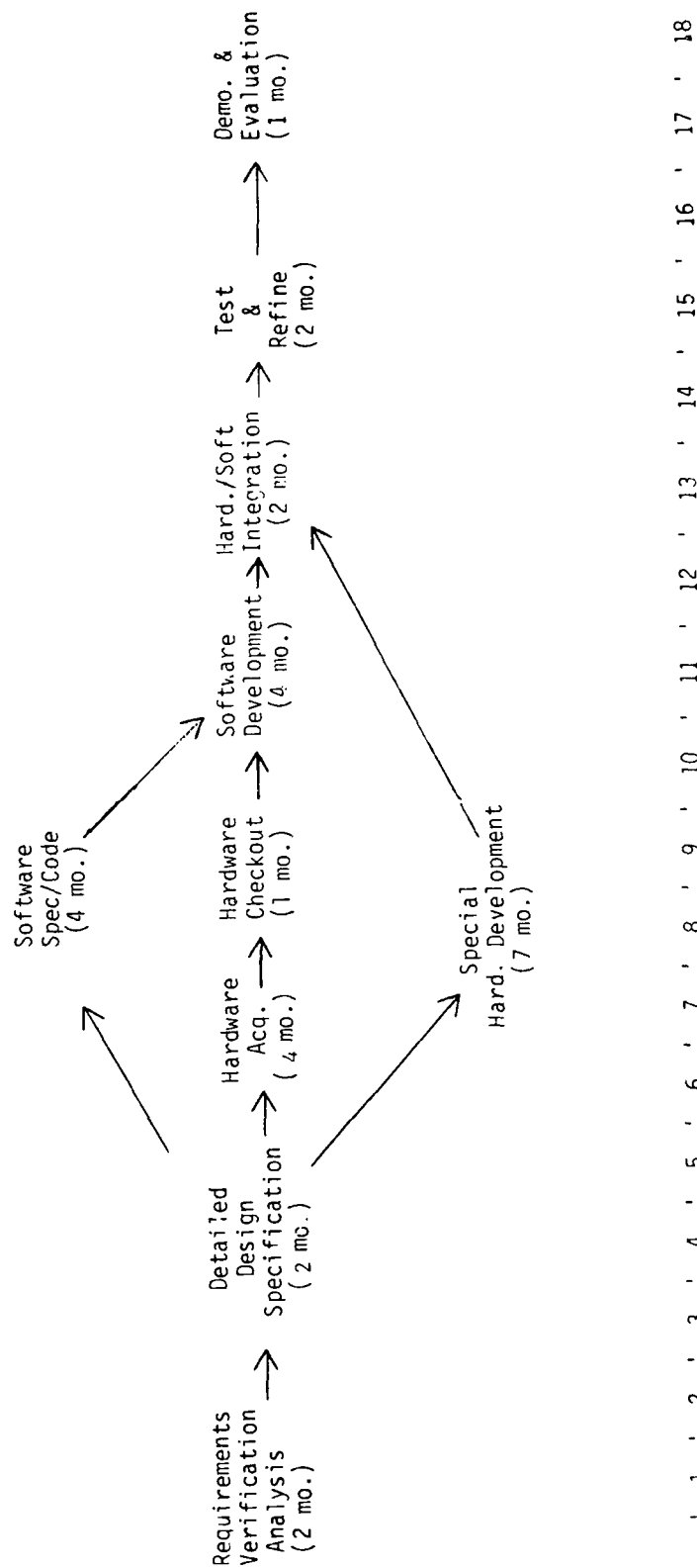


Figure 6-4 Development Schedule

7.0 SUMMARY

The Scientific Data Department, Data Analysis branch (SDDA) of the Defense Mapping Agency Aerospace Center (DMAAC) is responsible for :

- o Managing the selection and indexing of cartographic source materials
- o Recommending these sources for support of a variety of production and maintenance processes

SDDA must contend with a growing volume and diversifying selection of cartographic sources, and changing requirements for DMA support such that traditional methods of assessing these acquisitions and targetting them for specific applications are no longer adequate. As a step to alleviate this problem, this study analyzes the requirements for a Source Assessment System (SAS); presents and analyzes potential solutions; and develops a design plan for system development.

Primary capabilities that a SAS at DMAAC must provide are:

- o Superimposed or side-by-side viewing, at the same scale, of source materials and DMA products for one-to-one comparison
- o Input mechanisms to accept source and DMA products of many different formats and physical characteristics

To support these primary capabilities the SAS must also provide:

- o A formal system for source assessment
- o A well defined link between assessment procedures and support of production

- o High accessibility for cartographic specialists
- o Support of volume processing
- o Standardized assessment tools

The SAS must also address a phased development approach. Phase I (FY81-FY83) should be implemented as soon as possible and take into account the current mix of product and source formats. Phase II (FY81-FY86) should be implemented as an evolutionary extension of the Phase I SAS and provide for changing sources and DMA products, especially the increasingly important role of digital data.

The possible application of a similar SAS at the DMA Hydrographic and Topographic Center (DMAHTC) was investigated. While in general both centers have similar needs for improved assessment and support procedures, the assessment of hydrographic chart acquisitions and detection of hazards to navigation do not require the generalized mix of inputs that was evident at DMAAC. For this reason a simpler device that can efficiently compare pairs of nautical charts may be sufficient.

Four SAS design concepts, using known technologies to the best advantage, are presented. The Direct Optical Viewer (DOV) relies on a purely optical arrangement for imaging the inputs. The Microform Optical Projector (MOP) uses a photo reproduction step for maps and charts to improve image brightness. The Digital Video System (DVS) employs video imaging and display and digital electronics (the video data stream is digitized to permit digital image processing). The Advanced Interactive SAS (AIS) combines the features of the MOP with an advanced liquid crystal display to provide a bright optical image

for all hardcopy and the ability to input and display digital data for analysis and direct comparison to hardcopy inputs.

A trade-off and cost analysis was performed for all four concepts which resulted in the recommendation that the DVS is the best approach for a SAS design plan. The DVS was selected because of: its high ranking in the trade-off analysis; its high potential for Phase II augmentation; the availability of off-the-shelf components; and that its most serious limitation (relatively low resolution) can be overcome more readily than those limitations associated with the other design concepts. Because the DVS is a "high technology" concept and requires state-of-the-art video components to obtain the required resolution its cost performance was less than that of the DOV and MOP. To provide an economic option, a video system without digital capability and employing limited analog comparison techniques was considered. Such a system could function as an interim system to a Phase I SAS and be configured to accept phased upgrades for inclusion of digital input and digital image processing. A digital, video SAS design could also serve at DMAHTC but the more limited range of input formats required for routine assessment of chart acquisitions may make it feasible to employ a simpler and more economic MOP or analog video SAS as Phase I solution.

The Final SAS Design Plan was delivered as a separate contract deliverable but a design plan summary is included in Section 6.0 of this report. The design plan presents a relatively powerful Phase I digital, video SAS and the Phase II SAS represents minor technology upgrading. Phase II would be implementable by orderly upgrades of the Phase I SAS. The estimated repeat cost for the digital video design plan are \$413K and the estimated one time costs are \$203K, or \$616K for the total cost of the first system. The total costs for the analog option are estimated to be less than \$300K.

It is projected that the proposed SAS would require an 18 month development effort. Because the design plan represents a comprehensive SAS and the development of specialized input devices is required, it is recommended that the development effort should be directed toward a prototype model.

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APPENDIX A

Example Calculation for DOV Image Brightness

The principal limitation of a DOV would be image luminance for reflectively viewed inputs. The luminance of a rear projection screen can be approximated by the following equation:

$$B_s = \frac{T}{8 (f\#)^2 (M+1)^2} B_o$$

where B_s is the luminance of the image

T is the system transmission

B_o is the luminance of the object being viewed,
i.e., a source being assessed.

$(f\#)$ is the lens f number

M is the system magnification.

Best reasonable values for these variables are:

$$T = 90\%$$

$$B_o = 4,000 \text{ foot Lamberts}$$

$$(f\#) = 5.6$$

$$M = 1$$

Under these conditions, $B_s = 3.6$ foot Lamberts. A display of this sort would have to be used in almost total darkness for the operator to see the image. Even a transmission of 100% would produce only four (4) foot Lamberts and any increase in magnification will decrease B_s even further. In addition 4,000 foot Lamberts will require as much as 5KW of lighting necessitating a cooling system.

APPENDIX B

Examination of Video Resolution

An experiment was performed to determine the resolution required of the television system. A closed circuit camera-monitor system was used to view a JOG chart. Lens focal length and viewing distance were varied to vary the field of view on the map while keeping it in focus. The following observations were made:

- a. Lettering 0.030 inch high (consisting of 0.004 inch lines) was observed. If the lettering lay in the direction of scan, it could be read with the field of view as large as 3x4 inches. If the lettering lay perpendicular to the scan direction, it could be read with the field of view as large as 2½x3 inches.

The resolution of the system was measured with a bar chart. With a 3x4 inch field of view, bars and spaces 0.0095 inch wide could be resolved. This indicates that the resolution of the television system was 300 to 400 TV lines.

It is important to notice that 0.004 inch features were resolved even though the minimum resolution element of the system was 0.0095 inch. A system with 1000 TV lines resolution could be expected to resolve a 0.004 inch feature over a 6 to 8 inch field.

- b. Measurement was made of performance in a surveillance mode. The following levels of performance were observed at the stated field width:

o	0.004 inch line barely detectable	-	7.25 inch field
o	1/16 inch lettering readable	-	8 inch
o	1/16 inch lettering barely readable	-	9 inch
o	1/8 inch lettering readable	-	11 inch
o	1/8 inch lettering barely readable	-	> 12 inch

If a surveillance mode can be defined as allowing 1/8 inch letters to be readable with 1/16 inch letters barely readable, a 1000 line TV system would allow a field of view of approximately 20 inches.

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